Part 2 of 2

OREGON
ENVIRONMENTAL QUALITY
COMMISSION MEETING
MATERIALS 06/21/2007

DEQ

State of Oregon
Department of Environmental Quality

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Mayor's Office
Kitty Piercy

City of Eugene
777 Pearl Street, Room 105
Eugene, Oregon 97401-2793
(541) 682-5010
(541) 682-5414 Fax

June 20, 2007

Department of Environmental Quality
Environmental Quality Commission
811 SW 6th Avenue
Portland 97204-1390

Dear Chair Hampton and Members of the Commission:

On behalf of the City of Eugene, I write in support of Lane County's request to the Oregon Environmental Quality Commission (OEQC) to use its legislatively granted authority under ORS 468A.610(9) to issue a moratorium on all open field burning, propane flaming, stack and pile burning in the Willamette Valley for the 2007 and 2008 burning seasons. We also support the alternative request that the OEQC find that reasonable and economically feasible, environmentally acceptable alternatives have been developed that warrant cessation of this archaic, dangerous practice.

As you know, the Lane Regional Air Protection Agency (LRAPA) has reported that two-thirds of the field burning complaints received by the Oregon Department of Agriculture are from the Eugene-Springfield areas and other parts of the southern Willamette Valley. Each year, the southern Willamette Valley is plagued with smoke that rises hundreds of feet in the air, billowing across the valley. We are concerned that across our city, smoke and ash cover homes and streets, schoolyards and playgrounds, and parks and bike trails, subjecting our citizens to serious health and safety risks and endangering the lives of our citizens with preexisting respiratory ailments, as well as children and the elderly.

We are also concerned about the effect that field burning will have on the participants of the 2008 U.S. Olympic Track & Field Trials (Eugene 08). This event, to be held in Eugene, Oregon next summer, will host more than 1,000 athletes who will begin the pursuit of their 2008 Olympic dreams by competing for the right to represent Team USA at the 2008 Olympic Games in Beijing, China.

Because of these concerns, when State Representative Paul Holvey introduced House Bill 3000 this legislative session, which would have ended open field burning in Oregon, the City of Eugene readily and strongly supported that measure. We support these attempts to end field burning because we believe that the practice of field burning not only affects the health and safety of the residents of the Willamette Valley, but is extremely dangerous to all of Oregon's citizens.

Thank you and we greatly appreciate your attention to this vital issue of health and justice.

Sincerely,

Kitty Piercy

Kitty Piercy, Mayor

Index of Documents, Research, and Statistical Data for Environmental Quality Commission Letter Arranged by Footnote

Footnote 1:

- Oregon Seed Council, *Oregon Seed Industry – Fact Sheet*
- DEQ, DOA, and DHS, *Open Field Burning In the Willamette Valley*

Footnote 2:

- Oregon Department of Agriculture, Natural Resources Division, Smoke Management Program, *Summary of the 2006 Field Burning Season* (December 2006)

Footnote 3:

- Johnston and Colob, Washington State University, *Quantifying Post-Harvest Emissions from Bluegrass Seed Production Field Burning* (March 2004)
- Holvey letter to the Oregon Agriculture and Natural Resources Committee (April 30, 2007)

Footnote 4:

- American Academy of Pediatrics Committee on Environmental Health, Ambient Air Pollution: Health Hazards to Children. *Pediatrics* 2004
- American Lung Association of Oregon, Letter to Oregon House of Representatives Health Care Committee (April 6, 2007)

Footnote 5:

- Lane County Medical Society letter to state legislators (April 5, 2007)
- Grass Seed Field Smoke and Its Impact on Respiratory Health, *Environmental Health* (June 1998)

Footnote 6:

- Increased Particulate Air Pollution and the Triggering of Myocardial Infarction, *Circulation* (June 12, 2001)

Footnote 7:

- EPA, *Fact Sheet: Final Revisions to the National Ambient Air Quality Standards for Particle Pollution (Particulate Matter)* (September 21, 2006)
- Oregon Asthma Program, *Oregon Asthma Surveillance Summary Report*, 12 (January 2007)
- Behavioral Risk Factor Surveillance System, *Prevalence Data: Asthma 2005*

Footnote 8:

- Journal of the American Medical Association, *Fine Particulate Air Pollution and Hospital Admission for Cardiovascular and Respiratory Diseases* (March 8, 2006).

Footnote 9:

- *Open Field Burning In the Willamette Valley* – See Footnote 1

Footnote 10:

- *Open Field Burning In the Willamette Valley* – See Footnote 1

Footnote 11:

- *Summary of the 2006 Field Burning Season* – See Footnote 2

Footnote 12:
- LRAPA letter to Representative Paul Holvey, (Nov. 15, 2006)

Footnote 13:
- Declaration of Eric Skelton, *Safe Air for Everyone v. Wayne Meyer*, et al., Case # 02-0241N-EJL (June 1, 2002).

Footnote 14:
- ORS 468A.585
- *Open Field Burning In the Willamette Valley* – See Footnote 1

Footnote 15:
- *Open Field Burning In the Willamette Valley* – See Footnote 1

Footnote 16:
- OSU Extension, The Search for Solutions (Jan. 1989)
- CH2M Hill, Opportunities in Grass Straw Utilization (Feb. 1991)
- USDA and OSU Agricultural Experiment Station, Low-Input On-Farm Composting of Grass Straw Residue (Oct. 1998)

Footnote 17:
- ORS 468A.555

Footnote 18:
- ORS 468A.610
- *Summary of the 2006 Field Burning Season* – See Footnote 2

Footnote 19:
- ORS 468A.595(4)
- LRAPA letter to Representative Paul Holvey – See Footnote 12

Footnote 20:
- ORS 468A.610 – See Footnote 18

Footnote 21:
- No documentation associated with this footnote.

Footnote 22:
- ORS 468A.610 – See Footnote 18

Footnote 23:
- ORS 468A.610 – See Footnote 18

Footnote 24:
- ORS 468A.610 – See Footnote 18

Footnote 25:
- Statement of Dixie Maurer-Clemons of Eugene (Mar. 1, 2007)

Footnote 26:
- Statement of Maxine Kovarik, Springfield (Feb. 27, 2007).

Footnote 27:
- Statement of Penny Spencer, Creswell (Mar. 2, 2007)

Footnote 28:
- Statement of Dorothy Bucher, Eugene (Feb. 24, 2007)

Footnote 29:
- Statement of Pam Perryman, Eugene (Feb. 10, 2007)

Footnote 30:

- Statement of Ronald and Doris Gates, Springfield (Feb. 1, 2007)

Footnote 31:

- Statement of Victoria Whitman, Eugene (Feb. 8, 2007)

Footnote 32:

- Statement of Jeff Wyman, Eugene (Mar. 8, 2007)

Footnote 33:

- Statement of Hewitt and Patricia Berrien, Eugene (Mar. 7, 2007)

Footnote 34:

- Statement of R. Gunn, East Marion County (Apr. 1, 2007)

Footnote 35:

- Statement of Terry Sitton, Sweet Home (Apr. 4, 2007)

Footnote 36:

- Statement of Steve Nielsen, Mill City (Apr. 6, 2007)

Footnote 37:

- Statement of Glen and Thoda Love, Eugene (Mar. 18, 2007)

Footnote 38:

- WSU, Department of Agricultural and Resources Economics, Estimates of the Benefits and Costs from Reductions in Grass Seek Field Burning (Dec. 27, 1996)

Footnote 39:

- RCW 70.94.656 (3); WAC 173-430-045

Footnote 40:

- *Safe Air for Everyone v. US EPA*, 475 F.3d 1096, 1101(9th Cir. 2007), reaff'd 2007 WL 1531819 (9th Cir. May 29, 2007)

Footnote 1

OREGON SEED INDUSTRY - FACT SHEET

Prepared by
The Oregon Seed Council - 503-585-1157

Grass Seed Industry	The term "seed industry" generally refers to production and marketing of cool grass seeds in the state of Oregon. Cool season grasses are those adapted to the temperate climates of the world and includes six major species.
Species	Species include Annual and Perennial Ryegrass, Tall Fescue, Fine Fescue, Orchardgrass, Bluegrass, and Bentgrass. Warm season grass include Bermuda grass, St Augustine grass, Zoyzia, etc.
Number of Growers	There are about 1,500 grass seed growers in Oregon. The majority of grass seed is produced in the 9 Willamette Valley Counties. Other areas with significant acreage are Jefferson, Jackson, Union, Morrow and Umatilla Counties. Grass Seed is also produced in much smaller amounts in Washington, and Idaho.
Number of Companies	There are approximately 55 wholesale seed companies marketing grass seed.
Acreage	Grass seed is produced on nearly 530,000 acres; 485,000 acres in the Willamette Valley, the rest in Jefferson, Jackson, Union, Morrow, Umatilla, and Klamath Counties.
Production	In 2006 Oregon produced and marketed 788 million pounds of grass seed.
World Use	The total demand for cool season grass seed is about 1.3 billion pounds annually.
Value of Production	Agricultural crops are valued in various ways. The "farm gate" value is what the grower received for the seed. In 2006 the "farm gate" value was over $454 million. Grass seed companies added about 30% or $135 million in research, production and marketing services bringing the total value to over $590 million.
Where Sold	Nearly all of the grass seed produced in Oregon is sold outside of the state. It is estimated that only 1-2% of the grass seed produced in Oregon is needed here for new lawns and pastures.
Export	Approximately 12-15% of the grass seed produced in Oregon is exported. Major buyers include Europe, Pacific rim countries, South American countries, African countries, New Zealand and Australia, Canada and China. In total, grass seed is exported to about 60 countries.
Why Oregon	Oregon has a unique combination of cool moist winters and dry warm summers that are ideal for grass seed production. A high percentage of soils in the Willamette Valley are well suited to growing grass and of limited value for producing other crops. Using Oregon's natural advantages, grass seed growers have learned to produce very high quality seed cheaper than competitors.
Economic	Economic impact refers to the ripple effect of new money coming into an economy; how many times the dollar changes hands. Agricultural crops have an economic multiplier of about 3. That is a new dollar will result in about $3 worth of total economic activity. Using 3 as the multiplier, the seed industries economic impact is $1.77 billion (3 X $590 million).

Oregon
Theodore R. Kulongoski, Governor

Department of Environmental Quality
811 SW Sixth Avenue
Portland, OR 97204-1390
503-229-5696
TTY: 503-229-6993

June 27, 2007

Faye Stewart, Chair
Lane County Board of Commissioners
Lane County Board of Health
Public Service Building
125 East 8th Ave.
Eugene, OR 97401

Dear Commissioner Stewart:

Thank you for your letter of June 19, 2007 urging the Environmental Quality Commission to order a temporary cessation of open field burning in the Willamette Valley.

Your letter, along with comments provided by a number of stakeholders during the Commission's June 22nd meeting, has raised a number of policy and legal questions that must be carefully assessed before the Commission can respond. Attorneys at the Oregon Department of Justice are reviewing the relevant authorities and we anticipate that the Commission will have the information needed to respond by mid to late July.

Thank you for your interest in air quality and public health.

Sincerely,

Stephanie Hallock

Stephanie Hallock
Director

Cc: Environmental Quality Commission
Katy Coba, Director, Oregon Department of Agriculture
Katie Fast, Associate Director of Government Affairs, Oregon Farm Bureau
Rob Rockstroh, Health and Human Services Director, Lane County
Anthony S. Bieda, Intergovernmental Relations Manager, Lane County
Brenda Wilson, Intergovernmental Relations Manager, City of Eugene
Dan Galpern, Attorney, Western Environmental Law Center
Mark Riskedahl, Executive Director, Northwest Environmental Defense Center
Dave Nelson, Executive Secretary, Oregon Seed Council
Don Haagensen, Attorney, Cable, Huston, Benedict, Haagensen & Lloyd
Marrie H. Bowers

Statement on Ending Field Burning
Before the Oregon Environmental Quality Commission

Dan Galpern, Attorney
Western Environmental Law Center
June 22, 2007

Members of the Commission:

Thank you for the opportunity to urge an end to field burning in the Willamette Valley.

I testify today first as the father of two young children, one of whom is just 14 months. Like other children her age, her respiratory anatomy is immature and still developing, rendering her particularly vulnerable to contaminants in the air.

I speak secondly as an attorney who has closely examined the statutory structure governing the grass seed field burning program.

Lane County's letter makes clear that field burning contributes thousands of tons of fine particulates and toxic air pollutants to the Willamette Valley airshed.

That massive infusion, in fact, is small compared to total annual pollution from all sources, but it constitutes a severe short-term load when the winds turn south and communities are inundated by the smoke plumes in which these dangerous fine particulates and toxic pollutants are concentrated.

I have no doubt that the Department of Agriculture does its best to avoid such intrusions. But, try as it might, the state is unable to predict and control the wind.

The law in Oregon authorizes the EQC to limit, restrict, or prohibit field burning by rule. ORS 468A.595. It also authorizes you to order a temporary emergency cessation of all field burning, upon your finding of "extreme danger to public health or safety." ORS 468A.610. You are vested with these authorities to protect public health even though the burn program is otherwise established in law. In other words, the legislature anticipated and expects that you will exercise independent judgment to do what is right to protect the people.

There is simply no doubt that field burning in the Willamette Valley presents an extreme and particularly acute danger to people who already suffer from asthma, chronic bronchitis, cystic fibrosis, emphysema, as well as for persons with pre-existing cardiovascular disease. These dangers are presented even by short-term exposures to high levels of PM 2.5. That, in fact, is the conclusion of a 2006 study in the Journal of the American Medical Association that is cited in the County letter. County letter at 2.

Sent: Thursday, June 21, 2007 3:43 PM
Subject: Re: county letter

Dear Peter,

Thanks for urging the Environmental Quality Commission to exercise its authority under ORS 468A.610 (9) to stop open field burning in the Willamette Valley. I was sorry to miss the hearing.

As Bill Bowerman's and Steve Prefontaine's biographer, I'm often asked how they would feel about some issue of the day. Most of the time, I haven't got a clue. They were so unpredictable, I get queasy if I try to guarantee what they would support or oppose. But on one subject, my conscience is clear. Bill and Pre ached and worked for the prohibition of field burning.

In February of 1975, Bowerman and four distance runners he'd coached to be Olympians (Prefontaine, Steve Savage, Mike Manley and I) went to Salem to testify at a state senate hearing on rye grass burning. Pre was the star witness. He told how the summer before, he'd been in the best shape of his life. He was about to leave for big races in Europe. As a final tune-up, on Sept. 4, 1974, "to blow the carbon out," as he put it (with unknowing irony), he'd scheduled a mile time trial. A thousand fans showed up to watch.

A wall of field smoke rolled in as well. You could not see the length of Hayward Field. But because of his fans, his people, Pre ran anyway. He ran 3:58.3, and finished coughing blood. His hacking tore muscle fibers under his rib cage.

He didn't realize the extent of the damage until a two-mile in London a week later. He couldn't breathe with two laps to go, and had to step nauseous into the infield. In his entire career, that was the single race he did not finish.

The facts dramatized by Pre have not changed. Field smoke is a danger to the health of the strongest as well as to the infirm. It is inescapably a medical question.

There are a host of reasons to stop. The Olympic Trials are nearing. Oregon's alone in this now, with no other state burning. But those are matters legitimately weighable against the growers' financial contributions to the economy. Those are questions of nuisance vs. benefit.

The real reason is different. The real reason is the nature of that smoke invading Oregonians' lungs.

So you may tell the EQC don't do it for me, don't do it for the memory of Bill or Pre. Do it that the health of our citizens shall be compromised no longer.

Sincerely,

Kenny Moore
2793 Kincaid St.
Eugene, OR 97405

Footnotes 1, 9, 10
14

Fact Sheet

Open Field Burning In the Willamette Valley

Background

The Oregon Department of Agriculture (ODA) Smoke Management Program regulates the burning of up to 65,000 acres of annual and perennial grass seed crop residue and cereal grain residue within the Willamette Valley each summer.

Field burning disposes of leftover straw and stubble on fields after grass seed harvesting. It controls weeds, insects and plant diseases which helps maintain grass seed purity, reduces use of pesticides and herbicides, and improves yields. The practice began more than 50 years ago, with as much as 250,000 acres being burned in the mid-1980s.

A 1988 accident on Interstate 5 involving multiple cars and causing one fatality was attributed to decreased visibility due to field burning smoke. This led to passage of House Bill 3343, which called for the phase-down of field burning from 250,000 acres to the current 65,000 acres. Currently, the state's Smoke Management Program affords greatest protection to the Willamette Valley's major population centers, but offers lesser protection to some smaller population areas.

Quick Facts:

- *The phase-down of field burning occurred from 1991 to 1998, with the acreage limit reduced from 180,000 down to 40,000 acres. The current limit of 65,000 is based on 40,000 acres plus a 25,000-acre limitation for certain fire- dependent grass species and grasses grown on highly erodable soils on steep slopes.*
- *Although state law allows the burning of 65,000 acres, over the past five years actual burning has averaged about 50,000 acres.*
- *Field burning typically starts mid-July and ends mid-October, with a majority of burning in August/early September. Most fields are not burned every year.*
- *To avoid smoke impacts in populated areas, burning is permitted only after careful evaluation of weather conditions using the latest meteorological forecasting techniques.*
- *About 75% of all the acreage is burned on just 10 to 15 days during the summer.*
- *Currently there are about 150 growers who burn in the Willamette Valley.*
- *The Smoke Management Program is funded exclusively through grower fees.*
- *In 1995, ODA was directed by House Bill 3044 to operate the entire field burning program, through a contractual agreement with DEQ.*

Health effects from smoke

Field burning smoke is comprised of several pollutants that have the potential to cause health problems, depending on the level and duration of exposure. Field burning smoke contains fine particulate matter, which can be inhaled deep into the lungs. In addition, field burning smoke contains carbon monoxide and carcinogenic compounds such as polycyclic aromatic hydrocarbons, benzene, aldehydes and metals.

While efforts are made to conduct burning under optimum smoke dispersal conditions, some field burning smoke impacts do occur. However, these impacts rarely cause air quality to exceed the federal fine particulate health standard. This is because most field burning smoke impacts are of relatively short duration, and occur during the summer months, when particulate air pollution levels are generally much lower than they are in winter months.

Although field burning is unlikely to cause violations of federal health standards, exposure to field burning smoke can still pose health risks. Short-term exposure can cause health problems for people with pre-existing respiratory problems (e.g., asthma, bronchitis and chronic obstructive pulmonary disease), or to sensitive populations such as young children and the elderly.

For the general public, short-term exposure to smoke may result in eye irritation, scratchy throat, runny nose, headaches, and allergic reactions. While little is known about the long-term health effects from exposure to field burning smoke, some research has shown health effects can range from reduced lung function to development of chronic bronchitis, and even premature death.

The Oregon Department of Agriculture, in conjunction with researchers at Oregon State University, is currently planning to conduct a human health risk assessment of field burning in the Willamette Valley. This assessment will help

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Oregon Department of Agriculture

For more information:
ODA Smoke Management Program, Salem:
www.oregon.gov/ODA/
(503) 986-4701

DHS
Oregon Department of Human Services
Contact: Ken Kauffman, Portland, (971) 673-0435

Alternative formats:
Alternative formats (Braille, large type) of this document can be made available. Contact DEQ's Office of Communications & Outreach, Portland, (503) 229-5696 (toll-free in OR at 1-800-452-4011, x5696)

07--AQ-019

Last Updated: 2/13/07
By: Brian White

characterize exposure and risk in affected communities.

Visibility effects from smoke

In addition to health effects, smoke can affect outdoor recreation activities and impair visibility or the ability to view nearby mountains and other scenic areas. Federal visibility protection rules require states to adopt smoke management plans that address outdoor burning practices like field burning and forestry burning.

The phase down in Willamette Valley field burning over the years has led to some improvements in summertime visibility in Oregon's wilderness areas and Crater Lake National Park. This improvement can also be attributed to weekend restrictions on field burning, which are in place from July 1 through Sept. 15, to protect visibility in the Oregon Cascades during the highest visitation and recreation use period.

Alternatives to field burning

In addition to smoke management, ODA manages research and development into alternatives. This includes finding ways to maintain high yields without burning, straw removal and marketing, and alternative crops. Alternatives to field burning are currently practiced throughout the Willamette Valley. These include crop rotation, chemical applications, straw removal and propane flaming. The baling and selling of grass seed straw has become an important agricultural commodity. The straw is sold all over the world as an animal feed supplement and for other uses.

Grant funding from ODA and the Oregon Seed Council (OSC) is used for research into alternatives to field burning. In 2006, ODA and OSC distributed approximately $370,000 for "Alternatives to Field Burning" research projects. ODA and OSC have funded an average of $319,000 annually in research projects since the 1999-2000 funding cycle. State tax credits are also used to provide equipment and infrastructure to promote alternatives to burning.

Minimizing smoke impacts from burning

For the 65,000 acres currently allowed for burning, ODA controls the time, amount and location of burning in order to avoid smoke intrusions into cities or impacts on the public. The best conditions for burning are when smoke rises to high elevations, disperses, and is transported away from major populated areas. This practice makes the smoke plume visible from long distances, often causing public reaction and complaints, but actually minimizes ground smoke impacts to the public.

Quick facts:

- *Growers are required to register their fields and obtain burn permits. Permits require being able to light a field within one hour. This helps ensure that the burning takes place when conditions are still favorable.*
- *Growers must follow specific burning instructions issued by ODA. ODA also maintains an enforcement program which can result in fines for violations of program rules.*
- *Growers must also meet fire safety requirements set by the State Fire Marshal.*
- *ODA uses state-of-the-art weather forecasting techniques and computer models to determine geographic locations where fields can be ignited to minimize the smoke impact on the public.*
- *Other elements of the program include a network of air monitors placed in major population centers throughout the Willamette Valley, to track air quality and smoke impacts.*
- *The program is staffed full-time by a program manager, program coordinator and meteorologist. Seasonally, the program employs two inspectors and two field coordinators.*

Complaints about field burning

ODA operates two field burning complaint lines, which are available to the public year-round. The Salem number is for callers in the north Willamette Valley; the Eugene number is for callers in the south portion of the Valley.

Salem Complaint Line: (503) 986-4709
Eugene Complaint Line: (541) 686-7600

Comments and complaints provide supplemental information on the extent and location of smoke problems. Callers may receive a tape recording asking the caller to leave a message describing the smoke problem. Complaints are compiled weekly and reported to the Governor's Office. In 2006, ODA received 1,182 complaints, up slightly from 2005's total of 1,106. In previous years the numbers of complaints were as follows: 2004 (275), 2003 (206), 2002 (705), 2001 (608).

Footnote 2, 11, 18

SUMMARY OF THE 2006 FIELD BURNING SEASON

Oregon Department of Agriculture
Natural Resources Division
Smoke Management Program

Natural Resources Division
635 Capitol Street NE
Salem, OR 97301-2532
(503) 986-4701
www.oregon.gov/ODA/NRD

In compliance with the Americans with Disabilities Act, this publication will be made available in alternate formats upon request.
TTY: 503-986-4762

Contains Recycled Materials
December 2006

The information provided in this report is accurate as of 12/31/06.

SUMMARY OF THE 2006 FIELD BURNING SEASON

Prepared By

The Oregon Department of Agriculture
Natural Resources Division
Smoke Management Program

1. Introduction

This summary is prepared at the close of each burn season by the Oregon Department of Agriculture (ODA) Smoke Management Program staff to report the statistics of each field burning season.

2. Weather Discussion

Weather in the Willamette Valley presents a multitude of challenges to operating the Smoke Management Program. Predicting weather patterns that will take smoke up, out, and away from populated areas is an inexact science. Rapidly changing winds, lower than expected mixing heights (the height of smoke rise), unpredictable smoke down mixing, and inefficient field ignition procedures executed by growers can all contribute to a given burn day's potential for smoke impacts.

Early June was rather wet (see Figure 1), which slowed maturation of the grass seed crops causing harvest to begin a bit later than usual. In late June and early July growers were occupied with combining late maturing crops. Even so, ODA was able to orchestrate a modicum of burning in mid-July by working with individual growers who were able to prepare fields quickly for burning after harvest.

There were a few very hot days during late June and July (see Figure 2) which caused State Fire Marshall (SFM) fire-safety rules* to come into effect. This precluded burning of any kind during those days. The high temperature chart for the summer shows August and early September cyclically varying between warm and cool temperatures. These transitions from warm to cool were usually "marine pushes," which allowed for widespread burning opportunities at relatively regular intervals throughout the month.

The summer of 2006 did not have persistent low-level inversions as have been prevalent in previous summers. However, there was a dominant north wind pattern which precluded field burning on many days.

In 2006, the heaviest recorded number of smoke impact hours occurred on the evening of August 8th and morning of August 9th. On August 8th, on-shore pressure gradients were predicted and pilot balloon readings indicated a favorable west wind direction for field burning. Upper air

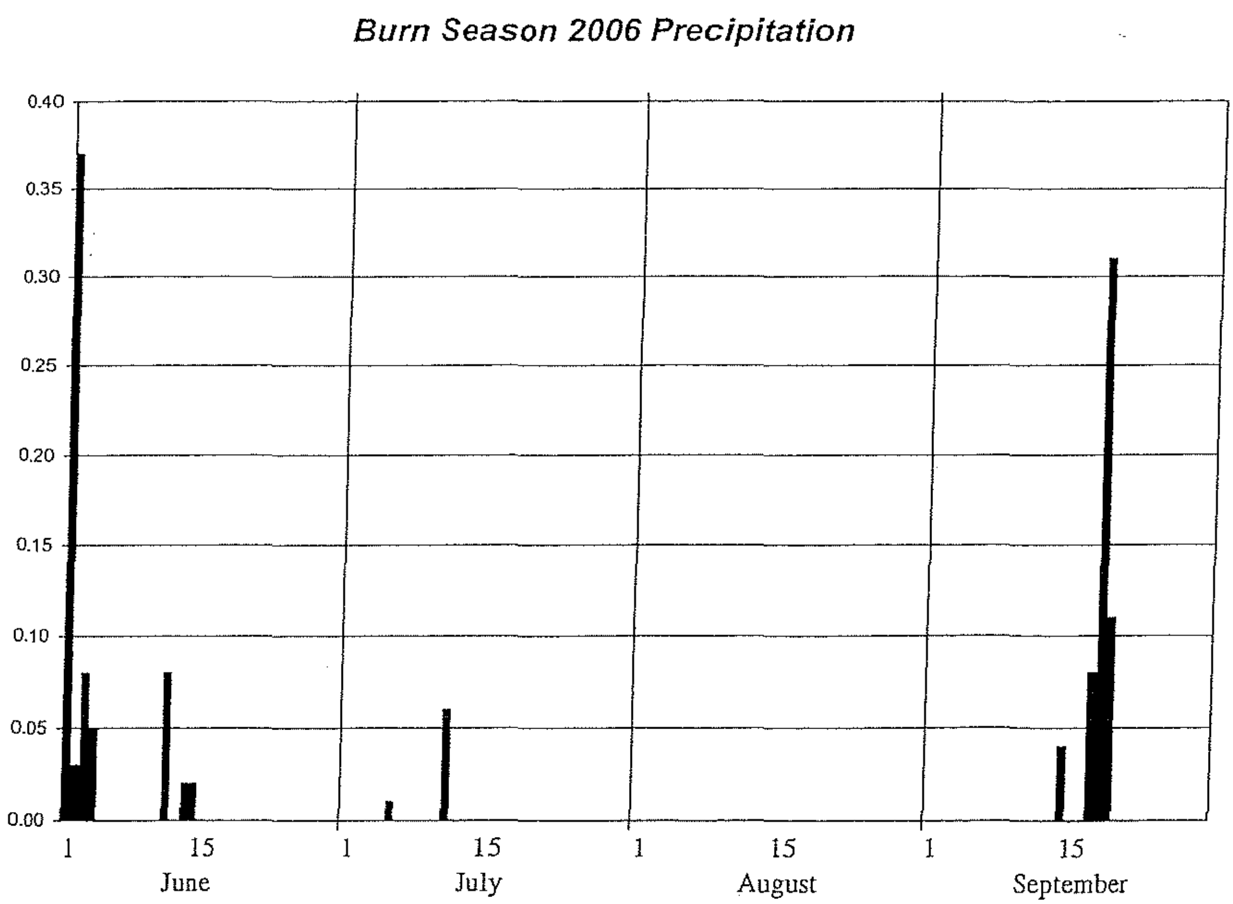
* SFM rules preclude burning on days in which any two of the following three criteria exist in the Willamette Valley: (1) temperature of 95° F or greater, (2) 30% relative humidity or less, and (3) 15 mph or greater surface winds.

charts revealed a minor short wave over northern California moving northeastward. However, it appeared that this short wave was far enough away that it would have no impact on smoke movement out of the Willamette Valley. Nearly 8,500 acres were burned on August 8th.

Unfortunately, as the short wave impulse moved northeast it altered the pressure pattern across the Cascades. Subsidence (sinking air motion) behind the axis of the trough caused a rapid rise in pressures in central Oregon. This collapsed the pressure gradient across the Cascades causing the smoke to "hang up" in the Cascades and associated foothills. As a result, the nephelometer at Lyons recorded 13 hours of smoke impact (8 hours light and 5 hours moderate). During the same period, the Sweet Home nephelometer recorded 1 hour of light impact.

ODA continues to refine techniques to identify individual fields and geographic locations which can be burned under specific weather conditions that are not conducive to large scale field burning yet can be used for limited localized burning. The addition of a third theodolite in 2006 allowed ODA to conduct mobile pilot balloon (pibal) readings in more areas throughout the Valley. A pibal is used to collect information about wind speeds and directions through the atmosphere from the surface to approximately 10,000 feet.

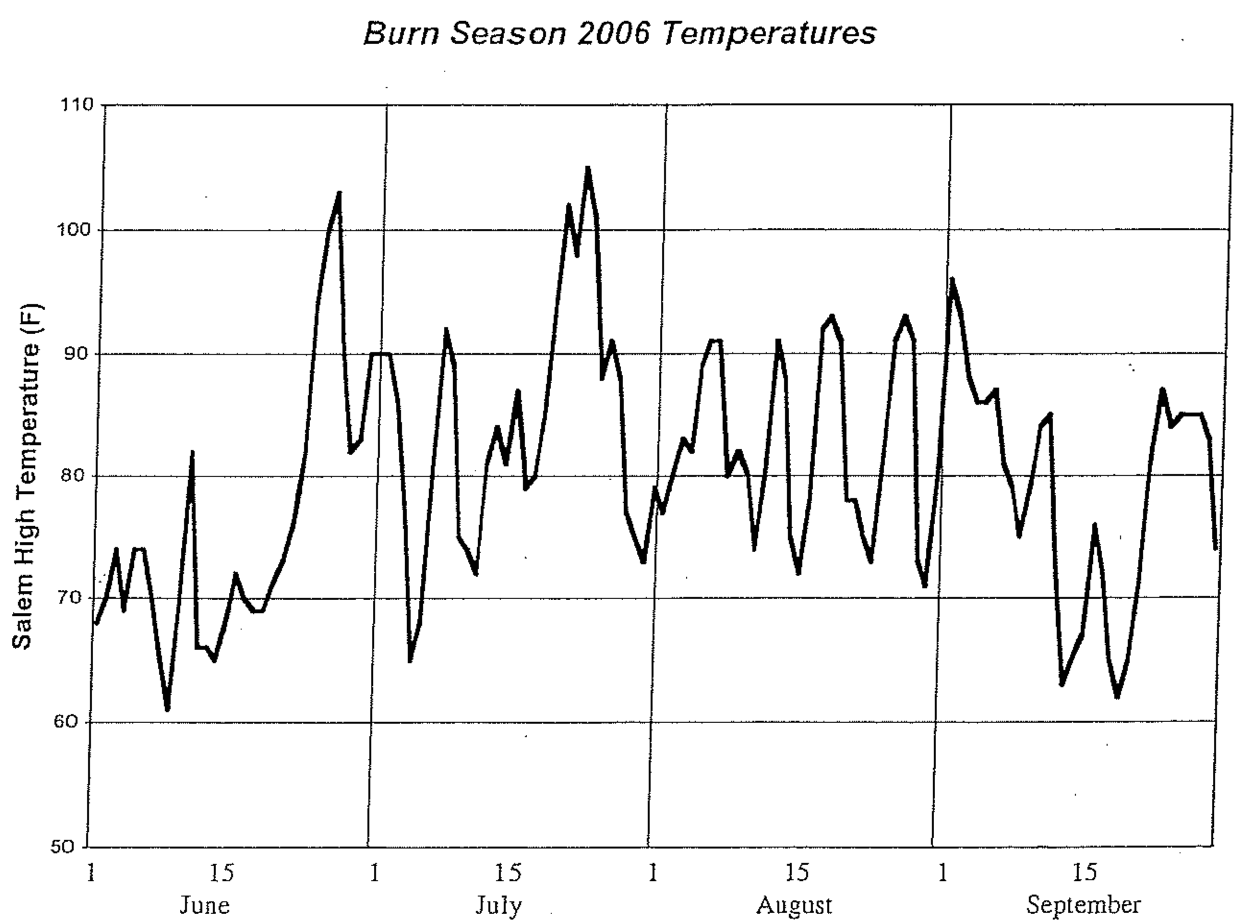
Figure 1



On August 25th, pibals were conducted on the west side of the Willamette Valley to confirm easterly winds aloft. These rare easterly winds are not suited for large-scale open field burning, but are very suitable for burning fields on the west side of the Valley. After east wind

confirmation, ODA authorized field burning on the west side of the Valley, expecting smoke to travel out over the relatively unpopulated coast range. Almost 1,700 acres were burned on the west side on the 25th. Unfortunately, one 62-acre field burn north of Corvallis was not ignited with "rapid ignition" techniques and produced a large amount of ground smoke. As such, this smoke did not rise into the easterly wind layer. Instead, it drifted southward on surface winds producing one hour of heavy smoke impact, and an inordinate number of complaint calls from Corvallis and some communities to the south.

Figure 2



3. Four-Day Burn Percentage

During the 2006 field-burning season, 56% of all the acreage open field burned occurred over 4 days. This compares with 53% of all acreage burned over 4 days in 2005. The chart below outlines the 2006 figures.

Tues. 8/8/06	Thu. 8/10/06	Mon. 8/28/06	Fri. 9/8/06	**4 Day Total**	**Percent**
8,412	5,275	7,018	6,932	**27,637**	**56%**

4. Registered Acres

Open field burning and propane flaming acreage pre-registration began on March 17th and continued through April 1st. The chart below shows the breakdown of acres registered by type, the statutory limitation of each type, and the final allocation of each type as imposed by the statutory limitation.

Type	**Limitation**	**Acres Registered**	**Allocation**
Regular	40,000	96,962	41%
Identified Species	22,000	16,294	100%
Steep Terrain	3,000	1,041	100%
Propane Flame	37,500	2,439	100%

Definitions

Type: Open Field Burning

- **Regular:** Perennial or annual grass seed, or cereal grain residue.
- **Identified Species:** Research has identified some species of grass seed that cannot be profitably produced without thermal sanitation. These identified species are Chewings Fescue, Creeping Red Fescue, and Highland Bentgrass.
- **Steep Terrain:** Locations in the Willamette Valley where grass seed is grown, but because of the steepness of the terrain, it is extremely difficult to apply alternatives to open field burning.

Type: Propane Flaming

- The process of sanitizing (burning) regular and identified species fields with a propane flamer; a mobile, fire-producing, sanitation device.

5. Open Field Burning

In the 2006 field burn season, a total of 114,297 acres were registered for open field burning compared to 114,299 in 2005. Registration included 96,962 acres of regular, 16,294 acres of identified species, and 1,041 acres of steep terrain. Regular registration exceeded the legislatively mandated limitation of 40,000 acres; therefore, the regular open field burning allocation rate for 2006 was 41%. The allocation rate for identified species and steep terrain for 2006 was 100%.

A total of 49,017 acres were open field burned during the 2006 burn season (34,971 regular limitation, 13,375 identified species, and 671 steep terrain). By comparison, a total of 49,225 acres were burned in 2005, 49,553 acres in 2004, 50,437 acres in 2003, and 51,374 acres in 2002.

2006 Open Field Burning by Crop

Species	Burned (acres)	% Of Total
Annual Ryegrass	27,640	56.39%
Chewings Fescue	8,714	17.78%
Perennial Ryegrass	4,867	9.93%
Creeping Red Fescue	3,824	7.80%
Tall Fescue	1,649	3.36%
Cereal Grain	970	1.98%
Highland Bentgrass	837	1.71%
Orchardgrass	299	0.61%
Fine Fescue	217	0.44%
TOTAL	**49,017**	**100%**

6. Propane Flaming

The maximum allowable acreage to be propane flamed is 37,500 acres (as set by the 1995 Oregon Legislature). In 2006 growers registered 2,439 acres of fields to be propane flamed and burned 1,466 of those registered acres. This compares to 1,631 acres propane flamed in 2005, 1,067 acres in 2004, 1,602 acres in 2003, and 1,582 acres in 2002.

2006 Propane Flame Burning by Crop

Species	Burned (acres)	% Of Total
Creeping Red Fescue	653	44.54%
Perennial Ryegrass	351	23.94%
Chewings Fescue	242	16.51%
Cereal Grain	100	6.82%
Kentucky Bluegrass	85	5.80%
Tall Fescue	35	2.39%
Highland Bentgrass	0	0%
Orchardgrass	0	0%
Fine Fescue	0	0%
TOTAL	**1,466**	**100%**

7. Stack Burning

Stack burning does not have an imposed acreage limitation, nor is registration required. Growers are obligated to secure a stack burning permit containing the responsible party's name, location of the burn, and acreage represented by the accumulated residue prior to ignition. The stack burning season lasts from April 1st to March 31st of the following year. As of October 31, 2006, growers had stack burned 1,061 acres since April 1, 2006. Previous years are as follows:

Historical Stack Burn Statistics

Year	Interim – October 31st	Final – March 31st
2006-2007	1,061	N/A
2005-2006	1,366	1,692
2004-2005	1,667	1,864
2003-2004	1211	1,636
2002-2003	616	1018

8. Total Thermal Residue Management

The chart below shows the figures for total thermal residue management, including stack-burning acreages.

Burn Type	2006	2005	2004	2003	2002
Open Field Burning	49,017	49,225	49,553	50,437	51,374
Propane Flaming	1,466	1,631	1,067	1,602	1,582
Stack Burning[†]	1,399	1,692	1,864	1,636	1,018
Total	**51,882**	**52,548**	**52,484**	**53,675**	**53,974**

9. Enforcement

The 2006 burn season marked the tenth year that the department has performed the enforcement function of the Smoke Management Program (as stipulated under a Memorandum of Understanding with the Oregon Department of Environmental Quality, Pursuant to Oregon Revised Statutes 468A.585).

There were 5 enforcement contacts during the 2006 season (as of October 31, 2006). This compares with 17 enforcement contacts during the 2005 season, 21 contacts in 2004, 2 contacts in 2003, 11 contacts in 2002, and 10 contacts in 2001.

Of the 5 enforcement contacts in 2006, all of them resulted in letters of warning; none resulted in notices of non-compliance, and none resulted in civil penalty assessments.

10. Smoke Impacts

It is the goal of the ODA Smoke Management Program, with the cooperation of the Willamette Valley growers, to reduce or eliminate smoke impacts in populated areas.

The combination of accurate weather prediction for burning, ODA field personnel observations, and grower experience all contribute to alleviate smoke impacts. However, smoke impacts still occur. Unexpected wind shifts, rapidly changing mixing heights, rapidly decreasing transport

[†] Estimated Total Stack Burn Acreage (April 1, 2006 – March 31, 2007)

The information provided in this report is accurate as of 12/31/06.

wind speeds and directions, other meteorological factors and inefficient lighting techniques all contribute to the occurrence of impacts.

Smoke intrusions attributable to open field burning occurred on 7 days in 2006. Previous years totals included 15 days in 2005, 10 days in 2004, 9 days in 2003, and 9 days in 2002.

The number of hours of recorded smoke impact‡ in cities monitored for smoke in 2006 are outlined below.

2006 Open Field Burning Impacts

Date	Acres Burned	Impact Hours			Location
		Heavy	Moderate	Light	
8-Aug	8,412		5	8	Lyons
8-Aug	8,412			1	Sweet Home
15-Aug	107			1	Sweet Home
21-Aug	3,833		2		Lyons
21-Aug	3,833			1	Sweet Home
23-Aug	1,097			1	Lyons
25-Aug	1,699	1			Corvallis
28-Aug	6,915		1		Lyons
28-Aug	6,915		1		Sweet Home
8-Sep	6,932			2	Lyons
8-Sep	6,932		2	2	Sweet Home

11. Complaints

Open field burning complaints received from Willamette Valley residents by the Smoke Management Program§ totaled 1,182 during the 2006 field-burning season. This compares with 1,106 complaints received for the 2005 season, 475 in 2004, 206 in 2003, 705 in 2002, and 608 in 2001.

‡ As defined in Oregon Administrative Rule (OAR) 603-077-105, cumulative hours of smoke impact result in hourly nephelometer measurements that exceed 1.8×10^{-4} b-scat above the average prior 3-hour background levels. For the purposes of this report, "heavy" hours of smoke impact are 5.0×10^{-4} b-scat or more above background (equivalent to visual range of 5 miles or less), "moderate" hours of smoke impact are 1.8×10^{-4} to 5.0×10^{-4} b-scat above background (equivalent to visual range of 12 miles or less), and "light" hours of smoke impact are 1.0×10^{-4} to 1.8×10^{-4} b-scat above the background. "Light" hours of smoke impact were not recorded prior to the 1999 season. The terms "light," "moderate," and "heavy," as used in relation to smoke impacts, are not defined in OAR, but are used by ODA to quantify the level of smoke impact on residents of the Willamette Valley. Nephelometers are located in Portland, Eugene, Springfield, Sweet Home, Lyons, Corvallis, Salem, and Carus.

§ Complaints received by the Lane Regional Air Protection Agency (LRAPA) are forwarded on to ODA at the end of every week during the field burning season. Those complaints are also included in the total presented in this report.

The information provided in this report is accurate as of 12/31/06.

2006 Open Field Burning Complaints by City

Albany	8	Noti	17
Brownsville	10	Portland Metro	0
Corvallis	75	Salem/Keizer	16
Cottage Grove/Lorane	13	Scio	3
Creswell	27	Silverton	7
Eugene	275	Springfield	65
Harrisburg	16	Stayton	19
Junction City/Monroe	49	Sublimity	6
Lebanon	59	Sweet Home	36
Lyons/Mehama	11	Veneta/Elmira	107
Mill City/Gates	27	Other	160
Mohawk Valley	131	Unknown	45
		Total	**1,182**

Breakdown of 2006 Open Field Burning Complaint Calls**

ODA tracks the number of complaint calls by individuals to determine the amount of repeat callers. Information is recorded by ODA in order to prevent the results from being skewed by multiple calls from one individual.

Number of People	Times Called	Number of Complaints
649	1	649
100	2	200
24	3	72
10	4	40
7	5	35
2	6	12
3	7	21
1	8	8
1	10	10
1	12	12
1	16	16
107	Unknown	107
	Total	**1,182**

** Chart outlines the number of individuals and how many times they called. For example; 3 people called 7 times each for a total of 21 complaints. 107 callers chose not to provide identifying information and, therefore, it is unknown if those callers called multiple times.

The information provided in this report is accurate as of 12/31/06.

5 Year Historical Comparative Open Field Burning Data

Season	2006	2005	2004	2003	2002
Acres Registered[††]	116,328	114,299	91,933	83,695	79,679
Acres Burned	49,017	49,225	49,553	50,437	51,374
Most burned in one day	8,412	9,311	10,252	8,617	9,994
Burn days accounting for 75% of total acres	7	10	7	9	6
Weekend burn days allowed	0	0	1	0	0
Number of Burn Days[‡‡]					
300 – 999 acres burned	15	15	8	11	2
1,000 – 4,999 acres burned	5	10	5	8	8
5,000 – 9,999 acres burned	4	2	3	3	4
10,000 or greater burned	0	0	1	0	0
Total Burn Days	**24**	**27**	**17**	**22**	**14**
Smoke Impact Hours total/heavy/mod/light(#days)[§§]	**2006**	**2005**	**2004**	**2003**	**2002**
Portland	0/0/0/0	0/0/0/0	0/0/0/0	0/0/0/0	0/0/0/0
Salem	0/0/0/0	0/0/0/0	0/0/0/0	0/0/0/0	0/0/0/0
Corvallis	1/1/0/0	0/0/0/0	0/0/0/0	0/0/0/0	0/0/0/0
Carus	0/0/0/0	0/0/0/0	1/0/1/1(1)	0/0/0/0	0/0/0/0
Lyons	8/0/8/11(5)	14/0/14/25(14)	5/1/4/5(5)	4/0/4/10(6)	3/0/3/11(4)
Sweet Home	3/0/3/5(5)	0/0/0/1(1)	2/0/2/9/(4)	2/0/2/2(3)	5/0/5/16(4)
Eugene	0/0/0/0	1/0/1/1(2)	0/0/0/0	0/0/0/0	0/0/0/0
Springfield	0/0/0/0	4/0/4/3/(3)	0/0/0/0	0/0/0/0	0/0/0/1(1)
Total (day total is of individual days not of days at each location)	12/1/11/16(7)	19/0/19/30(15)	8/1/7/15/(10)	6/0/6/12(9)	8/0/8/28(9)

†† All registered regular, identified species, and steep terrain open field-burning acres plus registered propane acres.

‡‡ Days with less than 300 acres burned are not counted as open field burning days.

§§ As defined in Oregon Administrative Rule (OAR), total hours of impact include hourly nephelometer measurements exceeding 1.8×10^{-4} b-scat above prior 3-hour background. For the purposes of this report, "heavy" hours of smoke impact are 5.0×10^{-4} b-scat or more above background (equivalent to visual range of 5 miles or less), "moderate" hours of smoke impact are 1.8×10^{-4} to 5.0×10^{-4} b-scat above background (equivalent to visual range of 12 miles or less), and "light" hours of smoke impact are 1.0×10^{-4} to 1.8×10^{-4} b-scat above the background. "Light" hours of smoke impact were not recorded prior to the 1999 season. The terms "light," "moderate," and "heavy," as used in relation to smoke impacts, are not defined in OAR, but are used by ODA to quantify the level of smoke impact on residents of the Willamette Valley. Nephelometers are located in Portland, Eugene, Springfield, Sweet Home, Lyons, Corvallis, Salem, and Carus.

The information provided in this report is accurate as of 12/31/06.

Footnote 3

PAUL R. HOLVEY
STATE REPRESENTATIVE
DISTRICT 8

HOUSE OF REPRESENTATIVES

To: House Agriculture and Natural Resources Committee
Date: April 30, 2007

Chair Roblan and Committee Members,

Thank you for hearing House Bill 3000. This bill prohibits open field burning, stack burning, pile burning, and propane flaming. It does allow for open burning of agriculture waste under permit and authority of the Department of Environmental Quality (DEQ). The bill also establishes the Smoke Management Program and the Open Burning Management Account under the Authority of the DEQ.

I have provided each of you with a packet of information. In this binder you will find information about fine particulate matter and its impact on health as well as information about alternatives that growers can and already use. I will reference many of these documents from this packet.

I introduced this legislation because of the extreme threat to the public health of Oregonians as a result of agricultural field burning. Since introducing HB 3000 I have heard from thousands of individuals across the state and many organizations all in support of eliminating field burning. Amongst those organizations are the Lane County Medical Society, the Oregon Medical Association, the American Lung Association of Oregon, the Oregon Lung Specialists, the Lane Regional Air Protection Agency, the City of Eugene and the Lane County Board of Commissioners.

There is clear and convincing scientific evidence that both long-term and short-term exposure to fine particulates and smoke have significant adverse human health effects. The emissions from field burning grass residues contain a mixture of solid and liquid particles, which include particulate matter, carbon monoxide, methane, and toxics like Acetaldehyde, Acrolein, Benzene, Butadiene, Formaldehyde, Methyl Chloride, Toluene, and Xylenes. The particulate matter is both large coarse particulates and fine particulates. Unlike the coarse particulate matter, fine particulates lodge deep in the lungs and the body's defenses are unable to remove them. Toxics from the emissions recombine and attach to these fine particulates.

To realize how detrimental smoke and fine particulate matter is to human health, one need only look at the extensive scientific research. The Journal of the American Medical Association states that "Even short-term exposure to fine particulate air pollution has been found to increase the risk for hospital admissions for cardiovascular and respiratory ailments." A study done in Washington State notes that "Epidemiological evidence has established a clear link between small airborne particles and health, particularly for an at-risk population comprising people with existing pulmonary conditions such as asthma, emphysema, chronic bronchitis or heart disease." The EPA, in a fact sheet about fine particulate matter states that "many scientific studies have found an association between exposure to particulate matter and a series of significant health problems, including: aggravated asthma; chronic bronchitis; reduced lung function; irregular heartbeat; heart attack; and premature death in people with heart or lung disease."

Statistics used to track these impacts, such as hospitalization rates for asthma, fall short of tracking the full impact. Hospitalization rates only capture on visit per person even if the same person comes in multiple times, cite asthma as the primary diagnosis even though we know that other cardiovascular and respiratory problems like bronchitis can result, and do not include visits people make to their doctor.

Office: 900 Court St NE, Salem, OR 97301 -- Phone: 503-986-1408 -- rep.paulholvey@state.or.us
District: PO Box 51048, Eugene, OR 97405 -- Phone: 541-344-5636

Footnote 3

Beyond these statements and data, there have been deaths in both Idaho and Washington that have been directly linked to exposure to field burning smoke, not to mention numerous traffic deaths and accidents caused by smoke. In your packet, exhibit E, you will find an affidavit from Henry D. Covelli, M.D. In this affidavit he states that he has "witnessed the immediate death of one patient who was exposed to field burning and experienced immediate respiratory difficulty and expired as a result of an exacerbation of his disease." In your packet I have also included an article "Fields of Fire" which talks about one specific death from field burning smoke.

I think it is also important to briefly talk about the effectiveness of smoke management and monitoring of the emissions from field burning. Smoke management is intended to burn when conditions are favorable in directing the smoke plumes away from the more densely populated areas. However, smoke management and conditions are not always predictable. This practice means that many of our smaller communities are literally designated as sacrifice zones.

The measurements data, and standards used by both the EPA and the DEQ are very site specific and most often based on averages that do not reflect the extremely high levels that much of our population is being subjected to. And frankly our smaller communities do not breathe averages.

Studies show that the smoke and fine particulate matter from field burning is a problem, but just how big of a problem is it? Throughout this debate you have heard, and will probably hear again today, that field burning contributes only 2% of the particulate pollution in the Willamette Valley annually. You have to be careful when looking at this statistic. First, directly after citing the 2% statistic, the DEQ states that "Occasional, short-term particulate sources such as field burning or prescribed field burning can have adverse health impacts on the public, especially sensitive groups like asthmatics." More importantly though, this statistic uses coarse particulate matter when calculating emissions totals. But, as I noted earlier, fine particulate matter is what causes the most harm.

When one looks at fine particulate matter pollution from field burning, a different picture emerges. During the season when growers burn their fields, exhibit H in your packet; they produce 40 percent of the total fine particulate matter in the Willamette Valley. On the four days when about half the total acreage is burned, open field burning produces 64 percent of the total fine particulate matter in the Willamette Valley. To put these numbers in perspective, mobile vehicles and equipment, the cars you and I drive, produce only 6 percent during the entire field burning season and 4 percent of the total fine particulate matter pollution on the largest burning days. To get the equivalent amount of pollution from vehicles on those four largest burning days we would have to increase the number of vehicles on the road by a factor of 16.

Another way to look at the scale of pollution is to examine the aggregate totals of pollutants that are produced. Over the course of the 2006 field burning season, growers produced almost 13,000 tons of pollutants. On the four biggest burning days in 2006, growers produced more than 770 tons of fine particulate matter, 4,885 tons of carbon monoxide, and more than 676 tons of toxics like benzene and formaldehyde. During those four days, the amount of carbon monoxide generated from burning equaled half the yearly amount produced by the largest smokestack polluter in the Southern Willamette Valley.

These statistics show that field burning smoke is not just a minor contributor of pollution in the Willamette Valley. When we combine these numbers with the scientific evidence about short-term exposure, it becomes apparent that field burning is a major threat to public health in Oregon.

Footnote 3

Thus far I have spoken to you about how field burning impacts a person's health and how much pollution is created and monitored. Now I want to examine how reducing and eliminating open field burning has impacted growers and discuss the available alternatives that many growers are already utilizing.

Today growers can burn up to 65,000 acres, but in 2006 they burned about 49,000 acres. That is less than 10% of the total acres of grass seed grown in Oregon today. As you will see from this chart and exhibit N in your packet, since the legislature began limiting the amount of acreage that can be burned, the total number of acres grown in the Willamette Valley has **increased** from roughly 375,000 in 1991 to just under 500,000 acres today. Sales have increased even more with sales reaching $481 million in 2006. That is more than double the total sales of $175 million in 1991.

This story is not unique to Oregon. Since eliminating the practice of grass seed burning in Washington State, yields of grass seed and legume production have increased by almost 50% from 500 lbs per acre to 740 lbs per acre. Production has increased from 250,000 CWT to 350,000 CWT, and the value of production has increased from $17.5 million in 1998 to $28 million in 2006. In addition to these benefits to seed growers, if you turn to exhibit M, researchers in Washington State found that eliminating field burning made good public health policy with probable benefits totaling $8.4 million versus $5.6 million in probable costs.

The grass seed industry is not the only industry impacted by field burning. Among the complaints I have received have been from people who bring friends and family to Oregon, only to have their trip ruined by the smoke from field burning. Oregon's tourism industry depends on our natural resources and outdoor activities to attract visitors to our state. These tourism activities contribute more than $6 billion in direct travel spending to the State.
Oregon's wine tourism industry, an industry impacted by field burning smoke, is a growing segment of the market that contributed $95 million to the economy in 2004.

These numbers do not show an industry ruined by not burning. Rather, they show an industry that has successfully adapted and developed economically viable alternative methods of managing residue. Research has shown that burning is not needed to preserve yields in many types of grasses grown in Oregon. Looking at Exhibit O, it reads that "Chastain et al. (2000) found that growing cool-season perennial grass seed crops without open-field burning did not reduce seed purity or germination in trials conducted over a six year period in Oregon."

Oregon has invested millions of dollars on tax credits to develop sustainable alternatives to field burning. Among these alternatives that growers are using and can use are removing and baling straw for resale, retaining grass seed residue on the field as compost or animal feed, planting alternative crops like meadowfoam, and using residue as an ingredient in the production of celluosic ethanol.

Post harvest grass seed residue is valuable commodity for growers. This straw can be baled and removed to be sold as livestock feed or as a way of protecting against soil erosion on fields, roadsides, and on hills following forest fires. Since reducing the acreage that can be burned, growers have taken advantage of this market opportunity and today Oregon exports 650,000 tons of straw, with a sales value of $65 million, to countries throughout Asia.

Second, growers can retain straw on their fields using a process called full straw management. Full straw management is a common practice that is already being utilized by many growers throughout the Southern Willamette Valley. This method returns valuable nutrients and moisture to

Footnote 3

the soil, protects against erosion, and helps fight against weeds. As noted earlier, research has shown that full straw management does not reduce seed yield or purity for many types of grass seed grown in Oregon.

Third, growers can rotate their grass seed crops with alternatives like meadowfoam. Meadowfoam seed oil is valuable commodity that has a variety of applications in the $27.1 billion cosmetics industry and industrial uses as a lubricant. Looking in your packet in exhibit Y you can also see that meadowfoam has additional benefits for growers in fighting weeds and preserving moisture in the soil. For growers meadowfoam is also grown in another season than grass seed and most of the equipment used to harvest the plant is the same used in grass seed meaning that farmers can grow it with a minimum of new investment in intrusion with other scheduled growing.

Lastly, as Oregon and the United States face an era of rising energy consumption, uncertainty about supply, and increasing environmental awareness, grass seed straw represents a valuable commodity for conversion to cellulosic ethanol. Recognizing this energy future, President Bush ahs called on the United States to reduce oil imports by more than 75% by 2025. The U.S. Department of Agriculture has stepped up to meet this goal, doubling funding research for cellulosic ethanol.

Oregon is ready to meet the cellulosic ethanol challenge. With more than 1 million tons of post harvest grass seed produced each year, roughly 500,000 of which is burned or retained on the soil, Oregon has the raw ingredients for production. In fact, a report by Oregon Department of Energy, Exhibit Z in your packet, found that Oregon "grass straw residues are well suited for conversion to ethanol." When combined with the alternative tax credits available to growers to find alternatives, production becomes attractive and feasible.

I have introduced an amendment to HB 3000 that you should each have a copy of before you. This amendment eliminates open field burning of grass seed in the Willamette Valley with the exception of a limited number of acres in the Silverton Hills that require burning to maintain yield and purity. Agricultural burning of such items as mint stubble and Christmas tree residue would be allowed with a permit issued by the DEQ. It also creates standards of monitoring for particulate matter by DEQ in conjunction with DHS.

Given that this information is available and known, I believe it is incumbent on the State of Oregon to end the unnecessary practice of field burning, whether it is accomplished by the Executive Branch, the Legislative Branch, or the Judicial Branch, it needs to happen, and I believe it would be negligent if this Legislature or Executive branch do not end field burning this year.

Mr. Chair and Members of the Committee, I urge you to pass House Bill 3000 and make every effort to ensure it is enacted into law. Thank you.

Respectfully,

Paul Holvey
State Representative
District 8

Lane County Board of Commissioners

Bill Dwyer
Bill Fleenor
Bobby Green, Sr.
Peter Sorenson
Faye Hills Stewart

June 19, 2007

Environmental Quality Commission
811 SW Sixth Avenue
Portland, OR 97204-1390

Dear Members of the Commission:

On behalf of the Lane County Board of Health and the Lane County Board of Commissioners, we write to urge the Commission to exercise its authority under ORS 468A.610(9) to order a temporary cessation of open field burning in the Willamette Valley.[1] This action is needed to protect the lives and health of Lane County residents and others throughout the state who otherwise will be subjected to the public health danger of smoke inhalation and related toxic substances generated by field burning this summer.

The annual practice of field burning of grass seed residue,[2] conducted under the auspices of the Oregon Department of Environmental Quality and the Oregon Department of Agriculture, injects tons of fine particulates[3] and chemicals associated with incomplete combustion into the public airshed. It therefore presents a danger to public health and safety, particularly for downwind residents who already suffer from respiratory illnesses including asthma and chronic obstructive pulmonary diseases, those who suffer cardiovascular disease or diabetes, children under 18 – whose lungs are still developing,[4] and elderly residents.

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[1] In Oregon, grass seed is grown by 1,400 growers on over 500,000 acres, 460,000 of which are in the Willamette Valley. Oregon Seed Council, *Oregon Seed Industry – Fact Sheet* (updated 12/6/2004). The Oregon Departments of Environmental Quality (DEQ), the Agriculture (DOA), and Human Services (DHS) report that about 150 growers in the Willamette Valley burn their fields. *Open Field Burning In the Willamette Valley* (updated 2/13/2007). Accordingly, the vast majority of Oregon grass seed growers do not engage in field burning.

[2] Acreage of grass seed fields burned in Oregon, although reduced from levels of the 1980s, remains substantial. In 2006, nearly 52,000 acres were subjected to thermal residue treatment, of which approximately 49,000 acres were open-burned. Oregon Department of Agriculture, *Summary of the 2006 Field Burning Season* (Dec. 2006) 5-7.

[3] A recent study of emissions produced by Kentucky Bluegrass seed field burning noted that the 56 to 58 lbs of PM 2.5 produced per ton of residue consumed greatly exceeded that reported for most other agricultural burns, as well as that produced in wildfires and forest fires. Johnston and Colob, Washington State University, *Quantifying Post-Harvest Emissions from Bluegrass Seed Production Field Burning* (March 2004) 26. Where residues had not been reduced by baling, burning consumed a total of 3.2 tons of total material per acre. *Id.* at III. Research provided by the Department of Environmental Quality to Representative Paul Holvey in April, 2007, shows that during the field burning season, 40 percent of fine particulate pollution in the Willamette Valley is attributable to field burning, while during the four days of greatest burning, when about 50 percent of field burning occurs, smoke from the burning fields contributes 64 percent of fine particulate emissions. (DEQ research retained in the files of the Western Environmental Law Center). While the Department of Agriculture, which manages the field burning smoke program, intends for much of this smoke to disperse and not impact local communities, DEQ and DOA both acknowledge that impacts at times occur despite best intentions. According to other research released by Rep. Holvey's office, on the four days of major field burning, the ensuing smoke contributes 770 tons of fine particulates, 4,885 tons of carbon monoxide, and more than 676 tons of toxic air pollutants. Holvey letter to the Oregon Agriculture and Natural Resources Committee (April 30, 2007).

[4] Particulate pollution has been linked to infant death, premature birth, and low birth weight. American Academy of Pediatrics Committee on Environmental Health, Ambient Air Pollution: Health Hazards to Children. *Pediatrics*

Oregon's present field burning program was developed in the early 1990's without full knowledge of the dangers presented by smoke that entrains fine particles. The medical evidence, now, is overwhelming. Particulates less than 2.5 micrometers in diameter (PM 2.5) are too small to be filtered effectively by the upper respiratory system.[5] They can travel to the alveoli at the base of the lungs and impact the cardiopulmonary and cardiovascular systems. Exposure to PM 2.5 has been found to aggravate asthma, chronic bronchitis, cystic fibrosis and emphysema, and has been implicated in reduced lung function, irregular heartbeat, heart attack[6] and premature death in people with cardiovascular disease.[7] A 2006 study in the Journal of the American Medical Association found that even short-term exposure to PM 2.5 increases the risk for hospital admission for cardiovascular and respiratory diseases.[8] Oregon state agencies similarly acknowledge that field burning can result in serious public health impacts.[9] While additional studies of the health impacts of field burning smoke could quantify the numbers of additional illnesses and deaths attributable to Oregon's program,[10] there is ample evidence presently in existence.

Under state law, the Oregon Department of Agriculture (ODA) regulates the practice of field burning in the Willamette Valley to reduce smoke impacts on populated areas, but its success is limited by "unexpected wind shifts, rapidly changing mixing heights, rapidly decreasing transport wind speeds and directions, other meteorological factors and inefficient lighting techniques."[11] Incursions into heavily populated areas of the Willamette Valley are

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2004; 114: 1699-1707. According to the American Lung Association of Oregon, "[c]hildren's lungs develop mostly after they're born and air pollution from burning can affect the ability of [their] lungs to develop normally, leading to a lifetime of breathing problems. Children are also outside more than adults, so they risk breathing more of this pollution." Letter to Oregon House of Representatives Health Care Committee (April 6, 2007).

[5] In addition to both coarse and fine particulates, the smoke from grass seed burning "contains a complex mixture of chemicals, known carcinogens such as benzene and acrolein." Lane County Medical Society letter to state legislators (April 5, 2007). The smoke also contains chemicals that are usually associated with the process of incomplete combustion, including polycyclic aromatic hydrocarbons (PAHs), phenols, and volatile organic compounds (VOC). Grass Seed Field Smoke and Its Impact on Respiratory Health, *Environmental Health* (June 1998) 10-11.

[6] Increased Particulate Air Pollution and the Triggering of Myocardial Infarction, *Circulation* (June 12, 2001) 2810-2815.

[7] EPA, *Fact Sheet: Final Revisions to the National Ambient Air Quality Standards for Particle Pollution (Particulate Matter)*, 1, (September 21, 2006), http://epa.gov/pm/pdfs/20060921_factsheet.pdf (last visited June 14, 2007). Oregonians may be particularly vulnerable to field burning smoke in light of the state's relatively high incidence of asthma. Oregon Asthma Program, *Oregon Asthma Surveillance Summary Report*, 12 (March 2007), http://oregon.gov/DHS/ph/asthma/docs/report.pdf (last visited January 26, 2007). Oregonians have the 4th worst prevalence of asthma in the nation. Behavioral Risk Factor Surveillance System, *Prevalence Data: Asthma 2005*, http://apps.nccd.cdc.gov/brfss/list.asp?cat=AS&yr=2005&qkey=4416&state=All (last visited June 14, 2007).

[8] Journal of the American Medical Association, *Fine Particulate Air Pollution and Hospital Admission for Cardiovascular and Respiratory Diseases* (March 8, 2006).

[9] The Oregon Departments of Environmental Quality (DEQ), Agriculture (DOA), and Human Services (DHS) note that although field burning events are too brief in duration to violate federal air quality standards, exposure "can still pose health risks" including, for the general public, "eye irritation, scratchy throat, runny nose, headaches, and allergic reactions" and serious problems "for people with pre-existing respiratory problems" or for "sensitive populations such as young children and the elderly." *Open Field Burning In the Willamette Valley* (updated 2/13/2007).

[10] *Open Field Burning In the Willamette Valley*, op. cit. note. 1, states that the "Oregon Department of Agriculture, in conjunction with researchers at Oregon State University, is currently planning to conduct a human health risk assessment of field burning in the Willamette Valley."

[11] Oregon Department of Agriculture, Natural Resources Division, Smoke Management Program, *Summary of the 2006 Field Burning Season*, 7-8 (December 2006), www.oregon.gov/ODA/NRD/docs/pdf/smoke_fb_sum2006.pdf, (last visited June 14, 2007).

common during the burn season. The Lane Regional Air Protection Agency (LRAPA) reports that one-third of the 1,030 air pollution complaints it receives annually on average are related to field burning.[12] Eugene, Springfield and other highly populated areas of Lane County are frequently impacted by smoke intrusions, a function of prevailing southerly winds and upper valley air stagnation. Surrounding communities of relatively lower population density, including Sweet Home, Mill City, and Harrisburg, among others, also suffer heavy intrusions because they are frequently in the pathway of the smoke plumes. Oregon's smoke management plan suffers the "critical defect" found in the State of Washington's smoke management plan: it is virtually impossible to predict wind behavior over a period of a few hours and "the outcome of any smoke management plan ... comes down to a choice as to which group of people is going to be the target."[13]

Since 1990, in conjunction with the grass seed industry, the state has funded over $300,000 annually for research into alternatives to field burning.[14] The state has also provided tax credits for growers to purchase equipment to promote alternatives to burning.[15] Markets for grass seed straw and practical, reasonable alternatives to burning have been developed.[16] And yet, although state public policy is "to reduce the practice of open field burning while developing and providing alternative methods,"[17] the numbers of acres burned has remained virtually unchanged since 1998,[18] while the population in downwind towns and cities has increased.

State law prohibits Lane County and other local governments from directly protecting the health of their residents by barring regional agencies, including the Lane Regional Air Protection Agency (LRAPA), from issuing their own restrictions on field burning.[19] State law also requires that permits for burning "shall be issued and burning shall be allowed for the maximum acreage specified" in the statute.[20] However, as noted, the law also authorizes the EQC to order a temporary emergency cessation of the program upon a finding of extreme danger to public health or safety. ORS 468A.610(9). We urge you to make the finding of a public health threat and exercise your power under ORS 468A.610(9) as the most direct means of protecting Lane County residents and other Oregonians this summer and next.[21] We note, in addition, that the relevant statutes invest in the Commission authority and responsibility:

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[12] LRAPA also reports that two-thirds of the complaints received by the Oregon Department of Agriculture are from the Eugene-Springfield areas and other parts of the southern Willamette Valley. LRAPA letter to Representative Paul Holvey, (November 15, 2006).

[13] Declaration of Eric Skelton, Director of the Spokane (WA) County Air Pollution Control Authority and National President of the Association of Local Air Pollution Control Officials, discussing Washington and Idaho Smoke Management Plan's impact on Spokane County. *Safe Air for Everyone v. Wayne Meyer, et al.*, Case # 02-0241N-EJL (June 1, 2002).

[14] ORS 468A.585; DEQ, DOA and DHS report, *supra.* note1.

[15] DEQ, DOA and DHS report, *supra* note 1.

[16] OSU Extension, *The Search for Solutions* (Jan. 1989); CH2M Hill, *Opportunities in Grass Straw Utilization* (Feb. 1991); USDA and OSU Agricultural Experiment Station, *Low-Input On-Farm Composting of Grass Straw Residue* (Oct. 1998).

[17] ORS 468A.555.

[18] *See* ORS 468A.610; and Oregon Department of Agriculture, *Summary of the 2006 Field Burning Season*, *supra* note 2, at 17.

[19] ORS 468A.595(4); Still, in light of LRAPA's mission "*{t}o protect public health, community well-being and the environment*," the agency urged the legislature in 2006 to "craft legislation to eliminate the practice [of field burning] in the Willamette Valley at the earliest possible date." LRAPA Letter to Representative Paul Holvey (November 15, 2006).

[20] *See* ORS 468A.610 (2) and (8).

[21] With Eugene hosting the U.S. Olympic Trials in 2008, more attention will be focused on Lane County air quality.

(1) To cease the issuance of burn permits after a hearing and then a finding that "other reasonable and economically feasible, environmentally acceptable alternatives have been developed." ORS 468A.610(8)(b).

(2) To "prohibit, restrict or limit" field burning, by rule, if necessary to carry out the policy of ORS 468A.010. ORS 468A.595(1).

(3) To "provide for a more rapid phased reduction," again by rule, of field burning in Willamette Valley counties. ORS 468A.595(2).[22]

Such determinations and rules, all long overdue, must be undertaken with state public policy in mind to "restore and maintain the quality of the air resources of the state in a condition as free from air pollution as is practicable, consistent with the overall public welfare of the state." ORS 468A.010.[23] The full statutory scheme illustrates that state law places the Commission at the center of the decision-making process over whether Lane County and other state residents will be protected, both in the short-term and in the long-run, or whether they will suffer again and again from the ill effects of smoke incursions and related toxins that predictably attend the summer field burning program. However, because the burning season and its consequential danger to public health is nearly upon us, specific emergency action pursuant to ORS 468A.610(9) is needed as a first step. A commencement of rulemaking to permanently end this archaic and harmful practice is warranted, but an immediate moratorium now is needed to protect public health.

We have been informed, through the testimony of neighbors, physicians, and local leaders, letters in local papers, sentiment conveyed to state legislators, and the sharp upward trend in complaints compiled by the Oregon Department of Agriculture – 1,182 received from Willamette Valley residents in 2006, exceeding the 1,106 complaints received in 2005, 475 in 2004, 206 in 2003, 705 in 2002, and 608 in 2001[24] – that public patience with field burning has been exhausted. Willamette Valley residents have written recently of being driven from their homes during field burning season,[25] of smoke-induced tearing too severe to enable them to locate the proper number so as to call-in a complaint,[26] of concern that a loved one driving in smoke-darkened conditions would be in an accident,[27] of suffering chronic sinus infections,[28] of exacerbated asthma with each smoke intrusion,[29] of headaches and nosebleeds,[30] of swollen glands, wheezing, fatigue, and migraines,[31] of burning lungs,[32] of children battling bronchial and nasal congestion,[33] of black ash as big as a fist drifting into ones yard,[34] of being trapped at home during 90 degree weather without air conditioning, unable to open windows for fear of the

[22] The Commission is also obliged to provide for "a more rapid phased reduction" of burns in Multnomah, Washington, Clackamas, Marion, Polk, Yamhill, Linn, and Benton Counties. *See* ORS 468A.610 (2) and (8).
[23] Toward that end, state and local government agencies are required to coordinate their air quality programs, working together to promote public welfare by restoring the air. *Id.*
[24] *Id.* at (8).
[25] Statement of Dixie Maurer-Clemons of Eugene (Mar. 1, 2007).
[26] Statement of Maxine Kovarik, Springfield (Feb. 27, 2007).
[27] Statement of Penny Spencer, Creswell (Mar. 2, 2007).
[28] Statement of Dorothy Bucher, Eugene (Feb. 24, 2007).
[29] Statement of Pam Perryman, Eugene (Feb. 10, 2007).
[30] Statement of Ronald and Doris Gates, Springfield (Feb. 1, 2007).
[31] Statement of Victoria Whitman, Eugene (Feb. 8, 2007).
[32] Statement of Jeff Wyman, Eugene (Mar. 8, 2007).
[33] Statement of Hewitt and Patricia Berrien, Eugene (Mar. 7, 2007).
[34] Statement of R. Gunn, East Marion County (Apr. 1, 2007).

smoke,[35] of smoke so thick it set off a school fire alarm,[36] of an elite track star coughing up blood after a meet that coincided with a burn day.[37] These are just a few of the examples of affects on the lives of Oregonians.

This year, the Lane County Board of Commissioners and citizens throughout the Willamette Valley urged the State Legislature to protect public health by ceasing the grass seed burning program. Toward that end, Representative Paul Holvey introduced HB 3000, a measure to end open field burning in Oregon. The measure was favorably reported out by the House Health Committee, but later held by the Agriculture Committee, without a vote, past the deadline for reporting measures to the House floor. We therefore appeal to the Commission almost as a last resort.

Action by the Commission to halt field burning would follow precedent established by the state of Washington. In 1996, the Washington Department of Ecology issued an emergency ruling that reduced the number of acres of grass fields that could be burned. A subsequent Washington State University report to the Department of Ecology's Air Quality Program concluded that the financial benefits of ending field burning, including reduced health care costs for the at-risk population of persons with existing cardiopulmonary conditions, would outweigh potentially reduced returns for growers.[38] In 1998, after the Department of Ecology concluded that mechanical residue management constitutes a practical alternative agricultural method for all phases of seed production, the agency banned open grass field burning.[39]

Moreover, grass seed field burning is illegal in Idaho. In 1972, Idaho submitted a State Implementation Plan (SIP) under the Clean Air Act, which stated, "No person shall allow, suffer, cause or permit any open burning operation which does not fall into at least one of the categories of Section 3." Field burning was included in the types of burning allowed by Section 3, but was significantly limited. In 1993, the Environmental Protection Agency (EPA) approved amendments to the Idaho SIP that contained a general prohibition on open air burning. In 2003, an amended SIP was filed, but did not change the language regarding the general prohibition to open air burning. In 2005, Idaho amended it's SIP once again. This amendment would have permitted open burning of crop residue in agricultural fields. The Environmental Protection Agency approved Idaho's amendment of it's SIP, and a lawsuit was filed to contest the approval. The 9th Circuit Federal Court of Appeals reversed the EPA's approval of Idaho's SIP. The Court found that the approval was based on an erroneous premise that the preexisting Idaho SIP did not ban field burning. The Court remanded the case to the EPA for it's consideration of Idaho's proposed amendment as a change in a preexisting SIP, rather than a clarification of the prior SIP. Therefore, at this time, open burning of crop residue is still illegal in Idaho. Evidence presented in that case demonstrated that field burning smoke inundates large portions of rural Idaho and surrounding states, that doctors regard the smoke to have severe consequences for

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[35] Statement of Terry Sitton, Sweet Home (Apr. 4, 2007).
[36] Statement of Steve Nielsen, Mill City (Apr. 6, 2007)
[37] Statement of Glen and Rhoda Love, Eugene (Mar. 18, 2007).
[38] Estimates of the Benefits and Costs from Reductions in Grass Seed Field Burning (Dec. 27, 1996). In fact, revenues for the Washington Grass Seed industry have increased since the ban was imposed, just as in Oregon the grass seed industry has grown even as acreage burned declined from pre-1991 burn levels.
[39] RCW 70.94.656(3); WAC 173-430-045. The Department of Ecology is authorized to grant limited exceptions to allow open field burning only if a grower, among other things, "establishes that mechanical residue management is not reasonably available on specific portions of a field under specific production conditions due to slope."

individuals with respiratory ailments, that such persons have fled their homes during burning season, and that a coroner's report linked at least one fatality to field burning.[40]

These developments now leave Oregonians as the only Pacific Northwest residents without effective protection from grass seed field burning, despite suffering from many, if not all, of the same problems identified in Idaho and Washington.

On behalf of the public health of residents within and around the Willamette Valley – particularly those whose present medical conditions or age render them highly vulnerable to injuries that result from the inhalation of fine particulates and chemicals entrained in field burning smoke, including those without air conditioning, those lacking the means or ability to flee and those who lack the understanding of the serious health effects that this practice has on them if allowed to continue – we urge you to take prompt, decisive action. Specifically, we urge you now to make the finding that field burning presents an extreme danger to public health, and to order a temporary emergency cessation of the practice in the Willamette Valley at least through the summer of 2008.

If you do not find that there is an extreme danger, warranting an order to temporarily cease the practice of grass seed burning immediately, we would ask you to begin a rule adoption process for Lane County and the Southern Willamette Valley to phase in a reduction or elimination of open field burning pursuant to ORS 468A.595(2).

Thank you,

Faye Stewart

Faye Stewart, Chair
Lane County Board of Commissioners
Lane County Board of Health

[40] *Safe Air for Everyone v. US EPA*, No. 05-75269, 475 F.3d 1096, 1101(9th Cir. 2007), reaff'd 2007 WL 1531819 (9th Cir. May 29, 2007).

Footnote 1.

OREGON SEED INDUSTRY - FACT SHEET

Prepared by
The Oregon Seed Council - 503-585-1157

Grass Seed Industry	The term "seed industry" generally refers to production and marketing of cool grass seeds in the state of Oregon. Cool season grasses are those adapted to the temperate climates of the world and includes six major species.
Species	Species include Annual and Perennial Ryegrass, Tall Fescue, Fine Fescue, Orchardgrass, Bluegrass, and Bentgrass. Warm season grass include Bermuda grass, St Augustine grass, Zoyzia, etc.
Number of Growers	There are about 1,500 grass seed growers in Oregon. The majority of grass seed is produced in the 9 Willamette Valley Counties. Other areas with significant acreage are Jefferson, Jackson, Union, Morrow and Umatilla Counties. Grass Seed is also produced in much smaller amounts in Washington, and Idaho.
Number of Companies	There are approximately 55 wholesale seed companies marketing grass seed.
Acreage	Grass seed is produced on nearly 530,000 acres; 485,000 acres in the Willamette Valley, the rest in Jefferson, Jackson, Union, Morrow, Umatilla, and Klamath Counties.
Production	In 2006 Oregon produced and marketed 788 million pounds of grass seed.
World Use	The total demand for cool season grass seed is about 1.3 billion pounds annually.
Value of Production	Agricultural crops are valued in various ways. The "farm gate" value is what the grower received for the seed. In 2006 the "farm gate" value was over $454 million. Grass seed companies added about 30% or $135 million in research, production and marketing services bringing the total value to over $590 million.
Where Sold	Nearly all of the grass seed produced in Oregon is sold outside of the state. It is estimated that only 1-2% of the grass seed produced in Oregon is needed here for new lawns and pastures.
Export	Approximately 12-15% of the grass seed produced in Oregon is exported. Major buyers include Europe, Pacific rim countries, South American countries, African countries, New Zealand and Australia, Canada and China. In total, grass seed is exported to about 60 countries.
Why Oregon	Oregon has a unique combination of cool moist winters and dry warm summers that are ideal for grass seed production. A high percentage of soils in the Willamette Valley are well suited to growing grass and of limited value for producing other crops. Using Oregon's natural advantages, grass seed growers have learned to produce very high quality seed cheaper than competitors.
Economic	Economic impact refers to the ripple effect of new money coming into an economy; how many times the dollar changes hands. Agricultural crops have an economic multiplier of about 3. That is a new dollar will result in about $3 worth of total economic activity. Using 3 as the multiplier, the seed industries economic impact is $1.77 billion (3 X $590 million).

Footnotes 1, 9, 10
14

Fact Sheet

Open Field Burning In the Willamette Valley

State of Oregon
Department of Environmental Quality

Air Quality Division
Airshed Planning Program
811 SW 6th Avenue
Portland, OR 97204
Phone: (503) 229-6278
(800) 452-4011
Fax: (503) 229-5675
Contact: Brian Finneran
www.oregon.gov/DEQ/

Background

The Oregon Department of Agriculture (ODA) Smoke Management Program regulates the burning of up to 65,000 acres of annual and perennial grass seed crop residue and cereal grain residue within the Willamette Valley each summer.

Field burning disposes of leftover straw and stubble on fields after grass seed harvesting. It controls weeds, insects and plant diseases which helps maintain grass seed purity, reduces use of pesticides and herbicides, and improves yields. The practice began more than 50 years ago, with as much as 250,000 acres being burned in the mid-1980s.

A 1988 accident on Interstate 5 involving multiple cars and causing one fatality was attributed to decreased visibility due to field burning smoke. This led to passage of House Bill 3343, which called for the phase-down of field burning from 250,000 acres to the current 65,000 acres. Currently, the state's Smoke Management Program affords greatest protection to the Willamette Valley's major population centers, but offers lesser protection to some smaller population areas.

Quick Facts:

- *The phase-down of field burning occurred from 1991 to 1998, with the acreage limit reduced from 180,000 down to 40,000 acres. The current limit of 65,000 is based on 40,000 acres plus a 25,000-acre limitation for certain fire- dependent grass species and grasses grown on highly erodable soils on steep slopes.*
- *Although state law allows the burning of 65,000 acres, over the past five years actual burning has averaged about 50,000 acres.*
- *Field burning typically starts mid-July and ends mid-October, with a majority of burning in August/early September. Most fields are not burned every year.*
- *To avoid smoke impacts in populated areas, burning is permitted only after careful evaluation of weather conditions using the latest meteorological forecasting techniques.*
- *About 75% of all the acreage is burned on just 10 to 15 days during the summer.*
- *Currently there are about 150 growers who burn in the Willamette Valley.*
- *The Smoke Management Program is funded exclusively through grower fees.*
- *In 1995, ODA was directed by House Bill 3044 to operate the entire field burning program, through a contractual agreement with DEQ.*

Health effects from smoke

Field burning smoke is comprised of several pollutants that have the potential to cause health problems, depending on the level and duration of exposure. Field burning smoke contains fine particulate matter, which can be inhaled deep into the lungs. In addition, field burning smoke contains carbon monoxide and carcinogenic compounds such as polycyclic aromatic hydrocarbons, benzene, aldehydes and metals.

While efforts are made to conduct burning under optimum smoke dispersal conditions, some field burning smoke impacts do occur. However, these impacts rarely cause air quality to exceed the federal fine particulate health standard. This is because most field burning smoke impacts are of relatively short duration, and occur during the summer months, when particulate air pollution levels are generally much lower than they are in winter months.

Although field burning is unlikely to cause violations of federal health standards, exposure to field burning smoke can still pose health risks. Short-term exposure can cause health problems for people with pre-existing respiratory problems (e.g., asthma, bronchitis and chronic obstructive pulmonary disease), or to sensitive populations such as young children and the elderly.

For the general public, short-term exposure to smoke may result in eye irritation, scratchy throat, runny nose, headaches, and allergic reactions. While little is known about the long-term health effects from exposure to field burning smoke, some research has shown health effects can range from reduced lung function to development of chronic bronchitis, and even premature death.

The Oregon Department of Agriculture, in conjunction with researchers at Oregon State University, is currently planning to conduct a human health risk assessment of field burning in the Willamette Valley. This assessment will help

Oregon Department of Agriculture

For more information:
ODA Smoke Management Program, Salem:
www.oregon.gov/ODA/
(503) 986-4701

DHS
Oregon Department of Human Services
Contact: Ken Kauffman, Portland, (971) 673-0435

Alternative formats:
Alternative formats (Braille, large type) of this document can be made available. Contact DEQ's Office of Communications & Outreach, Portland, (503) 229-5696 (toll-free in OR at 1-800-452-4011, x5696)

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Last Updated: 2/13/07
By: Brian White

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characterize exposure and risk in affected communities.

Visibility effects from smoke

In addition to health effects, smoke can affect outdoor recreation activities and impair visibility or the ability to view nearby mountains and other scenic areas. Federal visibility protection rules require states to adopt smoke management plans that address outdoor burning practices like field burning and forestry burning.

The phase down in Willamette Valley field burning over the years has led to some improvements in summertime visibility in Oregon's wilderness areas and Crater Lake National Park. This improvement can also be attributed to weekend restrictions on field burning, which are in place from July 1 through Sept. 15, to protect visibility in the Oregon Cascades during the highest visitation and recreation use period.

Alternatives to field burning

In addition to smoke management, ODA manages research and development into alternatives. This includes finding ways to maintain high yields without burning, straw removal and marketing, and alternative crops. Alternatives to field burning are currently practiced throughout the Willamette Valley. These include crop rotation, chemical applications, straw removal and propane flaming. The baling and selling of grass seed straw has become an important agricultural commodity. The straw is sold all over the world as an animal feed supplement and for other uses.

Grant funding from ODA and the Oregon Seed Council (OSC) is used for research into alternatives to field burning. In 2006, ODA and OSC distributed approximately $370,000 for "Alternatives to Field Burning" research projects. ODA and OSC have funded an average of $319,000 annually in research projects since the 1999-2000 funding cycle. State tax credits are also used to provide equipment and infrastructure to promote alternatives to burning.

Minimizing smoke impacts from burning

For the 65,000 acres currently allowed for burning, ODA controls the time, amount and location of burning in order to avoid smoke intrusions into cities or impacts on the public. The best conditions for burning are when smoke rises to high elevations, disperses, and is transported away from major populated areas. This practice makes the smoke plume visible from long distances, often causing public reaction and complaints, but actually minimizes ground smoke impacts to the public.

Quick facts:

- *Growers are required to register their fields and obtain burn permits. Permits require being able to light a field within one hour. This helps ensure that the burning takes place when conditions are still favorable.*
- *Growers must follow specific burning instructions issued by ODA. ODA also maintains an enforcement program which can result in fines for violations of program rules.*
- *Growers must also meet fire safety requirements set by the State Fire Marshal.*
- *ODA uses state-of-the-art weather forecasting techniques and computer models to determine geographic locations where fields can be ignited to minimize the smoke impact on the public.*
- *Other elements of the program include a network of air monitors placed in major population centers throughout the Willamette Valley, to track air quality and smoke impacts.*
- *The program is staffed full-time by a program manager, program coordinator and meteorologist. Seasonally, the program employs two inspectors and two field coordinators.*

Complaints about field burning

ODA operates two field burning complaint lines, which are available to the public year-round. The Salem number is for callers in the north Willamette Valley; the Eugene number is for callers in the south portion of the Valley.

Salem Complaint Line: (503) 986-4709
Eugene Complaint Line: (541) 686-7600

Comments and complaints provide supplemental information on the extent and location of smoke problems. Callers may receive a tape recording asking the caller to leave a message describing the smoke problem. Complaints are compiled weekly and reported to the Governor's Office. In 2006, ODA received 1,182 complaints, up slightly from 2005's total of 1,106. In previous years the numbers of complaints were as follows: 2004 (275), 2003 (206), 2002 (705), 2001 (608).

Footnote 2, 11

Oregon
Department
of Agriculture

SUMMARY OF THE 2006 FIELD BURNING SEASON

Oregon Department of Agriculture
Natural Resources Division
Smoke Management Program

Natural Resources Division
635 Capitol Street NE
Salem, OR 97301-2532
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www.oregon.gov/ODA/NRD

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December 2006

The information provided in this report is accurate as of 12/31/06.

SUMMARY OF THE 2006 FIELD BURNING SEASON

Prepared By

The Oregon Department of Agriculture
Natural Resources Division
Smoke Management Program

1. Introduction

This summary is prepared at the close of each burn season by the Oregon Department of Agriculture (ODA) Smoke Management Program staff to report the statistics of each field burning season.

2. Weather Discussion

Weather in the Willamette Valley presents a multitude of challenges to operating the Smoke Management Program. Predicting weather patterns that will take smoke up, out, and away from populated areas is an inexact science. Rapidly changing winds, lower than expected mixing heights (the height of smoke rise), unpredictable smoke down mixing, and inefficient field ignition procedures executed by growers can all contribute to a given burn day's potential for smoke impacts.

Early June was rather wet (see Figure 1), which slowed maturation of the grass seed crops causing harvest to begin a bit later than usual. In late June and early July growers were occupied with combining late maturing crops. Even so, ODA was able to orchestrate a modicum of burning in mid-July by working with individual growers who were able to prepare fields quickly for burning after harvest.

There were a few very hot days during late June and July (see Figure 2) which caused State Fire Marshall (SFM) fire-safety rules* to come into effect. This precluded burning of any kind during those days. The high temperature chart for the summer shows August and early September cyclically varying between warm and cool temperatures. These transitions from warm to cool were usually "marine pushes," which allowed for widespread burning opportunities at relatively regular intervals throughout the month.

The summer of 2006 did not have persistent low-level inversions as have been prevalent in previous summers. However, there was a dominant north wind pattern which precluded field burning on many days.

In 2006, the heaviest recorded number of smoke impact hours occurred on the evening of August 8th and morning of August 9th. On August 8th, on-shore pressure gradients were predicted and pilot balloon readings indicated a favorable west wind direction for field burning. Upper air

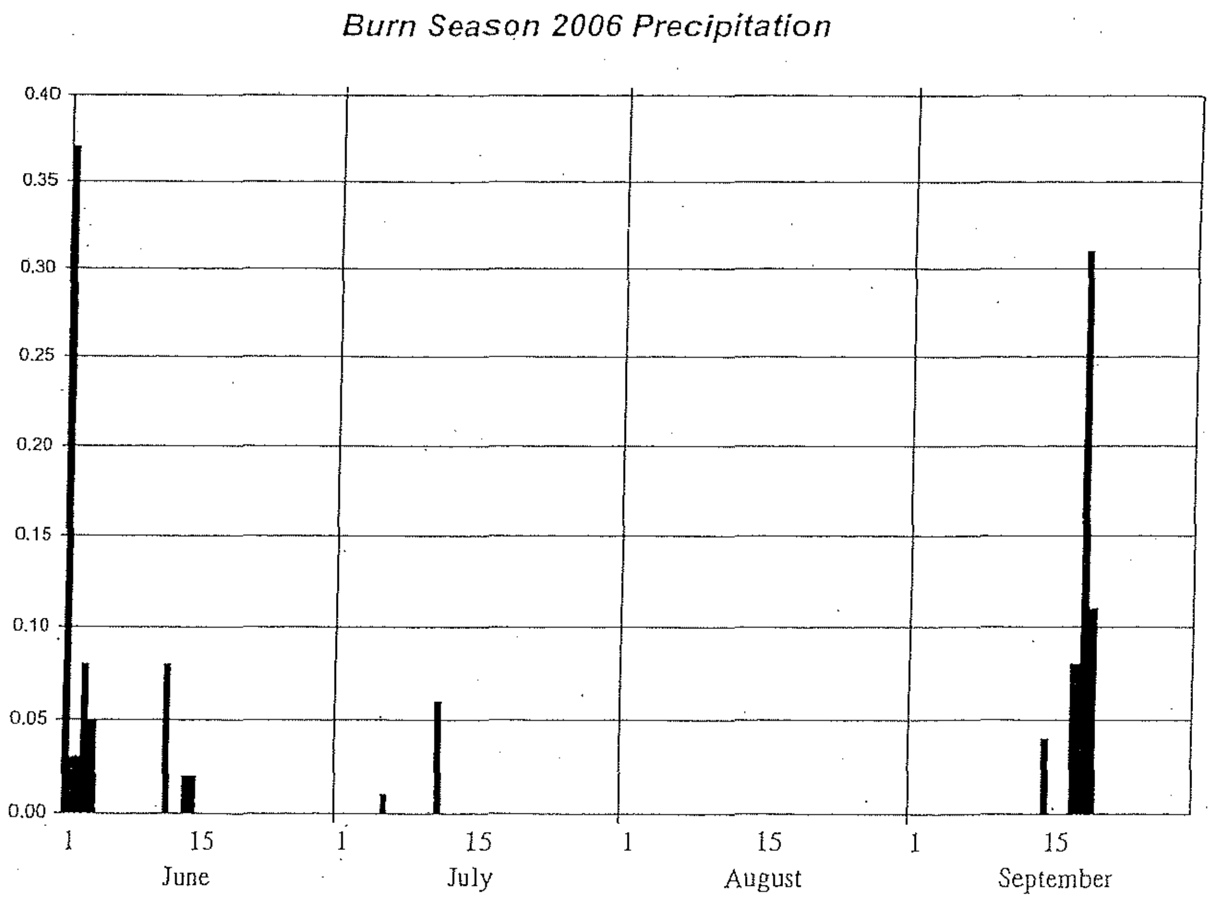
* SFM rules preclude burning on days in which any two of the following three criteria exist in the Willamette Valley: (1) temperature of 95° F or greater, (2) 30% relative humidity or less, and (3) 15 mph or greater surface winds.

charts revealed a minor short wave over northern California moving northeastward. However, it appeared that this short wave was far enough away that it would have no impact on smoke movement out of the Willamette Valley. Nearly 8,500 acres were burned on August 8th.

Unfortunately, as the short wave impulse moved northeast it altered the pressure pattern across the Cascades. Subsidence (sinking air motion) behind the axis of the trough caused a rapid rise in pressures in central Oregon. This collapsed the pressure gradient across the Cascades causing the smoke to "hang up" in the Cascades and associated foothills. As a result, the nephelometer at Lyons recorded 13 hours of smoke impact (8 hours light and 5 hours moderate). During the same period, the Sweet Home nephelometer recorded 1 hour of light impact.

ODA continues to refine techniques to identify individual fields and geographic locations which can be burned under specific weather conditions that are not conducive to large scale field burning yet can be used for limited localized burning. The addition of a third theodolite in 2006 allowed ODA to conduct mobile pilot balloon (pibal) readings in more areas throughout the Valley. A pibal is used to collect information about wind speeds and directions through the atmosphere from the surface to approximately 10,000 feet.

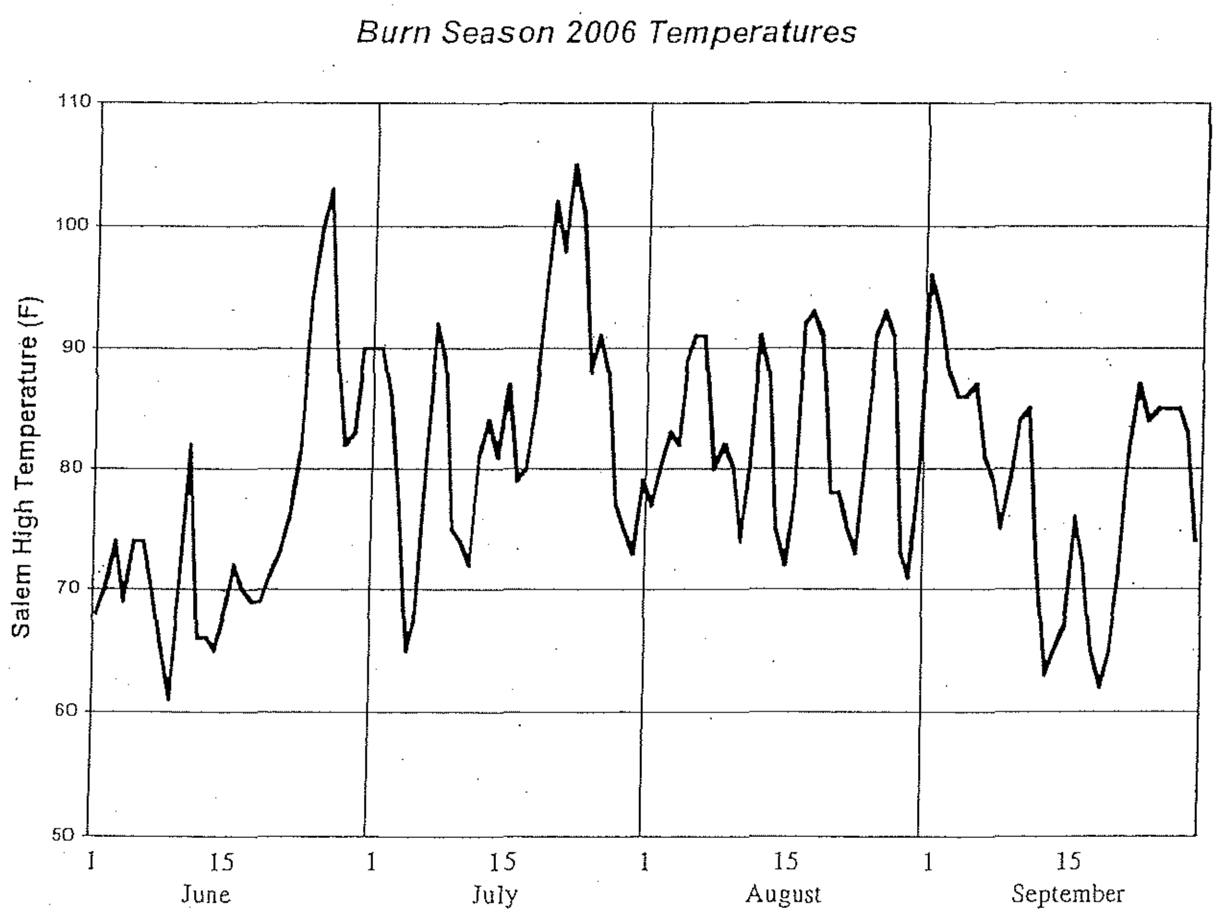
Figure 1



On August 25th, pibals were conducted on the west side of the Willamette Valley to confirm easterly winds aloft. These rare easterly winds are not suited for large-scale open field burning, but are very suitable for burning fields on the west side of the Valley. After east wind

confirmation, ODA authorized field burning on the west side of the Valley, expecting smoke to travel out over the relatively unpopulated coast range. Almost 1,700 acres were burned on the west side on the 25th. Unfortunately, one 62-acre field burn north of Corvallis was not ignited with "rapid ignition" techniques and produced a large amount of ground smoke. As such, this smoke did not rise into the easterly wind layer. Instead, it drifted southward on surface winds producing one hour of heavy smoke impact, and an inordinate number of complaint calls from Corvallis and some communities to the south.

Figure 2



3. Four-Day Burn Percentage

During the 2006 field-burning season, 56% of all the acreage open field burned occurred over 4 days. This compares with 53% of all acreage burned over 4 days in 2005. The chart below outlines the 2006 figures.

Tues. 8/8/06	Thu. 8/10/06	Mon. 8/28/06	Fri. 9/8/06	**4 Day Total**	**Percent**
8,412	5,275	7,018	6,932	**27,637**	**56%**

4. Registered Acres

Open field burning and propane flaming acreage pre-registration began on March 17th and continued through April 1st. The chart below shows the breakdown of acres registered by type, the statutory limitation of each type, and the final allocation of each type as imposed by the statutory limitation.

Type	Limitation	Acres Registered	Allocation
Regular	40,000	96,962	41%
Identified Species	22,000	16,294	100%
Steep Terrain	3,000	1,041	100%
Propane Flame	37,500	2,439	100%

<u>Definitions</u>

Type: Open Field Burning

- Regular: Perennial or annual grass seed, or cereal grain residue.
- Identified Species: Research has identified some species of grass seed that cannot be profitably produced without thermal sanitation. These identified species are Chewings Fescue, Creeping Red Fescue, and Highland Bentgrass.
- Steep Terrain: Locations in the Willamette Valley where grass seed is grown, but because of the steepness of the terrain, it is extremely difficult to apply alternatives to open field burning.

Type: Propane Flaming

- The process of sanitizing (burning) regular and identified species fields with a propane flamer; a mobile, fire-producing, sanitation device.

5. Open Field Burning

In the 2006 field burn season, a total of 114,297 acres were registered for open field burning compared to 114,299 in 2005. Registration included 96,962 acres of regular, 16,294 acres of identified species, and 1,041 acres of steep terrain. Regular registration exceeded the legislatively mandated limitation of 40,000 acres; therefore, the regular open field burning allocation rate for 2006 was 41%. The allocation rate for identified species and steep terrain for 2006 was 100%.

A total of 49,017 acres were open field burned during the 2006 burn season (34,971 regular limitation, 13,375 identified species, and 671 steep terrain). By comparison, a total of 49,225 acres were burned in 2005, 49,553 acres in 2004, 50,437 acres in 2003, and 51,374 acres in 2002.

2006 Open Field Burning by Crop

Species	Burned (acres)	% Of Total
Annual Ryegrass	27,640	56.39%
Chewings Fescue	8,714	17.78%
Perennial Ryegrass	4,867	9.93%
Creeping Red Fescue	3,824	7.80%
Tall Fescue	1,649	3.36%
Cereal Grain	970	1.98%
Highland Bentgrass	837	1.71%
Orchardgrass	299	0.61%
Fine Fescue	217	0.44%
TOTAL	49,017	**100%**

6. Propane Flaming

The maximum allowable acreage to be propane flamed is 37,500 acres (as set by the 1995 Oregon Legislature). In 2006 growers registered 2,439 acres of fields to be propane flamed and burned 1,466 of those registered acres. This compares to 1,631 acres propane flamed in 2005, 1,067 acres in 2004, 1,602 acres in 2003, and 1,582 acres in 2002.

2006 Propane Flame Burning by Crop

Species	Burned (acres)	% Of Total
Creeping Red Fescue	653	44.54%
Perennial Ryegrass	351	23.94%
Chewings Fescue	242	16.51%
Cereal Grain	100	6.82%
Kentucky Bluegrass	85	5.80%
Tall Fescue	35	2.39%
Highland Bentgrass	0	0%
Orchardgrass	0	0%
Fine Fescue	0	0%
TOTAL	1,466	**100%**

7. Stack Burning

Stack burning does not have an imposed acreage limitation, nor is registration required. Growers are obligated to secure a stack burning permit containing the responsible party's name, location of the burn, and acreage represented by the accumulated residue prior to ignition. The stack burning season lasts from April 1st to March 31st of the following year. As of October 31, 2006, growers had stack burned 1,061 acres since April 1, 2006. Previous years are as follows:

Historical Stack Burn Statistics

Year	Interim – October 31st	Final – March 31st
2006-2007	1,061	N/A
2005-2006	1,366	1,692
2004-2005	1,667	1,864
2003-2004	1211	1,636
2002-2003	616	1018

8. Total Thermal Residue Management

The chart below shows the figures for total thermal residue management, including stack-burning acreages.

Burn Type	2006	2005	2004	2003	2002
Open Field Burning	49,017	49,225	49,553	50,437	51,374
Propane Flaming	1,466	1,631	1,067	1,602	1,582
Stack Burning[†]	1,399	1,692	1,864	1,636	1,018
Total	**51,882**	**52,548**	**52,484**	53,675	53,974

9. Enforcement

The 2006 burn season marked the tenth year that the department has performed the enforcement function of the Smoke Management Program (as stipulated under a Memorandum of Understanding with the Oregon Department of Environmental Quality, Pursuant to Oregon Revised Statutes 468A.585).

There were 5 enforcement contacts during the 2006 season (as of October 31, 2006). This compares with 17 enforcement contacts during the 2005 season, 21 contacts in 2004, 2 contacts in 2003, 11 contacts in 2002, and 10 contacts in 2001.

Of the 5 enforcement contacts in 2006, all of them resulted in letters of warning; none resulted in notices of non-compliance, and none resulted in civil penalty assessments.

10. Smoke Impacts

It is the goal of the ODA Smoke Management Program, with the cooperation of the Willamette Valley growers, to reduce or eliminate smoke impacts in populated areas.

The combination of accurate weather prediction for burning, ODA field personnel observations, and grower experience all contribute to alleviate smoke impacts. However, smoke impacts still occur. Unexpected wind shifts, rapidly changing mixing heights, rapidly decreasing transport

[†] Estimated Total Stack Burn Acreage (April 1, 2006 – March 31, 2007)

The information provided in this report is accurate as of 12/31/06.

wind speeds and directions, other meteorological factors and inefficient lighting techniques all contribute to the occurrence of impacts.

Smoke intrusions attributable to open field burning occurred on 7 days in 2006. Previous years totals included 15 days in 2005, 10 days in 2004, 9 days in 2003, and 9 days in 2002.

The number of hours of recorded smoke impact[‡] in cities monitored for smoke in 2006 are outlined below.

2006 Open Field Burning Impacts

Date	Acres Burned	Impact Hours			Location
		Heavy	Moderate	Light	
8-Aug	8,412		5	8	Lyons
8-Aug	8,412			1	Sweet Home
15-Aug	107			1	Sweet Home
21-Aug	3,833		2		Lyons
21-Aug	3,833			1	Sweet Home
23-Aug	1,097			1	Lyons
25-Aug	1,699	1			Corvallis
28-Aug	6,915		1		Lyons
28-Aug	6,915		1		Sweet Home
8-Sep	6,932			2	Lyons
8-Sep	6,932		2	2	Sweet Home

11. Complaints

Open field burning complaints received from Willamette Valley residents by the Smoke Management Program[§] totaled 1,182 during the 2006 field-burning season. This compares with 1,106 complaints received for the 2005 season, 475 in 2004, 206 in 2003, 705 in 2002, and 608 in 2001.

[‡] As defined in Oregon Administrative Rule (OAR) 603-077-105, cumulative hours of smoke impact result in hourly nephelometer measurements that exceed 1.8×10^{-4} b-scat above the average prior 3-hour background levels. For the purposes of this report, "heavy" hours of smoke impact are 5.0×10^{-4} b-scat or more above background (equivalent to visual range of 5 miles or less), "moderate" hours of smoke impact are 1.8×10^{-4} to 5.0×10^{-4} b-scat above background (equivalent to visual range of 12 miles or less), and "light" hours of smoke impact are 1.0×10^{-4} to 1.8×10^{-4} b-scat above the background. "Light" hours of smoke impact were not recorded prior to the 1999 season. The terms "light," "moderate," and "heavy," as used in relation to smoke impacts, are not defined in OAR, but are used by ODA to quantify the level of smoke impact on residents of the Willamette Valley. Nephelometers are located in Portland, Eugene, Springfield, Sweet Home, Lyons, Corvallis, Salem, and Carus.

[§] Complaints received by the Lane Regional Air Protection Agency (LRAPA) are forwarded on to ODA at the end of every week during the field burning season. Those complaints are also included in the total presented in this report.

The information provided in this report is accurate as of 12/31/06.

2006 Open Field Burning Complaints by City

Albany	8	Noti	17
Brownsville	10	Portland Metro	0
Corvallis	75	Salem/Keizer	16
Cottage Grove/Lorane	13	Scio	3
Creswell	27	Silverton	7
Eugene	275	Springfield	65
Harrisburg	16	Stayton	19
Junction City/Monroe	49	Sublimity	6
Lebanon	59	Sweet Home	36
Lyons/Mehama	11	Veneta/Elmira	107
Mill City/Gates	27	Other	160
Mohawk Valley	131	Unknown	45
		Total	**1,182**

Breakdown of 2006 Open Field Burning Complaint Calls**

ODA tracks the number of complaint calls by individuals to determine the amount of repeat callers. Information is recorded by ODA in order to prevent the results from being skewed by multiple calls from one individual.

Number of People	Times Called	Number of Complaints
649	1	649
100	2	200
24	3	72
10	4	40
7	5	35
2	6	12
3	7	21
1	8	8
1	10	10
1	12	12
1	16	16
107	Unknown	107
	Total	1,182

** Chart outlines the number of individuals and how many times they called. For example; 3 people called 7 times each for a total of 21 complaints. 107 callers chose not to provide identifying information and, therefore, it is unknown if those callers called multiple times.

The information provided in this report is accurate as of 12/31/06.

5 Year Historical Comparative Open Field Burning Data

Season	2006	2005	2004	2003	2002
Acres Registered[††]	116,328	114,299	91,933	83,695	79,679
Acres Burned	49,017	49,225	49,553	50,437	51,374
Most burned in one day	8,412	9,311	10,252	8,617	9,994
Burn days accounting for 75% of total acres	7	10	7	9	6
Weekend burn days allowed	0	0	1	0	0
Number of Burn Days[‡‡]					
300 – 999 acres burned	15	15	8	11	2
1,000 – 4,999 acres burned	5	10	5	8	8
5,000 – 9,999 acres burned	4	2	3	3	4
10,000 or greater burned	0	0	1	0	0
Total Burn Days	**24**	**27**	**17**	**22**	**14**
Smoke Impact Hours **total/heavy/mod/light(#days)[§§]**	2006	2005	2004	2003	2002
Portland	0/0/0/0	0/0/0/0	0/0/0/0	0/0/0/0	0/0/0/0
Salem	0/0/0/0	0/0/0/0	0/0/0/0	0/0/0/0	0/0/0/0
Corvallis	1/1/0/0	0/0/0/0	0/0/0/0	0/0/0/0	0/0/0/0
Carus	0/0/0/0	0/0/0/0	1/0/1/1(1)	0/0/0/0	0/0/0/0
Lyons	8/0/8/11(5)	14/0/14/25(14)	5/1/4/5(5)	4/0/4/10(6)	3/0/3/11(4)
Sweet Home	3/0/3/5(5)	0/0/0/1(1)	2/0/2/9/(4)	2/0/2/2(3)	5/0/5/16(4)
Eugene	0/0/0/0	1/0/1/1(2)	0/0/0/0	0/0/0/0	0/0/0/0
Springfield	0/0/0/0	4/0/4/3/(3)	0/0/0/0	0/0/0/0	0/0/0/1 (1)
Total (day total is of individual days not of days at each location)	12/1/11/16(7)	19/0/19/30(15)	8/1/7/15/(10)	6/0/6/12(9)	8/0/8/28(9)

[††] All registered regular, identified species, and steep terrain open field-burning acres plus registered propane acres.

[‡‡] Days with less than 300 acres burned are not counted as open field burning days.

[§§] As defined in Oregon Administrative Rule (OAR), total hours of impact include hourly nephelometer measurements exceeding 1.8×10^{-4} b-scat above prior 3-hour background. For the purposes of this report, "heavy" hours of smoke impact are 5.0×10^{-4} b-scat or more above background (equivalent to visual range of 5 miles or less), "moderate" hours of smoke impact are 1.8×10^{-4} to 5.0×10^{-4} b-scat above background (equivalent to visual range of 12 miles or less), and "light" hours of smoke impact are 1.0×10^{-4} to 1.8×10^{-4} b-scat above the background. "Light" hours of smoke impact were not recorded prior to the 1999 season. The terms "light," "moderate," and "heavy," as used in relation to smoke impacts, are not defined in OAR, but are used by ODA to quantify the level of smoke impact on residents of the Willamette Valley. Nephelometers are located in Portland, Eugene, Springfield, Sweet Home, Lyons, Corvallis, Salem, and Carus.

The information provided in this report is accurate as of 12/31/06.

Footnote 3

QUANTIFYING POST-HARVEST EMISSIONS FROM BLUEGRASS SEED PRODUCTION FIELD BURNING

MARCH 2004

GRASS SEED CROPPING SYSTEMS FOR A SUSTAINABLE AGRICULTURE

WASHINGTON STATE DEPARTMENT OF ECOLOGY

IDAHO DEPARTMENT OF ENVIRONMENTAL QUALITY

ENVIRONMENTAL PROTECTION AGENCY REGION 10

WASHINGTON TURFGRASS SEED COMMISSION

COEUR D'ALENE TRIBE

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In collaboration with:

Air Sciences Inc.
Portland, OR

Missoula Fire Sciences Laboratory
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SUMMARY AND CONCLUSIONS

Summary:

Residue Loading. Removal of post-harvest residue by baling significantly reduced the amount of pre-burn residue at all sites. The high (i.e., no residue removed) residue loading and low (i.e., residue removed by baling) residue loading means averaged over all sites were 4.0 and 1.8 tons acre^{-1}, respectively. The low residue loading was similar at all sites (1.7 to 1.9 tons acre^{-1}). Pre-burn residue loading did not influence post-burn residue loading. The high and low pre-burn residue loading at Connell, WA (irrigated) and Worley, ID (dryland) sites burned down to similar post-burn residue loading. However, at Rathdrum, ID (irrigated) both high and low pre-burn residue loading had significantly lower post-burn residue loading relative to the other two sites.

Residue Consumption. Absolute residue consumption ($RC_{Absolute}$) was the same for high residue loading at all sites, approximately 3.2 ton acre^{-1}. The Rathdrum low residue loading treatment was unique and $RC_{Absolute}$ was more than two times greater than at the other two sites. There was a strong positive relationship between $RC_{Absolute}$ and the pre-burn residue loading. The higher the pre-burn residue loading, the higher the $RC_{Absolute}$. Since 89% of the variation in $RC_{Absolute}$ was explained by the variation in pre-burn residue loading, this would suggest that any practice that removes a significant portion of the post-harvest residue from a bluegrass seed production field (e.g., baling) would reduce the amount of residue consumed. Total $PM_{2.5}$ emissions (lbs acre^{-1}) would be reduced by a significant reduction in $RC_{Absolute}$ if the $PM_{2.5}$ emission factor (EF, lbs ton^{-1} of residue consumed) remained constant or did not increase markedly.

Emission Factors for $PM_{2.5}$, CO_2, CO, and CH_4. Since there were no statistical differences in $EF_{PM2.5}$ between Rathdrum and Worley residue loading treatments, $EF_{PM2.5}$ was pooled for these sites. Based on the pooled means, $EF_{PM2.5}$ for Connell high residue loading was greater than Rathdrum and Worley high residue loading. At Rathdrum and Worley, low pre-burn residue loading produced consistently greater $EF_{PM2.5}$ than high residue loading. This relationship could not be assessed at Connell due to a lack of replication (n=1) in the low residue loading treatment.

It should be noted that the $EF_{PM2.5}$ in this study are substantially greater than those reported for most agricultural burns, wildfires, and forest fires (Air Sciences Inc., 2003). The $EF_{PM2.5}$ for the cereal study conducted in eastern Washington (Air Sciences Inc., 2003) had a mean $EF_{PM2.5}$ of 7.4 lbs ton^{-1} of residue consumed while the mean $EF_{PM2.5}$ for this study was 57 lbs ton^{-1} of residue consumed. $EF_{PM2.5}$ was significantly higher for the Connell high residue loading treatment than for high residue loading at Rathdrum and Worley, 109 lbs of $PM_{2.5}$ ton^{-1} of residue consumed. There were no differences in $EF_{PM2.5}$ among the low pre-load residue treatments at Rathdrum or Worley.

There was a strong positive relationship between EF_{CO2} and CE (Combustion Efficiency, %). There also were strong negative relationships between CE and EF_{CO} and EF_{CH4}. These relationships are similar to those reported for other studies (Air Sciences Inc., 2003). Overall CO_2 emissions increased with increased CE while CO and CH_4 emissions decreased with increased CE.

Emission Factors Affected by Residue and Soil Moisture. There was no discernible relationship between residue moisture content (%, oven-dry weight basis) and $EF_{PM2.5}$. EF_{CO2} decreased with increasing residue moisture content, while EF_{CO} and EF_{CH4} increased with increasing residue moisture content. None of the pollutant emission factors was significantly related to soil moisture content.

Footnote 3

4.3 Emission Factors for $PM_{2.5}$, CO_2, CO, and CH_4

Since $PM_{2.5}$ was the main pollutant of interest, it alone was analyzed for statistical differences due to treatments, and it will be discussed in more detail than the other emission factors. The $EF_{PM2.5}$ for the Connell high residue loading units was higher (P=0.05; P=0.02 when Rathdrum and Worley data were pooled, see below) than $EF_{PM2.5}$ for the high residue loading units at Rathdrum and Worley. At Rathdrum, $EF_{PM2.5}$ was significantly greater for the low residue loading units than for the high residue loading units (P=0.05) (66 and 33 lbs of $PM_{2.5}$ ton^{-1} of residue for low and high loading, respectively, Table 3.2).

Since there were no statistical differences in $EF_{PM2.5}$ between Rathdrum and Worley residue treatments, $EF_{PM2.5}$ was pooled for these sites. Based on the pooled means, $EF_{PM2.5}$ at the Connell high residue loading units was greater than at the Rathdrum/Worley high residue loading units (P=0.02). At Rathdrum/Worley, low pre-burn residue loading produced consistently greater $EF_{PM2.5}$ than high residue loading (P=0.01,Table 3.2, Fig. 3.6B). This relationship could not be assessed at Connell due to a lack of replication (n=1) in the low residue loading treatment.

It should be noted that the $EF_{PM2.5}$ in this study are substantially greater than those reported for most agricultural burns, wildfires, and forest fires (Appendix 3). The $EF_{PM2.5}$ for the Cereal-Grain Open-Field Burning Emissions Study conducted in eastern Washington during 2000 (Air Sciences Inc., 2003) had $EF_{PM2.5}$ means of 6.2 and 8.6 lbs ton^{-1} of residue for low and high pre-burn residue loading, respectively, while the $EF_{PM2.5}$ means for this Kentucky bluegrass study were 56 and 58 lbs ton^{-1} for high residue loading and low residue loading, respectively. The eastern Washington cereal burn also had considerably higher CE and higher EF_{CO2}.

The relationships between emission factors and CE were studied based on linear regression analysis. As expected, there was a strong positive relationship between EF_{CO2} and CE (Fig. 3.2). There also were statistically significant negative relationships between CE and EF_{CO} and EF_{CH4}. These relationships are similar to those reported for other studies (Appendix 3). CO_2 emissions increased with increased CE while CO and CH_4 emissions decreased with increased CE.

Numerically, the highest CE occurred in the low residue loading treatment at Worley (dryland) and the lowest CE was at the Connell (irrigated) high residue loading treatment (Table 3.2). As expected, the lowest CE had the lowest EF_{CO2} and the highest CE had the highest EF_{CO2} (2843 and 3320 lbs ton^{-1} CO_2, respectively).

$PM_{2.5}$ is a product of incomplete combustion; however, there was a poor relationship between $EF_{PM2.5}$ and CE (Table 3.3, Fig. 3.5). Although the trend toward decreased $PM_{2.5}$ with increased CE was consistent with other reports, the relationship in bluegrass (P=0.04, R^2=0.22) was much weaker than in the eastern Washington cereal study (P<0.001, R^2=0.61) (Air Science Inc., 2003). Factors contributing to the poor relationship between CE and $EF_{PM2.5}$ in post-harvest Kentucky bluegrass residue burns are currently unknown. Site locations and/or crop management practices might play some role in the relationship, as described in Section 4.6.

4.4 Emission Factors Affected by Residue and Soil Moisture

There were no relationships between any residue moisture component and $EF_{PM2.5}$ (Table 3.4). It would be expected that $PM_{2.5}$ would increase with increased residue moisture as a result of less efficient combustion. In the eastern Washington cereal study (Air Sciences Inc., 2003), greater $PM_{2.5}$ emission factors were driven almost entirely by the higher residue moisture content in fall cereal residue relative to spring cereal residue moisture content.

Footnote 3

PAUL R. HOLVEY
STATE REPRESENTATIVE
DISTRICT 8

HOUSE OF REPRESENTATIVES

To: House Agriculture and Natural Resources Committee
Date: April 30, 2007

Chair Roblan and Committee Members,

Thank you for hearing House Bill 3000. This bill prohibits open field burning, stack burning, pile burning, and propane flaming. It does allow for open burning of agriculture waste under permit and authority of the Department of Environmental Quality (DEQ). The bill also establishes the Smoke Management Program and the Open Burning Management Account under the Authority of the DEQ.

I have provided each of you with a packet of information. In this binder you will find information about fine particulate matter and its impact on health as well as information about alternatives that growers can and already use. I will reference many of these documents from this packet.

I introduced this legislation because of the extreme threat to the public health of Oregonians as a result of agricultural field burning. Since introducing HB 3000 I have heard from thousands of individuals across the state and many organizations all in support of eliminating field burning. Amongst those organizations are the Lane County Medical Society, the Oregon Medical Association, the American Lung Association of Oregon, the Oregon Lung Specialists, the Lane Regional Air Protection Agency, the City of Eugene and the Lane County Board of Commissioners.

There is clear and convincing scientific evidence that both long-term and short-term exposure to fine particulates and smoke have significant adverse human health effects. The emissions from field burning grass residues contain a mixture of solid and liquid particles, which include particulate matter, carbon monoxide, methane, and toxics like Acetaldehyde, Acrolein, Benzene, Butadiene, Formaldehyde, Methyl Chloride, Toluene, and Xylenes. The particulate matter is both large coarse particulates and fine particulates. Unlike the coarse particulate matter, fine particulates lodge deep in the lungs and the body's defenses are unable to remove them. Toxics from the emissions recombine and attach to these fine particulates.

To realize how detrimental smoke and fine particulate matter is to human health, one need only look at the extensive scientific research. The Journal of the American Medical Association states that "Even short-term exposure to fine particulate air pollution has been found to increase the risk for hospital admissions for cardiovascular and respiratory ailments." A study done in Washington State notes that "Epidemiological evidence has established a clear link between small airborne particles and health, particularly for an at-risk population comprising people with existing pulmonary conditions such as asthma, emphysema, chronic bronchitis or heart disease." The EPA, in a fact sheet about fine particulate matter states that "many scientific studies have found an association between exposure to particulate matter and a series of significant health problems, including: aggravated asthma; chronic bronchitis; reduced lung function; irregular heartbeat; heart attack; and premature death in people with heart or lung disease."

Statistics used to track these impacts, such as hospitalization rates for asthma, fall short of tracking the full impact. Hospitalization rates only capture on visit per person even if the same person comes in multiple times, cite asthma as the primary diagnosis even though we know that other cardiovascular and respiratory problems like bronchitis can result, and do not include visits people make to their doctor.

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Footnote 3

Beyond these statements and data, there have been deaths in both Idaho and Washington that have been directly linked to exposure to field burning smoke, not to mention numerous traffic deaths and accidents caused by smoke. In your packet, exhibit E, you will find an affidavit from Henry D. Covelli, M.D. In this affidavit he states that he has "witnessed the immediate death of one patient who was exposed to field burning and experienced immediate respiratory difficulty and expired as a result of an exacerbation of his disease." In your packet I have also included an article "Fields of Fire" which talks about one specific death from field burning smoke.

I think it is also important to briefly talk about the effectiveness of smoke management and monitoring of the emissions from field burning. Smoke management is intended to burn when conditions are favorable in directing the smoke plumes away from the more densely populated areas. However, smoke management and conditions are not always predictable. This practice means that many of our smaller communities are literally designated as sacrifice zones.

The measurements data, and standards used by both the EPA and the DEQ are very site specific and most often based on averages that do not reflect the extremely high levels that much of our population is being subjected to. And frankly our smaller communities do not breathe averages.

Studies show that the smoke and fine particulate matter from field burning is a problem, but just how big of a problem is it? Throughout this debate you have heard, and will probably hear again today, that field burning contributes only 2% of the particulate pollution in the Willamette Valley annually. You have to be careful when looking at this statistic. First, directly after citing the 2% statistic, the DEQ states that "Occasional, short-term particulate sources such as field burning or prescribed field burning can have adverse health impacts on the public, especially sensitive groups like asthmatics." More importantly though, this statistic uses coarse particulate matter when calculating emissions totals. But, as I noted earlier, fine particulate matter is what causes the most harm.

When one looks at fine particulate matter pollution from field burning, a different picture emerges. During the season when growers burn their fields, exhibit H in your packet; they produce 40 percent of the total fine particulate matter in the Willamette Valley. On the four days when about half the total acreage is burned, open field burning produces 64 percent of the total fine particulate matter in the Willamette Valley. To put these numbers in perspective, mobile vehicles and equipment, the cars you and I drive, produce only 6 percent during the entire field burning season and 4 percent of the total fine particulate matter pollution on the largest burning days. To get the equivalent amount of pollution from vehicles on those four largest burning days we would have to increase the number of vehicles on the road by a factor of 16.

Another way to look at the scale of pollution is to examine the aggregate totals of pollutants that are produced. Over the course of the 2006 field burning season, growers produced almost 13,000 tons of pollutants. On the four biggest burning days in 2006, growers produced more than 770 tons of fine particulate matter, 4,885 tons of carbon monoxide, and more than 676 tons of toxics like benzene and formaldehyde. During those four days, the amount of carbon monoxide generated from burning equaled half the yearly amount produced by the largest smokestack polluter in the Southern Willamette Valley.

These statistics show that field burning smoke is not just a minor contributor of pollution in the Willamette Valley. When we combine these numbers with the scientific evidence about short-term exposure, it becomes apparent that field burning is a major threat to public health in Oregon.

Footnote 3

Thus far I have spoken to you about how field burning impacts a person's health and how much pollution is created and monitored. Now I want to examine how reducing and eliminating open field burning has impacted growers and discuss the available alternatives that many growers are already utilizing.

Today growers can burn up to 65,000 acres, but in 2006 they burned about 49,000 acres. That is less than 10% of the total acres of grass seed grown in Oregon today. As you will see from this chart and exhibit N in your packet, since the legislature began limiting the amount of acreage that can be burned, the total number of acres grown in the Willamette Valley has **increased** from roughly 375,000 in 1991 to just under 500,000 acres today. Sales have increased even more with sales reaching $481 million in 2006. That is more than double the total sales of $175 million in 1991.

This story is not unique to Oregon. Since eliminating the practice of grass seed burning in Washington State, yields of grass seed and legume production have increased by almost 50% from 500 lbs per acre to 740 lbs per acre. Production has increased from 250,000 CWT to 350,000 CWT, and the value of production has increased from $17.5 million in 1998 to $28 million in 2006. In addition to these benefits to seed growers, if you turn to exhibit M, researchers in Washington State found that eliminating field burning made good public health policy with probable benefits totaling $8.4 million versus $5.6 million in probable costs.

The grass seed industry is not the only industry impacted by field burning. Among the complaints I have received have been from people who bring friends and family to Oregon, only to have their trip ruined by the smoke from field burning. Oregon's tourism industry depends on our natural resources and outdoor activities to attract visitors to our state. These tourism activities contribute more than $6 billion in direct travel spending to the State.
Oregon's wine tourism industry, an industry impacted by field burning smoke, is a growing segment of the market that contributed $95 million to the economy in 2004.

These numbers do not show an industry ruined by not burning. Rather, they show an industry that has successfully adapted and developed economically viable alternative methods of managing residue. Research has shown that burning is not needed to preserve yields in many types of grasses grown in Oregon. Looking at Exhibit O, it reads that "Chastain et al. (2000) found that growing cool-season perennial grass seed crops without open-field burning did not reduce seed purity or germination in trials conducted over a six year period in Oregon."

Oregon has invested millions of dollars on tax credits to develop sustainable alternatives to field burning. Among these alternatives that growers are using and can use are removing and baling straw for resale, retaining grass seed residue on the field as compost or animal feed, planting alternative crops like meadowfoam, and using residue as an ingredient in the production of celluosic ethanol.

Post harvest grass seed residue is valuable commodity for growers. This straw can be baled and removed to be sold as livestock feed or as a way of protecting against soil erosion on fields, roadsides, and on hills following forest fires. Since reducing the acreage that can be burned, growers have taken advantage of this market opportunity and today Oregon exports 650,000 tons of straw, with a sales value of $65 million, to countries throughout Asia.

Second, growers can retain straw on their fields using a process called full straw management. Full straw management is a common practice that is already being utilized by many growers throughout the Southern Willamette Valley. This method returns valuable nutrients and moisture to

Footnote 3

the soil, protects against erosion, and helps fight against weeds. As noted earlier, research has shown that full straw management does not reduce seed yield or purity for many types of grass seed grown in Oregon.

Third, growers can rotate their grass seed crops with alternatives like meadowfoam. Meadowfoam seed oil is valuable commodity that has a variety of applications in the $27.1 billion cosmetics industry and industrial uses as a lubricant. Looking in your packet in exhibit Y you can also see that meadowfoam has additional benefits for growers in fighting weeds and preserving moisture in the soil. For growers meadowfoam is also grown in another season than grass seed and most of the equipment used to harvest the plant is the same used in grass seed meaning that farmers can grow it with a minimum of new investment in intrusion with other scheduled growing.

Lastly, as Oregon and the United States face an era of rising energy consumption, uncertainty about supply, and increasing environmental awareness, grass seed straw represents a valuable commodity for conversion to cellulosic ethanol. Recognizing this energy future, President Bush ahs called on the United States to reduce oil imports by more than 75% by 2025. The U.S. Department of Agriculture has stepped up to meet this goal, doubling funding research for cellulosic ethanol.

Oregon is ready to meet the cellulosic ethanol challenge. With more than 1 million tons of post harvest grass seed produced each year, roughly 500,000 of which is burned or retained on the soil, Oregon has the raw ingredients for production. In fact, a report by Oregon Department of Energy, Exhibit Z in your packet, found that Oregon "grass straw residues are well suited for conversion to ethanol." When combined with the alternative tax credits available to growers to find alternatives, production becomes attractive and feasible.

I have introduced an amendment to HB 3000 that you should each have a copy of before you. This amendment eliminates open field burning of grass seed in the Willamette Valley with the exception of a limited number of acres in the Silverton Hills that require burning to maintain yield and purity. Agricultural burning of such items as mint stubble and Christmas tree residue would be allowed with a permit issued by the DEQ. It also creates standards of monitoring for particulate matter by DEQ in conjunction with DHS.

Given that this information is available and known, I believe it is incumbent on the State of Oregon to end the unnecessary practice of field burning, whether it is accomplished by the Executive Branch, the Legislative Branch, or the Judicial Branch, it needs to happen, and I believe it would be negligent if this Legislature or Executive branch do not end field burning this year.

Mr. Chair and Members of the Committee, I urge you to pass House Bill 3000 and make every effort to ensure it is enacted into law. Thank you.

Respectfully,

Paul Holvey
State Representative
District 8

Footnote 4

AMERICAN LUNG ASSOCIATION of Oregon

MEASURE: HB 3000
EXHIBIT: J
House Committee on Health Care
DATE: 04/06/2007 PAGES: 2

OHA
Member, Oregon Health Appeal

7420 SW Bridgeport Road
Suite 200
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(503) 924-4094
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info@lungoregon.org
www.lungoregon.org

Improving Life, One Breath at a Time

To: Health Care Committee

From: Dana Kaye, MPH
American Lung Association of Oregon
7420 SW Bridgeport Road
Suite 200
Tigard, OR 97224

Date: April 6, 2007

Re: HB 3000 Open field, pile and stack burning

Chair Greenlick and Members of the Committee,

The American Lung Association of Oregon would like to express support of HB3000. The practice of burning crops or wood in fields produces large amounts of particle pollution, or particulate matter, which are tiny bits of ash and soot that can lodge deep inside the lungs and harm the body. They produce both fine (PM 2.5) and coarse particles (PM 10). Particle pollution from crop burning can cause these threats to human health:

- Particle pollution significantly increases the risk of dying early. High levels of particle pollution can shorten life, even if the exposure is over a short period, like hours or days. People can die within days or weeks when breathing high levels, which field burning can produce. Many studies over the past two decades have confirmed this, including large studies around the world. (Pope CA, Dockery DW. Health Effects of Fine Particulate Air Pollution: Lines that Connect. *J Air Waste Mange Assoc* 2006; 56:709-742.)

- More than 2,000 peer-reviewed studies on the subject have been published since 1996, confirming the strong relationship between particle pollution, illness, hospitalization and premature death. The U.S. Environmental Protection Agency recently completed a review of these studies and linked particle pollution to premature death from cardiovascular disease, heart attacks and strokes, as well as worsening asthma, COPD, and may cause lung cancer. (U.S. EPA. Air Quality Criteria for Particulate Matter, October 2004.)

- Those most at risk and the most vulnerable among us: children under 18, those over 65, those with lung diseases like asthma and COPD, those with cardiovascular diseases and diabetes.

- Children's lungs develop mostly after they're born and air pollution from burning can affect the ability of the lungs to develop normally, leading to a lifetime of breathing problems. Children are also outside more than adults, so they risk breathing more of this pollution. The American Academy of Pediatricians warns that particle pollution has been linked to infant death, low birth weight and premature birth. (American Academy of Pediatrics Committee on Environmental Health, Ambient Air Pollution: health hazards to children. *Pediatrics* 2004; 114: 1699-1707.)

- People with lung diseases already have difficulty breathing because their lungs don't work as well. Particle pollution triggers asthma attacks, increased risk of hospitalization and emergency room visits, increased use of medicines. New studies are finding that particles may increase risk of developing chronic bronchitis as well as lung cancer. (U.S. EPA, 2004).

Footnote 4

- People with cardiovascular diseases have an increased risk of developing problems and like diabetics can suffer increased heart disease, heart failure, heart attacks, and dysrhythmias, strokes and hospital admissions for these conditions. (Pope and Dockery, 2006).

- Seniors are also more likely to suffer from worsened cardiovascular and respiratory diseases as well as premature death because of breathing high levels of particle pollution. (U.S. EPA, 2004).

The affects of field burning affects the people of Oregon. These people live in your districts. Please join the American Lung Association and stand up for their health. Support HB 3000.

Because when you can't breathe nothing else matters.™

Footnote 4

OREGON MEDICAL ASSOCIATION

MEASURE: HB 3000
EXHIBIT: K
House Committee on Health Care
DATE: 04/06/2007 PAGES: 1
SUBMITTED BY: Dr. James Lace

Date: April 6, 2007

From: James K. Lace, M.D., F.A.A.P.
Oregon Pediatric Society
Oregon Medical Association

To: Representative Mitch Greenlick
Chair, House Health Care Committee

Re: HB 3000 Prohibits open field burning, stack burning, pile burning, and propane flaming

---

I am submitting testimony in favor of HB 3000. I have been a pediatrician in active practice in Salem for the last 30 years. The OMA's Community Health Committee supports HB 3000 because field burning increases air pollution and has adverse health effects on those exposed to it. As a pediatrician I am especially concerned with the most vulnerable populations including children with asthma and other respiratory problems. Other populations particularly at risk include older adults and those with health conditions that may be exacerbated by air pollution including bronchitis and cardiovascular disease.

There is no question that field burning increases air pollution, and while some may claim that the level of pollution is acceptable, this reasoning flies in the face of recent scientific studies. Even if exposure to particulate matter in the $PM_{2.5}$ range is short-term, there are still significant risks to public health, especially to people with asthma or other respiratory conditions. Both the EPA and Department of Environmental Quality agree that human health is adversely affected by short-term exposure to particulate sources such as field burning. Additionally, an article appearing in the February *New England Journal of Medicine* reported that "Long-term exposure to fine particulate air pollution is associated with the incidence of cardiovascular disease and death among post-menopausal women."

Exposure to fine particulate matter ($PM_{2.5}$) increases the number and severity of asthma attacks, bronchitis, may increase cardiovascular risk, or even lead to premature death. OMA has long been supportive of asthma education and prevention measures and believes that HB 3000 would make great strides toward preventing unnecessary air pollution and improving air quality for our patients.

Please vote YES on HB 3000 – for your health, the children's health and the health of your constituents.

Sincerely,

Dr. Jim Lace

5210 S.W. Corbett Avenue
Portland, Oregon 97239-3897
phone 503.226.1555
fax 503.241.7148
www.theOMA.org

SERVING AND SUPPORTING PHYSICIANS IN THEIR EFFORTS TO IMPROVE THE HEALTH OF OREGONIANS

Footnote 5

Lane County Medical Society

990 West 7th Avenue Eugene, Oregon 97402 (541) 686-0995
E-mail: lcms@rio.com Fax (541) 687-1554

Dear Honorable Representatives Barnhart and Nathanson; Senators Morrisette and Walker:

On behalf of the Lane County Medical Society (LCMS) I am writing to thank you for your sponsorship and support of House Bill 3000, the bill that eliminates field burning in Oregon.

The LCMS is a professional membership organization of more than 700 physicians dedicated to bringing the highest quality medical care to the citizens of Lane County. As an organization charged with protecting public health in Lane County, we feel that eliminating the practice of field burning is a prudent means of improving air quality and reducing a threat to the health of our citizens.

As you undoubtedly know, 49,000 acres of grass seed fields were burned in Lane County last year. The smoke from this burning contains a complex mixture of chemicals, known carcinogens such as benzene and acrolein, and coarse and fine particulate matter ($PM_{2.5}$). When inhaled, $PM_{2.5}$ lodges deeply and remains in the lungs, the particulates being too small for our bodies to defend against. The EPA in their *Fact Sheet: Proposal to Revise the National Ambient Air Quality Standards for Particulate Matter* states that "many scientific studies have found an association between exposure to particulate matter and a series of significant health problems including: aggravated asthma; chronic bronchitis; reduced lung function; irregular heartbeat; heart attack; and premature death in people with heart or lung disease."

The introduction of House Bill 3000 is an important step in improving air quality throughout the Willamette Valley. We are hopeful the Legislature will join the medical community in supporting this important legislation.

Sincerely,

Roger McKimmy, MD

Roger M. McKimmy, M.D., President,
Lane County Medical Society

Footnote 5

Grass Seed Field Smoke and Its Impact on Respiratory Health

Roe A. Roberts, Ph.D.
Jeff Corkill, Ph.D.

Abstract

A number of studies have established an association between increases in fine particulates ($PM_{2.5}$) and respiratory morbidity and mortality. High particulate levels in the city of Spokane, Washington, place it among the top 10 worst cities in the country in terms of air quality. Every year, during the months of August and September, 50 to 75 percent of particulates in Spokane originate from the burning of thousands of acres of Kentucky bluegrass in Eastern Washington and Northern Idaho. Burning in the region continues despite attempts by Washington's public officials to curtail it. To assess the potential health impacts of burning grass, this study determined Spokane's adult respiratory disease and hospitalization rates, examined medication use patterns, and identified the chemical content of the smoke. The study found levels of asthma, emphysema, and chronic bronchitis higher than the national average; asthma hospitalization rates higher than the state average; a correlation between weekend bronchodilator purchases and increased $PM_{2.5}$ levels during burns; and phenols and polycyclic aromatic hydrocarbons in grass smoke.

Introduction

Despite 30 years of protests by local citizens claiming that the burning of thousands of acres of grass in Eastern Washington and Northern Idaho has negatively affected their [illegible], grass field burning continues. Recently, [illegible]ure to alter the practice has grown as a [illegible]lt of a convergence of concerns among several diverse political, social, and economic groups. These groups are concerned about the potential health impacts of grass smoke, as well as about economic impacts on tourism. They include an area Chamber of Commerce, the Spokane County Medical Association, the American Lung Association, the Washington Environmental Council, an extremely active Spokane citizens' group, and the Spokane County Air Pollution Control Authority (SCAPCA) (1–5). Given the numbers of opponents, why does the practice of grass field burning continue? In part, the burning continues because no research has been undertaken to identify its potential health impacts. Furthermore, Kentucky bluegrass growers have not found any alternative methods of stimulating grass seed production that are as effective as field burning. Without studies identifying the health hazards of grass smoke, and with grass seed sales constituting a $75 million industry in the inland Northwest, economics have taken precedence over health concerns. In fact, the right to burn grass seed fields was written into a 1991 revision of the Washington State Clean Air Act (6).

In early discussions of the health effects of grass field burning, the president of the Inland Grass Growers Association (IGGA) stated that grass smoke was 80 percent steam and presented no health hazards to area residents, unlike wood smoke, which contains harmful airborne particulates. Opponents contend that the smoke produced by burning grass results in harmful airborne particulates and that grass burning is a virtually unregulated practice, unlike wood burning (7).

Airborne particulates are measured by diameter in microns (i.e., $PM_{2.5}$ refers to particles equal to or less than 2.5 microns [µm] in diameter). Particles 10 µm in diameter or more

Footnotes

(PM_{10}) do not remain airborne for long and are usually filtered by the nasal passages. The smaller the size of the particulates (especially 5 µm and under), the longer the particulates ...ulate in the air, and the deeper they pen... into the alveolar cells of the lungs.

In addition to particle size, health concerns ...late to the chemicals that are usually associated with the process of incomplete combustion (8,9). It has been shown that the concentration of polycyclic aromatic hydrocarbons (PAHs) in suspended particulates is inversely correlated to particle size and that 47 to 70 percent of PAH in smoke is contained in the $PM_{2.0}$ fraction (10,11).

The importance of air pollution in the pathogenesis of bronchial asthma and other pulmonary diseases has been of interest for decades. Considerable epidemiological evidence implicates fine-particulate air pollution, especially PM_{10} and $PM_{2.5}$, as a trigger that exacerbates respiratory conditions in some individuals with asthma and chronic obstructive pulmonary diseases (12–16). The biological mechanism for these effects is as yet unknown, but PM_{10} particulate matter has been demonstrated to have free radical activity and pro-inflammatory effects in lung tissue in vivo and in vitro, as well as immunosuppressive prop... (17,18).

...ne pro-inflammatory effects appear to ...tively affect individuals suffering from a variety of respiratory conditions such as asthma, chronic bronchitis, cystic fibrosis, and emphysema. Individuals whose respiratory conditions include a reactive airway disease (RAD) component appear to be most negatively affected. RAD is often diagnosed as chemically induced asthma and may account for up to 30 percent of diagnosed asthma cases. Chemically induced asthma occurs in response to triggers such as chemical irritants present in the smoke produced by the open burning of biomass (19–24).

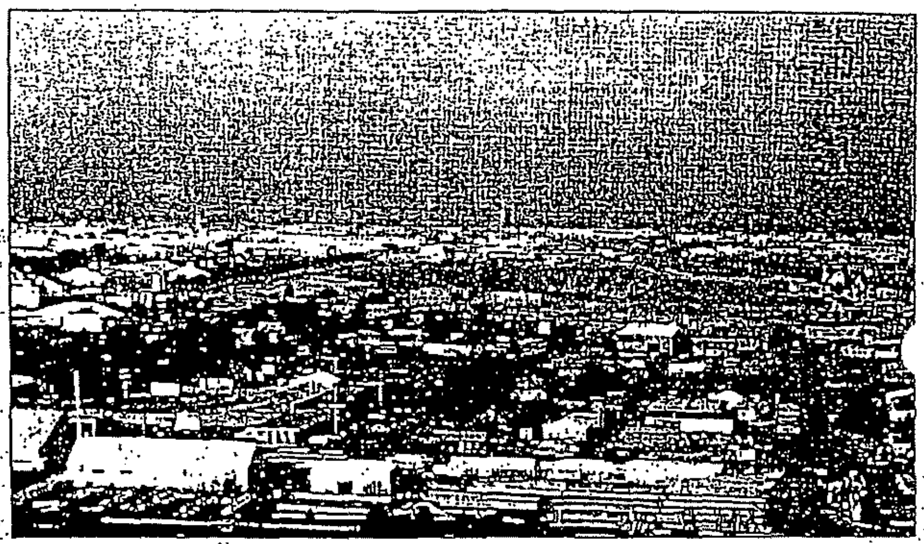
Open burning of biomass is a technique commonly used worldwide both for the disposal of crop and forest debris and for land preparation. This agricultural practice is known to produce significant amounts of volatile organic compounds (VOCs) such as phenols, as well as PAH either in a gaseous aerosol or adsorbed onto inert particulate matter (19,25). Currently, farmers in Eastern Washington and Northern Idaho burn thousands of acres of biomass, particularly Ken... bluegrass.

... the early 1990s, SCAPCA introduced a ...on burning acreage for Spokane County and reduced the number of permissible burn

TABLE 1

A Comparison of Spokane County Population Data and Survey Demographics for 1995

	1995 Census Data	Survey Demographics
Population	401,205	1,850
White	93.4 percent	95 percent
Black/African American	1.4 percent	0.6 percent
Hispanic	1.9 percent	1.5 percent
Asian/Pacific Islander	1.0 percent	1.8 percent
Native American	0.1 percent	1.5 percent
Median Age	44	42
Poverty 18 years and under	NA	20.8 percent



Smoke-filled air in Spokane, Washington due to the burning of grass fields.

days. These regulations did not, however, alter the numbers of acres of grassland burned in the county. The growers successfully argued against stronger limits by pointing out that previous studies on the negative impacts of smoke have been done on wood smoke, not grass smoke, and are therefore not applicable. At public hearings, growers dismissed individual claims of damage as anecdotal and unreliable. They argued that those who claimed to be negatively affected by grass smoke were already hypersensitized and that the true impacts of burning thus could not be clearly defined. In cases in which clear evidence of worsening health occurred, such as in extensive hospitalization of cystic fibrosis patients during burns, they attributed the sudden increase in disease severity to the unpredictable and progressive nature of the underlying disease (7,26). By the summer of 1995, local clean-air citizen groups, a small group of physicians, and even SCAPCA had met with little success in their quest to eliminate or restrict the practice of grass field burning.

Starting late in 1995, a series of events occurred that eventually led to more stringent limitations on grass burning in Washington state. The *Spokesman Review* became the battleground between the grass growers and their association and the area citizens' group. Numerous articles, letters to the editor, and editorial comments were published, both pro and con. In 1996, the Natural Resources Defense Council reported that particulate levels in Spokane County placed its air quality levels among the 10 worst in the country (22). Early in 1996, the Spokane County Medical Society and the Washington Thoracic Society issued statements charging that grass seed field burning represented a public health threat. Local busi-

Footnote 7

FACT SHEET
FINAL REVISIONS TO THE NATIONAL AMBIENT AIR QUALITY STANDARDS FOR PARTICLE POLLUTION (PARTICULATE MATTER)

SUMMARY OF ACTION

- To better protect public health and welfare for millions of Americans across the country, EPA on September 21, 2006 issued the Agency's most protective suite of national air quality standards for particle pollution ever.

- Particle pollution, also called particulate matter or PM, is a complex mixture of extremely small particles and liquid droplets in the air. When breathed in, these particles can reach the deepest regions of the lungs. Exposure to particle pollution is linked to a variety of significant health problems. Particle pollution also is the main cause of visibility impairment in the nation's cities and national parks.

- The final standards address two categories of particle pollution: *fine particles* ($PM_{2.5}$), which are 2.5 micrometers in diameter and smaller; and *inhalable coarse particles* (PM_{10}) which are smaller than 10 micrometers. (A micrometer is 1/1000th of a millimeter; there are 25,400 micrometers in an inch.)

- EPA is strengthening the 24-hour fine particle standard from the 1997 level of 65 micrograms per cubic meter (μg/m3) to 35μg/m^3, and retains the current annual fine particle standard at 15μg/m^3. The Agency also is retaining the existing national 24-hour PM_{10} standard of 150μg/m^3.

- The Agency is revoking the annual PM_{10} standard, because available evidence generally does not suggest a link between long-term exposure to current levels of coarse particles and health problems. EPA is protecting all Americans from effects of short-term exposure to inhalable coarse particles by retaining the existing daily PM_{10} standard of 150 micrograms per cubic meter.

- Scientific studies have found an association between exposure to particulate matter and significant health problems, including: aggravated asthma; chronic bronchitis; reduced lung function; irregular heartbeat; heart attack; and premature death in people with heart or lung disease.

- EPA selected levels for the final standards after completing an extensive review of thousands of scientific studies on the impact of fine and coarse particles on public health and welfare. The Agency also carefully reviewed and considered public comment on the proposed standards. EPA held three public hearings and received about 120,000 written comments.

- The Agency provisionally assessed new, peer-reviewed studies about particle pollution and health (including some studies received during the comment period) to ensure that the

Foot note 7

Oregon Asthma Surveillance Summary Report

March 2007

Oregon Asthma Program
Office of Disease Prevention and Epidemiology
Public Health Services
Oregon Department of Human Services

Foot note 7

Oregon Asthma Program

Mel Kohn, MD, MPH, State Epidemiologist

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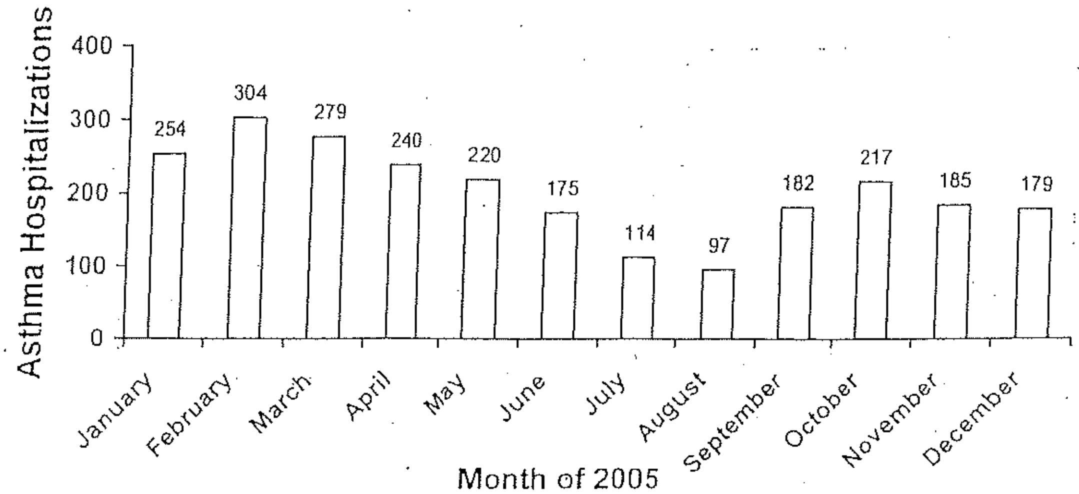
Web site: www.healthoregon.org/asthma

This project is supported by the Centers for Disease Control and Prevention, Cooperative Agreement #U59/CCU017777.

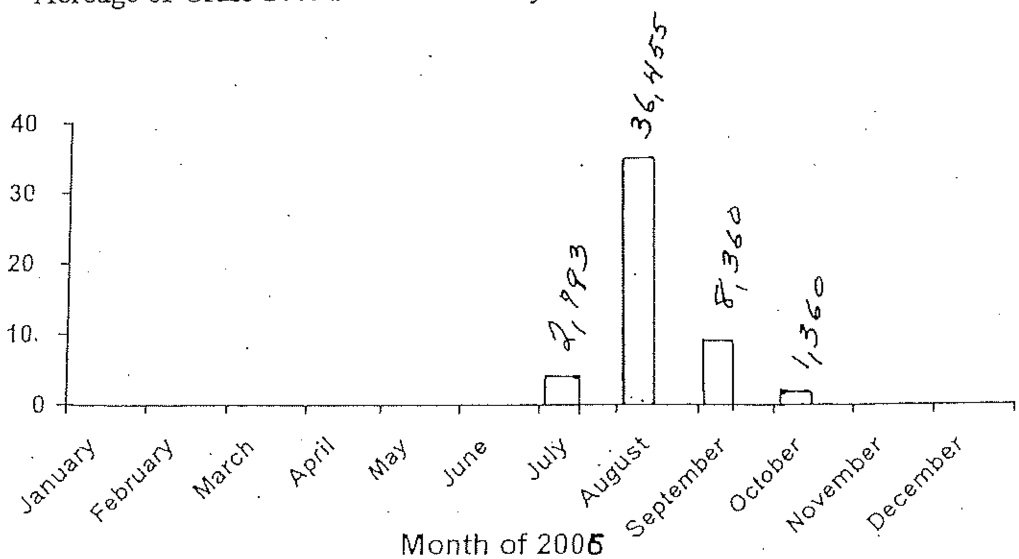
Footnote 7

Figure 22 Number of hospitalizations due to asthma by month in 2005



Source: Oregon Hospital Discharge Index, 2005

Acreage of Grass Seed Fields Burned by Month



Source Oregon Department of Agriculture

Lower Figure Inserted by OSC and not a part of original report.

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Original Contribution

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Fine Particulate Air Pollution and Hospital Admission for Cardiovascular and Respiratory Diseases

Francesca Dominici, PhD; Roger D. Peng, PhD; Michelle L. Bell, PhD; Luu Pham, MS; Aidan McDermott, PhD; Scott L. Zeger, PhD; Jonathan M. Samet, MD

JAMA. 2006;295:1127-1134.

ABSTRACT

Context Evidence on the health risks associated with short-term exposure to fine particles (particulate matter ≤2.5 µm in aerodynamic diameter [$PM_{2.5}$]) is limited. Results from the new national monitoring network for $PM_{2.5}$ make possible systematic research on health risks at national and regional scales.

Objectives To estimate risks of cardiovascular and respiratory hospital admissions associated with short-term exposure to $PM_{2.5}$ for Medicare enrollees and to explore heterogeneity of the variation of risks across regions.

Design, Setting, and Participants A national database comprising daily time-series data daily for 1999 through 2002 on hospital admission rates (constructed from the Medicare National Claims History Files) for cardiovascular and respiratory outcomes and injuries, ambient $PM_{2.5}$ levels, and temperature and dew-point temperature for 204 US urban counties (population >200 000) with 11.5 million Medicare enrollees (aged >65 years) living an average of 5.9 miles from a $PM_{2.5}$ monitor.

Main Outcome Measures Daily counts of county-wide hospital admissions for primary diagnosis of cerebrovascular, peripheral, and ischemic heart diseases, heart rhythm, heart failure, chronic obstructive pulmonary disease, and respiratory infection, and injuries as a control outcome.

Results There was a short-term increase in hospital admission rates associated with $PM_{2.5}$ for all of the health outcomes except injuries. The largest association was for heart failure, which had a 1.28% (95% confidence interval, 0.78%-1.78%) increase in risk per 10-µg/m^3 increase in same-day $PM_{2.5}$. Cardiovascular risks tended to be higher in counties located in the Eastern region of the United States, which included the Northeast, the Southeast, the Midwest, and the South.

Conclusion Short-term exposure to $PM_{2.5}$ increases the risk for hospital admission for cardiovascular and

respiratory diseases.

INTRODUCTION

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Numerous epidemiological studies have shown associations of acute and chronic exposures to airborne particles with risk for adverse effects on morbidity and mortality.[1-2] The recent evidence on adverse effects of particulate air pollution on public health has led to more stringent standards for levels of particulate matter in outdoor air in the United States and in other countries. In 1997, the US National Ambient Air Quality Standard for airborne particulate matter was revised, maintaining the previous indicator of particulate matter of less than or equal to 10 µm in aerodynamic diameter (PM_{10}) and creating a new indicator for fine particulate matter of less than or equal to 2.5 µm in aerodynamic diameter ($PM_{2.5}$).[3] Following the implementation of the $PM_{2.5}$ National Ambient Air Quality Standard, a nationwide monitoring system of this pollutant was implemented. Data on $PM_{2.5}$ are now available for many parts of the United States starting from 1999 through the present.

Although the US Environmental Protection Agency (EPA) added a $PM_{2.5}$ standard in 1997 based on available evidence that these small particles were particularly damaging, few epidemiological studies on this size range of particulate matter had been reported at that time. The EPA heavily weighted the few studies with available $PM_{2.5}$ data when it considered the level that should be set for the standard.[4] The EPA also considered the dosimetry of particles in the lung. Particles in the size range of $PM_{2.5}$ have a much greater probability of reaching the small airways and the alveoli of the lung than do larger particles. The availability of the new monitoring network for $PM_{2.5}$ allows epidemiological analyses at the national level on the health effects of fine particles.

The national data on $PM_{2.5}$ concentrations were used to assess associations of short-term exposure to $PM_{2.5}$ with risk for hospitalization regionally and by city among Medicare participants. We followed the model of the National Morbidity, Mortality and Air Pollution Study, which used PM_{10} data for time-series analyses.[5-8] The Medicare cohort covers nearly all members of an elderly population considered to be vulnerable to air pollution; the size of this population allows for assessments of specific cardiac and respiratory diagnostic categories that have been associated with particulate air pollution.

METHODS

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This analysis is based on daily counts of hospital admissions for 1999-2002 obtained from billing claims of Medicare enrollees. Because the Medicare data analyzed for this study did not involve individual identifiers, consent was not specifically obtained. This study was reviewed and exempted by the institutional review board at Johns Hopkins Bloomberg School of Public Health. Each billing claim contains the date of service, treatment, disease (*International Classification of Diseases, Ninth Revision*[9] *[ICD-9]* codes), age, sex, self-reported race, and place of residence (ZIP code and county). The daily counts of each health event within each county were obtained by summing the number of hospital admissions for each of the diseases considered a primary diagnosis. To calculate hospitalization rates, we constructed a time series of the numbers of individuals at risk in each county for each day (defined as the number of individuals enrolled in Medicare on a given day).

Eight outcomes were considered based on the *ICD-9* codes for 5 cardiovascular outcomes (heart failure [428], heart rhythm disturbances [426-427], cerebrovascular events [430-438], ischemic heart disease [410-414, 429], peripheral vascular disease [440-448]), 2 respiratory outcomes (chronic obstructive pulmonary disease [COPD; 490-492], respiratory tract infections [464-466, 480-487]), and hospitalizations caused by injuries and other external causes (800-849). The county-wide daily hospitalization rates for each outcome for 1999-2002 appear in Table 1.

View this table:
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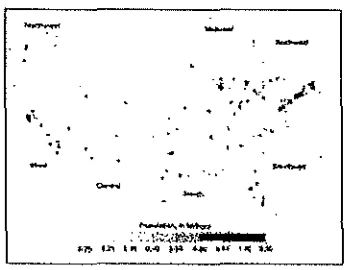
Table 1. Percentage Change in Hospitalization Rate per 10-µg/m^3 Increase in $PM_{2.5}$ on Average Across 204 Counties

The study population includes 11.5 million Medicare enrollees residing an average of 5.9 miles from a $PM_{2.5}$ monitor. The analysis was restricted to the 204 US counties with populations larger than 200 000. Of these 204 counties, 90 had daily $PM_{2.5}$ data across the study period and the remaining counties had $PM_{2.5}$ data collected once every 3 days for at least 1 full year. The locations of the 204 counties appear in Figure 1. The counties were clustered into 7 geographic regions by applying the K-means clustering algorithm to longitude and latitude for the counties.[10-11]



View larger version (102K):
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[in a new window]
[as a PowerPoint slide]

Figure 1. US Counties With Populations Larger Than 200 000 Included in Analysis

The $PM_{2.5}$ and ozone data were obtained from the EPA's Aerometric Information Retrieval Service (now referred to as the Air Quality System database). Temperature and dew-point temperature data were gathered from the National Climatic Data Center on the Earth-Info CD database.[12] To protect against consequences of outliers, we used a 10% trimmed mean to average across monitors after correcting for yearly averages for each monitor.

County names and location, air pollution data, weather data, county-specific estimates of health risk, and software developed to construct county-specific time-series data are available online (http://www.biostat.jhsph.edu/MCAPS). Billing claims of Medicare enrollees are not publicly available. Calculations were implemented using R statistical software version 2.2.0.[13]

We applied Bayesian 2-stage hierarchical models[14-16] to estimate county-specific, region-specific, and national average associations between day-to-day variation of $PM_{2.5}$ (at lags 0, 1, and 2 days) and day-to-day variation in the county-level hospital admission rates, accounting for weather, seasonality, and long-term trends. A lag of 0 days corresponds to the association between $PM_{2.5}$ concentration on a given day and the risk of hospitalization on the same day. We also applied distributed lag models[17-20] to the 90 counties with daily $PM_{2.5}$ data available to estimate the relative rate (RR) of hospitalization associated with cumulative exposure over the current day and the 2 previous days. Significance is assessed by the posterior probability that the RR is larger than zero. Values greater than .95 are considered significant.

In the first stage, single lag and distributed lag overdispersed Poisson regression models[21-22] were used for estimating county-specific RRs of hospital admissions associated with ambient levels of $PM_{2.5}$. These county-specific models include as explanatory variables: (1) the logarithm of the daily number of individuals at risk; (2) indicator variables for the day of the week to allow for different baseline hospital admission rates for each day; (3) smooth functions of calendar time (natural cubic splines) with 8 degrees of freedom per year to adjust for seasonality and for other time-varying influences on admissions (eg, influenza epidemics and longer-term trends due to changes in medical practice patterns); and (4) smooth functions of temperature (6 degrees of freedom) and dew-point temperature (3 degrees of freedom) on the same day and of the 3 previous days' temperature and dew-point temperature to control for the potential confounding effect of weather.

For the smooth functions of calendar time, we chose 8 degrees of freedom per year so that little information at the time scales of longer than 2 months would be retained in estimating the risks. For temperature, we chose 6 degrees of freedom so that the model has sufficient flexibility to take account of potential nonlinearity in the relationship of temperature with hospitalization.[23]

This modeling approach was developed for the National Morbidity, Mortality and Air Pollution Study analyses[22, 24] and applied to national databases for estimating short-term effects of PM_{10} and ozone on mortality.[5, 12] Statistical properties of this modeling approach and alternative modeling specifications for confounding adjustment are reported elsewhere.[7, 25]

In the second stage, to produce a national average estimate of the short-term association between $PM_{2.5}$ and hospital admissions, we used Bayesian hierarchical models[14-16,26] to combine RRs across counties accounting for within-county statistical error and for between-county variability of the "true" RRs (also called heterogeneity). To produce regional estimates, we used the same 2-stage hierarchical model described above but separately within each of the 7 regions.

To explore effect modification of air pollution risks by location-specific characteristics, we fitted a weighted linear regression model with the dependent variable as the location-specific RR estimate and the independent variable as the location-specific characteristic. The observations were weighted inversely to the statistical variance of the location-specific estimate.

The county and regional averages of $PM_{2.5}$ concentration, ozone concentration, and temperature for 2000 through 2002 were calculated as potential modifiers. A regional average was calculated by using all of the county-specific concentrations within the region.

Finally, the annual reduction in hospital admissions (H) attributable to a 10-$\mu g/m^3$ reduction in the daily $PM_{2.5}$ level for the 204 counties by cause-specific admissions were calculated. H is defined as

$H = (\exp(\beta\Delta x) - 1) \times N$

where β is the national RR estimate for a 1-μg/m³ increase in $PM_{2.5}$, Δx is 10-μg/m³, and N is the number of hospital admissions across the 204 counties for 2002.

The sensitivity of key findings was examined with respect to the lag of exposure; degrees of freedom in the smooth functions of time; and degrees of freedom in the smooth functions of temperature and dew-point temperature.

RESULTS

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More than 2 years of $PM_{2.5}$ data were available for most of the 204 counties. The average of the county mean annual values for 1999-2002 was 13.4 μg/m³ (interquartile range [IQR], 11.3-15.2 μg/m³). There was substantial homogeneity of fine particulate matter concentrations across geographic areas. The median of pairwise correlations among $PM_{2.5}$ monitors within the same county for 2000 was 0.91 (IQR, 0.81-0.95).

The point estimates and 95% posterior intervals (PIs) for the percentage increase in daily admission rates per 10-μg/m³ increase in $PM_{2.5}$ concentration (national average RRs) for single lags of 0, 1, and 2 days and the distributed lag models for lags 0 through 2 for all disease outcomes (total) appear in Figure 2. The single lag model estimates the effect of exposure on 1 day only, lagged by 0, 1, or 2 days, while the total estimate from the distributed lag model summarizes the effect of 3 days of exposure (lag 0, 1, and 2 days). We found evidence of positive associations between day-to-day variation in $PM_{2.5}$ concentration and hospital admissions for all outcomes, except injuries, for at least 1 exposure lag. The largest effect was found at lag 0 for all of the cardiovascular outcomes except ischemic heart disease, for which the largest effect was at lag 2. For respiratory outcomes, the largest effects occurred at lags 0 and 1 for COPD and at lag 2 for respiratory tract infections. Distributed lag estimates were statistically significant for heart failure. Compared with the single lag estimates, the wider 95% PIs for the distributed lag estimates reflect the restriction of the analysis to 90 of the 204 counties with daily data. The results for the single lag models were also stratified by age group at the lag with the greatest effect (Table 1). The national average RR estimates were larger for the oldest group for some outcomes including ischemic heart disease, heart rhythm disturbances, heart failure, and COPD.

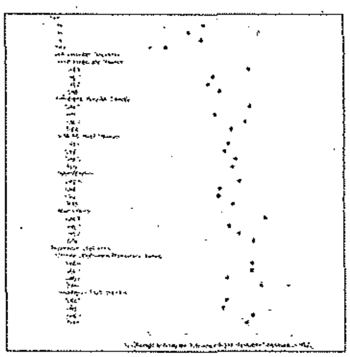

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Figure 2. Percentage Change in Hospitalization Rate by Cause per 10-μg/m³ Increase in $PM_{2.5}$ on Average Across 204 US Counties

Point estimates and 95% posterior intervals of the percentage change in admission rates per 10 μg/m³ (national average relative rates) for single lag (0,1, and 2 days) and distributed lag models for 0 to 2 days (total) for all outcomes. $PM_{2.5}$ indicates particulate matter of less than or equal to 2.5 μm in aerodynamic diameter.

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Several analyses were conducted as internal checks. Analyses for lag −1 were run to predict today's outcome by using the next day's pollution and for hospitalizations caused by injuries and other external causes. Positive associations were not found for injuries or for other external causes, which was expected. When lag −1 $PM_{2.5}$ was used as the exposure indicator, positive associations also were not found. The main results were robust to the number of degrees of freedom used to adjust for temporal confounding, to the adjustment for weather, and to adjust for the prior distributions used for the analysis.

The point estimates and 95% PIs of the heterogeneity parameter, defined as the between-county SD of the "true" county-specific rates in relation to their mean, appear in Table 1. For example, the estimate of the heterogeneity parameter for COPD is 1.61. This value indicates that with a national average RR of 0.91% per 10-μg/m^3 increase in $PM_{2.5}$, 95% of the "true" county-specific RRs are within the interval of 0.91 to 1.96 x 1.61 = −2.24% and 0.91 + 1.96 x 1.61 = 4.06%. To determine the strength of evidence supporting the null hypothesis of no heterogeneity, we calculated the posterior probability that the heterogeneity parameter is smaller than .05 (the Bayesian analogue of a *P* value) and this was found to be close to 0 for all outcomes.

To determine whether there was significant variation of risks across the 7 geographic regions, the RR for each outcome was estimated separately within the regions, which excluded Honolulu, Hawaii, and Anchorage, Alaska.The point estimates and 95% PIs of the regional RRs for each outcome at the lag with the greatest estimated RR appear in Figure 3 and Table 1. For the 2 groups of outcomes (cardiovascular and respiratory), the estimated RRs have distinct regional patterns. For cardiovascular diseases, all estimates in the Midwestern, Northeastern, and Southern regions were positive, while estimates in the other regions were close to 0. Compared with cardiovascular diseases, there was greater consistency between the regions for respiratory diseases. However, there were larger effects in the Central, Southeastern, Southern, and Western regions than in the other regions.

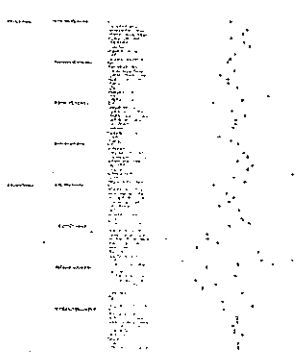

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Figure 3. Percentage Change in Hospitalization Rate by Region and Cause per 10-μg/m^3 Increase in $PM_{2.5}$ Within Each Region

Point estimates and 95% posterior intervals of the percentage change in admission rates per 10 μg/m^3 (regional relative rates). $PM_{2.5}$ indicates particulate matter of less than or equal to 2.5 μm in aerodynamic diameter; COPD, chronic obstructive pulmonary disease. *Honolulu, Hawaii, and Anchorage, Alaska, were excluded.

Regional differences were investigated by dividing the United States into an Eastern region (Northeast, Southeast, Midwest, and South) and a Western region (West, Central, and Northwest). The average effect estimates and 95% PIs of the RRs for each outcome and for the lags with the greatest estimated national average effects appear in Figure 4. There were 168 counties included in the Eastern region and 34 counties included in the Western region. Using analysis of variance, the differences in risk of hospitalization between the 2 regions were statistically significant for outcomes except for heart failure and COPD. All RR estimates for cardiovascular outcomes were positive in the US Eastern region but not in the US Western region. The RR estimates for respiratory tract infections were larger in the Western region than in the Eastern region.

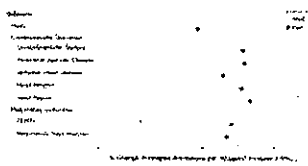

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Figure 4. Percentage Change in Hospitalization Rate by Cause per 10-μg/m^3 Increase in $PM_{2.5}$ for the US Eastern and Western Regions for all Outcomes

Point estimates and 95% posterior intervals of the percentage change in admission rates per 10 μg/m^3. $PM_{2.5}$ indicates particulate matter of less than or equal to 2.5 μm in aerodynamic diameter; COPD, chronic obstructive pulmonary disease.

Effect modification of short-term effects of $PM_{2.5}$ on hospital admission rates was investigated by using both county and regional averages of $PM_{2.5}$ concentrations, temperature, and ozone. Both county and regional average temperature positively modified the association between $PM_{2.5}$ and hospital admission rates for the 2 respiratory outcomes. For example, comparing 2 regions that differ by 1°C, there would be an estimated 18 additional hospital admissions per 10 000 individuals for COPD and 9 additional hospital admissions per 10 000 individuals for respiratory tract infections per 10-μg/m^3 increase in $PM_{2.5}$ in the warmer region. We did not find evidence of the effect modification by average concentrations of either $PM_{2.5}$ or ozone.

The yearly hospital admissions attributable to a 10-μg/m^3 reduction in the daily $PM_{2.5}$ also were calculated (Table 2). For example, a 10-μg/m^3 reduction in $PM_{2.5}$ would reduce the number of hospitalizations for heart failure by 3156 for the 204 urban counties in 2002.

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Table 2. Annual Reduction in Admissions Attributable to a 10-μg/m^3 Reduction in the Daily $PM_{2.5}$ Level for the 204 Counties in 2002

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The Medicare National Claims History Files were used in this study to estimate the short-term effects of $PM_{2.5}$ on cause-specific hospitalization rates. Data obtained from national databases on health were combined with data on air pollution and weather.[5,]

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[27] This is a replicable approach that can be applied periodically for air pollutants or other environmental factors as a component of a national health surveillance system to track adverse health effects. This approach also has the strength of analyzing the national data uniformly, avoiding the potential for publication bias that occurs when data from only 1 or several counties are analyzed and positive findings are selectively reported.[27]

In interpreting the findings, consideration needs to be given to the inherent limitations of the data analyzed and to the possibility that even the complex statistical models used are not adequate to eliminate all bias. Medicare data are collected for administrative purposes and diagnoses are known to be subject to some degree of misclassification[28-30] and to vary geographically.[31-32] The resulting misclassification and geographic variability would introduce a bias in daily time-series analyses only if patterns of diagnosis and coding were associated with level of $PM_{2.5}$. We used only primary diagnosis, an approach that should reduce misclassification of outcomes. To investigate whether geographic differences in diagnosis rates could modify the risks, a second-stage analysis was performed using county-specific hospital admission rates (number of admissions per 100 000 individuals) as an independent variable and county-specific RR estimates as a dependent variable. This analysis did not find such evidence of effect modification by underlying diagnosis rates. While we relied on monitors cited for regulatory purposes, the average distance from the centroid of a ZIP code to the monitor was only 5.9 miles and $PM_{2.5}$ levels tend to be uniform across such distances.

The modeling approach used in this study enabled extensive exploration of the sensitivity of the findings. At the first stage of the hierarchical model, we specified the same number of degrees of freedom in the smooth functions of time and temperature used to control for confounding for all the locations. This approach does not necessarily lead to a similar degree of control for confounding across counties, but it does give similar flexibility to the smooth functions, allowing their shape to vary across counties. An alternative is to allow a different number of degrees of freedom across counties, an approach used in multisite time-series studies in Europe.[33-36] Recently we have compared these 2 modeling strategies and found that national estimates of PM_{10} risks were robust to the choice of method.[19] We also have explored the sensitivity of the estimated RRs to different degrees of adjustment for weather and seasonality and found the results to be robust. Statistical challenges inherent to the adjustment for temporal confounding have been explored elsewhere.[19, 25, 37]

Overall, we found evidence of an association between recently measured $PM_{2.5}$ concentrations and daily hospitalizations on a national scale. Our findings complement substantial evidence on particulate matter and hospitalization for respiratory or cardiovascular causes using exposure measures other than $PM_{2.5}$ and the more limited evidence using $PM_{2.5}$ specifically. While mechanisms underlying the adverse effects of particulate matter on the respiratory and cardiac systems remain a focus of research, the leading hypotheses emphasize inflammatory responses in the lung and release of cytokines with local and systemic consequences.[1, 38-40] In the lung, particulate matter may promote inflammation and thereby exacerbate underlying lung disease and reduce the efficacy of lung-defense mechanisms. Cardiovascular effects may reflect neurogenic and inflammatory processes.[40] Experimental studies of atherosclerosis using genetically susceptible mice also suggest that particulate matter may accelerate the development of atherosclerosis[41]; parallel human findings also were found.[42]

Although many time-series studies have used PM_{10} as an exposure indicator, only a few studies have specifically assessed associations of $PM_{2.5}$ with hospitalization or other morbidity measures.[43] Lippmann et al[44] and Ito et al[45] used Medicare admission data for Detroit, Mich, for 1992-1994, along with size-fractionated particle concentration data from a nearby monitoring station in Windsor, Ontario. As reported by Ito et al,[45] updated analyses of these data showed positive associations of $PM_{2.5}$ for hospitalization for pneumonia, COPD, ischemic heart disease, and heart failure. In comparison with the present study, the reported risk estimates were several-fold higher. Moolgavkar[46-47] used data for Los Angeles County, California, for 1987-1995 and found that $PM_{2.5}$ was significantly associated with risk for hospital admission for cardiovascular disease in persons aged 65 years or older. Sheppard et al[48-49] reported a positive association of $PM_{2.5}$ with risk for hospital admission for asthma in Seattle, Wash, for 1987-2004, but elderly persons were excluded. Finally, Burnett et al[50] assessed risk for hospitalization for cardiorespiratory diseases in relation to particulate air pollution over 3 summers in Toronto, Ontario. Positive associations were found in univariate models that were attenuated with consideration of gaseous pollutants in bivariate models.

There is much more literature on PM_{10} and risk for hospitalization, which generally shows positive associations.[2, 51] In most urban locations across the United States, $PM_{2.5}$ accounts for at least half of the PM_{10} mass, and a scaling factor of 0.55 has been used to convert PM_{10} concentrations to $PM_{2.5}$. With this assumption, our quantitative findings for $PM_{2.5}$ are quite similar to those for both PM_{10} and for $PM_{2.5}$ as recently summarized by the EPA.[43] The comparability of the PM_{10} and $PM_{2.5}$ estimates suggests that the effect of PM_{10} on hospital admissions largely reflects its $PM_{2.5}$ component.

The sources of particles contributing to the observed risks need to be identified so that control strategies can be targeted efficiently. Because the source mix for $PM_{2.5}$ varies across locations, we explored spatial variation of the effect of $PM_{2.5}$ on risk for hospitalization. Strong evidence for spatial heterogeneity in the effect of $PM_{2.5}$ on risk for hospitalization was found. The pattern and degree of heterogeneity tended to vary by outcome measure. Because the magnitude of the effects contrasted greatly in the comparisons between the 7 regions, counties were grouped into an Eastern region and a Western region. There are known differences in the composition of particles at this geographic scale, including a greater sulfate component in the East and a greater nitrate component in the West.[2] There are also well-characterized differences in the mix of sources across these broad areas that may be relevant, including power generation and the smokestack industry in the East and a larger contribution from transportation sources in parts of the West.

With clear and continuing indication that inhaled particles affect public health adversely, the emphasis of research should shift toward the difficult issue of identifying those characteristics of particles that determine their toxicity.[1] The EPA's Speciation Trends Network, which is now providing extensive data on characteristics of $PM_{2.5}$ at selected sites, offers a needed resource for this research.[52]

Under the Clean Air Act,[53] the EPA is required to set a particulate matter National Ambient Air Quality Standard that protects public health with an "adequate margin of safety." Our findings indicate an ongoing threat to the health of the elderly population from airborne particles and provide a rationale for setting a $PM_{2.5}$ National Ambient Air Quality Standard that is as protective of their health as possible. Our national approach offers a method for continuing to search for the characteristics of particles that determine their toxicity.[53]

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Study concept and design: Dominici, Peng, Zeger, Samet.

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Analysis and interpretation of data: Dominici, Peng, Bell, Pham, McDermott, Zeger.

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Critical revision of the manuscript for important intellectual content: Dominici, Peng, Bell, McDermott, Zeger, Samet.

Statistical analysis: Dominici, Peng, Bell, Pham, McDermott, Zeger.

Obtained funding: Dominici, Bell, Samet.

Administrative, technical, or material support: Dominici.

Study supervision: Dominici.

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Footnote 12, 19

LRAPA
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November 15, 2006

Representative Paul Holvey
PO Box 51048
Eugene, OR 97405

Re: Request for Legislative Action Regarding Grass Field Burning

Dear Representative Holvey:

Request. The Lane Regional Air Protection Agency (LRAPA), entrusted with air quality protection in Lane County, respectfully requests that the Oregon Legislature revisit the issue of grass field burning in the coming session and craft legislation to eliminate the practice in the Willamette Valley at the earliest possible date.

Roles. LRAPA's mission is "*To protect public health, community well-being and the environment as a leader and advocate for the continuous improvement of air quality in Lane County, Oregon.*" Grass field burning in the Willamette Valley is regulated by the Legislature under Oregon Revised Statutes 468A.550 through 468A.620 and managed by the Oregon Department of Agriculture under Oregon Administrative Rules and contractual agreement with the Oregon Department of Environmental Quality. The Legislature declared it to be the public policy of the state to reduce the practice of open field burning while developing and providing alternative methods of field sanitization and alternative methods of utilizing and marketing crop residues. The goal of the Oregon Department of Agriculture is to offer maximum opportunities for open field burning, propane flaming, and stack burning with minimal smoke impacts on the public.

Problem. A large number of the air pollution complaints received by LRAPA involve field burning, and the majority of the field burning complaints received by the Oregon Department of Agriculture are from Lane County residents. During 1990-2005, LRAPA received an average of 1,030 air pollution complaints per year; about one-third of these (335) were related to field burning during July-September, which were recorded and forwarded to the Oregon Department of Agriculture. Some of these complaints were from residents with asthma or other respiratory problems and their physicians; others were from residents concerned about soot fallout, obstruction of blue skies, impaired visibility of scenic views, or other interference with their outdoor enjoyment. During 2000-2005, the average number of field burning complaints recorded by the Oregon Department of Agriculture was 596 per year; about 400 of these (or about two-thirds) came from Eugene-Springfield or other parts of the southern Willamette Valley.

Footnote 12, 19

Past efforts. The Oregon Legislature adopted a phase-down plan in 1991 that reduced the amount of grass field burning in 1998 and future years to no more than 65,000 acres per year. The Oregon Department of Agriculture has operated a sophisticated smoke management program designed to minimize smoke impacts to major urban areas. The State of Oregon has invested over $1.3 million in research on field burning alternatives since 1998 (and the Oregon Seed Council has provided a similar amount) and over $4.7 million in tax credits for field burning alternatives since 1998 (and over $11.9 million in tax credits since 1991).

Why now? The high numbers of air pollution complaints in recent years indicate that field burning smoke continues to be a serious concern to residents of Lane County, despite the best efforts of the Oregon Department of Agriculture to minimize smoke impacts. The Legislature last adopted a phase-down in field burning acreage in 1991, and the amount of annual field burning acreage has been essentially constant since 1998. Since adopting the 1991 legislation, Oregon has invested millions of dollars in tax credits and research for field burning alternatives. Meanwhile, the State of Washington has identified alternatives available at reasonable costs, has determined that the benefits of a ban outweigh the costs of the alternatives, and has banned the practice except for very limited waivers.

We are committed to working with the Oregon Legislature to protect air quality in Lane County. LRAPA respectfully requests that you work with your colleagues in the Oregon Legislature to eliminate grass field burning in the Willamette Valley.

Sincerely,

Dave Ralston, Chair
LRAPA Board of Directors

MLH:mlh

Footnote 13

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Attorney for Plaintiff Safe Air for Everyone

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF IDAHO

SAFE AIR FOR EVERYONE, Plaintiff, v. WAYNE MEYER, *et al.*, Defendants.	Case No. 02-0241N-EJL DECLARATION OF ERIC SKELTON

Pursuant to 28 U.S.C. § 1746, Eric Skelton declares as follows:

1. I am employed as the Director of the Spokane County Air Pollution Control Authority ("SCAPCA") and have held that position since 1991. I oversee all programs implemented by SCAPCA, including permitting, compliance assurance, enforcement, planning, technical services and air monitoring, education and outreach, and administration. I served as the State Chairman of the Washington Air Quality Managers Group from 2000 to 2001 and was National President of the Association of Local Air Pollution Control Officials in the 1999-2000 term. I am making this declaration in my personal capacity as an individual and not as a representative of SCAPCA.

2. Through my professional work with SCAPCA, I am very familiar with the history and practice of agricultural burning in Washington and North Idaho including the annual burning of Kentucky bluegrass post-harvest crop residue. Specifically, I am familiar with: (i) past Kentucky bluegrass crop residue burning in Washington and present bluegrass crop residue burning in North Idaho; (ii) the Washington Department of Ecology's regulations which phased down and banned (except under very limited circumstances) the burning of Kentucky bluegrass crop residue in Washington; (iii) the air quality impacts in Spokane County, Washington of Kentucky bluegrass crop residue burning in North Idaho; and (iv) the effectiveness of agricultural burning smoke management. A copy of my resume is attached as Exhibit A.

3. Prior to 1996, Kentucky bluegrass seed growers in Washington used open field burning as the primary method of disposing of post-harvest crop residue. From a period typically beginning as early as late August and running through the end of September, Washington bluegrass growers would burn tens of thousands of acres of fields containing the waste bluegrass straw that remains after harvesting the bluegrass seed crop, as well as the stubble still attached to the ground. For example, over a sixteen day period in 1993 bluegrass growers burned 24,471.5 acres of bluegrass crop residue in Spokane County, Washington. This caused significant amounts of smoke, containing high levels of particulate matter ("PM") harmful to human health, including PM2.5 and PM10. PM2.5 is measured as the mass, in micrograms, of all particles below 2.5 micrometers in diameter that are suspended in a unit volume of air, typically a cubic meter. Similarly, PM10 represents the mass, in micrograms of all particles in a unit volume (e.g., a cubic meter) of air below 10 micrometers in diameter. SCAPCA received

426 complaints during the 1993 bluegrass burning season. A follow up survey, conducted by the local chapter of the American Lung Association, leads me to conclude that most of the complaints were related to people's difficulty breathing because of their chronic or acute respiratory problems such as allergies and asthma. Prior to 1996, bluegrass crop residue burning in Spokane County and other parts of Washington occurred under so-called "smoke management plans." The smoke management plan applicable in Spokane County: (i) required bluegrass growers to obtain a burn permit; (ii) limited burning to a sixteen day burn season; and (iii) limited burning to designated burn days during the sixteen day burn season. Designated burn days are a common feature of smoke management plans. By limiting burning to designated burn days, smoke management plan administrators seek to minimize the impacts of the smoke by allowing burning only when wind direction, wind speed, and other meteorological conditions are anticipated to direct most of the smoke away from communities.

4. Smoke management plans however have proven ineffective at protecting public health from the adverse health effects of smoke from crop residue burning for a number of reasons.

> a. First, winds are not predictable. Although it is generally possible to make reliable predictions about the behavior of seasonally prevailing winds, it is virtually impossible to make consistently accurate predictions about wind behavior over a period of a few hours. This is a critical defect in smoke management plans. Winds that may direct smoke from burning bluegrass fields toward an unpopulated area may suddenly shift and direct smoke to populated areas.
>
> b. Second, even if winds could be predicted with certainty, there is often no good place to send the smoke. A smoke management plan is not an emission reduction plan. Smoke management plans do not control or reduce PM emissions. They merely move PM emissions around, spatially and temporally, in hopes of mitigating the impacts

of smoke. This is almost certain to fail in North Idaho where populated communities exist in virtually every direction. The outcome of any smoke management plan in North Idaho comes down to a choice as to which group of people is going to be the target of the smoke plumes. Smoke from a burning bluegrass field is capable of hitting a community in nearly any direction that the wind blows. To use a North Idaho example, if on a burn day on the Rathdrum Prairie, the smoke travels away from Post Falls and Coeur d'Alene (a satisfactory burn day for those communities) the smoke is likely to travel toward Athol, Sandpoint, or Chattaroy, Washington (an unsatisfactory burn day for those communities).

c. Third, the smoke and pollution can persist in the air for some time during which wind directions can change. Smoke management plans typically do not limit the acreage that may be burned in a single day. On a designated burn day, growers may burn thousands of acres of bluegrass crop residue, causing an immense volume of smoke to rise into the atmosphere. This smoke does not merely dissipate in the atmosphere. Smoke particles persist, often suspended in the atmosphere for days after burning ceases and become trapped in the air mass, near the ground as a result of nightly temperature inversions. This is confirmed by data, which show elevated PM2.5 concentrations persisting for one or more days after a burn day, especially when large numbers of acres have been burned on a given day.

5. Given the limitations identified above, the smoke management plan applicable in Spokane County was incapable of guaranteeing that there would not be one or more significant smoke intrusion episodes in the course of a burn season. For example, the week of September 6, 1993 was dominated by high barometric pressure and persistent temperature inversions. Bluegrass growers on the Rathdrum Prairie in North Idaho burned fields on September 9th. Winds carried the smoke west to the Spokane Valley, the City of Spokane, and North Spokane. A burn day was also designated in Spokane County early on September 9th when winds appeared to be conducive to carrying the smoke away from populated areas. However, early in the afternoon a

significant amount of smoke began impacting Cheney, Washington. Although burning was curtailed by 2 p.m., the winds shifted and carried the smoke north toward Spokane. SCAPCA air monitoring stations recorded significant smoke intrusions and SCAPCA received 260 complaints.

6. In part due to the inability of smoke management plans to protect public health, the Washington Department of Ecology announced in 1995 that it would implement a provision of the Washington Clean Air Act which authorized the Department of Ecology to minimize the adverse effects of burning bluegrass crop residue. Specifically, Section 70.94.656(3) of the Revised Code of Washington authorized the Department of Ecology to: (i) research alternatives to burning bluegrass post-harvest bluegrass crop residue; (ii) limit the number of acres of bluegrass crop residue burned; and (iii) certify alternatives to burning bluegrass crop residue, as a means of ending grass field burning. Section 70.94.656(3), a copy of which is attached as Exhibit B, further provides, "in any case which any such approved alternate is reasonably available, the open burning of field and turf grasses grown for seed shall be disallowed and no permit shall issue therefore."

7. Acting under this statutory authority, the Department of Ecology phased down and banned bluegrass crop residue burning in Washington in two steps. First, the Department of Ecology adopted a rule in March 1996 which reduced the total acreage of bluegrass crop residue in Washington authorized for burning by one-third in 1996 and by an additional one-third in 1997. Second, in 1998, the Department of Ecology certified mechanical residue management as an alternative to open field burning of bluegrass crop residue and banned open field burning except under very limited circumstances. (A copy

of the rules and a summary of the Department of Ecology's rulemaking are attached as Exhibit C. The entire rule making record is a matter of public record.) The Department of Ecology considered an extensive amount of information before it concluded that mechanical residue management is a certifiable alternative to open field burning, including nearly 300 studies on alternatives to burning grass seed crop residue. The Department of Ecology defined mechanical residue management as the procedure or technique of managing grass seed fields by non-thermal methods using techniques such as baling, raking, flailing, swathing, chopping, tilling, etc. The Department of Ecology determined that mechanical residue management is reasonably available in all cases except wherever the technique of baling straw cannot be used. Baling of residue straw may not be reasonably available in circumstances of steep slopes or other extreme conditions. The Department of Ecology's rules establish a process a grower must follow to establish that mechanical residue management is not reasonably available. In Spokane County, only a few growers have received permission to utilize this exception, effectively reducing annual grass field burning to around 200 acres per season, or less.

8. While the Department of Ecology was proposing the phase down and ban on grass seed field burning in Washington, bluegrass growers repeatedly asserted that they could not successfully grow and harvest bluegrass seed without open field burning. That contention has been proven incorrect. Following the 1998 burn ban, Washington bluegrass growers have continued to grow and harvest bluegrass seed without open field burning. In fact, the acreage of bluegrass seed harvested in Washington and in Spokane County has remained steady or increased since 1998. I am aware, however, that some farmers in Spokane County have had difficulty disposing of bales of residue straw and

some farmers have requested authorization from SCAPCA to burn large quantities of rotting or moldy residue straw.

9. Bluegrass growers in Washington have on occasion complained that bluegrass growers in North Idaho enjoy an unfair competitive advantage because they are able to dispose of unwanted post-harvest crop residue through open field burning, and allegedly have greater seed yield per acre, as a result of burning.

10. The burn ban in Washington has significantly improved air quality in Spokane County, by eliminating smoke intrusion episodes caused by Spokane County grass growers. The significant smoke intrusion episode described above which occurred in Spokane on September 9, 1993 is representative of significant smoke intrusion episodes which were a common occurrence on one or more days during any given season in which bluegrass crop residue was burned in Washington prior to 1998. Each significant smoke intrusion episode typically triggered one to two hundred air quality complaints to SCAPCA, the majority of which people complained about suffering from significant health problems related to adverse respiratory conditions, triggered by exposure to the smoke. The burn ban has eliminated smoke intrusion episodes caused by burning in Washington and eliminated the suffering that those episodes inflicted. Residents of Eastern Washington and North Idaho breathe better air as a result. Over the years, I have repeatedly heard representatives of the grass seed industry (e.g., farmers, seed processors) state that there is no significant adverse environmental or health impact from the burning of field residue, as evidenced by the fact that the smoke emissions do not cause exceedances of the 24-hour or annual National Ambient Air Quality Standards (NAAQS) for fine particles (i.e., PM2.5 or PM10). These statements are typically

coupled with declarations that the public and the regulators should keep out of the business of farmers and seed processors and let them continue their burning practices without interference. This popular industry position totally disregards the fact that people suffer respiratory distress, typically for several hours, when a smoke intrusion episode envelops areas where people live and breathe. The concept of compliance with a NAAQS is completely immaterial to a person who is suffering from the impacts of smoke from field residue burning.

11. Unlike their neighbors across the state line in Washington, Kentucky bluegrass seed growers in the Rathdrum Prairie area and within the Coeur d'Alene Reservation of North Idaho continue to use open field burning to dispose of unwanted post-harvest bluegrass crop residue. This causes significant harm to the health of people in Spokane County, Washington, as evidenced by the nature of the complaints. Farmers in North Idaho typically begin burning bluegrass waste straw in mid-August, and the burning may continue through the end of September. As stated above, smoke from bluegrass crop residue burning in North Idaho routinely travels to Eastern Washington, affecting the City of Spokane, the populated, unincorporated East Valley of Spokane County, and other Washington communities. Smoke behavior is affected by air sheds, not political boundaries. Eastern Washington and North Idaho share an air shed that is shaped like a backwards "L". The Cities of Spokane and Coeur d'Alene are, respectively, at the western and eastern ends of the horizontal axis of the L. The Cities of Sandpoint and Coeur d'Alene are, respectively, at the northern and southern ends of the vertical axis of the L. This air shed is bounded by high hills and mountains. Once smoke gets into the air shed, it tends to become trapped by inversions. Depending on wind

direction, smoke from bluegrass fields burned on the Rathdrum Prairie in North Idaho may travel west to Spokane and the Spokane Valley, east to Coeur d'Alene, or north to Sandpoint. The same phenomenon occurs with smoke from bluegrass fields burned within the boundaries of the Coeur d'Alene Indian Reservation. The waters of Lake Coeur d'Alene have a cooling effect on the air mass above the lake. Cooled air is less buoyant than warm air, meaning it tends not to rise. Smoke from burning on the Coeur d'Alene Indian Reservation becomes trapped in this cooled, less buoyant air, and will remain near the ground, exposing people in the vicinity to fine particles.

12. The number of public complaints to SCAPCA often rises suddenly and dramatically when bluegrass farmers in North Idaho dispose of grass residue through open field burning. On August 17, 1999, for example, more than 2000 acres of bluegrass fields were burned in the Rathdrum Prairie area and within the boundaries of the Coeur d'Alene Reservation in North Idaho. Much of the smoke, particularly from the fields burned on the Rathdrum Prairie, drifted into the Spokane Valley in eastern Spokane County. As shown in the materials attached at Exhibit D, SCAPCA received 61 complaints over a 17-hour period on August 17, 1999, all on the subject of grass field burning in North Idaho. This is a large number of complaints for this period of time. Most of the complainants stated they suffered adverse health effects, as opposed to complaining about aesthetic issues. The burning in North Idaho essentially covered the entire eastern Spokane Valley with smoke, including the communities of Newman Lake, Liberty Lake, Otis Orchards, and Greenacres. The closest SCAPCA air monitoring site – the Crown Z site – was about 20 miles away from the source of the smoke, the Rathdrum Prairie. Nonetheless, the Crown Z site reported uncharacteristically high concentrations

of PM. PM2.5 concentrations were above 30 $\mu g/m^3$ for 4 hours, with a high of 70 $\mu g/m^3$. PM10 concentrations were above 40 $\mu g/m^3$ for 8 hours, with a high of more than 90 $\mu g/m^3$. It is a reasonable conclusion that the particulate levels were considerably higher in the areas where the complaints were concentrated (i.e., closer to the source of the air pollution) than at the Crown Z monitoring site miles away.

13. Similar complaints were made to SCAPCA on August 19, 1997, when North Idaho farmers disposed of 1900 acres of bluegrass crop residue through open field burning. (This was before the Washington burn ban and growers in Spokane County burned 370 acres that day). SCAPCA received 92 complaints, primarily related to smoke from North Idaho. The Crown Z monitoring site – again, about 20 miles from the source of the smoke in North Idaho – reported high concentrations of PM, including PM10 concentrations that exceeded 75 $\mu g/m^3$ for nearly 6 hours with a high of 110 $\mu g/m^3$, and PM2.5 readings of over 50 $\mu g/m^3$ for 4 hours with a high of 75 $\mu g/m^3$. Details about the August 19, 1997 smoke intrusion from North Idaho are included in Exhibit D.

14. I have reviewed the smoke management plans applicable to Kentucky bluegrass field burning in North Idaho and within the boundaries of the Coeur d'Alene Reservation. This includes the Idaho Crop Residue Disposal Rules proposed by the Idaho Department of Agriculture in 2001. My professional opinion is that these plans are inadequate to protect the public health of citizens in Spokane County and North Idaho from the significant adverse health effects of open field burning of bluegrass crop residue. As explained in paragraph 5 above, smoke management plans: (i) are overly dependent on predictions of wind speed and direction which are impossible to consistently make with accuracy; (ii) simply send smoke toward other communities

rather than reduce or eliminate PM emissions; and (iii) are associated with the phenomenon of the "smoke coming back at you" because it is not possible to account for meteorological conditions on the day following the burn day; and the North Idaho smoke management plans share these defects. Given the single air shed which links North Idaho to Spokane County, depending on wind direction, bluegrass field burning in North Idaho is bound to send smoke toward Spokane, other communities in Eastern Washington, Coeur d'Alene, or Sandpoint, Idaho. This has occurred repeatedly in the past as demonstrated by the smoke intrusion episodes summarized in this declaration.

15. The Idaho Crop Residue Disposal Rules prohibit burning of bluegrass waste straw if it would result in a violation of ambient air quality standards. This does not protect public health. Experience shows that the worst agricultural smoke intrusion episodes cause very poor air quality and considerable complaints about health effects for several hours. However, since the particulate matter ambient air quality standards are based on annual or 24-hour averages, it is virtually impossible to register a standards violation, even under the worst of conditions. Therefore, this alleged restriction on burning is really no restriction at all. Even if an agricultural smoke intrusion causes a standards violation, the violation would not be registered until after the burning was already over, and therefore too late to mitigate the impacts.

16. If open field burning of Kentucky bluegrass crop residue continues in North Idaho, I anticipate that smoke intrusion episodes will continue to cause people in Spokane County to suffer when they breathe smoke from North Idaho. This is deeply unfair. The State of Washington has virtually eliminated bluegrass field burning yet its citizens are forced to breathe bluegrass smoke from Idaho. And the success of

Footnote 13

Washington farmers in growing and harvesting bluegrass without burning shows that bluegrass farmers in North Idaho are profiting at the expense of public health by clinging to a cheap, yet harmful method of disposing of waste straw.

I declare under penalty of perjury that the foregoing is true and correct.

EXECUTED

this 1st day of June, 2002

by: Eric Skelton

Eric Skelton

Footnote 14, 15

(2) By rule the Environmental Quality Commission may delegate to any county court, board of county commissioners, fire chief of a rural fire protection district or other responsible person the duty to deliver permits to burn acreage if the acreage has been registered under ORS 468A.615 and fees have been paid as required in ORS 468A.615. [1991 c.920 §7]

468A.580 Permits; inspections; planting restrictions. (1) Permits under ORS 468A.575 for open field burning of cereal grain crops shall be issued in the counties listed in ORS 468A.595 (2) only if the person seeking the permit submits to the issuing authority a signed statement under oath or affirmation that the acreage to be burned will be planted to seed crops other than cereal grains which require flame sanitation for proper cultivation.

(2) The Department of Environmental Quality shall inspect cereal grain crop acreage burned under subsection (1) of this section after planting in the following spring to determine compliance with subsection (1) of this section.

(3) Any person planting contrary to the restrictions of subsection (1) of this section shall be assessed by the department a civil penalty of $25 for each acre planted contrary to the restrictions. Any fines collected by the department under this subsection shall be deposited by the State Treasurer in the Department of Agriculture Service Fund to be used in carrying out the smoke management program in cooperation with the Oregon Seed Council and for administration of this section.

(4) Any person planting seed crops after burning cereal grain crops under subsection (1) of this section may apply to the department for permission to plant contrary to the restrictions of subsection (1) of this section if the seed crop fails to grow. The department may allow planting contrary to the restrictions of subsection (1) of this section if the crop failure occurred by reasons other than the negligence or intentional act of the person planting the crop or one under the control of the person planting the crop. [1991 c.920 §8]

468A.585 Memorandum of understanding with Department of Agriculture. (1) The Environmental Quality Commission shall enter into a memorandum of understanding with the State Department of Agriculture that provides for the State Department of Agriculture to operate all of the field burning program.

(2) Subject to the terms of the memorandum of understanding required by subsection (1) of this section, the State Department of Agriculture:

(a) May perform any function of the Environmental Quality Commission or the Department of Environmental Quality relating to the operation and enforcement of the field burning smoke management program.

(b) May enter onto and inspect, at any reasonable time, the premises of any person conducting an open field burn to ascertain compliance with a statute, rule, standard or permit condition relating to the field burning smoke management program.

(c) May conduct a program for the research and development of alternatives to field burning. [1991 c.920 §4; 1995 c.358 §3; 2001 c.70 §2]

Steiner - footnote 16

$3.50

BURNING GRASS SEED FIELDS
IN OREGON'S WILLAMETTE VALLEY

THE SEARCH FOR SOLUTIONS

EXTENSION MISCELLANEOUS 8397 JANUARY 1989

OREGON STATE UNIVERSITY EXTENSION SERVICE,
OREGON AGRICULTURAL EXPERIMENT STATION,
AND USDA–ARS COOPERATING

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BURNING GRASS SEED FIELDS IN OREGON'S WILLAMETTE VALLEY

THE SEARCH FOR SOLUTIONS

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OREGON STATE UNIVERSITY EXTENSION SERVICE,
OREGON AGRICULTURAL EXPERIMENT STATION,
AND USDA–ARS COOPERATING

PREFACE

This publication is prepared as a public service by faculty members at Oregon State University in response to a perceived need for information on field burning. The report has been prepared as a reference and source document for 1989 legislative and agency deliberations on further adjustments in thermal sanitation of grass seed fields in the Willamette Valley of Oregon.

The legislative agenda may include a broader state-wide perspective than that presented here. To date, however, control of agricultural burning in Oregon has been confined to open-field burning of grass seed in the Valley. Consequently, adjustment and research activities have been confined to the Valley. The report addresses four major areas:

1. historical background of field burning and description of the industry;
2. compilation of research and development activities from 1968 to 1988 associated with the search for viable alternatives to field burning;
3. structural adjustments made to date and economic issues which will affect future adjustments; and
4. review of possible alternative policy choices for consideration by the 1989 Oregon Legislature.

This report is intended specifically for use by industry leaders, concerned citizens, agency administrators and legislators as a working document in legislative committee sessions throughout the 1989 legislative session. As the report was prepared on short notice, the background and research and development activities treated herein were compiled in part from selected key reports.

Those relied upon heavily included *Synopsis of Grass Straw Research in Oregon, 1968-1986* by Thomas R. Miles, Jr. and Thomas R. Miles, May 1987; *Final Report, Field Burning R&D Program Evaluation* by Nero and Associates, January 1987; and *DEQ Annual Reports on Field Burning*. Direct excerpts from those sources were taken in several instances. Use of these sources is gratefully acknowledged.

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EXECUTIVE SUMMARY

STATUS OF THE GRASS SEED INDUSTRY

Oregon is the world's major producer of cool-season forage and turf grass seed. The Willamette Valley is the national center of cool-season grass seed production with 330,000 acres harvested on 700 to 800 farms in 1988.

The farm gate value[1] of 1987 Willamette Valley production was $140 million. Farm gate value of Oregon grass seed production was $156 million, ranking grass seed the number one field crop by value in Oregon. Processing contributed an additional $34 million. The total effect on the state's economy from sales, using a 2.0 business output multiplier[2], is estimated at $380 million. Farm gate value in 1988 in the Valley rose to $190 million, while total Oregon farm gate value of grass seed production rose to $211 million. Valley grass seed acreage has expanded by 95,000 acres (from 235,000 to 330,000 acres) during the past decade. The acreage and income increases are due largely to expanding consumer demand for turf-type perennial grasses, especially tall fescue and perennial ryegrasses.

Grass seed is grown on 32% of the total harvested cropland in the Willamette Valley. In the southern Valley where large tracts of poorly-drained soils have limited cropping alternatives, more than 56% of the total harvested cropland is in grass seed.

Overall, 75 to 80% of Oregon seed is sold domestically with the remaining 20 to 25% going into foreign markets which include the European Community, Japan, Canada, Korea, and Australia.

Markets for grass seed are distinguished by end use needs. They include lawn and turf use (fine fescues, bentgrass, turf-type tall fescue, turf-type perennial ryegrass, and Kentucky bluegrasses), cover-crop and pasture use (orchardgrass and tall fescue), and multi-purpose use (annual and perennial ryegrass).

Oregon grown seed represents two-thirds of all U.S. cool-season grass seed production with the other one-third coming from competing regions which include Washington, Idaho, and Missouri. Minor foreign competition in U.S. markets comes from Canada, New Zealand, The Netherlands, and Denmark. Oregon historically has had an economic advantage in domestic and foreign markets due largely to high mechanical and genetic quality of its grass seed.

HISTORICAL DEVELOPMENT OF THE GRASS SEED INDUSTRY

Although climate in the Willamette Valley is ideal for grass seed production, disease problems limited the growth of the industry during its infancy in the 1930's. *Open-field burning* was developed as a *solution* to disease problems and permitted the fledgling grass seed industry to expand dramatically in the 1940's. Other benefits from open-field burning include effective weed control, stimulation of seed yield, partial control of several insect pests, recycling of nutrients, decreased initial nitrogen fertilizer demand for annual crops, easy and low cost stand establishment, higher quality seed, ability to meet strict certification standards, minimal need for pesticides and efficient and economical residue removal from fields that are not tilled annually because of perennial crop production.

The practice of field burning led to a new *problem* -- smoke as a by-product of grass seed production. This smoke is an air pollutant during the field burning season in the Willamette Valley.

ATTEMPTS TO OVERCOME PROBLEMS ARISING FROM FIELD BURNING

The search for solutions to problems arising from field burning seeks to reduce or remove smoke problems while protecting the economic vitality of the grass seed industry, or identify an alternative industry. The new production practices sought must permit individual grass seed growers to produce an

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[1] Farm Gate Value is defined as the gross value of production for a given crop year; estimated as the average total annual production by growers x averaged annual price received by growers.

[2] The business output multiplier measures the total change in local sales generated by a one dollar increase in sales of the product outside the state. For the agricultural sector of Oregon the range in the business output multiplier is 1.4-2.7 with a mean of 2.2. The authors used a conservative value of 2.0 for the grass seed industry. Although most processing is done in state, its value added compared to final product is relatively small (Mandelbaum et al., 1984).

economically viable crop in the short run, and must not result in building up of disease, weed, and pest problems that could threaten the industry as a whole in the long run.

Given the current state of knowledge, all alternatives to open-field burning will represent increased costs and, other things being equal, decreased returns to growers. These alternatives are discussed below.

Smoke Management

Smoke management was the first measure instituted to deal with the smoke produced by field burning. Initial measures were implemented during the late 1960's with growers, fire districts, and state authorities cooperating. At that time more than 300,000 acres of grass seed and small grain fields were open burned. In 1971, the State Legislature placed field burning under state regulatory powers of the DEQ (Department of Environmental Quality).

The DEQ has responsibility for regulating the amount of burning consistent with air quality considerations. The State Legislature instituted a system of grower fees to pay the administrative cost of the regulatory smoke management program and to establish a research and development (R&D) program to seek alternatives, study smoke management, and study health effects.

The system of grower fees continues in force and currently provides about $550,000 annually for smoke management and $250,000 to $350,000 annually for R&D. The R&D activities during the past 17 years have totaled nearly $7 million. Most of the R&D activities to date have come from the self-sustaining grower fee program rather than from public funds.

The maximum number of acres allowable for open burning was set at 250,000 acres by the State Legislature in 1978 and has continued to date. Actual acres burned under the DEQ managed smoke management program has continued at about 220,000 acres annually during the past decade except for 1988 when it declined to about 150,000 acres due to an 8-day temporary burning moratorium. The current DEQ smoke management program utilizes meteorological conditions to specify timing, method of field firing, and acreage levels to minimize smoke impacts upon the Valley population, particularly in urban centers.

Research and development activities have focused principally upon thermal sanitation alternatives, alternative crops, agronomic alternatives, uses for grass straw, and a preliminary examination of public health effects.

Thermal Sanitation Alternatives

Field sanitizers

Thermal sanitation alternatives developed to date have been in the form of machine sanitizers. Several sanitizer designs were developed by OSU and private engineers starting in 1969 and field tested throughout the 1970's. These units used some or all of the straw residue as a fuel source to sanitize the fields under conditions that would complete the combustion process and minimize emissions. Although agronomic studies and field tests demonstrated that the units provided an effective technical substitute for open burning over a range of field conditions, difficulties with short machine life, high operating cost, high energy use, and slow operating speed made commercial sanitizer use an economically prohibitive option. By the late 1970's the emphasis was placed on smoke management and research shifted to alternative sanitation methods.

Propane flaming

Agronomic studies and field tests showed that thermal sanitation achieved by propane flaming could be similar to open burning without major seed yield loss, but only if most of the straw residue were removed prior to propane flaming. Higher residue levels left on the ground provided a greater combustible mass during dry weather thereby permitting faster field operation but generating greater emissions near ground level. Thus, residue removal, except for the stubble, and slow field operation are necessary for good results. This means that to be effective, the large volume of residue, some 2 to 4 tons per acre, has to be removed as a companion process to propane flaming, with subsequent use or disposal of the residue. The cost of the propane flaming ranges from $8 to $32 per acre depending upon level of residue and speed of operation. Residue removal represents an additional cost if a market is not found for the straw.

Propane flaming is being used by an increasing number of growers, especially in the North Valley. An estimated 56,000 acres were sanitized by propane flaming in 1988 (T.L. Cross, personal communication).

Non-Thermal Sanitation Alternatives in Perennial Grass Seed Production

Grass seed production in the Valley is a diverse activity. It differs from many field crops in that two-thirds of the acreage is in perennial grass crops which have a productive life of four to eight years. The fields are not tilled during that time but require special field management instead. Following harvest the straw residue must be removed to assure a satisfactory crop in the following season. The remaining one-third of grass seed acreage is in annual ryegrass production which can be tilled each year. Grass seed farmers in the south Valley tend to be specialized in production of the ryegrasses while those in the north Valley are diversified with several grass seed species and other crops.

Mechanical Straw Removal

Baling was found to be the most economical removal option in situations where there is a market for the straw. Cost of baling and roadsiding approaches $40 per acre. In the absence of a straw market, the lower cost choice of raking and use of stack wagons to position the straw at the side of the field for later burning is preferred. Burning of bales or loaves after placement at fieldside is used to dispose of unmarketable residue.

Crew Cutting or Close Clip Stubble Removal

In the absence of burning, the bulk of the straw must be removed mechanically, and followed by a "clean up" operation. The best non-thermal method of "clean up" is the clip and vacuum, or "crew cut" treatment, which involves special equipment not yet commercially available. The flail chop treatment is a chaff and stubble removal treatment using the best currently available equipment, a forage harvester. Both straw and stubble treatment methods involve significant labor and equipment costs as compared to open burning. The operations also generate considerable low level dust emissions.

Less Than Annual Burning

This practice includes alternating various combinations of burning and mechanical removal techniques over a period of several years. In perennial ryegrass, alternate year burning averaged 93% of annual burning yield over a five year period regardless of whether plots were crew cut or flail chopped during the non-burning year. No deleterious effects on seed yield were reported for fine fescue or bluegrass when averaged over four years.

Chemical Treatment

Chemical treatment with monocarbamide dihydrogensulfate (Enquik^R), a urea-sulfuric acid reaction product, applied at 15 to 20 gallons of product per acre during mid-October has shown some potential for reducing fall germinating unwanted grass seedlings, controlling some weeds, increasing effectiveness of specific herbicides, and accelerating decomposition of old crown growth left at harvest. Results vary with grass species and weather, especially temperature and rainfall.

Shorter Crop Rotation

Perennial grass seed crops historically have produced for up to 10 to 12 years as a single stand without re-establishment. This has been reduced to about five years for proprietary varieties grown under contract. In the absence of annual open-field burning, further shortening of the rotation may be necessary to decrease the incidence of disease and pests. However, production costs increase significantly as establishment costs (including one season of lost income in several species) are amortized over fewer production years and thermal sanitation costs from propane flaming and residue removal are included.

No Thermal Sanitation

Seed production without field sanitation in the Willamette Valley has not been successfully demonstrated on a large scale. Several serious diseases of seed crops have been held in check with field sanitation but are still present at low levels. Diseases might increase quickly if thermal sanitation were discontinued entirely.

Non-Thermal Sanitation Alternatives In Annual Ryegrass Production

Annual ryegrass represents one-third of total grass seed acreage in the Valley. Historically, it has been reseeded each fall in the ash of open-field burning. Some growers are shifting to less than annual burning. The cultural practice generally involves flail chopping of the straw residue and its incorporation into the soil by plow-down. In some instances, the straw is removed before plow-down. Growers feel that some, or all, of the straw must be removed as most annual ryegrass is grown on poorly drained clay soils in which incorporation of residue is difficult.

Control of Pests and Diseases

While significant work has focused upon thermal and non-thermal sanitation, the collective or cumulative effect upon the seed industry of non-burning upon incidence of disease, insect, and other pests and their cost of control are unknown. Cultural, chemical, and field management measures for disease and weed control in grass seed crops in the absence of burning were initiated in the early 1980's and have had limited testing to date. Certain insects may be controlled by grazing or mechanical removal of crop residue while some may require thermal control methods. The extent to which thermal sanitation can be reduced as a cultural practice on a farm-by-farm and grass-seed-species basis without major consequences upon yield and seed quality due to disease, insect, weed, and other pest effects requires additional research.

ALTERNATIVE CROPS

Alternative crops to grass seed production are influenced by technical and economic factors. In the north Valley where soil drainage is good, the profitability of grass seed types and their markets relative to other crop choices becomes the overriding factor. In the south Valley, poor soil drainage is a technical factor severely limiting crop choices as most crops will not survive soil moisture saturated winter conditions.

Meadowfoam, the only known winter annual crop that will tolerate such a condition, was identified as a potential crop with preliminary plot trials initiated in the mid-1970's. Since that time, studies of yield increase, seed dormancy, production, and economic feasibility and market development analyses have been done. Oil extracted from meadowfoam appears to have potential for industrial and cosmetic trade utilization. Two principle factors limit its use at this point. The first is low yield. A major effort is being made to improve seed yield and to reduce production costs enough to compete with oils currently used in the market. The second factor is that no industrial utilization research yet has been conducted to ascertain the qualities and properties of meadowfoam and hence potential role(s) in industrial and cosmetic markets. Research has been initiated in this area (C.D. Craig, personal communication). Potential technical viability of meadowfoam as an alternative crop for adoption is estimated to be 5 to 10 years away from consideration. Whether it will be an economically viable choice at that time is questionable. Its potential scope is unknown but appears to be limited. Currently, some 20 to 25 growers produce less than 200 acres annually with excess inventory of oil on hand.

STRAW UTILIZATION

Straw removal and utilization or disposal have been essential companions to the viability of alternatives to open-field burning. Straw must be removed for mobile sanitizers, flamers, alternate year burning, and mechanical or chemical methods of disease, pest, and insect control to be effective.

From a technical standpoint, straw can be used as a raw material to make a wide range of products for fiber (paper, particleboard, fuel logs, hydromulch, composted fertilizer, etc.), chemical products (oil, gasoline, plastics, microbial protein, etc.), and livestock feed. Economically, it has been difficult for grass straw to compete in existing markets as a raw material source. Low bulk density of the straw which requires costly densification, high cost transportation, uncertainty of long-term supply, and low volume of supply in fiber markets have made straw non-competitive with other raw materials. The traditional base for making pulp and paper in the Pacific Northwest is wood chips which are cheap, adequate in continuing supply and volume with manufacturing technology adapted to that source and require no storage from rainy weather. Converting to straw would involve major retooling in the wood fiber industry.

As a feedstuff for livestock, untreated straw is of poor quality because of low protein and high fiber content. With appropriate treatment, such as ammoniation, the digestibility and palatability of straw can be increased substantially making straw a potential component of maintenance diets for ruminant livestock. Costs of physical and chemical treatment have made the process marginal in an economic sense.

To date less than 20% of annual residue is being used in domestic and export markets as a supplemental livestock feed. During periods of short supply and/or excess demand for forages in U.S. markets, such as experienced during the major drought of 1988, a relatively small quantity of grass straw is marketed. Extended dry weather conditions in the Valley through October permitted more straw to be sold. Japan, the major current market, utilized an estimated 125,000 to 150,000 tons in 1988 for supplemental livestock feed.

THE PUBLIC CONCERN

Research activities involving health, soiling, nuisance, hazards, and aesthetic influences from open-field burning in the Willamette Valley have been extremely limited. Nearly all of such activities have been financially supported by the DEQ Field Burning R&D Program.

Initial work in the early 1970's focused upon air quality and its measurement. From 1971 to 1977, limited surveys of respiratory patients in the Valley and respiratory patients statewide provided inconclusive results relative to health effects.

In 1977 health effects research was given top priority status in the Field Burning R&D Program. Funds were set aside for preliminary studies and for planning a major health effects research project. In doing so it became apparent that research on this issue would require multi-disciplinary research activities and be very costly, the magnitude could easily divert all R&D funds available annually for several years. Consequently, the Field Burning R&D Committee decided to:

1. support preliminary studies based on local data, if possible, to identify evidence that health impacts do indeed exist;
2. follow up such evidence with a planning effort to design a more extensive research effort; and
3. solicit the necessary funding for such an effort and contract the work.

Each of these activities were completed: physician visit and hospital admission surveys in 1980; a field burning health effects workshop in 1986; and a preliminary field burning health effects assessment in 1987. The health effects assessment, conducted to provide quantitative measures of exposures, health effects/risk, and related costs from field burning, slash burning, and residential wood burning, has not been released. A technical review of the assessment raised serious questions concerning the appropriateness of the methodology used and hence conclusions of the study for Willamette Valley conditions.

A 1986 DEQ contracted study provides an initial attempt to assess the importance of air quality through estimation of the amount the public would be willing to pay for improved visibility. No attempt was made to link the study to smoke impact.

In the case of the Willamette Valley grass seed industry, the desired level of environmental quality is made more complex in that a simple inverse trade-off between improved air quality and economic well-being of the industry does not exist. Although known for air pollution, the grass seed industry also provides positive environmental effects through low levels of soil erosion on hillside lands, low levels of dust emissions throughout the year which are more common with other crops and a buffer from urban/industrial development.

STRUCTURAL ADJUSTMENTS TO DATE

Open-field burning has declined from a high of 315,000 acres in 1968 to about 220,000 acres annually during the 1980's. In 1988, 330,000 acres of grass seed were produced in the Valley of which 206,000 acres were thermally treated. An estimated 150,000 acres were field burned and 56,000 acres propane flamed. The remaining 124,000 acres employed other field cultural practices. In general, the net effect to the public has been reduced emissions by more than one-half from reduced acreage burned.

Less obvious grower adjustments have been made. They include changes in thermal sanitation practices to propane, changes in field cultivation practices which substitute for field burning, adjustment among the mix of grass seed species grown both at the farm and industry level, increased use of proprietary varieties, and adjustment to external market forces which have enhanced the industry in recent years.

With annual ryegrass, growers have reduced the acreage planted and made a shift to fall plow-down and reseeding to partially replace field burning. Some straw is removed from the field for disposal by stackburning as a companion practice. On the perennial grasses, especially those grown in the north Valley, a definite increase in straw removal followed by propane flaming has been observed. The volume of straw intended for sale has increased. Several storage units have been built and baling for commercial sale has become more common. During the early 1980's, a definite shift toward proprietary varieties under forward contracting was employed, largely as a mechanism for reducing the risk of low market prices. Some shifting away from this has occurred since 1985 as market prices improved significantly for grass seeds, especially for turf-type tall fescue and perennial ryegrasses resulting in a 23,000 acre increase from 1987 to 1988 for those two grass seed species.

TECHNICAL AND ECONOMIC CONSIDERATIONS FOR FUTURE ADJUSTMENTS

The Willamette Valley grass seed industry may be called upon to make further adjustments in response to the public desire to reduce smoke emissions from open-field burning. Understanding the past provides guidelines of issues to expect when one considers adjustment possibilities for the future.

Important technical and economic factors will influence the ability of the industry to make further adjustments. These include:

1. Ability of the industry to retain its relative economic advantage in the marketplace while responding to cost increasing alternatives to replace open-field burning is unknown. Positive market forces in the 1980's, which provided a measure of industry well being to offset cost increases, may not continue into the 1990's.
2. Incidence of future disease, insect, and weed pests without thermal sanitation is unknown.
3. The impact of straw removal, an important companion to propane flaming, comes at a high cost to growers if little of it is marketable.
4. The role of meadowfoam as a new crop is not expected to have strong economic potential for several years. Low yield and market potential persist as limiting factors.
5. Shifts by growers to crops previously grown are unlikely as their margin of return is very low.
6. Existence of public health effects from thermal sanitation has not been quantified.
7. Extent of public hazard, nuisance, soiling, and aesthetic effects from open burning has not been adequately measured.[3]
8. Ability to conduct required tests using *currently registered* pesticides for disease and weed control to remove EPA label restrictions on use of crop regrowth, straw, or seed screenings for livestock feeding or grazing is uncertain.
9. Ability to conduct necessary tests to obtain EPA registration of *new pesticides* is needed for seed production in the absence of field burning to permit legal access of straw residues to livestock feeding markets.

A VIEW TOWARDS FURTHER ADJUSTMENTS

In considering reduced open-field burning, it is important to examine what alternatives might be considered and what impacts such choices might have. One needs to consider the livelihood of the industry and its individual growers on the one hand, and the general public and its concern about the quality of air it breathes on the other.

[3]Particulate emission (PM 10) quantities are estimable and available for different levels and sources of smoke. They serve largely as a limited proxy for estimating haze level. They should be used in conjunction with meteorological variables under actual conditions as air mixing is an important influencing factor.

Because little substantive research evidence is available to provide measurement estimates on the impacts of improved air quality to the public, currently it is not possible to make direct comparisons between economic losses to grass seed growers and air quality gains to the Oregon public from further reductions in open-field burning. Instead, what is done here is to provide a selected list of possible policy alternatives which simply are ranked in order of increasing improvement in air quality and decreasing economic well being to grass seed growers.

1. Maintain the current field burning program but impose further controls to minimize the risk hazard from open burning that may endanger human lives.
2. Implement negotiable burning rights to grass seed growers.
3. Use public funds for subsidies and expanded R&D on pollution abating technology.
4. Continue with the controlled open burning program but reduce the maximum burned acreage to some lower level with the actual number of acres burned determined by meteorological conditions.
5. Continue with the controlled open burning program but accomplish a reduction in the number of acres burned through an increased per acre burning fee which is of a magnitude large enough to serve as an economic disincentive.
6. Provide a phased reduction in open burned acreage over a set period of time until the practice is eliminated entirely.
7. Eliminate open burning for residue disposal purposes but permit thermal sanitation on a "prescription" basis for disease, weed, and insect control.
8. Eliminate open-field burning entirely.

As the emphasis shifts away from open burning toward greater reliance on propane flaming, production costs would increase accordingly. Increased costs would involve cost of propane flaming and cost for residue removal and disposal. An indirect effect would be reduction in grower fees available for needed smoke management and research and development activities unless alternative mechanisms for funding these activities are identified. Fees generated in policy choice 5 might be used, in part, for such activities.

The discussion of the net impact of further adjustments in grower production practices is complicated by the lack of reliable information on air quality associated with propane flaming and stack burning, practices developed as alternatives to open burning. Preliminary observations suggest that low level emissions from propane flaming may lead to widespread and persistent haze throughout the Valley if the practice gains greater use. Studies are underway to ascertain more precisely the air quality tradeoffs between open burning, propane flaming and stack burning. At issue for policy makers is the impact on air quality from further regulations of post-harvest management practices as they will not provide simple trade-offs in air quality changes.

CHAPTER 1

INTRODUCTION AND BACKGROUND

OREGON'S GRASS SEED INDUSTRY

Oregon is the world's major producer of cool-season forage and turf grass seed and a widely recognized center of expertise in seed production. Most of the acreage is located in the Willamette Valley, the "grass seed capital of the world." Farm gate value of the Valley's 1987 production was $140 million (Miles, 1988). Preliminary data for 1988 show a substantial increase to $190 million. Oregon growers produce essentially all of the U.S. production of annual ryegrass, perennial ryegrass, bentgrass, and fine fescue. Smaller but significant amounts of bluegrass, orchardgrass, and tall fescue are produced. Collectively, Oregon's Willamette Valley produces almost two-thirds of the total U.S. production of cool-season grasses.

Grass seed typically is produced on nearly 800 family farms, averaging 700 acres, with more than 60% of the total labor requirements provided by family members. Seed production of one or more seed species are the major enterprises, with growers using machine technology especially adapted to small seeds. Mild and moist winters with dry summers favoring seed maturation and harvest make the Valley an ideal place to produce high quality seed. Over 360 seed conditioning plants located in the Willamette Valley prepare the seed for market once the harvest operation is complete.

Linn County, with about 156,000 acres of grass seed production in 1987, is the leading grass seed producing county in the state. Linn County produces more than 40% of Oregon grass seed and 75% of the ryegrass produced in the U.S. (Miles, 1988).

Grass seed growers in Linn, Benton, and Lane counties, in the southern Willamette Valley, tend to specialize in grass seed crops because of the extensive area of poorly-drained soils in the region. Most other crops will not survive the winter flooding on these soils.

Grass seed crops are grown on more than 56% of the total harvested cropland in the southern Willamette Valley and 32% of all Willamette Valley counties (Table 1.1) (Miles, 1988).

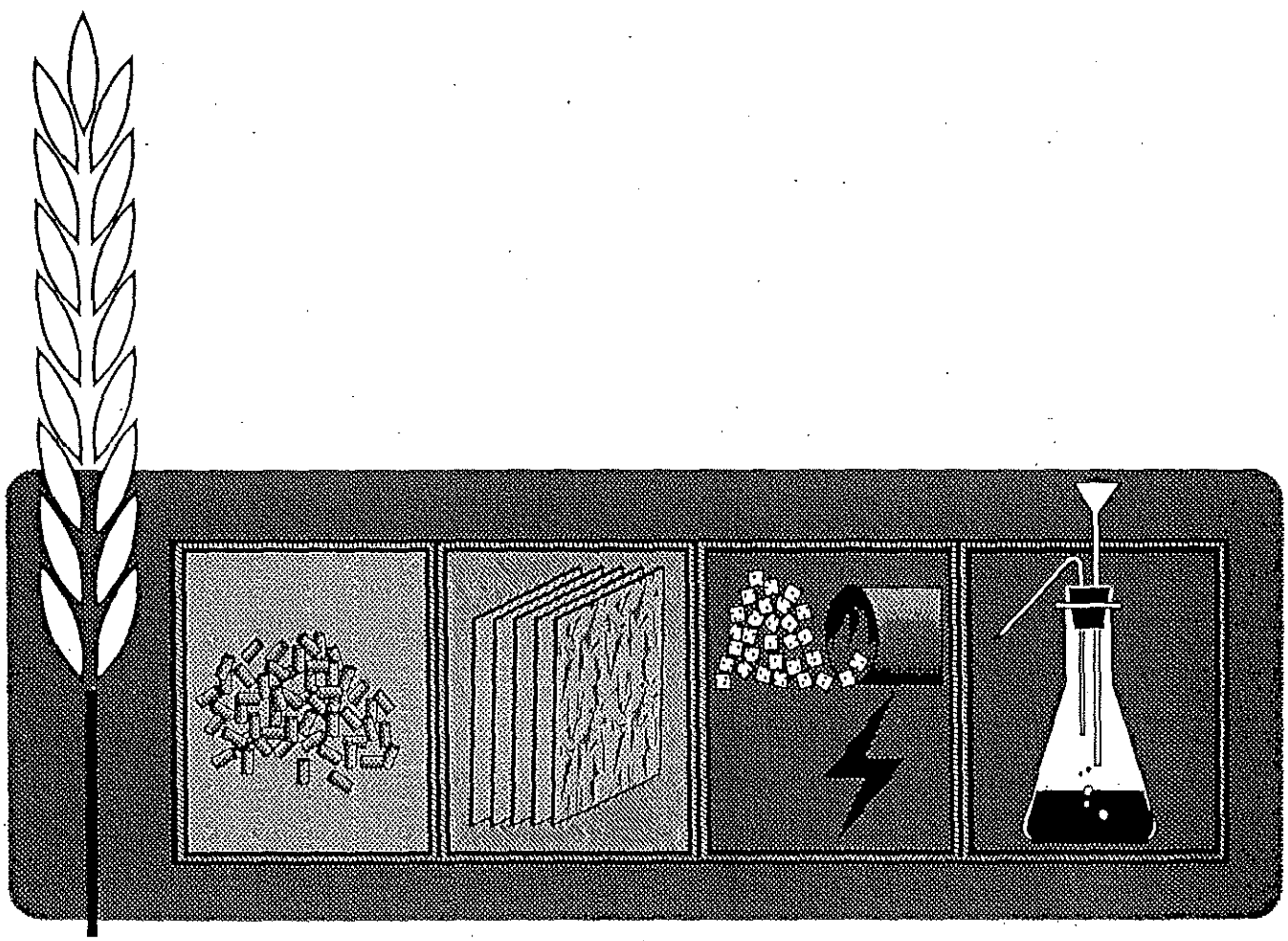
Annual and perennial ryegrass are adapted to soils in the southern Willamette Valley, but have low net returns per acre. Although draining and supplemental summer irrigation of the soils is technically possible, market conditions and improvement costs generally preclude opportunities for improving soils and producing cereals or intensive fruit and vegetable crops. Availability of contracts for alternate crops is limited.

Significant grass seed production also occurs in Lane, Benton, Polk, Yamhill and Marion counties. Small amounts are produced in Washington and Clackamas counties. Seed farms in Polk, Yamhill, Marion, Clackamas, and Washington counties are smaller and more diversified than those in the south Valley. Soils in these areas are more variable, providing opportunities for a variety of crop alternatives and rotations. Crop choices are definitely limited in the hilly areas where soil erosion can be a problem. Grasses are adapted and provide greater protection against soil erosion than annual cereals or row crops.

Outside the Willamette Valley, small amounts of grass seed are produced in Union, Jefferson, Jackson, Sherman, Malheur, Crook, Douglas, Morrow, and Baker counties.

Footnote 16

Opportunities in Grass Straw Utilization



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Preface

This study has been prepared as a reference document for use by the state legislature, industry leaders, private investors, growers, and interested citizenry as a foundation for making informed choices about utilization of Willamette Valley grass seed straw. The study examined existing research in this area to determine what technologies for straw utilization, based on economic and technologic factors of today's marketplace, are most likely to be implemented in the next decade.

The Oregon Economic Development Department (OEDD) was considered as the lead state agency working in cooperation with the Oregon Department of Agriculture (ODA), the Oregon Department of Environmental Quality (DEQ), and the Linn-Benton Regional Strategy. Industry financial support was obtained from the Oregon Seed Council and the grass seed commissions. State funds came from the state Lottery Fund and through grants from the Center for Applied Agricultural Research (CAAR) Board.

This work has built upon the considerable foundation of research done in the area of straw utilization throughout the last two decades and supported by the grass seed industry, state agencies, agricultural associations, individual growers, and private citizens.

Focus

A 10-year time frame for implementation of viable technologies was assumed.

The purpose of this study is to facilitate opportunities for grass straw utilization technologies in the state of Oregon.

Objectives of this study were to 1) determine what technologies could be implemented within the next 10 years to utilize significant amounts of grass seed straw, assuming that open-field burning will be phased down during this time period, and 2) present information so that the parties interested in straw use projects could determine the direction, problems, risks, and benefits of any particular technology.

A 10-year goal towards implementation was established, and represents a realistic appraisal of time to identify technology, obtain political and financial support, provide the first several key projects (with others to follow), and phase down to limited open-field burning as a farming activity. It is difficult to predict how the remaining thermal sanitation techniques (e.g., stack-burning) will survive this 10-year period, but it is assumed these also will be significantly reduced. This emphasizes the importance of having established straw utilization techniques in place.

Several straw utilization alternatives in specific markets were analyzed, along with the assumed economic feasibility, technical factors, and regulatory/social impacts (Table ES-1). These straw uses are the focus of this study and are presented here in order of highest to lowest perceived market value for straw and technical viability. (Further discussion of the alternatives is provided in a later section, Implementation Strategies, of this executive summary.)

The first straw utilization plants, be they for straw processing or burning, could be implemented within 5 of these 10 years. By the end of 10 years, they could be operating on a reliable basis, along with several other new plants. It is assumed that these plants will utilize significant amounts of available straw.

Approach of the Study

This study is based upon a three-phase approach towards implementation of grass straw utilization options. The first stage is this study effort, which examines the current agricultural and economic situation

Table ES-1

Summary of Straw Utilization Technologies

STRAW USE	ECONOMIC FEASIBILITY	TECHNICAL VIABILITY	REGULATORY & SOCIAL
Animal Feed	Current market for straw. Some 150,000 tons exported annually to Japan. Market expansion is uncertain. Domestic market is small and competes with roughage when alfalfa hay is scarce/expensive.	Low bulk density and low feed value require costly preparation for market. Suitable as supplement feed. Endophyte in straw presents new problems as feed source.	Some possible social impacts with transportation. No forseen regulatory impacts.
Pulp & Paper (existing plant)	Attractive potential market. Straw value is highest in this market. Potential volume of straw use is large as a supplement.	Pulping characteristics different for straw than wood. Requires dedicated digester and some modification of existing equipment.	Air, water, noise, land use changes. Social benefits of employment.
Fuel Supplement (existing plant)	Straw can be used as a supplemental fuel at existing facilities. Natural gas may be more competitive than straw or wood.	Should be used in addition to the fuels originally designated for the equipment. Some modification of existing equipment may be required.	Not much change from existing impacts.
Fiberboard (existing plant)	Straw as an extender material or as new product. Potential volume of straw use will be large if enough plants are involved. Straw costs difficult to compete with wood if densification is required.	Straw is implemented differently than wood, and processing will require changes.	Not much change from existing impacts. Social benefit from employment. Public scrutiny of resins and chemicals used, and acceptance of product will be necessary.
Power Plant (new plant)	Straw can be used as a supplemental fuel. Hog fuel costs and availability help straw compete. Potential large use of straw. Changes in PNW power supply will affect rates and plant economics.	Straw creates problems for most combustion equipment with deposits and slagging. Straw preparation and handling is difficult.	Air, water, noise, land use changes. Social benefits of employment. Public scrutiny is expected.
On-Farm Composting	Major "wild card" use of straw. Too preliminary for economic evaluation. Some benefits perceived through improved soil tilth.	Aerobic composting is feasible. Farm level testing is underway. Incorporation into fields not yet developed.	Social benefits to farmer. Limited impacts to environment.

Table ES-1 (continued)

Summary of Straw Utilization Technologies

STRAW USE	ECONOMIC FEASIBILITY	TECHNICAL VIABILITY	REGULATORY & SOCIAL
Home Stove Fuels	Straw costs difficult to compete with wood sources. Potential volume of straw use lower than other options.	Testing has been underway to improve burning properties.	Air quality impacts. Social impacts regarding smoke and airborne chemicals. Social benefits from locally-made products.
Commercial Soil Amendments (hydromulch, potting medium, compost)	Economic feasibility unknown. Hydromulch market potentially large. Potting medium market very small. Compost market unknown. Straw volume use unknown.	Testing underway for commerical composting; only grain straw used in potting medium. Unknown why straw in hydromulch market is not expanding.	Limited impacts to environment.
Chemical Digestion	Markets for products (eg: methane) not commercially established in the PNW. Feasibility of straw use not established in PNW.	Straw conversion into feed most probable. Chemical compound production not past pilot stages.	Air, water, noise, land use changes. Social benefits of employment. Public scrutiny of chemicals used in process.
Pyrolysis/ Gasification	Markets for products (eg: fuels) not commercially established in the PNW. Feasibility of straw use not established in PNW.	Chemical compound production not past pilot stages. Present pilot tests have not become commercial concerns.	Air, water, noise, land use changes. Social benefits of employment. Public scrutiny of chemicals used in process.
Hydrolysis	Markets for products (eg: ethanol) not commercially established in the PNW. Feasibility of straw use not established in PNW	Chemical compound production not past pilot stages. Most testing done with non-straw biomass materials.	Air, water, noise, land use changes. Social benefits of employment. Public scrutiny of chemicals used in process.

of the grass seed growers and identifies technologies that could utilize straw.

The study is based on a three-phased approach of investigation, design, and implementation.

The second phase will follow later with specific plans for preliminary design details of straw use processes. This phase will emphasize straw supply, and straw use technology, a specific choice of sites, permits, and sales contracts. There are, in fact, several particular straw market activities at or near Phase II today, including a straw pulping operation, a potential strawboard plant, straw addition to existing wood-fired boilers, and a potential straw-fired powerplant.

There also are a number of small-scale market uses of straw moving towards Phase II development. While most activities involve private sector sponsorship of a new enterprise, a powerplant activity is one area that will not proceed through Phase II without assistance from public and private agencies.

The third phase will be actual implementation of technology and economics, where projects are financed and constructed. Funding in Phase III will be largely private (developers, third party investors, some grass seed grower interests). This phase will produce bid documents that will also be used to secure final permits, financing, and contracts.

Summary of Grass Straw Utilization Options

There are many potential uses of grass straw in a variety of markets. Several are large users of straw, whereas some markets will not use significant amounts. This study focuses on major users of straw, since implementation of their projects can be more easily identified and supported than many small projects. However, we will discuss in general the uses of straw, without regard to size of project, or its profitability to demonstrate the potential available.

Grass straw has market potential as feed; fiber for pulp products and structural board; fuel for industry, homes, and power generation; agricultural uses such as soil amendments and erosion control; and raw material for chemicals production.

Grass straw first and foremost can be used as a *feed* material. In fact, markets exist and straw is currently used as feed both domestically and internationally. Straw is primarily used as a supplement to traditional protein rich feed materials, but straw can also be treated to improve its nutritive value.

Next, straw can be used as a ***fiber*** source. This is particularly significant to a region of the country that already handles millions of tons of wood fiber and wood residue in a variety of product markets. A particularly attractive market is the pulp and paper industry, which obtains a strong product value from the fiber raw materials it uses to produce paper and kraft, cardboard and cardboard liner, as well as other products.

Also predominant in Oregon are *structural board* plants producing plywood, particle board, and other types of hardboard and fiberboard.

The millions of tons of fiber used from wood residue in these industries are good candidates for replacement by straw, especially as an extender or bulking agent.

Straw also can be used as a *fuel* source. Again, Oregon and the Pacific Northwest are particularly strong in the use of bark and hogged fuel in boilers and dryers that support pulp and paper mills and structural board plants. Huge quantities of materials are needed for these industrial uses, not to mention power generating facilities and other commercial uses of wood as a fuel. Projects could include new plants or retrofit of existing plants (e.g., closed sawmills and hardboard plants).

Straw also has a ***home market*** in regards to use as a fuel. Work done in the 1970s and 1980s confirms that straw can be densified into various forms (e.g., straw cubes, straw logs, or straw pellets) that can be fed into home stoves as a replacement for wood.

In addition, grass straw can be used for on-farm and off-farm ***agricultural uses***, including hydromulch, potting medium, erosion control, and compost. Composting has been field tested this past year and had promising results. Incorporation of compost back to the fields has not been fully evaluated.

Straws from some grass species are particularly suited for specific markets; additional testing will be required.

Finally, grass straw can be used as raw material in ***chemical production*** processes. Work is being done across the country in converting agricultural wastes (biomass) into a variety of chemicals, including alcohol, ethanol, methane, furfural, ammonia, and acetic acid. Processes vary from those that produce fuel gases (pyrolysis and gasification), fuels (hydrolysis and fermentation), and animal feeds (digestion). These processes can be performed at large, industrial type commercial plants or on-farm using small scale equipment and immediate farm use of the products.

Straws from some grass species are particularly suited for specific markets, for example, Forage-type tall fescue, bentgrass, and perennial ryegrass for feed, and annual ryegrass for pulping. However, it is unknown how other varieties may serve the various markets. As the different markets develop, additional testing will be required to determine how straw from different seed types will affect the feed, fuels, chemical, and fiber markets.

Grass Seed Farming in Oregon

Grass Seed Types Planted

Grass seed has been grown in the state of Oregon since the 1920s and 1930s. A significant expansion began in the 1940s, accompanied by open-field burning. By the late 1960s, grass seed farming occupied over 300,000 acres. Today almost 400,000 acres are planted. During the past decade there has been a marked expansion in turf-type tall fescue and perennial ryegrasses. In many areas growers have shifted among grass seed types as well as from other crops.

The steady growth of the grass seed industry in the past 2 decades is not likely to occur in the 1990s, because production could now easily outstrip demand, seed amounts in storage will increase, and prices will drop. Already, declining prices in ryegrass, bluegrass, and other types have been affecting expansion in these areas.

Ryegrass grows well on even the poorest of soils.

The most prevalent grass types grown today in the Willamette Valley are the annual and perennial ryegrasses, representing over 200,000 acres planted in 1990 (Table ES-2). Ryegrass grows well even on the poorest of soils and is one of the easiest types to produce. Next are the fescue varieties, including tall fescue, chewings fescue, and red fescue. These varieties account for over 100,000 acres planted

Total straw production is based upon species and acreage (Table ES-2 and Figure ES-1). Both perennial ryegrass and tall fescue will remain stable in acres planted for the short term, but this may change if seed market demand declines for these types because of economic and supply conditions.

Table ES-2

Total 1990 Statewide Straw Production, Removal, and Export by Grass Type

Grass Seed Types	Acres Planted[1]	Potentially Available Straw (tons)[2]	Current Straw Removed (tons)[3]	Exported for Feed (tons)[4]
Tall fescue	91,510	291,328	206,968	43,345[5]
Annual ryegrass	109,180	272,019	0	0
Perennial ryegrass	108,340	244,266	194,521	106,409
Kentucky bluegrass	25,620	41,205	18,973	544
Orchardgrass	19,950	44,638	29,465	904
Bentgrass, creeping	7,160	15,955	14,096	2,425[6]
Bentgrass, colonial	7,780	9,569	3,794	NA[7]
Hard fescue	2,060	3,605	3,245	NA
Chewings fescue	17,710	2,435	2,361	NA
Red fescue	8,870	1,227	1,416	NA
TOTAL	398,180	926,246	474,839	153,627

[1] Based upon regional data in Table 4-1, which was derived combining data for counties.

[2] Based upon low and high tonnage of maximum potential available straw removed from field, as listed in Table 4-1, Columns 9 and 10.

[3] Based upon low and high tonnage of current grass straw removed from field (roadsided, stack-burned, or marketed), as listed in Table 4-2, Columns 19 and 20.

[4] Based upon Table 6-1.

[5] Includes all types of fescue.

[6] Includes all types of bentgrass.

[7] Not applicable because included in total elsewhere.

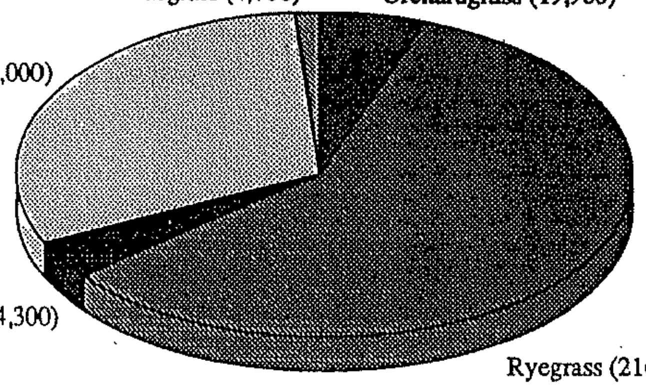

Figure ES-1
1990 Grass Seed Grown in the Willamette Valley by Type (acres)

Orchardgrass represents almost 20,000 acres, bentgrass has about 14,000 acres planted, and Kentucky bluegrass has about 5,000 acres.

A steady trend has developed towards production of proprietary seed varieties. Future varieties may tend to be dwarf or semidwarf, which will affect the amount of straw produced by the length of stem and leaf.

There are some concerns with the proprietary seed varieties.

Two general concerns have been raised about the increase in proprietary grass seed varieties: 1) a narrow genetic base for these seed types makes them more susceptible to disease problems, and 2) phytosanitary (plant cleanliness) requirements for export of straw may become more difficult for the new varieties.

Grass Seed Regions

Most of the grass seed is grown in seven Willamette Valley counties: Lane, Linn, Benton, Polk, Marion, Yamhill, and Clackamas. There is some grass seed production in Washington and Multnomah counties and in eastern Oregon (Jefferson and Union Counties), but the scale is much smaller. For the purposes of this study, four growing regions in the Willamette Valley were identified for analysis: South Valley, Foothills, Marion County Lowlands, and North Valley (Figure ES-2).

The southern Willamette Valley has the most farms over 1,000 acres.

The South Valley region, comprising Lane, Linn, Benton, and southern Polk counties, has the largest proportion of large farms (over 1,000 acres), many of which produce grass seed exclusively. Many farms are managed by fourth and fifth generation growers. Much of the soil is poorly drained, unsuited to most crops other than grass seed. Growers in this region have few if any productive options to grass seed farming.

Nearly all the annual ryegrass is grown in this region, with large amounts of perennial ryegrass and tall fescue as well. Soil types dictate the farming of annual ryegrass and may prohibit the investment cost of shifting to perennial grass seed types. Other seed types include orchardgrass, Kentucky bluegrass, bentgrass, and fescues. Roughly

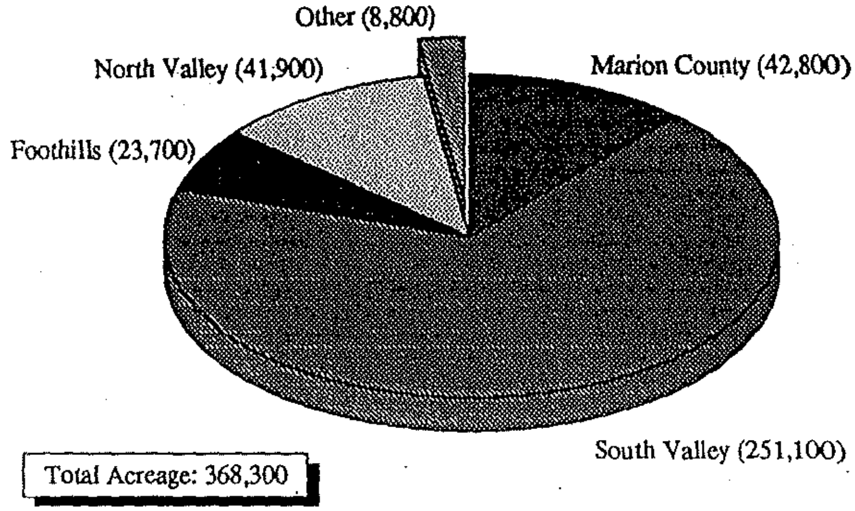

Figure ES-2
1990 Grass Seed Farming in the Willamette Valley by Regional Distribution (acres)

half the region grows proprietary varieties, and the area has seen a shift from wheat and row crops to grass seed as well.

The Foothills region consists of Marion County (Silverton Hills, north Linn, and southern Clackamas Counties). Grass seed growing began here after World War II, particularly with fine fescues and bentgrasses. The area is hilly with shallow soils, and soil erosion has been a historical problem.

Annual rainfall for the region is at least 20 inches greater than on the valley floor, which promotes growth but impacts field burning. Fine-leafed fescues dominate the hill acreage, followed by bentgrass and small amounts of perennial ryegrass and hard fescue.

The Marion County Lowlands region consists of Marion County bottom and benchland, and includes a small portion of southern Clackamas County. Grass seed production began in the late 1960s, and accounts for one third of total farm acreage in Marion County. Proprietary varieties of tall fescue and perennial ryegrass are the predominant type grown, with smaller amounts of bentgrass, Kentucky bluegrass, and orchardgrass also planted.

The Marion County Lowlands region has some of the most productive farmland in Oregon.

This region has some of the most productive—and expensive—farmland in Oregon, with the highest comparable yields available for many crops. Growers here have the greatest number of options available for crops, especially if grass seed markets decline.

The North Valley region consists of Yamhill and northern Polk Counties, and represents the newest growers to grass seed of all regions. About half the total acreage is now planted in grass seed, the remainder being traditional small grain, legume seed, and cannery crops. Land quality is lower than Marion County, with hilly areas in the west that have low water retention capacities (resulting in lower seed and straw yields).

Nearly all grass seed produced in the North Valley is proprietary turf-type tall fescue, perennial ryegrass, and orchardgrass, with some small amounts of fine fescue and bentgrass.

Farming Practices

Straw management practices developed out of significant restrictions and reductions in open-field burning starting in the early 1970s. Traditional open-field burning, which preceded straw management practices, had relatively simple operations and costs, and included the use of straw choppers or spreaders, preparation of fire breaks, and the actual field burn and burn management (fire protection). Today, the grass seed farmer utilizes three processes as part of straw management: straw removal, stubble management, and field sanitation.

Today's grass seed farmers use straw removal, stubble management, and field sanitation to manage straw.

Two options exist for straw removal, each with different equipment and costs. These options are roadsiding and marketing. Roadsiding usually involves temporary storage and/or stack-burning, and includes raking, transport (stack wagon), and baling (round bales or two-tie bales). Straw for market would involve raking and either three-tie bales together with transport (bale stack wagon) or "big bales" together with fork lifts. The bales are then transported via truck to market.

Stubble management consists of various alternatives to remove stubble and residue from the fields and to trim the crowns of plants, thus stimulating seed development for the subsequent year. Alternatives include propane-burning, cutting/clipping, and raking.

Field sanitation is an important and required part of grass seed farming. Sanitation can be implemented either thermally or chemically (herbicides). In the past, farmers tended to utilize thermal sanitation extensively on their fields, but this trend is now changing. For example, 10 years ago 75 to 80 percent of annual ryegrass fields in the South Valley region were open-burned, and today only about 50 percent of the fields are open-burned, with the rest using plowdown techniques .

Today, perennial ryegrass growers in the South Valley region use stubble management techniques for 3 of 4 years in a crop cycle. Open-burning is used in the fourth year for only about 25 percent of perennial ryegrass fields.

The same is true for tall fescue, where only 25 percent of the acreage is open-burned, with the remaining 75 percent subject to stubble management techniques.

Straw Handling

Straw production for 1990 is estimated to be between 1.0 million and 1.2 million tons (Figures ES-3 and ES-4) produced on almost 400,000

Between 800,000 and 1.0 million tons of straw are potentially available for market.

planted acres in the state of Oregon. Of this amount, between 800,000 and 1.0 million tons of straw are potentially available from the fields for market. The largest potential volume of straw is from farms in the southern Willamette Valley, with about 700,000 tons produced.

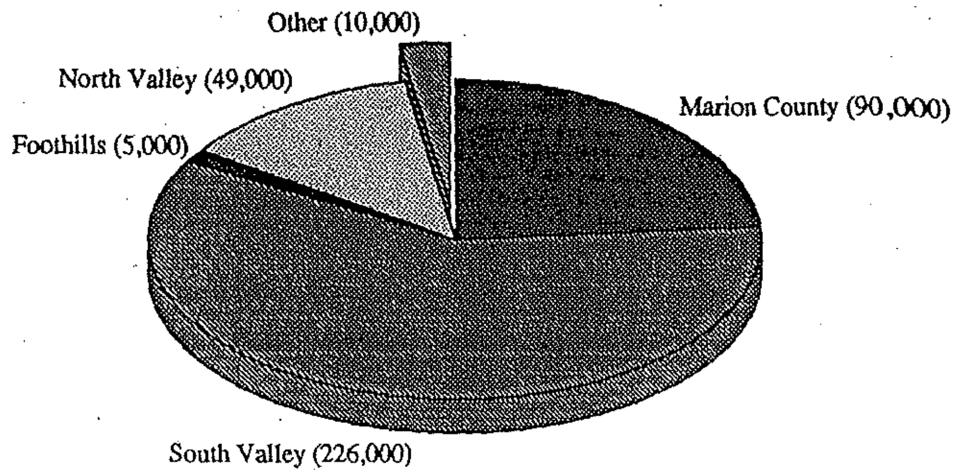

Figure ES-3
1990 Minimum Available Straw Statewide (tons)

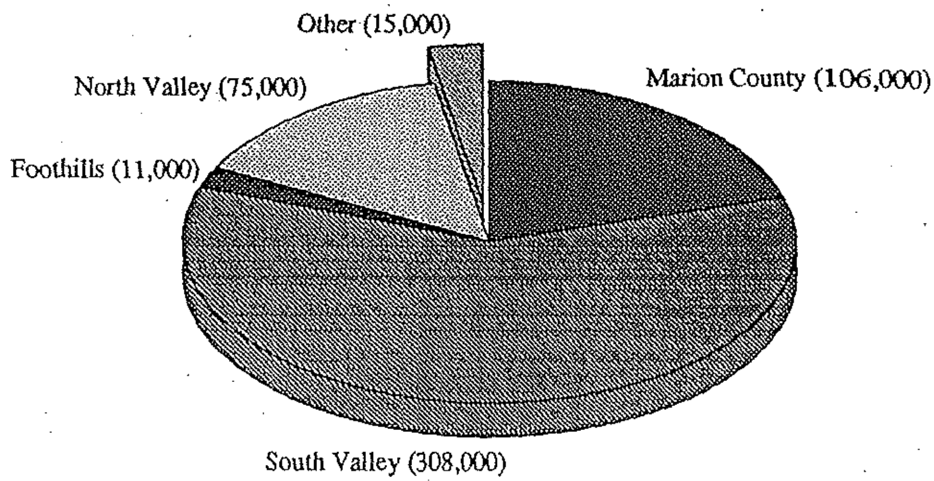

Figure ES-4
1990 Maximum Available Straw Statewide (tons)

In 1990, 156,000 acres were open-burned, and it is estimated that between 60,000 and 80,000 acres were plowed down. The remaining 150,000 to about 175,000 acres had grass straw removed and stack-burned or brought to market. This equates to approximately 150,000 tons of straw for export and between 250,000 and 400,000 tons of straw roadsided and/or stack-burned. Only about 60 percent of the 1990 straw removed is from the southern Willamette Valley, with Marion County and North Valley region producing most of the remainder.

Marketed straw is densified in small bales (100 pounds) or large "super" bales (1,600-2,000 pounds) and shipped to Portland for export as feed. Prior to overseas shipment, the straw is compressed into 5,600-pound blocks.

Nonmarketed straw is densified into round bales or loaves for roadsiding/stack-burning, with some being used for on-farm straw use testing. This form of densification is relatively cost effective, and stack-burns are short and efficient.

Straw brokers exist to a limited degree in the valley. Limited straw storage is available both with the straw brokers and with some individual growers. However, since only 150,000 tons of straw are marketed presently, the amount of storage needed for 800,000 to 1,000,000 tons of potentially available straw would demand significantly more storage be provided. Densifying and baling equipment, needed for straw marketing, must be developed and provided.

Straw as a Byproduct

Straw is a byproduct of grass seed farming, and hence has not commanded economic or agricultural importance in the past. The fact that about 200,000 tons of straw are plowed down and at least 500,000 tons open-burned or stack-burned in 1990 clearly shows that the farmer today continues to dispose of straw rather than market it. If the markets are established for straw use, the farmer must decide whether to plowdown or compost straw for soil amendments, roadside and stack-burn straw for rapid disposal, or gather straw and prepare it for market.

The cost of straw for market is sensitive to the amount of required preparation.

The cost of straw is sensitive to the amount of preparation required for market. Straw that is baled and roadsided costs $12 to $15 per ton. Transportation (150 miles) adds $15 to $25 per ton. Storage of straw adds another $7 to $10 per ton. This places straw costs in the range of $34 to $50 per ton, stored and delivered to market.

Implementation Strategies

This study identifies technologies that satisfy the "10-year goal" for significant grass straw use with processes that are proven to be commercially viable. It has also identified technology that needs more time and development before it can be counted on as a solid market for straw.

Straw for feed is already a successful market with some room for growth.

The first successful market for straw utilization is the export ***feed*** market. This use of straw is proven and can be expanded to other countries. An increased domestic market for straw feed is also a viable option. Technology is available to treat the straw for nutrients, but "raw" straw is already marketable and is successful. Straw can be chemically converted (hydrolyzed) to create a more digestible product as feed. Grass straw has enjoyed a stable export market in recent years, but it is far less stable in domestic markets, depending on supplies and accompanying costs of alfalfa and other forage feed. The problem with endophyte (a fungus that in some cases is toxic to livestock) must be considered for all feed markets.

The cost of wood chips is increasing as supply decreases. Straw can be an alternative fiber source and may command an attractive price.

One potential market is ***pulp and paper***, particularly in cardboard and liner production. Straw has been utilized in Europe for this purpose, and the technology exists to utilize it here in the Northwest. The delivered cost of grass straw is competitive with wood chips, which is the current fiber source. Straw obtains the highest value from this market, since pulp obtains the highest product value from fiber markets.

Pulp mills already handle recycled newsprint and recycled cardboard, and this market could utilize large quantities of straw to replace wood fiber. Production of paper products is less vulnerable to changes in the economy or housing starts as are other wood products industries. The cost for straw-related digestion and handling equipment could be a major capital expense. A new plant, or one that uses only straw to make pulp may not be economically reasonable today. Plants that use existing equipment and blend straw with other materials may be the most feasible.

Straw use as ***supplementary fuel*** in existing heating plants, dryers, and power boilers is also a possible market, and has been demonstrated in several Oregon wood-fired boilers over the years. Technology will support this option only if straw is mixed with wood and other materials to accommodate equipment limitations. In addition, some changes to plant equipment may be unavoidable when handling and firing straw. Some plants are also considering conversion to natural gas fuels from wood; straw cannot easily compete with natural gas costs as a primary or supplemental fuel.

Straw can also be used in ***structural board*** plants as a raw material or "extender" to wood residues. Changes must be made to the manufacturing process in handling and utilizing straw, and the price of wood fiber may have to increase above current levels to economically justify straw use. Also, public acceptance both at the product level and in building codes and standards must be obtained to make this a viable market item. Development of straw processing and use in strawboard and similar products could provide sufficient use of straw to compare with the options listed above. Several plants in Oregon are now considering straw.

The future looks promising for the economics of straw as a fuel source.

The ***powerplant*** market may also be a viable use of grass straw especially when straw co-fired with other materials. Several straw fired plants now operate in California and in other parts of the Unite(States, as well as abroad. Technology is available to bum straw (wit some unresolved problems), and improvements are continuously be ing made to improve performance on straw fuels. The economics of straw-fired powerplant will benefit from changes in the Pacific Northwest power pool, which should help increase power sales rates and hence increase revenues available to the plant.

On-farm composting, while still under development, may be a major use of straw in the near future. It is somewhat unknown what volumes of straw can be processed and incorporated into the fields, but this alternative could divert a large percentage of otherwise available straw from other straw use options. The benefits to soil tilth and perhaps more importantly the independence from straw market conditions to influence straw disposal make this alternative attractive to the farmer.

Most alternatives will take advantage of existing technologies and changing conditions.

Most of these alternatives will take some advantage of existing conditions to help promote the technology and acceptance of straw as a raw material. Pulp mills with appropriate digesters and boilers suitable for firing straw cubes are examples of existing conditions that can be exploited for straw use.

There are many technology areas that will take several years to develop into a commercial enterprise, too long to achieve the "10-year goal" of this study. One such area is the ***chemical production*** market. This technology needs time to develop pilot plants, especially when using straw as the input material, and then commercial scale plants will follow. Also, markets for the products from these plants need to mature, to ensure that consistent financial return is provided to the enterprise.

There are other straw uses that have sufficient technology to produce viable businesses, but the amount of straw used is small, and established markets need to be developed. Included in this category are the ***home fuel*** markets, and ***commercial soil amendments***.

Interestingly enough, all of these straw use processes (home fuels, composting, hydromulching, soil amendments) have been tested and tried for at least the last 10 years, but markets have not grown nor have the number of firms producing these products increased significantly. The amount of straw used in these areas appears to be no more than 50,000 tons per year and is probably much less.

Straw use for on-farm purposes is increasing, especially for plowdown. This will affect the straw supply for other alternatives, but it does provide the farmer with an alternative to field burning.

Regulatory and Social Issues

Social impacts vary for each technology, as do the regulatory implications. Projects implemented at existing plants have positive benefits in terms of land use, social impacts, and jobs. Some straw use alternatives, such as feed or composting, have very limited social impacts. Other alternatives are expected to have much higher impacts to the environment and will experience greater regulatory requirements. These other alternatives will also have higher social rewards in terms of jobs and benefits to the economy.

The public's acceptance of straw utilization technologies is key.

The public has a large role in determining whether straw utilization options are successful. The public must learn to accept straw-based products. Sophisticated utilization systems must be accepted with the understanding that this sophistication will carry with it certain controls and safeguards to the environment.

The use of straw as an extender or supplement to existing processes should not provide many noticeable impacts. Increased employment and the return of operating plants will favor straw use at existing and closed plants. The public will see value in straw use as a sustainable resource.

Public scrutiny is expected to be strongest with technology that deals with chemicals, hazardous waste streams, or clearly visual impacts on the environment. Public participation in the planning, permitting, and siting of new projects will be instrumental in gaining public trust and support.

Market Trends

Various market trends will affect the status of the farmer and the straw produced, just as the farmers' activities also will impact the markets and technology.

For example, expansion of the grass seed market appears to be over. Markets for proprietary varieties, turf-type tall fescue, and perennial ryegrass in particular, have recently become saturated in production volume, and prices have fallen.

The farmers' activities and choices of straw management depend on various markets.

Also, plant breeds will continue to change. Growers will continue to develop proprietary varieties of dwarf and semidwarf types, and this will change the character and volume of straw available.

Straw feed markets and the presence of endophyte will be a continuing concern for growers. Identification and certification of endophyte-free tall fescue and perennial ryegrass varieties will expand as the market demands such information. Specific knowledge of endophyte infestation in all grass seed types will help in stabilizing this market.

The ability to obtain a stable supply of straw will be important to any project. An adequate infrastructure must be created to manage straw inventory, protect it from the elements, and deliver it as needed.

The public's attitude about land use is changing. Many new residents to the state of Oregon view land as a place to live on and not to earn a living from. This view will challenge new projects and reward existing plant sites that are reworked for new technology.

Another very obvious trend is the decline of timber harvest in the Northwest, due to habitat preservation (e.g., the spotted owl), lagging regeneration, and the general shift to the southeast for timber production. Supplies of wood fiber will vary in cost and volume as forest products plants vacillate in response to housing starts. Competition for limited supplies of wood chips and hogged fuel will continue between local mills and out-of-state powerplants.

Dwindling surplus power reserves in the Northwest are now becoming evident. Power production in the region will likely diminish as decisions regarding salmon runs on the Columbia River impact hydropower plants. Also, decisions are pending on how Bonneville Power Authority finances debt, which will affect their wholesale rates for power. Power reserves, now sold to California, have steadily declined and are now predicted to diminish in the mid to late 1990s. New sources of power production will be carefully scrutinized, and traditional types of plants (eg: coal, nuclear, hydropower) are likely to be challenged when proposed.

Revenues for new powerplants should be better in the future.

Power rates will increase as replacement power sources are added to the power pool. Revenues for new powerplants should be better than available today, and power sales contracts will be tied to fuel supplies (including straw supplies) as they impact power production.

On The Horizon

So much work has been done over the years towards straw utilization, yet the situation continues to demand support towards success. It appears that now is the time to unite the public, the legislature, and the grass seed farmer in establishing viable markets for straw use. This effort should include consideration of the farmer's situation, provisions for realistic straw storage and distribution, and favorable support by the public towards straw use projects.

This study is a "snapshot" in time.

It should be recognized that this study is a "snapshot" in time, and that economic and social factors are always changing. The assessments of straw utilization options provided in this study will be affected over time, but the need for action will not.

Footnote 116

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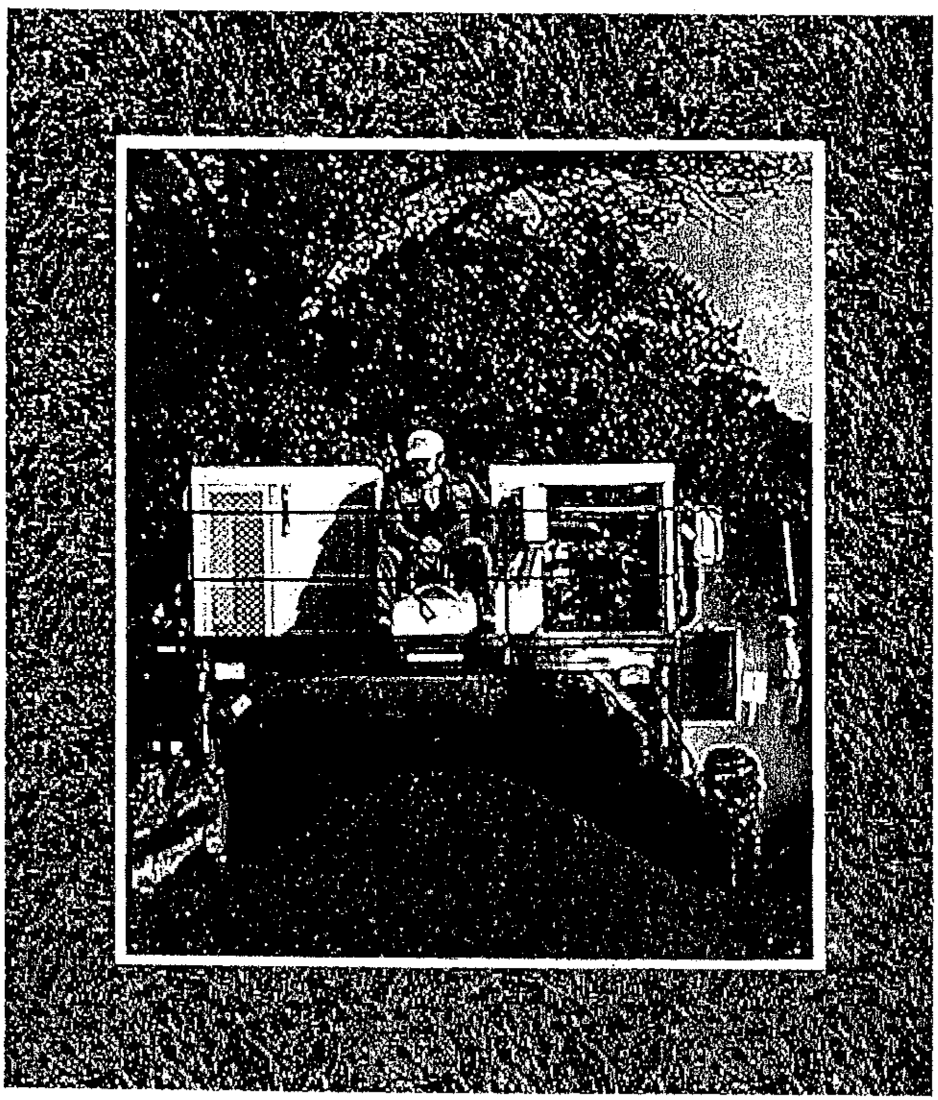
ARS–142

October 1998

Low-Input On-Farm Composting of Grass Straw Residue

in cooperation with the Agricultural Experiment Station,
Oregon State University, Corvallis



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Low-Input On-Farm Composting of Grass Straw Residue

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Abstract

Churchill, D.B., W.R. Horwath, L.F. Elliott, and D.M. Bilsland. 1998. Low-Input On-Farm Composting of Grass Straw Residue. U.S. Department of Agriculture, Agricultural Research Service, ARS–142, 32 pp.

In cropping fields of grass seed, straw removal is required to promote tiller growth and reduce pest incidence. In the past, straw removal was done by open field burning, which is being phased out in many regions through legislative mandates. Composting grass residue provides a possible alternative to open field burning in grass seed and other cropping systems in which plant residue waste presents cultural management problems.

Laboratory and field studies showed that composting of grass seed straw with a C:N ratio above 30:1 was feasible without the addition of N or water beyond normal yearly rainfall. Repeated turning with a front-end loader or a straddle-type turner to encourage decomposition reduced the straw volume significantly. Two turns with a flail-type compost turner or four or more turns with a front-end loader during decomposition reduced the bulk straw volume in windrows by 80 percent. More turns reduced the straw bulk by 88 percent and influenced the quality of the end product. The cost of on-farm composting of straw ranges from as low as $47 per hectare ($19 per acre) to more than $62 per hectare ($25 per acre), depending on the equipment used for windrow formation and turning.

This report will be useful to grass seed growers in the Pacific Northwest and to professional and technical workers concerned with recycling farm products.

Keywords: carbon mineralization, composting, crop residue, C:N ratio, decomposition, field composting, microorganisms, perennial ryegrass, straw, straw composting, thermophiles

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While supplies last, single copies of this publication may be obtained at no cost from Donald Churchill, USDA–ARS, National Forage Seed Production Research Center, 3450 S.W. Campus Way, Corvallis, OR 97331–7102.

Copies of this publication may be purchased from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161; telephone 703–605–6000.

Acknowledgments

The authors thank Dennis Glaser, Dwight Coon, Brian Glaser, and Wendell Manning for their advice and help with straw composting. We also thank Thom G. Edgar and Hudson Minshew for collaborative research assistance.

Footnote 17

FIELD BURNING AND PROPANE FLAMING

468A.550 Definitions for ORS 468A.555 to 468A.620 and 468A.992. (1) As used in ORS 468A.555 to 468A.620 and 468A.992:

(a) "Research and development of alternatives to field burning" includes, but is not limited to, projects concerned with cultural practices for producing grass seed without field burning, environmental impacts of alternative seed production methods, straw marketing and utilization and alternative crops.

(b) "Smoke management" means the daily control of the conducting of open field burning to such times and places and in such amounts so as to provide for the escape of smoke and particulate matter therefrom into the atmosphere with minimal intrusion into cities and minimal impact on public health and in such a manner that under existing meteorological conditions a maximum number of acres registered can be burned in a minimum number of days without substantial impairment of air quality.

(c) "Smoke management program" means a plan or system for smoke management. A smoke management program shall include, but not be limited to, provisions for:

(A) Annual inventorying and registering, prior to the burning season, of agricultural fields for open field burning;

(B) Preparation and issuance of open field burning permits by affected governmental agencies;

(C) Gathering and disseminating regional and sectional meteorological conditions on a daily or hourly basis;

(D) Scheduling times, places and amounts of agricultural fields that may be open burned daily or hourly, based on meteorological conditions during the burning season;

(E) Conducting surveillance and gathering and disseminating information on a daily or more frequent basis;

(F) Effective communications between affected personnel during the burning season; and

(G) Employment of personnel to conduct the program.

(2) As used in this section, "open field burning" does not include propane flaming of mint stubble or stack or pile burning of residue from Christmas trees, as defined in ORS 571.505. [Formerly 468.453; 1997 c.473 §3; 1999 c.439 §2; 2001 c.70 §1]

468A.555 Policy to reduce open field burning. The Legislative Assembly declares it to be the public policy of this state to reduce the practice of open field burning while developing and providing alternative methods of field sanitization and alternative methods of utilizing and marketing crop residues. [1991 c.920 §3]

468A.560 Applicability of open field burning, propane flaming and stack and pile burning statutes. (1) Except for the fee imposed under ORS 468A.615 (1)(c), the provisions of ORS 468A.550 to 468A.620 and 468A.992 shall apply only to open field burning, propane flaming and stack or pile

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Conservation Service, or its successor agency; the Agricultural Stabilization Commission, the state Soil and Water Conservation Commission and other interested agencies. The Department of Environmental Quality shall advise the commission in the promulgation of such rules. The commission must review and show on the record the recommendations of the department in promulgating such rules.

(4) No regional air quality control authority shall have authority to regulate burning of perennial grass seed crops, annual grass seed crops and grain crops. *

(5) Any amendments to the State Implementation Plan prepared by the state pursuant to the federal Clean Air Act, as enacted by Congress, December 31, 1970, and as amended by Congress August 7, 1977, and November 15, 1990, and Acts amendatory thereto shall be only of such sufficiency as to gain approval of the amendment by the United States Environmental Protection Agency and shall not include rules promulgated by the commission pursuant to subsection (1) of this section not necessary for attainment of national ambient air quality standards. [Formerly 468.460; 1997 c.249 §163]

* SIP
Do not update

468A.597 Duty to dispose of straw. Unless otherwise specifically agreed by the parties, after straw is removed from the fields of the grower, the responsibility for the further disposition of the straw, including burning or disposal, shall be upon the person who bales or removes the straw. [1993 c.414 §2]

468A.600 Standards of practice and performance. The Environmental Quality Commission shall establish standards of practice and performance for open field burning, propane flaming, stack or pile burning and certified alternative methods to open field burning. [1991 c.920 §10]

Has DOA done this?

468A.605 Duties of Department of Environmental Quality. The Department of Environmental Quality, in coordinating efforts under ORS 468.140, 468.150, 468A.020, 468A.555 to 468A.620 and 468A.992, shall:

(1) Enforce all field burning rules adopted by the Environmental Quality Commission and all related statutes; and

(2) Monitor and prevent unlawful field burning. [1991 c.920 §11; 1995 c.358 §4]

468A.610 Reduction in acreage to be open burned, propane flamed or stack or pile burned. (1) Except as provided under ORS 468A.620, no person shall open burn or cause to be open burned, propane flamed or stack or pile burned in the counties specified in ORS 468A.595 (2), perennial or annual grass seed crop or cereal grain crop residue, unless the acreage has been registered under ORS 468A.615 and the permits required by ORS 468A.575, 476.380 and 478.960 have been obtained.

(2) The maximum total registered acreage allowed to be open burned per year pursuant to subsection (1) of this section shall be:

(a) For 1991, 180,000 acres.

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(b) For 1992 and 1993, 140,000 acres.

(c) For 1994 and 1995, 120,000 acres.

(d) For 1996 and 1997, 100,000 acres.

(e) For 1998 and thereafter, 40,000 acres.

(3) The maximum total acreage allowed to be propane flamed under subsection (1) of this section shall be:

(a) In 1991 through 1997, 75,000 acres per year; and

(b) In 1998 and thereafter, 37,500 acres per year may be propane flamed.

(4)(a) After January 1, 1998, fields shall be prepared for propane flaming by removing all loose straw or vacuuming or prepared using other techniques approved by rule by the Environmental Quality Commission.

(b) After January 1, 1998, propane equipment shall satisfy best available technology.

(5) Notwithstanding the limitations set forth in subsection (2) of this section, in 1991 and thereafter, a maximum of 25,000 acres of steep terrain and species identified by the Director of Agriculture by rule may be open burned and shall not be included in the maximum total permitted acreage.

(6) Acreage registered to be open burned under this section may be propane flamed at the registrant's discretion without reregistering the acreage.

(7) In the event of the registration of more than the maximum allowable acres for open burning in the counties specified in ORS 468A.595 (2), after 1996, the commission, after consultation with the State Department of Agriculture, by rule or order may assign priority of permits based on soil characteristics, the crop type, terrain or drainage.

(8) Permits shall be issued and burning shall be allowed for the maximum acreage specified in subsection (2) of this section unless:

(a) The daily determination of suitability of meteorological conditions, regional or local air quality conditions or other burning conditions requires that a maximum number of acres not be burned on a given day; or

(b) The commission finds after hearing that other reasonable and economically feasible, environmentally acceptable alternatives to the practice of annual open field burning have been developed.

(9) Upon a finding of extreme danger to public health or safety, the commission may order temporary emergency cessation of all open field burning, propane flaming or stack or pile burning in any area of the counties listed in ORS 468A.595 (2).

(10) The commission shall act on any application for a permit under ORS 468A.575 within 60 days of registration and receipt of the fee required under ORS 468A.615. The commission may order

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emergency cessation of open field burning at any time. Any other decision required under this section must be made by the commission on or before June 1 of each year. [1991 c.920 §12; 1995 c.358 §5]

468A.615 Registration of acreage to be burned; fees. (1)(a) On or before April 1 of each year, the grower of a grass seed crop shall register with the county court or board of county commissioners, the fire chief of a rural fire protection district, the designated representative of the fire chief or other responsible persons the number of acres to be open burned or propane flamed in the remainder of the year. At the time of registration, the Department of Environmental Quality shall collect a nonrefundable fee of $2 per acre registered to be sanitized by open burning or $1 per acre to be sanitized by propane flaming. The department may contract with counties and rural fire protection districts or other responsible persons for the collection of the fees which shall be forwarded to the department. Any person registering after April 1 of each year shall pay an additional fee of $1 per acre registered if the late registration is due to the fault of the late registrant or one under the control of the late registrant. Late registrations must be approved by the department. Copies of the registration form shall be forwarded to the department. The required registration must be made and the fee paid before a permit shall be issued under ORS 468A.575.

(b) Except as provided in paragraph (d) of this subsection, the department shall collect a fee in accordance with paragraph (c) of this subsection for issuing a permit for open burning, propane flaming or stack or pile burning of perennial or annual grass seed crop or cereal grain crop residue under ORS 468A.555 to 468A.620 and 468A.992. The department may contract with counties and rural fire protection districts or other responsible persons for the collection of the fees which shall be forwarded to the department.

(c) The fee required under paragraph (b) of this subsection shall be paid within 10 days after a permit is issued and shall be:

(A) $8 per acre of crop sanitized by open burning in the counties specified in ORS 468A.595 (2);

(B) $4 per acre of perennial or annual grass seed crop sanitized by open burning in any county not specified in ORS 468A.595 (2);

(C) $2 per acre of crop sanitized by propane flaming;

(D) For acreage from which 100 percent of the straw is removed and burned in stacks or piles:

(i) $2 per acre from January 1, 1992, to December 31, 1997;

(ii) $4 per acre in 1998;

(iii) $6 per acre in 1999;

(iv) $8 per acre in 2000; and

(v) $10 per acre in 2001 and thereafter; and

So now, it's changed to open ban in A.595 counties!

(E) For acreage from which less than 100 percent of the straw is removed and burned in stacks or piles, the same per acre as the fee imposed under subparagraph (D) of this paragraph, but with a

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468A.590 Duties of Department of Agriculture. Pursuant to the memorandum of understanding established under ORS 468A.585, the State Department of Agriculture:

(1) Shall:

(a) Conduct the smoke management program established by rule by the Environmental Quality Commission as it pertains to open field burning, propane flaming and stack or pile burning.

(b) Aid fire districts and permit agents in carrying out their responsibilities for administering field sanitization programs.

(c) Subject to available funding, conduct a program for the research and development of alternatives to field burning.

(2) May:

(a) Enter into contracts with public and private agencies to carry out the purposes set forth in subsection (1) of this section;

(b) Obtain patents in the name of the State of Oregon and assign such rights therein as the State Department of Agriculture considers appropriate;

(c) Employ personnel to carry out the duties assigned to it; and

(d) Sell and dispose of all surplus property of the State Department of Agriculture related to smoke management, including but not limited to straw-based products produced or manufactured by the State Department of Agriculture. [1991 c.920 §9; 2001 c.70 §3]

468A.595 Commission rules to regulate burning pursuant to ORS 468A.610. In order to regulate open field burning pursuant to ORS 468A.610:

(1) In such areas of the state and for such periods of time as it considers necessary to carry out the policy of ORS 468A.010, the Environmental Quality Commission by rule may prohibit, restrict or limit classes, types and extent and amount of burning for perennial grass seed crops, annual grass seed crops and grain crops. EQC can prohibit

(2) In addition to but not in lieu of the provisions of ORS 468A.610 and of any other rule adopted under subsection (1) of this section, the commission shall adopt rules for Multnomah, Washington, Clackamas, Marion, Polk, Yamhill, Linn, Benton and Lane Counties, which provide for a more rapid phased reduction by certain permit areas, depending on particular local air quality conditions and soil characteristics, the extent, type or amount of open field burning of perennial grass seed crops, annual grass seed crops and grain crops and the availability of alternative methods of field sanitation and straw utilization and disposal. more rapid phased reduction

(3) Before promulgating rules pursuant to subsections (1) and (2) of this section, the commission shall consult with Oregon State University and may consult with the United States Natural Resources

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Conservation Service, or its successor agency; ~~the Agricultural Stabilization Commission, the state Soil~~ and Water Conservation Commission and other interested agencies. The Department of Environmental Quality shall advise the commission in the promulgation of such rules. The commission must review and show on the record the recommendations of the department in promulgating such rules.

(4) No regional air quality control authority shall have authority to regulate burning of perennial grass seed crops, annual grass seed crops and grain crops. *

(5) Any amendments to the State Implementation Plan prepared by the state pursuant to the federal Clean Air Act, as enacted by Congress, December 31, 1970, and as amended by Congress August 7, 1977, and November 15, 1990, and Acts amendatory thereto shall be only of such sufficiency as to gain approval of the amendment by the United States Environmental Protection Agency and shall not include rules promulgated by the commission pursuant to subsection (1) of this section not necessary for attainment of national ambient air quality standards. [Formerly 468.460; 1997 c.249 §163] * SIP Do not update

468A.597 Duty to dispose of straw. Unless otherwise specifically agreed by the parties, after straw is removed from the fields of the grower, the responsibility for the further disposition of the straw, including burning or disposal, shall be upon the person who bales or removes the straw. [1993 c.414 §2]

468A.600 Standards of practice and performance. The Environmental Quality Commission shall establish standards of practice and performance for open field burning, propane flaming, stack or pile burning and certified alternative methods to open field burning. [1991 c.920 §10] Has DEQ done this?

468A.605 Duties of Department of Environmental Quality. The Department of Environmental Quality, in coordinating efforts under ORS 468.140, 468.150, 468A.020, 468A.555 to 468A.620 and 468A.992, shall:

(1) Enforce all field burning rules adopted by the Environmental Quality Commission and all related statutes; and

(2) Monitor and prevent unlawful field burning. [1991 c.920 §11; 1995 c.358 §4]

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(2) The maximum total registered acreage allowed to be open burned per year pursuant to subsection (1) of this section shall be:

(a) For 1991, 180,000 acres.

Foot note 25

From: Dixie Maurer-clemons
To: dwmonk@oregontoxics.org
Cc: prton@comcast.net
Sent: Thursday, March 01, 2007 12:27 AM
Subject: field burning

I am a life long resident of the Willamette Valley and from a family that now has 6 generations who have been raised in the southern end of the valley.
My strikingly beautiful mother suffered a bout with Bell's Palsy one summer when she was in her mid-thirties. After much therapy and many trips to a specialist in Portland her face was no longer distorted. The following summer it returned much to her distress; as it did the third summer. The fourth year she realized that it returned during the field burning season. In those days Eugene literally sat in a dark cloud of smoke on many days. In spite of the lessening of smoke intrusions into the south end of the valley due to legislation in following years, mother became more and more sensitive to the smoke. Finally, she was driven out of her home for several weeks each summer in order to avoid a return of palsy every summer. She always hoped to see an end to field burning in the valley. She died in 2001 without seeing that occur and still having to leave her home and the valley in her last summer due to several days of discomfort.
I have never known whether it was the smoke itself or the chemicals in the smoke that caused mother's problem; but I know that field burning was the source.
Please do what needs to be done to stop this practice. I know it is not necessary for good grass seed farming practices. There are other ways to achieve the same result without endangering the health of everyone who lives in the southern end of the valley.
Thank you for your attention.

Sincerely,

Dixie Maurer
339 W. 22nd Ave.
Eugene, Or 97405

Phone: (541) 343-3028

Footnote 26

From: George & Maxine Kovarik
To: OTA
Sent: Tuesday, February 27, 2007 3:19 PM
Subject: Field Burning

OTA, This letter is to give my support to banning the practice of field burning in Oregon. I live on the Marcola Road side of the Coburg Hills, at the Hill road, Donna Road intersection. The smoke boils up over the hills and makes it's way downward on into the valley. It was so bad this last fall, that I could'nt read the phone book to locate a phone number, to call in a complaint. My eyes burned so badly, and tears poured down my face,

messed up my eyeglasses, so I could barely see. This was inside my house. I live on just under an acre, smoke was so bad at times I could barely see my back fence. I also suffer severe allergy problems all year long. This smoke worsens this condition, to the point I have difficulty breathing. Also covers every thing with sooty particles from the burned material in the fields. I have utmost sympathy for those afflicted with asthma, COPD, and other respiratory problems. With our short summers, it is an absolute shame, that people are driven inside, to try to escape the smoke and related discomfort it brings us. This was not a single occasion, it was many days the winds did'nt do what they were supposed to. It is way past time we put an end to this. I don't have a lot of years left. I would like to be able to go out into my yard, and enjoy the last good days of summer and fall. Thank You, so much for representing my thoughts about this serious issue. Maxine Kovarik 91127 Hill Road Springfield, Oregon 97478.

Foot note 27

March 2, 2007
Dear State Legislators:

~~I have lived in the Willamette Valley since 1960.~~ I graduated high school in Cottage Grove in 1962 and married in 1963 and worked at the Pacific NW Bell telephone company downtown Eugene. I can remember many times of coming out of work during my lunch hour and after work and it being smokey and it was as thick as the fog at the Oregon Coast. I also remember the horrible day that Governor Tom McCall was on the news because you couldn't see 10 feet in front of your face in downtown Eugene. I had taken my child to the cinema and walked out and thought main street of Eugene must be on fire as the smoke was so thick.

We then moved to the Mohawk Valley and put in a swimming pool. The smoke would drift over the Coburg hills right towards our house and pool. Their would be 2 – 4 inch long pieces of black straw heading right for our bright shiny blue pool and of course it would leave a black smear like someone had taken a black marker and wrote on the pool. We called and complained and of course nothing was ever done.

The smoke was diverted toward Eugene, or west or east but heaven forbid never North toward Salem.

I also remember the young college student who was living with us and his family lived in Hillsboro and he was headed home when the 7 car pileup happened. I was almost hysterical waiting for a phone call from him or his mother who was watching the scene unfold live on television both of us praying he was not in that mess on the freeway. He wasn't thank God.

I thought at the time maybe this will finally be the end of this – maybe God actually stepped in to signal to the people in Salem to show the legislators that it is killing people slowly but tragically all at once.

It slowed a little but not much.

We moved to Creswell and built a new home and this last summer were dismayed at the actually straw that floated in our neighbor hood. This time the pieces were 8 – 10" long. I called the number in the book to complain and the young man who answered said, "Lady, we don't have anyone for Creswell, you will have to find out who represents your district and contact them by writing a letter. So since 1960 to 2007 which is 47 years I and my family have suffered so the grass seed farmer could get richer. Meanwhile the rest of us have just had to live with it. It is like being next to someone smoking a cigarette – second hand smoking kills or don't any Legislators read the science about the smoke. I believe it is past time for this to stop and take care of our earth – has any of you read "An Inconvenient Truth"? I suggest it become mandatory reading for every Legislator and every grass seed farmer. It is now a new century and certainly time to find a way to help the grass seed industry find a more viable way to control disease without killing the rest of us.

Sincerely
Penny Spencer
644 Creswood Drive
Creswell, OR 97426
541-895-9858

Foot note 28

From: dorothyblueeyes
To: dwmonk@oregontoxics.org
Sent: Saturday, February 24, 2007 7:50 PM
Subject: The Past of My Family In the Valley,and Grass Seed Burning here.

Dear Sir: Thank you for being concerned about the noses and sinuses of the people of Willamette Valley. My family has lived here for about 50 years, my dad built our house during the 50's,and planted all the trees,and we had orchards in back. My poor dad, who has always had sinus trouble, was made so miserable, by all the grass seed burning of the farmers, every summer, that he was sick, and got bloody sinuses all the time. I remember his handkerchiefs always being stained with blood.

Now, I know that he probably had sinus infections all the time, from the burning of seed,and stuff burning in Willamette Valley, (we are in Eugene, on river Rd.)but he never went to a doctor for it,he just put up with it,and was always blowing his nose. I was not so lucky; I got sinus infections,and hay fever, from the grass burning, and all the lumber mills burning all the time. I pretty much have chronic sinusitus,and I get a sinus infection every once in a while.

Even living in California did not help it any, for some years, when i was working,as they also have a lot of pollen. But the burning of seeds,and grass,and agricultural burning here, was always much worse,and it made my poor dad who had the "River Rd. Watchmaker" and small jewelry business, on River Rd., miserable all the years we lived here. He did not have the option of moving, or leaving and going someplace else,his home, place, and his small business was right here. It's not so easy to just leave a business,and move away cause the air is bad. He had a family to support, for a long time,and my sister and I went to the University of Oregon, finally, too,while we were living at home.

Because I was born here, in Eugene,and grew up with all that grass seed burning,and all that bad agricultrual burning every summer, I started out with a bad sinus, just growing up here. I have to use nasal sprays, special ones,and antihistimines, all the time, every day, to help the bad condition, which is very inflamed,and also I have to regularly "decongest" my sinus, by using a bronchial steamer almost every day,to loosen up the congestion more easily. (I cannot take pill decongestants.)

Summer should be very nice, here, in Oregon, but it is often Hell for all of us, cause we cannot BREATHE here, cause of all the grass seed burning,and agricultural burning. People tell me,it is illegal for the farmers to burn grass seed,and they get PAID TO NOT BURN IT,BUT THEY DO IT ANYHOW, cause there is no law, or money, to stop them from doing it.

If you can put any "teeth" in any laws, or legislation, to stop all this grass seed burning,and the farmers from burning all their agricultural stuff, during the whole summer, in an enclosed valley, you would be helping all of us,and the ghost of my dad would probably be very happy too. He was a good gardener,and he loved Oregon,and I hate to think how he suffered, just cause of the bad air,when this could be such a wonderful place to live.

Thank you, sincerely, Dorothy H. Bucher, jr., of 2980 River Rd., Eugene, Oregon 97404 at bucher1045@comcast.net 541-463-7605.

Footnote 29

From: "Pam Perryman" <pam@bobwhitman.com>
To: <dwmonk@oregontoxics.org>
Sent: Saturday, February 10, 2007 3:51 PM
Subject: field burning testimony

> Dear Oregon State Legislator.
>
> I have a medical diagnosis of exercised-induced asthma. I never had
> it until I moved here in 1972 when field burning was more prevalent
> than today. When there is particulate matter in the air from field
> burning smoke, I get wheezy and it is difficult to walk. I have to
> stay inside. My eyes sting as well. 34 years later, I still get
> wheezy when the field burning smoke blows into town. I called LRAPA
> to complain this year, and I called at least once before about 2-3
> years ago, but the official complaints I filed do not reflect the
> frequency of my problem -- it happens with every smoke intrusion.
>
> I realize that the farmers and the state have been working to
> minimize the smoke intrusions, but you can't predict which way the
> wind will really blow. That's the problem with field burning smoke.
> You can't plan your day around it.

> When I was a student teacher in Junction City in 1974, I had a
> student whose father was a grass seed farmer. She told me, "We can't
> make money if we don't burn our fields." I told here, "But I can't
> make money if I can't breathe!"
>
> Please pass legislation ending field burning. There are other ways to
> remove grass straw and weed seeds from the field; I only have one way
> to get air into my lungs.
>
> Pam Perryman
> 3025 Neslo Lane
> Eugene, OR 97405

Footnote 30

Original Message -----
From: RGates7390@aol.com
To: DWMONK@oregontoxics.org
Sent: Thursday, February 01, 2007 12:03 PM
Subject: FIELD BURNING

DEAR OREGON LEGISLATORS

EVERY YEAR THE SMOKE ROLLS ACROSS THE COBURG HILLS FROM FIELD BURNING AND IWE BOTH HAVE TROUBLE BREATHING AND HAVE HEADACHES AND NOSE BLEEDS. THIS WAS ESPECIALLY BAD THREE DIFFERENT TIMES LAST SUMMER/FALL. WE CALLED EACH TIME AND COMPLAINED, BUT NEVER HAD A CALL BACK.
WE HAVE LIVED AND PUT UP WITH THIS THE LAST 35 YEARS AND ENOUGH ALREADY
THE SMOKE IN OUR VALLEY SEEMS TO HAVE GOTTEN WORSE AS THEY HAVE TRIED TO KEEP THE SMOKE FROM THE EUGENE/SPRINGFIELD AREA. WE LIVE IN THE MOHAWK VALLEY AND THE ASH AND PARTICULATE COVER OUR CARS, DECK AND THE CLEAN CLOTHES HANGING ON THE LINE (YES, WE TRY TO OUTGUESS THE BURNERS AND HANG THE CLOTHES OUT TO DRY). NOT ONLY IS THIS UNNECESSARY, BUT A HEALTH ISSUE. LAST SUMMER COMING FROM PORTLAND BETWEEN ALBANY AND EUGENE THE SMOKE WAS THICK AND TRAFFIC HAD TO SLOW AND HAD TO HAVE THEIR LIGHTS ON. WE WONDERED IF WE WOULD BE REAR-ENDED. WHY DO THE FARMERS GET PAID A SUBSIDY FROM THE GOVERNMENT AND STILL BURN THEIR FIELDS?

RONALD and DORIS GATES
90429 SHADOWS DR.
SPRINGFIELD, OR. 97478

541-747-8667
RGATES7390@AOL.COM

Footnote 31

----- Original Message -----
From: Victoria Whitman
To: dwmonk@oregontoxics.org
~~Sent: Thursday, February 08, 2007 11:00 PM~~
Subject: Field burning

Dear Oregon State Legislators;

For me field burning is a horrible problem. I am allergic to both smoke and pollen, and with exposure I can go into an asthma attack. My condition is not daily asthma but smoke and allergy triggered asthma. This is the medical diagnosis.

When I have an attack I get a swollen face, I have trouble breathing, I get wheezy, and I get sinus headaches that do not just disappear when the smoke does. I am very fatigued. Attacks weaken my immune system. Attacks trigger migraines as well. I cannot function normally; ike with anyone who is very ill. I get spacey, disoriented, having trouble tracking what I'm doing and even conversing. It really levels me. My husband can notice when I'm on the verge of an incident because I begin to blacken underneath my eyes due to the lack of oxygen. He worries about me driving, although he knows I try not to when I feel badly. I have to stay inside, preferably in a place with airconditioning and filters. I did buy a car with a hepa allergy filter to help with this problem, but still often feel it would just be better not to drive. Being a realtor, this can make doing my job very difficult.

You would not know any of this to look at me. When I am not having or recovering from an attack I look like a healthy, young, energetic person with a successful career. I am active in the community, volunteer, love the outdoors - especially hiking, and live a full life. I am not considered a "wimp" nor am I easily dissuaded from doing the things I love.

I have been treated for this condition for years, but I was feeling my treatment regimen and quality of life were not satisfactory. So, last fall, I spent three weeks in Denver at National Jewish Hospital, the hospital ranked #1 the past 9 years in the USA for asthma and allergies. They did multiple tests, and confirmed the connection between my smoke and pollen allergies and my asthma. They also confirmed that I do not have daily asthma, nor excercise induced asthma. ONLY ALLERGY INDUCED ASTHMA - which is often triggered by smoke burning. This three-week stay cost me $24,000. And that's just the medical bills, not the hotels and food. My insurance originally tried to deny my claim, but eventually they paid what my policy was written for.

Footnote 31

~~One thing I know now after the visit to this clinic and getting a more precise diagnosis is~~ that many people with asthma are overmedicated. Most people see their family practicioner for asthma, and because asthma can kill you, these doctors, for liability reasons, prescribe lots of medications. But all these medications have side effects. I know, bacuse I've taken many of them. Over time they can actually weaken your lungs, making a person's asthma worse.

I am a real estate salesperson. The smoke has had serious imapcts on my job. Last summer during the field burning season I missed a part of the working day for one entire month. I'd have to go home. I couldn't drive clients around to look at property because I felt so bad that I did not think it was safe to be driving. I continue working during the field burning season until I absolutely can't, becasue I'm self-employed, and when I don't work, I don't get paid. And here I am, sick from the smoke and trying to convince my clients how wonderful it is to live in Eugene!

I've often treid to leave town for the weekend to get away from the smoke, but that also means leaving work (and the rest of my life). I can't just do that any time. And there isn't any warning about when the smoke will hit. Even when the news tries to send out warnings, who can predict the weather (and wind!) with that much accuracy?

Field burning has also had negative impacts on my personal life. It's very hard on my family life when I'm sick and irritable for much of the summer.

I called LRAPA about three times last year to complain. Even though I've lived here 15 years, I didn't call before that because I was unaware there was someone to complain to.

I love living in Oregon and Eugene. I have a family, friends and a successful career. I do not want to leave, but do consider it due to my health. Ending field burning could substantially improve my ability to manage my health and make me feel far more comfortable with living here.

Sincerely,

Victoria Whitman

"I appreciate your business and referrals!"
http://whitman.mywindermere.com

Footnote 32

msn Hotmail®

From : Jeff Wyman <jwyman44@comcast.net>
Sent : Thursday, March 8, 2007 8:15 PM
To : banfieldburning@hotmail.com
Subject : Letter of support

Dear Oregon State Legislators,

My wife and I have lived in Eugene for four years now, and we truly love it. Lane County is a wonderful area in all respects: culturally, physically, and environmentally. However, there's one notable exception that is an issue of grave concern to me, and that is the annual burning of grass seed fields in the Southern Willamette Valley every August and September. It's bad enough that, for a couple of months every year, our lovely area looks like Los Angeles. We caution our out of town friends not to visit us in August because, frankly, it's embarrassing. What I can't live with is the health hazard this pollution creates for many of us. My wife has spent days in bed with severe headaches; my lungs burn and sometimes I have trouble breathing. Our energy is sluggish and our eyes are bloodshot - every year at this time.

My family's health problems are small compared to the thousands of Oregon citizens who suffer from asthma, other respiratory diseases, and heart conditions. These people are incapacitated by exposure to field burning smoke, and, in many cases, their very lives are in danger. Please do whatever you can to support Rep. Paul Holvey's House Bill #3000 to ban field burning, so we can enjoy the quality of life in our state that we should have.

Sincerely,

Jeff Wyman
2966 Riverview St.
Eugene, OR 97403
email: jwyman44@comcast.net

Footnote 33

msn® Hotmail®

banfieldburning@hotmail.com   Printed: Wednesday, April 4, 2007 2:10 PM

From : Berrien, Hewitt <HBerrien@peacehealth.org>
Sent : Wednesday, March 7, 2007 9:19 AM
To : banfieldburning@hotmail.com
Subject : stop the burning

I moved with my young family to Eugene a little less than 15 years ago. Both of us now have asthma and must broncho-dialate daily, often more than once, with steroid medications. Our children have intermittent bouts with bronchial and nasal congestion, commonly during the latter part of summers. None of us had any health problems before moving here. My wife and I both work in the healthcare fields and fail to understand how this practice of field-burning could be permitted to go on for so many years. We are confident in our perception that the reason for its sanction is largely related to big money and political clout. What's new in the present era? We are tired of the lack of "pull" the commonwealth have in it; on all levels. May our individual wills, framed in this small email message, carry the "winds of the commonwealth" back into the face of all those responsible for the fires and the unnecessary suffering of others. Just say NO to field-burning!!!

Hewitt and Patricia Berrien

Footnote 34

msn Hotmail

banfieldburning@hotmail.com Printed: Wednesday, April 4, 2007 2:01 PM

From : RAG <sublimey2u@wbcable.net>
Sent : Sunday, April 1, 2007 10:24 PM
To : banfieldburning@hotmail.com
Subject : Choking smoke

My wife is an Asthma sufferer and it is disgusting that she should have to breath in this crap.

I have found black ash in our local park and our back yard as big as my fist.

There is no need for this habit to continue, it belongs with the Model T Ford, along with backyard burning.

We are sick and tired of these selfish grass seed farmers, who obviously don't give a damn about the public's health and welfare, or for that matter there own families health.

The time is long overdue in putting a permanent lid on field burning, I don't give a damn if their families have been doing it for decades. Put a stop to it now.

I sincerely hope the Salem crowd have not only the will, but the guts to face up to these grass burning yokels.

It is time to sow the seed of a very upset general public.

Yours truly,

R Gunn. East Marion County.

Footnote 35

msn Hotmail

From : Terry Sitton <serpico52us@yahoo.com>
Sent : Wednesday, April 4, 2007 12:02 PM
To : Holly Higgins <banfieldburning@hotmail.com>
Subject : Re: Please Support Banning Field Burning April 6 in Salem

To Whom it may concern.
I have lived in Sweet Home for nearly 14 years now. 10 years ago my docter told me in order to better my health I would need to purchase a second home over at the coast. One reason the smoke from field burning. Field burning was a big concern to him. I can get liver damage from the smoke if I take in to much. There are days when I see it coming over the hills and I must rush to shut all the windows asap or it will invelope inside my home. It still can get in to a degree even with the windows closed. There is a gentleman that I call in Salem to ask if they are going to burn etc. and he has been very polite and I thank him. If I know a heavy burn is coming I will leave the valley and head over to the coast asap which is called now! It puts myself in a frantic situation. One of the problems to of the burns is it can be up to 90 degress out and I am unable to open up the windows at night when one so needs to cool ones home. We in Sweet Home and nearby areas are targeted so Eugene and Salem etc. can be spared. My guess all combined 50,000 people are affected and more. It is time to consider stopping field burning and let those live a longer healthier life please.
Sincerely,
Terry Sitton

Footnote 36

House Health Committee Testimony
Re: Field Burning and HB 3000
April 6, 2007

Dear Members of the Health Committee:

My name is Steve Nielsen and I live in Mill City, thirty miles east of here in the beautiful North Santiam Canyon. I come before you today on behalf of my family and the citizens of the canyon in full support of House Bill 3000 and would like to thank Representative Holvey for bringing it forward for us to discuss today.

I have been an Oregon resident for eighteen years and have lived in the Canyon for eight of those years. Each summer, our health, along with the beauty, peace and serenity of our area is assaulted by harmful field burning smoke on a daily basis in August and September. This outdated and harmful practice eliminates the many reasons people choose to live here in the first place.

First and foremost is the impact that field burning has on public health. I know the medical research has been or will be presented to you, but field burning smoke is very dangerous, especially for children, the elderly and anyone who suffers from asthma. As a result, there are many residents in our area that are literally held hostage in their own homes on field burning days because they either can't breathe and/or can't see due to burning and irritated eyes.

This issue has affected my family personally as well. My wife and two youngest sons became ill last August and went to our doctor to be checked. They were diagnosed with bronchitis and irritant related asthmatic symptoms, which the doctor firmly believed was a direct result of the field burning smoke. In my wife's case, she had never suffered from any symptoms of asthma prior to being exposed to this dangerous smoke.

It offends me that we are essentially tagged as 'expendable' and thrown to 'slaughter' since those of us east of the burns make up less of the population than those west of the burns. I wonder what the reaction would be if burning was allowed when the wind blows from the east? We are respectful, law abiding taxpayers just like those in the densely populated areas and deserve equal air quality rights. It is worth mentioning that the smoke was so heavy one day last August that it set off the fire alarm in our high school building.

Please support House Bill 3000 for the health of all Oregonians. It's time for this dangerous and outdated practice to stop. I recognize that grass seed farming is important to our economy, but I feel that there are healthier alternatives to choose from. I truly want their businesses to succeed, but only in a way that is healthy for the thousands of Oregonians who are suffering unfairly by the current practice. Thank you for your time and attention to this matter.

Sincerely,

Steve Nielsen
Mill City Resident
Supporter of House Bill 3000

Footnote 37

msn Hotmail®

From : Glen and Rhoda Love <rglove@uoregon.edu>
Sent : Sunday, March 18, 2007 11:39 AM
To : banfieldburning@hotmail.com

As Eugene residents since 1965, we both have been adversely affected by fieldburning smoke through the years. We deeply resent having to hole up inside when the smoke drifts in to ruin a lovely day. Fieldburning is an affront to everyone's health and quality of life. If other western states can ban it; why should we continue to be subjected to it. We remember the deaths from a huge pile-up on I-5 caused by field-burning smoke. We have fled to the mountains to escape the smoke, only to have it blow into the mountains and ruin the beautiful days there. We remember the day that Steve Prefontaine coughed up blood after running in a big track meet in Eugene while fieldburning smoke was thick in the air of Hayward Field. (If Eugene is to be the running capital of the world, we cannot have bad air. And that does not just apply to the days of track meets, but to the everyday life of the many who are already here, or will come here to live, and enjoy our reputation as a clean and healthy place to live and work and enjoy the outdoors.)

The Willamette Valley populace should not have to breathe the garbage from the grass-seed-growing operations. Why should we do this so that these operations can enjoy a financial advantage over growers in other states who are not permitted to torch their fields. It is time to bring Oregon farming methods into the twenty-first century, as other neighboring states have done. No more open-field burning.

Sincerely,

Glen and Rhoda Love,
Eugene, Oregon

Footnote 38

FILE

Estimates of the Benefits and Costs From Reductions in Grass Seed Field Burning

June 1997*

*Revised publication version. The version contains format edits and copy edits to the "Estimates" report dated January 7, 1997. Both versions are available for review. No substantive changes were made from the January 7, 1997 version.

Report Summary

On March 29, 1996, the Department of Ecology issued an emergency ruling that called for a one-third reduction in the number of acres of field and turf grasses that could be burned in Washington in 1996. A permanent rule requiring an additional one-third reduction in 1997 is currently being considered. Specifically, the proposed rule would modify WAC 173-430, to require "burning of field and turf grasses for seed in 1997 and thereafter (until approved alternatives become available) be limited to no more than the larger of one-third of the number of acres permitted to burn in 1995 or in grass seed production on May 1, 1996. This report presents information on the probable economic benefits and costs that would result from a limitation on grass seed field burning and a consequent reduction in grass smoke.

Benefits and Costs:

We estimate that probable benefits of the proposed reduction in grass seed field burning will exceed probable costs. Our best estimate of probable benefits is **$8.4 million** per year and our best estimate of probable costs is **$5.6 million** per year. Both costs and benefits include uncertainty so we estimated ranges for the probable values. We estimate total probable benefits between $6.6 and $10.2 million and total probable costs between $3.9 million and $7.9 million. There is considerable overlap in these ranges, but in our estimation the probable benefits are greater than the probable costs. Our estimates compare the pre-rule situation with the reduction of burning on two-thirds of bluegrass acreage.

Probable economic costs of the proposed rule stem from the limitation on grass seed field burning. Limitations on grass seed field burning reduces returns for grass seed farmers. Farm losses may come from reduced bluegrass yields, increased costs, or the reduced returns from an alternative crop. Besides these direct farm income losses, costs include environmental costs due to increases in soil loss from wind and water erosion, losses in the seed processing sector, and losses in jobs and income in the wider community. Other costs include emotional costs to those who lose jobs or suffer business losses, potential changes in farm accident rates due to changes in farm practices, and the costs of administering the program. The largest share of the cost is incurred by the grass-seed production sector.

The largest potential benefit of the proposed rule is improved air quality from reduced smoke emissions. Epidemiological evidence has established a clear link between small airborne particles and health, particularly for an at-risk population comprising people with existing cardio-pulmonary conditions such as asthma, emphysema, chronic bronchitis or heart disease.[1]

[1] There is also some speculation that the higher rate of asthma found in Spokane compared to other regions may be due to the higher levels of particulate pollution in the Spokane area. Since this possibility is still speculative it was not counted in the study. Recent work at Eastern Washington University also indicates a possible link between smoke from field burning and cancer.

Additional benefits from the proposed rule include the benefits of traffic accident reductions, enhanced recreational opportunities, ~~reduced dirt and nuisance effects from~~ smoke particles, and the aesthetic effects of improved visibility.

In our studies we constructed some greatly higher cost estimates and some significantly lower cost estimates. Likewise we generated some significantly lower benefit estimates and some vastly higher benefit estimates compared to those reported above. However, these higher and lower cost and benefit estimates were based on less dependable estimation procedures or on unrealistic premises and were therefore not reported as part of the probable range. Those interested are directed to the detailed and technical reports.

The basic results of our study are described in the following summary. The larger report details how the estimates of probable benefits and costs were estimated. A series of technical appendices contain the detailed studies that generated the data leading to the benefit and cost estimates.

Estimated Costs

Since there is uncertainty about the impact of the proposed rule, our estimation of probable costs began by examining a number of possible scenarios for the impact of the rule. The final estimated range for economic costs was based on two scenarios that represent the likely outcomes of the rule. A final, best estimate was based on the most realistic features of these two benchmark scenarios.[2]

Cost estimates were based on an estimate of a little over 60,000 acres of planted bluegrass. We used past burn permits, conservation plans filed with the Farm Service Agency, and processor information about seed volume to estimate this acreage. Since the rule permits continued burning on one-third of the acreage until suitable non-burn technologies are certified, our estimates are based on the two-thirds or about 40,000 acres affected by the rule.

Table one shows the breakdown of the costs for each scenario. This table shows the estimated costs for the alternative version of the rule that includes a 5 percent exemption for land that is deemed extraordinarily difficult to cultivate using alternative (non-burn) technologies and a provision allowing growers to trade burn permits within local jurisdictions. Under this rule, fields that were certified by a conservation official as being extraordinarily difficult to cultivate would be given an exemption--with exemptions limited to 5 percent of the fields. In other words, burning would be allowed on at least 33 percent and as much as 38 percent of a farmer's fields depending on field conditions.

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[2]We calculated costs for about a dozen different scenarios. Many of these scenarios were calculated to test the impact of particular effects by taking them to an extreme; for example the loss of all affected grass acres. These different scenarios generated costs ranging from about $1.4 million to as much as $14 million--a tenfold difference. However, the range of estimates on the scenarios considered probable are those given above.

Adoption of the alternative version of the rule reduced costs by about $300,000 on the best cost estimate compared to the rule version that includes no exemption. (Analysis of the basic version of the rule can be found in the full report and the technical appendices.) This rule will also reduce benefits, but our benefits estimates were not finely tuned enough to estimate the value of this variation of the rule.

The benefits from trading were not explicitly estimated due to lack of appropriate data. The benefits of trading are that, once the overall desired limit on burning is set, farmers are able to increase efficiency--"fine-tuning" their farming by using burned bluegrass on the fields most productive under burning. Since we modeled farms in only two broad classes, irrigated and dryland, we were not able to capture the efficiencies that result from shifting burning from one field to another with different productivity and farming cost characteristics. We therefore expect costs lower than those reported here under the alternative version of the rule. In principle, the trading provision will not decrease benefits because it does not change the overall level of burning. However, in practice it is possible that some fields will be burnt that would otherwise not be burned. For instance, if a farmer had most of his bluegrass fields in a rotation (establishment, "take-out" year) where he did not need to burn, he might sell his permit and thereby increase the total burn.

It is also important to note that the impact of the trading provision will depend, among other things, on the scope of area for the rule. If permits were tradable across all of eastern Washington, it is likely that irrigated farmers would sell permits to dryland farmers, especially those in the Spokane area. Such a version of the rule would reduce the benefits of the rule, perhaps substantially. It is therefore assumed here that trading will be within local jurisdictions only.

Rotational Burn Cost Scenario

The estimate of total costs of a little under $4 million for the lower end of the probable cost range is based on an assumption that farmers will innovatively adapt to the rule change. We used a scenario of rotational burning to represent this innovation.

Burning is used in bluegrass farming primarily to remove residue--straw and thatch. If residue is not burned it must be removed some other way, generally by mechanically raking and bundling; otherwise seed yields will be drastically reduced. Even with mechanical raking and disposal of the residue, many studies show a yield penalty compared to burning. Our analysis assumes such a yield penalty. Therefore, use of non-burn technologies affects farm returns through both lower yields and higher costs compared to annual burning.

Under rotational burning of bluegrass fields, farmers would burn all bluegrass acres, but burn each field only every other year. Non-burn technologies would be employed in the alternate year. Because of the reduced yields and increased costs of mechanical residue removal, we

Table 1: The Probable Costs

Cost component	Cost estimates ($1000s)		
	Rotation Scenario	Half-out scenario	Most probable scenario
Farm costs	$3,000	$5,120	$3,548
(No. jobs lost)	(+3)	(21)	(0)
Environmental costs	$0	$270	$270
Processing costs	$0	$477	$369
(No. jobs lost)	(0)	(9)	(0)
Economic impact costs	$552	$1,098	$586
(No. jobs lost)	(18)	(19)	(18)
Other costs	$388	$944	$790
TOTAL COSTS	$3,940	$7,909	$5,562

estimate that farmers and farm workers would lose about $3 million of income compared to pre-rule circumstances. While substantial, these losses are lower than the farm losses that would occur under most alternative scenarios we analyzed.

By using rotational burning, bluegrass acreage can be maintained at pre-rule levels. In a six year rotation farmers burn two times or one-third of the time. The reason that farmers can burn only two of six years in a rotation instead of three of six years is that fields are not burned in the establishment year. We also assumed that fields are not burned in the last ("take-out") year. Under current conditions some farmers like to burn in the last year, but this burn is for disease and weed control rather than for enhancing yields. So, in a six year rotation farmers would burn the third and fifth years and use non-burn residue removal in the second and fourth years. (A table in the full report shows the rotation more clearly.)

Some land is not suitable for non-burn technology and so would have to be burned every year or go out of bluegrass (for example, because it is too steep). However, the 5 percent exemption and the trading provision of this version of the rule should permit continued bluegrass cultivation on all acreage in this scenario.

Because bluegrass acreage is not reduced in this scenario, there are no environmental costs. Bluegrass reduces wind and water erosion compared to alternatives like wheat and is often recommended as part of conservation rotations. Also, since bluegrass seed production is reduced minimally, processors are not affected.

We also estimated impacts on the rest of the economy due to the "ripple" effects from reduced spending by farmers and workers in the bluegrass sector. We estimate these impacts at $552,000 in the rotational burning case. Generally, benefit cost studies do not count the indirect loss of jobs and the ripple effect of lost income in the rest of the economy. It is usually assumed that this secondary lost business and jobs will be made up elsewhere in the economy. However, in this case the comments at hearings and the results of the survey we conducted (primarily for our contingent valuation estimate of benefits) made it clear that people were concerned about the potential economic impact on the local economy of any losses to the bluegrass seed industry. We therefore examined these impacts more closely than is customary. We used a regional economic impact model to analyze the probable community economic impacts. Input-output estimates are biased upwards because they assume all job losses or business income losses are permanent. Our economic impact cost estimates are therefore adjusted to account for the rate at which lost jobs and business are made up by economic activity elsewhere. We used relatively high estimates of these "ripple" impact costs.

The rotational burning scenario is an example of the kind of innovation that may follow adoption of the burn rule. Other innovations might include better mechanical thatch removal and the development of seed varieties that maintain high yields under non-burn cultivation methods. Past experience indicates that it is highly likely that the agricultural industry will find an innovative way to adapt to the rule change so we place a high probability on this scenario. (See, e.g., Moore and Villarejo.) However, it will also take time for such innovations to be developed and shorter term losses are likely to be greater than those portrayed in this innovative technology scenario.

Half-Out Scenario

The estimate of about **$7.9 million** for the high end of the range of probable costs is based on the assumption that no change is made from currently available technology and current farm practices. We should be clear that this is not the highest cost we explored but the high end of what we estimate to be the range of probable costs[3]. In the half-out scenario we assume that farmers respond to the rule change using only current technology and farming practices. Current technology includes the machinery now developed for thatch removal and the current seed stocks. This estimate is also based on the current cost of non-burn technology for straw removal and a prediction of little or no increase in bluegrass seed prices even if production falls.

These assumptions are cautious. It is possible that the price of machinery for non-burn residue removal will fall somewhat when machinery is produced in larger quantities, and it is probable that some improvements in machinery will be made. It is likely that seed varieties optimized for non-burning cultivation will be developed. Also, it is very likely that grass seed prices will rise if supply is reduced. There are also emerging industries that would create a market for bluegrass straw, thereby reducing the cost of straw removal, and perhaps even generating a payment for the straw. Since any straw market is still speculative, we have made the assumption that there is no market for bluegrass straw (although we studied the potential impacts of such a market). In short, we assume none of these potentially mitigating developments in our half-out scenario which is why we consider it the top end of the probable cost range.

[3] For instance, we analyzed the impact if all of the affected bluegrass acres (two-thirds of the total) go out of production and all job and income losses are permanent in one of the scenarios of our input-output model. While it is possible that all of the irrigated farms could switch out of bluegrass, it is very unlikely that all dryland fields will be switched to other crops. It is also very unlikely that all those who lose jobs will never again be employed.

The half-out scenario also assumes that most of the lost bluegrass acreage would go into wheat while a small proportion goes out of production altogether. For dryland fields this is the most likely outcome, but for irrigated fields there are more profitable alternatives than wheat, so this estimate is probably a bit high. Overall, we estimate that the bluegrass farm sector would lose about $5.1 million in lost farm returns and lost jobs in these circumstances.

In this scenario we estimate substantial lost bluegrass acreage in Washington--about 20,000 out of an estimated 60,000 total acres. We estimate that about half the affected bluegrass acres will move to an alternative use and half will stay in bluegrass production using non-burn technology. (This means that two-thirds of the original acreage will remain in bluegrass.) Switching one-third of the land from bluegrass to wheat will create environmental costs of about $270,000. It also means that the processing industry will suffer losses due to reduced bluegrass supply--though some or all of this might be made up by bluegrass seed planted elsewhere. We assumed about half would be replaced. The processing industry will suffer income and job losses of about $477,000.

We also estimate that the rest of the economy would suffer economic losses of about $1.1 million of lost jobs and business income. These are secondary losses due to lost purchases by the bluegrass production and processing sectors. They were estimated with the input-output model and account for re-employment using the same assumptions as for the rotational burn scenario.

Other costs include the cost of some bluegrass smoke which will be shifted to residents of northern Idaho as more production is moved into Idaho. We counted $324,000 in damages from the shifted smoke. The shifted cost estimate was based on the fact that these households would not get the full amount of the benefits from the adoption in the rule. Specifically, we calculated that half the lost grass-seed production would be replaced by Idaho grown grass-seed and that half of that would be grown in the Coeur d'Alene area.

We also included $160,000 in administrative costs. We added an extra margin of 5 percent on potential job and business losses to account for the emotional costs of these losses--about $460,000 in this scenario.

Another potential cost is the change in accident rates for farmers as they change production practices. We found no data on changes in accidents rates on which to build a cost estimate. However, we did make an illustrative calculation of the possible actuarial costs of any increases in accidents. Although any specific accident may have high medical and emotional costs, we found the potential monetary value of such costs low compared to the other costs, based on the probability of an accident in any given year.

Most Probable Cost Scenario

The above two scenarios bracket what we think are probable costs. Some innovative scenario like the rotational scenario is highly probable, but its actual nature is unknown so the cost estimates are imprecise. On the other hand, the estimate based on the half-out scenario is likely to be a bit high, but the costs are based on what is known to be feasible under current technology and farming practices. The half-out scenario is probably a good representation of what will happen in the short run while the industry adjusts to new conditions. However, a more likely estimate of costs after a year or two of adjustment can be obtained. We estimated a most probable impact based on using cautious, but more realistic assumptions from the two bracketing scenarios.

We believe that the most realistic assumption is that the bluegrass industry would adapt to a large degree but that some bluegrass production would nonetheless be lost. It is also probable that there would be some increase in bluegrass seed prices but, to be cautious, we assume none. To approximate the most likely outcome, we constructed a scenario in which half of the affected acreage (20,000 acres) switches out of bluegrass, but the acreage remaining in bluegrass (40,000 acres) adopts an innovative technology like the rotational burning cultural practice.

For this scenario we estimate total probable costs of about $5.6 million. The cost breakdown (Table 1) follows the same patterns explained for the other two cost scenarios. Direct farm income and job costs are a little higher than for the rotational burn scenario at $3.5 million. This estimate includes environmental costs which are the same as for the half-out scenario at $270,000. It also includes impacts on the processing sector of about $369,000 since some seed production is lost. Impacts on the general economy are about $586,000 in lost job and business income with the same assumptions about the rate at which lost jobs and business are replaced in the economy. Costs of shifted smoke, program administration, and emotional losses for lost jobs and income total $790,000.

Economic Benefits

We estimate probable benefits of the rule at between $6.6 to $10.2 million. Our most reliable estimate is that benefits will be about **$8.4 million.** This is a reliable, but cautious estimate of benefits. For instance, using an alternative, less dependable estimation technique, we estimate potential benefits of between $9 and $18 million. While these estimates are less reliable than the primary estimate, they suggest that it is unlikely that the primary estimate is overstated.

Willingness to Pay--Survey Estimates

Our principal estimation method is based on directly estimating the value of smoke reduction from the point of view of the average household in the affected area. This method estimates combined health and non-health benefits. To estimate this value we conducted a scientific, random sample survey of households in Spokane, other affected areas of Eastern Washington, and parts of Northern Idaho. We obtained 1,561 completed surveys. We used a standard economic valuation technique called the contingent valuation method. In the contingent valuation method households are asked how much they would be willing to pay (WTP) for implementation of the rule to reduce smoke from bluegrass seed field burning. To get reliable estimates survey respondents were asked to imagine they were voting in a referendum about whether to approve and pay for the smoke reduction program--the proposed rule. The willingness to pay estimate for the sample is then extrapolated to the overall population of the area.

Our best estimate of $8.4 million in benefits is based on this technique. The range around the estimate is based on the margin of error in extrapolating the benefit value from the sample population to the total population. Our use of a relatively large sample (1,561 households) compared to many studies of this type helps to minimize this margin of error.

Epidemiological-Economic Estimates

The alternative benefits estimation method uses an indirect method based only on potential health benefits. This is a two step procedure based on combining epidemiological and economic techniques. We first estimate the potential exposure of the affected population and the resulting probable change in medical and mortality impacts due to the improvements in air quality using the results of epidemiological studies. There is a large epidemiological literature documenting the health effects of small airborne particles. Particles from combustion processes appear to have larger health impacts than ordinary dust particles. The potential impacts of reduced particles include reduced medical costs, reduced loss of wages due to lost work, reduced "pain and suffering" and, most importantly, reduced mortality.[4] Once the potential improvements are identified, monetary values are estimated. The monetary values for impacts like asthma attacks are obtained from standardized values based on previous economic studies. We estimated benefits of between $9 and $18 million using this two step procedure.

The estimates based on this epidemiological-economic approach are imprecise. We lack detailed information on how the smoke reduced by the rule would reduce the exposure of the affected population. We had to use general estimates of this exposure, since the detailed monitoring and smoke modeling necessary to determine exposures have not been done. More detailed exposure knowledge would allow us to make more precise estimates of the health effects because we have very good information on the effects of particulate exposure from the extensive epidemiological literature on the impacts of airborne particles on human health. However, we had to use available estimates of the smoke exposure, which means these health cost estimates are imprecise.[5]

It is interesting to note, however, that the estimate of health benefits from reducing smoke actually exceeds the willingness-to-pay estimate. This is a paradox because the WTP estimate is supposed to include both health and non-health benefits. There are several reasons for this apparent paradox. One has been mentioned; the epidemiological-economic estimates of health benefits are imprecise.

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[4] The health effects of exposure to other constituents of smoke (such as volatile gases) were not estimated. Moreover the possibility that long term exposure to smoke and particles may increase the rate of asthma or of lung cancer were not used because reliable epidemiological estimates are not available.

[5] Another source of variance in the estimates is the assumed cost of mortality. The cost of mortality is the major component of benefits in this approach. We used medium to low estimates for the cost of mortality.

A second reason that the WTP estimate may be lower than the health based estimate is that many respondents did not like the fact that the proposed rule to reduce smoke would impose a burden on local farmers. They, therefore, discounted the value they were willing to pay for the program to account for this negative impact. This can be seen especially outside the Spokane and North Idaho areas. While the majority of households in Spokane and Northern Idaho favor the proposed rule, the majority of residents in other areas of Eastern Washington oppose the rule. Moreover, statistical analysis showed that those who felt the proposed rule would impose a burden on agriculture were more likely to oppose the proposed rule. These results imply that the willingness to pay for the smoke production is a net value: that is, the value of the benefits of smoke reduction to households reduced by a penalty or cost for the burdens of the program.

Finally, a third reason that the WTP estimate is low is that it measures benefits only from a private perspective. This means that, in evaluating their costs, households consider their costs for, say, hospitalization, but not the cost paid by insurance, other businesses, or government programs. This means that the survey based WTP benefit estimate is likely to be understated because it does not include costs to general businesses and the public. Thus, losses to the recreation industry in Northern Idaho are not included, though the cost of lost recreation days to the individual are included. The health exposure based estimates are also understated because they do not include non-health benefits at all. Therefore, the primary estimate of benefits is a conservative estimate.

Compensation Based Estimate

Besides the willingness to pay and epidemiological-economic estimates, a third estimate of benefits could be made based on the assumption that the population affected by smoke has the right to be free of smoke. If they have the right to be free of smoke they should not have to pay to get reduced smoke, they should be compensated for any damages caused by continued burning. This approach produces much larger estimates of the value of smoke reduction, over $30 million.

We put less emphasis on these estimates than the other two benefits estimates for conceptual and practical reasons. Conceptually, the question of whether it is the right of farmers to burn their fields or the right of local residents to clean air that should be paramount is a legal and moral question beyond the scope of this study. However, the main reason we put less emphasis on this estimate is that the method used for estimation of compensation is unreliable. We used the same survey to estimate compensation as we did for willingness to pay. However the compensation value is based on a very small number of respondents making it hard to generalize to the whole population, and respondent reporting patterns are less stable for compensation questions giving rise to a great range of individual value estimates. Most economists and government agencies disallow compensation estimates for these practical reasons. For instance, the National Oceanic and Atmospheric Administration disallows compensation estimates based on the recommendations of a blue ribbon panel of economists.

Footnote 38

Estimates of the Benefits and Costs from Reductions in Grass Seed Field Burning

Project Report

December 27, 1996

Submitted to:

Washington Department of Ecology
Air Quality Program
P.O. Box 47600
Olympia WA 98504-7600

Submitted by:

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Revised publication version. The version contains format edits and copy edits to the "Estimates" report dated January 7, 1997. Both versions are available for review. No substantive changes were made from the January 7, 1997 version.

Footnote 39

RCW 70.94.656

Open burning of grasses grown for seed — Alternatives — Studies — Deposit of permit fees in special grass seed burning account — Procedures — Limitations — Report.

It is hereby declared to be the policy of this state that strong efforts should be made to minimize adverse effects on air quality from the open burning of field and turf grasses grown for seed. To such end this section is intended to promote the development of economical and practical alternate agricultural practices to such burning, and to provide for interim regulation of such burning until practical alternates are found.

(1) The department shall approve of a study or studies for the exploration and identification of economical and practical alternate agricultural practices to the open burning of field and turf grasses grown for seed. Any study conducted pursuant to this section shall be conducted by Washington State University. The university may not charge more than eight percent for administrative overhead. Prior to the issuance of any permit for such burning under RCW 70.94.650, there shall be collected a fee not to exceed one dollar per acre of crop to be burned. Any such fees received by any authority shall be transferred to the department of ecology. The department of ecology shall deposit all such acreage fees in a special grass seed burning research account, hereby created, in the state treasury.

(2) The department shall allocate moneys annually from this account for the support of any approved study or studies as provided for in subsection (1) of this section. Whenever the department of ecology shall conclude that sufficient reasonably available alternates to open burning have been developed, and at such time as all costs of any studies have been paid, the grass seed burning research account shall be dissolved, and any money remaining therein shall revert to the general fund. The fee collected under subsection (1) of this section shall constitute the research portion of fees required under RCW 70.94.650 for open burning of grass grown for seed.

(3) Whenever on the basis of information available to it, the department after public hearings have been conducted wherein testimony will be received and considered from interested parties wishing to testify shall conclude that any procedure, program, technique, or device constitutes a practical alternate agricultural practice to the open burning of field or turf grasses grown for seed, the department shall, by order, certify approval of such alternate. Thereafter, in any case which any such approved alternate is reasonably available, the open burning of field and turf grasses grown for seed shall be disallowed and no permit shall issue therefor.

(4) Until approved alternates become available, the department or the authority may limit

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the number of acres on a pro rata basis among those affected for which permits to burn will be issued in order to effectively control emissions from this source.

(5) Permits issued for burning of field and turf grasses may be conditioned to minimize emissions insofar as practical, including denial of permission to burn during periods of adverse meteorological conditions.

(6) By November 1, 1996, and every two years thereafter until grass seed burning is prohibited, Washington State University may prepare a brief report assessing the potential of the university's research to result in economical and practical alternatives to grass seed burning.

[1998 c 245 § 130; 1995 c 261 § 1; 1991 sp.s. c 13 § 28; 1991 c 199 § 413; 1990 c 113 § 1; 1985 c 57 § 69; 1973 1st ex.s. c 193 § 7.]

Notes:

Effective dates -- Severability -- 1991 sp.s. c 13: See notes following RCW 18.08.240.

Finding -- 1991 c 199: See note following RCW 70.94.011.

Effective date -- 1985 c 57: See note following RCW 18.04.105.

Grass burning research advisory committee: Chapter 43.21E RCW.

Footnote 39

WAC 173-430-045

Alternatives to burning field and/or turf grasses grown for seed.

(1) When is open burning of field and turf grasses grown for seed prohibited?

The Washington Clean Air Act prohibits open burning of field and turf grasses grown for seed whenever ecology has concluded, through a process spelled out in the act, that any procedure, program, technique, or device constitutes a practical alternate agricultural practice to open burning, and that alternate is reasonably available.

(2) Has ecology certified practical alternatives to open burning of field or turf grasses grown for seed?

Yes. Ecology concludes that mechanical residue management constitutes a practical alternate agricultural practice to the open burning of field and/or turf grasses grown for seed. Mechanical residue management means removing, including arranging for removal of, the residue using nonthermal, mechanical techniques including, but not limited to: Tilling, swathing, chopping, baling, flailing, mowing, raking, and other substantially similar nonthermal, mechanical techniques. Ecology further concludes that mechanical residue management is practical throughout all phases of seed production including:

(a) When the field is planted (establishment);

(b) When the field is producing seed (harvest years);

(c) When the field is prepared for replanting (tear-out).

(3) Are the alternatives to open burning that have been certified by ecology reasonably available?

Ecology concludes that mechanical residue management is reasonably available throughout the state wherever baling can be used. Baling is the process of gathering the residue and moving it off the field. Typically, a machine known as a "baler" is used to gather and bundle residue that is already cut.

Based on this conclusion, the open burning of field and/or turf grasses grown for seed is prohibited except as described in subsection (4) of this section. This rule does not require the use of any particular practice or technique. A farmer may use any alternate practice that does not involve field burning.

(4) Under what circumstances may open burning of field or turf grasses grown for seed be allowed?

(a) Where a farmer establishes that mechanical residue management is not reasonably available on specific portions of a field under specific production conditions due to slope. In a request for a waiver, a farmer must certify in writing to ecology or local air authority the following:

(i) Baling is not reasonably available due to slope. A farmer must explain why baling is not reasonably available, referring to specific facts supporting this belief. Unacceptable facts include, but are not limited to, general statements about burning as a tool for the routine control of weed and disease, for seed propagation purposes, or as a less costly alternative to mechanical residue management. A farmer may use statements from three separate businesses providing baling services as part of their commercial operation to support the belief that baling is not reasonably available due to slope. In the statements, the businesses must certify that they are independent from the farmer and have no financial interest in the farmer's operation;

(ii) Current harvest practices have not diminished the ability to use mechanical residue management;

(iii) Field production is after the first harvest season and prior to the fourth harvest season;

(iv) The ground or portions of the field have not been burned three years in a row in the three years preceding the request for a waiver;

(v) The ground or portions of the field will remain, without replanting, in grass production at least through the next harvest season following burning;

(vi) Residue from any neighboring fields or portions of fields under the control of the farmer will be removed prior to burning and reasonable precautions will be taken to prevent fire from spreading to areas where burning is not allowed; and

(vii) Adjustments in field rotations and locations cannot be made at any time during the rotational cycle and could not have been made when planted to allow the use of mechanical residue management techniques.

(b) Where a farmer establishes that extreme conditions exist. Ecology or a local air authority, at their discretion, may grant a request for a waiver for extreme conditions. The farmer must certify in writing the following:

(i) Why mechanical residue management is not reasonably available, referring to specific facts supporting this belief. Unacceptable facts include, but are not limited to, general statements about burning as a tool for the routine control of weed and disease, for seed propagation purposes, or as a less costly alternative to mechanical residue management;

(ii) He/she did not cause or create the condition to purposefully avoid using mechanical residue management techniques;

(iii) Field production is after the first harvest season and prior to the fourth harvest season;

(iv) The ground or portions of the field have not been burned three years in a row in the three years preceding the request for a waiver;

(v) The field will remain, without replanting, in grass production at least through the next harvest season following burning;

(vi) Residue from any neighboring fields or portions of fields under the control of the farmer will be removed prior to burning and that reasonable precautions will be taken to prevent fire from spreading to areas where burning is not allowed; and

(vii) Adjustments in field rotations and locations cannot be made at any time during the rotational cycle, and could not have been made when planted to allow the use of mechanical residue management techniques.

(c) Where a farmer demonstrates to ecology or local air authority that his/her small agricultural operation is eligible for mitigation.

For 1998 only, ecology or a local air authority may allow burning on a small agricultural operation. A small agricultural operation owner has a gross 1997 revenue from all agricultural operations of less than $300,000. A farmer must show information of sufficient quantity and quality to ecology or a local air authority to establish gross revenue from agricultural operations. A small farm owner may burn current acreage up to 25% of 1997 acreage burned under a valid permit. Fields taken out of production after the 1997 harvest season and in 1998 cannot be counted in the determination of 1997 acreage burned for the purpose of eligible burn acreage.

(d) Where a request for a waiver is approved under (a), (b), and (c) of this subsection, the following additional limitations also apply:

Total burn acreage must not exceed 1/3 of a farmer's acreage in production on May 1, 1996. Permits issued pursuant to (a), (b), or (c) of this subsection are not eligible for the permit trading program identified in WAC 173-430-040.

(5) What is the process for a farmer to request a waiver for circumstances described in subsection (4) of this section?

(a) A farmer submits a request for a waiver.

Sixty days prior to the planned burn date, a farmer must submit in writing a request to ecology or a local air authority. In the request, the farmer must identify the circumstances and meet the specific requirements of subsection (4)(a), (b), and/or (c) of this section. Ecology or the local air authority may require the request to be submitted on a form or in a format provided by ecology or the local air authority.

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~~(b) Ecology or local air authority evaluates the request for a waiver.~~

Upon receiving a request for a waiver, ecology or the local air authority will determine if the necessary documents and information provided is complete enough to evaluate the request. If incomplete, ecology or local air authority will advise the farmer and suspend further evaluation until the request for a waiver is complete. The documents and information identified as necessary to complete the request must be delivered to ecology or the local air authority at least thirty days prior to burning. Once a request for a waiver is deemed complete, ecology or the local air authority will evaluate the request and decide whether the burning waiver is appropriate. As part of the evaluation, ecology or the local air may conduct an on-site inspection.

If ecology or local air authority denies a request for a waiver, the reasons will be provided to the farmer in writing. If approved, ecology or the local air authority will notify the farmer by convenient means. Ecology will also notify the appropriate delegated authority.

(c) The farmer applies for an agricultural burning permit.

If ecology or local air authority approves a request for a waiver, the farmer must complete a permit application and pay the fee as described in WAC 173-430-040. A delegated authority must receive written authorization from ecology that a waiver has been approved prior to processing a permit application.

[Statutory Authority: RCW 70.94.656. 98-12-016 (Order 97-45), § 173-430-045, filed 5/26/98, effective 6/26/98.]

Footnote 3

QUANTIFYING POST-HARVEST EMISSIONS FROM BLUEGRASS SEED PRODUCTION FIELD BURNING

MARCH 2004

GRASS SEED CROPPING SYSTEMS FOR A SUSTAINABLE AGRICULTURE

WASHINGTON STATE DEPARTMENT OF ECOLOGY

IDAHO DEPARTMENT OF ENVIRONMENTAL QUALITY

ENVIRONMENTAL PROTECTION AGENCY REGION 10

WASHINGTON TURFGRASS SEED COMMISSION

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Missoula, MT

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SUMMARY AND CONCLUSIONS

~~Summary:~~

Residue Loading. Removal of post-harvest residue by baling significantly reduced the amount of pre-burn residue at all sites. The high (i.e., no residue removed) residue loading and low (i.e., residue removed by baling) residue loading means averaged over all sites were 4.0 and 1.8 tons acre^{-1}, respectively. The low residue loading was similar at all sites (1.7 to 1.9 tons acre^{-1}). Pre-burn residue loading did not influence post-burn residue loading. The high and low pre-burn residue loading at Connell, WA (irrigated) and Worley, ID (dryland) sites burned down to similar post-burn residue loading. However, at Rathdrum, ID (irrigated) both high and low pre-burn residue loading had significantly lower post-burn residue loading relative to the other two sites.

Residue Consumption. Absolute residue consumption ($RC_{Absolute}$) was the same for high residue loading at all sites, approximately 3.2 ton acre^{-1}. The Rathdrum low residue loading treatment was unique and $RC_{Absolute}$ was more than two times greater than at the other two sites. There was a strong positive relationship between $RC_{Absolute}$ and the pre-burn residue loading. The higher the pre-burn residue loading, the higher the $RC_{Absolute}$. Since 89% of the variation in $RC_{Absolute}$ was explained by the variation in pre-burn residue loading, this would suggest that any practice that removes a significant portion of the post-harvest residue from a bluegrass seed production field (e.g., baling) would reduce the amount of residue consumed. Total $PM_{2.5}$ emissions (lbs acre^{-1}) would be reduced by a significant reduction in $RC_{Absolute}$ if the $PM_{2.5}$ emission factor (EF, lbs ton^{-1} of residue consumed) remained constant or did not increase markedly.

Emission Factors for $PM_{2.5}$, CO_2, CO, and CH_4. Since there were no statistical differences in $EF_{PM2.5}$ between Rathdrum and Worley residue loading treatments, $EF_{PM2.5}$ was pooled for these sites. Based on the pooled means, $EF_{PM2.5}$ for Connell high residue loading was greater than Rathdrum and Worley high residue loading. At Rathdrum and Worley, low pre-burn residue loading produced consistently greater $EF_{PM2.5}$ than high residue loading. This relationship could not be assessed at Connell due to a lack of replication (n=1) in the low residue loading treatment.

It should be noted that the $EF_{PM2.5}$ in this study are substantially greater than those reported for most agricultural burns, wildfires, and forest fires (Air Sciences Inc., 2003). The $EF_{PM2.5}$ for the cereal study conducted in eastern Washington (Air Sciences Inc., 2003) had a mean $EF_{PM2.5}$ of 7.4 lbs ton^{-1} of residue consumed while the mean $EF_{PM2.5}$ for this study was 57 lbs ton^{-1} of residue consumed. $EF_{PM2.5}$ was significantly higher for the Connell high residue loading treatment than for high residue loading at Rathdrum and Worley, 109 lbs of $PM_{2.5}$ ton^{-1} of residue consumed. There were no differences in $EF_{PM2.5}$ among the low pre-load residue treatments at Rathdrum or Worley.

There was a strong positive relationship between EF_{CO2} and CE (Combustion Efficiency, %). There also were strong negative relationships between CE and EF_{CO} and EF_{CH4}. These relationships are similar to those reported for other studies (Air Sciences Inc., 2003). Overall CO_2 emissions increased with increased CE while CO and CH_4 emissions decreased with increased CE.

Emission Factors Affected by Residue and Soil Moisture. There was no discernible relationship between residue moisture content (%, oven-dry weight basis) and $EF_{PM2.5}$. EF_{CO2} decreased with increasing residue moisture content, while EF_{CO} and EF_{CH4} increased with increasing residue moisture content. None of the pollutant emission factors was significantly related to soil moisture content.

Emission Factors for Polyaromatic Hydrocarbons (PAHs). Fourteen samples were analyzed for PAHs. Of these, two samples taken at the Worley high residue loading units showed PAH concentrations above the method of analysis detection limit. The emission factors in this study for benzo(a)anthracene and chrysene ranged from 0.39 to 0.42 mg kg^{-1} of residue consumed and were in the range reported in other crops (Ramdahl and Moller, 1983; Jenkins et al., 1996a, 1996b, and 1996c). Similarly, the emission factor for benzo(b)fluoranthene of 1.6 mg kg^{-1} of residue consumed was in the range reported for other crops.

Total $PM_{2.5}$ Emissions. Total $PM_{2.5}$ emissions for the Connell high residue loading treatment were significantly higher than for any other treatment, 350 lbs of $PM_{2.5}$ $acre^{-1}$. The differences in total $PM_{2.5}$ are mostly attributable to differences in $EF_{PM2.5}$ and not $RC_{Absolute}$. The Worley and Connell (n=1) low residue loading treatment produced 30 lbs of $PM_{2.5}$ $acre^{-1}$ and the Rathdrum high residue loading, Rathdrum low residue loading, and Worley high residue loading treatments were intermediate at approximately 100 lbs of $PM_{2.5}$ $acre^{-1}$.

The management practice of baling and burning (propane flaming at Connell and open-field burning at Worley), significantly reduced total $PM_{2.5}$ $acre^{-1}$ at Worley and numerically at Connell (n=1). At Rathdrum, baling followed by burning did not reduce total $PM_{2.5}$ emissions $acre^{-1}$ relative to open-field burning of the high residue load. Higher $RC_{Absolute}$, potentially leading to higher total emissions, was compensated for by a lowered $EF_{PM2.5}$ at the high residue loading at Rathdrum.

$PM_{2.5}$ emissions $acre^{-1}$ was regressed as a linear function to assess the relative contribution of $RC_{Absolute}$ and $EF_{PM2.5}$ to total $PM_{2.5}$ $acre^{-1}$. These two factors combined explained 95% of the total variation in total $PM_{2.5}$ emissions. When regressed individually, $RC_{Absolute}$ and $EF_{PM2.5}$ explained 21 and 45 %, respectively, of the variation in total $PM_{2.5}$ emissions $acre^{-1}$. Independently they are affected by site and residue loading and it is difficult to consider the individual effect of these parameters on total $PM_{2.5}$ emissions $acre^{-1}$. In this study, both the $RC_{Absolute}$ and $EF_{PM2.5}$ were needed to explain the total $PM_{2.5}$ emissions $acre^{-1}$. So, while it is probably valid to attribute the high total emissions for the Connell high residue loading treatment, relative to the other two sites, to a high $EF_{PM2.5}$, and the high total emissions at the Rathdrum low residue loading treatment, relative to the other two sites, to a high $RC_{Absolute}$, one must use caution when discussing cause and effect in this study.

Conclusions:

High pre-burn residue loading had significantly more pre-burn residue on the field than the low loading residue treatment.

Post-burn residue loading was independent of pre-burn residue loading, i.e., the high and low pre-burn residue loading (baled) treatments burned down to the same post-burn residue loading at each site. Following burning the same amount of residue remained on the field regardless of the initial residue loading.

Residue consumption (tons of residue consumed per acre, tons $acre^{-1}$) increased with pre-burn residue loading, i.e., the higher the pre-burn residue loading, the higher the consumption. The implication is that baling is an effective method to reduce residue consumption.

There was no apparent relationship between residue consumption and soil moisture or any environmental factors monitored during the burns.

The residue stratification (residue architecture above the soil surface) and the bulk densities of the residue layers may affect $RC_{absolute}$, $EF_{PM2.5}$, and total $PM_{2.5}$ emissions (pounds per acre, lbs $acre^{-1}$).

Both $RC_{absolute}$ and $EF_{PM2.5}$ are required to predict (together they explained 95% of the variation in the data) total $PM_{2.5}$ emissions (lbs $acre^{-1}$) at any site.

At Rathdrum, baling did not reduced total $PM_{2.5}$ emissions (lbs $acre^{-1}$), while at Worley, baling significantly reduced total $PM_{2.5}$ emissions (lbs $acre^{-1}$) by 66%. At Connell, baling followed by propane flaming of the low residue loading treatment numerically reduced total $PM_{2.5}$ emissions (lbs $acre^{-1}$) by 91%, compared to the high residue open-field burn. Due to lack of replication of the low residue loading treatment, no statistical conclusion can be made for the Connell site.

1. INTRODUCTION

1.1 Statement of Problem

Fire has long been used as a management tool in grass seed production (Burton, 1944; Conklin, 1976; Chilcote et al., 1978; Hardison, 1980; Kamm and Montgomery, 1990; Johnston et al., 1996; Mazzola et al., 1997; Schirman, 1997). However, increasing concerns over the health impact of emissions from open-field burning have pointed to the need for information on grass fire emissions. Although some data are currently available that identify and quantify the various chemical components of grassfire emissions in the Pacific northwest (Boubel et al., 1969; Adams, 1976), and biomass burning (Crutzen and Andreae, 1990; Kuhlbusch et al., 1991; Jenkins et al., 1996a), little research has been performed with residue reduction and burning systems. Because mechanical residue removal is an option growers can use to reduce the residue load on grass fields, emissions from fields where residue has been removed and fields with typical post-harvest residue loads need to be studied.

In a never-completed study, Adams (1976) found indications of higher emissions with open-field burning following residue removal than with open-field burning alone. However, current WSU research with diesel or propane flaming following residue reduction (baling) indicates the possibility of reduced emissions and reduced smoldering while maintaining good seed yield (Felgenhauer, personal communication, 1999). Characterization of particulate-matter emissions from the bale-and-flame system are needed because the combustion efficiencies of these burns may be different from conventional open-field burns, with either higher or lower particulate-matter emissions per mass of residue consumed.

The Washington State Department of Ecology (WDOE), based on statements of concern for public health, in 1996 reduced the acres of Kentucky bluegrass (*Poa pratensis* L.) seed production fields that were burned in Washington State by 33%. In 1997, the number of burned acres were reduced 67% from pre-1996 levels, and in 1998, bluegrass burning was virtually eliminated. Are there options other than a restriction on number of acres burned to reduce emissions? Currently, insufficient research on grassy residues has been conducted to characterize emissions to the degree necessary to resolve this issue. Additional research is needed to establish Best Management Practices (BMPs) under the conditions typically found in open-field burns of dryland and irrigated bluegrass post-harvest residue in eastern Washington and northern Idaho.

Several groups recognized the need for emissions research on post-harvest burning of Kentucky bluegrass seed production fields and provided financial support for this study: Washington Department of Ecology (WDOE), Idaho Department of Environmental Quality (IDEQ), Grass Seed Cropping Systems for a Sustainable Agriculture (GSCSSA), Washington Turfgrass Seed Commission (WTSC), Coeur d'Alene Tribe, and Environmental Protection Agency Region 10. The WTSC stated in a letter to the GSCSSA Administrative Committee (January 28, 2000) that "[this] project will parallel the procedures for emissions data collection and analysis established by the WDOE and Washington Association of Wheat Growers (WAWG) in order to create a reliable baseline for emissions from our industries agricultural burning. Our ability to participate in these studies brings the cost for both industries down and begins to establish a very important body of information for agriculture. Although Washington currently allows no grass seed field burning, Idaho will greatly benefit from these studies." (Lee Morris, WTSC, 2000).

Therefore, this study evaluated emissions generated from grass seed production fields with post-harvest residue reduction compared to those burned without post-harvest residue reduction. The information obtained from this study will help establish appropriate residue management and burning practices needed to significantly reduce emissions, enhance the scientific database on emissions from grassy residues, and provide data to direct future research.

1.2 Objectives

1. To characterize post-harvest residue and field conditions of Kentucky bluegrass seed production fields at the time of burning.

2. To quantify, under field conditions at dryland and irrigated sites, with and without post-harvest residue removal, the quantity of emissions generated by Kentucky bluegrass field burning and relate these emissions to conditions evaluated in Objective 1.

1.3 Treatments and Emissions Characterization

The planned experimental treatments consisted of two pre-burn residue loads (no residue removed, or high residue load; and baling and removal of post-harvest residues, or low residue load), three locations (Connell, Washington; Worley, Idaho; and Rathdrum, Idaho), and two irrigation practices (irrigated [Connell and Rathdrum], and non-irrigated or dryland [Worley]). The emission species to be characterized were designated by the WDOE as follows:

Carbon monoxide (CO)
Particulate matter less than 2.5 micrometers in diameter ($PM_{2.5}$)
Particulate matter less than 10 micrometers in diameter (PM_{10})
Benzo(a)pyrene (BaP)
Six additional BaP-equivalent carcinogens, including benzo(a)anthracene, benzo(b)fluroanthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and idenol(1,2,3-cd)pyrene

Two other carbon species, methane (CH_4) and carbon dioxide (CO_2), were included in the investigation because they are required in the calculation of emission factors using the carbon mass balance method.

2 METHODS

2.1 Study Locations and Design

This field investigation included 18 burn units at three locations (6 per location): at Connell in the Columbia Basin of eastern Washington, and at Rathdrum and Worley in northern Idaho (Figure 2.1; Appendix 4). At each location, the six burn units comprised two residue treatments (high residue loading, and low residue loading) with three replications of each treatment (Table 2.1).

All of the burn units were combined up to three weeks prior to burning. On the low-residue-loading units, the residue was also removed (baled) up to three weeks prior to burning (Table 2.1).

Each burn unit consisted of a square area measuring 417 feet on a side (4 acres), surrounded by a fuel break. The fuel break consisted of either a 50-foot-wide area disked to mineral soil, or a 20- to 60-foot-wide area in which the residue was removed (Appendix 4). All of the treatment units within the fields were selected based on uniformity of pre-burn loading conditions.

Prior to igniting the fires, sampling to determine pre-burn residue loading and residue moisture content was performed in each unit (Section 2.2, Sampling Procedures), and the emissions sampling equipment was erected (Section 2.2.4, Emissions). Growers utilized water trucks to wet the border of each burn unit so the burn would be contained to the 4-acre burn unit. The growers performed the ignition of fires at the Rathdrum and Worley locations. The ignition of the fires at the Connell location was performed by WSU personnel. The meteorological and residue moisture conditions at the time of each burn are summarized in Tables 2.2 and 2.3, respectively.

Table 2.1. Combining, harvesting, and burn dates of the experimental units.

Study Site	Irrigation Treatment	Combine Date	Residue Removal (Bale) Date	Burn Date
Connell, WA	Irrigated	July 31, 2001	August 1, 2001	August 7-9, 2001
Rathdrum, ID	Irrigated	July 23, 2001	August 6, 2001	August 21-22, 2001
Worley, ID	Dryland	August 3, 2001	August 6, 2001	August 15-16, 2001

Figure 2.1. Geographic locations of study sites.

The study sites were located at Connell, WA (irrigated); Rathdrum, ID (irrigated); and Worley, ID (dryland).

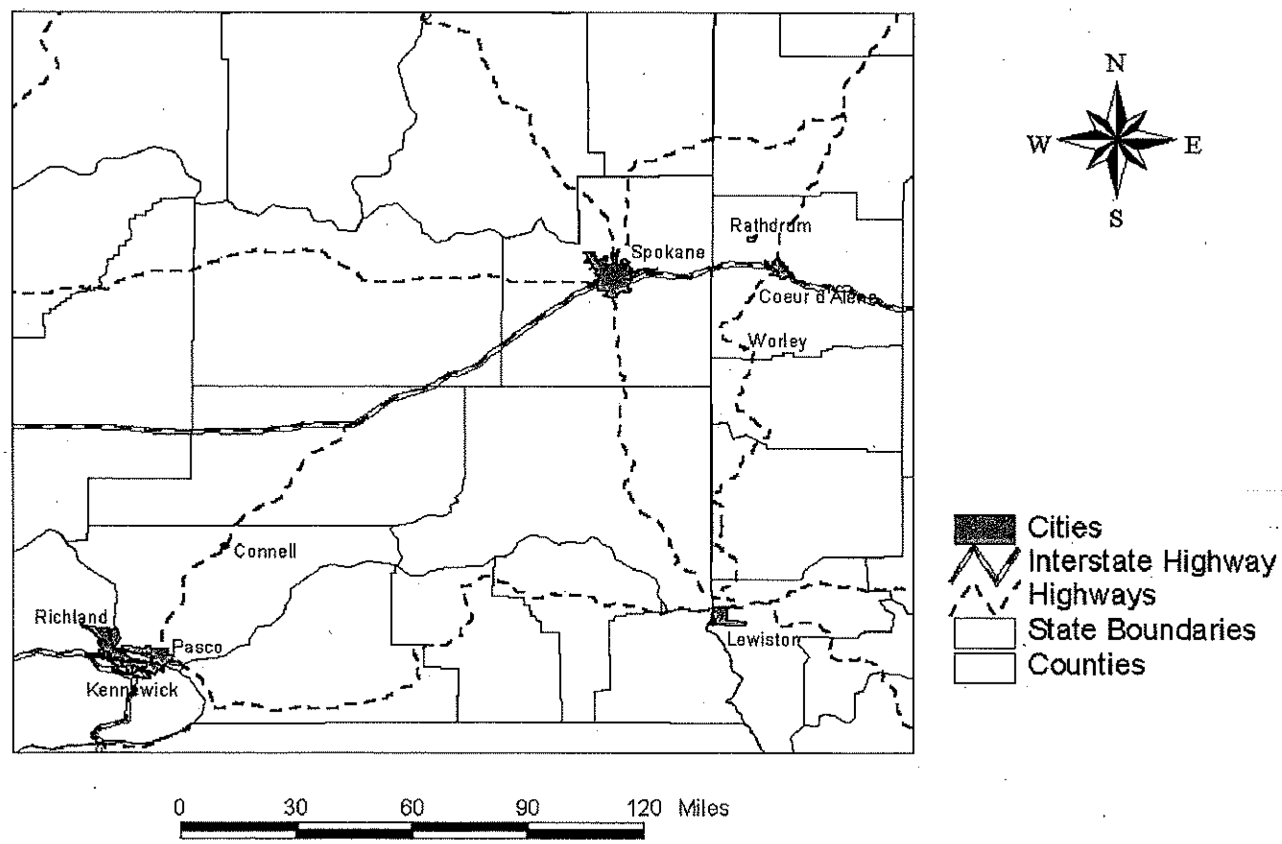


Table 2.2. Meteorology by site and pre-burn residue loading
Values shown are means ± 1 standard error (SE). The sample size varied from 7 to 20 (2-minute means for each unit average).

Study Site and Residue Loading	Wind Speed (mph)	Temperature (°F)	Relative Humidity (%)	Wind Direction (° from true N)
Connell, WA, irrigated				
High loading (*n*=3)	10.0 ± 2.0	88.6 ± 0.6	14 ± 3	274 ± 32
Low loading (*n*=1)	7.8	94.4 ± 0.2	14 ± 0.1	238 ± 24 (n=2)
Rathdrum, ID, irrigated				
High loading (*n*=3)	7.3 ± 1.4	74.2 ± 2.5	31 ± 10	205 ± 8
Low loading (*n*=3)	6.8 ± 0.8	72.1 ± 1.5	33 ± 7	200 ± 9
Worley, ID, dryland				
High loading (*n*=3)	6.5 ± 1.4	87.2 ± 0.6	19 ± 2	147 ± 20
Low loading (*n*=3)	6.3 ± 0.7	91.8 ± 0.3	14 ± 1	130 ± 12
All (n=16)	7.4 ± 0.6	83.5 ± 2.3	22 ± 3	

Table 2.3. Fuel- and soil-moisture percent by site and pre-burn residue loading.
Values are expressed as % H_2O per g dry weight, as a function of study site and residue loading. Values shown are means ± SE. Statistically significant differences (1-way ANOVA with Bonferroni post-hoc test (see Section 2.4.4, Statistical Analysis; $P<0.05$) are indicated with different letters (compare within columns only).

Study Site and Residue Loading	Entire Residue Layer (%)	Upper Residue Layer (%)	Lower Residue Layer (%)	Soil Layer (%)
Connell, WA, irrigated				
High loading (*n*=3)	13.5 ± 5.0 ab	2.8 ± 0.3 a	26.7 ± 7.6	4.7 ± 0.1 a
Low loading (*n*=1)	22.1			4.4
Rathdrum, ID, irrigated				
High loading (*n*=3)	16.2 ± 1.8 ab	6.5 ± 1.2 b	21.7 ± 3.2	8.6 ± 0.6 b
Low loading (*n*=3)	21.6 ± 3.9 a			7.4 ± 0.2 b
Worley, ID, dryland				
High loading (*n*=3)	14.8 ± 2.2 ab	3.6 ± 0.6 ab	22.3 ± 1.0	5.5 ± 0.3 a
Low loading (*n*=3)	9.3 ± 0.8 b			5.0 ± 0.3 a
All (n=7, 9, 9, 17) (n=8)	16.4 ± 2.9 (Low) 14.8 ± 1.5 (High)	4.3 ± 0.7	23.6 ± 2.5	6.1 ± 0.4

All fires, except for two units, were ignited as "head fires." A head fire is one that is ignited at the upwind edge of the unit to be burned and pushed across the unit by the wind. Head fires are typically fast moving, and the forward "lean" of the fire over the unburned residue creates forward heating of the residues and a correspondingly wider fireline depth (i.e., greater width of burning residues). The low loading unit #1 (replication 1) at the Connell site was ignited using a head fire pattern, but the fire never developed properly over the whole unit. A post-burn residue loading could not be taken, and the unit was disqualified for the study (data not included in report). Consequently, the low loading units #2 (replication 2) and #3 (replication 3) at the Connell site were ignited using a propane burner, using the pattern of a "strip head fire." A strip head fire is a head fire that is ignited in strips, starting at the downwind side of the unit to be burned and proceeding upwind. By igniting in strips, the downwind distance the fire is allowed to burn is limited. Each strip runs into the previously burned strip, which causes it to be extinguished. At the Connell site all the strips did not come together (see Discussion, Section 4.7).

2.2 Sampling Procedures

2.2.1 Residue Load

Pre- and post-burn residue loading was sampled in order to assess the total residue consumption following each test burn. Within each burn unit, eight to 12 sampling locations were randomly chosen throughout each experimental unit, to characterize the pre-burn residue loading (three per unit were taken at Connell for stubble length). Similarly, four sampling locations were randomly chosen throughout each experimental unit, to characterize the post-burn residue loading. At each sampling location a 1-square foot (12 by 12 inches) area was sampled.

The pre-burn sampling protocol is summarized as follows. On each of the high residue units, stratified samples were taken and stored in labeled paper bags for transport to the laboratory at WSU. The upper residue layer was qualified as all those grass residues swathed and combined with post-harvest residue scattered on the field by the combine. This residue rests on top of the stubble that is still attached to the root system. The lower residue layer was all those residues still attached to the root system plus any post-harvest residue that filtered down into the standing stubble. On each of the low residue units an entire layer residue sample was taken, which consisted of standing stubble plus any post-harvest residue remaining following raking and baling. At the flat, irrigated study sites, Connell and Rathdrum, the residue depth of vertically oriented residue was 2 inches and approximately 9 to 10 inches, respectively, and the length of the standing stubble was not affected by residue load (Table 2.4). The dryland Worley site was on rolling terrain with slopes and draws. At Worley, mean standing stubble height with high residue loading was 9.3 inches (slope = 8.3 inches; draw = 10.3 inches). The low residue loading units had standing stubble of approximately 3 to 4 inches (slope = 3.9 inches; draw = 3.1 inches) (Table 2.4).

Table 2.4. Stubble and residue height by site and pre-burn residue loading.

Study Site and Residue Loading	Standing Stubble (inches)	Ground to Top of Residue (inches)	Ground to Residue Layer (inches)	Thickness of Residue Layer (inches)
Connell, WA, irrigated				
High loading	2	6-9 estimated	0	6-7 estimated
Low loading	2			
Rathdrum, ID, irrigated				
High loading	9-10 estimated	7.8 (8.0-10.0)	4.2 (1.5-6.0)	3.7 (3.0-4.0)
Low loading	9.7 (7.3-10.8)			
Worley, ID, dryland				
High loading	8.3 (7.0-9.3) (slope) 10.3 (7.3-12.5) (draw)	6.1 (2.8-8.0)	2.6 (0.0-4.5)	3.5 (2.8-4.5)
Low loading	3.9 (2.5-4.8) (slope) 3.1 (2.0-4.8) (draw)			

Table 2.5. Bulk density of pre-burn residue by site, loading, and residue layer.

Calculated from residue moisture dry weights, n=3. Values are means ± standard error. Statistically significant differences (1-way ANOVA with Bonferroni test (see Section 2.4.4, Statistical Analysis); $P<0.05$) are indicated with different letters to compare within column for each site.

Study Site and Residue Loading	Residue Layer	Bulk Density (lbs ft^{-3})
Connell, WA, irrigated		
High loading	Entire	0.27 ± 0.02 b
High loading	Upper	0.20 ± 0.03 b
High loading	Lower	0.51 ± 0.04 a
Low loading	Entire	0.48 ± 0.00 a
Rathdrum, ID, irrigated		
High loading	Entire	0.26 ± 0.05 a
High loading	Upper	0.24 ± 0.06 a
High loading	Lower	0.28 ± 0.04 a
Low loading	Entire	0.11 ± 0.01 b
Worley, ID, dryland		
High loading	Entire	0.39 ± 0.02 bc
High loading	Upper	0.24 ± 0.03 c
High loading	Lower	0.60 ± 0.05 a
Low loading	Entire	0.30 ± 0.02 bc

At each experimental unit four random samples were taken to determine post-burn residue loading. Only entire residue was determined to assess post-burn residue loading. The post-burn loading determination was performed within 10 minutes following the end of each burn to ensure that the ash and unburned materials were collected before any material was blown into, or out of, the measurement areas.

All of the pre- and post-burn sample bags were placed in large cloth bags marked with the burn unit name and number, and transported to WSU for subsequent drying, weighing, and recording. In the laboratory, the sample bags and the contents were oven-dried at 140°F for five days and then weighed.

Pre-burn and post-burn loading for each test unit were calculated according to:

$$L_{Pre\text{-}Burn} \text{ or } L_{Post\text{-}Burn} \text{ (tons acre}^{-1}) = \frac{(W_{OD})(43560 \text{ feet}^2 \text{ acre}^{-1})}{(907184.8 \text{ g ton}^{-1})} \quad (1)$$

In Equation (1), $L_{Pre\text{-}Burn}$ and $L_{Post\text{-}Burn}$ are the pre-burn and post-burn loadings (tons dry biomass acre^{-1}), respectively. W_{OD} is the oven-dry sample weight (g feet^{-2}; measured to 1/100th of a gram). $L_{Pre\text{-}Burn}$ and $L_{Post\text{-}Burn}$ were calculated for each experimental unit by taking the averages of all sub-samples.

2.2.2 Residue Moisture Content

Moisture sampling of residue strata and soil was performed to assist in explaining any variation in residue consumption and emissions that occurred. Higher residue moisture may be expected to produce lower residue consumption and combustion efficiencies, and higher particulate matter, CO, and CH_4 emission factors. The sampling protocol was as follows. Within each burn unit, four randomly located samples were taken during the 30-minute period preceding the start of ignition, to determine pre-burn residue moisture content. High loading residue moisture samples were stratified, as described under the pre-burn residue loading methodology, into upper, lower, and entire residue layers.

All moisture content samples were placed in 'Ziploc' plastic bags, to seal in moisture, and transported to the laboratory for analysis at WSU at Pullman, WA. In the laboratory, the sample bags were weighed to determine fresh weight (W_{Field}) then oven-dried at a temperature of 140°F for five days and then weighed to determine the dry weight (W_{OD}). The relative residue moisture contents of the three residue layer strata and the soil layer were calculated according to:

$$\text{RMC (\%)} = \left[\frac{(W_{Field} - W_{OD})}{W_{OD}}\right] \cdot 100 \quad (2)$$

where RMC is the residue moisture content (relative to dry weight), W_{Field} the fresh weight of the samples (g), and W_{OD} is the oven-dried weight (g). The relative moisture content of the entire layer of the high loading sites was calculated as the weighted average of the RMC of the upper- and lowers residues at each unit (Anderson and Grant, 1993).

2.2.3 Bulk Density of Residue Layers

The bulk density (BD) in lbs ft^{-3} was calculated for each residue layer. High loading-Upper layer, High loading-Lower layer, and Low loading-Entire layer were calculated as:

$$BD_{layer} = \frac{W_{od}}{H_{layer} * (1 ft^2)} \quad (3)$$

In Equation (3), BD_{layer} is the calculated bulk density of a specific residue layer (lbs ft^{-3}), W_{OD} the oven-dry sample weight (lbs), and H_{layer} the height of the residue layer (feet).

Bulk density for the High loading-Entire layer was calculated as the weighted average of the bulk densities of the upper- and lower-residue layers:

$$BD_{entire} = BD_{upper} * \left(\frac{H_{upper}}{H_{upper} + H_{lower}} \right) + BD_{lower} * \left(\frac{H_{lower}}{H_{upper} + H_{lower}} \right) \quad (4)$$

In Equation (4), BD_{entire}, BD_{upper}, and BD_{lower} represent the bulk densities (lbs ft^{-3}) of the entire layer (high loading units), upper layer, and the lower layer, respectively. H_{upper} and H_{lower} stand for the height (feet) of the upper and lower residues layers, respectively.

2.2.4 Emissions

The USDA Forest Service's Missoula Fire Sciences Laboratory's (MFSL) Fire Atmosphere Sampling System (FASS) was used to measure the emissions of carbon species (i.e., CO_2, CO, CH_4, and $PM_{2.5}$) and other fire-related parameters such as temperature and combustion efficiency, in real time (Ward et al., 1992b; Susott et al., 1991). Combustion efficiency (CE) is the proportion of total carbon emissions (including all carbon species such as CO_2, CO, CH_4, and others) that is emitted as CO_2. The more complete the combustion, the greater the fraction of total carbon emitted as CO_2, and the higher the combustion efficiency.

The field sampling procedure involved setting up two FASS packages about 140 feet apart on the downwind side of the residue sampling area. To avoid edge effects, the tower pairs were placed at least 140 feet from the burn unit edge. Each FASS package was triggered independently and switched from a background mode to a sampling mode when CO reached 1000 ppm (Ward et al., 1992a). Each sampling package was programmed to switch from sampling of flaming combustion to smoldering combustion after 3 minutes, which was the expected fire residence time for the ignition determined by MFSL.

2.3 Laboratory Analysis of Emissions

2.3.1 Canister Gases

The canister gas samples and filters were analyzed at the Intermountain Fire Sciences Laboratory at Missoula, Montana (MFSL). Canister samples were analyzed for CO_2, CO, CH_4, and hydrocarbons using gas chromatography (Hewlett Packard Model 5890 Series II). The canisters were pressurized with sample gas to approximately 20 pounds per square inch absolute (psia). Two columns and two chromatography systems were used, one for CO_2 and CO, and another for CH_4 and carbon-2 (C_2) and carbon-3 (C_3) gases. The CO_2 and CO analysis was performed using a 1-milliliter (ml) sample loop filled directly from the canister. The column used in the analysis consisted of a 6-foot-long, 1/8-inch diameter Carbosphere (Alltech) carbon molecular sieve with helium carrier gas (flow rate of 16 ml min^{-1}) passing through a methanizer and FID at 300°C. CO and CO_2 were analyzed in separate isothermal runs, with CO run at 30°C and CO_2 run at 100°C.

The CH_4, C_2, and C_3 analysis was performed with a 0.53-millimeter (mm) diameter by 35-m long GS-Q (J&W Scientific) megabore column with a 0.53-mm diameter by 6-foot long HP-1 pre-column. The sample is directly injected from the canister into a 0.25-ml sample loop. The carrier gas was helium (flow rate of 4 ml min^{-1}), with an FID at 200°C and helium makeup gas. The temperature was programmed at 30°C for six minutes, then increasing at a rate of 10°C min^{-1} to a final temperature of 90°C.

Chromatogram data were collected and processed using Hewlett-Packard ChemStation II software connected via a computer link to the gas chromatograph. The ChemStation II software also controlled the operating parameters of the gas chromatograph and performed the integration of the peaks of the chromatograms. Three gas standards were analyzed with each set of samples in order to construct a standard curve for each gas based on integrated peak area, from which sample concentrations are calculated.

2.3.2 Teflon Filters

The Teflon filters used in the $PM_{2.5}$ determination were conditioned and weighed in a controlled-environment room at 68°F and 50% relative humidity at the MFSL at Missoula, MT. Prior to weighing, the filters were conditioned for at least 24 hours to stabilize the particulate matter weights and to reduce the effects of static electricity on the weighing process. Each filter was weighed three times on a Mettler M4 microbalance to a precision of one microgram (μg). The balance was linked to a software program that collects and stores the weights and room condition. Filters were re-weighed until weights were reproducible to within 5 μg. Before each weighing the balance tare was zeroed. A calibration weight was used once every five filters to verify the accuracy and calibration of the microbalance. Each filter was pre-weighed prior to sample collection using this procedure, and then again after field collection. Control filters were used to correct for environmental and handling variability in the filter weights. The control filters were handled in the same manner as the treatment filters. $PM_{2.5}$ concentrations were based on the final particulate matter weights (post-weight minus pre-weight) and the volume of air drawn through the filter at about 2 L min^{-1} during the emission sampling.

A small subset of the Teflon filters was selected for PAH analysis. The PAH sample analysis was performed at the Southwest Research Institute, San Antonio, Texas. PAH samples were taken using high volume samplers with a total volume of 30 L for the flaming phase (based on a 3-min sampling period and a flow of 10 L min^{-1}).

2.4 Data Analysis

2.4.1 Fuel Consumption

The absolute residue consumption, referred to as the residue consumption (RC), was calculated as:

$$RC_{Absolute}\ (\text{tons acre}^{-1}) = L_{Pre\text{-}Burn} - L_{Post\text{-}Burn} \tag{5}$$

where $RC_{Absolute}$ is the residue burned (tons acre^{-1}), and $L_{Pre\text{-}Burn}$ and $L_{Post\text{-}Burn}$ are the residue loadings (tons acre^{-1}) for each of the test units before and after the burn, respectively. The relative residue consumption, $RC_{Relative}$, was calculated according to:

$$RC_{Relative}\ (\%\ \text{Consumed}) = \frac{RC_{Absolute}}{L_{Pre\text{-}Burn}} * 100\% \tag{6}$$

2.4.2 Pollutant-Specific Emission Factors

Pollutant specific emission factors were calculated according to a carbon mass method. This method calculates the pollutant-specific emission factors (lbs pollutant per ton residue consumed) by dividing the concentration of the emission above background by the total airborne carbon concentration times an empirically derived residue mass-to-carbon mass ratio of 2.0:

$$EF_x\ (\text{lbs ton}^{-1}\ \text{fuel}) = \left. \frac{\chi_x\big|_{Fire}\ \left(2{,}000\ \text{lbs ton}^{-1}\right)}{2.0 \cdot \left(\chi_{C\text{-}CO_2}\big|_{Fire} + \chi_{C\text{-}CO}\big|_{Fire} + \chi_{C\text{-}CH_4}\big|_{Fire} + \chi_{C\text{-}PM2.5}\big|_{Fire}\right)} \right|_j \tag{7}$$

Here, χ_x is the air concentration of pollutant species x (where x = CO_2, CO, CH_4, or $PM_{2.5}$) in milligrams per cubic meter (mg m^{-3}), and j is the combustion phase (j = 1, flaming phase; j = 2, smoldering phase).

This method assumes that the carbon content of the residue was the same for the pre- and post-burn residue. A representative value for the pre-burn carbon fraction in cereal-grains and grasses is 50%, i.e., 0.50 grams of carbon per gram of dry biomass (Hurst et al., 1994a and 1994b; Turn et al., 1997; Hughes et al., 2000). Although the carbon fraction after the burn is dependent on the weight fractions of ash and unburned residue after the fire (Kuhlbusch and Crutzen, 1995) a constant value of 0.50 grams carbon per kilogram of dry biomass was used since the effect of ash weight on the total post-burn sample weight was considered negligible. The emission factor for PM_{10} was estimated by dividing $EF_{PM2.5}$ by a scaling factor of 0.8 (Magliano et al., 1999; Purvis et al., 2000). Finally, the combustion efficiency (CE), expressed as percent, was calculated as the ratio of the actual CO_2 emission factor (lbs ton^{-1}) over the estimated CO_2 emission factor assuming that 100 percent of the carbon emissions occur as CO_2.

The emission factors for selected PAH species was scaled to the $PM_{2.5}$ emission factor by calculating the ratio of the specific-PAH mass to the total fine-particle mass measured on the filters:

$$EF_{PAH}\ (\text{lbs ton}^{-1}) = \left(\frac{M_{PAH}}{M_{PM2.5}}\right) * Flow\_correction * EF_{PM2.5} \tag{8}$$

where M is the filter-based mass ($PM_{2.5}$ or PAH-specific, g), "Flow_correction" a factor to account for the difference on total flow between the PAH and $PM_{2.5}$ samplers, and $EF_{PM2.5}$ is the fine-particulate emission factor calculated from Equation (7) (lbs ton^{-1}). EF_{PAH} was converted from lbs ton^{-1} residue to $\mu g\ kg^{-1}$ residue, since the latter is a more common measure of reporting emission factors for PAHs.

The FASS units are specifically designed to make the measurements needed in each combustion phase. Although residue loading could be measured only before and after the fire, residue consumption in the flaming and smoldering phase was estimated from the FASS data (Ron Babbitt, personal communication, 2003). Since the majority of the fire emissions occurred in the flaming phase, the emission factors were based on the flaming phase only, with the exception of one site (FASS tower #2 at Rathdrum, high loading, replication 1), where the majority of the emissions occurred during the smoldering phase. For this site the smoldering emission factors were used.

2.4.3 Total $PM_{2.5}$ Emissions

The total emissions from a proposed burn can be predicted using the following equation:

$$PM_{2.5}\ \text{Total (lbs acre}^{-1}) = (L_{\text{Pre-Burn}})(RC_{\text{relative}})(EF_{PM2.5}) \tag{9}$$

where $L_{Pre\text{-}Burn}$ is the pre-burn residue loading (tons $acre^{-1}$), $RC_{Relative}$ the relative residue consumption (%), and $EF_{PM2.5}$ the emission factor for $PM_{2.5}$ (lbs ton^{-1}). Equation 9 is equivalent to multiplying the emission factor ($EF_{PM2.5}$, lbs ton^{-1}) and the absolute residue consumption ($RC_{Absolute}$, tons $acre^{-1}$), also yielding the total emissions on a per-acre basis:

$$PM_{2.5}\ \text{Total (lbs acre}^{-1}) = (RC_{\text{Absolute}})(EF_{PM2.5}) \tag{10}$$

2.4.4 Statistical Analysis

Statistical analyses of the data set were carried out in SYSTAT 10 (SPSS Inc., 2000). All statistical analyses were based on mean values for the test units. Thus, when multiple sub-samples were taken, i.e., in the case of residue loadings (4 to 12 sub-samples per unit), moisture contents (4 sub-samples per unit) and pollutant emissions (1 or 2 sub-samples per unit, FASS towers-), the sub-samples were averaged to obtain a value for the unit as a whole. These values were then used to test for statistical differences in residue consumption, moisture contents, emission factors, as well as total emissions based on the site, irrigation treatment, and pre-burn residue loading. If data were approximately normally distributed, then analysis of variance (ANOVA) was used, indicated by "$F_{\text{df between, df error term}}$ = F-statistic, P= significance level." To distinguish between different combinations of treatments, a Bonferonni post-hoc test (i.e., a statistical test used to determine difference between more than two sample means) was used within ANOVA. A non-parametric Kruskal-Wallis test, indicated by "χ^2=Chi-squared test statistic, P= significance level," was used when criteria for a normal distribution of the data were not met. Basically, all of the above tests indicate whether two (Kruskal-Wallis) or multiple groups (ANOVA) were statistically different for a particular parameter. The tested parameters were "continuous" variables, such as residue loading, residue moisture content, and emission factors. The grouping variables were categorical, i.e., pre-burn residue loading (high versus low), or treatment (irrigated versus dryland). An important value in the statistical interpretation is the P-value. This value indicates the probability that an observed difference is due to (random) chance rather than due to patterns of variation in the tested variables. A minimum P-value of 0.05 was used to consider differences between groups that are statistically different. This P-value (i.e., 0.05) represents a 5% chance of the observed difference being due to random variation in the data, rather than a "real" difference between categories. In this study, if the P-value was less than or equal to 0.05, differences were declared to exist between or among categories.

It is important to characterize the data for the presence of outliers, or extreme values. The presence of outliers can cause the distribution of data to deviate substantially from a normal distribution. This is an undesired effect because normality of data distributions is one of the underlying assumptions of the statistical techniques described above. When the normality criterion is not met the results from t-tests and ANOVA are not reliable, and these techniques cannot be used. Statistical outliers were identified based on t-tests of the studentized (i.e., normalized) residual in SYSTAT 10 (SPSS Inc., 2000). In the final analysis, one extreme value of pre-burn residue loading was removed from the dataset for the high loading treatment at Connell, i.e., 13.0 tons $acre^{-1}$ (+ 4 standard deviations; mean 4.5 tons $acre^{-1} \pm 2.2$). Since only one of the 12 sub-samples was deleted from the dataset, this experimental unit was still included in the dataset.

Finally, it should be mentioned that the analyses of the residue consumption relationships with moisture were based on 17 sites total, as post-burn loading data was missing for one of the low loading units at Connell. However, the statistical analyses for the emission factors were based on a sample size of 15. This is because the Connell low loading treatment only had one unit with emission factor data. Therefore this site by loading combination lacked replication and was excluded from the emission factor analyses. Also, the field sites are indicated in the summary graphs as follows: Connell as "CO", Rathdrum as "RA", and Worley as "WO."

3. RESULTS

3.1 Residue Consumption

Table 3.1 summarizes the pre-burn residue loading, post-burn residue loading, and residue consumption by study site location and pre-burn residue loading category. Pre-burn residue loading was significantly higher for the high loading sites compared to the low loading sites (Table 3.1; 2-way ANOVA, factors site and loading, $F_{2,1,12}$=202.90, P<0.001). The pre-burn residue loading at the high loading sites at Rathdrum was lower than at the other two locations, but this difference was not statistically different (Table 3.1; 2-way ANOVA, factors site and loading, $F_{2,1,12}$=2.87, P=0.096).

Post-burn residue loading was not influenced by pre-burn residue loading (Table 3.1; 2-way ANOVA, factors site and loading, $F_{2,1,11}$=1.10, P=0.316). Both the Connell and the Worley sites tended to burn down to a similar post-burn residue loading. However, both high and low pre-burn residue loading units at Rathdrum had significantly lower post-burn residue loading compared to the other two study locations (Table 3.1; 2-way ANOVA, factors site and loading, $F_{2,1,11}$=19.32, P<0.001).

Residue consumption was expressed in both absolute and relative terms using Equations (5) and (6). Absolute residue consumption ($RC_{Absolute}$) was significantly higher for the high loading units than for the low loading units at each site (Table 3.1; 2-way ANOVA, factors site and loading, $F_{2,1,11}$=131.32, P<0.001). At Rathdrum, $RC_{Absolute}$ was higher for the low residue loading units compared to the low residue units at the other sites (Table 3.1, 1-way ANOVA, $F_{2,5}$=12.21, *P=0.01*).

Similarly, the relative residue consumption ($RC_{Relative}$) was significantly higher for the high residue loading units compared to the low loading units at each site (Table 3.1; 2-way ANOVA, factors site and loading, $F_{2,1,11}$=59.99, P<0.001). At Rathdrum, $RC_{Relative}$ was higher for the low residue loading units compared to the low residue units at the other sites (Table 3.1; 2-way ANOVA, factors site and loading, $F_{2,1,11}$=59.99, P<0.001).

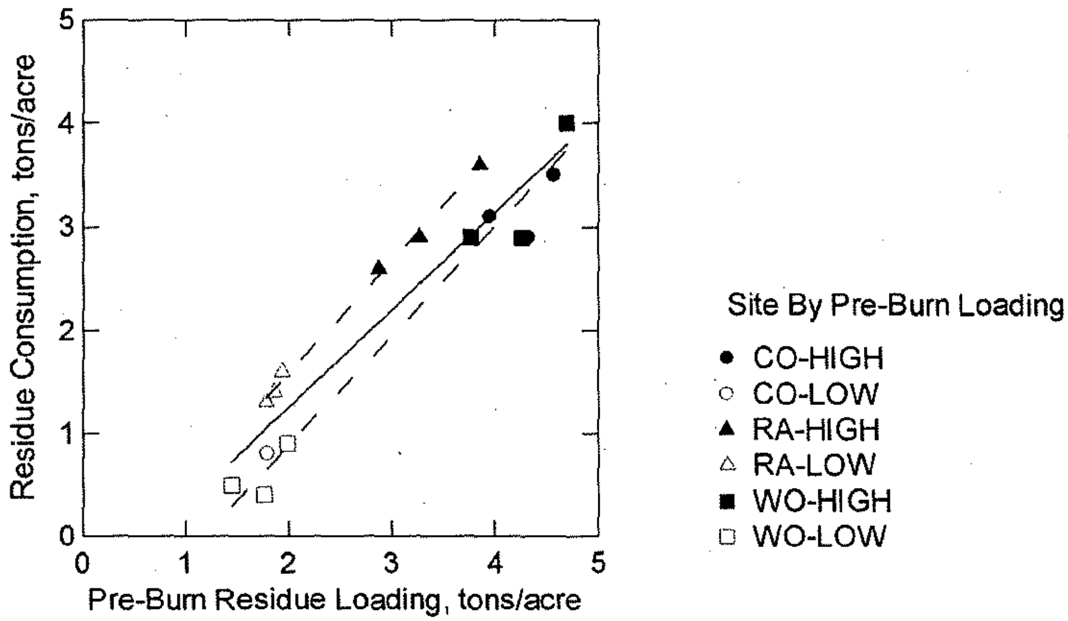
Although $RC_{Relative}$ tended to be higher at the Rathdrum high residue loading units, the differences were not statistically significant at the 95% confidence level.

Table 3.1. Pre-burn residue loading, post-burn residue loading and residue consumption. Values shown are means ± SE. Statistically significant differences are indicated with different letters (compare within columns only).

Study Site and Residue Loading	Pre-burn Residue Loading (tons $acre^{-1}$)	Post-burn Residue Loading (tons $acre^{-1}$)	Residue Consumption Absolute (tons $acre^{-1}$)	Residue Consumption Relative (%)
Connell, WA, irrigated				
High loading (*n*=3)	4.3 ± 0.2	1.1 ± 0.2	3.2 ± 0.2	74 ± 4
Low loading (*n*=2)	1.7 ± 0.1	1.1 ± 0.1	0.6 ± 0.2	32 ± 10
Rathdrum, ID, irrigated				
High loading (*n*=3)	3.3 ± 0.3	0.3 ± 0.04	3.0 ± 0.3	91 ± 2
Low loading (*n*=3)	1.9 ± 0.05	0.4 ± 0.05	1.4 ± 0.1	76 ± 3
Worley, ID, dryland				
High loading (*n*=3)	4.2 ± 0.3	1.0 ± 0.2	3.3 ± 0.4	77 ± 5
Low loading (*n*=3)	1.7 ± 0.2	1.1 ± 0.1	0.6 ± 0.2	33 ± 7
High loading, all (*n*=9)	4.0 ± 0.2 a	0.8 ± 0.1	3.2 ± 0.2 a	81 ± 3 a
Low loading, all (n=8)	1.8 ± 0.1 b	0.9 ± 0.1	0.9 ± 0.2 b	49 ± 9 b

There was a positive relationship between the absolute residue consumption and the pre-burn residue loading (Fig. 3.1; R^2=0.89, $F_{1,15}$=125.24, P<0.001). The R^2 value (coefficient of determination) of 0.89 indicated that almost 90% of the observed variation in absolute residue consumption was explained by the initial pre-burn residue loading. This relationship was even stronger when the regression analyses were carried for Rathdrum and Connell/Worley separately (dashed lines in Fig. 3.1), with R^2 values of 0.99 (n=6) and 0.97 (n=10), respectively. This suggests that the relationship between absolute residue consumption and pre-burn residue loading was site specific. Although relative residue consumption tended to be higher with higher pre-burn residue loading, the relationship between these two variables was not statistically significant. In summary, residue consumption was most strongly correlated with the pre-burn loading: the higher the pre-burn residue loading, the higher the absolute residue consumption.

Figure 3.1 Residue consumption as a function of pre-burn residue loading.
The relationship for all data points can be described as follows:
Residue consumption = -0.75 + (0.97*Pre-Burn Residue Loading), R^2=0.89, $F_{1,15}$=125.24, P<0.001 (intercept with x-axis at ~0.8 tons/acre). Note that the Rathdrum units (triangles) are systematically above the best linear fit line based on the other sites, Connell (circles) and Worley (squares).



3.2 Emission Factors for $PM_{2.5}$, CO_2, CO, and CH_4

Most of the available emission factors were used in the analysis. An exception was the Connell low loading treatment, because of the lack of replication within this treatment (n=1). Emission factors, as well as the combustion efficiency (CE), varied considerably between sites and pre-burn residue loading (Table 3.2). Since the Connell high loading sites had unusually low combustion efficiency and CO_2 emission factors, data summaries are shown with and without this treatment (Table 3.2). However, because of the internal consistency within and between the Connell high loading burn units, these units cannot be considered statistical outliers, but should be treated as real observations.

Table 3.2. Emission factors by site and pre-burn residue loading.
Values shown are means ± SE.

Study Site and Residue Loading	Emission Factors (lbs ton^{-1}) CO_2	CO	CH_4	$PM_{2.5}$	PM_{10}*	Combustion Efficiency (%)
Connell, WA, irrigated						
High loading (*n*=3)	2843 ± 30	480 ± 49	53 ± 5	109 ± 25	136 ± 31	78 ± 1
Low loading (*n*=1)**	3207	314	19	50	63	88
Rathdrum, ID, irrigated						
High loading (*n*=3)	3199 ± 74	360 ± 90	24 ± 3	33 ± 3	41 ± 3	87 ± 2
Low loading (*n*=3)	3084 ± 41	369 ± 28	26 ± 3	66 ± 12	82 ± 15	84 ± 1
Worley, ID, dryland						
High loading (*n*=3)	3092 ± 136	429 ± 102	39 ± 13	28 ± 3	35 ± 4	84 ± 4
Low loading (*n*=3)	3320 ± 37	214 ± 14	9.0 ± 2.6	51 ± 9	64 ± 11	91 ± 11
High loading, all (*n*=9)	3044 ± 70	423 ± 45	40 ± 6	56 ± 15	70 ± 19	83 ± 2
High loading, (*n*=6) *(Connell excluded)*	3145 ± 73	394 ± 63	33 ± 8	30 ± 2	38 ± 3	86 ± 2
Low loading, (n=6) *(Connell excluded)*	3202 ± 58	291 ± 37	18 ± 4	58 ± 7	73 ± 9	87 ± 2

* Calculated as: PM_{10}= $PM_{2.5}$/0.8 (Section 2.4.2); ** Data included in table but not in statistical analysis.

Emission factors were only checked for statistical differences in the $PM_{2.5}$ emission factors, $EF_{PM2.5}$, since $PM_{2.5}$ is the main pollutant of interest. The comparisons were based a (non-parametric) Kruskal-Wallis test, since the graphic analysis of the data showed that the normality requirements (Section 2.4.4) were not met. $EF_{PM2.5}$ at the Connell with high residue loading was statistically different than at Rathdrum and Worley high residue loading units (Kruskal-Wallis, χ^2=3.86, P=0.05). There were no differences in $EF_{PM2.5}$ between high residue loading at Rathdrum and Worley (Kruskal-Wallis, χ^2=1.19, P=0.28). Similarly, there were no differences in $EF_{PM2.5}$ between the low residue loading sites Rathdrum and Worley (Kruskal-Wallis, χ^2=0.43, P=0.51). The $EF_{PM2.5}$ at the Rathdrum low residue loading units was statistically greater than at Rathdrum high residue loading units (Kruskal-Wallis, χ^2=3.86, P=0.05).

Since there were no statistical differences between the Rathdrum and Worley sites within pre-burn residue loading category, $EF_{PM2.5}$ was pooled for these two sites. Based on the pooled means, $EF_{PM2.5}$ at Connell high residue loading was statistically greater than at Rathdrum and Worley high loading (Kruskal-Wallis, χ^2=5.40, P=0.02). Moreover, at Rathdrum and Worley , the low residue loading units had significantly higher $EF_{PM2.5}$ than the high residue loading units (Kruskal-Wallis, χ^2=6.56, P=0.01)

The relationships between the emission factors for CO_2 (EF_{CO2}), CO (EF_{CO}), CH_4 (EF_{CH4}), and $PM_{2.5}$ ($EF_{PM2.5}$) versus the combustion efficiency (CE) were explored based on linear regression analysis. As expected, there was a strong positive relationship between EF_{CO2} and CE (Fig. 3.2, Table 3.3). Also, there were statistically significant negative relationships between EF_{CO} and EF_{CH4} versus CE (Fig. 3.3 and 3.4, Table 3.3). These patterns make sense as the incomplete combustion products (CO and CH_4) decreased with increasing CE (Fig. 3.3 and 3.4), while CO_2 emissions increased with increasing CE (Fig. 3.2). However, even though $PM_{2.5}$ is a product of incomplete combustion, there was no relationship between $EF_{PM2.5}$ and CE (Fig. 3.5, Table 3.3). This relationship was largely driven by the Connell high residue loading units, it was statistically significant (P=0.04) with a R^2 of 0.22 (Fig. 3.5, Table 3.3). Moreover, when the Connell high residue loading units were taken out of the analysis the R^2 became 0.00, indicating no relationship at all between these variables (Table 3.3). Therefore, although EF_{CO2}, EF_{CO}, and EF_{CH4} showed relationships with CE consistent with what is known about fire emissions, the $EF_{PM2.5}$ did not correlate with CE.

Similarly, the data were examined for relationships between EF_{CO2}, EF_{CO}, EF_{CH4}, and $EF_{PM2.5}$ versus the residue and soil moisture parameters (Table 3.4). Statistically significant relationships only existed between EF_{CO2}, EF_{CO}, and EF_{CH4} versus the moisture content of the entire surface layer (Table 3.4). However, $EF_{PM2.5}$ did not correlate with any of the moisture content measures (Table 3.4). Furthermore, none of the emission factors were related significantly to the upper or lower residue moistures (high residue loading units) or the soil moistures.

Figure 3.2. Linear regression of the CO_2 emission factor versus the combustion efficiency (CE).

(The CO_LOW unit is included in the graph, but is not included in regression)

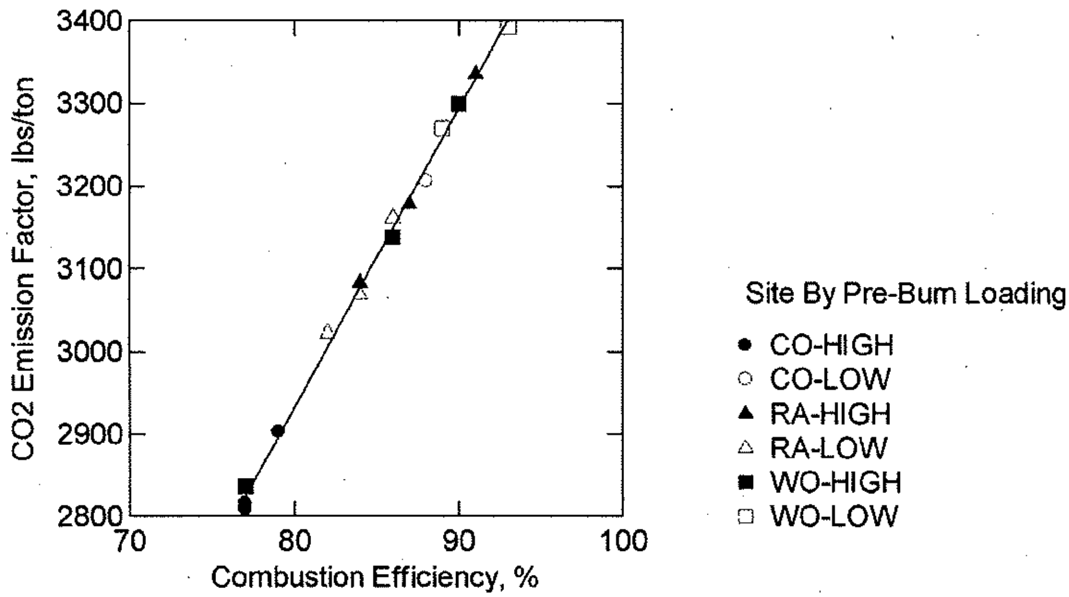


Figure 3.3. Linear regression of the CO emission factor versus the combustion efficiency (CE).

(The CO_LOW unit is included in the graph, but is not included in the regression)

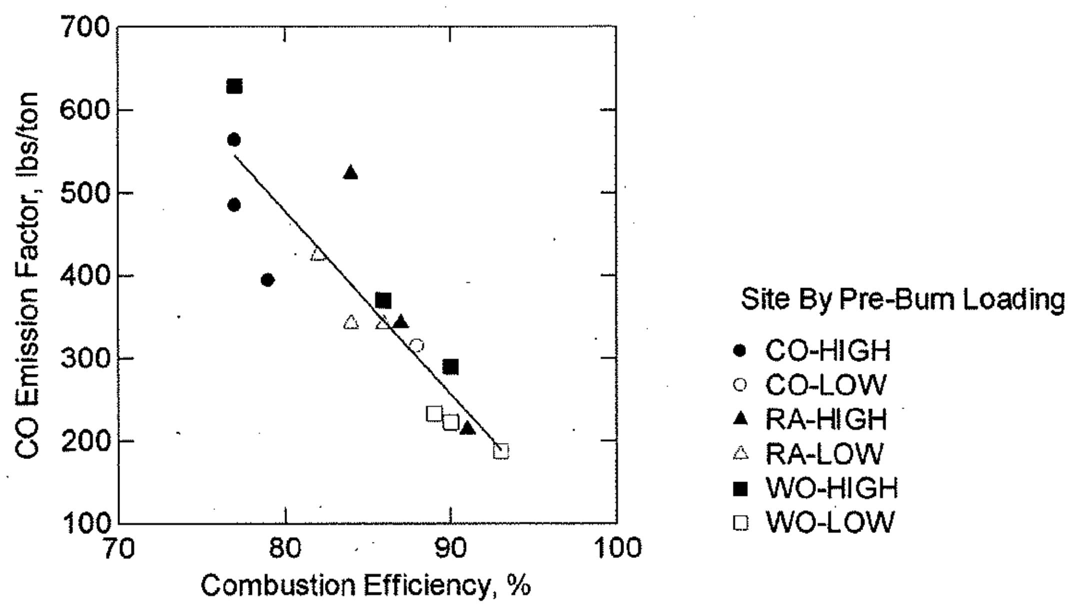


Figure 3.4. Linear regression of the CH_4 emission factor versus the combustion efficiency (CE).

(The CO_LOW unit is included in the graph, but is not included in the regression)

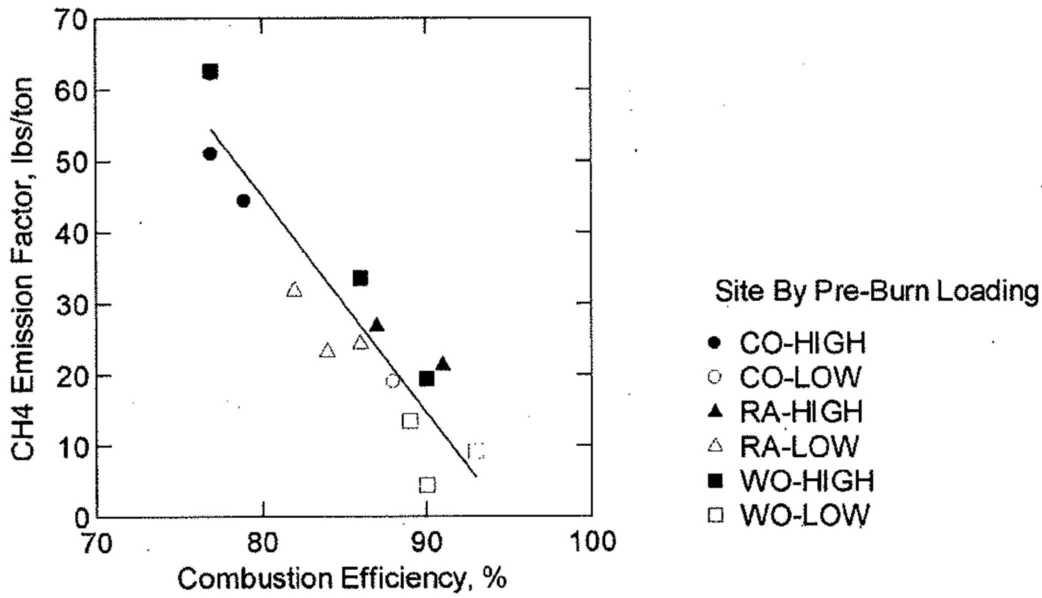


Figure 3.5. Linear regression of the $PM_{2.5}$ emission factor versus the combustion efficiency (CE).

(The CO_LOW unit is included in the graph, but is not included in the regression)

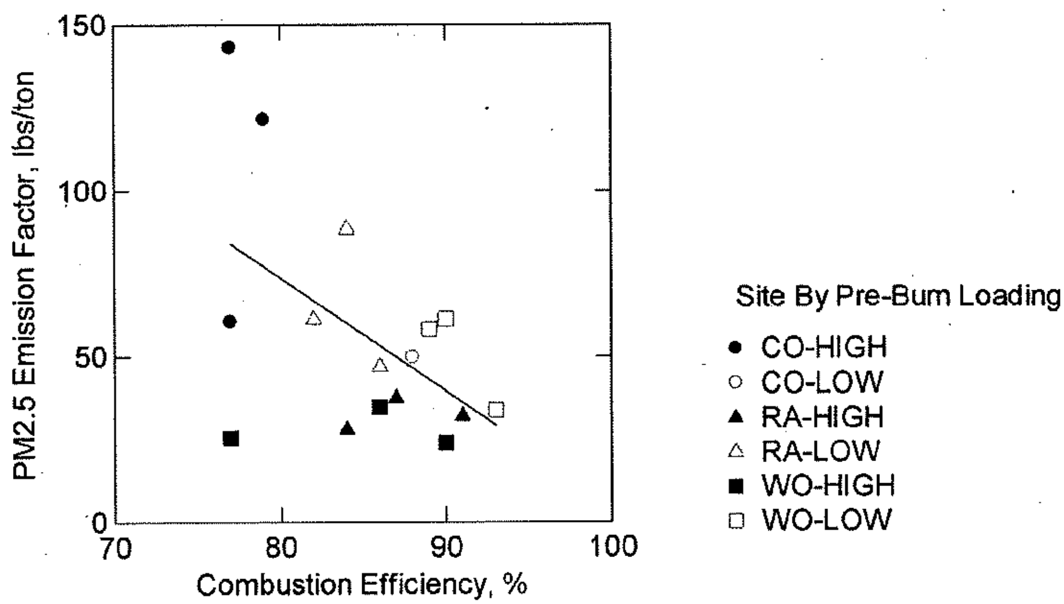


Table 3.3. Relationships between the emission factors and combustion efficiency. Relationships that are statistically significant ($P<0.05$) are shown in **BOLD**. All others are not statistically significant.

Emission Factor	Sign of Slope	All Units	
		R^2	*P*-Value
CO_2	Positive	**1.00**	**<0.005**
CO	Negative	**0.79**	**<0.005**
CH_4	Negative	**0.85**	**<0.005**
$PM_{2.5}$	Negative	**0.22**	**0.04**

Table 3.4. Relationships between emission factors and pre-burn residue moisture content. Fuel moisture content is shown for the entire surface layer (low residue loading units), upper and lower surface layers (high residue loading units), and soil layers (all units). Relationships that are statistically significant ($P<0.05$) are shown in **BOLD**. All others are not statistically significant.

Emission Factor/ Residue Component	Sign of Slope	All Units	
		R^2	*P*-Value
Emission Factor CO_2			
Entire Layer	Negative	**0.75**	**0.02**
Upper Layer	Negative	0.22	0.12
Lower Layer	---	0.00	0.37
Soil	---	0.00	0.43
Emission Factor CO			
Entire Layer	Positive	**0.82**	**0.01**
Upper Layer	---	0.00	0.39
Lower Layer	---	0.00	0.37
Soil	---	0.00	0.99
Emission Factor CH_4			
Entire Layer	Positive	**0.76**	**0.01**
Upper Layer	Positive	0.24	0.12
Lower Layer	Positive	0.07	0.26
Soil	---	0.00	0.40
Emission Factor $PM_{2.5}$			
Entire Layer	---	0.00	0.42
Upper Layer	Positive	0.10	0.21
Lower Layer	---	0.00	0.94
Soil	---	0.00	0.16

3.3 Emission Factors for Polycyclic Aromatic Hydrocarbons (PAH)

The PAH emission factors for the compounds prescribed by WDOE (specifically, benzo(a)pyrene (BaP), and six additional BaP-equivalent carcinogens including benzo(a)anthracene, benzo(b)fluroanthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and idenol(1,2,3-cd)pyrene) were generally below the method detection limit (the lowest concentration that can be detected by the instrument in the extracted sample). In 12 out of the 14 PAH samples the concentrations were below the detection limit. At two of the high residue loading units at Worley benzo(a)anthracene and chrysene were found, with emission factors of ~410 and ~400 μg kg^{-1}, respectively. In addition, at the high residue loading, replication 2, at Worley benzo(b)fluroanthene was found, with an emission factor of ~1593 μg kg^{-1}.

3.4 Total $PM_{2.5}$ Emissions

The total $PM_{2.5}$ emissions were calculated as a function of the $RC_{Absolute}$ and the $PM_{2.5}$ emission factor, $EF_{PM2.5}$, based in Equation 10). The absolute residue consumption, $EF_{PM2.5}$, and total $PM_{2.5}$ emissions are summarized by site and pre-burn residue loading in Fig. 3.6A and 3.7. Total $PM_{2.5}$ emissions were significantly higher for the Connell high residue loading units compared to the Rathdrum and Worley high residue loading units (Fig. 3.7; Kruskal-Wallis, χ^2=3.86, P=0.05). Also, total $PM_{2.5}$ emissions at the Worley low residue loading units were significantly lower than those at the Worley high residue loading unit as well as the Rathdrum low residue loading unit (Fig. 3.7; Kruskal-Wallis, χ^2=3.86, P=0.05).

Total $PM_{2.5}$ emissions did not differ between the Rathdrum and Worley high residue loading (Fig. 3.7; Kruskal-Wallis, χ^2=0.05, P=0.83). Therefore, the total $PM_{2.5}$ emissions for the Rathrum and Worley high residue loading units were pooled. Based on the pooled data the total $PM_{2.5}$ emissions at the Connell high residue loading units were significantly higher than at the Rathdrum and Worley high residue loading treatments (Figure 3.7; Kruskal-Wallis, χ^2=5.40, P=0.02).

There was no difference in total $PM_{2.5}$ emissions between the high and low residue loading at Rathdrum (Fig. 3.7; Kruskal-Wallis, χ^2=0.05, P=0.83). At this site, higher $RC_{Absolute}$ (Fig. 3.6A), potentially leading to higher total emissions (Fig. 3.7), was compensated by a lower $EF_{PM2.5}$ at the high residue loading units (Fig. 3.6B). A similar pattern was observed at Worley. However, a lower $EF_{PM2.5}$ with high residue loading did not completely compensate for the higher $RC_{Absolute}$, leading to lower total $PM_{2.5}$ emissions with low residue loading (Kruskal-Wallis, χ^2=3.86, P=0.05).

Finally, the total $PM_{2.5}$ emissions were regressed as a linear function of the $RC_{Absolute}$ and the emission factor, $EF_{PM2.5}$, to assess the relative contribution of each of these factors to the total $PM_{2.5}$ emissions. When the Connell high residue loading units were included in the regression, $RC_{Absolute}$ and $EF_{PM2.5}$ combined explained 95% of the variation in the total $PM_{2.5}$ emissions. When regressed individually, $RC_{Absolute}$ and $EF_{PM2.5}$ explained 21 and 71% of the variation in the total $PM_{2.5}$ emissions, respectively. This pattern was influenced mostly by the high $EF_{PM2.5}$ at the Connell high residue loading units. This was confirmed by the regression results without Connell high residue loading units. When based on Rathdrum and Worley only, $RC_{Absolute}$ and $EF_{PM2.5}$ combined explained 89% of the variation in the total $PM_{2.5}$ emissions. However, when regressed individually, $RC_{Absolute}$ and $EF_{PM2.5}$ explained 45 and 0% of the variation in the total $PM_{2.5}$ emissions, respectively. Overall, both the $RC_{Absolute}$ and $EF_{PM2.5}$ are needed to explain the total $PM_{2.5}$ emissions. Moreover, it is difficult to consider the effect of these parameters on the total $PM_{2.5}$ emissions individually.

Figure 3.6. Summary of absolute residue consumption and $PM_{2.5}$ emission factor.
(The CO_LOW unit "*" is included in the figure, but is not included in the statistics)

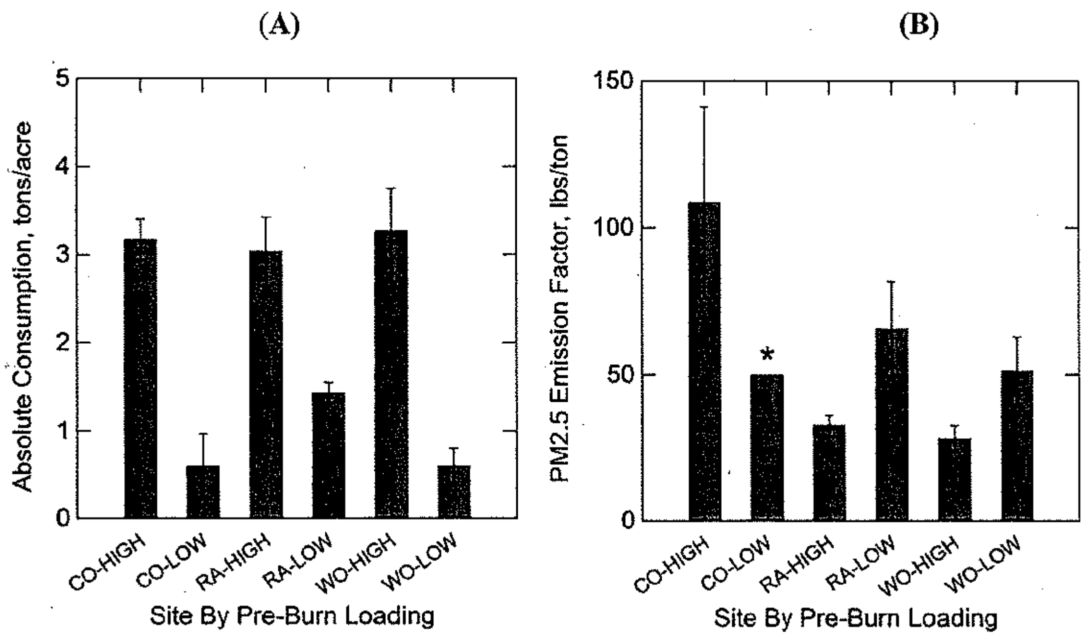
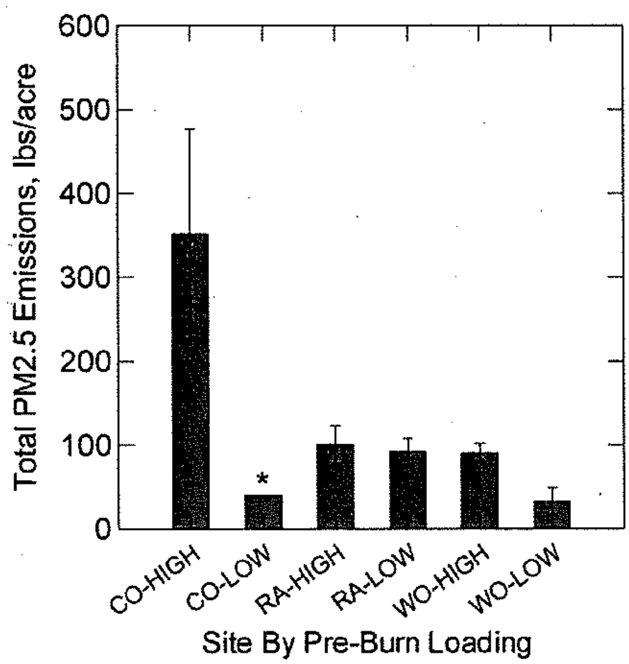


Figure 3.7. Summary of total $PM_{2.5}$ emissions.
(The CO_LOW unit "*" is included in the figure, but is not included in the statistics)



4. DISCUSSION

4.1 Residue Loading

As expected, removal of post-harvest residue by baling (i.e., low residue loading) significantly reduced the amount of pre-burn residue at all sites compared to high residue loading (Table 3.1). The high residue (i.e., no residue removed) loading and low residue (i.e., residue removed by baling) loading means averaged over all sites were 4.0 and 1.8 tons $acre^{-1}$, respectively. Baling of residue reduced the residue load by 2.2 tons $acre^{-1}$. Although the pre-burn high residue loading was numerically different among sites, i.e., Rathdrum was lower than the other two locations, statistically they were not different (P=0.096). The low residue loading was very similar at all sites (range of 1.7 to 1.9 tons $acre^{-1}$).

Post-burn residue loading was not influenced by pre-burn residue loading (Table 3.1). Connell and Worley sites burned down to similar post-burn residue loading. However, at Rathdrum, both high and low pre-burn residue loading had significantly lower post-burn residue loading compared to the other two sites.

4.2 Residue Consumption

There was a positive relationship between the ($RC_{Absolute}$ and the pre-burn residue loading (Figure 3.1; R^2=0.89, P<0.001). An R^2 value (coefficient of determination) of 0.89 indicates that 89% of the observed variation in $RC_{Absolute}$ was explained by the initial pre-burn residue loading. $RC_{Absolute}$ was significantly greater for the high residue loading units than the low residue loading units. Similarly, the $RC_{Relative}$ was significantly greater for the high residue loading units than for the low residue loading units.

The relationship between $RC_{Absolute}$ and pre-burn residue loading was possibly site specific as R^2 values of 0.99 and 0.97 were obtained when regression was performed separately for Rathdrum and for Connell/Worley, respectively (dashed lines in Fig. 3.1). Also, the Rathdrum site was quite unique in that the low residue loading units had higher $RC_{Absolute}$ and higher $RC_{Relative}$ than the low residue loading units at the other locations. The $RC_{Absolute}$ on the high residue loading units was also higher at Rathdrum (91%) than at Connell/Worley, 74 and 77%, respectively (Table 3.1).

The $RC_{Relative}$ was somewhat lower at the low residue loading of bluegrass compared to cereal residue (49 and 58%, respectively), but the $RC_{Relative}$ was much greater for high residue loading of bluegrass compared to cereal (81 and 62%, respectively)(Table 3.1; Air Science Inc., 2003). Some of this response can be explained by residue moisture. For the entire residue layer, moisture at the low residue load treatment was quite similar (Table 2.3), 16% and 10 to 14% for Kentucky bluegrass and cereal (Air Science Inc., 2003), respectively. However, at high residue loading the cereal entire residue layer moisture was 10 to 30% (Air Science Inc., 2003, see Table 2.3 high cereal residue loading), while that of the bluegrass was 15% (Table 2.3). This in part could account for the more complete burns observed in Kentucky bluegrass when a drier high residue load was burned relative to cereal.

In summary, residue consumption was strongly correlated with pre-burn residue loading, i.e., the higher the pre-burn residue loading the higher the $RC_{Absolute}$ (Fig. 3.1). Since 89% of the variation in $RC_{Absolute}$ was explained by the variation in pre-burn residue loading, this would suggest that any practice (e.g., baling) that removes a significant portion of the post-harvest residue from a bluegrass seed production field would reduce the amount of residue consumed. Total $PM_{2.5}$ (lbs $acre^{-1}$) would be reduced by a significant reduction in $RC_{Absolute}$ if $EF_{PM2.5}$ remained constant or did not increase markedly (Equation 10).

4.3 Emission Factors for $PM_{2.5}$, CO_2, CO, and CH_4

Since $PM_{2.5}$ was the main pollutant of interest, it alone was analyzed for statistical differences due to treatments, and it will be discussed in more detail than the other emission factors. The $EF_{PM2.5}$ for the Connell high residue loading units was higher (P=0.05; P=0.02 when Rathdrum and Worley data were pooled, see below) than $EF_{PM2.5}$ for the high residue loading units at Rathdrum and Worley. At Rathdrum, $EF_{PM2.5}$ was significantly greater for the low residue loading units than for the high residue loading units (P=0.05) (66 and 33 lbs of $PM_{2.5}$ ton^{-1} of residue for low and high loading, respectively, Table 3.2).

Since there were no statistical differences in $EF_{PM2.5}$ between Rathdrum and Worley residue treatments, $EF_{PM2.5}$ was pooled for these sites. Based on the pooled means, $EF_{PM2.5}$ at the Connell high residue loading units was greater than at the Rathdrum/Worley high residue loading units (P=0.02). At Rathdrum/Worley, low pre-burn residue loading produced consistently greater $EF_{PM2.5}$ than high residue loading (P=0.01,Table 3.2, Fig. 3.6B). This relationship could not be assessed at Connell due to a lack of replication (n=1) in the low residue loading treatment.

It should be noted that the $EF_{PM2.5}$ in this study are substantially greater than those reported for most agricultural burns, wildfires, and forest fires (Appendix 3). The $EF_{PM2.5}$ for the Cereal-Grain Open-Field Burning Emissions Study conducted in eastern Washington during 2000 (Air Sciences Inc., 2003) had $EF_{PM2.5}$ means of 6.2 and 8.6 lbs ton^{-1} of residue for low and high pre-burn residue loading, respectively, while the $EF_{PM2.5}$ means for this Kentucky bluegrass study were 56 and 58 lbs ton^{-1} for high residue loading and low residue loading, respectively. The eastern Washington cereal burn also had considerably higher CE and higher EF_{CO2}.

The relationships between emission factors and CE were studied based on linear regression analysis. As expected, there was a strong positive relationship between EF_{CO2} and CE (Fig. 3.2). There also were statistically significant negative relationships between CE and EF_{CO} and EF_{CH4}. These relationships are similar to those reported for other studies (Appendix 3). CO_2 emissions increased with increased CE while CO and CH_4 emissions decreased with increased CE.

Numerically, the highest CE occurred in the low residue loading treatment at Worley (dryland) and the lowest CE was at the Connell (irrigated) high residue loading treatment (Table 3.2). As expected, the lowest CE had the lowest EF_{CO2} and the highest CE had the highest EF_{CO2} (2843 and 3320 lbs ton^{-1} CO_2, respectively).

$PM_{2.5}$ is a product of incomplete combustion; however, there was a poor relationship between $EF_{PM2.5}$ and CE (Table 3.3, Fig. 3.5). Although the trend toward decreased $PM_{2.5}$ with increased CE was consistent with other reports, the relationship in bluegrass (P=0.04, R^2=0.22) was much weaker than in the eastern Washington cereal study (P<0.001, R^2=0.61) (Air Science Inc., 2003). Factors contributing to the poor relationship between CE and $EF_{PM2.5}$ in post-harvest Kentucky bluegrass residue burns are currently unknown. Site locations and/or crop management practices might play some role in the relationship, as described in Section 4.6.

4.4 Emission Factors Affected by Residue and Soil Moisture

There were no relationships between any residue moisture component and $EF_{PM2.5}$ (Table 3.4). It would be expected that $PM_{2.5}$ would increase with increased residue moisture as a result of less efficient combustion. In the eastern Washington cereal study (Air Sciences Inc., 2003), greater $PM_{2.5}$ emission factors were driven almost entirely by the higher residue moisture content in fall cereal residue relative to spring cereal residue moisture content.

In the current Kentucky bluegrass study, residue moisture contents were low, and over a narrow range. There may be a relationship between bluegrass residue moisture and $EF_{PM2.5}$, but it may not be resolvable within such a narrow range of moisture conditions observed in this study.

Statistically significant relationships existed only between EF_{CO2}, EF_{CO}, and EF_{CH4} and percent moisture of the entire residue layer (Table 3.4). EF_{CO2} decreased with increasing residue moisture, while EF_{CO} and EF_{CH4} increased with increasing residue moisture. These relationships are to be expected and it is well documented that moist residue does not burn efficiently.

None of the emission factors were significantly related to soil moisture (Table 3.4). This might be expected as these soils were quite dry (6% moisture as compared to 25% moisture for the eastern Washington cereal study (Air Sciences Inc., 2003)) and varied over a small range (4.5 to 8.6%).

4.5 Emission Factors for Polyaeromatic Hydrocarbons (PAHs)

In this study, 14 samples out of 36 samples possible (18 units x 2 FASS towers per unit) were analyzed for PAHs. Of these samples, two samples, taken at the Worley high residue loading units (replication 2 and 3) showed PAH concentrations above the method of detection limit (i.e., the minimum concentration in the filter extract that can be measured in the laboratory[1]). The samples that were below the detection limit represented all the possible combinations of site and residue loading categories, with up to three replications per combination.

The emission factors for individual PAH species reported in the literature range from less than detection limits to about 20 mg kg^{-1} of residue consumed (Ramdahl and Moeller, 1983; Jenkins et al., 1996a, 1996b, and 1996c). The emission factors in this study for benzo(a)anthracene and chrysene, range 0.39 to 0.42 mg kg^{-1} of residue consumed, were in the range reported for cereal crops by Ramdahl and Moeller (1983; range ~0.4 to 2.1 mg kg^{-1} of residue consumed), and by Jenkins et al. (1996a and 1996b; range 0.04 to ~2.5 mg kg^{-1} residue consumed). Similarly, the emission factor for benzo(b)fluoranthene in this study, 1.6 mg kg^{-1} residue consumed, was in the range reported for cereal crops by Ramdahl and Moeller (1983; range ~0.5 to ~1.0 mg kg^{-1} of residue consumed), and by Jenkins et al. (1996a, 1996b, 1996c; range ~0.011 to ~2.9 mg kg^{-1} of residue consumed).

4.6 Total $PM_{2.5}$ Emissions

Total $PM_{2.5}$ (Fig. 3.7) was calculated as a function of the $RC_{Absolute}$ and $EF_{PM2.5}$ utilizing Equation 10. $RC_{Absolute}$ was the same for high pre-burn residue loading at all sites, approximately 3.2 ton $acre^{-1}$ (Table 3.1). The Rathdrum low residue loading treatment was unique and $RC_{Absolute}$ was more than two times greater than at the other two sites (Table 3.1, Fig. 3.6A).

$EF_{PM2.5}$, 109 lbs of $PM_{2.5}$ ton^{-1} of residue consumed, was significantly higher for the Connell high residue loading treatment than for high residue loading at Rathdrum and Worley (Table 3.2, Fig. 3.6B). There were no differences in $EF_{PM2.5}$ among the low loading pre-burn treatments at Rathdrum or Worley (Connell was numerically similar to Worley, but was omitted from analysis, n=1).

[1] Two types of detection limits can be distinguished. The *sampling and analytical detection limit* (expressed as air concentration, in micrograms per liter of air) is simply the *method detection limit* (or minimum detectable PAH concentration in extract) converted to a mass (in micrograms) and divided by the sampled air volume (in liters). The sampling and analytical detection limit only applies to samples that are below the method detection limit. For samples that are below the method detection limit, the higher the sampled air volume, the lower the sampling and analytical detection limit.

Total $PM_{2.5}$ emissions for Connell high residue loading were significantly greater than for any other treatment, at 350 lbs of $PM_{2.5}$ acre^{-1} (Fig. 3.7). The Worley and Connell (n=1) low residue loading treatment produced 30 lbs of $PM_{2.5}$ acre^{-1} and the Rathdrum high residue loading, Rathdrum low residue loading, and Worley high residue loading treatments were intermediate at approximately 100 lbs of $PM_{2.5}$ acre^{-1} (Fig. 3.7).

The management practice of post-harvest residue baling and burning (propane flaming at Connell and open-field burning at Worley), significantly reduced total $PM_{2.5}$ acre^{-1} at Worley and numerically at Connell (n=1) (Fig. 3.7). Pre-burn residue loading, post-burn residue loading, $RC_{Absolute}$, and $RC_{Relative}$ where similar for Connell and Worley within residue loading levels (high or low) (Table 3.1).

At Rathdrum, post-harvest residue baling followed by burning did not reduce total $PM_{2.5}$ emissions acre^{-1} compared to open-field burning of the high residue load, i.e., there was no effect of residue loading (P=0.83) on total $PM_{2.5}$ emissions acre^{-1}. Higher $RC_{Absolute}$ (Fig. 3.6A), potentially leading to higher total emissions (Fig. 3.7), was compensated for by a lowered $EF_{PM2.5}$ at the high residue loading units.

To assess the relative contribution of $RC_{Absolute}$ and $EF_{PM2.5}$ to total $PM_{2.5}$ acre^{-1}, the total $PM_{2.5}$ emissions acre^{-1} were regressed as a linear function of these two factors. $RC_{Absolute}$ and $EF_{PM2.5}$ combined explained 95% of the total variation in total $PM_{2.5}$ emissions (Connell high units included in regression) and 89% of the total variation in total $PM_{2.5}$ emissions (Rathdrum and Worley, only). When regressed individually, $RC_{Absolute}$ and $EF_{PM2.5}$ explained 21 and 71% (Connell high included) and 45 and 0% (Rathdrum and Worley, only), respectively, of the variation in total $PM_{2.5}$ emissions acre^{-1}. Independently they are affected by site and residue loading and it is difficult to consider the individual effect of these parameters on total $PM_{2.5}$ emissions acre^{-1}. In this study, both the $RC_{Absolute}$ and $EF_{PM2.5}$ are needed to explain the total $PM_{2.5}$ emissions acre^{-1}. So, while it is probably valid to attribute the high total $PM_{2.5}$ emissions for the Connell high residue loading treatment relative to the other two sites to a high $PM_{2.5}$ emission factor, and the high total emissions at the Rathdrum low residue loading treatment relative to the other two sites to a high $RC_{Absolute}$, one must use caution when discussing cause and effect in this study given the large variability in these factors among treatments.

Finally, while total emissions of 350 lbs of $PM_{2.5}$ acre^{-1} produced at the high residue loading Connell units was high, other values (30 to 123 lbs of $PM_{2.5}$ acre^{-1}) in this Kentucky bluegrass study are also high, compared to other combustion studies (Appendix 3). However, they are within the range of those reported for smoldering emissions measured by Ward et al. (1992a) for forest wildfires in British Columbia, Canada.

4.7 Results Evaluated on a Treatment Basis (Location and Loading)

In this Kentucky bluegrass study, as noted above, burn characteristics were often site and residue loading specific, and did not always conform to emission patterns observed in other studies. To better understand the results, sites and residue loading treatments will be discussed individually, as it was hypothesized that the makeup of the residue loading (residue architecture) had an influence on combustion and emission factors at each site.

Connell irrigated site in the Columbia Basin of eastern Washington – high residue loading:

The Connell, Columbia Basin, high residue loading treatment produced the highest emissions. It also had the lowest CE. Since the high total emissions cannot be attributed to the amount of residue consumed (Table 3.7), other factors must be explored.

The Connell site was very flat and the soil was a sandy loam containing few rocks and the grower was able to swath at a very low height (2 inches). A low swathing height was used because the grower was selling the residue for hay and a high production of hay was desirable, as there was a good market for bluegrass hay in 2001. To maintain high hay quality, the post-harvest bluegrass residue was raked, baled, and hauled off the field shortly after combining the bluegrass seed field.

The high residue load units were not baled, but had the post-harvest residue distributed (scattered) over the field as it came out of the combine. The post-harvest, pre-burn residue architecture (soil surface to top of residue) was 6 to 7 inches of residue over 2 inches of stubble (2 inches was the stubble length, i.e., soil surface to top of stubble when stubble was held erect). In the original experimental design, in this large field (several hundred acre Kentucky bluegrass seed production field) the research area was to be combined first to facilitate drying of the stubble and post-harvest residue (Dave Johnson, personnel communication, 2001). Unfortunately, this did not occur and the research site was the last area at the site to be combined. The grower had some concern that there was a possibility of the research burn escaping into the bluegrass seed production field prior to the end of harvest.

The field prior to burning had a soil moisture content of 4.7%. Due to the low swathing height the post-harvest, overlying residue filtered down into the stubble to the soil surface. The lower residue layer, which consisted of the stubble and post-harvest residue, had a moisture content of 27%. The 6 to 7 inches of overlying residue has a moisture content of 2.8%. The calculated bulk density of the lower and upper residue layers were 0.51 and 0.20 lbs ft^{-3}, respectively (Table 2.5). The entire canopy moisture content was 14% and had a bulk density of 0.27 lbs ft^{-3}. Therefore, there was a very dry layer of residue, approximately 6 to 7 inches thick, over moist stubble that contained a dense post-harvest residue.

It is hypothesized that upon ignition, the upper dry residue layer was rapidly consumed. Then the more moist and dense lower residue layer would begin to burn and smolder. Due to the dense residue in the lower canopy there was probably poor flow of air into and through the remaining residue, which led to the lowest CE of any treatment in the study (Table 3.2). The smoldering phase accounted for 7% of the $PM_{2.5}$ collected, which was the highest percentage for any of the high residue burn treatments in the study (Appendix 5).

Connell irrigated site in the Columbia Basin of eastern Washington – low residue loading:

The low residue loading treatment prior to burning had a soil moisture content of 4.4%, which was slightly lower (but probably not significantly different, n=1) than that of the high residue loading treatment (Table 2.3). A lack of difference in soil moisture due to residue loading is supported by the fact that the level of pre-burn residue loading had no effect on soil moisture at the other sites.

There was 2 inches of standing stubble (erect stubble length=2 inches) that contained some residue following raking and baling; however, there was little, or no, residue layer above the standing stubble. The entire residue layer was at 22% moisture content with a bulk density of 0.48 lbs ft^{-3} (Table 2.5). Thus, there was a moist, dense residue layer that contained stubble and essentially all of the post-baled residue.

This field was combined (July 31) and raked and baled (August 1) a few days prior to burning (August 7); therefore, there was only marginal drying of the field. Since the research plots were in the last area the grower harvested, and the field had to be irrigated quickly by the grower prior to planting a following crop, it was not possible to permit a significant "dry down" of the field.

Predictably, this somewhat green, closely cut field was difficult to burn. When ignition was attempted, by lighting the edge of the field with a propane torch, the residue failed to ignite and carry the fire across the low residue loading treatment. Replication 1 was lost because the field would not burn using an open-field burn head fire.

The remaining two low residue loading units (replications) were burned using a tractor pulling a propane burner with an 18-foot boom. This was essentially the technique utilized by growers in the Columbia Basin when a crop of bluegrass was to be harvested the following year. Also, in the irrigated Rathdrum Prairie of north Idaho, in low, moist draws, the post-harvest residue often will not carry a fire and will be propane or diesel burned by some growers. MFSL was unable to collect data from either of the two FASS towers in replication 2; however, both FASS towers collected data in replication 3, making this a non-replicated treatment (n=1).

The propane burner transversed each burn unit, beginning downwind, creating a series of strip head fires across the burn unit. The flame from the propane burner was essentially "blasted" onto the residue, there was some flaming of the residue, and then the residue began to smolder and was quickly extinguished as the flame front created by the propane burner moved forward. However, the strips did not always coalesce completely.

The CE using the propane burner was 88%, which is numerically greater than the CE of the high residue loading burn. The smolder phase accounted for 29% of the $PM_{2.5}$ collected, which was the highest percent in any of the six treatments (3 sites x 2 pre-burn residue loading levels) in the study (Appendix 5). The high amount of $PM_{2.5}$ captured during the smoldering phase was probably due to the length of time it took to burn the numerous strips (numerous transverses across the burn unit). The FASS setting for a 3-minute flaming phase was exceeded during the multiple passes needed to cover the burn unit. Thus, any flaming emissions captured in passes with the propane burner after the 3-minute setting for the flaming phase were "artificially" added to the smoldering phase. The low $RC_{Absolute}$ combined with an intermediate amount of $PM_{2.5}$ ton^{-1} of residue consumed produced a relatively low total $PM_{2.5}$ emissions for this non-replicated treatment (Fig. 3.6A and B and 3.7). The "bale and flame" technique utilizing strip head fires warrants additional research, as the total $PM_{2.5}$ $acre^{-1}$ was significantly reduced (91%) using this technique compared to open-field burning of the high residue load (Fig. 3.7).

Over all burn units in the study, the percent moisture of the entire canopy was negatively correlated with EF_{CO_2} (P=0.02, R^2=0.75) (Table 3.4). As residue moisture content of the entire canopy increased the amount of CO_2 produced decreased, which suggested the burns smoldered more as moisture increased in the entire residue layer.

The Kentucky bluegrass cultivar (variety) at this site may also have affected the burn. Compared to the other cultivars in this study, 'Total Eclipse' is a newer, "elite", turf-type Kentucky bluegrass cultivar. Such bluegrass cultivars typically are low growing, have higher shoot density, and more basal leaves in the lower canopy than the older, taller, more erect "common" cultivars. When swathed low these cultivars could still have a fairly dense, possibly lush, lower canopy. This dense, lower canopy may affect CE when such fields are open-field burned rather than propane burned. Although the CE at this site was quite good utilizing the propane burner, cultivar effects on traditional methods of open-field burning and/or propane flaming could be a possible area of future research.

Rathdrum irrigated site in the Rathdrum Prairie of north Idaho – high residue loading:

The Rathdrum site was unique in this study since total $PM_{2.5}$ emissions were not affected by the level of residue loading (Fig. 3.7). Although total $PM_{2.5}$ ranged from 92 to 123 lbs $acre^{-1}$ and are intermediate for this study, these levels of total $PM_{2.5}$ are quite high compared to those from other burn studies (Appendix 3). Also unique to the Rathdrum site was the low amount of residue left in the field following burning (Table 3.1).

Unlike the Connell site that was swathed at a height of 2 inches, the Rathdrum site was swathed at 9 to 10 inches (Table 2.4). Several factors contributed to the higher swathing height at Rathdrum. First, due to the gravel soil at this site the grower typically cuts at a high height to reduce the risk of damaging the swather's cutting bar. Second, the grower was not going to market the post-harvest residue as hay, so a low cutting height to maximize hay yield was not necessary. Third, the cultivar 'Alene' at Rathdrum is a taller, more erect growing Kentucky bluegrass that when not lodged can be swathed higher and not reduce seed yield. Fourth, at a higher swathing height less material passes through the combine and combine speed can be increased, which would decrease harvest time.

The high residue loading units were swathed, combined, and the residue was scattered as it came out the back of the combine over the top of the standing stubble. The standing stubble height in the high residue loading treatment was estimated at 9 to 10 inches based on the stubble height in the low residue loading treatment (Table 2.4). The post-harvest residue that was scattered across the field tended to flatten the tall stubble and the height from the soil surface to the top of the residue layer was 7.8 inches. The residue architecture was a 4-inch layer of loose, dry (6.5% moisture content, 0.24 lbs ft^{-3} bulk density) residue suspended approximately 4 inches above the soil surface (Table 2.4 and 2.5). Below the 4-inch layer of suspended dry residue was a lower residue layer that consisted of a more moist stubble and loose post-harvest material (22% moisture content, 0.28 lbs ft^{-3} bulk density).

The field, prior to burning, had a soil moisture content of 8.6%. This was almost twice the percent soil moisture relative to the soil moisture at the hotter, drier, Connell site. It was also significantly greater that the soil moisture at the dryland Worley site (Table 2.1). The temperature and relative humidity at the time of the Rathdrum burns were also much lower and higher, respectively, than at other two sites (Table 2.2). Although there were no statistical relationships shown between soil moisture and emissions factors (Table 3.4), a greater soil moisture content could contribute to a higher residue moisture and higher relative humidity in the lower canopy near the soil surface. Given time, a greater soil moisture content could also contribute to enhanced regrowth of the bluegrass stand. The stubble underlying the residue was observed to be fairly green at Rathdrum. Burning any green residue would lower CE and increase emission factors (Air Sciences Inc., 2003).

Upon ignition, the drier upper residue layer began to burn. Since the lower residue layer in the Rathdrum high residue loading was more loosely packed (bulk density=0.28 lbs ft^{-3}, Table 2.5), relative to the lower residue layer in the high residue loading treatment at Connell or Worley (bulk densities = 0.51 and 0.60 lbs ft^{-3}, respectively), air may have been more easily drawn into the lower canopy at Rathdrum. The burning residue and heated air drove off much of the moisture from the lower residue layer making it conducive to a more efficient burn (CE = 87%). The CE at Rathdrum high residue loading was numerically greater than the high residue loading treatment at the other two sites. There was little residue on the field following burning (0.3 ton $acre^{-1}$, Table 3.1). The post-burn residue in the burn units was essentially black ash.

The plumes at Rathdrum were observed to be lighter in color compared to the plumes from the high residue burns at Connell. $EF_{PM2.5}$ were 109 and 33 lbs ton^{-1} of residue consumed for high residue loading at Connell and Rathdrum, respectively, and the total $PM_{2.5}$ emissions were 349 and 123 lbs of $PM_{2.5}$ $acre^{-1}$ at Connell and Rathdrum, respectively (Table 3.2). The plumes at

Connell also contained approximately 12% less water vapor (12% water content assumed that all the moisture in the entire residue layer was driven off as water vapor).

Rathdrum irrigated site in the Rathdrum Prairie of north Idaho – low residue loading:

The amount of post-harvest residue on the field following combining (i.e., high residue loading) was significantly less than that at the other two sites; however, following baling there was slightly, but not statistically, more pre-burn low residue loading compared to the other two sites (1.9 tons $acre^{-1}$ versus 1.7 ton $acre^{-1}$, Table 3.1). Baling removed 1.4 tons of post-harvest residue $acre^{-1}$. Since the low residue loading stubble length was approximately 2 and 3.5 inches at Connell and Worley, respectively, the taller (9.7 inch) residue at Rathdrum may account for the increase in pre-burn residue loading following baling (Table 3.1). Due to the high swathing height, raking and baling were less efficient. Also the stand was observed to be less dense (thinner), which may contribute to the lower amount of biomass initially on the field (Table 3.1).

Soil moisture with low loading was 7.4%, 1.2% less than high residue loading, but this difference was not statistically significant (Table 2.3). Soil moisture content for the irrigated Rathdrum site was significantly greater than at the other sites. Although soil moisture was not correlated with any emission factor (Table 3.4), a higher soil moisture should increase the moisture content of the residue in immediate contact with the soil surface.

Compared to the low residue treatments at Worley and Connell, the low loading treatment at Rathdrum had the highest residue consumption (1.4 tons $acre^{-1}$, Table 3.1, Fig. 3.7). The high residue consumption was probably the major contributing factor to the higher total $PM_{2.5}$ emissions at Rathdrum compared to those at Connell or Worley (Fig. 3.7). However, as discussed earlier, to more completely explain total $PM_{2.5}$ $acre^{-1}$ the $EF_{PM2.5}$ must also be taken into account in this bluegrass study.

Compared to the low residue loading treatments at Connell or Worley, the low residue loading architecture was quite different at Rathdrum. The residue consisted of a tall (10 inch stubble length), erect stubble with pre-burn residue (1.9 tons $acre^{-1}$) distributed thorough out the tall, erect stubble. The entire residue layer bulk density was 0.11 lbs ft^{-3} at Rathdrum low residue loading compared to 0.30 and 0.48 lbs ft^{-3} at Worley and Connell, respectively.

Since the low residue treatment had been swathed on July 4, combined on July 23, and raked and baled on August 6, it was anticipated that considerable drying of the standing stubble and loosely packed residue would have occurred prior to field burning on August 21 or 22. However, this was not the case and the entire residue layer moisture content was 22% (Table 2.3).

It was hypothesized that although the entire residue layer was at a moisture content of 22%, there would be a moisture gradient from higher moisture residue (residue that was on the soil surface) to lower moisture residue at the top of the entire residue layer. Upon ignition, the drier material of the upper canopy burned and air was drawn into the loose residue (bulk density=0.11 lbs ft^{-3}). The burning residue and hot air drove off the moisture in the lower residue. The CE was fairly high (84%) and the $RC_{Relative}$ was over two times greater than the low residue loading burns at Connell or Worley (Table 3.1). The low residue loading burn was a very complete burn leaving essentially black ash on the field (0.4 tons $acre^{-1}$, Table 3.1). It is interesting to note that post-burn residue loading was the same in the high and low residue loading treatments at Rathdrum, i.e., 0.3 and 0.4 tons $acre^{-1}$, respectively. Although a very complete burn, the low residue loading burn has some smoldering, as indicated by the lower EF_{CO2} (3084 lbs ton^{-1}) and higher $EF_{PM2.5}$ (66 lbs ton^{-1}) compared to the high residue emission factors (Table 3.2). This might be due in part to the cooler temperature and higher relative humidity that occurred during these burns (Table 2.2). Trace precipitation occurred not long after the final unit was burned on August 22.

Worley dryland site in north Idaho – high residue loading:

The Worley site was the only dryland Kentucky bluegrass seed production field in the study. Unlike the flat Connell and Rathdrum sites, the Worley site was a rolling field. Although residue treatments within a replication were side-by-side (Appendix 4), there was an estimated 50 foot change in elevation within and between some burn units. It was noted that the length of the standing stubble was taller in draws than on slopes (Table 2.4). These variations in stubble length due to topography were taken into account in the pre-burn and post-burn sampling, i.e., if a burn unit had 25% of the area in draws then 25% of the samples for each parameter would be randomly taken in draws.

The site was swathed about July 22 (exact date not recorded but swathing in the Worley area is typically done 10 to 14 days prior to combining). The field was combined on August 3 with the post-harvest residue scattered on the field as it came out of the combine.

The Kentucky bluegrass cultivar at Worley was 'Garfield', which is a "common" bluegrass that has a tall, erect growth habit. The mean (average of slope and draw) stubble length was 9.3 inches (Table 2.4). Like the Rathdrum high residue loading treatment, the post-harvest residue scattered across the field during combining tended to flatten the stubble, as a result, the measured height from the soil surface to the top of the residue layer was 6.1 inches (Table 2.4). The residue high loading architecture was a 3.5-inch layer of dry (3.6% moisture, 0.24 lbs ft^{-3} bulk density) residue suspended 2.6 inches above the soil surface. Below the 3.5-inch layer of suspended residue was a lower residue layer of stubble and post-harvest material with a moisture content of 22% and a bulk density of 0.60 lbs ft^{-3}. The entire residue layer moisture content was 15%, which is very similar to that at Rathdrum or Connell (Table 2.3). Worley and Rathdrum were similar in that post-harvest residue was scattered over a 9 to 10 inch standing stubble. Two noted differences between the sites were that the distance from the soil surface to the suspended residue was 3.9 inches at Rathdrum versus 2.6 inches at Worley, and the soil moisture at the dryland Worley site was, as expected, less than at the irrigated Rathdrum site, soil moisture content=5.5 and 8.6%, respectively (Table 2.3).

It was hypothesized that upon ignition the drier, looser packed, upper residue layer began burning. The heated air caused by the burning upper residue layer drove off moisture. The plumes at Worley, like Rathdrum, were observed to be lighter in color than the plumes from the high residue burns at Connell. The $RC_{Absolute}$ was 77% and the CE was 84% (Table 3.1 and 3.2). Some smoldering was observed, which is alos indicated by the low EF_{CO2} (3092 lbs ton^{-1}, Table 3.2). The high standard errors associated with emission factors and CE at the Worley site (taking both high and low residue loading into account, Table 3.2) indicated more variability among treatments than at the other two sites, which may be due, in part, to variability of the rolling terrain at Worley compared to the flat terrain at the other two sites.

The $RC_{Absolute}$ at Worley was similar to that observed at the other two sites with high residue loading (Fig. 3.6A). $EF_{PM2.5}$ for Worley (28 lbs ton^{-1}) was similar to that for Rathdrum, but significantly less than that for Connell (Table 3.2, Fig. 3.6B). The total lbs of $PM_{2.5}$ emissions $acre^{-1}$ for high residue loading was similar to that seen at Rathdrum and was significantly less than that for the high residue loading at Connell (Fig.3.7).

Worley dryland site in north Idaho – low residue loading:

Following combining on August 3, the low residue loading units were re-swathed and raked on August 5 and baled on August 6. The low residue loading burn units were burned on August 15 or 16, which allowed for good "dry down" and was reflected in the low entire residue layer moisture content, 9.3% (Table 2.3). The $RC_{Relative}$ at 76% was more than two times greater than the $RC_{Relative}$ of the other low residue loading treatments at Connell and Rathdrum, which probably was due to the dryness of the entire residue layer at Worley. There was very little smoldering observed (Appendix 4 and 5). The Worley low residue loading treatment had the highest CE (91%) and the highest EF_{CO2} (3320 lbs acre^{-1}) of any treatment in the study. While these values are not as high as those observed in the cereal study in eastern Washington (Air Sciences Inc., 2003), they are very comparable to those seen in the flaming phase of forest fires (Appendix 3). Although the low entire residue layer moisture content was probably the major reason (9% moisture content at Worley versus 22% moisture content at Connell and Rathdrum, respectively) for the efficient burns, other factors may have played some role.

Cultivar growth habit may also have contributed to a more efficient combustion at Worley. At Connell the cultivar was the low growing, denser, elite-type 'Total Eclipse' Kentucky bluegrass, while at Worley the cultivar was 'Garfield', a taller, less dense "common" bluegrass. When swathed at 3.5 inches, 'Garfield' had more stem and less leaf biomass than 'Total Eclipse'. As previously discussed, residue architecture and cultivar effects on burning and emissions are potential areas for future research.

Another factor could be management of Kentucky bluegrass seed fields. Burned fields tend to be thinner and more open, while non-burned field tend to become sod bound, produce fewer seed heads, and leafier biomass. If there is a sufficiently dry residue load to carry a fire, an open stand may enhance air flow into the residue and led to more efficient and cleaner burns. At Connell the stand had not been burned, was two-years-old, in its second harvest, and was a dense stand. In contrast, at Worley and Rathdrum, the stands had been continually burned, so they may have been thinner and more open. The exceptionally high total $PM_{2.5}$, for the high residue loading burns at Connell may be, in part, due to this factor. Total emissions for a bluegrass seed production field burned year after year could possible be less over time. Future research should address this issue.

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APPENDIX 1: LIST OF SYMBOLS

BD	Bulk density (lbs ft^{-3})
CO	Connell site in Columbia Basin of eastern Washington
CE	Combustion efficiency (%)
EF_x	Emission factor (lbs ton^{-1} of residue); x stands for CO_2, CO, CH_4, or $PM_{2.5}$
EF_{PAH}	Emission factor (lbs ton^{-1} of residue) for polyaromatic hydrocarbons
$EF_{PM2.5}$	Emission factor (g kg^{-1} of residue or lbs ton^{-1} of residue) for $PM_{2.5}$
Flow_correction	Factor to correct for air flow difference in PAH and $PM_{2.5}$ samples (dimensionless)
χ_x	Measured concentration of pollutant x above background (ppmv)
$\chi_{x, Fire}$	Measured concentration of pollutant x above background (mg m^{-3})
$\chi_{C\text{-}x, Fire}$	Carbon mass of pollutant x above background (mg m^{-3})
$L_{Pre\text{-}Burn}$	Fuel load before the burn (tons $acre^{-1}$)
$L_{Post\text{-}Burn}$	Fuel load after the burn (tons $acre^{-1}$)
$M_{PM2.5}$	Mass of $PM_{2.5}$ collected on filter (g)
M_{PAH}	Mass of polyaromatic hydrocarbon species in the $PM_{2.5}$ fraction (g)
PAH	Polyaromatic hydrocarbons
$PM_{2.5}$ Total	Total $PM_{2.5}$ emissions on a per acre basis (lbs $acre^{-1}$)
RA	Rathdrum, ID site
RMC	Residue moisture content (% H_2O per g dry weight)
$RC_{Absolute}$	Absolute residue consumption (tons $acre^{-1}$)
$RC_{Relative}$	Relative residue consumption (% of pre-burn residue loading, $L_{Pre\text{-}Burn}$)
W_{field}	Fresh weight of residue or soil sample (g)
W_{OD}	Oven dried weight of residue or soil sample (g)
WO	Worley, ID site
X	Subscript used to indicate pollutant species, CO_2, CO, CH_4, or $PM_{2.5}$

APPENDIX 2:SUMMARY OF PHYSICAL SITE DATA, BY BURN UNIT

Summary Physical Site Data, By UNIT 6/2/2003 **0=NO DATA**

Site_Load_Unit	Parameter	tons/acre Pre_Load	tons/acre Post_Load	% H2O_tot	% H2O_up	% H2O_low	% H2O_soil	lbs/ton CO2	lbs/ton CO	lbs/ton CH4	lbs/ton PM2.5	% CE
CB_LOW_1	N of cases	11	0	4	0	0	4	0	0	0	0	0
CB_LOW_1	Minimum	1.1	.	23.5	.	.	4.1	.	.	.	.	
CB_LOW_1	Maximum	2.5	.	45.0	.	.	5.1	.	.	.	.	
CB_LOW_1	Mean	1.6	.	35.5	.	.	4.6	.	.	.	.	
CB_LOW_1	Std. Error	0.1	.	4.8	.	.	0.2	.	.	.	.	
CB_HIGH_1	N of cases	12	4	0	4	4	4	1	1	1	1	1
CB_HIGH_1	Minimum	1.6	1.1	.	2.0	18.7	3.4	2817	562.8	62.2	60.7	0.77
CB_HIGH_1	Maximum	8.9	1.7	.	4.4	64.1	5.6	2817	562.8	62.2	60.7	0.77
CB_HIGH_1	Mean	4.3	1.4	.	3.3	40.3	4.9	2817	562.8	62.2	60.7	0.77
CB_HIGH_1	Std. Error	0.6	0.2	.	0.7	11.4	0.5	.	.	.	.	
CB_LOW_2	N of cases	10	3	4	0	0	4	0	0	0	0	0
CB_LOW_2	Minimum	1.1	1.0	6.8	.	.	4.3	.	.	.	.	
CB_LOW_2	Maximum	2.8	1.5	58.8	.	.	5.2	.	.	.	.	
CB_LOW_2	Mean	1.7	1.3	23.1	.	.	4.8	.	.	.	.	
CB_LOW_2	Std. Error	0.2	0.1	12.1	.	.	0.2	.	.	.	.	
CB_HIGH_2	N of cases	11	4	0	4	4	4	2	2	1	2	2
CB_HIGH_2	Minimum	2.1	0.8	.	2.0	11.5	3.6	2746	461.2	51.0	130.2	0.75
CB_HIGH_2	Maximum	7.1	1.5	.	4.9	61.8	5.4	2872	507.8	51.0	156.1	0.78
CB_HIGH_2	Mean	4.6	1.1	.	2.9	25.7	4.7	2809	484.5	51.0	143.2	0.77
CB_HIGH_2	Std. Error	0.4	0.2	.	0.7	12.1	0.4	63	23.3	.	12.9	0.02
CB_LOW_3	N of cases	12	4	4	0	0	4	2	2	1	2	2
CB_LOW_3	Minimum	0.9	0.8	9.1	.	.	3.9	3197	308.8	19.0	39.9	0.87
CB_LOW_3	Maximum	3.2	1.4	40.9	.	.	4.9	3216	319.2	19.0	59.7	0.88
CB_LOW_3	Mean	1.8	1.0	22.1	.	.	4.4	3207	314.0	19.0	49.8	0.88
CB_LOW_3	Std. Error	0.2	0.1	7.5	.	.	0.2	10	5.2	.	9.9	0.01
CB_HIGH_3	N of cases	12	4	0	4	4	4	1	1	1	1	1
CB_HIGH_3	Minimum	2.0	0.4	.	1.9	7.0	3.8	2903	393.6	44.4	121.5	0.79
CB_HIGH_3	Maximum	6.8	1.1	.	3.1	24.4	5.1	2903	393.6	44.4	121.5	0.79
CB_HIGH_3	Mean	3.9	0.9	.	2.4	14.1	4.6	2903	393.6	44.4	121.5	0.79
CB_HIGH_3	Std. Error	0.4	0.2	.	0.3	3.7	0.3	.	.	.	.	
WO_LOW_1	N of cases	7	3	4	0	0	4	2	2	1	2	2
WO_LOW_1	Minimum	1.1	1.0	4.2	.	.	4.4	3290	200.6	4.4	52.4	0.90
WO_LOW_1	Maximum	2.7	1.2	13.5	.	.	6.5	3308	242.8	4.4	70.2	0.90
WO_LOW_1	Mean	2.0	1.1	8.6	.	.	5.0	3299	221.7	4.4	61.3	0.90
WO_LOW_1	Std. Error	0.2	0.1	2.2	.	.	0.5	9	21.1	.	8.9	0.00
WO_HIGH_1	N of cases	8	4	0	4	4	4	1	1	1	1	1
WO_HIGH_1	Minimum	2.7	1.0	.	1.7	18.2	4.4	2837	628.6	62.6	25.5	0.77
WO_HIGH_1	Maximum	5.5	2.2	.	3.3	29.6	7.7	2837	628.6	62.6	25.5	0.77
WO_HIGH_1	Mean	4.3	1.3	.	2.4	24.3	5.4	2837	628.6	62.6	25.5	0.77
WO_HIGH_1	Std. Error	0.3	0.3	.	0.4	3.1	0.8	.	.	.	.	
WO_LOW_2	N of cases	7	3	4	0	0	4	2	2	2	2	2
WO_LOW_2	Minimum	1.0	0.9	6.6	.	.	4.8	3268	220.6	11.8	52.3	0.89
WO_LOW_2	Maximum	1.9	1.0	10.6	.	.	6.2	3271	244.2	15.2	64.1	0.89
WO_LOW_2	Mean	1.4	1.0	8.5	.	.	5.5	3270	232.4	13.5	58.2	0.89
WO_LOW_2	Std. Error	0.1	0.0	1.0	.	.	0.3	2	11.8	1.7	5.9	0.00
WO_HIGH_2	N of cases	8	4	0	4	4	4	1	1	1	1	1
WO_HIGH_2	Minimum	2.0	0.8	.	3.4	8.8	4.6	3139	369.2	33.6	34.8	0.86
WO_HIGH_2	Maximum	5.6	1.1	.	6.4	27.7	6.2	3139	369.2	33.6	34.8	0.86
WO_HIGH_2	Mean	3.8	0.9	.	4.4	20.9	5.1	3139	369.2	33.6	34.8	0.86
WO_HIGH_2	Std. Error	0.5	0.1	.	0.7	4.2	0.4	.	.	.	.	
WO_LOW_3	N of cases	7	3	4	0	0	4	2	2	1	2	2
WO_LOW_3	Minimum	0.7	1.3	3.9	.	.	4.2	3373	186.8	9.2	19.1	0.92
WO_LOW_3	Maximum	3.4	1.5	22.2	.	.	5.2	3411	187.4	9.2	48.6	0.93
WO_LOW_3	Mean	1.8	1.4	10.8	.	.	4.5	3392	187.1	9.2	33.8	0.93
WO_LOW_3	Std. Error	0.4	0.1	4.1	.	.	0.2	19	0.3	.	14.8	0.01
WO_HIGH_3	N of cases	8	4	0	4	4	4	2	2	1	2	2
WO_HIGH_3	Minimum	3.7	0.5	.	3.7	14.5	5.1	3272	238.0	19.4	23.5	0.89
WO_HIGH_3	Maximum	6.0	0.9	.	4.3	30.2	7.1	3327	341.0	19.4	24.5	0.91
WO_HIGH_3	Mean	4.7	0.7	.	4.0	21.7	6.0	3299	289.5	19.4	24.0	0.90
WO_HIGH_3	Std. Error	0.3	0.1	.	0.1	3.3	0.4	28	51.5	.	0.5	0.01

APPENDIX 2:SUMMARY OF PHYSICAL SITE DATA, BY BURN UNIT (CONTINUED)

Summary Physical Site Data, By UNIT 6/2/2003 **0=NO DATA**

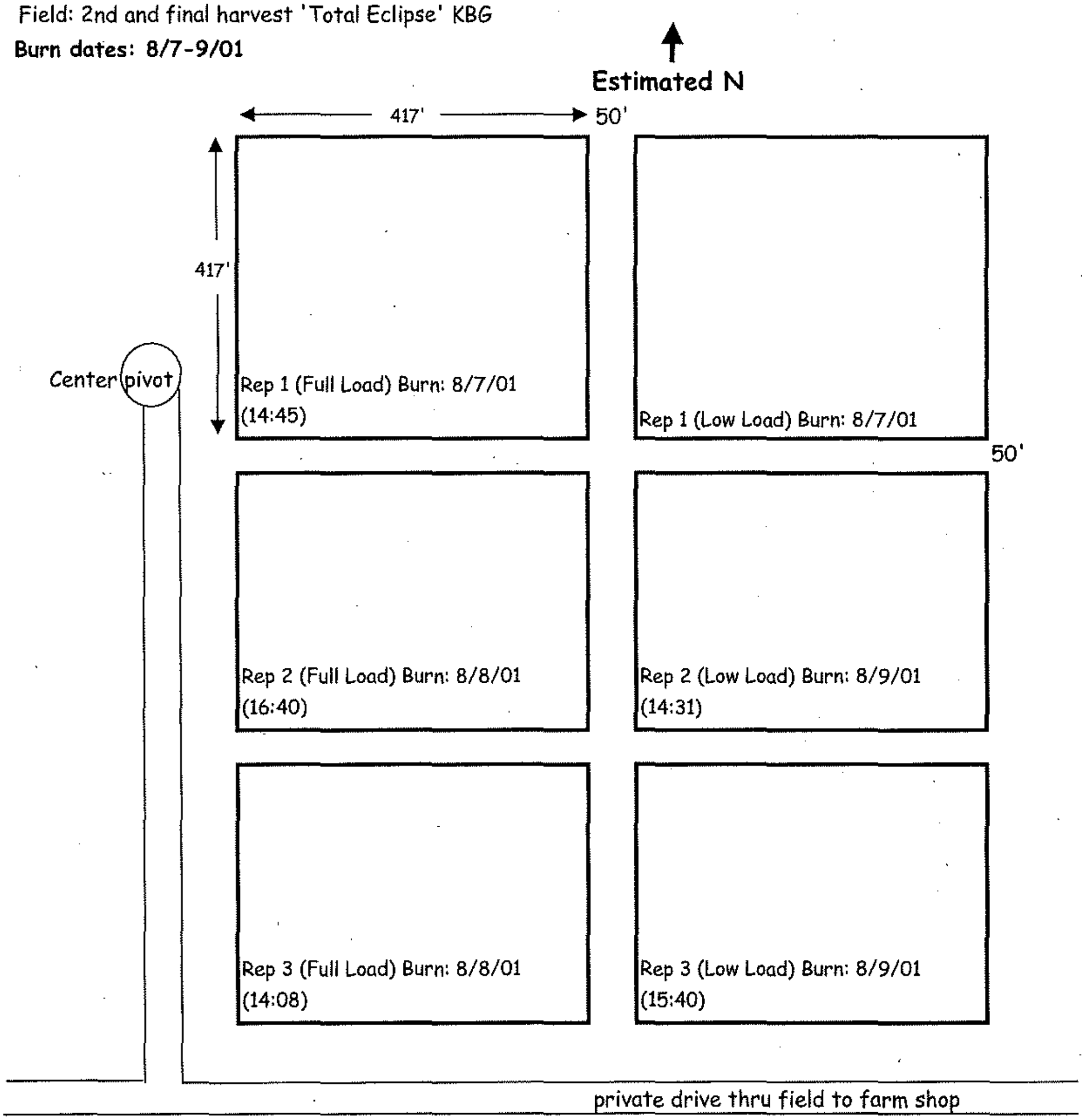
Site_Load_Unit	Parameter	tons/acre Pre_Load	tons/acre Post_Load	% H2O_tot	% H2O_up	% H2O_low	% H2O_soil	lbs/ton CO2	lbs/ton CO	lbs/ton CH4	lbs/ton PM2.5	% CE
RA_LOW_1	N of cases	7	3	4	0	0	4	1	1.0	1.0	1.0	1.00
RA_LOW_1	Minimum	1.1	0.2	12.0	.	.	6.0	3069	341.8	23.2	88.4	0.84
RA_LOW_1	Maximum	2.2	1.0	40.1	.	.	8.7	3069	341.8	23.2	88.4	0.84
RA_LOW_1	Mean	1.8	0.5	20.9	.	.	7.2	3069	341.8	23.2	88.4	0.84
RA_LOW_1	Std. Error	0.2	0.3	6.5	.	.	0.6	.	.	.	.	
RA_HIGH_1	N of cases	6	4	0	2	2	4	2	2	2	2	2
RA_HIGH_1	Minimum	1.9	0.2	.	8.4	21.2	6.3	3110	293.6	21.0	35.8	0.85
RA_HIGH_1	Maximum	5.9	0.3	.	8.7	34.1	9.2	3246	391.6	32.6	39.3	0.88
RA_HIGH_1	Mean	3.8	0.3	.	8.6	27.6	7.5	3178	342.6	26.8	37.6	0.87
RA_HIGH_1	Std. Error	0.6	0.0	.	0.1	6.4	0.7	68	49.0	5.8	1.8	0.02
RA_LOW_2	N of cases	7	3	4	0	0	4	1	1	1	1	1
RA_LOW_2	Minimum	1.6	0.3	9.3	.	.	4.9	3022	424.2	31.8	61.2	0.82
RA_LOW_2	Maximum	2.2	0.6	52.1	.	.	10.4	3022	424.2	31.8	61.2	0.82
RA_LOW_2	Mean	1.9	0.5	28.7	.	.	7.7	3022	424.2	31.8	61.2	0.82
RA_LOW_2	Std. Error	0.1	0.1	11.1	.	.	1.1	.	.	.	.	
RA_HIGH_2	N of cases	8	4	0	4	4	4	2	2	0	2	2
RA_HIGH_2	Minimum	2.5	0.3	.	3.9	12.4	8.0	3081	521.4	.	26.8	0.84
RA_HIGH_2	Maximum	4.6	0.6	.	13.1	21.0	11.2	3085	522.6	.	29.2	0.84
RA_HIGH_2	Mean	3.3	0.4	.	6.3	16.5	9.5	3083	522.0	.	28.0	0.84
RA_HIGH_2	Std. Error	0.2	0.1	.	2.2	1.8	0.8	2	0.6	.	1.2	0.00
RA_LOW_3	N of cases	7	3	4	0	0	4	2	2	2	2	2
RA_LOW_3	Minimum	1.5	0.3	7.5	.	.	4.7	3113	307.4	21.2	43.6	0.85
RA_LOW_3	Maximum	2.8	0.4	25.5	.	.	9.0	3209	374.8	27.4	50.0	0.87
RA_LOW_3	Mean	1.9	0.3	15.2	.	.	7.2	3161	341.1	24.3	46.8	0.86
RA_LOW_3	Std. Error	0.2	0.0	3.8	.	.	0.9	48	33.7	3.1	3.2	0.01
RA_HIGH_3	N of cases	8	4	0	4	4	4	2	2	2	2	2
RA_HIGH_3	Minimum	2.0	0.1	.	3.6	12.8	7.0	3212	91.6	14.2	25.7	0.88
RA_HIGH_3	Maximum	4.3	0.5	.	6.1	28.3	13.2	3458	334.8	28.4	38.7	0.94
RA_HIGH_3	Mean	2.9	0.3	.	4.5	21.1	8.9	3335	213.2	21.3	32.2	0.91
RA_HIGH_3	Std. Error	0.2	0.1	.	0.6	3.4	1.5	123	121.6	7.1	6.5	0.03

APPENDIX 3: EMISSION FACTOR COMPARISON WITH OTHER STUDIES

Summary of Emission Factors for CO_2, CO, CH_4, and $PM_{2.5}$ From Other Reports in the Literature

Source	Residue Type	Emission Factor, lbs ton^{-1} of residue consumed			
		CO_2	CO	CH_4	$PM_{2.5}$
Air Sciences Inc., 2003	Wheat Residue				
	Spring (95% C.I.)	3527 - 3561 (mean 3546)	57 - 77 (mean 67)	1.3 – 2.0 (mean 1.6)	4.0 – 6.9 (mean 5.3)
	Fall (95% C.I.)	3396 – 3495 (mean 3447)	93 - 141 (mean 117)	2.6 – 4.5 (mean 3.6)	7.3 – 12.4 (mean 9.8)
Jenkins and Turn, 1994	Cereal Straw		64 – 198	1.6 – 5.0	6.4 – 15.4
Turn et al., 1997	Cereal Straw				mean ~12.2
Ward et al., 1996	Savanna, Africa	mean ~3500	mean ~90	mean ~1.6	mean ~7.0
Yamasoe et al., 2000	Forest, Brazil				
	Flaming				mean ~6.6
	Smoldering				mean ~12.2
Ward and Hardy, 1991	Wildfires, U.S.A.				
	CE > 90 %				2 - 12
	CE 74 to 90 %				12 – 40
Ward et al., 1992a	Wildfires, U.S.A.				
	Flaming	3424 – 3518	72 – 116	2.8 – 5.8	4.0 – 12.8
	Smoldering	2472 – 2580	490 – 526	34.8 – 42.8	44.4 – 65.2
Ward et al., 1992b	Cerrado Forest, Brazil				
	Flaming	3380 – 3498	92 – 140	2.0 – 3.2	1.0 – 2.4
	Smoldering	3062 - 3304	182 – 304	8.6 – 18.0	4.8 – 9.8

Kentucky bluegrass emissions on an irrigated site in the Columbia Basin
Location: Connell, WA
Field: 2nd and final harvest 'Total Eclipse' KBG
Burn dates: 8/7-9/01



Kentucky bluegrass emissions on an irrigated site in the Columbia Basin
Location: Connell, WA
Field: 2nd and final harvest 'Total Eclipse' KBG
Burn date: 8/7/01

Site	Rep	Residue Load	Ignition Time	Flames to Towers	Smolder Only to Tower	Smolder Past Tower	Plot Out
Columbia Basin (irrigated)	1	Low					

Pre-burn residue load 8-1 ft2 samples/plot

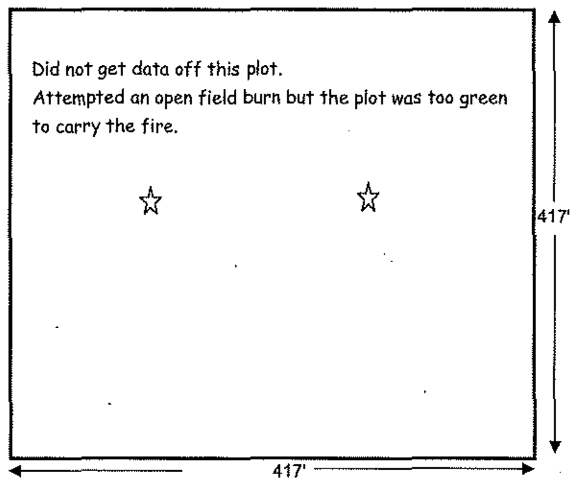
Pre-burn residue moisture 4-1 ft2 samples/plot

Post-burn residue 4-1 ft2 sample/plot

Soil moisture 4 samples/plot

☆ FASS Tower

FASS setting:
min. flame
min. smolder



COMMENTS:

Combine harvest 7/31/01 with residue scattered onto field.
Raked and baled 8/1/01.
Lit plot with a propane torch mounted on an four wheel ATV. Plot too green did not carry a fire.
Stubble height approximately 2". (Mean of 3 measurements)

Kentucky bluegrass emissions on an irrigated site in the Columbia Basin
Location: Connell, WA
Field: 2nd and final harvest 'Total Eclipse' KBG
Burn date: 8/7/01

Site	Rep	Residue Load	Ignition Time	Flames to Towers	Smolder Only to Tower	Smolder Past Tower	Plot Out
Columbia Basin (irrigated)	1	Full	14:45				15:15

Pre-burn residue load 8-1 ft2 samples/plot

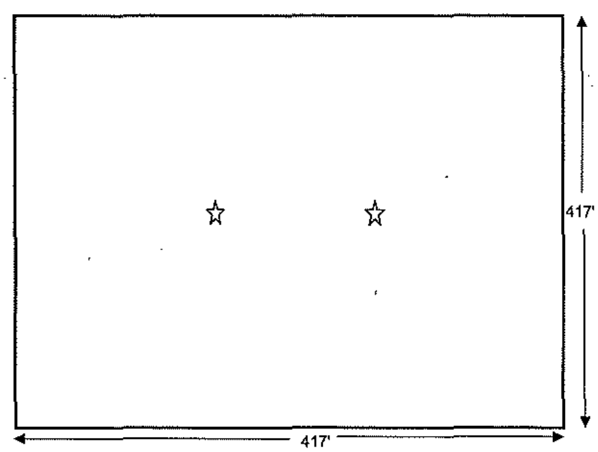
Pre-burn residue moisture 4-1 ft2 upper samples/plot and 4 lower stubble samples/plot

Post-burn residue 4-1 ft2 sample/plot

Soil moisture 4 samples/plot

☆ FASS Tower

FASS setting:
min. flame
min. smolder



COMMENTS:

Combine harvest 7/31/01 with residue scattered onto field.
Lit fire with propane torch mounted on a four wheel ATV.
Stubble height approximately 2". (Mean of 3 measurements)

Kentucky bluegrass emissions on an irrigated site in the Columbia Basin
Location: Connell, WA
Field: 2nd and final harvest 'Total Eclipse' KBG
Burn date: 8/9/01

Site	Rep	Residue Load	Propane Ignition Time	Flames to Towers	Smolder Only to Tower	Smolder Past Tower	Plot Out
Columbia Basin (irrigated)	2	Low	NW	14:30			15:07

Pre-burn residue load 8-1 ft2 samples/plot

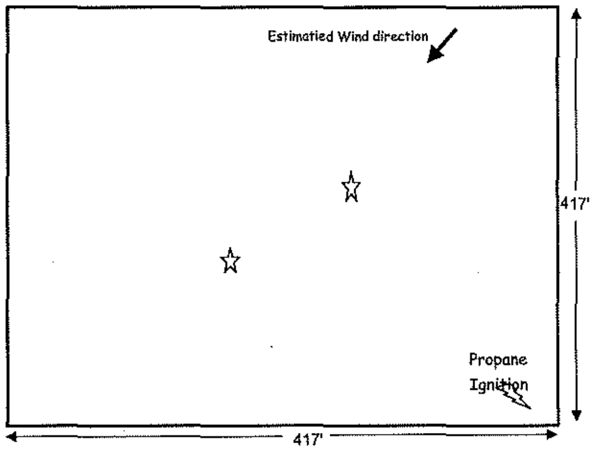
Pre-burn residue moisture 4-1 ft2 samples/plot

Post-burn residue 4-1 ft2 sample/plot

Soil moisture 4 samples/plot

☆ FASS Tower

FASS setting:
min. flame
min. smolder



COMMENTS:
Combine harvest 7/31/01 with residue scattered onto field.
Raked and baled 8/1/01.
Lit fire with an 18' wide propane flamer pulled with a tractor.
9 loops (18 passes) with propane burner (time to complete propane burn 25 min).
Stubble height approximately 2". (Mean of 3 measurements)

Kentucky bluegrass emissions on an irrigated site in the Columbia Basin
Location: Connell, WA
Field: 2nd and final harvest 'Total Eclipse' KBG
Burn date: 8/8/01

Site	Rep	Residue Load	Ignition Time	Flames to Towers	Smolder Only to Tower	Smolder Past Tower	Plot Out
Columbia Basin (irrigated)	2	Full	16:40				17:10

Pre-burn residue load 8-1 ft2 samples/plot

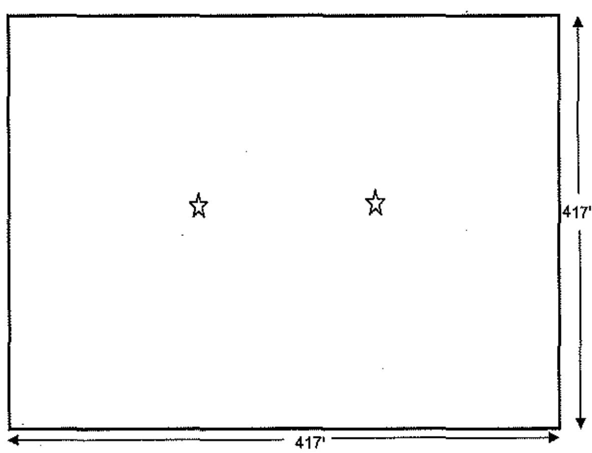
Pre-burn residue moisture 4-1 ft2 upper samples/plot and 4 lower stubble samples/plot

Post-burn residue 4-1 ft2 sample/plot

Soil moisture 4 samples/plot

☆ FASS Tower

FASS setting:
min. flame
min. smolder



COMMENTS:
Combine harvest 7/31/01 with residue scattered onto field.
Lit fire with burning residue and a pitchfork.
Stubble height approximately 2". (Mean of 3 measurements)

Kentucky bluegrass emissions on an irrigated site in the Columbia Basin

Location: Connell, WA

Field: 2nd and final harvest 'Total Eclipse' KBG

Burn date: 8/9/01

Site	Rep	Residue Load	Propane Ignition Time	Flames to Towers	Smolder Only to Tower	Smolder Past Tower	Plot Out
Columbia Basin (irrigated)	3	Low	15:40				16:20

Pre-burn residue load 8-1 ft2 samples/plot

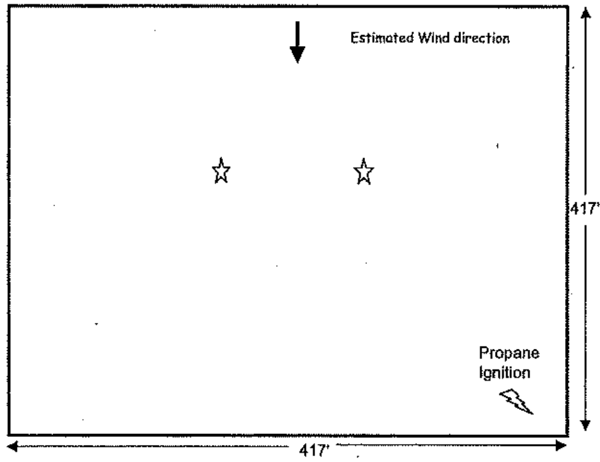
Pre-burn residue moisture 4-1 ft2 samples/plot

Post-burn residue 4-1 ft2 sample/plot

Soil moisture 4 samples/plot

☆ FASS Tower

FASS setting:
min. flame
min. smolder



COMMENTS:

Combine harvest 7/31/01 with residue scattered onto field.
Raked and baled 8/1/01.
Lit fire with an 18' wide propane flamer pulled with a tractor. Only 2 of the three burner booms worked. Therefore, only 12' swath burned behind flamer.
6 loops (12 passes) with propane burner (time to complete propane burn 20-25 min).
Stubble height approximately 2". (Mean of 3 measurements)

Location: Connell, WA (Columbia Basin)

Field: 2nd and final harvest 'Total Eclipse' KBG

Burn date: 8/8/01

Site	Rep	Residue Load	Ignition Time	Flames to Towers	Smolder Only to Tower	Smolder Past Tower	Plot Out
Columbia Basin (irrigated)	3	Full	14:08				14:31

Pre-burn residue load 8-1 ft2 samples/plot

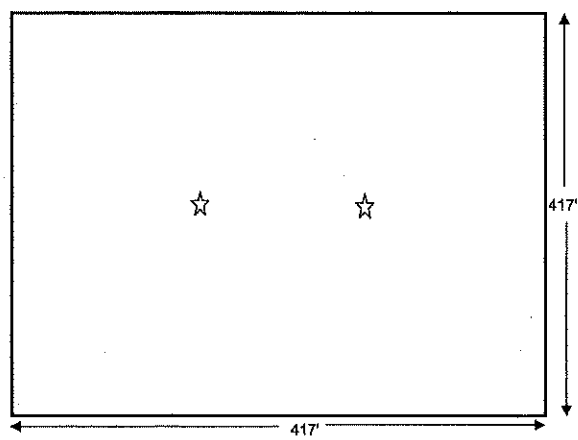
Pre-burn residue moisture 4-1 ft2 upper samples/plot and 4 lower stubble samples/plot

Post-burn residue 4-1 ft2 sample/plot

Soil moisture 4 samples/plot

☆ FASS Tower

FASS setting:
min. flame
min. smolder

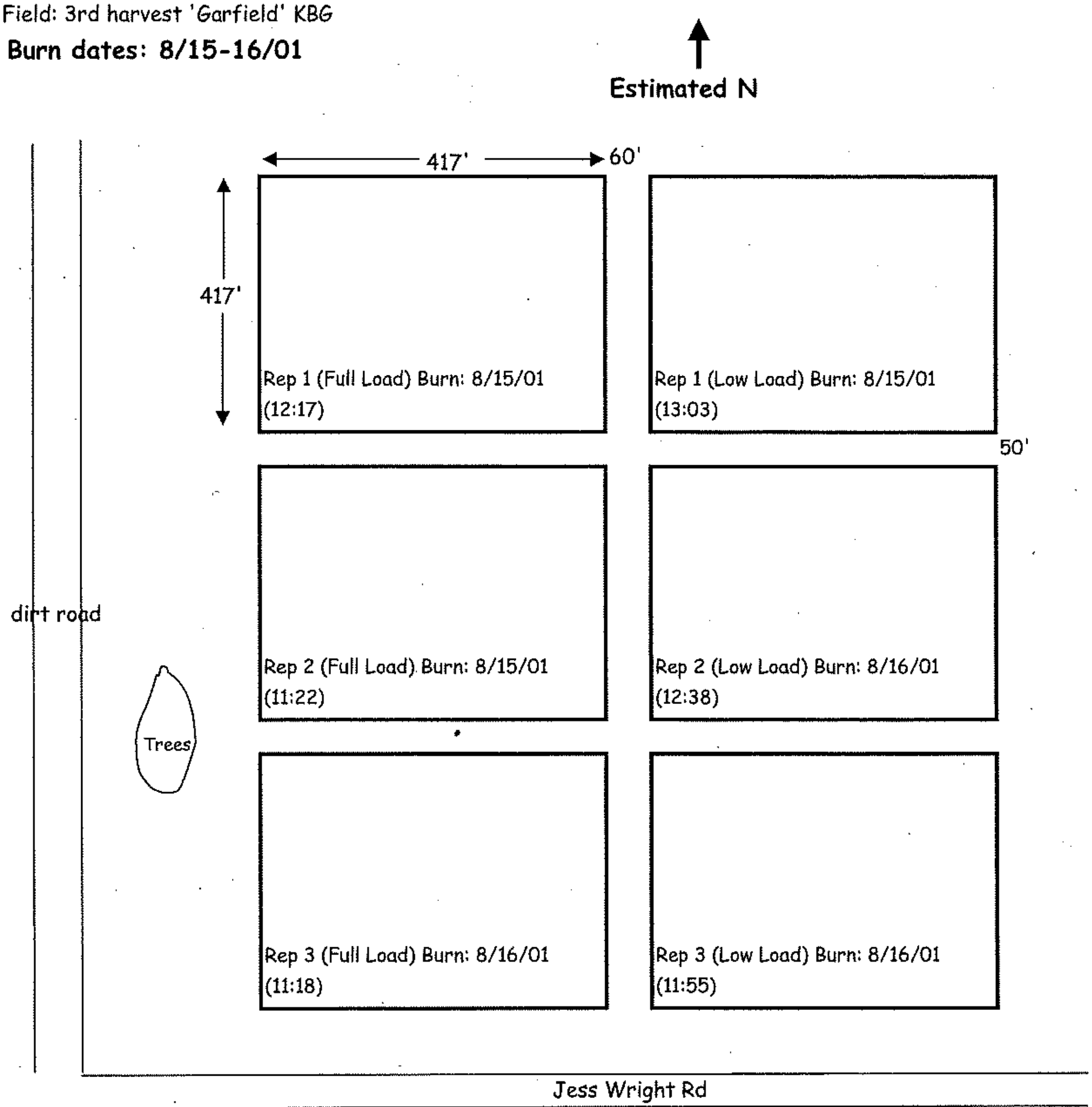


COMMENTS:

Combine harvest 7/31/01 with residue scattered onto field.
Lit fire with burning residue and a pitchfork.
Stubble height approximately 2". (Mean of 3 measurements)

Kentucky bluegrass emissions on a nonirrigated site in Northern Idaho
Location: Worley, ID
Field: 3rd harvest 'Garfield' KBG

Burn dates: 8/15-16/01



Kentucky bluegrass emissions on a dryland site in Northern Idaho
Location: Worley, ID
Field: 3rd harvest 'Garfield' KBG
Burn date: 8/15/01

Site	Rep	Residue Load	Ignition Time	Flames to Towers	Smolder Only to Tower	Smolder Past Tower	Plot Out
Worley (dryland)	1	Low	13:03	13:13		13:16	13:23

Pre-burn residue load 4-1 ft2 samples/plot

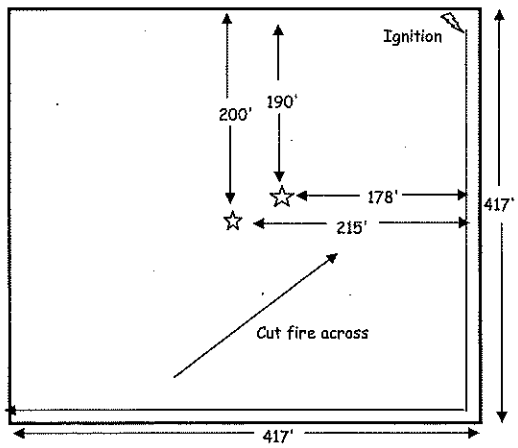
Pre-burn residue moisture 4-1 ft2 samples/plot

Post-burn residue 4-1 ft2 sample/plot

Soil moisture 4 samples/plot

☆ FASS Tower

FASS setting:
3 min. flame
20 min. smolder



COMMENTS:
Combine harvest 8/3/01 with residue scattered onto field.
Low residue reswathed and raked 8/5/01.
Low residue baled 8/6/01.
Lit fire with a propane torch mounted on an ATV.
Area burned in front of towers: 2.2 Acres

Kentucky bluegrass emissions on a dryland site in Northern Idaho
Location: Worley, ID
Field: 3rd harvest 'Garfield' KBG
Burn date: 8/15/01

Site	Rep	Residue Load	Ignition Time	Flames to Towers	Smolder Only to Tower	Smolder Past Tower	Plot Out
Worley (dryland)	1	Full	12:17	12:25		12:34	12:45

Pre-burn residue load 4-1 ft2 samples/plot

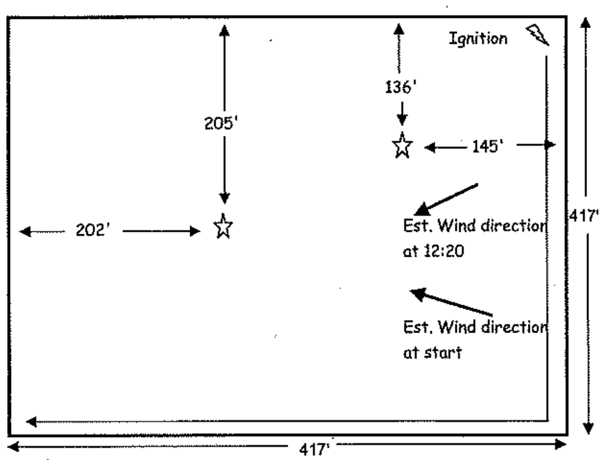
Pre-burn residue moisture 4-1 ft2 upper samples/plot and 4 lower stubble samples/plot

Post-burn residue 4-1 ft2 sample/plot

Soil moisture 4 samples/plot

☆ FASS Tower

FASS setting:
3 min. flame
20 min. smolder



COMMENTS:
Combine harvest 8/3/01 with residue scattered onto field.
Lit fire with a propane torch mounted on an ATV.
Wind direction at ignition NNE and wind shifted to NNW at 12:20.

Kentucky bluegrass emissions on a dryland site in Northern Idaho
Location: Worley, ID
Field: 3rd harvest 'Garfield' KBG
Burn date: 8/16/01

Site	Rep	Residue Load	Ignition Time	Flames to Towers	Smolder Only to Tower	Smolder Past Tower	Plot Out
Worley (dryland)	2	Low	12:38	12:41	12:43	12:52	12:53

Pre-burn residue load 4-1 ft2 samples/plot

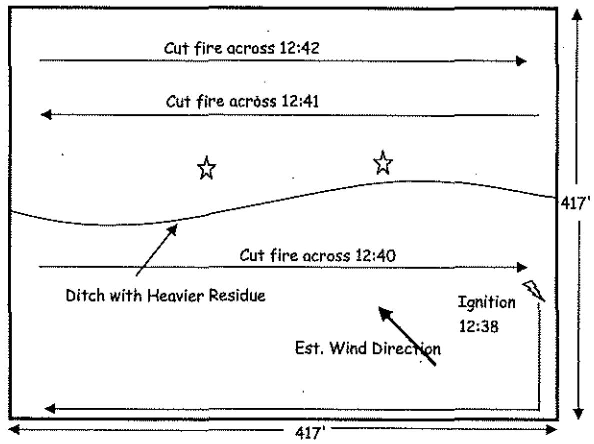
Pre-burn residue moisture 4-1 ft2 samples/plot

Post-burn residue 4-1 ft2 sample/plot

Soil moisture 4 samples/plot

☆ FASS Tower

FASS setting:
3 min. flame
20 min. smolder



COMMENTS:
Combine harvest 8/3/01 with residue scattered onto field.
Low residue reswathed and raked 8/5/01.
Low residue baled 8/6/01.
Lit fire with a propane torch mounted on an ATV.
Candice Claiborn samplers placed on top of hill east of this burn unit.

Kentucky bluegrass emissions on a dryland site in Northern Idaho
Location: Worley, ID
Field: 3rd harvest 'Garfield' KBG
Burn date: 8/15/01

Site	Rep	Residue Load	Ignition Time	Flames to Towers	Smolder Only to Tower	Smolder Past Tower	Plot Out
Worley (dryland)	2	Full	11:22			11:29	11:38

Pre-burn residue load 4-1 ft2 samples/plot

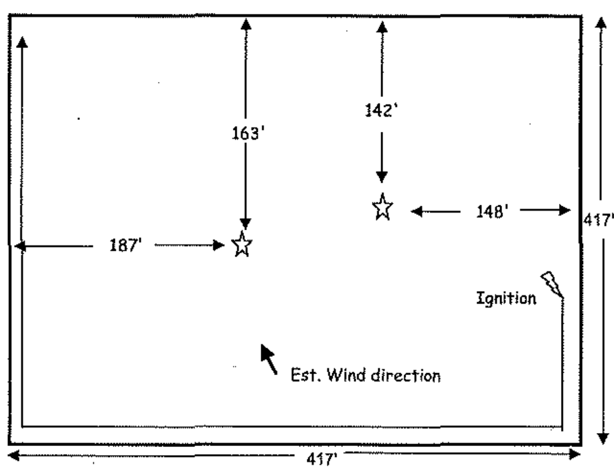
Pre-burn residue moisture 4-1 ft2 upper samples/plot and 4 lower stubble samples/plot

Post-burn residue 4-1 ft2 sample/plot

Soil moisture 4 samples/plot

☆ FASS Tower

FASS setting:
3 min. flame
20 min. smolder



COMMENTS:
Combine harvest 8/3/01 with residue scattered onto field.
Lit fire with a propane torch mounted on an ATV.

Kentucky bluegrass emissions on a dryland site in Northern Idaho
Location: Worley, ID
Field: 3rd harvest 'Garfield' KBG
Burn date: 8/16/01

Site	Rep	Residue Load	Ignition Time	Flames to Towers	Smolder Only to Tower	Smolder Past Tower	Plot Out
Worley (dryland)	3	Low	11:55	11:58		12:17	12:22

Pre-burn residue load 4-1 ft2 samples/plot

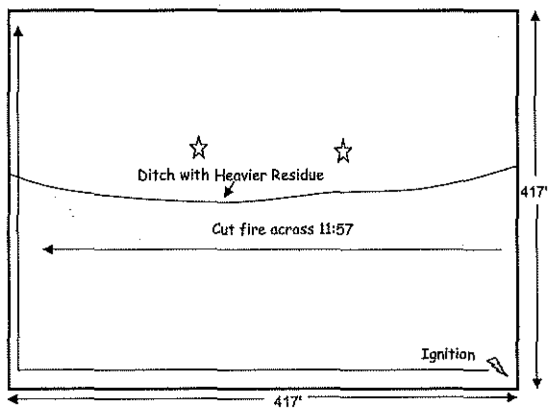
Pre-burn residue moisture 4-1 ft2 samples/plot

Post-burn residue 4-1 ft2 sample/plot

Soil moisture 4 samples/plot

☆ FASS Tower

FASS setting:
3 min. flame
20 min. smolder



COMMENTS:

Combine harvest 8/3/01 with residue scattered onto field.
Low residue reswathed and raked 8/5/01.
Low residue baled 8/6/01.
Lit fire with a propane torch mounted on an ATV.
Left tower got a lot of late smolder from ditch.

	Stubble Height (in)		
	slope		draw
	4.25		4.75
	4.25		2.75
	2.50		2.00
Avg	3.94	Avg	3.06

Kentucky bluegrass emissions on a dryland site in Northern Idaho
Location: Worley, ID
Field: 3rd harvest 'Garfield' KBG
Burn date: 8/16/01

Site	Rep	Residue Load	Ignition Time	Flames to Towers	Smolder Only to Tower	Smolder Past Tower	Plot Out
Worley (dryland)	3	Full	11:18	11:20		11:44	12:00

Pre-burn residue load 4-1 ft2 samples/plot

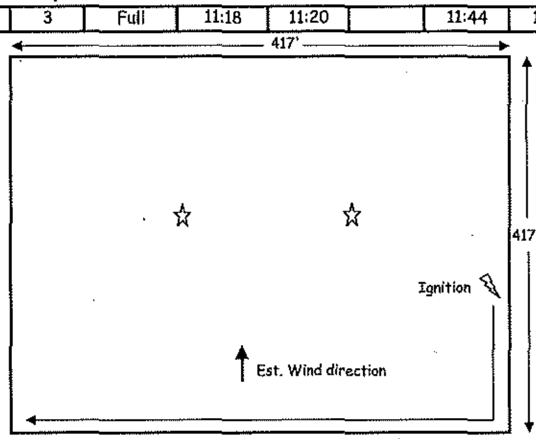
Pre-burn residue moisture 4-1 ft2 upper samples/plot and 4 lower stubble samples/plot

Post-burn residue 4-1 ft2 sample/plot

Soil moisture 4 samples/plot

☆ FASS Tower

FASS setting:
3 min. flame
20 min. smolder



COMMENTS:

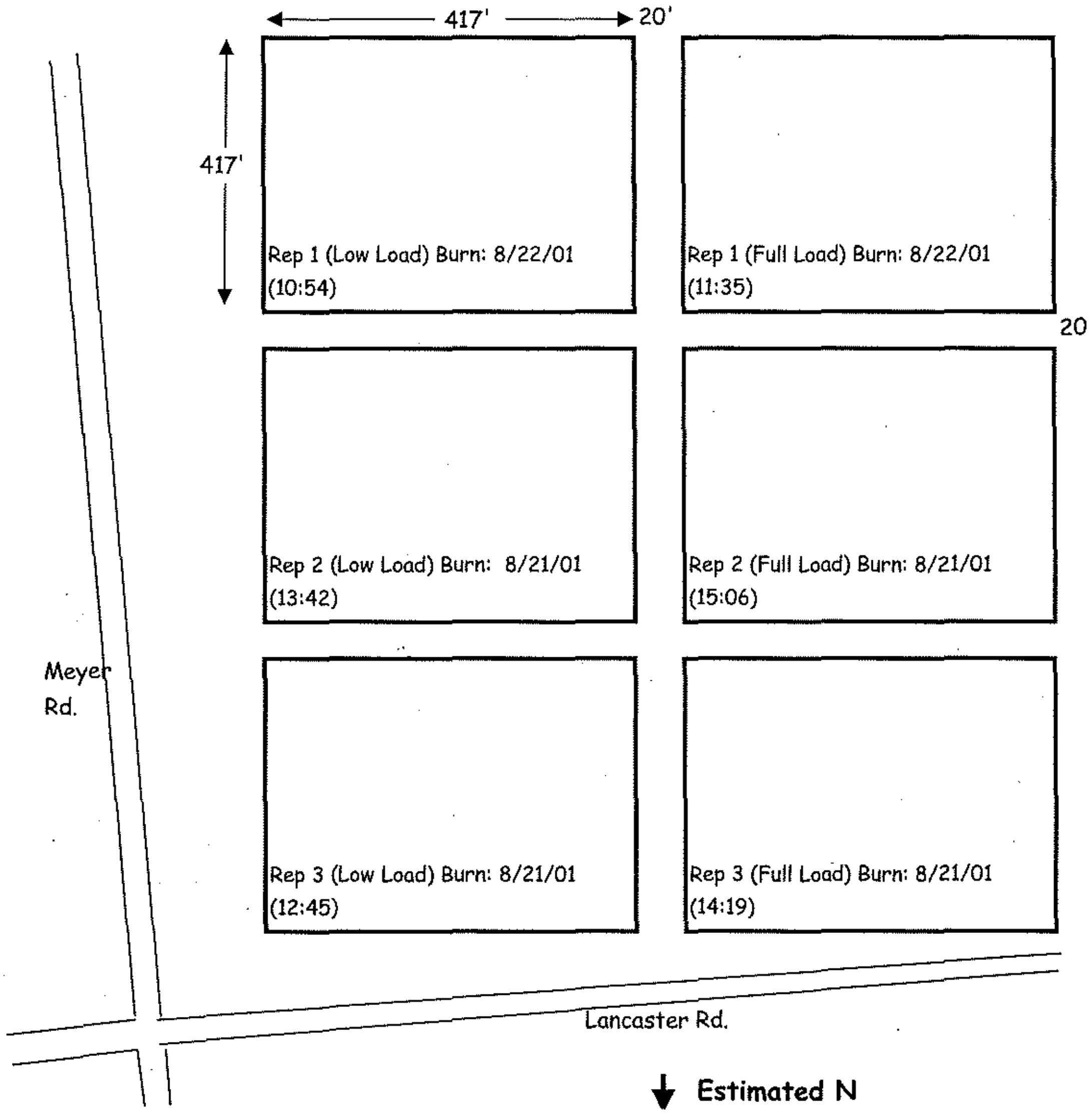
Combine harvest 8/3/01 with residue scattered onto field.
Lit fire with a propane torch mounted on an ATV.

Residue architecture:

	Top of Residue		Thickness of Top Residue	Soil Surface to bottom of Residue		Stubble Height (in)	
	8.00		3.50	4.50		7.00	11.25
	7.75		4.50	3.25		9.25	12.00
	5.75		3.25	2.50		7.75	7.25
	2.75		2.75	0.00		9.25	10.50
Avg	6.06	Avg	3.50	Avg 2.56	Avg	8.31	10.25

APPENDIX 4.2: RATHDRUM - PLOT PLANS AND FIELD NOTES

Kentucky bluegrass emissions on an irrigated site on the Rathdrum Prairie
Location: Rathdrum, ID
Field: 3rd harvest 'Alene' KBG
Burn dates: 8/21-22/01



Kentucky bluegrass emissions on an irrigated site on the Rathdrum Prairie
Location: Rathdrum, ID
Field: 3rd harvest 'Alene' KBG
Burn date: 8/22/01

Site	Rep	Residue Load	Ignition Time	Flames to Towers	Smolder Only to Tower	Smolder Past Tower	Plot Out
Rathdrum Prairie (irrigated)	1	Low	10:54	11:06	11:10	11:17	11:25

Pre-burn residue load 4-1 ft2 samples/plot

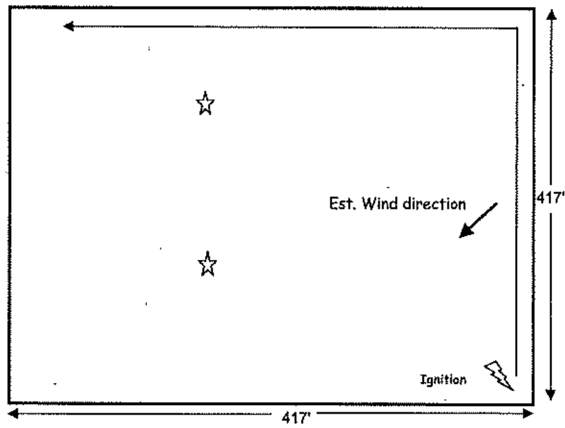
Pre-burn residue moisture 4-1 ft2 samples/plot

Post-burn residue 4-1 ft2 sample/plot

Soil moisture 4 samples/plot

☆ FASS Tower

FASS setting:
3 min. flame
20 min. smolder



Stubble Ht (in)
7.25
9.50
11.25
10.75
Avg 9.69

COMMENTS:
Swathed 7/4/01.
Combine harvest 7/23/01 with residue scattered onto field.
Raked and baled 8/6/01.
Lit fire with with a propane torch while driving pickup around burn unit.

Kentucky bluegrass emissions on an irrigated site on the Rathdrum Prairie
Location: Rathdrum, ID
Field: 3rd harvest 'Alene' KBG
Burn date: 8/22/01

Site	Rep	Residue Load	Ignition Time	Flames to Towers	Smolder Only to Tower	Smolder Past Tower	Plot Out
Rathdrum Prairie (irrigated)	1	Full	11:35	11:44	11:46	12:00	12:15

Pre-burn residue load 4-1 ft2 samples/plot

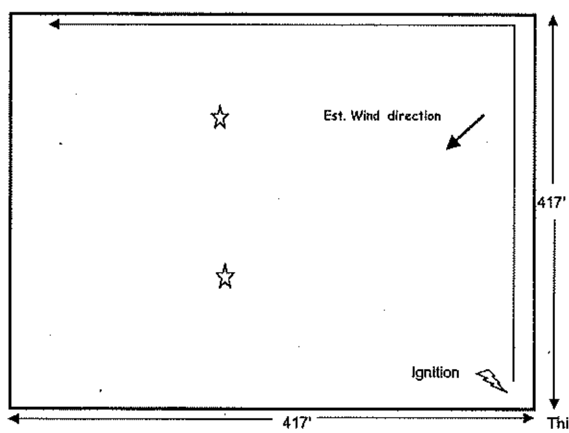
Pre-burn residue moisture 4-1 ft2 upper samples/plot and 4 lower stubble samples/plot

Post-burn residue 4-1 ft2 sample/plot

Soil moisture 4 samples/plot

☆ FASS Tower

FASS setting:
3 min. flame
20 min. smolder



COMMENTS:
Swathed 7/4/01.
Combine harvest 7/23/01 with residue scattered onto field.
Lit fire with with a propane torch while driving pickup around burn unit.

Top of Residue (in)	Thickness of Top Residue layer (in)	Surface to bottom of Residue layer (in)
8.00	3.00	5.00
5.50	4.00	1.50
10.00	4.00	6.00
Avg 7.83	Avg 3.67	Avg 4.17

Kentucky bluegrass emissions on an irrigated site on the Rathdrum Prairie

Location: Rathdrum, ID

Field: 3rd harvest 'Alene' KBG

Burn date: 8/21/01

Site	Rep	Residue Load	Ignition Time	Flames to Towers	Smolder Only to Tower	Smolder Past Tower	Plot Out
Rathdrum Prairie (irrigated)	2	Low	13:42			13:55	

Pre-burn residue load 4-1 ft2 samples/plot

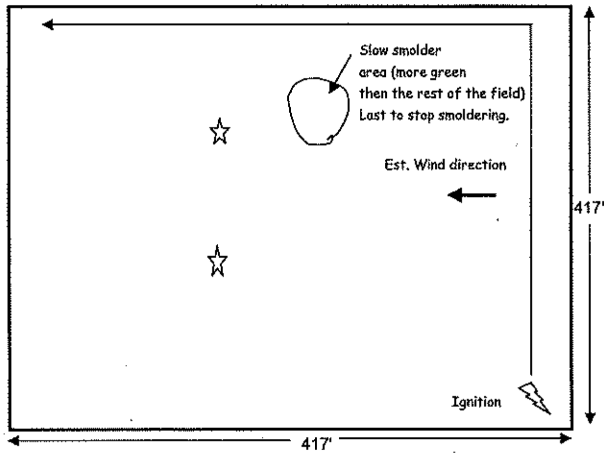
Pre-burn residue moisture 4-1 ft2 samples/plot

Post-burn residue 4-1 ft2 sample/plot

Soil moisture 4 samples/plot

☆ FASS Tower

FASS setting:
3 min. flame
20 min. smolder



COMMENTS:

Swathed 7/4/01.
Combine harvest 7/23/01 with residue scattered onto field.
Raked and baled 8/6/01.
Lit fire with with a propane torch while driving pickup around burn unit.

Location: Rathdrum, ID

Field: 3rd harvest 'Alene' KBG

Burn date: 8/21/01

Site	Rep	Residue Load	Ignition Time	Flames to Towers	Smolder Only to Tower	Smolder Past Tower	Plot Out
Rathdrum Prairie (irrigated)	2	Full	15:06			15:17	

Pre-burn residue load 4-1 ft2 samples/plot

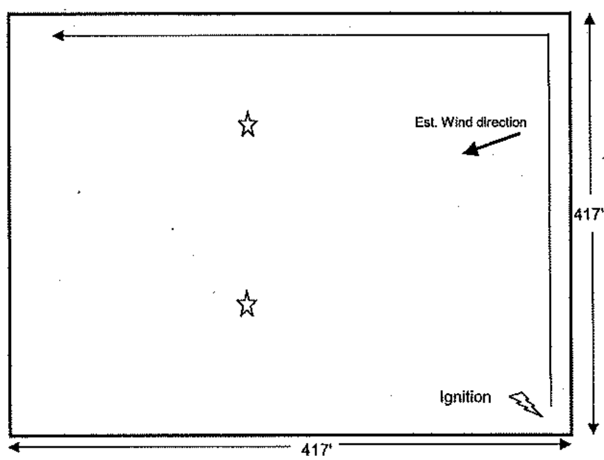
Pre-burn residue moisture 4-1 ft2 upper samples/plot and 4 lower stubble samples/plot

Post-burn residue 4-1 ft2 sample/plot

Soil moisture 4 samples/plot

☆ FASS Tower

FASS setting:
3 min. flame
20 min. smolder



COMMENTS:

Swathed 7/4/01.
Combine harvest 7/23/01 with residue scattered onto field.
Lit fire with with a propane torch while driving pickup around burn unit.

Kentucky bluegrass emissions on an irrigated site on the Rathdrum Prairie
Location: Rathdrum, ID
Field: 3rd harvest 'Alene' KBG
Burn date: 8/21/01

Site	Rep	Residue Load	Ignition Time	Flames to Towers	Smolder Only to Tower	Smolder Past Tower	Plot Out
Rathdrum Prairie (irrigated)	3	Low	12:45			13:03	

Pre-burn residue load 4-1 ft2 samples/plot

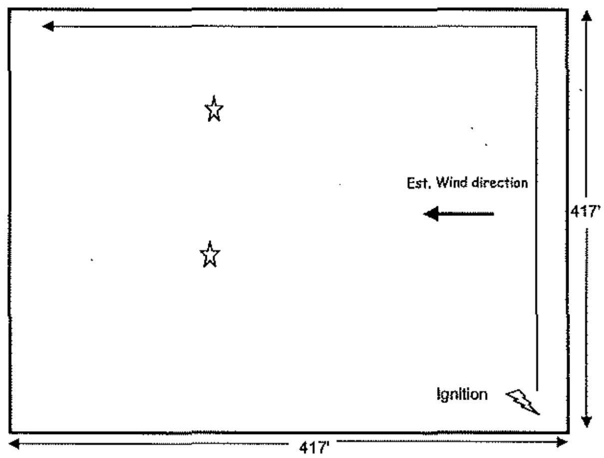
Pre-burn residue moisture 4-1 ft2 samples/plot

Post-burn residue 4-1 ft2 sample/plot

Soil moisture 4 samples/plot

☆ FASS Tower

FASS setting:
3 min. flame
20 min. smolder



COMMENTS:
Swathed 7/4/01.
Combine harvest 7/23/01 with residue scattered onto field.
Raked and baled 8/6/01.
Lit fire with with a propane torch while driving pickup around burn unit.

Kentucky bluegrass emissions on an irrigated site on the Rathdrum Prairie
Location: Rathdrum, ID
Field: 3rd harvest 'Alene' KBG
Burn date: 8/21/01

Site	Rep	Residue Load	Ignition Time	Flames to Towers	Smolder Only to Tower	Smolder Past Tower	Plot Out
Rathdrum Prairie (irrigated)	3	Full	14:19			14:37	

Pre-burn residue load 4-1 ft2 samples/plot

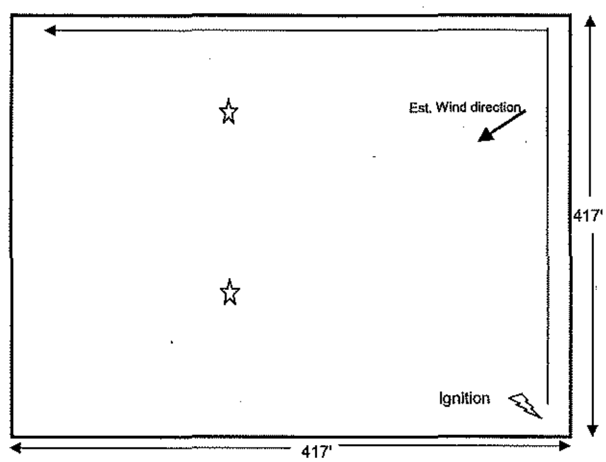
Pre-burn residue moisture 4-1 ft2 upper samples/plot and 4 lower stubble samples/plot

Post-burn residue 4-1 ft2 sample/plot

Soil moisture 4 samples/plot

☆ FASS Tower

FASS setting:
3 min. flame
20 min. smolder



COMMENTS:
Swathed 7/4/01.
Combine harvest 7/23/01 with residue scattered onto field.
Lit fire with with a propane torch while driving pickup around burn unit.

APPENDIX 5. Percentage of $PM_{2.5}$ emissions in flaming and smoldering combustion phases.

Study Site and Residue Loading	Flaming (%)	Smoldering (%)
Connell WA, irrigated		
High loading	93.0 (n=4)	7.0 (n=4)
Low loading	71.0 (n=2)	29.0 (n=2)
Rathdrum ID, irrigated		
High loading *	99.3 (n=4)	0.7 (n=4)
Low loading **	100.0 (n=3)	0.0 (n=4)
Worley ID, dryland		
High loading	95.8 (n=4)	4.2 (n=4)
Low loading ***	98.8 (n=5)	1.2 (n=5)

* Exclude 2 outliers; ** Excluded 1 outlier; *** Excluded 1 outlier

Appendix 6. QUALITY ASSURANCE PROJECT PLAN FOR THE WASHINGTON STATE UNIVERSITY FIELD RESEARCH ON QUANTIFYING POST-HARVEST EMISSIONS FROM GRASS FIELD BURNING

Prepared by Dan Redline, Idaho Department of Environmental Quality
Prepared for:

Washington State University
Department of Crop and Soil Sciences
Pullman, Washington 99164-6420

6.1. QUALITY ASSURANCE PROJECT PLAN IDENTIFICATION

Title: Quality Assurance Project Plan for Washington State University Field Research on Quantifying Post-harvest Emissions from Grass Field Burning

*This QAPP became a requirement after the field work for the project was already complete, therefore, the approval page has been modified to show the various project managers and grant coordinators associated with this study.

Project Manager -- William. J. Johnston, Professor/Agronomist, Department of Crop and Soil Sciences, WSU, Pullman, WA

Assistant Project Manager -- Mark. D. Schaaf, Associate Atmospheric Scientist, Air Sciences Inc., Portland, OR.

Assistant Project Manager – Ron Babbitt, Electrical Engineer, USFS Missoula Fire Science Lab, Missoula, MT.

USEPA Grant Manager – Robert Kotchenruther, Ph.D. Environmental Scientist, EPA Region 10 Seattle, WA.

Idaho Department of Environmental Quality Project Coordinator – Dan Redline, Air Quality Analyst, Coeur d'Alene Regional Office, ID.

Washington Department of Ecology Project Coordinator – Karen Wood, Agricultural Burn Team Leader, Spokane Regional Office, WA.

Coeur d'Alene Indian Tribe Coordinator – Marvin Sonder**, Agricultural Burn Team, Plummer, ID.
**As of April 2003, Mr. Sonder is no longer a member of the Coeur d'Alene Tribe Agricultural burn team.

6.2. TABLE OF CONTENTS

DISTRIBUTION LIST

William Johnston	Washington State University
Mark Schaaf	Air Sciences Inc.
Ron Babbitt	USFS Missoula Fire Science Laboratory
Robert Kotchenruther	EPA Region 10
Karen Wood	Washington Department of Ecology
Les Higgins	Coeur d'Alene Indian Tribe
Linda Clovis	North Idaho Farmers' Association
Art Schultheis	Washington Turfgrass Seed Commission
Dan Redline	Idaho DEQ

6.4. PROJECT ORGANIZATION

6.4.1 Principal Investigators:

W. J. Johnston, Professor/Agronomist, Department of Crop and Soil Sciences, WSU, Pullman, WA.

M. D. Schaaf, Associate Atmospheric Scientist, Air Sciences Inc., Portland, OR.

6.4.2 Cooperators:

Missoula Fire Sciences Laboratory, USDA Forest Service, Missoula, MT. Will provide instrumentation and staff for emissions collection at the burn sites.

DataChem Laboratories*, Salt Lake City, UT. Will perform chemical analysis.
*Southwest Research Institute, San Antonio, TX, was subcontracted by MFSL. Southwest Research Institute was the same subcontractor utilized by MFSL in the eastern Washington cereal emissions study.

C. Claiborn, Assoc. Professor, CEE, WSU. Will participate in emissions monitoring as able.

Washington Turfgrass Seed Commission, Pasco, WA. Growers will provide research sites and provide field assistance as necessary.

North Idaho Farmers' Association, Coeur d'Alene, ID. Growers will provide research sites and provide field assistance as necessary.

6.4.3 Potential Data Users:

WA DOE and IDEQ -- Will use emission estimates for evaluating the impacts of agricultural burning to the environment.

Idaho State Department of Agriculture (ISDA) and WA DOE -- Will use data to assist with policy decisions regarding agricultural smoke management programs.

Growers and Grower Organizations. Use data to improve their understanding of air quality impacts and better manage KBG residue burning.

6.5. PROBLEM DEFINITION AND BACKGROUND

6.5.1. Objective

Quantify, under field conditions at dryland and irrigated sites, with and without residue removal, amount of selected emissions generated by Kentucky bluegrass seed production post-harvest residue field burning.

6.5.2. Description of Problem

The amount of residue loading is one of the factors used to estimate emissions from burning residue in KBG fields. It has been hypothesized that reducing the residue loading should reduce the amount of emissions produced by open-field burning. Others have speculated that reducing the residue loading will lower the combustion efficiency of the burn and actually increase emissions from the same field. Growers have experimented with residue reduction followed by open-field burning over the past few years with anecdotal observations of the smoke plumes. To date, the research community has not conducted scientific measurements of the emissions from KBG fields with residue treatments combined with open-field burning.

This study was designed to quantify emissions from burning full-straw load fields versus the emissions from burning fields treated by residue removal. This study will measure the emissions for the following list of pollutants/compounds; $PM_{2.5}$, PM_{10}, carbon monoxide, benzo(a)pyrene (BaP) [a PAH], and six additional BaP-equivalent carcinogens listed in WAC 173-460-050(4)(c), including benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indenol(1,2,3-cd)pyrene.

This study will evaluate emissions generated from grass seed production fields with fuel reductions in comparison to those burned without fuel reductions in an effort to reduce emissions. The information obtained from this study will help establish appropriate burning practices needed to significantly reduce emissions, contribute to the scientific database on agricultural burning emissions, as well as provided data to direct future research. This study will provide the public with additional information about the chemical make-up of smoke from burning KBG fields following harvest. This has been an on-going concern related to the public health impacts often associated with this agricultural practice.

A similar study was conducted on cereal grain residue in Washington in 2000. A final report entitled, "Cereal-Grain Residue Open-field Burning Emissions Study" is available through the Washington State Department of Ecology.

6.5.3. Background

Fire has long been used as a management tool in grass seed production (Burton, 1944; Conklin, 1976; Chilcote et al., 1978; Hardison, 1980; Johnston et al., 1996; Kamm and Montgomery, 1990; Mazzola et al., 1997; Schirman, 1997). However, increasing concerns over the health impact of emissions from open-field burning have pointed to the need for information on grass fire emissions. Although some data are currently available that identify and quantify the various chemical components of grassfire emissions in the Pacific Northwest (Adams, 1976; Boubel et al., 1969; Jenkins, et al., 1996), and biomass burning (Crutzen and Andreae, 1990; Kuhlbusch et al., 1991), little research has been performed with residue reduction-flaming (bale and burn) systems. Because mechanical residue removal is an option growers can use to reduce the fuel load on grass fields, emissions from fields where residue has been removed and fields with typical post-harvest residue fuel loads will be studied. Although past WSU research, in a never completed project, indicated increased emissions with residue removal and open-field burning (Adams, 1976), current WSU research with residue reduction (baling) followed by diesel or propane flaming indicates the possibility of reduced emissions and reduced smoldering while maintaining good seed yield (Felgenhauer, personal communication, 1999; Johnston, 1997). Characterization of particulate emissions from the 'bale and flame/burn' system are needed since a cooler burn, compared to open-field burning, is possible. Ultimately, smoke reduction and management should be based on emissions rather than number of acres burned. However, insufficient research on grassy fuels has been conducted to characterize emissions to the degree necessary for the development of BMPs.

6.6. PROJECT/TASK DESCRIPTION

The study design and work plans for this project evolved from previous efforts to complete this work with other partners. The project managers reworked the tasks and work teams to meet the financial limitations and time constraints this project faced. The project tasks and work assignments are described below.

Task 1: Experimental Plan. Washington State University (WSU) will prepare the proposal and a comprehensive experimental monitoring plan (Task list).

Task 2: Unit Identification and Treatments. WSU will identify three, 20- to 50-acre minimum (depending on size of burn units) study sites in eastern Washington (Site 1, Columbia Basin) and northern Idaho (Site 2, dryland site in north Idaho and Site 3, irrigated site in north Idaho) during late spring and early summer, 2001. Two alternative residue treatments will be evaluated at each site: no residue treatment ("full load"), and pre-burn baling ("reduced load"). Each treatment will consist of three separate 2- to 8-acre burn units (replications). A total of 18 burns will be conducted (3 sites, 2 residue loads, and 3 replications).

Task 3: Unit Layout. WSU will stake the corners of each burn unit with wooden stakes. A firebreak will be constructed around each burn unit of a type and size adequate to stop the forward progress of fire under the most extreme conditions that are likely to occur at each site. The host grower will be responsible for constructing and maintain the firebreak, for igniting the fire under the conditions prescribed by the principle investigators, and for providing fire suppression equipment and personnel during the burn in order to respond in the event of an escaped fire.

Task 4: Pre-burn Residue Loading. The pre-burn surface fuel loading within each burn unit will be characterized. The residue loading will be determined by destructive sampling at random locations within the burn units. Air Sciences Inc. will provide one technician with past residue sampling experience at the initial burn site (Site 1, Columbia Basin) to assist in performing pre-burn fuel sampling (on site labor 6 hours). WSU will provide 3 technicians to assist at initial site (Site 1) and will be responsible for performing the pre-burn fuel sampling at Sites 2 and 3. Following sampling, WSU will be responsible for handling the samples, laboratory analysis, and transmitting the pre-burn residue dry weight data electronically to Air Sciences Inc.

Task 5: Pre-burn Moisture Sampling. Immediately prior to the burn, the moisture content of the grass residue and the upper layer of soil will be characterized. Air Sciences Inc. will provide one technician with past residue and moisture sampling experience at the initial burn site (Site 1) to assist in performing sampling. WSU will provide 3 technicians to assist Air Sciences at Site 1 and will be responsible for performing the pre-burn moisture characterization at additional sites. Following sampling, Washington State University will be responsible for handling the samples, laboratory analysis, and transmitting the pre-burn residue moisture and soil moisture data electronically to Air Sciences Inc.

Task 6: Emissions Monitoring. Missoula Fire Science Laboratory (MFSL) will perform the emissions monitoring using the Missoula Fire Science Laboratory's Fire-Atmosphere Sampling System (FASS). FASS is a tower-based system that measures real-time emissions (Susott et al., 1991b; Ward et al., 1992a). The computer control system, battery, pumps and flow meter, manifolds, particulate matter filters (Teflon and glass), real time analyzers, and the three-part gas collection system (one part for each phase of the burn, i.e., flaming, transitional, and smoldering;

note: in study only two phases were recorded, flaming and smoldering) are buried near the instrumentation towers. Two guyed instrument towers (two sub-samples per plot) holding the FASS equipment will be erected on each plot. Air Sciences Inc. will also provide one experienced field technician for directing the emissions sampling, given the assistance of at least two experienced field technicians provided under a contract with the Missoula Fire Sciences Laboratory.

Air Sciences will provide a portable meteorological station for use in monitoring and recording the meteorological events during each of the burns at each of the sites.

Task 6 also includes post-burn residue sampling of each of the 18 burn units. WSU will provide 3 technicians to assist Air Sciences in performing the post-burn residue sampling at Site 1. WSU will perform the post-burn residue sampling at Sites 2 and 3. Following sampling, WSU will be responsible for handling the samples, laboratory analysis, and transmitting the post-burn residue dry weight data electronically to Air Sciences Inc.

Task 7: Sample Analyses. The Missoula Fire Sciences Laboratory will be responsible for Task 7. Following the burn, MFSL will analyze the filter and gas samples for the following constituents: PM_{10}, $PM_{2.5}$, CO, benzo(a)pyrene (BaP) [a PAH], and six additional BaP-equivalent carcinogens listed in WAC 173-460-050(4)(c), including benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indenol(1,2,3-cd)pyrene. PAHs need not be measured directly in the field; they will be determined from laboratory analysis of the filter samples. The $PM_{2.5}$ samples collected on glass-fiber filters for total mass and speciated PAH mass will be analyzed at DataChem Laboratories (DCL) at Salt Lake City, UT. The DCL facility in Salt Lake City is the National Institute for Occupational Safety and Health contract laboratory for analytical chemistry services. The Missoula Fire Sciences Laboratory will be responsible for all gas and filter sample analysis and for providing the data to Air Sciences Inc.

Task 8: Burn Characteristics. WSU and Air Sciences will share the responsibility of documenting the characteristics of each experimental burn. Burn characteristics will include: date and time of burning, type of fire and ignition pattern, air temperature, relative humidity, and mid-flame wind speed. Flame length, flame depth, flame angle, flame height, fire line depth, and rate of fire spread will be estimated and recorded on each burn if the conditions permit. In addition, each burn may be videotaped in order to more fully document the evolution and characteristics of each burn. Air Sciences and WSU will perform these tasks in conjunction with those listed under Task 6, Emissions Monitoring.

Task 9: Calculations, Data Analysis, and Interpretation. Air Science will compute the residue consumption, pollutant-specific emission factors, and total pollutant-specific emissions according to standard calculating procedures:

Equation 1. Pre- and Post-burn loading – Standard units conversion.

Equation 2. Residue Moisture Content – Calculated (Air Sciences Inc., 2002).

Equation 3. Bulk density, layer – Defined as dry weight (mass) per volume (Turgeon, 2002).

Equation 4. Bulk density, entire – Standard calculation by addition.

Equations 5 and 6. Residue consumption, absolute and relative – Calculated (Air Sciences Inc., 2002).

Equation 7. Emissions factors - Calculated (Ward et al., 1992b).

Equation 8. Emission factor for PAH – (Ward et al., 1992b).

Equations 9 and 10. Total $PM_{2.5}$ emissions – Standard calculation, units canceling.

Air Sciences will be responsible for interpretation of emissions data.

Task 10: Report. The results will be documented in a technical report (e.g., Air Sciences Inc., Experimental design: cereal grain crop open-field burning emissions study [draft], Project 152-01, Sect. 6.6, January 2000). WSU and Air Sciences Inc. will share the responsibility for completing this task. Air Sciences will provide technical assistance in developing the report (maximum of 32 hours). WSU will assume primary responsibility for oral reports and presentations to grower groups, environmental agencies, and other stakeholders as warranted and residual project funding permits.

Plot Layout in Test Fields: Plot size = 4 acres per treatment (experimental unit)

Full residue Load	Full residue Load	Full residue Load
Residue Reduced	Residue Reduced	Residue Reduced

Test Field Locations:

Connel, WA – irrigated field in Franklin County; cultivar 'Total Eclipse'

Rathdrum, ID – irrigated field (Rathdrum Prairie) Kootenai County; cultivar 'Alene'

Worley, ID – dryland field (Coeur d'Alene Tribe Reservation) in Kootenai County; cultivar 'Garfield'

6.7 DATA QUALITY OBJECTIVES

This project will collect field and laboratory data to determine the following parameters for each field type (dryland or irrigated) and residue treatment (full-load or baled) burned under the test conditions described earlier.

Pre-burn Residue Loading (dry mass) = tons/acre
Post-burn Residue Loading (dry mass) = tons/acre
Residue Moisture Content = percent moisture on dry weight basis
Residue Consumption = pre-burn minus post-burn residue loading (tons/acre)
Residue Thickness = inches
Combustion Efficiency = percent
PM_{10} emission factor = lb/ton residue consumed
$PM_{2.5}$ emission factor = lb/ton residue consumed
CO emission factor = lb/ton residue consumed
Emission factors for PAH's; benzo(a)pyrene , benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indenol(1,2,3-cd)pyrene = tons/acre

For this project, the emission measurements are collected with the intent to quantify the effect of residue management on open-field burning of KBG fields. The information obtained from this study will help establish appropriate burning practices needed to significantly reduce emissions, contribute to the scientific database on agricultural burning emissions, as well as provide data to direct future research.

For certain parameters, such as residue loading, the data is based on well-established techniques that have been used countless other agricultural studies. Because there has been little or no quantitative field measurements in past of emissions from Kentucky bluegrass seed fields or other grassy fuels, the emissions portion of this project is more research oriented which entails the use of trial and error techniques to establish proven methods for future studies. The emission measurement techniques were originally developed for forest fuel types and the equipment was modified for grassy fuels in this study. The modified technique was field tested for the cereal grain emission study conducted in the spring and fall of 2000 (Air Sciences Inc., 2003).

6.7.1 Data Quality Indicators

This project will rely on experienced field and laboratory personnel to collect data that will meet accepted data quality indicators. Data quality indicators are listed below.

- ***Precision*** - "Precision is a measure of agreement between two replicate measurements of the same property, under prescribed similar conditions. This agreement is calculated as either the range or as the standard deviation." (US EPA QA/G-5, Appendix D). This is the random component of error.

- ***Bias*** - "Bias is the systematic or persistent distortion of a measurement process that causes errors in one direction." (US EPA QA/G-5, Appendix D) Bias is determined by estimating the positive and negative deviation from the true value as a percentage of the true value.

- ***Comparability*** - "Comparability is the qualitative term that expresses the confidence that two data sets can contribute to a common analysis and interpolation. Comparability must be carefully evaluated to establish whether two data sets can be considered equivalent in regard to the measurement of a specific variable or groups of variables." (US EPA QA/G-5, Appendix D).

- **Representativeness** - "Representativeness is a measure of the degree to which data accurately and precisely represent a characteristic of a population parameter at a sampling point or for a process condition or environmental condition. Representativeness is a qualitative term that should be evaluated to determine whether in situ or other measurements are made and physical samples collected in such a manner that the resulting data appropriately reflect the media and phenomenon measured or studied." (US EPA QA/G-5, Appendix D).

- ***Completeness*** – "Completeness is a metric quantifying the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under correct, normal conditions. Completeness can be expressed as a ratio or a percentage." Data completeness requirements are included in the reference methods (40 CFR Part 50).

6.7.2 General Data Quality Objectives

All data shall be of a known and documented quality. The level of quality required for each specific monitoring project shall be established during the initial planning stages of the project and will depend upon the data's intended use. Two major measurements used to define quality are precision and bias. Refer to Section 6.7.1 for definitions of the metrics precision and bias.

All data shall be comparable. This means all data shall be produced in a similar and scientific manner. The use of the standard methodologies for sampling, calibration, audition, etc. found in the QAPP should achieve this goal.

All data shall be representative of the parameters being measured with respect to time, location, and the conditions from which the data are obtained. The use of the standard methodologies contained in the QAPP should ensure that the data generated are representative.

Ideally, a 95% confidence of both precision and bias should be maintained with a ±15% difference or better between the actual amount of an introduced parameter (to a measurement system) and the indicated response of the measurement system.

6.8 TRAINING REQUIREMENTS

No special training for the field staff or the laboratory staff was required prior to completion of this project. Because this project involved the cooperation of growers and the use of their fields for the test burns, the project managers and technical staff will discuss specific tasks and needs with the growers to best coordinate the research work with the farm operations. Field technicians were advised of fire safety concerns during the test burns to insure personnel safety and to protect equipment and property.

6.9 DOCUMENTS AND RECORDS

6.9.1 Notebooks

Each field and laboratory technician will be responsible for obtaining appropriate field notebooks. These notebooks will be uniquely numbered and associated with the individual and/or a specific program. The notebooks will be used to record information about the field sampling and laboratory operations, as well as document routine operations.

Field Notebooks - Notebooks will be used for each sampling site, specific program, or individual. Each notebook should be hardbound and paginated. Appropriate data entry forms may be used instead of notebooks; however, these forms are not required for routine operations, inspection and maintenance operations, or SOP activities as long as the information is contained in a notebook.

Lab Notebooks – An electronic database typically exists in which the laboratory retains all records pertaining to equipment calibrations and materials tracking, preparation, storage, and disposal, as well as general comments and notations and other pertinent information required for support of the analytical activities completed by the laboratory.

6.9.2 Electronic Data Collection

Certain instruments can provide an automated means for collecting information that would otherwise be recorded on data entry forms. In order to reduce the potential for data entry errors, automated systems will be utilized where appropriate and will record the same information that would be recorded on data entry forms. In order to provide a backup, a hard copy of automated data collection information will be stored for the appropriate time frame in project files.

6.10 DATA GENERATION AND ACQUISITION

The following sections describe the experimental design for this research project with major tasks organized together and a discussion of the quality control measures employed for each section where appropriate. The experimental design was used as the basis for grant work plans and contractual agreements to complete various tasks or subtasks.

6.10.1 Experimental Design

Task 1: Experimental Plan.
Washington State University (WSU) will prepare the proposal and a comprehensive experimental monitoring plan (Task list). Air Sciences Inc. will review the experimental plan (Air Sciences labor 4 hour).

Task 2: Unit Identification and Treatments.
Washington State University will identify three, 20- to 50-acre minimum (depending on size of burn units) study sites in eastern Washington (Site 1, Columbia Basin) and northern Idaho (Site 2, dryland site in north Idaho and Site 3, irrigated site in north Idaho) during late spring and early summer, 2001. Two alternative residue treatments will be evaluated at each site: no residue treatment ("full load"), and pre-burn baling ("reduced load"). Each treatment will consist of three separate 2- to 8-acre burn units (replications). A total of 18 burns will be conducted (3 sites, 2 residue loads, and 3 replications). WSU will select the burn units in consultation with Air Sciences Inc. (Air Sciences may, but will not be required to, make site visits for unit identification and can lend expertise via phone, email, etc.). WSU will be responsible for contacting the prospective host growers to obtain their consent.

Task 3: Unit Layout.
WSU will be responsible for Task 3. WSU will stake the corners of each burn unit with wooden stakes. A firebreak will be constructed around each burn unit of a type and size adequate to stop the forward progress of fire under the most extreme conditions that are likely to occur at each site. The host grower will be responsible for constructing and maintain the firebreak, for igniting the fire under the conditions prescribed by the principle investigators, and for providing fire suppression equipment and personnel during the burn in order to respond in the event of an escaped fire. The grower(s) will be responsible for any and all costs related to establishing the firebreak around each burn unit and any costs incurred in the event of an escaped fire.

Task 4: Pre-burn Residue Loading.
The pre-burn surface residue loading within each burn unit will be characterized. The residue loading will be determined by collecting all above ground residue at random locations within the burn units. Air Sciences will provide 3 cordless rechargeable grass clippers to aid in the pre-burn sampling. WSU will supply additional materials required to obtain pre-burn residue samples (Air Sciences and WSU will consult, via phone, etc., as to sampling technique and materials required). Following sampling, WSU will be responsible for handling the samples, laboratory analysis, and transmitting the pre-burn residue dry weight data electronically to Air Sciences Inc.

Surface residue loading will be taken at 4 random locations (subsamples) within each treatment at the Worley and Rathdrum sites and at 8 random locations at the Columbia Basin site.

- A 1-foot square constructed of PVC pipe will be used to determine the area to sample.
- Battery powered clippers will be used to cut vertically down through the residue around the perimeter of the PVC square and to cut the standing stubble as close to the ground as possible. Extra care will be taken to make sure that noncombustible material (i.e. soil, rocks,

etc.) will not be included in any sample. All residue within the one square foot area, which includes standing and loose straw, will be taken for surface residue loading.

- The clipped residue will be put into paper bags (labeled by site, treatment, replication and subsample), stapled shut, transported to WSU, dried in a forced air oven at 50°C for 5 to 7 days, and weighed to determine amount of pre-burn surface fuel. Samples will be weighed on a Mettler balance to two decimals. Any samples with outlying values will be examined to determine if they contain noncombustible material. If so, that material will be removed and the samples will be redried and reweighed. Residue will be expressed on a dry weight basis per unit area.
- Data will be emailed to Air Sciences Inc. in an Excel spreadsheet.

Pre-burn Fuel Load Architecture

- Stubble height will be measured with a ruler at 3 to 4 random locations (subsamples) within each burn unit.
- In the full residue treatment where residue layering is anticipated, the residue will be partitioned and measured to top of residue, thickness of residue, and soil surface to bottom of the residue layer. This will be done by carefully exposing a profile of the residue (cross-section) prior to measurement.
- Thickness of the residue layer is determined by subtraction.

Task 5: Pre-burn Moisture Sampling.

Immediately prior to the burn, the moisture content of the grass residue and the upper layer of soil will be characterized. Following sampling, WSUwill be responsible for handling the samples, laboratory analysis, and transmitting the pre-burn residue moisture and soil moisture data electronically to Air Sciences Inc. If possible, these tasks will be performed in conjunction with those listed under Task 4, Pre-burn Residue Loading.

Residue Samples:

- Pre-burn residue moisture will be taken at 4 random locations (sub-samples), each one square foot in area, within each treatment (burn unit) at each of the three sites.
- Residue from the full residue load burn units will be divided and bagged separately into upper (loose grass straw) and lower (standing grass stubble) samples. Sample procedures will be the same as mentioned in Task 4.
- Residue will be put into pre-dried, pre-weighed, and pre-numbered 'Ziploc' plastic bags immediately after being sampled.
- The samples will be kept in an ice chest, transported to WSU, weighed to determine fresh weight, dried at 50°C for 5 to 7 days, and weighed. Residue moisture will be determined by subtracting dry weight from fresh weight divided by dry weight. Residue will be expressed on a dry weight basis.
- Data will be emailed to Air Sciences Inc. in an Excel spreadsheet.

Soil Samples:

- A soil probe will be used to take several soil samples 4 inches deep for a composite pre-burn soil moisture sample at each of 4 random locations in each of the treatments (burn units) at the Columbia Basin and the Worley sites. Soil moisture samples from the Rathdrum site will be taken using a shovel because the soil is very rocky.
- Each composite soil sample will be placed in a pre-numbered plastic 'Ziploc' bag, transported to WSU, in the laboratory approximately 100 g of soil will be transferred from the 'Ziploc' bag to a pre-weighed soil moisture drying can, weighed for fresh weight, dried at 105°C for 24 hours, and weighed.

- Soil moisture will be determined by subtracting dry weight from fresh weight divided by dry weight. Soil moisture will be expressed on a dry weight basis.
- Pre-burn soil moisture data will be emailed to Air Sciences Inc. in an Excel spreadsheet.

Task 6a: Emissions Monitoring.
Missoula Fire Science Laboratory will perform the emissions monitoring using the Missoula Fire Science Laboratory's Fire-Atmosphere Sampling System (FASS). FASS is a tower-based system that measures real-time emissions (Susott et al., 1991b; Ward et al., 1992a). The computer control system, battery, pumps and flow meter, manifolds, particulate matter filters (Teflon and glass), real time analyzers, and the three-part gas collection system (one part for each phase of the burn, i.e., flaming, transitional, and smoldering) are buried near the instrumentation towers. Two guyed instrument towers (two sub-samples per plot) holding the FASS equipment will be erected on each plot.

Air Sciences will provide a portable meteorological station for use in monitoring and recording the meteorological events during each of the burns at each of the sites.

Task 6 also includes post-burn residue sampling of each of the 18 burn units. WSU and ASI will jointly conduct the post-burn residue sampling at Site 1. WSU will perform the post-burn residue sampling at Sites 2 and 3. Following sampling, WSU will be responsible for handling the samples, laboratory analysis, and transmitting the post-burn residue dry weight data electronically to Air Sciences Inc.

Task 6b. Post-burn Residue Samples
- Post-burn residue will be taken at 4 random locations within each of the burn units. Sampling procedures will be the same as mentioned in Task 4.
- A technician will collect the ash plus all bluegrass residue not combusted in the fire within the square foot area for the post-burn residue sample. Extra care will be taken to make sure that noncombustible materials (i.e., soil, rocks, etc.) will not be included in any sample.
- Residue will be put into pre-labeled paper bags, stapled shut, transported to WSU, dried in a forced air oven at 50°C for 5 to 7 days, and weighed to determine post-burn residue remaining. Residue will be expressed on a dry weight basis per unit area.
- Post-burn residue data will be emailed to Air Sciences Inc. in an Excel spreadsheet.

Task 7: Sample Analyses.
The Missoula Fire Sciences Laboratory will be responsible for Task 7. Following the burn, analyze the filter and gas samples for the following constituents: PM_{10}, $PM_{2.5}$, CO, benzo(a)pyrene (BaP) [a PAH], and six additional BaP-equivalent carcinogens listed in WAC 173-460-050(4)(c), including benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indenol(1,2,3-cd)pyrene. PAHs need not be measured directly in the field; they will be determined from laboratory analysis of the filter samples. The $PM_{2.5}$ samples collected on glass-fiber filters for total mass and speciated PAH mass will be analyzed at DataChem Laboratories (DCL) at Salt Lake City, UT. The DCL facility in Salt Lake City is the National Institute for Occupational Safety and Health contract laboratory for analytical chemistry services. The Missoula Fire Sciences Laboratory will be responsible for all gas and filter sample analysis and for providing the data to Air Sciences Inc.

Task 8: Burn Characteristics.
WSU and Air Sciences Inc. will share the responsibility of documenting the characteristics of each experimental burn. Burn characteristics will include: date and time of burning, type of fire and

ignition pattern, air temperature, relative humidity, and mid-flame wind speed. Flame length, flame depth, flame angle, flame height, fire line depth, and rate of fire spread will be estimated and recorded on each burn if the conditions permit. In addition, each burn may be videotaped in order to more fully document the evolution and characteristics of each burn. Videotaping may be omitted if deemed not warranted by WSU. If burns are videotaped, WSU will provided needed equipment. Air Sciences Inc. will be responsible for documenting the burn characteristics listed herein for Sites 1 and 2. WSU will be responsible for documenting the burn characteristics at Site 3. Air Sciences and WSU will perform these tasks in conjunction with those listed under Task 6, Emissions Monitoring.

Task 9: Calculations, Data Analysis, and Interpretation.

Air Science will compute the residue consumption, pollutant-specific emission factors, and total pollutant-specific emissions according to standard calculating procedures :

Equation 1. Pre- and Post-burn loading - Standard units conversion.

Equation 2. Residue Moisture Content – Calculated (Air Sciences Inc., 2002).

Equation 3. Bulk density, layer – Defined as dry weight (mass) per volume (Turgeon, 2002).

Equation 4. Bulk density, entire – Standard calculation by addition.

Equations 5 and 6. Residue consumption, absolute and relative – Calculated (Air Sciences Inc., 2002).

Equation 7. Emissions factors – Calculated (Ward et al., 1992b).

Equation 8. Emission factor for PAH – (Ward et al., 1992b).

Equations 9 and 10. Total $PM_{2.5}$ emissions – Standard calculation, units canceling.

Air Sciences will be responsible for interpretation of emissions data. Air Sciences will not exceed 100 labor hours on this task, nor will Air Sciences be responsible for costs related to shipping or sharing of data.

Task 10: Report.

The results will be documented in a technical report (e.g., Air Sciences Inc., Experimental design: cereal grain crop open-field burning emissions study [draft], Project 152-01, Sect. 6.6, January 2000.

6.10.2 Description of Quality Control Measures Implemented

This section provides a brief description of the quality control (QC) measures that were taken by Air Sciences Inc. (ASI), Washington State University (WSU), and Intermountain Fire Sciences Laboratory at Missoula, MT (MFSL) to ensure a consistent, high quality data set. Included is a discussion of the following: site selection and unit layout criteria, number of replications, pre- and post-burn residue sampling, measurements and description of residue architecture, weather conditions at time of burning, recording of moisture fresh weights, data handling including chain of custody, screening criteria used by MFSL to identify unsuitable data, statistical evaluation of data and identification of outliers, check of SYSTAT results against Excel spreadsheet, and calculation of emission factors using two independent calculation methods.

Task 2 Site and Burn Unit Selection

All the study fields and units within the fields were selected based on the uniformity of pre-burn residue loading, site physiographic conditions, and the availability of grower cooperators (cooperators were required to provide personnel and equipment, e.g., swathers, baling equipment, ignition equipment, water trucks, etc.). All cooperators had been growing Kentucky bluegrass for seed for many years (10+ years). Fields with uniform site conditions (irrigated sites at Connell [Circle P Farms, T14 R31 E1/2, Sect. 22, NW1/4; cultivar 'Total Eclipse'] and Rathdrum Prairie SW of the intersection of Meyer and Lancaster Roads; cultivar 'Alene') or typical of dryland Kentucky bluegrass dryland production fields (Worley [Coeur d'Alene Tribe land at the west end and the north side of Jess Wright Road, cultivar 'Garfield']) were chosen by WSU personnel. Later, WSU selected the locations of individual 4-acre burn units within the fields. The location of individual burn units was as close together as possible to ensure similar site conditions within all three replications of a treatment.

Task 4a Pre-burn Residue Load

Pre- and post-burn residue loading was sampled in order to accurately assess the total residue consumption following each test burn. To determine pre-burn residue load, within each 4-acre burn unit, 8 to 12 (12 at Connell, and 8 at Worley and Rathdrum Prairie) sampling locations were randomly chosen. At each sampling location, the residue within a 0.09-m^2 constructed of 1-inch PVC pipe was clipped to the soil surface with electronic clippers. Considerable care was taken to keep soil aggregates and/or rocks out of the sample bags. Two of the WSU personnel taking samples have been utilizing this methodology for approximately 10 years and are quite skilled in the technique (Johnston and Golob, 1992).

Paper sample bags were clearly labeled with the field and unit name, date, treatment description, and type of sample (e.g., pre-burn residue), folded, and sealed using staples. All the residue sample bags from each field were assembled in cloth bags, labeled with the field name, and transported by WSU personnel to Pullman, WA. There the samples were dried (5 days at 140°F) and weighed to determine oven-dried weight (1/100th gram resolution). A tare weight for the paper bags was obtained by averaging the oven-dry weights of four paper bags identical to those used for sampling. The oven-dried bag tare weight was subtracted from the total dry weight (residue sample + bag) to obtain the Kentucky bluegrass residue dry weight.

Task 4b Pre-burn Fuel Load Architecture

The fuel load architecture of the pre-burn residue was determined by WSU personnel for all sites. At the Connell site, 18 measurements (3 per burn unit) of stubble height were taken at random.

Standing stubble height was measured with a ruler from the soil surface to the estimated mean stubble height. Due to the short swathing height, to maximize hay yield by the grower, there was no suspended residue in any of the low residue load burn units following raking and baling. Residue had filtered through the standing stubble to the soil surface. At the Worley and Rathdrum Prairie sites, one replication of a low residue load burn unit was chosen at random in which stubble height was measured at four randomly chosen locations. In addition, due to topographic variability in the burn unit at Worley, stubble height was measured in two locations, i.e., slope and draw. Within one randomly chosen high residue load burn unit at each of the Worley and Rathdrum sitess additional characterization of the residue load architecture was determined. At 4 randomly selected locations within the high residue load burn unit the height from the soil surface to the top of the residue and the height from the soil surface to the bottom of the suspended residue was measured. Thickness of the top (suspended) residue layer was then determined by subtraction.

Task 5a Pre-burn Residue Moisture

Residue moisture was sampled at four randomly selected locations in a burn unit by WSU personnel. Oven-dried weight of each sample bag (plastic 'Ziploc' bags) was determined for tare weight prior to collection, weighed to 1/100th gram resolution. All moisture samples were collected within a 30-minute period immediately preceding the ignition time. Four samples at randomly selected locations within each burn unit were taken. Each sample was taken from 1 square foot (0.09-m^2) area using the same sampling techniques as described for pre-burn residue and immediately sealed and place on ice in a cooler. All sample bags were clearly labeled as discussed above. Samples were transported to WSU in Pullman, where they were weighed for fresh weight, the 'Ziploc' bags were then opened and a 2-inch-long section of 3-inch diameter pipe was inserted in the bags to keep them open while drying. Samples were dried (5 days at 140°F), and weighed to determine oven-dried weight (1/100th g resolution). WSU calculated percent moisture on a dry weight basis following the procedure outlined by Anderson and Grant (1993). Data were transmitted electronically to ASI ASI calculated percent moisture on a dry weight basis to determine pre-burn residue moisture of each sample. In addition, residue dry weight from each of the residue moisture samples was incorporate to determine average residue load for that burn unit.

Task 5b Pre-burn Soil Moisture

Soil moisture was sampled at 4 randomly selected locations within each burn unit prior to ignition by WSU personnel. At each location, six to seven 2-inch deep soil samples were taken with a soil probe (except at the Rathdrum Prairie site where a shovel was used due to the gravelly soil at that site), placed in plastic 'Ziploc' bags, and sealed. The samples were immediately placed on ice in an ice chest and transported to Pullman, WA. Prior to analysis all samples were thoroughly mixed with an approximate 100 g sub-sample removed and placed in pre-weighed metal soil moisture cans and weighed to determine wet weight of sample. Soil samples were dried at 105°C for 24 hours and weighed. Percent soil moisture was determined by subtracting the oven dried weight from the wet weight divided by the oven dry weight.

Task 6a Ignition of Test Plots

At all sites, burns were done on days and under environmental conditions that burning was permitted (Washington DOE for the Connell site and Idaho DEQ for the Worley and Rathdrum sites). All burns, at all sites, were ignited between late morning and early afternoon and ignited upwind (open-field head fires or strip head fires) from the MFSL's Fire Atmospheric Sampling System (FASS) apparatus. There were two FASS sampling towers per burn unit. Ignition ~~techniques were essentially those used as current practices by growers. Growers utilized their~~ own equipment at the Worley and Rathdrum sites to perform ignition of the burn units. At the Worley site, each burn unit was ignited using a propane torch and a 4-wheel ATV. At the Rathdrum site, ignition was performed by lighting the edge of a burn unit using a propane torch from the cab of a pick-up truck. At the Connell site, ignition of the burn units was performed by WSU personnel. In the high residue load units, residue was ignited with a small propane torch and three people moving ignited residue with pitchforks rapidly moved the fire along the burn front. Two low residue load burn units were ignited with an 18-foot propane burner (12-foot burn in one replication as one 6-foot section of the burner malfunctioned) making multiple passes across the burn unit upwind (strip head fires) from the FASS towers. An attempt to burn one low residue load burn unit as an open-field head fire failed and was deleted from the study.

Task 6b Emissions Collection

MFSL collected emissions samples using two FASS towers per burn unit utilizing procedures outlined by ASI (2003) for the Cereal-Grain Residue Open-Field Burning Emissions Study conducted in eastern Washington during April and October 2000.

Task 6c Meteorology

Variations in weather conditions were minimized between burns by burning between treatments as soon as possible on a given day and burning on consecutive days (2-day period at Worley and Rathdrum Prairie, 3-day period at Connell). Meteorological parameters, i.e., wind speed and direction, temperature, and relative humidity were monitored with a 2-meter meteorological tower by ASI before, during, and after each burn.

Task 6d Post-burn Residue Load

The post-burn sampling was conducted immediately following each burn (within 10 minutes following the end of the set sampling time of the FASS towers) by WSU and ASI personnel. Post-burn residue was collected using the same technique as described for pre-burn residue sampling. Care was taken to avoid possible disturbance of the post-burn sample area. In the few incidences, where it appeared that wind could disturb the burned residue, the post-burn sample area was shielded during sample collection. Samples were take at 4 randomly selected locations within each burn unit.

Task 7 Emissions Analysis

The MFSL and their subcontractor, Southwest Research Institute, analyzed the atmospheric concentration data collected by the FASS towers. In the laboratory, data from the FASS towers were processed and the canister- and filter-data analyzed. MFSL provided the following description of methodology.

Canister Analysis:

Canister samples were analyzed by gas chromatography (Hewlett Packard model 5890 Series II) for CO_2, CO, CH_4, and hydrocarbons. The canisters were pressurized with sample to approximately 20 pounds per square inch absolute (pisa). Two columns and chromatography systems are used, one for CO_2 and CO, and another for CH_4, and C_2 and C_3 gases.

The CO_2 and CO analysis setup has a 1-ml sample loop that is filled directly from the canister. The column for this analysis is a 1/8 in x 6 ft. Carbosphere (Alltech) carbon molecular sieve, with He carrier gas, 16 ml/min., subsequently passing through a methanizer, and FID at 300°C. CO and CO_2 are analyzed for in separate isothermal runs, CO at 30°C, and CO_2 at 100°C.

CH_4, C_2, and C_3 analysis is performed with a 0.53 mm x 35 m GS-Q (J&W Scientific) megabore column with a 0.53 mm x 6ft HP-1 pre-column. The sample is directly injected from the canister into a 0.25-ml sample loop. The carrier gas is He, 4 ml/min., with an FID at 200°C, and He makeup gas. The temperature program is 30°C for 6 min, then increasing at 10°C/min to a final temperature of 90°C.

Chromatogram data is collected and processed by Hewlett Packard ChemStation II software via a computer link to the gas chromatograph. The ChemStation software also controls operating parameters of the gas chromatograph and does the integration of the peaks of the chromatograms. Three gas standards are analyzed with each set of samples to construct a standard curve for each gas, based on integrated peak area, from which sample concentrations are calculated.

Filter Analysis:

Teflon filters for $PM_{2.5}$ determination were conditioned and weighed in controlled environment room at 68°F, and 50% RH. Prior to weighing the filters are conditioned for at least 24 hours to stabilize the particulate weight and reduce the effects of static electricity on the weighing process. The filters are weighed three times on a Mettler M4 microbalance to 1 microgram precision. The balance is linked to a software program that collects the weight and room condition data. Filters whose weight is not reproducible to within 5 micrograms are kept for further analysis and not used if this reproducibility is not reached. Before each sample was weighed the balance tare was zeroed. A control calibration weight is weighed every five filter weights to verify balance accuracy and calibration. Each filter is pre-weighed prior to sample collection using this procedure, and then again after particulate collection. Control filters follow the same protocol and are used to correct for environmental and handling variability on filter weight.

The $PM_{2.5}$ concentration is calculated by the software based on the final particulate weight (post-weight minus pre-weight) and the volume of air that was collected through the filter during emission sampling.

Data were screened for internal consistency (ASI personal communication with MFSL, R. Susott). The consistency checks including the following procedures. First, FASS data and canister data for CO_2 and CO emissions were compared. If results from these two methods agreed, then the samples were maintained in the database. If on the other hand, a discrepancy existed between the two methods, the samples were given a closer look in order to discover the reason for the difference. Potential error sources leading to the deletion of sample data included: air leaks in the field equipment, electrical failure of the field equipment, and laboratory errors that occurred during analysis of the canisters (ASI personal communication with MFSL, R. Susott). Second, filter data were checked for internal consistency against CO concentrations. CO concentrations and $PM_{2.5}$ mass should approximately track each other, as both are products of incomplete residue combustion. If a large discrepancy existed between the two values, samples were given a closer look. Again, samples with large discrepancies that could not be explained or fixed were deleted from the database (ASI personal communication with MFSL, R. Susott).

A complete set of data on residue loading and residue moisture content was provided to ASI by WSU. ASI processed the meteorological data. The MFSL provided ASI with the screened atmospheric concentration data, and the calculated emission factors of all atmospheric species in MS Excel. Data for all the units were summarized at the sub-sample level to obtain mean values for each unit. The unit averages were then used in subsequent statistical analysis. Both at the sample and at the unit level, statistical procedures were used to identify outliers and extreme values that were then eliminated from the data set. Summaries by unit for both the complete and the screened database are summarized in Appendix 2. PAH emission factor calculations were checked by both the MFSL (Steve Baker) and Air Sciences (Maarten Schreuder), to ensure that both the input data and the calculations were correct.

ASI performed statistical analyses in SYSTAT 10 (SPSS, 2000). The database in SYSTAT was carefully checked against the database in MS Excel, to assure that no errors occurred in the data transfer between the two software packages. Only the screened data were used in the final statistical analysis.

6.11 ASSESSMENTS AND OVERSIGHT

6.11.1 Assessments

An assessment is the process used to measure the performance or effectiveness of the quality system for the project. Due to limited scope and duration of this research project, assessments were conducted internally utilizing replicate sampling of the field data. For this research project, the data analysis process, including all the statistical computations, that will become part of the final report provide for the assessment of the quality assurance components. The final report will identify the field variables that significantly influence the computation of the different emissions evaluated in this project and from that, identify the field parameters and data collection techniques that critical to completing high quality, reliable research. Because this is a research-based project, standard methodologies are still evolving. At the completion of this Kentucky bluegrass emission study, researchers will have completed two recent studies on evaluating combustion emissions from burning agricultural fields utilizing similar sampling techniques.

6.11.2 Oversight

The research group organized for this project completed this work fairly independent of any external oversight. The collaborative nature of this project, as described in Section 4, identifies an informal network of individuals and organizations that followed this project closely. Annual progress reports were prepared and presented to the Grass Seed Cropping System for Sustainable Agriculture (GSCSSA) organization. The annual reports are reviewed by the GSCSSA's Industry Advisory Committee and Technical Advisory Committee. The committees make recommendations to the Agricultural Experiment Station Directors for Washington, Oregon, and Idaho. These directors have the ability to allocate USDA research funds in the tri-state region. This project was the recipient of a USDA research grant through the GSCSSA process.

6.12 DATA VALIDATION AND USABILITY

Data validation was performed by the various research cooperators for each of the data parameters identified in Section 7. For example, in Section 10.2, the filter analysis section describes how the Missoula Fire Science Lab and Air Science staff reviewed the PM2.5 mass derived from the filter analysis process and compared that data to the carbon monoxide concentrations. Discrepancies lead to a further review of the field sampling data and laboratory data. If large discrepancies could not be resolved, the data were removed from the data set. Outliers were identified in other data sets such as residue loading and then were examined for possible sources of error. Emission factors were compared to literature values and against results obtained from recent emission studies on cereal grain burning.

The database used for statistical analysis was carefully checked against the original data sets to verify the accuracy of the data. The research team independently checked each other's data sets for completeness and accuracy. The project coordinators, especially those that provided funding to the project, will review the draft reports and datasets to verify completeness and conformance with contractual obligations.

Eventually, the final results and report may go through the peer review process prior to publishing in a relevant professional journal. This last step would ensure the usability of the results drawn from this research project.

Footnote 4

AMERICAN ACADEMY OF PEDIATRICS

POLICY STATEMENT

Organizational Principles to Guide and Define the Child Health Care System and/or Improve the Health of All Children

Committee on Environmental Health

Ambient Air Pollution: Health Hazards to Children

ABSTRACT. Ambient (outdoor) air pollution is now recognized as an important problem, both nationally and worldwide. Our scientific understanding of the spectrum of health effects of air pollution has increased, and numerous studies are finding important health effects from air pollution at levels once considered safe. Children and infants are among the most susceptible to many of the air pollutants. In addition to associations between air pollution and respiratory symptoms, asthma exacerbations, and asthma hospitalizations, recent studies have found links between air pollution and preterm birth, infant mortality, deficits in lung growth, and possibly, development of asthma. This policy statement summarizes the recent literature linking ambient air pollution to adverse health outcomes in children and includes a perspective on the current regulatory process. The statement provides advice to pediatricians on how to integrate issues regarding air quality and health into patient education and children's environmental health advocacy and concludes with recommendations to the government on promotion of effective air-pollution policies to ensure protection of children's health. *Pediatrics* 2004;114:1699–1707; *air pollution, adverse effects, children, asthma, environmental health.*

ABBREVIATIONS. $PM_{2.5}$, particulate matter with a median aerodynamic diameter less than 2.5 μm; PM_{10}, particulate matter with a median aerodynamic diameter less than 10 μm; EPA, Environmental Protection Agency; HAP, hazardous air pollutant; AQI, air quality index.

INTRODUCTION

Although it has been 3 decades since passage of the Clean Air Act in 1970 (Pub L No. 91–604), the air in many parts of the United States is far from clean. Air quality has improved in some areas but decreased in others.[1] In addition, there are important health effects from air pollutants at levels once considered safe. Children and infants are among the most susceptible to many of the air pollutants.

In 2002, approximately 146 million Americans were living in areas where monitored air failed to meet the 1997 National Ambient Air Quality Standards for at least 1 of the 6 "criteria air pollutants": ozone, particulate matter, sulfur dioxide, nitrogen dioxide, carbon monoxide, and lead (Table 1).[1] Although the standards for ozone and particulate matter were revised in 1997, legal barriers have delayed timely implementation.[2] Recent reports have identified adverse health effects at levels near or below the current standards for ozone, particulate matter, and nitrogen dioxide. Thus, the 1997 federal standards may not adequately protect children. Additionally, numerous other toxic air pollutants are of public health concern.[3]

Outdoor air pollution is also a major problem in developing countries. The World Health Organization found that the air quality in large cities in many developing countries is remarkably poor and that very large numbers of people in those countries are exposed to ambient concentrations of air pollutants well above the World Health Organization guidelines for air quality (www.who.int/ceh/publications/en/11airpollution.pdf).

Scientific understanding of the health effects of air pollution, including effects on children, has increased in the last decade. This statement updates a 1993 American Academy of Pediatrics (AAP) statement titled "Ambient Air Pollution: Respiratory Hazards to Children."[4]

EFFECTS OF AIR POLLUTION ON CHILDREN

Children are more vulnerable to the adverse effects of air pollution than are adults. Eighty percent of alveoli are formed postnatally, and changes in the lung continue through adolescence.[5] During the early postneonatal period, the developing lung is highly susceptible to damage after exposure to environmental toxicants.[5–7]

Children have increased exposure to many air pollutants compared with adults because of higher minute ventilation and higher levels of physical activity.[8] Because children spend more time outdoors than do adults, they have increased exposure to outdoor air pollution.[9,10]

Infants, children, the elderly, and those with cardiopulmonary disease are among the most susceptible to adverse health effects from criteria pollutants.[11–15] Lead is neurotoxic, especially during early childhood. Carbon monoxide interferes with oxygen transport through the formation of carboxyhemoglobin. Other criteria pollutants (ozone, sulfur dioxide, particulate matter, nitrogen dioxide) have respiratory effects in children and adults, including increased respiratory tract illness, asthma exacerbations, and decreased lung function (eg, changes in peak flow).[11–12] In adults, particulate air pollution is associated with respiratory and cardiovascular hos-

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TABLE 1. National Ambient Air Quality Standards for Criteria Air Pollutants, 1997

Pollutant	Primary Standards*
Ozone	
1-h average	0.12 ppm (235 μg/m³)
8-h average	0.08 ppm (157 μg/m³)
PM_{10}	
Annual arithmetic mean	50 μg/m³
24-h average	150 μg/m³
$PM_{2.5}$	
Annual arithmetic mean	15 μg/m³
24-h average	65 μg/m³
Sulfur dioxide	
Annual arithmetic mean	0.03 ppm (80 μg/m³)
24-h average	0.14 ppm (365 μg/m³)
Nitrogen dioxide	
Annual arithmetic mean	0.053 ppm (100 μg/m³)
Carbon monoxide	
8-h average	9 ppm (10 mg/m³)
1-h average	35 ppm (40 mg/m³)
Lead	
Quarterly average	1.5 μg/m³

Additional information on air quality standards are available at www.epa.gov/air/criteria.html.
* People residing in regions with pollutant concentrations above the primary standard may experience adverse health effects from poor air quality.

pitalizations, cardiovascular mortality,[16] and lung cancer.[17] Air pollution also has effects on indirect health indicators such as health care utilization and school absences.[11–13]

Although numerous studies have shown that outdoor air pollution exacerbates asthma, the effect of outdoor air pollution on the development of asthma has been less clear. Recently, a prospective study found that the risk of developing asthma was not greater, overall, in children living in communities with high levels of ozone or particulate air pollution. However, in communities with high levels of ozone, there was an increased risk of developing asthma in a small subset of children involved in heavy exercise (participation in 3 or more team sports per year [relative risk: 3.3; 95% confidence interval: 1.9–5.8]). This increased risk with heavy exercise was not seen in low-ozone communities. Time spent outside was also associated with new cases of asthma in high-ozone communities (relative risk: 1.4; 95% confidence interval: 1.0–2.1) but not in low-ozone communities.[18] Additional studies are needed to define the role of outdoor air pollution in the development of asthma.

Children in communities with higher levels of urban air pollution (acid vapor, nitrogen dioxide, particulate matter with a median aerodynamic diameter less than 2.5 μm [$PM_{2.5}$], and elemental carbon [a component of diesel exhaust]) had decreased lung function growth, and children who spent more time outdoors had larger deficits in the growth rate of lung function.[19,20] Ambient air pollution (especially particulate matter with a median aerodynamic diameter less than 10 μm [PM_{10}]) has also been associated with several adverse birth outcomes, as discussed in the next section.

Levels of ozone and particulate matter are high enough in many parts of the United States to present health hazards to children.[1] Additionally, National Ambient Air Quality Standards for nitrogen dioxide may not be protective. Findings on these pollutants are summarized here.

Ozone

Ambient ozone is formed by the action of sunlight on nitrogen oxides and reactive hydrocarbons, both of which are emitted by motor vehicles and industrial sources. The levels tend to be highest on warm, sunny, windless days and often peak in midafternoon, when children are most likely to be playing outside.

Ozone is a powerful oxidant and respiratory tract irritant in adults and children, causing shortness of breath, chest pain when inhaling deeply, wheezing, and cough.[11] Children have decreases in lung function, increased respiratory tract symptoms, and asthma exacerbations on days with higher levels of ambient ozone.[11,21–23] Increases in ambient ozone have been associated with respiratory or asthma hospitalizations,[24,25] emergency department visits for asthma,[26] and school absences for respiratory tract illness.[27] In Atlanta, Georgia, summertime children's emergency department visits for asthma increased 37% after 6 days when ozone levels exceeded 0.11 ppm.[25] In southern California, school absences for respiratory tract illness increased 63% in association with a 0.02-ppm increase in ozone.[27]

In healthy adults, ozone causes airway inflammation and hyperreactivity, decrements in pulmonary function, and increased respiratory tract symptoms.[11] Ozone exposures at concentrations of 0.12 ppm or higher can result in decrements in lung function after subsequent challenge with aeroallergen.[28] Although most of the controlled studies of ozone exposure have been performed with adults, it is reasonable to believe that the results of these findings could be extended to children.

Ozone may be toxic at concentrations lower than 0.08 ppm, the current federal regulatory standard. Field studies suggest potential thresholds of between 0.04 and 0.08 ppm (1-hour average) for effects on lung function.[29–31] Recent studies of hospitalizations for respiratory tract illness in young children and emergency department visits for asthma suggest that the effects of ozone may occur at ambient concentrations below 0.09 ppm.[32,33] Another study found associations of ozone and respiratory symptoms in children with asthma at levels below the current US Environmental Protection Agency (EPA) standards.[34] If these findings are confirmed, the ozone standards may need additional revision.

In addition to studies on short-term effects, 2 recent studies of college freshmen suggest that increasing cumulative childhood exposure to ozone may affect lung function when exposed children reach young adulthood, particularly in measures of flow in small airways.[35,36] Early childhood exposures may, therefore, be particularly important.[35]

Particulate Matter

PM_{10} is small enough to reach the lower respiratory tract and has been associated with a wide range of serious health effects. PM_{10} is a heterogeneous mixture of small solid or liquid particles of varying composition found in the atmosphere. Fine particles ($PM_{2.5}$) are emitted from combustion processes (especially diesel-powered engines, power generation, and wood burning) and from some industrial activities. Coarse particles (diameter between 2.5 and 10 μm) include windblown dust from dirt roads or soil and dust particles created by crushing and grinding operations. Toxicity of particles may vary with composition.[37,38]

Particle pollution contributes to excess mortality and hospitalizations for cardiac and respiratory tract disease.[14,39–41] The mechanism for particulate matter–associated cardiac effects may be related to disturbances in the cardiac autonomic nervous system, cardiac arrhythmias, or increased blood concentrations of markers of cardiovascular risk (eg, fibrinogen).[16,42]

Daily changes in mortality rates and numbers of people hospitalized are linked to changes in particulate air pollution.[14,39–41] These studies and others have estimated that for every 10 $\mu g/m^3$ increase in PM_{10}, there is an increase in the daily mortality rate between 0.5% and 1.6%. Effects were seen even in cities with mean annual PM_{10} concentrations between 25 and 35 $\mu g/m^3$. These recent studies suggest that even the current federal standards for $PM_{2.5}$ (24-hour standard = 65 $\mu g/m^3$; annual standard = 15 $\mu g/m^3$) and PM_{10} (24-hour standard = 150 $\mu g/m^3$; annual standard = 50 $\mu g/m^3$) should be lowered to protect public health. In 2002, California adopted more stringent standards for particulate matter: the annual average standard for $PM_{2.5}$ is 12 $\mu g/m^3$ and for PM_{10} is 20 $\mu g/m^3$.[43]

In children, particulate pollution affects lung function[44–46] and lung growth.[19] In a prospective cohort of children living in southern California, children with asthma living in communities with increased levels of air pollution (especially particulates, nitrogen dioxide, and acid vapor) were more likely to have bronchitis symptoms. In this study, bronchitis symptoms refers to a parental report of "one or more episodes of 'bronchitis' in the past 12 months" or report that, "apart from colds, the child usually seems to be congested in the chest or able to bring up phlegm").[47] The same mix of air pollutants was also associated with deficits in lung growth (as measured by lung function tests).[19] Recent studies in different countries have also found associations between ambient air pollution (especially particulates and/or carbon monoxide) and postneonatal infant mortality (attributable to respiratory causes and possibly sudden infant death syndrome),[48,49] low birth weight,[50–53] and preterm birth.[51,54–56]

The relative contribution of fine versus coarse particles to adverse health effects is being investigated. In studies of cities on the East Coast, fine particles seem to be important.[57] In other areas, coarse particles have a stronger or similar effect.[58] Several studies have found that fine particles from power plants and motor vehicles[59] or industrial sources[60] may be more closely associated with mortality.

Nitrogen Dioxide

Nitrogen dioxide is a gaseous pollutant produced by high-temperature combustion. The main outdoor sources of nitrogen dioxide include diesel and gasoline-powered engines and power plants. Levels of nitrogen dioxide around urban monitors have decreased over the past 20 years. Currently, all areas of the country meet the national air quality standard for nitrogen dioxide of 0.053 ppm (100 $\mu g/m^3$), measured as an annual arithmetic mean. However, national emissions (overall production) of nitrogen oxides have actually increased in the past 20 years because of an increase in nitrogen oxide emissions from diesel vehicles.[1] This increase is of concern, because nitrogen oxide emissions contribute to ground-level ozone (smog) and other environmental problems such as acid rain.[1]

Controlled-exposure studies of people with asthma have found that short-term exposures (30 minutes) to nitrogen dioxide at concentrations as low as 0.26 ppm can enhance the allergic response after subsequent challenge with allergens.[61,62] These findings are of concern, because some urban communities that are in compliance with the federal standards for nitrogen dioxide (annual average) may experience substantial short-term peak concentrations (1-hour average) that exceed 0.25 ppm. Confirmation of these studies is needed.

Epidemiologic studies have reported relationships between increased ambient nitrogen dioxide and risks of respiratory tract symptoms[63,64] and asthma exacerbations.[65] As noted previously, children with asthma living in communities with increased levels of air pollution (especially nitrogen dioxide, acid vapor, and particulates) were more likely to have bronchitis symptoms.[47] The same mix of air pollutants was also associated with deficits in lung growth (as measured by lung function tests).[19] These effects were increased in children who spent more time outdoors.

The epidemiologic studies of health effects associated with nitrogen dioxide should be interpreted with caution. Increased levels of ambient nitrogen dioxide may be a marker for exposure to traffic emissions or other combustion-related pollution. An independent role of nitrogen dioxide cannot be clearly established because of the high covariation between ambient nitrogen dioxide and other pollutants. Nonetheless, these studies illustrate that adverse respiratory tract effects are seen in urban areas where traffic is a dominant source of air pollution.

Traffic-Related Pollution

Motor vehicles pollute the air through tailpipe exhaust emissions and fuel evaporation, contributing to carbon monoxide, $PM_{2.5}$, nitrogen oxides, hydrocarbons, other hazardous air pollutants (HAPs), and ozone formation. Motor vehicles represent the principal source of air pollution in many communities, and concentrations of traffic pollutants are greater near major roads.[66] Recently, investigators (primarily in Europe and Japan) have found increased adverse health effects among those living near busy roads.

Studies examining associations between adverse respiratory tract health and traffic have been reviewed.[67] Increased respiratory tract complications in children (eg, wheezing, chronic productive cough, and asthma hospitalizations) have been associated with residence near areas of high traffic density (particularly truck traffic).[68–71] Other investigators have linked various childhood cancers to proximity to traffic.[72–74]

Diesel exhaust, a major source of fine particulates in urban areas, is carcinogenic. Numerous studies have found an association between occupational exposure to diesel exhaust and lung cancer.[75] On the basis of extensive toxicologic and epidemiologic evidence, national and international health authorities, including the EPA and the International Agency for Research on Cancer, have concluded that there is considerable evidence of an association between exposure to diesel exhaust and an increased risk of lung cancer.[76,77] Additionally, fine particles in diesel exhaust may enhance allergic and inflammatory responses to antigen challenge and may facilitate development of new allergies.[78,79] Thus, diesel exhaust exposure may worsen symptoms in those with allergic rhinitis or asthma.

School buses operate in proximity to children, and most of the nation's school bus fleets run on diesel fuel. The EPA and some state agencies are establishing programs to eliminate unnecessary school bus idling and to promote use of cleaner buses to decrease children's exposures to diesel exhaust and the amount of air pollution created by diesel school buses (www.epa.gov/cleanschoolbus). A recent pilot study found that a child riding inside a school bus may be exposed to as much as 4 times the level of diesel exhaust as someone riding in a car.[80] These findings underscore the importance of advocating for school districts to replace diesel buses or retrofit them with pollution-reducing devices and limit school bus idling where children congregate as soon as possible.

Other Air Pollutants

Airborne levels of lead, sulfur dioxide, and carbon monoxide have decreased dramatically because of the implementation of control measures. However, levels of these pollutants may still be high near major sources. For example, high lead levels may be found near metals-processing industries, high sulfur dioxide levels may occur near large industrial facilities (especially coal-fired power plants), and high levels of carbon monoxide may occur in areas with heavy traffic congestion.[1]

In addition to criteria air pollutants, there are numerous other air pollutants produced by motor vehicles, industrial facilities, residential wood combustion, agricultural burning, and other sources that are hazardous to children. More than 50000 chemicals are used commercially, and many are released into the air. For most of these chemicals, data on toxicity are sparse.[81] Some pollutants remain airborne or react in the atmosphere to produce other harmful substances. Other air pollutants deposit into and contaminate land and water. Some toxic air pollutants such as lead, mercury, and dioxins degrade slowly or not at all. These pollutants may bioaccumulate in animals at the top of the food chain, including humans. Children can be exposed to toxic air pollutants through contaminated air, water, soil, and food.[3] One example of a persistent pollutant emitted into ambient air that leads to exposure through another route is mercury, a developmental neurotoxicant.[82] Industrial emissions, especially from coal-fired power plants, are the leading source of environmental mercury. Although the levels of airborne mercury may not be hazardous, mercury deposits into soil and surface waters and ultimately accumulates in fish.[82]

The HAPs, often referred to as "toxic air contaminants" or "air toxics," refer to 188 pollutants and chemical groups known or suspected to cause serious health effects including cancer, birth defects, and respiratory tract and neurologic illness.[3,83] The Clean Air Act directs the EPA to regulate HAPs, which include compounds such as polycyclic aromatic hydrocarbons, acrolein, and benzene from fuel or fuel combustion; solvents such as hexane and toluene; hexavalent chromium from chrome-plating facilities; perchloroethylene from dry-cleaning plants; asbestos; metals (eg, mercury and cadmium); and persistent organic pollutants such as polychlorinated biphenyls. In 2001, diesel exhaust was listed as a mobile-source HAP. Many of these compounds are included in a priority list of 33 HAPs that are of special concern because of their widespread use and potential carcinogenicity and teratogenicity.[81] The priority list and general sources of these compounds are available on the EPA Web site (www.epa.gov/ttn/atw/nata).

Limited monitoring data suggest that concentrations of some HAPs may exceed the goals of the Clean Air Act in many cities.[84] Mobile sources (on- and off-road vehicles) account for approximately half of the emissions[3] but may contribute to 90% of the cancer risk (www.scorecard.org/env-releases/hap/us.tcl). A number of studies assessing health risks have found that estimated levels of some of the HAPs are a potential public health problem in many parts of the United States.[3,84–86] For example, estimated concentrations of benzene, formaldehyde, and 1,3-butadiene may contribute to extra cases of cancer (at least 1 extra case per million population exposed) in more than 90% of the census tracts in the contiguous United States. Additionally, the most recent national cancer-risk assessment for HAPs (1996 data) did not include diesel exhaust in the risk estimates.[3] The health risks may also be underestimated, because there is limited information on toxicity values for many of the HAPs,[87] and the risk models did not consider the potential for increased risk in children. These findings underscore the need for better ways to decrease toxic air emissions and assess exposures and risks.

Air-pollution episodes created by disasters (eg, accidents, volcanoes, forest fires, and acts of terrorism) can also create hazards for children. A discussion of these events and of bioaerosols in ambient air (eg, fungal spores and pollen) is beyond the scope of this policy statement. Additionally, this statement does not address the hazards of indoor air pollution.

PREVENTION

Public health interventions to improve air quality can improve health at the population level. A decrease in levels of air pollution in former East Germany after reunification was associated with a decrease in parent-reported bronchitis[88] and improved lung function.[89] During the 1996 Summer Olympics in Atlanta, Georgia, extensive programs were implemented to improve mass transportation and decrease anticipated downtown traffic congestion. These programs were successful and were associated with a prolonged decrease in ozone pollution and significantly lower rates of childhood asthma visits during this period.[90] Closure of a steel mill in Utah Valley and resultant reductions in particulate matter were associated with a twofold decrease in hospitalizations for asthma in preschool children.[91,92] Finally, lung function improved in children who moved away from communities with high particulate air pollution, compared with those who remained or moved to communities with comparable particulate air pollution.[93] These studies provide support for continued efforts to decrease air pollution and improve health via decreases in motor vehicle traffic and industrial emissions. Dietary factors may play a role in modulating the effects of air pollution in children. A recent study in Mexico City, Mexico, found that children with asthma given antioxidant supplements were less affected by ozone compared with a control group that did not receive supplementation.[94] Additional studies are needed to explore this issue further.

Air Pollution and the Regulatory Process

The Clean Air Act of 1970 mandated the EPA to establish the National Ambient Air Quality Standards (Table 1). Standards were set for criteria air pollutants because they are common, widespread, and known to be harmful to public health and the environment.[11,12,83,95] The standards are reviewed every 5 years and set to protect public health, including the health of "sensitive" populations such as people with asthma, children, and the elderly. These standards are set without considering the costs of attaining these levels.

The standards for ozone and particulate matter were revised in 1997 on the basis of numerous scientific studies showing that the previous standards were not adequate to ensure health protection. Legal challenges were made by the American Trucking Associations, the US Chamber of Commerce, and other state and local business groups. However, the Supreme Court ultimately supported the EPA and ordered implementation of the standards.[2] Establishing implementation plans will be a lengthy process that will require the coordinated efforts of the EPA, state and local governments, and industry and environmental organizations.

Population exposures to toxic air contaminants may be of substantial public health concern.[84,86] In contrast to criteria pollutants, monitoring of toxic air contaminants is more limited. Exposures are estimated on the basis of reported emissions and may underestimate actual exposures.[87] The EPA is mandated to develop regulations through a lengthy process that first sets standards to control emissions on the basis of best-available technology. After maximum available control technology emission standards are established, the EPA must assess the risk remaining after emission decreases for the source take effect (residual risk).

To date, the EPA has focused primarily on establishing technology-based emission standards,[3] and this has been a slow process for some sources (eg, mobile toxic air contaminants and mercury emissions). Nationwide, emissions of toxic air contaminants have dropped approximately 24% from baseline (1990–1993) because of regulation and voluntary decreases by industry. With the current plans for gradual fleet turnover and implementation of controls for motor vehicles and fuels, the EPA projects that toxic air-contaminant emissions from gasoline-powered and diesel mobile sources will not be decreased to 75% and 90% of baseline (1990–1993) levels, respectively, until the year 2020.[3] However, major decreases could be more rapidly achieved simply from a prompt, wider application of existing technology.

Protecting populations from exposure to the harmful effects of air pollutants will require effective control measures. Industry (eg, coal-burning power plants, refineries, and chemical plants) and motor vehicles (both gasoline- and diesel-powered) are major sources of criteria pollutants and HAPs.[11,12] For example, coal-fired power plants are important sources of nitrogen oxides (precursors of ozone), particulates, and sulfur dioxide and are the largest sources of mercury emission in the United States. Smaller sources such as dry cleaners, auto body shops, and wood-burning fireplaces can also affect air quality locally. Municipal and hospital waste incinerators release toxic air pollutants including mercury, lead, cadmium, and dioxin emissions. Depending on weather conditions and individual physicochemical properties, some pollutants can be carried by air currents to areas many miles from the source.

In numerous cities in the United States, the personal automobile is the single greatest polluter, because emissions from millions of vehicles on the road add up. Despite significant technologic advances that have led to tighter pollution control from vehicles, emissions vary substantially between vehicles, particularly between classes of vehicles, because of differences in fuel-economy standards set by regulatory agencies. For instance, the corporate average fuel-economy standards have less stringent fuel-economy requirements (average: 20.7 miles per gallon) for light-duty trucks, sport utility vehicles, and minivans, compared with passenger cars (average: 27.5 miles per gallon). The former group of vehicles tends to have higher emissions of air pollutants, higher fuel consumption, and higher emissions of greenhouse gases.[96,97] Information on emissions and fuel-economy ratings for recent models and a guide for choosing clean, fuel-efficient vehicles are available from the EPA Web site (www.epa.gov/greenvehicles/index.htm). The high levels of particulate emissions from diesel-powered buses and trucks must also be addressed. More than 70% of fine particle emissions from traffic are attributable to diesel-powered buses and trucks.

Driving a private car is probably a typical citizen's most "polluting" daily activity, yet in many cases, individuals have few alternative forms of transportation. Thus, urban planning and smart growth are imperative. Urban sprawl affects land use, transportation, and social and economic development and ultimately has important implications for public health.[98] Ways in which individuals can help to decrease air pollution are available at www.epa.gov/air/actions and www.arb.ca.gov/html/brochure/50things.htm.

Air Quality Index

The air quality index (AQI) provides local information on air quality and potential health concerns at the observed (or forecasted) levels of air pollution and can be a useful tool for educating families about local air quality and health.[99] The AQI is reported daily in metropolitan areas, often as part of local weather forecasts on television or radio or in newspapers. The AQI divides air-pollution levels into 6 categories of risk for 5 common pollutants (ozone, PM_{10}, nitrogen dioxide, carbon monoxide, and sulfur dioxide). Each category has a descriptive name reflecting levels of health concern (ranging from good through very hazardous), an associated color, and an advisory statement. Information about air quality in a specific area can be obtained from www.epa.gov/air/urbanair/index.html, www.scorecard.org, or www.weather.com. Although many states and local air districts actively forecast and disseminate health warnings, the challenge is to have people take actions to protect themselves and decrease activities that cause air pollution.

Pediatric Environmental Health[100] from the AAP provides additional information about the outdoor air pollutants and the use of the AQI.

CONCLUSIONS

Ambient air pollution has important and diverse health effects, and infants and children are among the most susceptible. Currently, levels of ozone and particulates remain unhealthful in many parts of the United States, and the current National Ambient Air Quality Standards may not protect the public adequately. There is a compelling need to move forward on efforts to ensure clean air for all.

The assurance of healthy air for children to breathe is beyond the control of an individual pediatrician, and there are no easy solutions. State chapters of the AAP, as well as individual members, can play an important role as advocates for children's environmental health. Areas of involvement might include working with community coalitions in support of strong pollution-control measures and informing local and national representatives and policy makers about the harmful effects of the environment on children's health. Advocates for children's health are needed in discussions about land use and transportation issues. Pediatricians can also advocate for energy-saving (and pollution-minimizing) lifestyles to their patients' families, especially regarding vehicles driven.

In communities with poor air quality, pediatricians can play a role in educating children with asthma or other chronic respiratory tract disease and their families about the harmful effects of air pollution. Patients and families can be counseled on following the AQI to determine when local air-pollution levels pose a health concern. Ozone levels tend to be highest in the afternoon, and it may be possible to decrease children's exposure by scheduling strenuous outdoor activity earlier in the day.

As pediatricians become better informed about local air quality issues in their communities (eg, ozone, nearby industrial facilities, traffic, diesel buses, wood burning, etc), these local concerns can provide a starting point for discussion and education.

Pediatricians who serve as physicians for schools or for team sports should be aware of the health implications of pollution alerts to provide appropriate guidance to school and sports officials, particularly in communities with high levels of ozone.

RECOMMENDATIONS

1. The National Ambient Air Quality Standards are designed to protect the public. To achieve this, the following points should be addressed:
   - The revised standards for ozone and particulate matter adopted by the EPA in 1997 should be promptly implemented.
   - During implementation, the standards should not be weakened in any way that decreases the protection of children's health.
   - Because recent studies suggest that current standards for PM_{10}, $PM_{2.5}$, ozone, and nitrogen dioxide may not be protecting children, the standards should be promptly reviewed and revised.
   - Because the law requires that the most vulnerable groups be protected when setting or revising the air quality standards, the potential effects of air pollution on the fetus, infant, and child should be evaluated, and all standards should include a margin of safety for protection of children.
2. The current measures to protect children from exposures to HAPs are not effective and should be critically reevaluated. The EPA should focus on prompt implementation of the Clean Air Act Amendments of 1990 (Pub L No. 101–549) to decrease HAPs. Additional monitoring for HAPs should be undertaken to allow more accurate characterization of children's exposures to these compounds. Risk assessments for HAPs should be reviewed to ensure that goals are protective of children. Control measures that specifically protect children's health should be implemented.
3. States and local air districts with air quality concerns should actively implement forecasting and

dissemination of health warnings in ways that help people take actions to protect themselves and decrease activities that cause air pollution.

4. Children's exposure to diesel exhaust particles should be decreased. Idling of diesel vehicles in places where children live and congregate should be minimized. Ongoing programs to fund conversion of diesel school bus fleets to cleaner alternative fuels and technologies should be pursued.
5. Industrial emissions of mercury should be decreased.
6. Federal and state governments' policies should encourage reductions in mobile and stationary sources of air pollution, including increased support for mass transit, carpooling, retiring or retrofitting old power plants that do not meet current pollution-control standards, and programs that support marked improvements in fuel emissions of gasoline- and diesel-powered vehicles. Additionally, the development of alternative fuel fleets, low-sulfur diesel, and other "low-emission" strategies (eg, retrofit of existing diesel engines) should be promoted. Before promoting new alternative fuels, these alternative fuel sources should be critically evaluated and determined by governmental authorities to have a good safety profile.
7. The same overall fuel-economy standard should apply to all passenger vehicles. Programs that allow certain passenger vehicles to be exempt from the usual fuel-economy standards should be abolished.
8. City and land-use planning should encourage the design and redevelopment of communities to promote mass transit, carpooling, pedestrian walkways, and bicycle use.
9. Siting of school and child care facilities should include consideration of proximity to roads with heavy traffic and other sources of air pollution. New schools should be located to avoid "hot spots" of localized pollution.

COMMITTEE ON ENVIRONMENTAL HEALTH, 2003–2004
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All policy statements from the American Academy of Pediatrics automatically expire 5 years after publication unless reaffirmed, revised, or retired at or before that time.

Footnote 4

AMERICAN LUNG ASSOCIATION of Oregon

MEASURE: HB 3000
EXHIBIT: J
House Committee on Health Care
DATE: 04/06/2007 PAGES: 2
SUBMITTED BY: Dana Kaye

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Improving Life, One Breath at a Time

To: Health Care Committee

From: Dana Kaye, MPH
American Lung Association of Oregon
7420 SW Bridgeport Road
Suite 200
Tigard, OR 97224

Date: April 6, 2007

Re: HB 3000 Open field, pile and stack burning

Chair Greenlick and Members of the Committee,

The American Lung Association of Oregon would like to express support of HB3000. The practice of burning crops or wood in fields produces large amounts of particle pollution, or particulate matter, which are tiny bits of ash and soot that can lodge deep inside the lungs and harm the body. They produce both fine (PM 2.5) and coarse particles (PM 10). Particle pollution from crop burning can cause these threats to human health:

- Particle pollution significantly increases the risk of dying early. High levels of particle pollution can shorten life, even if the exposure is over a short period, like hours or days. People can die within days or weeks when breathing high levels, which field burning can produce. Many studies over the past two decades have confirmed this, including large studies around the world. (Pope CA, Dockery DW. Health Effects of Fine Particulate Air Pollution: Lines that Connect. *J Air Waste Mange Assoc* 2006; 56:709-742.)

- More than 2,000 peer-reviewed studies on the subject have been published since 1996, confirming the strong relationship between particle pollution, illness, hospitalization and premature death. The U.S. Environmental Protection Agency recently completed a review of these studies and linked particle pollution to premature death from cardiovascular disease, heart attacks and strokes, as well as worsening asthma, COPD, and may cause lung cancer. (U.S. EPA. Air Quality Criteria for Particulate Matter, October 2004.)

- Those most at risk and the most vulnerable among us: children under 18, those over 65, those with lung diseases like asthma and COPD, those with cardiovascular diseases and diabetes.

- Children's lungs develop mostly after they're born and air pollution from burning can affect the ability of the lungs to develop normally, leading to a lifetime of breathing problems. Children are also outside more than adults, so they risk breathing more of this pollution. The American Academy of Pediatricians warns that particle pollution has been linked to infant death, low birth weight and premature birth. (American Academy of Pediatrics Committee on Environmental Health, Ambient Air Pollution: health hazards to children. *Pediatrics* 2004; 114: 1699-1707.)

- People with lung diseases already have difficulty breathing because their lungs don't work as well. Particle pollution triggers asthma attacks, increased risk of hospitalization and emergency room visits, increased use of medicines. New studies are finding that particles may increase risk of developing chronic bronchitis as well as lung cancer. (U.S. EPA, 2004).

Footnote 4

- People with cardiovascular diseases have an increased risk of developing problems and like diabetics can suffer increased heart disease, heart failure, heart attacks, and dysrhythmias, strokes and hospital admissions for these conditions. (Pope and Dockery, 2006).

- Seniors are also more likely to suffer from worsened cardiovascular and respiratory diseases as well as premature death because of breathing high levels of particle pollution. (U.S. EPA, 2004).

The affects of field burning affects the people of Oregon. These people live in your districts. Please join the American Lung Association and stand up for their health. Support HB 3000.

Because when you can't breathe nothing else matters.™

Footnote 9

OREGON MEDICAL ASSOCIATION

MEASURE: HB 3000
EXHIBIT: K
House Committee on Health Care
DATE: 04/06/2007 PAGES: 1
SUBMITTED BY: Dr. James Lace

Date: April 6, 2007

From: James K. Lace, M.D., F.A.A.P.
Oregon Pediatric Society
Oregon Medical Association

To: Representative Mitch Greenlick
Chair, House Health Care Committee

Re: HB 3000 Prohibits open field burning, stack burning, pile burning, and propane flaming

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I am submitting testimony in favor of HB 3000. I have been a pediatrician in active practice in Salem for the last 30 years. The OMA's Community Health Committee supports HB 3000 because field burning increases air pollution and has adverse health effects on those exposed to it. As a pediatrician I am especially concerned with the most vulnerable populations including children with asthma and other respiratory problems. Other populations particularly at risk include older adults and those with health conditions that may be exacerbated by air pollution including bronchitis and cardiovascular disease.

There is no question that field burning increases air pollution, and while some may claim that the level of pollution is acceptable, this reasoning flies in the face of recent scientific studies. Even if exposure to particulate matter in the $PM_{2.5}$ range is short-term, there are still significant risks to public health, especially to people with asthma or other respiratory conditions. Both the EPA and Department of Environmental Quality agree that human health is adversely affected by short-term exposure to particulate sources such as field burning. Additionally, an article appearing in the February *New England Journal of Medicine* reported that "Long-term exposure to fine particulate air pollution is associated with the incidence of cardiovascular disease and death among post-menopausal women."

Exposure to fine particulate matter ($PM_{2.5}$) increases the number and severity of asthma attacks, bronchitis, may increase cardiovascular risk, or even lead to premature death. OMA has long been supportive of asthma education and prevention measures and believes that HB 3000 would make great strides toward preventing unnecessary air pollution and improving air quality for our patients.

Please vote YES on HB 3000 – for your health, the children's health and the health of your constituents.

Sincerely,

Dr. Jim Lace

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Portland, Oregon 97239-3897
phone **503.226.1555**
fax **503.241.7148**
www.**theOMA.org**

SERVING AND SUPPORTING PHYSICIANS IN THEIR EFFORTS TO IMPROVE THE HEALTH OF OREGONIANS

Footnote 5

Lane County Medical Society

990 West 7th Avenue Eugene, Oregon 97402 (541) 686-0995
E-mail: lcms@rio.com Fax (541) 687-1554

Dear Honorable Representatives Barnhart and Nathanson; Senators Morrisette and Walker:

On behalf of the Lane County Medical Society (LCMS) I am writing to thank you for your sponsorship and support of House Bill 3000, the bill that eliminates field burning in Oregon.

The LCMS is a professional membership organization of more than 700 physicians dedicated to bringing the highest quality medical care to the citizens of Lane County. As an organization charged with protecting public health in Lane County, we feel that eliminating the practice of field burning is a prudent means of improving air quality and reducing a threat to the health of our citizens.

As you undoubtedly know, 49,000 acres of grass seed fields were burned in Lane County last year. The smoke from this burning contains a complex mixture of chemicals, known carcinogens such as benzene and acrolein, and coarse and fine particulate matter ($PM_{2.5}$). When inhaled, $PM_{2.5}$ lodges deeply and remains in the lungs, the particulates being too small for our bodies to defend against. The EPA in their *Fact Sheet: Proposal to Revise the National Ambient Air Quality Standards for Particulate Matter* states that "many scientific studies have found an association between exposure to particulate matter and a series of significant health problems including: aggravated asthma; chronic bronchitis; reduced lung function; irregular heartbeat; heart attack; and premature death in people with heart or lung disease."

The introduction of House Bill 3000 is an important step in improving air quality throughout the Willamette Valley. We are hopeful the Legislature will join the medical community in supporting this important legislation.

Sincerely,

Roger McKimmy, MD

Roger M. McKimmy, M.D., President,
Lane County Medical Society

footnote 5

Grass Seed Field Smoke and Its Impact on Respiratory Health

Roe A. Roberts, Ph.D.
Jeff Corkill, Ph.D.

Abstract

A number of studies have established an association between increases in fine particulates ($PM_{2.5}$) and respiratory morbidity and mortality. High particulate levels in the city of Spokane, Washington, place it among the top 10 worst cities in the country in terms of air quality. Every year, during the months of August and September, 50 to 75 percent of particulates in Spokane originate from the burning of thousands of acres of Kentucky bluegrass in Eastern Washington and Northern Idaho. Burning in the region continues despite attempts by Washington's public officials to curtail it. To assess the potential health impacts of burning grass, this study determined Spokane's adult respiratory disease and hospitalization rates, examined medication use patterns, and identified the chemical content of the smoke. The study found levels of asthma, emphysema, and chronic bronchitis higher than the national average; asthma hospitalization rates higher than the state average; a correlation between weekend bronchodilator purchases and increased $PM_{2.5}$ levels during burns; and phenols and polycyclic aromatic hydrocarbons in grass smoke.

Introduction

Despite 30 years of protests by local citizens claiming that the burning of thousands of acres of grass in Eastern Washington and Northern Idaho has negatively affected their ..., grass field burning continues. Recently, ...ure to alter the practice has grown as a ...lt of a convergence of concerns among several diverse political, social, and economic groups. These groups are concerned about the potential health impacts of grass smoke, as well as about economic impacts on tourism. They include an area Chamber of Commerce, the Spokane County Medical Association, the American Lung Association, the Washington Environmental Council, an extremely active Spokane citizens' group, and the Spokane County Air Pollution Control Authority (SCAPCA) (1–5). Given the numbers of opponents, why does the practice of grass field burning continue? In part, the burning continues because no research has been undertaken to identify its potential health impacts. Furthermore, Kentucky bluegrass growers have not found any alternative methods of stimulating grass seed production that are as effective as field burning. Without studies identifying the health hazards of grass smoke, and with grass seed sales constituting a $75 million industry in the inland Northwest, economics have taken precedence over health concerns. In fact, the right to burn grass seed fields was written into a 1991 revision of the Washington State Clean Air Act (6).

In early discussions of the health effects of grass field burning, the president of the Inland Grass Growers Association (IGGA) stated that grass smoke was 80 percent steam and presented no health hazards to area residents, unlike wood smoke, which contains harmful airborne particulates. Opponents contend that the smoke produced by burning grass results in harmful airborne particulates and that grass burning is a virtually unregulated practice, unlike wood burning (7).

Airborne particulates are measured by diameter in microns (i.e., $PM_{2.5}$ refers to particles equal to or less than 2.5 microns [μm] in diameter). Particles 10 μm in diameter or more

(PM_{10}) do not remain airborne for long and are usually filtered by the nasal passages. The smaller the size of the particulates (especially 5 μm and under), the longer the particulates -i--ulate in the air, and the deeper they pen- into the alveolar cells of the lungs.

In addition to particle size, health concerns -late to the chemicals that are usually associated with the process of incomplete combustion (8,9). It has been shown that the concentration of polycyclic aromatic hydrocarbons (PAHs) in suspended particulates is inversely correlated to particle size and that 47 to 70 percent of PAH in smoke is contained in the $PM_{2.0}$ fraction (10,11).

The importance of air pollution in the pathogenesis of bronchial asthma and other pulmonary diseases has been of interest for decades. Considerable epidemiological evidence implicates fine-particulate air pollution, especially PM_{10} and $PM_{2.5}$, as a trigger that exacerbates respiratory conditions in some individuals with asthma and chronic obstructive pulmonary diseases (12–16). The biological mechanism for these effects is as yet unknown, but PM_{10} particulate matter has been demonstrated to have free radical activity and pro-inflammatory effects in lung tissue in vivo and in vitro, as well as immunosuppressive prop- (17,18).

-ne pro-inflammatory effects appear to -tively affect individuals suffering from a variety of respiratory conditions such as asthma, chronic bronchitis, cystic fibrosis, and emphysema. Individuals whose respiratory conditions include a reactive airway disease (RAD) component appear to be most negatively affected. RAD is often diagnosed as chemically induced asthma and may account for up to 30 percent of diagnosed asthma cases. Chemically induced asthma occurs in response to triggers such as chemical irritants present in the smoke produced by the open burning of biomass (19–24).

Open burning of biomass is a technique commonly used worldwide both for the disposal of crop and forest debris and for land preparation. This agricultural practice is known to produce significant amounts of volatile organic compounds (VOCs) such as phenols, as well as PAH either in a gaseous aerosol or adsorbed onto inert particulate matter (19,25). Currently, farmers in Eastern Washington and Northern Idaho burn thousands of acres of biomass, particularly Ken- bluegrass.

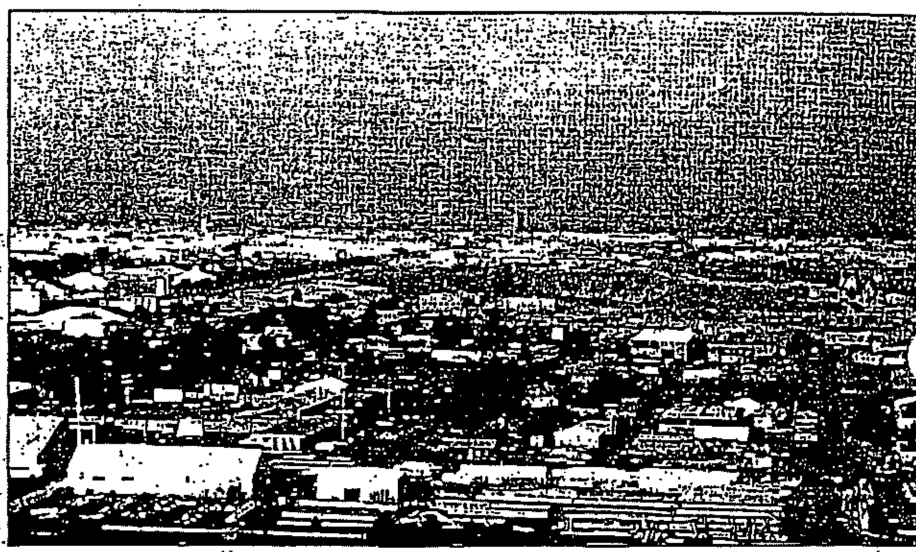
- the early 1990s, SCAPCA introduced a -n burning acreage for Spokane County and reduced the number of permissible burn days. These regulations did not, however, alter the numbers of acres of grassland burned in the county. The growers successfully argued against stronger limits by pointing out that previous studies on the negative impacts of smoke have been done on wood smoke, not grass smoke, and are therefore not applicable. At public hearings, growers dismissed individual claims of damage as anecdotal and unreliable. They argued that those who claimed to be negatively affected by grass smoke were already hypersensitized and that the true impacts of burning thus could not be clearly defined. In cases in which clear evidence of worsening health occurred, such as in extensive hospitalization of cystic fibrosis patients during burns, they attributed the sudden increase in disease severity to the unpredictable and progressive nature of the underlying disease (7,26). By the summer of 1995, local clean-air citizen groups, a small group of physicians, and even SCAPCA had met with little success in their quest to eliminate or restrict the practice of grass field burning.

Starting late in 1995, a series of events occurred that eventually led to more stringent limitations on grass burning in Washington state. The *Spokesman Review* became the battleground between the grass growers and their association and the area citizens' group. Numerous articles, letters to the editor, and editorial comments were published, both pro and con. In 1996, the Natural Resources Defense Council reported that particulate levels in Spokane County placed its air quality levels among the 10 worst in the country (22). Early in 1996, the Spokane County Medical Society and the Washington Thoracic Society issued statments charging that grass seed field burning represented a public health threat. Local busi-

TABLE 1

A Comparison of Spokane County Population Data and Survey Demographics for 1995

	1995 Census Data	Survey Demographics
Population	401,205	1,850
White	93.4 percent	95 percent
Black/African American	1.4 percent	0.6 percent
Hispanic	1.9 percent	1.5 percent
Asian/Pacific Islander	1.0 percent	1.8 percent
Native American	0.1 percent	1.5 percent
Median Age	44	42
Poverty 18 years and under	NA	20.8 percent



Smoke-filled air in Spokane, Washington due to the burning of grass fields.

TABLE 2

Preliminary Identification of Phenols and PAHs in Smoke from the Burning of Kentucky Bluegrass

PAHs	Phenols
Acenaphthene	4'-Methoxy Actophenone
Anthracene	2,6 Dimethoxy Phenol "Syringol"
Benzo[α]pyrene	4-Methoxyphenol
Chrysene	2-Methylphenol
Pyrene	Phenol
Phenanthrene	

ness owners and university researchers added their voices to the fray as well. Once again the testimony of the doctors was dismissed by the grass growers as anecdotal. Nevertheless, when combined with epidemiological research citing correlations between increased morbidity levels and increases in $PM_{2.5}$, the medical testimony forced politicians to acknowledge that a problem did exist. In April 1996, the Washington Department of Ecology (DOE) issued an emergency order stating that grass field burning posed a significant health hazard. The DOE order required that burning be phased out over a three-year period (7).

In 1997, DOE reworded the original order from a complete phase-out to a partial burn reduction over a two-year period. The revised rule reduced burning by 66 percent of the acreage burned in 1995, with an exemption for areas with steep slopes (27). Two legal attempts by farmers to overturn this order failed. The farmers are now suing DOE, arguing that the methods used by DOE to institute the reduction were flawed. Some growers, having seen the writing on the wall, have shifted their operations a few miles to the east, into nearby Northern Idaho or onto reservation lands. So, although the battle appears to be going in favor of health proponents in Washington state, it is far from over; smoke from the Idaho and reservation fields still blankets the region (28).

This study hypothesized that the high levels of particulates (as quantified by PM_{10} and $PM_{2.5}$) would result in higher levels of respiratory diseases, increased hospitalization rates for asthmatics, and an increase in medication purchases during the burn season. As the exact causative agents of the expected medical effects remain unknown, this study further hypothesized that the smoke produced by the incomplete combustion of organic matter (grass) contained chemical irritants.

Materials and Methods

Respiratory disease rates among adults were assessed in Spokane County. The database used to assess the disease rate in the adult population was obtained from an early 1995 Spokane County Regional Health Department survey. The survey results were evaluated to establish the percentage of individuals in the county affected by asthma, chronic bronchitis, and emphysema. Before this 1995 survey, neither the state nor the county had assessed specific respiratory disease rates. In an attempt to better understand what the data might mean, the results were compared with national data. The 1995 national disease data for asthma, chronic bronchitis, and emphysema are unavailable, so the 1995 disease estimates for asthma were derived by estimating the rate of increase from 1992 disease rates to 1994 disease rates (29–31). The final estimate was derived only from 1993 and 1994 data as the World Health Organization's International Classification of Diseases numeric asthma code has changed. The codes for emphysema and chronic bronchitis have remained the same, so the 1995 estimates for these diseases were based on data from 1990 through 1994. The authors found that these rates were very stable.

The SF12 and SF36 questionnaires, distributed by the Medical Outcomes Trust, were used as the county survey instrument. This survey has been thoroughly tested for reliability and validity; one study specifically examined the survey's asthma questions for validity (32). The survey was randomly administered throughout the county and was completed by 71 percent (1,850) of the subjects. The respondents' demographic profiles matched those of the county almost identically (Table 1). A Spokane County Regional Health Department representative felt that the survey results could be applied analogously to children (33). Prior research has shown, however, that adult rates are lower than those of children, so the authors attempted to identify the asthma rate for children in the county (34).

The authors conducted phone surveys of the area public schools and preschools. When re-calling sites to recheck the survey data, the authors found that the data obtained from many of the schools and daycare centers was not reliable. The authors were able to establish asthma rates for low-income children attending Head Start. These programs had excellent health collection instruments and processes for obtaining reliable data on the children in their programs. As that rate can be accurately applied only to low-income children (20.8 percent) residing in Spokane County, it was not possible to develop a rate for all of the children in the county (35).

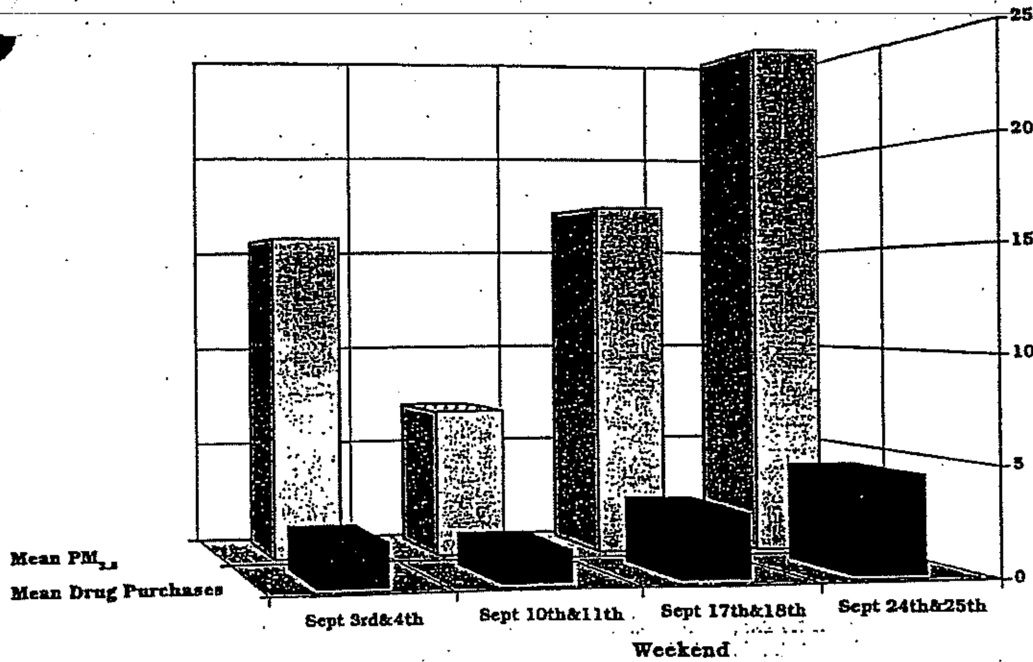
Hospitalization rates for asthma were established with data from the Comprehensive Hospital Abstract Reporting System (CHARS). These data are collected by the state health department from all state-licensed hospitals except federal institutions. Records are kept by hospitalization, not by individual, and do not include Washington State residents who are cared for in another state. The data contain several fields into which the International Classification of Diseases asthma code can be entered (36).

An additional data set used in this study consisted of two years of asthma-related drug purchase records drawn from the pharmacy database of Group Health Northwest (GHNW). GHNW is a managed care organization with approximately 160,000 members. It contracts with individuals, private and public businesses, the federal government (the military and Medicare), and the state (Medicaid and two special sliding-scale programs for individuals who would otherwise be uninsured) (37). The county survey revealed that 10 percent of the population remains without medical insurance and thus would not be included in this database.

The analysis and quantitation of the compounds was carried out with a Hewlett Packard gas chromatograph/mass spectrometer (GC/MS) (HP5890II/HP5971A) controlled by an HPCHEM software program. Individual phenols and PAH were determined by correlations with a National Bureau of Standards mass spectrometry library and by comparison with authentic and commercially available phenols (from Sigma) and PAH (from Supelco).

FIGURE 1

Correlation Between Weekend Drug Purchases and $PM_{2.5}$ Levels (in micrograms per cubic meter) for September 1994



urethane foam (PUF) plug from University Research Glassware. Twenty-five-minute samples were taken of all of the smoke and of smoke with a particle size 2.5 µm or less ($PM_{2.5}$).

In the controlled burns, the charcoal, with the smoke compounds adsorbed, was transferred from the glass tubes to an empty stainless steel tube (25 cm long by 3 mm in internal diameter). The charcoal was immobilized in the tube by acid-washed silanised glass wool. The steel tube was placed in the thermal desorption trap position in a purge and trap (HP 7965) sampler. Using an HP software program, the trap was heated for 4 minutes at 300°C, during which time helium (at 30 pounds per square inch) was passed through the trap. The thermally desorbed compounds were automatically transferred from the charcoal to an RTx capillary column (from Restex) in a gas chromatograph (HP5890 II). The capillary column was 105 m long and had an internal diameter of 0.32 mm. The PUF plugs used in the sampling of the controlled burns were heated to 80° C for 15 minutes in 25 mL of a polar organic solvent, acetonitrile, and then filtered. This extract was reduced in volume to 0.2 mL by evaporation under pressure. Finally, 2 µL of this solution was injected into the gas chromatograph with a DB-624 capillary column (from J&W Scientific) 30 m long by 0.32 mm in internal diameter.

Data Collection

The county survey contained two questions that pertained directly to respiratory health. The first question asked if the respondent had been diagnosed with asthma. The purpose of this question was to ascertain the childhood asthma rate. The second question asked if the respondent had been diagnosed with emphysema or chronic bronchitis.

Pharmacists from GHNW identified four drugs (Beclovent, Intal, Azmacort, and Ventolin) as strongly associated with the treatment of asthma. GHNW's pharmacy provided the study with two years of purchase data for these four drugs. The correlation between the purchase patterns for these drugs and PM_{10} and $PM_{2.5}$ levels were examined statistically. First, the daily number of drugs purchased was compared with the PM_{10} and $PM_{2.5}$ levels in the air, then nonstandard weekend purchase totals were separately compared with $PM_{2.5}$ levels (Figures 1 and 2). In 1994 and 1995, grass fields were burned on 12 nonconsecutive days. These burn days occurred over a period of about one to two months; the number of acres burned varied, as did the location, wind speed, and direction. These facts, along with other confounding variables, made more detailed statistical analysis unreliable.

The hourly and daily PM_{10} and $PM_{2.5}$ data were collected by SCAPCA with tapered-element oscillating microbalances (TEOMs) (Rupprecht & Patashnick series 1400a) to continuously monitor the particulate loading in the air. These instruments determine the mass loading on a Teflon-coated, quartz-fiber filter (15 millimeters in diameter). A U.S. EPA-equivalent method was used for mass analysis of PM_{10}. For the $PM_{2.5}$ measurements, a calibrated cyclonic separator is positioned upstream of the flow splitter.

Two sampling methods were used to concentrate the smoke. In the initial approach, smoke was collected during the burning of Kentucky bluegrass fields in southern Spokane County in the fall of 1991. The air samples containing smoke were drawn over charcoal (130 mg) in glass tubes (from SKC) by battery-driven personal sampling pumps (also from SKC) at a rate of 5.0 liters per hour. The samplers were placed at distances ranging from 1 to 8 kilometers from the combustion sites for periods ranging from 24 to 48 hours.

A later study that involved a controlled open burn of Kentucky bluegrass field residues used a different sampling technique. Smoke from this controlled burn was sampled at a rate of 5 liters per minute (L/min) with a Lane County sampler situated 1 meter from the fire. The smoke was trapped with a poly-

Results

Chronic Bronchitis and Emphysema

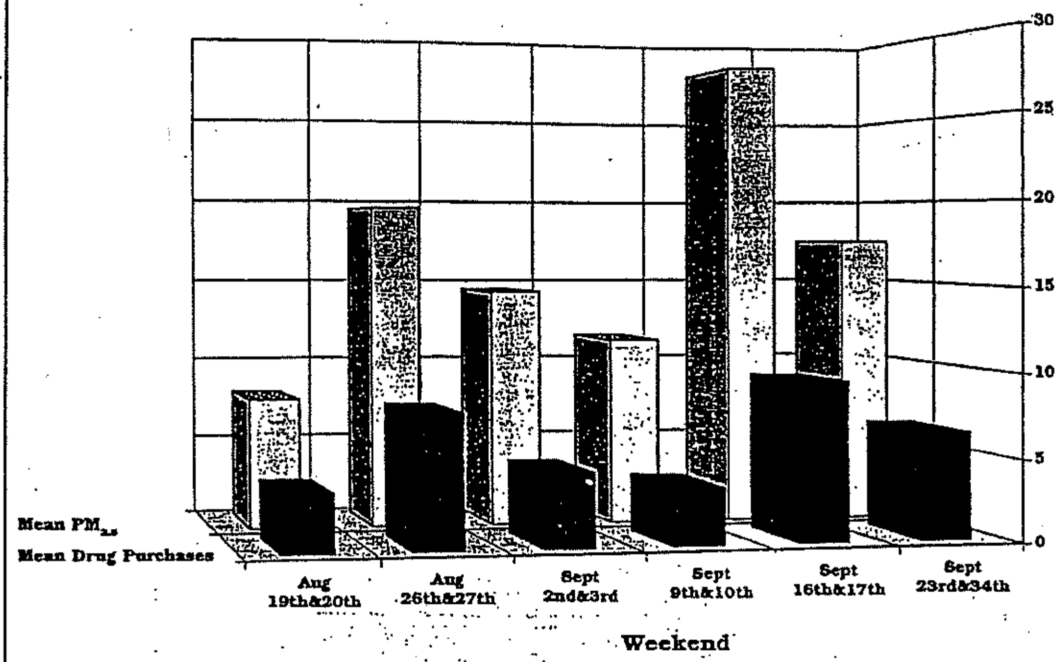
The results of the county survey indicated that 7.4 percent of the population in Spokane has chronic bronchitis or emphysema (1995); the 1995 estimated national rate is 6.2 percent, a rate that has remained constant since 1990 (34). This difference was significant ($p = .013$) and will result in 4,013 excess disease cases in the county. Although smoking is strongly associated with these diseases, a Regional Health Department representative stated that the percentage of smokers (23.9 percent) does not exceed national levels (25 percent) (33).

Asthma

After identifying the percentage increase in asthma from 1993 to 1994 (0.7 percent), the authors added this figure to the 1994 data and estimated that 5.8 percent of the nation's adults had asthma in 1995 (30,31). A chi square analysis of the actual rates of adult asthma in Spokane County in relation to the expected rates resulted in a *p* value of less than .01. To assess the number of potential excess asthma deaths in the county, the total number of 1994 asthma deaths, 2.1 per 100,000 population, was compared with the overall asthma rate (5,610 per 100,000 population) to establish the percentage of asthmatics who died in 1994 (37). By dividing the number of deaths per hundred thousand into the number of asthmatics per hundred thousand, it was possible to calculate the expected percentage of deaths among asthmatics: 0.0374 percent. This figure was then multiplied by the number of excess disease cases among adults (15,341) in the county. The results revealed that expected excess deaths per year would be 5.74.

FIGURE 2

Correlation Between Weekend Drug Purchases and $PM_{2.5}$ Levels (in micrograms per cubic meter) for August and September 1995



Death Rates for Asthma

A 1993 study of death certificates suggests that the base figure used for calculating the numbers of asthma deaths per year may be too low. That study found that asthma may be greatly under-reported as a cause of death; 16 percent of the deaths among asthmatics were caused by asthma but were miscoded (38). If this figure is confirmed in future studies, the actual number of deaths caused by asthma in the general population will turn out to be higher than the 2.1 per 100,000 figure reported by Sly and O'Donnell (37).

Hospitalization Admission Rates for Asthma

A review of the CHARS data for 1995 showed that hospitalizations for asthma in Spokane County exceed the state levels. The first data are recorded in several formats and are reported as the number of cases per hundred thousand population (e.g., 86.1 per 100,000). The first format is for unduplicated admissions in which asthma is the primary diagnosis. (Unduplicated admissions do not count the individual again if he or she is readmitted during the year with the same primary diagnosis.) Spokane's rate was 91.7 admissions per 100,000; the state average was 86.1. Duplicated admissions with asthma as the primary diagnosis for Spokane were 111.9 per 100,000 in 1995; the state average was 102.3. This study also examined hospitalization through duplicated admissions in which asthma showed up in any of the diagnosis fields. For example, if a patient was admitted for heart surgery but needed an asthma treatment during the course of the admission, asthma would then show in one of the diagnosis fields. The rate for Spokane County for 1995 was 371.7 per 100,000; the average rate for the state was 301.4.

Pharmaceutical Use Patterns

An analysis of daily purchase data during the burn season showed a positive but not significant correlation between increases in $PM_{2.5}$ levels and drug purchases. No correlation was found between changes in particulate levels and drug purchase patterns during the weeks before grass burning. The weekend drug purchases were then compared to PM levels.

An analysis of mean nonscheduled weekend asthma-related drug purchases during burn season produced correlation coefficients of 0.94 ($n = 4$) in 1994 and 0.96 ($n = 6$) in 1995; these coefficients, when compared with $PM_{2.5}$ levels, yielded a significance level of $p < .01$ (Figures 1 and 2). PM_{10} levels and 1995 purchase patterns returned a positive but not significant correlation of 0.67. An analysis of weekend purchase patterns and $PM_{2.5}$ levels one month before the burning period did not indicate any clear correlation between purchase patterns and either PM_{10} and $PM_{2.5}$ levels. These analyses returned correlation values of 0.1 and −0.2 respectively.

The chemical analysis of the smoke samples revealed at least five different phenols in the smoke produced by combustion of Kentucky bluegrass residues in controlled open burning. Six PAHs were identified as components in air samples collected 1 to 5 kilometers from where the uncontrolled open burning of grass seed fields was conducted (Table 2).

Discussion

Lack of existing data limited this study in a number of ways. The first limitation stems from the fact that no previous attempt has been made to accurately ascertain disease rates at the local and state levels. This lack of state and local data limits the authors' ability to identify disease trends. Although national respiratory disease rates for 1995 have not yet been calculated, it was possible to estimate 1995 rates by examining the rates from previous years. Asthma rates for 1995 were estimated from 1993 and 1994 data.

Another limitation stems from the fact that purchase patterns do not necessarily reflect use patterns. Most inhalers are designed to last at least one month, and many long-time asthmatics tend to stock up. Also, some doctors acknowledged premedicating sensitive patients in anticipation of adverse reactions to the smoke. Given these facts, the authors speculated that purchase patterns would not reflect the actual use patterns of all asthmatic individuals. Discussions with two GHNW pharmacists led the authors to conclude that weekend drug purchase data might provide insights into some of the health effects of increases in $PM_{2.5}$. The pharmacists felt, based on their experiences, that many weekend drug purchases occur because of unplanned or emergency needs and newly diagnosed cases. The authors hypothesized that if grass field smoke were not affecting health, they should find no change in the purchase levels for emergency or unplanned needs or for newly diagnosed conditions during periods of increased particulate levels caused by grass burning.

Although many variables may contribute to the respiratory rates in Spokane County, the data described in this paper suggest that the county and the region face a number of health-related problems that appear to be associated with the high levels of fine particulates ($PM_{2.5}$) produced by grass field burning. For individuals with chemically induced asthma (RAD) caused by grass seed field burning, the recurrent nature of the practice continues to pose a health risk. A 1996 study found that 10 percent of the residents in eastern Washington and northern Idaho reported needing to purchase more medical care and supplies during field burning and eight percent were forced to leave the area entirely (21). For most of these individuals, asthmatic symptoms rarely result in death. For cystic fibrosis patients with RAD, however, the cumulative effects of exposures eventually can lead to respiratory failure and death (20).

An explanation for the way grass smoke appears to act as a trigger can be found in the Material Safety Data Sheets (MSDS). The MSDS state that all of the phenolic compounds that were identified have acute effects and "may be harmful by inhalation, ingestion, or skin absorption, may cause eye and skin irritation" (39). In addition, some of these phenols are "irritating to mucous membranes and the upper respiratory tract; depending on the intensity and duration of the exposure, the effects may vary from mild irritation to severe destruction of tissue" (39). The PAHs found are generally considered to be carcinogenic, although some (e.g., pyrene and acenaphthene) are also listed as being irritants to mucous membranes and eye, skin, and lung tissue (40).

The high county rates of adult asthma and hospitalization of asthmatics, as well as the drug purchase patterns, suggest an association between the $PM_{2.5}$ levels produced by grass field burning and morbidity. It would appear that the fine particulates produced by combustion and the chemical irritants in the smoke have combined to negatively affect the health of individuals suffering from RAD. Of course, further study will be necessary to ascertain if any other factors are acting in concert with the smoke to produce these results.

Some individuals believe that the newly proposed $PM_{2.5}$ particulate standards suggested by the U.S. Environmental Protection Agency (U.S. EPA) will solve agricultural burning problems of this type. The proposed U.S. EPA daily average standard for $PM_{2.5}$ is 65 micrograms per cubic meter ($\mu g/m^3$). Farmers tend, however, to restrict their burning activities to a few hours each day. This pattern would only produce transient increases in particulate levels. Since $PM_{2.5}$ is considered to contribute 30 to 90 percent of PM_{10}, the authors believe that average daily $PM_{2.5}$ levels will remain below the new daily standard (39). For example, in 1995, a review of hourly PM_{10} data during open field burning near Spokane produced extremely high hourly PM_{10} values of between 145 and 246 $\mu g/m^3$, but only resulted in a PM_{10} 24-hour average of 60 $\mu g/m^3$. Calculated at 30 to 90 percent of PM_{10}, the average daily $PM_{2.5}$ level remains below the new standard. Thus it would appear that the new standard, as currently proposed, will have no effect on the regulation of open field burning. It is therefore imperative that environmental health researchers evaluate the health impacts of agricultural burning even when particulate standards are not exceeded.

Acknowledgements

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Footnote 6

Increased Particulate Air Pollution and the Triggering of Myocardial Infarction

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Background—Elevated concentrations of ambient particulate air pollution have been associated with increased hospital admissions for cardiovascular disease. Whether high concentrations of ambient particles can trigger the onset of acute myocardial infarction (MI), however, remains unknown.

Methods and Results—We interviewed 772 patients with MI in the greater Boston area between January 1995 and May 1996 as part of the Determinants of Myocardial Infarction Onset Study. Hourly concentrations of particle mass <2.5 μm ($PM_{2.5}$), carbon black, and gaseous air pollutants were measured. A case-crossover approach was used to analyze the data for evidence of triggering. The risk of MI onset increased in association with elevated concentrations of fine particles in the previous 2-hour period. In addition, a delayed response associated with 24-hour average exposure 1 day before the onset of symptoms was observed. Multivariate analyses considering both time windows jointly revealed an estimated odds ratio of 1.48 associated with an increase of 25 $\mu g/m^3$ $PM_{2.5}$ during a 2-hour period before the onset and an odds ratio of 1.69 for an increase of 20 $\mu g/m^3$ $PM_{2.5}$ in the 24-hour period 1 day before the onset (95% CIs 1.09, 2.02 and 1.13, 2.34, respectively).

Conclusions—The present study suggests that elevated concentrations of fine particles in the air may transiently elevate the risk of MIs within a few hours and 1 day after exposure. Further studies in other locations are needed to clarify the importance of this potentially preventable trigger of MI. (***Circulation*. 2001;103:2810-2815.**)

Key Words: myocardial infarction ■ air pollution ■ heart disease ■ epidemiology

Epidemiological analyses throughout the world have shown that high 24-hour average levels of ambient particulate air pollution are associated with an increase in all-cause, respiratory, and cardiovascular disease mortality[1–4]; nevertheless, little information is available on the effect of shorter-term exposures. The harmful effects of elevation of ambient concentrations of particulate matter are well documented in multiple studies of hospital admissions and emergency department visits for respiratory diseases.[1,4] In addition, increased hospital admissions for cardiovascular diseases have been associated with particulate air pollution in studies of numerous American, Canadian, and European cities.[5–9] These results indicate that ambient particulate air pollution is a risk factor not only for respiratory diseases but also for acute cardiovascular events.

Inhaled particles could lead to acute exacerbation of cardiovascular disease through pulmonary inflammation triggering systemic hypercoagulability.[10] Increases in plasma viscosity[11] and C-reactive protein[12] were observed in randomly selected healthy adults after episodes of high particulate air pollution. Increased heart rate,[13,14] decreased heart rate variability,[15–17] and increased risk of implanted cardioverter-defibrillator discharges[18] associated with episodes of particulate air pollution indicate an autonomic nervous system response.

The US Environmental Protection Agency has promulgated a new ambient air quality standard for fine particles (particulate matter <2.5 μm aerodynamic diameter, $PM_{2.5}$).[19] This new standard regulates 24-hour and annual average concentrations and does not address transient elevations (minutes to hours) in fine-particle concentration. There are no published data on the risk of myocardial infarction (MI) in human populations after transient exposures to elevated concentrations of ambient fine particles.

We therefore evaluated the effect of short-term exposure to fine-particulate air pollution on the risk of acute MIs, comparing data from the Determinants of Myocardial Infarction Onset Study (Onset Study) with hourly measurements of fine particles in Boston. We used a case-crossover design[20,21] to specifically assess the risk of exposure to high levels of $PM_{2.5}$ and the timing of the impact of this exposure on the onset of MI.

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Methods

Study Design

The design of the Onset Study has been described in detail elsewhere.[20–23] In brief, we used a case-crossover study design to assess the change in risk of acute MI during a brief "hazard period" after exposure to potential triggers of MI onset. An important feature of the case-crossover design is that control information for each patient is based on his or her own past exposure experience. Self-matching results in freedom from confounding by risk factors that are stable over time within an individual but often differ between study subjects.

Patient Population

The Onset Study is a multicenter case-crossover study conducted between 1989 and 1996 in 64 centers throughout the United States.[24] Participants were interviewed a median of 4 days after their MI. We analyzed data from 772 Onset Study participants living in the greater Boston area collected between January 20, 1995, and May 25, 1996. Data were collected in 6 centers with ≥50 cases (455 cases), 6 centers with 25 to 49 cases (209 cases), and 14 centers with <25 cases (108 cases).

Interviewers identified eligible cases by reviewing coronary care unit admission logs and patients' charts. For inclusion in the study, patients were required to meet all of the following criteria: symptom onset while in the greater Boston area, ≥1 creatine kinase level above the upper limit of normal for the clinical laboratory performing the test, positive MB isoenzymes, an identifiable onset of pain or other symptoms typical of infarction, and the ability to complete a structured interview. The protocol was approved by the Institutional Review Board at each participating center, and informed consent was obtained from each patient.

Detailed chart reviews and patient interviews were conducted by trained research personnel.[22,23] Data were collected on standard demographic variables as well as risk factors for coronary artery disease. The interview identified the time, place, and characteristics of MI pain and other symptoms.

Air Pollution Measurements

Daily air pollution measurements were collected at a Harvard School of Public Health–operated monitoring site in South Boston starting January 15, 1995.[18] $PM_{2.5}$ and PM_{10} concentrations were measured continuously with a Tapered Element Oscillating Microbalance (Rupprecht and Patashnick model 1400A TEOM). Elemental carbon concentration was determined continuously with an Aethalometer (Magee Scientific Inc), a light-absorption method to measure "black carbon." Ozone concentration was measured with a UV photometer analyzer (TECO model 49, Thermal Environmental). CO concentration was measured with a continuous nondispersive infrared analyzer (Bendix model 8501-5CA). Relative humidity and temperature were measured continuously (Vaisala model MP113Y). The Massachusetts Department of Environmental Protection measured concentrations of sulfur dioxide and nitrogen dioxide hourly in Chelsea, which is ≈7.5 km north of the South Boston site. We calculated 24-hour mean values when ≥16 valid hourly measurements were available.

Statistical Analyses

The analysis of case-crossover data is an application of standard methods for stratified data analysis.[20,21] The stratifying variable is the individual patient, as in a crossover experiment. For each subject, 1 case period was matched to 3 control periods exactly 24 hours apart. Thus, by matching time of day for case and control periods, potential confounding by the circadian pattern of MI onset or diurnal patterns in the air pollution were controlled.

Conditional logistic regression analyses were used to analyze the data. Exposure to particles and gases were entered into the model as continuous variables. Odds ratios are expressed for a change in air pollution concentrations from the 5th to the 95th percentile for all measurements available. Separate models were constructed to evaluate the impact of hourly and 24-hour average air pollution concentrations on the onset of MI.

We also evaluated the effect of hourly (2-hour average) and daily (24-hour average) exposures jointly in 1 model. Control periods were selected as multiples of 24 hours starting 3 days before the date and time of the onset of the symptoms. In addition, multivariate analyses adjusting for season, day of the week, and meteorological parameters on the same time scales were estimated. The final model included sine and cosine functions with periods of 1 year plus ½, ⅓, ¼, ⅕, and ⅙ of a year. It also included quadratic terms for minimum temperature and relative humidity during the 2-hour and 24-hour period of exposure and an indicator for the day of week. Results are presented as odds ratios (OR) and 95% CI.

The unidirectional case-crossover analyses might be sensitive to trends in the outcome and the exposure.[25,26] Therefore, control periods close to the event were chosen to minimize the impact of a potential trend. Particulate air pollution concentrations increased over time (0.4 $\mu g/m^3$ per 100 days, P=0.0002). Although there was weak evidence of a linear downward trend in the number of cases (−0.05 cases per 100 days, P=0.23), the sampling fraction of cases decreased substantially during 1996. Consequently, a downward bias of the estimates would have been expected. This could be demonstrated by choosing control periods >5 days before the event. The bidirectional design has been shown to give unbiased estimates when full case ascertainment was present.[26] Analyses of the present data, however, indicated a bias with the bidirectional design due to incomplete case ascertainment during 1996.

TABLE 1. Characteristics of the Study Population (n=772)

Age, y	
Mean±SD	61.6±13.4
<50	164 (21)
50–69	365 (47)
70+	243 (32)
Sex	
Male	489 (63)
Female	283 (37)
Medical history	
Prior myocardial infarction	237 (31)
Prior angina	174 (23)
Any coronary artery disease	302 (39)
Hypertension	319 (41)
Diabetes mellitus	143 (19)
Obese	261 (34)
Ever smoker	558 (72)
Current smoker	246 (32)

Values are n (%).

Results

The baseline characteristics of the study population are shown in Table 1. The distribution of 24-hour average and 1-hour average concentrations of the particulate and gaseous air pollutants is presented in Table 2. $PM_{2.5}$ and PM_{10} were highly correlated, whereas the coarse fraction of PM_{10}, ie, difference of PM_{10} and $PM_{2.5}$, and the gaseous pollutants were only moderately correlated with $PM_{2.5}$.

Figures 1 and 2 show results from the conditional logistic regression models, in which $PM_{2.5}$ was entered as a linear continuous variable. Odds ratios are expressed for an hourly change of 25 $\mu g/m^3$ in $PM_{2.5}$ (Figure 1) or a daily change of

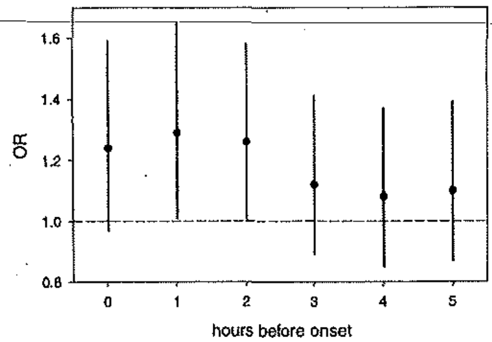

Figure 1. Univariate analyses for association between onset of MI and hourly concentrations of $PM_{2.5}$. Odds ratios and 95% CIs for an increase of 25 $\mu g/m^3$ $PM_{2.5}$.

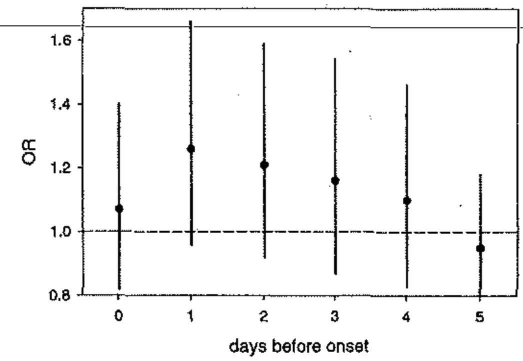

Figure 2. Univariate analyses for association between onset of MI and 24-hour average concentrations of $PM_{2.5}$. Odds ratios and 95% CIs for an increase of 20 $\mu g/m^3$ $PM_{2.5}$.

20 $\mu g/m^3$ $PM_{2.5}$ (Figure 2) corresponding the 5th to 95th percentile intervals (Table 2).

A positive association between the onset of MI and the concentrations of $PM_{2.5}$ was observed within the first 3 hours (Figure 1) that was statistically significant for the $PM_{2.5}$ concentrations 1 hour and 2 hours before the onset of symptoms of an MI. Exposures before this time period seemed to have little impact on the risk of acute MI. In addition, a more delayed response to air pollution was observed when 24-hour averages of the particles were considered (Figure 2). A positive association was observed with

TABLE 2. Distribution of the Air Pollutants for the Time Period January 15, 1995, to May 25, 1996, in Boston, Mass

							Correlation With $PM_{2.5}$	
	n	Mean	SD	5%	50%	95%	1-Hour	24-Hour
Particles								
$PM_{2.5}$, $\mu g/m^3$								
1-hour	11 457	12.1	8.9	2.6	9.7	29.6	1.00	
24-hour	490	12.1	6.8	4.6	10.4	24.3		1.00
PM^{10}, $\mu g/m^3$								
1-hour	11 698	19.4	12.8	4.5	16.7	43.7	0.87	
24-hour	497	19.4	9.4	7.8	17.6	37.0		0.90
Coarse mass, $\mu g/m^3$								
1-hour	11 357	7.3	6.6	−0.7	6.2	19.4	0.33	
24-hour	490	7.4	4.4	1.6	6.8	15.2		0.38
Black carbon, $\mu g/m^3$								
1-hour	11 466	1.34	1.21	0.27	0.97	3.71	0.68	
24-hour	488	1.35	0.72	0.49	1.18	2.83		0.74
Gases								
Ozone, ppb								
1-hour	10 884	19.8	14.8	1	18	46	−0.03	
24-hour	460	19.9	10.0	6	19	36		0.10
Carbon monoxide, ppm								
1-hour	11 843	1.09	0.58	0.30	1.00	2.10	0.54	
24-hour	497	1.09	0.40	0.49	1.07	1.78		0.57
Nitrogen dioxide, ppm								
1-hour	11 671	0.023	0.013	0.007	0.021	0.047	0.51	
24-hour	494	0.024	0.009	0.011	0.022	0.039		0.60
Sulfur dioxide, ppm								
1-hour	11 796	0.007	0.010	0	0.005	0.023	0.38	
24-hour	497	0.007	0.007	0.001	0.006	0.020		0.43

TABLE 3. Odds Ratios for 2-Hour (1 Hour Before Onset) and 24-Hour Average (on the Previous Day) Concentrations of $PM_{2.5}$ Considered Jointly

	Quintile					Trend Test *P*
	I	II	III	IV	V	
2-hour average $PM_{2.5}$						
Range, μg/m³	0–5.2	5.3–7.9	7.9–11.5	11.6–17.0	17.1–74.8	
Odds ratios (CI)	1.00	1.15 (0.90, 1.48)	1.09 (0.84, 1.41)	1.27 (0.99, 1.64)	1.44 (1.12, 1.87)	0.025
24-hour average $PM_{2.5}$						
Range, μg/m³	1.6–6.4	6.5–8.6	8.7–11.5	11.6–16.2	16.3–52.2	
Odds ratios (CI)	1.00	1.12 (0.87, 1.45)	1.15 (0.89, 1.48)	1.31 (1.01, 1.69)	1.32 (1.01, 1.72)	0.008

elevated concentrations between 24 and 48 hours before the onset of the symptoms.

A combined analysis considered 2-hour averages (between 60 and 180 minutes before the onset of symptoms) and 24-hour averages (between 24 and 48 hours before the onset of the symptoms) jointly, with pollution levels divided into quintiles (Table 3). When concentrations of $PM_{2.5}$ were elevated immediately before the onset of symptoms as well as 1 day before the onset of symptoms, the risk of an MI was increased.

Table 4 summarizes the association between ambient air pollution as a continuous measure and the risk of onset of MI. The estimates of the combined analyses of 2-hour averages and 24-hour averages were larger than the analyses considering the time periods individually. Statistically significantly elevated risks of MI were observed for $PM_{2.5}$. The coarse

TABLE 4. Odds Ratios for 2-Hour and 24-Hour Average Concentrations of Single Pollutants Estimated Jointly.

	Increase (5th to 95th Percentile)	Unadjusted OR (95% CI) (n=772)	Adjusted* OR (95% CI) (n=764)
Particles			
$PM_{2.5}$, μg/m³			
2-hour	25	1.43 (1.13, 1.81)	1.48 (1.09, 2.02)
24-hour	20	1.44 (1.11, 1.86)	1.62 (1.13, 2.34)
PM_{10}, μg/m³			
2-hour	40	1.45 (1.11, 1.88)	1.51 (1.06, 2.15)
24-hour	30	1.31 (0.99, 1.73)	1.66 (1.11, 2.49)
Coarse mass, μg/m³			
2-hour	15	1.13 (0.92, 1.40)	1.16 (0.89, 1.51)
24-hour	15	1.18 (0.85, 1.64)	1.39 (0.89, 2.15)
Black carbon, μg/m³			
2-hour	3	1.32 (1.06, 1.65)	1.27 (0.97, 1.68)
24-hour	2	1.08 (0.84, 1.39)	1.21 (0.87, 1.70)
Gases			
Ozone, ppb			
2-hour	45	1.05 (0.76, 1.46)	1.31 (0.85, 2.03)
24-hour	30	1.21 (0.88, 1.67)	0.94 (0.60, 1.49)
Carbon monoxide, ppm			
2-hour	1.0	1.27 (0.98, 1.63)	1.22 (0.89, 1.67)
24-hour	0.6	0.99 (0.77, 1.27)	0.98 (0.70, 1.36)
Nitrogen dioxide, ppm			
2-hour	0.040	1.20 (0.91, 1.59)	1.08 (0.76, 1.53)
24-hour	0.030	1.03 (0.77, 1.39)	1.19 (0.81, 1.77)
Sulfur dioxide, ppm			
2-hour	0.020	1.00 (0.87, 1.14)	0.96 (0.83, 1.12)
24-hour	0.020	0.92 (0.71, 1.20)	0.91 (0.67, 1.23)

Estimates are calculated for a change from 5th to 95th percentile of the pollutants.
*Adjusted for season, meteorological parameters, and day of the week.

fraction of PM_{10}, black carbon, and the gaseous air pollutants including carbon monoxide, NO_2, SO_2, and ozone showed positive associations, but none were statistically significant.

A strong seasonal pattern was observed, with increased risks of MI between May and December. Temperature and humidity immediately before the onset of symptoms were not associated with the onset of symptoms, but the 24-hour averages of higher temperatures and lower humidity 1 day before the onset of symptoms showed an increased risk. After adjustment for seasonal and meteorological conditions, the association of $PM_{2.5}$ with the onset of MI was sustained (Table 4).

Discussion

Elevated concentrations of fine particles ($PM_{2.5}$) were associated with a transient risk of acute MI onset. High 24-hour average concentrations of fine particles were also associated with an elevated risk of MI with a 24-hour delay. The elevated risks during 2 separate time periods appear to be independent of each other. In addition, even changes from low to moderate ambient concentrations were associated with an increased risk of MI, although $PM_{2.5}$ concentrations were below the new standards.[23] Particles >2.5 μm, which consist primarily of resuspended crustal material, showed a substantially smaller association than particles <2.5 μm. Other pollutants, such as black carbon, carbon monoxide, nitrogen dioxide, and sulfur dioxide, showed positive associations, but none of them achieved statistical significance in the single-pollutant multivariate analyses.

These results are consistent with time-series analyses on hospital admissions for cardiac diseases.[5–9] Hospital admission data collected for administrative purposes were positively associated with 24-hour average particle mass concentrations collected for regulatory compliance monitoring. The effect of ambient particles on hospital admissions was reported to vary between an immediate response on the same day[5–7,9] and a 1-day lagged response.[8]

There are several biological effects of ambient particles that may lead to cardiac events. First, particles deposited in the alveoli lead to activation of cytokine production by alveolar macrophages[27] and epithelial cells[28] and to recruitment of inflammatory cells.[29] Second, increases in plasma viscosity[11] and C-reactive protein[12] have been observed in randomly selected healthy adults in association with episodes of high particulate air pollution. Third, acceleration of heart rates and diminished heart rate variability in association with air pollution have been documented in elderly persons[13,15–17] and in a random population sample.[14] One study reported that heart rate variability started to decrease within hours of exposure.[17] Controlled-exposure experiments in dogs exposed to concentrated ambient particles indicated changes in the ECG within an hour of the onset of exposure.[30] Fourth, ambient concentrations of $PM_{2.5}$ have been associated with ventricular fibrillation and an increased number of therapeutic interventions in patients with implanted cardioverter-defibrillators.[18]

A proposed mechanism for triggering of MI is that onset occurs when a vulnerable but not necessarily stenotic atherosclerotic plaque disrupts in response to hemodynamic stress; thereafter, hemostatic and vasoconstrictive forces determine whether the resultant thrombus becomes occlusive.[31] As reviewed above, particulate air pollution is associated with hemodynamic and hemostatic alterations, which may contribute to MI onset.

Previous studies have shown that physical[23,32] and psychological[24] stress as well as substances such as cocaine[22] can trigger the onset of MI. In this report, we demonstrate that transient exposures to an environmental factor, ie, ambient air pollution, appear to increase the risk of an acute MI.

The available evidence suggests that the mechanisms responsible for the impact of ambient particles on MI may be similar to the mechanisms responsible for triggering by other stressors. If these findings are substantiated, susceptible subgroups could be identified and possible pharmacological interventions could be developed to protect the public from transient exposures to ambient particles, such as that experienced during rush-hour traffic.

Limitations

The case-crossover design controls for chronic risk factors for MI such as sex, age, and hypertension. Confounding may occur because of time-varying risk factors,[26] such as time of day, season, or weather. These potential confounders, however, were considered in the multivariate analyses.

Another potential limitation of the study is that only 1 air pollution monitoring site was available. Air pollution measurements throughout the east coast indicate that the elevated concentrations of particulate matter during the summer months are due to regional transport.[33] For 11 months, starting in October 1995, concurrent $PM_{2.5}$ measurements were collected every other day in South Boston and 3 other sites in eastern Massachusetts. There was high concordance between these 24-hour samples, with Pearson correlation between South Boston and downtown Boston (Beacon Hill, 3 km northwest) of 0.86, Lynn (16 km north) of 0.86, and Brockton (27 km south) of 0.81. On a larger scale, a high correlation (0.76) was found between daily concentrations of fine particles measured at sites 200 km apart in Washington and Philadelphia.[33] Data on the correlation between hourly concentrations of fine particles at different locations within a metropolitan area are not available.

Conclusions

Knowledge of the induction time between the exposure to particulate air pollution and adverse health effects is crucial to understanding the biological mechanisms responsible for these associations and to setting of standards that reduce the risk for the population. The present study suggests that elevated concentrations of fine particles may transiently increase the risk of MI for several hours as well as for several days after exposure. As a consequence, 24-hour averages might underestimate the association between air pollution and acute cardiovascular events.

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FACT SHEET
FINAL REVISIONS TO THE NATIONAL AMBIENT AIR QUALITY STANDARDS FOR PARTICLE POLLUTION (PARTICULATE MATTER)

SUMMARY OF ACTION

- To better protect public health and welfare for millions of Americans across the country, EPA on September 21, 2006 issued the Agency's most protective suite of national air quality standards for particle pollution ever.

- Particle pollution, also called particulate matter or PM, is a complex mixture of extremely small particles and liquid droplets in the air. When breathed in, these particles can reach the deepest regions of the lungs. Exposure to particle pollution is linked to a variety of significant health problems. Particle pollution also is the main cause of visibility impairment in the nation's cities and national parks.

- The final standards address two categories of particle pollution: *fine particles* ($PM_{2.5}$), which are 2.5 micrometers in diameter and smaller; and *inhalable coarse particles* (PM_{10}) which are smaller than 10 micrometers. (A micrometer is 1/1000th of a millimeter; there are 25,400 micrometers in an inch.)

- EPA is strengthening the 24-hour fine particle standard from the 1997 level of 65 micrograms per cubic meter (µg/m3) to 35µg/m^3, and retains the current annual fine particle standard at 15µg/m^3. The Agency also is retaining the existing national 24-hour PM_{10} standard of 150µg/m^3.

- The Agency is revoking the annual PM_{10} standard, because available evidence generally does not suggest a link between long-term exposure to current levels of coarse particles and health problems. EPA is protecting all Americans from effects of short-term exposure to inhalable coarse particles by retaining the existing daily PM_{10} standard of 150 micrograms per cubic meter.

- Scientific studies have found an association between exposure to particulate matter and significant health problems, including: aggravated asthma; chronic bronchitis; reduced lung function; irregular heartbeat; heart attack; and premature death in people with heart or lung disease.

- EPA selected levels for the final standards after completing an extensive review of thousands of scientific studies on the impact of fine and coarse particles on public health and welfare. The Agency also carefully reviewed and considered public comment on the proposed standards. EPA held three public hearings and received about 120,000 written comments.

- The Agency provisionally assessed new, peer-reviewed studies about particle pollution and health (including some studies received during the comment period) to ensure that the

Agency was aware of new science before setting the final standards. That assessment did not materially change EPA's understanding of PM. EPA did not base its decision on these new studies, however, because they have not been through as rigorous a level of review as the science on which the Agency based its December 2005 proposal. EPA will consider these new studies during the next review of the PM standards.

- EPA has issued rules that will help states meet the standards by making significant strides toward reducing fine particles. These rules include the Clean Air Interstate Rule to dramatically reduce and cap particle pollution-forming emissions from power plants in the eastern United States, the Clean Diesel Program to dramatically reduce emissions from highway, nonroad and stationary diesel engines, and the Clean Air Visibility rule, which will reduce emissions affecting air quality in national parks.

THE FINAL STANDARDS

- For both fine and coarse particles, EPA sets two types of standards: primary standards, to protect public health; and secondary standards, to protect the public welfare from effects including visibility impairment, damage to building and national monuments, and damage to ecosystems.

Fine Particle Standards

- EPA has two primary standards for fine particles: an annual standard, designed to protect against health effects caused by exposures ranging from days to years; and a 24-hour standard, designed to provide additional protection on days with high peak $PM_{2.5}$ concentrations.

24-hour standards

- o *Primary* -- EPA has substantially strengthened the primary 24-hour fine particle standard, lowering it from the current level of 65 micrograms per cubic meter (μg/m3) to 35μg/m^3. EPA based this decision on an assessment of a significantly expanded body of scientific information. The assessment concluded that the standard should be strengthened to better protect the public from the health effects associated with short-term fine particle exposures.

- o *Secondary* -- The Agency has set the secondary standard at the same level as the primary standard (35μg/m^3).

Annual standards

- o *Primary* -- EPA is retaining the primary annual standard at 15μg/m^3 based on its assessment of several expanded, re-analyzed and new studies that have increased the Agency's confidence in associations between long-term $PM_{2.5}$ exposure and serious health effects that were documented in the prior review. The assessment concluded that this standard continues to be appropriate to protect the public from heath effects associated with long-term fine particle exposures.
  Secondary -- The Agency has set the secondary standard at the same level as the primary standard (15μg/m^3).

Coarse Particle Standards

24-hour standards

- EPA is retaining the current 24-hour PM_{10} standards to protect against health and welfare effects associated with exposure to some types of coarse particles. Short-term exposure to coarse particles in urban and industrial areas is associated with serious health effects. Retaining this standard will provide protection in all areas of the country against the effects of short-term exposure to such coarse particles.

- Scientific evidence links health problems to coarse particle exposure in urban and industrial areas, but evidence about exposure in rural areas is limited. The Agency is recommending that States focus their control programs on urban and industrial sources that are contributing to air quality violations.

- The Agency intends to characterize uncertainties in the currently available information on coarse particles as part of the Agency's ongoing PM research program.

Annual standards

- EPA is revoking the annual PM_{10} standards, because there is insufficient evidence linking health problems to long-term exposure to inhalable coarse particle pollution.

THE FORM OF THE STANDARDS

- When EPA sets air quality standards, it also must specify the air quality statistics that the Agency will use to determine whether an area is meeting the standards. These statistics are known as the "form of the standard" and are derived separately for each standard.

Fine particles – form of the 24-hour standard

- An area will meet the 24-hour standard if the 98^{th} percentile of 24-hour $PM_{2.5}$ concentrations in a year, averaged over three years, is less than or equal to the level of the standard of 35 $\mu g/m^3$. This is the same form as the current 24-hour standard.

Fine particles – form of the annual standard

- An area will meet the annual $PM_{2.5}$ standard when the three-year average of the annual average $PM_{2.5}$ concentration is less than or equal to 15 $\mu g/m^3$. This is the same form as the current annual standard.

- The revisions limit the conditions under which some areas may average measurements from multiple community-oriented monitors to determine compliance with the annual standard.

Inhalable coarse particles – form of the 24-hour standard

- An area will meet the 24-hour PM_{10} standard when the 150µg/m^3 level is not exceeded more than once per year on average over a three year period. This is the same form as the current 24-hour standard.

SOURCES OF PARTICLE POLLUTION

Fine particles

- Fine particles can be emitted directly, such as in smoke from a fire, or they can form from chemical reactions of gases such as sulfur dioxide, nitrogen dioxide and some organic gases.
- Sources of fine particle pollution (or the gases that contribute to fine particle formation) include power plants, gasoline and diesel engines, wood combustion, high-temperature industrial processes such as smelters and steel mills, and forest fires.

Coarse particles

- Coarse particles can be generally divided into rural, natural crustal material such as dust and urban particles such as road dust kicked up by traffic (called *resuspended* dust), construction and demolition, industries; and biological sources.

PARTICLE POLLUTION AND PUBLIC HEALTH

- Thousands of new scientific studies on particulate matter have been published and peer-reviewed since EPA last reviewed the standards in 1997, and before the "cutoff date" for inclusion in the "criteria document" of studies for this review. These include several studies used in the 1997 review that have been extended, and the data reanalyzed.

- The majority of the studies assessed for the current review were published prior to 2003. To ensure that the EPA Administrator was fully aware of new science before making a final decision on the standards, EPA conducted a survey and provisional assessment of relevant new studies. The Agency did not rely on these studies in making its decision on the standards, however, because they have not been through as rigorous a level of review as the science on which the Agency based its December 2005 proposal. EPA will consider these studies in its next review.

Exposure to fine particle pollution

- **Health effects associated with short-term exposure to fine particles ($PM_{2.5}$) include:**
    - Premature death in people with heart and lung disease
    - Non-fatal heart attacks
    - Increased hospital admissions, emergency room visits and doctor's visits for respiratory diseases
    - Increased hospital admission and ER visits for cardiovascular diseases
    - Increased respiratory symptoms such as coughing, wheezing and shortness of breath
    - Lung function changes, especially in children and people with lung diseases such as asthma.
    - Changes in heart rate variability
    - Irregular heartbeat

- **Health effects associated with long-term exposure to fine particles ($PM_{2.5}$) include:**
  - Premature death in people with heart and lung diseases, including death from lung cancer
  - Reduced lung function
  - Development of chronic respiratory disease in children

Exposure to coarse particle pollution

- **Health effects associated with short-term exposure to coarse particles include:**
  - Premature death in people with heart or lung disease
  - Hospital admissions for heart disease
  - Increased hospital admissions and doctors' visits for respiratory disease
  - Increased respiratory symptoms in children
  - Decreased lung function

- Available evidence generally does not suggest a link between *long-term* exposure to coarse particles and health problems.

IMPLEMENTING THE STANDARDS

- The Clean Air Act requires EPA to designate areas as attainment (meeting the standards) or nonattainment (not meeting the standards) when the Agency sets a new standard, or revises an existing standard.

- **The following schedule will apply to areas not meeting the 24-hour fine particle standard:**

  - States will make recommendations by Nov. 2007 for areas to be designated attainment (meeting the standards) and nonattainment (violating the standards).
  - EPA will make designations by November 2009; those designations will become effective in April 2010.
  - State Implementation Plans, which outline how states will reduce pollution to meet the standards, will be due three years after designations, in April 2013.
  - States must meet the standards by April 2015, with a possible extension to April 2020.

- EPA has issued a number of rules to help states to meet the standards. These rules make significant strides toward reducing fine particle pollution both regionally and across the country. These rules include the Clean Air Interstate Rule to reduce emissions from power plants in the eastern United States; the Clean Diesel Program to reduce emissions from highway, nonroad and stationary diesel engines nationwide, and the Clean Air Visibility Rule to reduce emissions affecting air quality in national parks.

- EPA will not designate new attainment and nonattainment areas for the 24-hour PM_{10} standards.

BENEFITS AND COSTS

- While the Clean Air Act prevents EPA from considering costs in setting or revising National Ambient Air Quality Standards, the Agency does analyze the benefits and costs of implementing standards as required by Executive Order 12866 and guidance from the White House Office of Management and Budget.

- To estimate the benefits of meeting a standard, EPA uses peer-reviewed studies of air quality and health and welfare effects, sophisticated air quality models, and peer-reviewed studies of the dollar values of public health improvements.

  When fully met, the revised 24-hour $PM_{2.5}$ standards are estimated to yield between $9 billion and $75 billion a year in health and visibility benefits in 2020. This estimate is based on the opinions of outside experts on PM and the risk of premature death, along with other benefits information.

- Based on published scientific studies alone, EPA estimates that the most likely benefits of meeting the revised 24-hour PM 2.5 standards will range from $17 billion to $35 billion.

- The benefits of meeting the revised 24-hour $PM_{2.5}$ standards include the value of an estimated reduction in:
  - 2,500 premature deaths in people with heart or lung disease.
  - 2,600 cases of chronic bronchitis.
  - 5,000 nonfatal heart attacks,
  - 1,630 hospital admissions for cardiovascular or respiratory symptoms,
  - 1,200 emergency room visits for asthma,
  - 7,300 cases of acute bronchitis,
  - 97,000 cases of upper and lower respiratory symptoms,
  - 51,000 cases of aggravated asthma,
  - 350,000 days when people miss work or school, and
  - 2 million days when people must restrict their activities because of particle pollution-related symptoms.

- As with any scientific analysis, actual results could be higher or lower. EPA will outline the uncertainties inherent in these estimates in a Regulatory Impact Analysis, which the Agency will issue shortly.

- EPA estimates the cost of meeting the revised 24-hour PM 2.5 standards at $6 billion.

- The benefits of meeting the revised 24-hour standards are in addition to the benefits of meeting the 1997 annual fine particles standards, which EPA has retained.

- Based on recently updated estimates, meeting the annual standard will result in benefits ranging from $20 billion to $160 billion a year in 2015. These updated estimates include the opinion of outside experts on the risk of premature death, along with other benefits information. EPA estimates the cost of meeting the 1997 standards at $7 billion.

BACKGROUND ON THE STANDARDS REVIEW

- The Clean Air Act directs EPA to set National Ambient Air Quality Standards for pollutants that the Agency has listed as "criteria pollutants," based on their likelihood of harming public health and welfare. EPA sets national air quality standards for six common air pollutants: ground-level ozone (smog), carbon monoxide, lead, nitrogen dioxide, sulfur dioxide, and particulate matter.

- For each of these pollutants, EPA has set health-based or "primary" standards to protect public health, and "secondary" standards to protect the public welfare from harm to crops, vegetation, wildlife, buildings and national monuments, and visibility.

- The Clean Air Act requires EPA to review the standards once every five years to determine whether revisions to the standards are appropriate.

- EPA has regulated particulate matter since 1971. The Agency added specific standards for fine particles following its last review, in 1997.

- Under terms of a consent decree, EPA agreed to issue a proposal on the particulate matter standards by December 20, 2005; and committed to finalizing any revisions to the standards by September 27, 2006.

- The review of a standard begins with an assessment of science about the particular pollutant and its effects on public health and welfare. EPA's National Center for Environmental Assessment undertakes an extensive scientific and technical assessment process during the standard review for any pollutant. The first step in the process is the preparation of an "Air Quality Criteria Document," an extensive assessment of scientific data pertaining to the health and environmental effects associated with the pollutant under review.

- EPA's Office of Air Quality Planning and Standards then prepares a document (known as a "staff paper") that interprets the most relevant information in the "criteria document" and identifies: 1) factors EPA staff believes should be considered in the standard review; 2) uncertainties in the scientific data; and 3) ranges of alternative standards the staff believes should be considered. Technical staff then compiles a paper that outlines the policy implications of the science. This paper represents the views of the staff and, in final form, is ultimately used as the basis for staff recommendations to the EPA Administrator.

- Drafts of both the "criteria document" and the "staff paper," which are based on thousands of peer-reviewed scientific studies, receive extensive review by representatives of the scientific community, industry, public interest groups and the public, as well as the Clean Air Scientific Advisory Committee (CASAC) -- a group of independent scientific and technical experts established by Congress.

- As part of its mandate, CASAC makes recommendations to EPA on the adequacy of the existing standards and revisions it believes would be appropriate. Based on the scientific assessments, and taking into account the recommendations of CASAC and public comments, the EPA Administrator must judge whether it is appropriate to propose revisions to the standards.

- EPA undertakes an extensive public review and comment process, considering and analyzing issues raised in public comments before announcing a final decision. As with every proposed and final rule, all other relevant federal agencies are given the opportunity to participate in the process.

- The law requires that the EPA Administrator set the primary standards at a level he judges to be "requisite to protect the public health with an adequate margin of safety" and establish secondary standards that are "requisite" to protect public welfare. The Clean Air Act defines welfare as including environmental effects such as visibility impairment, damage to crops and ecosystems, deterioration of manmade materials, among others.

- The Clean Air Act bars the Administrator from considering costs when setting the standards. The U.S. Supreme Court upheld this requirement in a 2001 decision.

FOR MORE INFORMATION

- Interested parties can download the notice from EPA's Web site at: http://www.epa.gov/air/particles/actions.html

Foot note †

Oregon Asthma Surveillance Summary Report

March 2007

Oregon Asthma Program
Office of Disease Prevention and Epidemiology
Public Health Services
Oregon Department of Human Services

Foot note 1

Oregon Asthma Program

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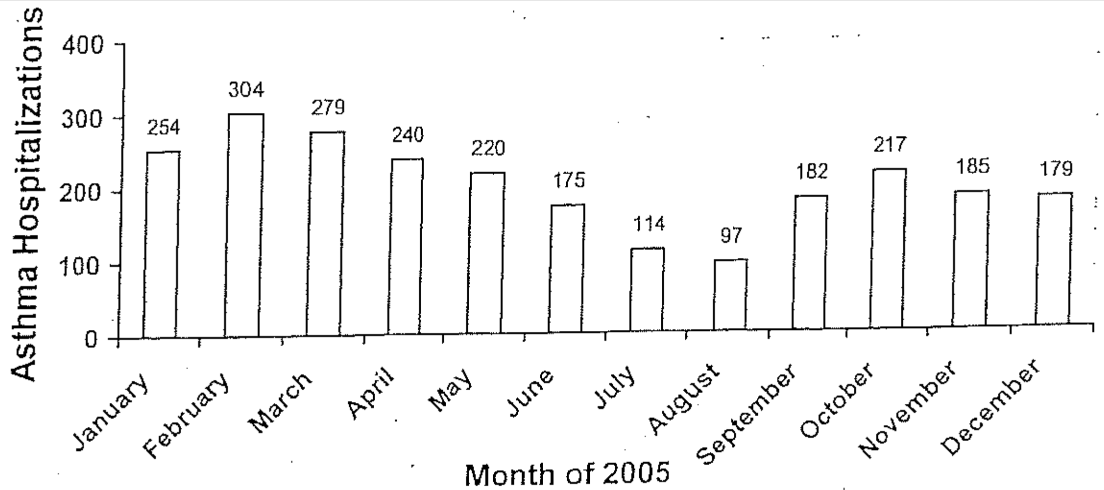
This project is supported by the Centers for Disease Control and Prevention, Cooperative Agreement #U59/CCU017777.

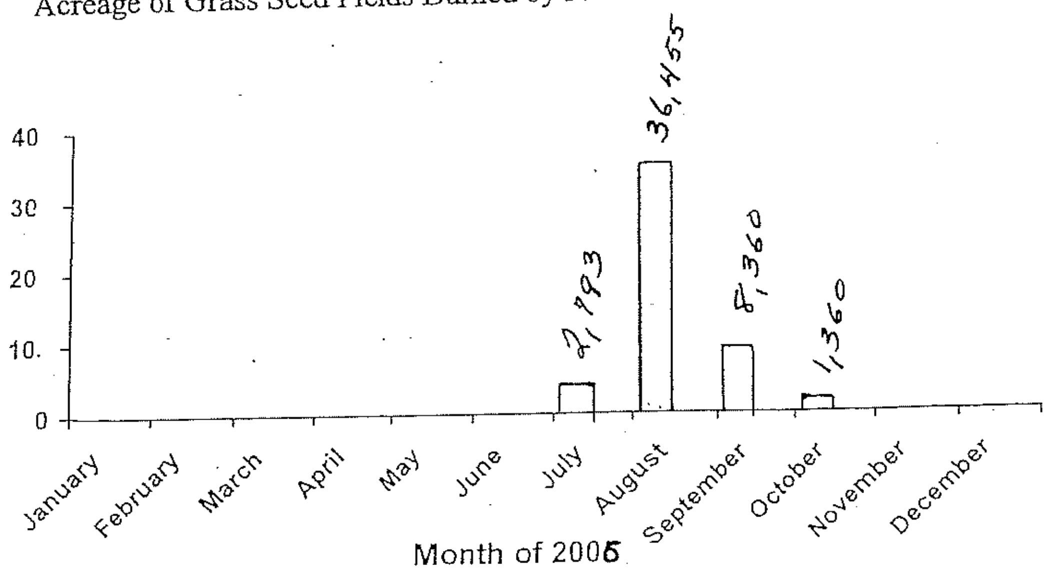
Footnote 7

Figure 22 Number of hospitalizations due to asthma by month in 2005



Source: Oregon Hospital Discharge Index, 2005

Acreage of Grass Seed Fields Burned by Month



Source Oregon Department of Agriculture

Lower figure inserted by OSC and not a part of original report.

Footnote 7

National Center for Chronic Disease Prevention & Health Promotion

Behavioral Risk Factor Surveillance System

Select Another Question
Compare to Another State or Year
List All States

Prevalence Data

Asthma - 2005

Adults who have been told they currently have asthma

To see a specific state's data, click on the state name.

State:	Yes	No
Nationwide (States, DC, and Territories)	8.0	92.0
Nationwide (States and DC)	8.0	92.0
Alabama	7.1	92.9
Alaska	7.8	92.2
Arizona	7.4	92.6
Arkansas	7.5	92.5
California	7.2	92.8
Colorado	8.2	91.8
Connecticut	8.0	92.0
Delaware	8.5	91.5
District of Columbia	9.2	90.8
Florida	6.8	93.2
Georgia	7.3	92.7
Hawaii	7.5	92.5
Idaho	7.3	92.7
Illinois	7.0	93.0
Indiana	8.2	91.8
Iowa	7.2	92.8
Kansas	6.9	93.1

Kentucky	8.8	91.2
Louisiana	5.9	94.1
Maine	10.2	89.8
Maryland	8.3	91.7
Massachusetts	9.6	90.4
Michigan	9.1	90.9
Minnesota	8.4	91.6
Mississippi	7.2	92.8
Missouri	9.0	91.0
Montana	7.9	92.1
Nebraska	6.7	93.3
Nevada	7.1	92.9
New Hampshire	10.3	89.7
New Jersey	7.5	92.5
New Mexico	8.9	91.1
New York	9.3	90.7
North Carolina	6.5	93.5
North Dakota	7.3	92.7
Ohio	8.0	92.0
Oklahoma	8.5	91.5
Oregon	10.1	89.9
Pennsylvania	8.1	91.9
Puerto Rico	8.8	91.2
Rhode Island	10.7	89.3
South Carolina	6.6	93.4
South Dakota	7.3	92.7
Tennessee	7.7	92.3
Texas	6.8	93.2
Utah	8.0	92.0
Vermont	9.8	90.2
Virginia	8.7	91.3
Virgin Islands	4.4	95.6
Washington	9.2	90.8

West Virginia	9.2	90.8
Wisconsin	9.2	90.8
Wyoming	7.8	92.2

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United States Department of Health and Human Services
Centers for Disease Control and Prevention
National Center Chronic Disease Prevention and Health Promotion
Division of Adult and Community Health

footnote O

JAMA®

The Journal of the American Medical Association — To Promote the Science and Art of Medicine and the Betterment of the Public Health

Vol. 295 No. 10, March 8, 2006
Original Contribution

Fine Particulate Air Pollution and Hospital Admission for Cardiovascular and Respiratory Diseases

Francesca Dominici, PhD; Roger D. Peng, PhD; Michelle L. Bell, PhD; Luu Pham, MS; Aidan McDermott, PhD; Scott L. Zeger, PhD; Jonathan M. Samet, MD

JAMA. 2006;295:1127-1134.

ABSTRACT

Context Evidence on the health risks associated with short-term exposure to fine particles (particulate matter ≤2.5 μm in aerodynamic diameter [$PM_{2.5}$]) is limited. Results from the new national monitoring network for $PM_{2.5}$ make possible systematic research on health risks at national and regional scales.

Objectives To estimate risks of cardiovascular and respiratory hospital admissions associated with short-term exposure to $PM_{2.5}$ for Medicare enrollees and to explore heterogeneity of the variation of risks across regions.

Design, Setting, and Participants A national database comprising daily time-series data daily for 1999 through 2002 on hospital admission rates (constructed from the Medicare National Claims History Files) for cardiovascular and respiratory outcomes and injuries, ambient $PM_{2.5}$ levels, and temperature and dew-point temperature for 204 US urban counties (population >200 000) with 11.5 million Medicare enrollees (aged >65 years) living an average of 5.9 miles from a $PM_{2.5}$ monitor.

Main Outcome Measures Daily counts of county-wide hospital admissions for primary diagnosis of cerebrovascular, peripheral, and ischemic heart diseases, heart rhythm, heart failure, chronic obstructive pulmonary disease, and respiratory infection, and injuries as a control outcome.

Results There was a short-term increase in hospital admission rates associated with $PM_{2.5}$ for all of the health outcomes except injuries. The largest association was for heart failure, which had a 1.28% (95% confidence interval, 0.78%-1.78%) increase in risk per 10-μg/m^3 increase in same-day $PM_{2.5}$. Cardiovascular risks tended to be higher in counties located in the Eastern region of the United States, which included the Northeast, the Southeast, the Midwest, and the South.

Conclusion Short-term exposure to $PM_{2.5}$ increases the risk for hospital admission for cardiovascular and

respiratory diseases.

INTRODUCTION

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Numerous epidemiological studies have shown associations of acute and chronic exposures to airborne particles with risk for adverse effects on morbidity and mortality.[1-2] The recent evidence on adverse effects of particulate air pollution on public health has led to more stringent standards for levels of particulate matter in outdoor air in the United States and in other countries. In 1997, the US National Ambient Air Quality Standard for airborne particulate matter was revised, maintaining the previous indicator of particulate matter of less than or equal to 10 µm in aerodynamic diameter (PM_{10}) and creating a new indicator for fine particulate matter of less than or equal to 2.5 µm in aerodynamic diameter ($PM_{2.5}$).[3] Following the implementation of the $PM_{2.5}$ National Ambient Air Quality Standard, a nationwide monitoring system of this pollutant was implemented. Data on $PM_{2.5}$ are now available for many parts of the United States starting from 1999 through the present.

Although the US Environmental Protection Agency (EPA) added a $PM_{2.5}$ standard in 1997 based on available evidence that these small particles were particularly damaging, few epidemiological studies on this size range of particulate matter had been reported at that time. The EPA heavily weighted the few studies with available $PM_{2.5}$ data when it considered the level that should be set for the standard.[4] The EPA also considered the dosimetry of particles in the lung. Particles in the size range of $PM_{2.5}$ have a much greater probability of reaching the small airways and the alveoli of the lung than do larger particles. The availability of the new monitoring network for $PM_{2.5}$ allows epidemiological analyses at the national level on the health effects of fine particles.

The national data on $PM_{2.5}$ concentrations were used to assess associations of short-term exposure to $PM_{2.5}$ with risk for hospitalization regionally and by city among Medicare participants. We followed the model of the National Morbidity, Mortality and Air Pollution Study, which used PM_{10} data for time-series analyses.[5-8] The Medicare cohort covers nearly all members of an elderly population considered to be vulnerable to air pollution; the size of this population allows for assessments of specific cardiac and respiratory diagnostic categories that have been associated with particulate air pollution.

METHODS

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This analysis is based on daily counts of hospital admissions for 1999-2002 obtained from billing claims of Medicare enrollees. Because the Medicare data analyzed for this study did not involve individual identifiers, consent was not specifically obtained. This study was reviewed and exempted by the institutional review board at Johns Hopkins Bloomberg School of Public Health. Each billing claim contains the date of service, treatment, disease (*International Classification of Diseases, Ninth Revision*[9] *[ICD-9]* codes), age, sex, self-reported race, and place of residence (ZIP code and county). The daily counts of each health event within each county were obtained by summing the number of hospital admissions for each of the diseases considered a primary diagnosis. To calculate hospitalization rates, we constructed a time series of the numbers of individuals at risk in each county for each day (defined as the number of individuals enrolled in Medicare on a given day).

Eight outcomes were considered based on the *ICD-9* codes for 5 cardiovascular outcomes (heart failure [428], heart rhythm disturbances [426-427], cerebrovascular events [430-438], ischemic heart disease [410-414, 429], peripheral vascular disease [440-448]), 2 respiratory outcomes (chronic obstructive pulmonary disease [COPD; 490-492], respiratory tract infections [464-466, 480-487]), and hospitalizations caused by injuries and other external causes (800-849). The county-wide daily hospitalization rates for each outcome for 1999-2002 appear in Table 1.

View this table:
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Table 1. Percentage Change in Hospitalization Rate per 10-µg/m^3 Increase in $PM_{2.5}$ on Average Across 204 Counties

The study population includes 11.5 million Medicare enrollees residing an average of 5.9 miles from a $PM_{2.5}$ monitor. The analysis was restricted to the 204 US counties with populations larger than 200 000. Of these 204 counties, 90 had daily $PM_{2.5}$ data across the study period and the remaining counties had $PM_{2.5}$ data collected once every 3 days for at least 1 full year. The locations of the 204 counties appear in Figure 1. The counties were clustered into 7 geographic regions by applying the K-means clustering algorithm to longitude and latitude for the counties.[10-11]

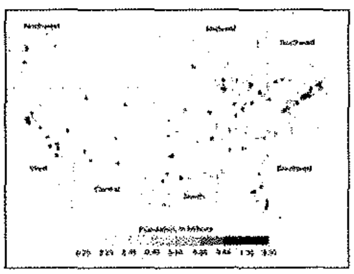

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Figure 1. US Counties With Populations Larger Than 200 000 Included in Analysis

The $PM_{2.5}$ and ozone data were obtained from the EPA's Aerometric Information Retrieval Service (now referred to as the Air Quality System database). Temperature and dew-point temperature data were gathered from the National Climatic Data Center on the Earth-Info CD database.[12] To protect against consequences of outliers, we used a 10% trimmed mean to average across monitors after correcting for yearly averages for each monitor.

County names and location, air pollution data, weather data, county-specific estimates of health risk, and software developed to construct county-specific time-series data are available online (http://www.biostat.jhsph.edu/MCAPS). Billing claims of Medicare enrollees are not publicly available. Calculations were implemented using R statistical software version 2.2.0.[13]

We applied Bayesian 2-stage hierarchical models[14-16] to estimate county-specific, region-specific, and national average associations between day-to-day variation of $PM_{2.5}$ (at lags 0, 1, and 2 days) and day-to-day variation in the county-level hospital admission rates, accounting for weather, seasonality, and long-term trends. A lag of 0 days corresponds to the association between $PM_{2.5}$ concentration on a given day and the risk of hospitalization on the same day. We also applied distributed lag models[17-20] to the 90 counties with daily $PM_{2.5}$ data available to estimate the relative rate (RR) of hospitalization associated with cumulative exposure over the current day and the 2 previous days. Significance is assessed by the posterior probability that the RR is larger than zero. Values greater than .95 are considered significant.

In the first stage, single lag and distributed lag overdispersed Poisson regression models[21-22] were used for estimating county-specific RRs of hospital admissions associated with ambient levels of $PM_{2.5}$. These county-specific models include as explanatory variables: (1) the logarithm of the daily number of individuals at risk; (2) indicator variables for the day of the week to allow for different baseline hospital admission rates for each day; (3) smooth functions of calendar time (natural cubic splines) with 8 degrees of freedom per year to adjust for seasonality and for other time-varying influences on admissions (eg, influenza epidemics and longer-term trends due to changes in medical practice patterns); and (4) smooth functions of temperature (6 degrees of freedom) and dew-point temperature (3 degrees of freedom) on the same day and of the 3 previous days' temperature and dew-point temperature to control for the potential confounding effect of weather.

For the smooth functions of calendar time, we chose 8 degrees of freedom per year so that little information at the time scales of longer than 2 months would be retained in estimating the risks. For temperature, we chose 6 degrees of freedom so that the model has sufficient flexibility to take account of potential nonlinearity in the relationship of temperature with hospitalization.[23]

This modeling approach was developed for the National Morbidity, Mortality and Air Pollution Study analyses[22, 24] and applied to national databases for estimating short-term effects of PM_{10} and ozone on mortality.[5, 12] Statistical properties of this modeling approach and alternative modeling specifications for confounding adjustment are reported elsewhere.[7, 25]

In the second stage, to produce a national average estimate of the short-term association between $PM_{2.5}$ and hospital admissions, we used Bayesian hierarchical models[14-16, 26] to combine RRs across counties accounting for within-county statistical error and for between-county variability of the "true" RRs (also called heterogeneity). To produce regional estimates, we used the same 2-stage hierarchical model described above but separately within each of the 7 regions.

To explore effect modification of air pollution risks by location-specific characteristics, we fitted a weighted linear regression model with the dependent variable as the location-specific RR estimate and the independent variable as the location-specific characteristic. The observations were weighted inversely to the statistical variance of the location-specific estimate.

The county and regional averages of $PM_{2.5}$ concentration, ozone concentration, and temperature for 2000 through 2002 were calculated as potential modifiers. A regional average was calculated by using all of the county-specific concentrations within the region.

Finally, the annual reduction in hospital admissions (H) attributable to a 10-μg/m^3 reduction in the daily $PM_{2.5}$ level for the 204 counties by cause-specific admissions were calculated. H is defined as

$$H = (\exp(\beta \Delta x) - 1) \times N$$

where β is the national RR estimate for a 1-µg/m^3 increase in $PM_{2.5}$, Δx is 10-µg/m^3, and N is the number of hospital admissions across the 204 counties for 2002.

The sensitivity of key findings was examined with respect to the lag of exposure; degrees of freedom in the smooth functions of time; and degrees of freedom in the smooth functions of temperature and dew-point temperature.

RESULTS

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More than 2 years of $PM_{2.5}$ data were available for most of the 204 counties. The average of the county mean annual values for 1999-2002 was 13.4 µg/m^3 (interquartile range [IQR], 11.3-15.2 µg/m^3). There was substantial homogeneity of fine particulate matter concentrations across geographic areas. The median of pairwise correlations among $PM_{2.5}$ monitors within the same county for 2000 was 0.91 (IQR, 0.81-0.95).

The point estimates and 95% posterior intervals (PIs) for the percentage increase in daily admission rates per 10-µg/m^3 increase in $PM_{2.5}$ concentration (national average RRs) for single lags of 0, 1, and 2 days and the distributed lag models for lags 0 through 2 for all disease outcomes (total) appear in Figure 2. The single lag model estimates the effect of exposure on 1 day only, lagged by 0, 1, or 2 days, while the total estimate from the distributed lag model summarizes the effect of 3 days of exposure (lag 0, 1, and 2 days). We found evidence of positive associations between day-to-day variation in $PM_{2.5}$ concentration and hospital admissions for all outcomes, except injuries, for at least 1 exposure lag. The largest effect was found at lag 0 for all of the cardiovascular outcomes except ischemic heart disease, for which the largest effect was at lag 2. For respiratory outcomes, the largest effects occurred at lags 0 and 1 for COPD and at lag 2 for respiratory tract infections. Distributed lag estimates were statistically significant for heart failure. Compared with the single lag estimates, the wider 95% PIs for the distributed lag estimates reflect the restriction of the analysis to 90 of the 204 counties with daily data. The results for the single lag models were also stratified by age group at the lag with the greatest effect (Table 1). The national average RR estimates were larger for the oldest group for some outcomes including ischemic heart disease, heart rhythm disturbances, heart failure, and COPD.

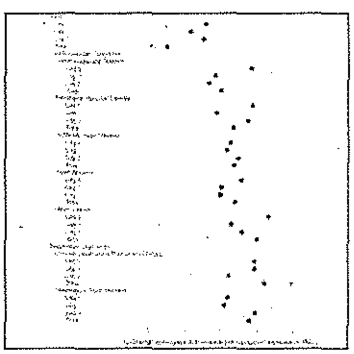

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Figure 2. Percentage Change in Hospitalization Rate by Cause per 10-µg/m^3 Increase in $PM_{2.5}$ on Average Across 204 US Counties

Point estimates and 95% posterior intervals of the percentage change in admission rates per 10 µg/m^3 (national average relative rates) for single lag (0,1, and 2 days) and distributed lag models for 0 to 2 days (total) for all outcomes. $PM_{2.5}$ indicates particulate matter of less than or equal to 2.5 µm in aerodynamic diameter.

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Several analyses were conducted as internal checks. Analyses for lag −1 were run to predict today's outcome by using the next day's pollution and for hospitalizations caused by injuries and other external causes. Positive associations were not found for injuries or for other external causes, which was expected. When lag −1 $PM_{2.5}$ was used as the exposure indicator, positive associations also were not found. The main results were robust to the number of degrees of freedom used to adjust for temporal confounding, to the adjustment for weather, and to adjust for the prior distributions used for the analysis.

The point estimates and 95% PIs of the heterogeneity parameter, defined as the between-county SD of the "true" county-specific rates in relation to their mean, appear in Table 1. For example, the estimate of the heterogeneity parameter for COPD is 1.61. This value indicates that with a national average RR of 0.91% per 10-μg/m^3 increase in $PM_{2.5}$, 95% of the "true" county-specific RRs are within the interval of 0.91 to 1.96 x 1.61 = −2.24% and 0.91 + 1.96 x 1.61 = 4.06%. To determine the strength of evidence supporting the null hypothesis of no heterogeneity, we calculated the posterior probability that the heterogeneity parameter is smaller than .05 (the Bayesian analogue of a *P* value) and this was found to be close to 0 for all outcomes.

To determine whether there was significant variation of risks across the 7 geographic regions, the RR for each outcome was estimated separately within the regions, which excluded Honolulu, Hawaii, and Anchorage, Alaska.The point estimates and 95% PIs of the regional RRs for each outcome at the lag with the greatest estimated RR appear in Figure 3 and Table 1. For the 2 groups of outcomes (cardiovascular and respiratory), the estimated RRs have distinct regional patterns. For cardiovascular diseases, all estimates in the Midwestern, Northeastern, and Southern regions were positive, while estimates in the other regions were close to 0. Compared with cardiovascular diseases, there was greater consistency between the regions for respiratory diseases. However, there were larger effects in the Central, Southeastern, Southern, and Western regions than in the other regions.

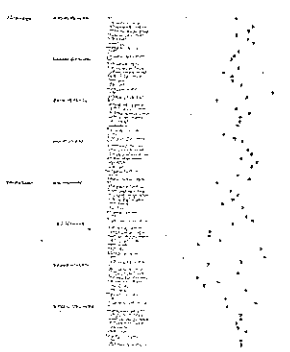

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Figure 3. Percentage Change in Hospitalization Rate by Region and Cause per 10-μg/m^3 Increase in $PM_{2.5}$ Within Each Region

Point estimates and 95% posterior intervals of the percentage change in admission rates per 10 μg/m^3 (regional relative rates). $PM_{2.5}$ indicates particulate matter of less than or equal to 2.5 μm in aerodynamic diameter; COPD, chronic obstructive pulmonary disease. *Honolulu, Hawaii, and Anchorage, Alaska, were excluded.

Regional differences were investigated by dividing the United States into an Eastern region (Northeast, Southeast, Midwest, and South) and a Western region (West, Central, and Northwest). The average effect estimates and 95% PIs of the RRs for each outcome and for the lags with the greatest estimated national average effects appear in Figure 4. There were 168 counties included in the Eastern region and 34 counties included in the Western region. Using analysis of variance, the differences in risk of hospitalization between the 2 regions were statistically significant for outcomes except for heart failure and COPD. All RR estimates for cardiovascular outcomes were positive in the US Eastern region but not in the US Western region. The RR estimates for respiratory tract infections were larger in the Western region than in the Eastern region.

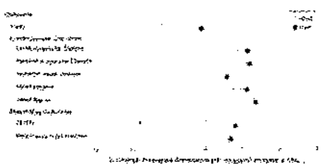

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Figure 4. Percentage Change in Hospitalization Rate by Cause per 10-µg/m^3 Increase in $PM_{2.5}$ for the US Eastern and Western Regions for all Outcomes

Point estimates and 95% posterior intervals of the percentage change in admission rates per 10 µg/m^3. $PM_{2.5}$ indicates particulate matter of less than or equal to 2.5 µm in aerodynamic diameter; COPD, chronic obstructive pulmonary disease.

Effect modification of short-term effects of $PM_{2.5}$ on hospital admission rates was investigated by using both county and regional averages of $PM_{2.5}$ concentrations, temperature, and ozone. Both county and regional average temperature positively modified the association between $PM_{2.5}$ and hospital admission rates for the 2 respiratory outcomes. For example, comparing 2 regions that differ by 1°C, there would be an estimated 18 additional hospital admissions per 10 000 individuals for COPD and 9 additional hospital admissions per 10 000 individuals for respiratory tract infections per 10-µg/m^3 increase in $PM_{2.5}$ in the warmer region. We did not find evidence of the effect modification by average concentrations of either $PM_{2.5}$ or ozone.

The yearly hospital admissions attributable to a 10-µg/m^3 reduction in the daily $PM_{2.5}$ also were calculated (Table 2). For example, a 10-µg/m^3 reduction in $PM_{2.5}$ would reduce the number of hospitalizations for heart failure by 3156 for the 204 urban counties in 2002.

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Table 2. Annual Reduction in Admissions Attributable to a 10-µg/m^3 Reduction in the Daily $PM_{2.5}$ Level for the 204 Counties in 2002

COMMENT

The Medicare National Claims History Files were used in this study to estimate the short-term effects of $PM_{2.5}$ on cause-specific hospitalization rates. Data obtained from national databases on health were combined with data on air pollution and weather.[5,]

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[27] This is a replicable approach that can be applied periodically for air pollutants or other environmental factors as a component of a national health surveillance system to track adverse health effects. This approach also has the strength of analyzing the national data uniformly, avoiding the potential for publication bias that occurs when data from only 1 or several counties are analyzed and positive findings are selectively reported.[27]

In interpreting the findings, consideration needs to be given to the inherent limitations of the data analyzed and to the possibility that even the complex statistical models used are not adequate to eliminate all bias. Medicare data are collected for administrative purposes and diagnoses are known to be subject to some degree of misclassification[28-30] and to vary geographically.[31-32] The resulting misclassification and geographic variability would introduce a bias in daily time-series analyses only if patterns of diagnosis and coding were associated with level of $PM_{2.5}$. We used only primary diagnosis, an approach that should reduce misclassification of outcomes. To investigate whether geographic differences in diagnosis rates could modify the risks, a second-stage analysis was performed using county-specific hospital admission rates (number of admissions per 100 000 individuals) as an independent variable and county-specific RR estimates as a dependent variable. This analysis did not find such evidence of effect modification by underlying diagnosis rates. While we relied on monitors cited for regulatory purposes, the average distance from the centroid of a ZIP code to the monitor was only 5.9 miles and $PM_{2.5}$ levels tend to be uniform across such distances.

The modeling approach used in this study enabled extensive exploration of the sensitivity of the findings. At the first stage of the hierarchical model, we specified the same number of degrees of freedom in the smooth functions of time and temperature used to control for confounding for all the locations. This approach does not necessarily lead to a similar degree of control for confounding across counties, but it does give similar flexibility to the smooth functions, allowing their shape to vary across counties. An alternative is to allow a different number of degrees of freedom across counties, an approach used in multisite time-series studies in Europe.[33-36] Recently we have compared these 2 modeling strategies and found that national estimates of PM_{10} risks were robust to the choice of method.[19] We also have explored the sensitivity of the estimated RRs to different degrees of adjustment for weather and seasonality and found the results to be robust. Statistical challenges inherent to the adjustment for temporal confounding have been explored elsewhere.[19, 25, 37]

Overall, we found evidence of an association between recently measured $PM_{2.5}$ concentrations and daily hospitalizations on a national scale. Our findings complement substantial evidence on particulate matter and hospitalization for respiratory or cardiovascular causes using exposure measures other than $PM_{2.5}$ and the more limited evidence using $PM_{2.5}$ specifically. While mechanisms underlying the adverse effects of particulate matter on the respiratory and cardiac systems remain a focus of research, the leading hypotheses emphasize inflammatory responses in the lung and release of cytokines with local and systemic consequences.[1, 38-40] In the lung, particulate matter may promote inflammation and thereby exacerbate underlying lung disease and reduce the efficacy of lung-defense mechanisms. Cardiovascular effects may reflect neurogenic and inflammatory processes.[40] Experimental studies of atherosclerosis using genetically susceptible mice also suggest that particulate matter may accelerate the development of atherosclerosis[41]; parallel human findings also were found.[42]

Although many time-series studies have used PM_{10} as an exposure indicator, only a few studies have specifically assessed associations of $PM_{2.5}$ with hospitalization or other morbidity measures.[43] Lippmann et al[44] and Ito et al[45] used Medicare admission data for Detroit, Mich, for 1992-1994, along with size-fractionated particle concentration data from a nearby monitoring station in Windsor, Ontario. As reported by Ito et al,[45] updated analyses of these data showed positive associations of $PM_{2.5}$ for hospitalization for pneumonia, COPD, ischemic heart disease, and heart failure. In comparison with the present study, the reported risk estimates were several-fold higher. Moolgavkar[46-47] used data for Los Angeles County, California, for 1987-1995 and found that $PM_{2.5}$ was significantly associated with risk for hospital admission for cardiovascular disease in persons aged 65 years or older. Sheppard et al[48-49] reported a positive association of $PM_{2.5}$ with risk for hospital admission for asthma in Seattle, Wash, for 1987-2004, but elderly persons were excluded. Finally, Burnett et al[50] assessed risk for hospitalization for cardiorespiratory diseases in relation to particulate air pollution over 3 summers in Toronto, Ontario. Positive associations were found in univariate models that were attenuated with consideration of gaseous pollutants in bivariate models.

There is much more literature on PM_{10} and risk for hospitalization, which generally shows positive associations.[2, 51] In most urban locations across the United States, $PM_{2.5}$ accounts for at least half of the PM_{10} mass, and a scaling factor of 0.55 has been used to convert PM_{10} concentrations to $PM_{2.5}$. With this assumption, our quantitative findings for $PM_{2.5}$ are quite similar to those for both PM_{10} and for $PM_{2.5}$ as recently summarized by the EPA.[43] The comparability of the PM_{10} and $PM_{2.5}$ estimates suggests that the effect of PM_{10} on hospital admissions largely reflects its $PM_{2.5}$ component.

The sources of particles contributing to the observed risks need to be identified so that control strategies can be targeted efficiently. Because the source mix for $PM_{2.5}$ varies across locations, we explored spatial variation of the effect of $PM_{2.5}$ on risk for hospitalization. Strong evidence for spatial heterogeneity in the effect of $PM_{2.5}$ on risk for hospitalization was found. The pattern and degree of heterogeneity tended to vary by outcome measure. Because the magnitude of the effects contrasted greatly in the comparisons between the 7 regions, counties were grouped into an Eastern region and a Western region. There are known differences in the composition of particles at this geographic scale, including a greater sulfate component in the East and a greater nitrate component in the West.[2] There are also well-characterized differences in the mix of sources across these broad areas that may be relevant, including power generation and the smokestack industry in the East and a larger contribution from transportation sources in parts of the West.

With clear and continuing indication that inhaled particles affect public health adversely, the emphasis of research should shift toward the difficult issue of identifying those characteristics of particles that determine their toxicity.[1] The EPA's Speciation Trends Network, which is now providing extensive data on characteristics of $PM_{2.5}$ at selected sites, offers a needed resource for this research.[52]

Under the Clean Air Act,[53] the EPA is required to set a particulate matter National Ambient Air Quality Standard that protects public health with an "adequate margin of safety." Our findings indicate an ongoing threat to the health of the elderly population from airborne particles and provide a rationale for setting a $PM_{2.5}$ National Ambient Air Quality Standard that is as protective of their health as possible. Our national approach offers a method for continuing to search for the characteristics of particles that determine their toxicity.[53]

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Study concept and design: Dominici, Peng, Zeger, Samet.

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Obtained funding: Dominici, Bell, Samet.

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November 15, 2006

Representative Paul Holvey
PO Box 51048
Eugene, OR 97405

Re: Request for Legislative Action Regarding Grass Field Burning

Dear Representative Holvey:

Request. The Lane Regional Air Protection Agency (LRAPA), entrusted with air quality protection in Lane County, respectfully requests that the Oregon Legislature revisit the issue of grass field burning in the coming session and craft legislation to eliminate the practice in the Willamette Valley at the earliest possible date.

Roles. LRAPA's mission is "*To protect public health, community well-being and the environment as a leader and advocate for the continuous improvement of air quality in Lane County, Oregon*." Grass field burning in the Willamette Valley is regulated by the Legislature under Oregon Revised Statutes 468A.550 through 468A.620 and managed by the Oregon Department of Agriculture under Oregon Administrative Rules and contractual agreement with the Oregon Department of Environmental Quality. The Legislature declared it to be the public policy of the state to reduce the practice of open field burning while developing and providing alternative methods of field sanitization and alternative methods of utilizing and marketing crop residues. The goal of the Oregon Department of Agriculture is to offer maximum opportunities for open field burning, propane flaming, and stack burning with minimal smoke impacts on the public.

Problem. A large number of the air pollution complaints received by LRAPA involve field burning, and the majority of the field burning complaints received by the Oregon Department of Agriculture are from Lane County residents. During 1990-2005, LRAPA received an average of 1,030 air pollution complaints per year; about one-third of these (335) were related to field burning during July-September, which were recorded and forwarded to the Oregon Department of Agriculture. Some of these complaints were from residents with asthma or other respiratory problems and their physicians; others were from residents concerned about soot fallout, obstruction of blue skies, impaired visibility of scenic views, or other interference with their outdoor enjoyment. During 2000-2005, the average number of field burning complaints recorded by the Oregon Department of Agriculture was 596 per year; about 400 of these (or about two-thirds) came from Eugene-Springfield or other parts of the southern Willamette Valley.

Past efforts. The Oregon Legislature adopted a phase-down plan in 1991 that reduced the amount of grass field burning in 1998 and future years to no more than 65,000 acres per year. The Oregon Department of Agriculture has operated a sophisticated smoke management program designed to minimize smoke impacts to major urban areas. The State of Oregon has invested over $1.3 million in research on field burning alternatives since 1998 (and the Oregon Seed Council has provided a similar amount) and over $4.7 million in tax credits for field burning alternatives since 1998 (and over $11.9 million in tax credits since 1991).

Why now? The high numbers of air pollution complaints in recent years indicate that field burning smoke continues to be a serious concern to residents of Lane County, despite the best efforts of the Oregon Department of Agriculture to minimize smoke impacts. The Legislature last adopted a phase-down in field burning acreage in 1991, and the amount of annual field burning acreage has been essentially constant since 1998. Since adopting the 1991 legislation, Oregon has invested millions of dollars in tax credits and research for field burning alternatives. Meanwhile, the State of Washington has identified alternatives available at reasonable costs, has determined that the benefits of a ban outweigh the costs of the alternatives, and has banned the practice except for very limited waivers.

We are committed to working with the Oregon Legislature to protect air quality in Lane County. LRAPA respectfully requests that you work with your colleagues in the Oregon Legislature to eliminate grass field burning in the Willamette Valley.

Sincerely,

Dave Ralston, Chair
LRAPA Board of Directors

MLH:mlh

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Attorney for Plaintiff Safe Air for Everyone

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF IDAHO

SAFE AIR FOR EVERYONE, Plaintiff, v. WAYNE MEYER, *et al.*, Defendants.	Case No. 02-0241N-EJL DECLARATION OF ERIC SKELTON

Pursuant to 28 U.S.C. § 1746, Eric Skelton declares as follows:

1. I am employed as the Director of the Spokane County Air Pollution Control Authority ("SCAPCA") and have held that position since 1991. I oversee all programs implemented by SCAPCA, including permitting, compliance assurance, enforcement, planning, technical services and air monitoring, education and outreach, and administration. I served as the State Chairman of the Washington Air Quality Managers Group from 2000 to 2001 and was National President of the Association of Local Air Pollution Control Officials in the 1999-2000 term. I am making this declaration in my personal capacity as an individual and not as a representative of SCAPCA.

2. Through my professional work with SCAPCA, I am very familiar with the history and practice of agricultural burning in Washington and North Idaho including the annual burning of Kentucky bluegrass post-harvest crop residue. Specifically, I am familiar with: (i) past Kentucky bluegrass crop residue burning in Washington and present bluegrass crop residue burning in North Idaho; (ii) the Washington Department of Ecology's regulations which phased down and banned (except under very limited circumstances) the burning of Kentucky bluegrass crop residue in Washington; (iii) the air quality impacts in Spokane County, Washington of Kentucky bluegrass crop residue burning in North Idaho; and (iv) the effectiveness of agricultural burning smoke management. A copy of my resume is attached as Exhibit A.

3. Prior to 1996, Kentucky bluegrass seed growers in Washington used open field burning as the primary method of disposing of post-harvest crop residue. From a period typically beginning as early as late August and running through the end of September, Washington bluegrass growers would burn tens of thousands of acres of fields containing the waste bluegrass straw that remains after harvesting the bluegrass seed crop, as well as the stubble still attached to the ground. For example, over a sixteen day period in 1993 bluegrass growers burned 24,471.5 acres of bluegrass crop residue in Spokane County, Washington. This caused significant amounts of smoke, containing high levels of particulate matter ("PM") harmful to human health, including PM2.5 and PM10. PM2.5 is measured as the mass, in micrograms, of all particles below 2.5 micrometers in diameter that are suspended in a unit volume of air, typically a cubic meter. Similarly, PM10 represents the mass, in micrograms of all particles in a unit volume (e.g., a cubic meter) of air below 10 micrometers in diameter. SCAPCA received

426 complaints during the 1993 bluegrass burning season. A follow up survey, conducted by the local chapter of the American Lung Association, leads me to conclude that most of the complaints were related to people's difficulty breathing because of their chronic or acute respiratory problems such as allergies and asthma. Prior to 1996, bluegrass crop residue burning in Spokane County and other parts of Washington occurred under so-called "smoke management plans." The smoke management plan applicable in Spokane County: (i) required bluegrass growers to obtain a burn permit; (ii) limited burning to a sixteen day burn season; and (iii) limited burning to designated burn days during the sixteen day burn season. Designated burn days are a common feature of smoke management plans. By limiting burning to designated burn days, smoke management plan administrators seek to minimize the impacts of the smoke by allowing burning only when wind direction, wind speed, and other meteorological conditions are anticipated to direct most of the smoke away from communities.

4. Smoke management plans however have proven ineffective at protecting public health from the adverse health effects of smoke from crop residue burning for a number of reasons.

a. First, winds are not predictable. Although it is generally possible to make reliable predictions about the behavior of seasonally prevailing winds, it is virtually impossible to make consistently accurate predictions about wind behavior over a period of a few hours. This is a critical defect in smoke management plans. Winds that may direct smoke from burning bluegrass fields toward an unpopulated area may suddenly shift and direct smoke to populated areas.

b. Second, even if winds could be predicted with certainty, there is often no good place to send the smoke. A smoke management plan is not an emission reduction plan. Smoke management plans do not control or reduce PM emissions. They merely move PM emissions around, spatially and temporally, in hopes of mitigating the impacts of smoke. This is almost certain to fail in North Idaho where populated communities exist in virtually every direction. The outcome of any smoke management plan in North Idaho comes down to a choice as to which group of people is going to be the target of the smoke plumes. Smoke from a burning bluegrass field is capable of hitting a community in nearly any direction that the wind blows. To use a North Idaho example, if on a burn day on the Rathdrum Prairie, the smoke travels away from Post Falls and Coeur d'Alene (a satisfactory burn day for those communities) the smoke is likely to travel toward Athol, Sandpoint, or Chattaroy, Washington (an unsatisfactory burn day for those communities).

c. Third, the smoke and pollution can persist in the air for some time during which wind directions can change. Smoke management plans typically do not limit the acreage that may be burned in a single day. On a designated burn day, growers may burn thousands of acres of bluegrass crop residue, causing an immense volume of smoke to rise into the atmosphere. This smoke does not merely dissipate in the atmosphere. Smoke particles persist, often suspended in the atmosphere for days after burning ceases and become trapped in the air mass, near the ground as a result of nightly temperature inversions. This is confirmed by data, which show elevated PM2.5 concentrations persisting for one or more days after a burn day, especially when large numbers of acres have been burned on a given day.

5. Given the limitations identified above, the smoke management plan applicable in Spokane County was incapable of guaranteeing that there would not be one or more significant smoke intrusion episodes in the course of a burn season. For example, the week of September 6, 1993 was dominated by high barometric pressure and persistent temperature inversions. Bluegrass growers on the Rathdrum Prairie in North Idaho burned fields on September 9th. Winds carried the smoke west to the Spokane Valley, the City of Spokane, and North Spokane. A burn day was also designated in Spokane County early on September 9th when winds appeared to be conducive to carrying the smoke away from populated areas. However, early in the afternoon a

significant amount of smoke began impacting Cheney, Washington. Although burning was curtailed by 2 p.m., the winds shifted and carried the smoke north toward Spokane. SCAPCA air monitoring stations recorded significant smoke intrusions and SCAPCA received 260 complaints.

6. In part due to the inability of smoke management plans to protect public health, the Washington Department of Ecology announced in 1995 that it would implement a provision of the Washington Clean Air Act which authorized the Department of Ecology to minimize the adverse effects of burning bluegrass crop residue. Specifically, Section 70.94.656(3) of the Revised Code of Washington authorized the Department of Ecology to: (i) research alternatives to burning bluegrass post-harvest bluegrass crop residue; (ii) limit the number of acres of bluegrass crop residue burned; and (iii) certify alternatives to burning bluegrass crop residue, as a means of ending grass field burning. Section 70.94.656(3), a copy of which is attached as Exhibit B, further provides, "in any case which any such approved alternate is reasonably available, the open burning of field and turf grasses grown for seed shall be disallowed and no permit shall issue therefore."

7. Acting under this statutory authority, the Department of Ecology phased down and banned bluegrass crop residue burning in Washington in two steps. First, the Department of Ecology adopted a rule in March 1996 which reduced the total acreage of bluegrass crop residue in Washington authorized for burning by one-third in 1996 and by an additional one-third in 1997. Second, in 1998, the Department of Ecology certified mechanical residue management as an alternative to open field burning of bluegrass crop residue and banned open field burning except under very limited circumstances. (A copy

of the rules and a summary of the Department of Ecology's rulemaking are attached as Exhibit C. The entire rule making record is a matter of public record.) The Department of Ecology considered an extensive amount of information before it concluded that mechanical residue management is a certifiable alternative to open field burning, including nearly 300 studies on alternatives to burning grass seed crop residue. The Department of Ecology defined mechanical residue management as the procedure or technique of managing grass seed fields by non-thermal methods using techniques such as baling, raking, flailing, swathing, chopping, tilling, etc. The Department of Ecology determined that mechanical residue management is reasonably available in all cases except wherever the technique of baling straw cannot be used. Baling of residue straw may not be reasonably available in circumstances of steep slopes or other extreme conditions. The Department of Ecology's rules establish a process a grower must follow to establish that mechanical residue management is not reasonably available. In Spokane County, only a few growers have received permission to utilize this exception, effectively reducing annual grass field burning to around 200 acres per season, or less.

8. While the Department of Ecology was proposing the phase down and ban on grass seed field burning in Washington, bluegrass growers repeatedly asserted that they could not successfully grow and harvest bluegrass seed without open field burning. That contention has been proven incorrect. Following the 1998 burn ban, Washington bluegrass growers have continued to grow and harvest bluegrass seed without open field burning. In fact, the acreage of bluegrass seed harvested in Washington and in Spokane County has remained steady or increased since 1998. I am aware, however, that some farmers in Spokane County have had difficulty disposing of bales of residue straw and

some farmers have requested authorization from SCAPCA to burn large quantities of rotting or moldy residue straw.

9. Bluegrass growers in Washington have on occasion complained that bluegrass growers in North Idaho enjoy an unfair competitive advantage because they are able to dispose of unwanted post-harvest crop residue through open field burning, and allegedly have greater seed yield per acre, as a result of burning.

10. The burn ban in Washington has significantly improved air quality in Spokane County, by eliminating smoke intrusion episodes caused by Spokane County grass growers. The significant smoke intrusion episode described above which occurred in Spokane on September 9, 1993 is representative of significant smoke intrusion episodes which were a common occurrence on one or more days during any given season in which bluegrass crop residue was burned in Washington prior to 1998. Each significant smoke intrusion episode typically triggered one to two hundred air quality complaints to SCAPCA, the majority of which people complained about suffering from significant health problems related to adverse respiratory conditions, triggered by exposure to the smoke. The burn ban has eliminated smoke intrusion episodes caused by burning in Washington and eliminated the suffering that those episodes inflicted. Residents of Eastern Washington and North Idaho breathe better air as a result. Over the years, I have repeatedly heard representatives of the grass seed industry (e.g., farmers, seed processors) state that there is no significant adverse environmental or health impact from the burning of field residue, as evidenced by the fact that the smoke emissions do not cause exceedances of the 24-hour or annual National Ambient Air Quality Standards (NAAQS) for fine particles (i.e., PM2.5 or PM10). These statements are typically

coupled with declarations that the public and the regulators should keep out of the business of farmers and seed processors and let them continue their burning practices without interference. This popular industry position totally disregards the fact that people suffer respiratory distress, typically for several hours, when a smoke intrusion episode envelops areas where people live and breathe. The concept of compliance with a NAAQS is completely immaterial to a person who is suffering from the impacts of smoke from field residue burning.

11. Unlike their neighbors across the state line in Washington, Kentucky bluegrass seed growers in the Rathdrum Prairie area and within the Coeur d'Alene Reservation of North Idaho continue to use open field burning to dispose of unwanted post-harvest bluegrass crop residue. This causes significant harm to the health of people in Spokane County, Washington, as evidenced by the nature of the complaints. Farmers in North Idaho typically begin burning bluegrass waste straw in mid-August, and the burning may continue through the end of September. As stated above, smoke from bluegrass crop residue burning in North Idaho routinely travels to Eastern Washington, affecting the City of Spokane, the populated, unincorporated East Valley of Spokane County, and other Washington communities. Smoke behavior is affected by air sheds, not political boundaries. Eastern Washington and North Idaho share an air shed that is shaped like a backwards "L". The Cities of Spokane and Coeur d'Alene are, respectively, at the western and eastern ends of the horizontal axis of the L. The Cities of Sandpoint and Coeur d'Alene are, respectively, at the northern and southern ends of the vertical axis of the L. This air shed is bounded by high hills and mountains. Once smoke gets into the air shed, it tends to become trapped by inversions. Depending on wind

direction, smoke from bluegrass fields burned on the Rathdrum Prairie in North Idaho may travel west to Spokane and the Spokane Valley, east to Coeur d'Alene, or north to Sandpoint. The same phenomenon occurs with smoke from bluegrass fields burned within the boundaries of the Coeur d'Alene Indian Reservation. The waters of Lake Coeur d'Alene have a cooling effect on the air mass above the lake. Cooled air is less buoyant than warm air, meaning it tends not to rise. Smoke from burning on the Coeur d'Alene Indian Reservation becomes trapped in this cooled, less buoyant air, and will remain near the ground, exposing people in the vicinity to fine particles.

12. The number of public complaints to SCAPCA often rises suddenly and dramatically when bluegrass farmers in North Idaho dispose of grass residue through open field burning. On August 17, 1999, for example, more than 2000 acres of bluegrass fields were burned in the Rathdrum Prairie area and within the boundaries of the Coeur d'Alene Reservation in North Idaho. Much of the smoke, particularly from the fields burned on the Rathdrum Prairie, drifted into the Spokane Valley in eastern Spokane County. As shown in the materials attached at Exhibit D, SCAPCA received 61 complaints over a 17-hour period on August 17, 1999, all on the subject of grass field burning in North Idaho. This is a large number of complaints for this period of time. Most of the complainants stated they suffered adverse health effects, as opposed to complaining about aesthetic issues. The burning in North Idaho essentially covered the entire eastern Spokane Valley with smoke, including the communities of Newman Lake, Liberty Lake, Otis Orchards, and Greenacres. The closest SCAPCA air monitoring site – the Crown Z site – was about 20 miles away from the source of the smoke, the Rathdrum Prairie. Nonetheless, the Crown Z site reported uncharacteristically high concentrations

of PM. PM2.5 concentrations were above 30 μg/m³ for 4 hours, with a high of 70 μg/m³. PM10 concentrations were above 40 μg/m³ for 8 hours, with a high of more than 90 μg/m³. It is a reasonable conclusion that the particulate levels were considerably higher in the areas where the complaints were concentrated (i.e., closer to the source of the air pollution) than at the Crown Z monitoring site miles away.

13. Similar complaints were made to SCAPCA on August 19, 1997, when North Idaho farmers disposed of 1900 acres of bluegrass crop residue through open field burning. (This was before the Washington burn ban and growers in Spokane County burned 370 acres that day). SCAPCA received 92 complaints, primarily related to smoke from North Idaho. The Crown Z monitoring site – again, about 20 miles from the source of the smoke in North Idaho – reported high concentrations of PM, including PM10 concentrations that exceeded 75 μg/m³ for nearly 6 hours with a high of 110 μg/m³, and PM2.5 readings of over 50 μg/m³ for 4 hours with a high of 75 μg/m³. Details about the August 19, 1997 smoke intrusion from North Idaho are included in Exhibit D.

14. I have reviewed the smoke management plans applicable to Kentucky bluegrass field burning in North Idaho and within the boundaries of the Coeur d'Alene Reservation. This includes the Idaho Crop Residue Disposal Rules proposed by the Idaho Department of Agriculture in 2001. My professional opinion is that these plans are inadequate to protect the public health of citizens in Spokane County and North Idaho from the significant adverse health effects of open field burning of bluegrass crop residue. As explained in paragraph 5 above, smoke management plans: (i) are overly dependent on predictions of wind speed and direction which are impossible to consistently make with accuracy; (ii) simply send smoke toward other communities

rather than reduce or eliminate PM emissions; and (iii) are associated with the phenomenon of the "smoke coming back at you" because it is not possible to account for meteorological conditions on the day following the burn day; and the North Idaho smoke management plans share these defects. Given the single air shed which links North Idaho to Spokane County, depending on wind direction, bluegrass field burning in North Idaho is bound to send smoke toward Spokane, other communities in Eastern Washington, Coeur d'Alene, or Sandpoint, Idaho. This has occurred repeatedly in the past as demonstrated by the smoke intrusion episodes summarized in this declaration.

15. The Idaho Crop Residue Disposal Rules prohibit burning of bluegrass waste straw if it would result in a violation of ambient air quality standards. This does not protect public health. Experience shows that the worst agricultural smoke intrusion episodes cause very poor air quality and considerable complaints about health effects for several hours. However, since the particulate matter ambient air quality standards are based on annual or 24-hour averages, it is virtually impossible to register a standards violation, even under the worst of conditions. Therefore, this alleged restriction on burning is really no restriction at all. Even if an agricultural smoke intrusion causes a standards violation, the violation would not be registered until after the burning was already over, and therefore too late to mitigate the impacts.

16. If open field burning of Kentucky bluegrass crop residue continues in North Idaho, I anticipate that smoke intrusion episodes will continue to cause people in Spokane County to suffer when they breathe smoke from North Idaho. This is deeply unfair. The State of Washington has virtually eliminated bluegrass field burning yet its citizens are forced to breathe bluegrass smoke from Idaho. And the success of

footnote 13

Washington farmers in growing and harvesting bluegrass without burning shows that bluegrass farmers in North Idaho are profiting at the expense of public health by clinging to a cheap, yet harmful method of disposing of waste straw.

I declare under penalty of perjury that the foregoing is true and correct.

EXECUTED

this 1st day of June, 2002

by: [signature]

Eric Skelton

Footnote 14, [redacted]

(2) By rule the Environmental Quality Commission may delegate to any county court, board of county commissioners, fire chief of a rural fire protection district or other responsible person the duty to deliver permits to burn acreage if the acreage has been registered under ORS 468A.615 and fees have been paid as required in ORS 468A.615. [1991 c.920 §7]

468A.580 Permits; inspections; planting restrictions. (1) Permits under ORS 468A.575 for open field burning of cereal grain crops shall be issued in the counties listed in ORS 468A.595 (2) only if the person seeking the permit submits to the issuing authority a signed statement under oath or affirmation that the acreage to be burned will be planted to seed crops other than cereal grains which require flame sanitation for proper cultivation.

(2) The Department of Environmental Quality shall inspect cereal grain crop acreage burned under subsection (1) of this section after planting in the following spring to determine compliance with subsection (1) of this section.

(3) Any person planting contrary to the restrictions of subsection (1) of this section shall be assessed by the department a civil penalty of $25 for each acre planted contrary to the restrictions. Any fines collected by the department under this subsection shall be deposited by the State Treasurer in the Department of Agriculture Service Fund to be used in carrying out the smoke management program in cooperation with the Oregon Seed Council and for administration of this section.

(4) Any person planting seed crops after burning cereal grain crops under subsection (1) of this section may apply to the department for permission to plant contrary to the restrictions of subsection (1) of this section if the seed crop fails to grow. The department may allow planting contrary to the restrictions of subsection (1) of this section if the crop failure occurred by reasons other than the negligence or intentional act of the person planting the crop or one under the control of the person planting the crop. [1991 c.920 §8]

468A.585 Memorandum of understanding with Department of Agriculture. (1) The Environmental Quality Commission shall enter into a memorandum of understanding with the State Department of Agriculture that provides for the State Department of Agriculture to operate all of the field burning program.

(2) Subject to the terms of the memorandum of understanding required by subsection (1) of this section, the State Department of Agriculture:

(a) May perform any function of the Environmental Quality Commission or the Department of Environmental Quality relating to the operation and enforcement of the field burning smoke management program.

(b) May enter onto and inspect, at any reasonable time, the premises of any person conducting an open field burn to ascertain compliance with a statute, rule, standard or permit condition relating to the field burning smoke management program.

(c) May conduct a program for the research and development of alternatives to field burning. [1991 c.920 §4; 1995 c.358 §3; 2001 c.70 §2]

Steiner

$3.50

BURNING GRASS SEED FIELDS IN OREGON'S WILLAMETTE VALLEY

THE SEARCH FOR SOLUTIONS

EXTENSION MISCELLANEOUS 8397 JANUARY 1989

OREGON STATE UNIVERSITY EXTENSION SERVICE,
OREGON AGRICULTURAL EXPERIMENT STATION,
AND USDA–ARS COOPERATING

REPORT TASK FORCE

The following individuals contributed to this report. Appreciation is extended to each of them and to the many others who provided information, encouragement, and critical review.

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BURNING GRASS SEED FIELDS IN OREGON'S WILLAMETTE VALLEY

THE SEARCH FOR SOLUTIONS

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OREGON STATE UNIVERSITY EXTENSION SERVICE,
OREGON AGRICULTURAL EXPERIMENT STATION,
AND USDA–ARS COOPERATING

PREFACE

This publication is prepared as a public service by faculty members at Oregon State University in response to a perceived need for information on field burning. The report has been prepared as a reference and source document for 1989 legislative and agency deliberations on further adjustments in thermal sanitation of grass seed fields in the Willamette Valley of Oregon.

The legislative agenda may include a broader state-wide perspective than that presented here. To date, however, control of agricultural burning in Oregon has been confined to open-field burning of grass seed in the Valley. Consequently, adjustment and research activities have been confined to the Valley. The report addresses four major areas:

1. historical background of field burning and description of the industry;
2. compilation of research and development activities from 1968 to 1988 associated with the search for viable alternatives to field burning;
3. structural adjustments made to date and economic issues which will affect future adjustments; and
4. review of possible alternative policy choices for consideration by the 1989 Oregon Legislature.

This report is intended specifically for use by industry leaders, concerned citizens, agency administrators and legislators as a working document in legislative committee sessions throughout the 1989 legislative session. As the report was prepared on short notice, the background and research and development activities treated herein were compiled in part from selected key reports.

Those relied upon heavily included *Synopsis of Grass Straw Research in Oregon, 1968-1986* by Thomas R. Miles, Jr. and Thomas R. Miles, May 1987; *Final Report, Field Burning R&D Program Evaluation* by Nero and Associates, January 1987; and *DEQ Annual Reports on Field Burning.* Direct excerpts from those sources were taken in several instances. Use of these sources is gratefully acknowledged.

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EXECUTIVE SUMMARY

STATUS OF THE GRASS SEED INDUSTRY

Oregon is the world's major producer of cool-season forage and turf grass seed. The Willamette Valley is the national center of cool-season grass seed production with 330,000 acres harvested on 700 to 800 farms in 1988.

The farm gate value[1] of 1987 Willamette Valley production was $140 million. Farm gate value of Oregon grass seed production was $156 million, ranking grass seed the number one field crop by value in Oregon. Processing contributed an additional $34 million. The total effect on the state's economy from sales, using a 2.0 business output multiplier[2], is estimated at $380 million. Farm gate value in 1988 in the Valley rose to $190 million, while total Oregon farm gate value of grass seed production rose to $211 million. Valley grass seed acreage has expanded by 95,000 acres (from 235,000 to 330,000 acres) during the past decade. The acreage and income increases are due largely to expanding consumer demand for turf-type perennial grasses, especially tall fescue and perennial ryegrasses.

Grass seed is grown on 32% of the total harvested cropland in the Willamette Valley. In the southern Valley where large tracts of poorly-drained soils have limited cropping alternatives, more than 56% of the total harvested cropland is in grass seed.

Overall, 75 to 80% of Oregon seed is sold domestically with the remaining 20 to 25% going into foreign markets which include the European Community, Japan, Canada, Korea, and Australia.

Markets for grass seed are distinguished by end use needs. They include lawn and turf use (fine fescues, bentgrass, turf-type tall fescue, turf-type perennial ryegrass, and Kentucky bluegrasses), cover-crop and pasture use (orchardgrass and tall fescue), and multi-purpose use (annual and perennial ryegrass).

Oregon grown seed represents two-thirds of all U.S. cool-season grass seed production with the other one-third coming from competing regions which include Washington, Idaho, and Missouri. Minor foreign competition in U.S. markets comes from Canada, New Zealand, The Netherlands, and Denmark. Oregon historically has had an economic advantage in domestic and foreign markets due largely to high mechanical and genetic quality of its grass seed.

HISTORICAL DEVELOPMENT OF THE GRASS SEED INDUSTRY

Although climate in the Willamette Valley is ideal for grass seed production, disease problems limited the growth of the industry during its infancy in the 1930's. *Open-field burning* was developed as a *solution* to disease problems and permitted the fledgling grass seed industry to expand dramatically in the 1940's. Other benefits from open-field burning include effective weed control, stimulation of seed yield, partial control of several insect pests, recycling of nutrients, decreased initial nitrogen fertilizer demand for annual crops, easy and low cost stand establishment, higher quality seed, ability to meet strict certification standards, minimal need for pesticides and efficient and economical residue removal from fields that are not tilled annually because of perennial crop production.

The practice of field burning led to a new *problem* -- smoke as a by-product of grass seed production. This smoke is an air pollutant during the field burning season in the Willamette Valley.

ATTEMPTS TO OVERCOME PROBLEMS ARISING FROM FIELD BURNING

The search for solutions to problems arising from field burning seeks to reduce or remove smoke problems while protecting the economic vitality of the grass seed industry, or identify an alternative industry. The new production practices sought must permit individual grass seed growers to produce an

[1] Farm Gate Value is defined as the gross value of production for a given crop year; estimated as the average total annual production by growers x averaged annual price received by growers.

[2] The business output multiplier measures the total change in local sales generated by a one dollar increase in sales of the product outside the state. For the agricultural sector of Oregon the range in the business output multiplier is 1.4-2.7 with a mean of 2.2. The authors used a conservative value of 2.0 for the grass seed industry. Although most processing is done in state, its value added compared to final product is relatively small (Mandelbaum et al., 1984).

economically viable crop in the short run, and must not result in building up of disease, weed, and pest problems that could threaten the industry as a whole in the long run.

Given the current state of knowledge, all alternatives to open-field burning will represent increased costs and, other things being equal, decreased returns to growers. These alternatives are discussed below.

Smoke Management

Smoke management was the first measure instituted to deal with the smoke produced by field burning. Initial measures were implemented during the late 1960's with growers, fire districts, and state authorities cooperating. At that time more than 300,000 acres of grass seed and small grain fields were open burned. In 1971, the State Legislature placed field burning under state regulatory powers of the DEQ (Department of Environmental Quality).

The DEQ has responsibility for regulating the amount of burning consistent with air quality considerations. The State Legislature instituted a system of grower fees to pay the administrative cost of the regulatory smoke management program and to establish a research and development (R&D) program to seek alternatives, study smoke management, and study health effects.

The system of grower fees continues in force and currently provides about $550,000 annually for smoke management and $250,000 to $350,000 annually for R&D. The R&D activities during the past 17 years have totaled nearly $7 million. Most of the R&D activities to date have come from the self-sustaining grower fee program rather than from public funds.

The maximum number of acres allowable for open burning was set at 250,000 acres by the State Legislature in 1978 and has continued to date. Actual acres burned under the DEQ managed smoke management program has continued at about 220,000 acres annually during the past decade except for 1988 when it declined to about 150,000 acres due to an 8-day temporary burning moratorium. The current DEQ smoke management program utilizes meteorological conditions to specify timing, method of field firing, and acreage levels to minimize smoke impacts upon the Valley population, particularly in urban centers.

Research and development activities have focused principally upon thermal sanitation alternatives, alternative crops, agronomic alternatives, uses for grass straw, and a preliminary examination of public health effects.

Thermal Sanitation Alternatives

Field sanitizers

Thermal sanitation alternatives developed to date have been in the form of machine sanitizers. Several sanitizer designs were developed by OSU and private engineers starting in 1969 and field tested throughout the 1970's. These units used some or all of the straw residue as a fuel source to sanitize the fields under conditions that would complete the combustion process and minimize emissions. Although agronomic studies and field tests demonstrated that the units provided an effective technical substitute for open burning over a range of field conditions, difficulties with short machine life, high operating cost, high energy use, and slow operating speed made commercial sanitizer use an economically prohibitive option. By the late 1970's the emphasis was placed on smoke management and research shifted to alternative sanitation methods.

Propane flaming

Agronomic studies and field tests showed that thermal sanitation achieved by propane flaming could be similar to open burning without major seed yield loss, but only if most of the straw residue were removed prior to propane flaming. Higher residue levels left on the ground provided a greater combustible mass during dry weather thereby permitting faster field operation but generating greater emissions near ground level. Thus, residue removal, except for the stubble, and slow field operation are necessary for good results. This means that to be effective, the large volume of residue, some 2 to 4 tons per acre, has to be removed as a companion process to propane flaming, with subsequent use or disposal of the residue. The cost of the propane flaming ranges from $8 to $32 per acre depending upon level of residue and speed of operation. Residue removal represents an additional cost if a market is not found for the straw.

Propane flaming is being used by an increasing number of growers, especially in the North Valley. An estimated 56,000 acres were sanitized by propane flaming in 1988 (T.L. Cross, personal communication).

Non-Thermal Sanitation Alternatives in Perennial Grass Seed Production

Grass seed production in the Valley is a diverse activity. It differs from many field crops in that two-thirds of the acreage is in perennial grass crops which have a productive life of four to eight years. The fields are not tilled during that time but require special field management instead. Following harvest the straw residue must be removed to assure a satisfactory crop in the following season. The remaining one-third of grass seed acreage is in annual ryegrass production which can be tilled each year. Grass seed farmers in the south Valley tend to be specialized in production of the ryegrasses while those in the north Valley are diversified with several grass seed species and other crops.

Mechanical Straw Removal

Baling was found to be the most economical removal option in situations where there is a market for the straw. Cost of baling and roadsiding approaches $40 per acre. In the absence of a straw market, the lower cost choice of raking and use of stack wagons to position the straw at the side of the field for later burning is preferred. Burning of bales or loaves after placement at fieldside is used to dispose of unmarketable residue.

Crew Cutting or Close Clip Stubble Removal

In the absence of burning, the bulk of the straw must be removed mechanically, and followed by a "clean up" operation. The best non-thermal method of "clean up" is the clip and vacuum, or "crew cut" treatment, which involves special equipment not yet commercially available. The flail chop treatment is a chaff and stubble removal treatment using the best currently available equipment, a forage harvester. Both straw and stubble treatment methods involve significant labor and equipment costs as compared to open burning. The operations also generate considerable low level dust emissions.

Less Than Annual Burning

This practice includes alternating various combinations of burning and mechanical removal techniques over a period of several years. In perennial ryegrass, alternate year burning averaged 93% of annual burning yield over a five year period regardless of whether plots were crew cut or flail chopped during the non-burning year. No deleterious effects on seed yield were reported for fine fescue or bluegrass when averaged over four years.

Chemical Treatment

Chemical treatment with monocarbamide dihydrogensulfate (Enquik^R), a urea-sulfuric acid reaction product, applied at 15 to 20 gallons of product per acre during mid-October has shown some potential for reducing fall germinating unwanted grass seedlings, controlling some weeds, increasing effectiveness of specific herbicides, and accelerating decomposition of old crown growth left at harvest. Results vary with grass species and weather, especially temperature and rainfall.

Shorter Crop Rotation

Perennial grass seed crops historically have produced for up to 10 to 12 years as a single stand without re-establishment. This has been reduced to about five years for proprietary varieties grown under contract. In the absence of annual open-field burning, further shortening of the rotation may be necessary to decrease the incidence of disease and pests. However, production costs increase significantly as establishment costs (including one season of lost income in several species) are amortized over fewer production years and thermal sanitation costs from propane flaming and residue removal are included.

No Thermal Sanitation

Seed production without field sanitation in the Willamette Valley has not been successfully demonstrated on a large scale. Several serious diseases of seed crops have been held in check with field sanitation but are still present at low levels. Diseases might increase quickly if thermal sanitation were discontinued entirely.

Non-Thermal Sanitation Alternatives In Annual Ryegrass Production

Annual ryegrass represents one-third of total grass seed acreage in the Valley. Historically, it has been reseeded each fall in the ash of open-field burning. Some growers are shifting to less than annual burning. The cultural practice generally involves flail chopping of the straw residue and its incorporation into the soil by plow-down. In some instances, the straw is removed before plow-down. Growers feel that some, or all, of the straw must be removed as most annual ryegrass is grown on poorly drained clay soils in which incorporation of residue is difficult.

Control of Pests and Diseases

While significant work has focused upon thermal and non-thermal sanitation, the collective or cumulative effect upon the seed industry of non-burning upon incidence of disease, insect, and other pests and their cost of control are unknown. Cultural, chemical, and field management measures for disease and weed control in grass seed crops in the absence of burning were initiated in the early 1980's and have had limited testing to date. Certain insects may be controlled by grazing or mechanical removal of crop residue while some may require thermal control methods. The extent to which thermal sanitation can be reduced as a cultural practice on a farm-by-farm and grass-seed-species basis without major consequences upon yield and seed quality due to disease, insect, weed, and other pest effects requires additional research.

ALTERNATIVE CROPS

Alternative crops to grass seed production are influenced by technical and economic factors. In the north Valley where soil drainage is good, the profitability of grass seed types and their markets relative to other crop choices becomes the overriding factor. In the south Valley, poor soil drainage is a technical factor severely limiting crop choices as most crops will not survive soil moisture saturated winter conditions.

Meadowfoam, the only known winter annual crop that will tolerate such a condition, was identified as a potential crop with preliminary plot trials initiated in the mid-1970's. Since that time, studies of yield increase, seed dormancy, production, and economic feasibility and market development analyses have been done. Oil extracted from meadowfoam appears to have potential for industrial and cosmetic trade utilization. Two principle factors limit its use at this point. The first is low yield. A major effort is being made to improve seed yield and to reduce production costs enough to compete with oils currently used in the market. The second factor is that no industrial utilization research yet has been conducted to ascertain the qualities and properties of meadowfoam and hence potential role(s) in industrial and cosmetic markets. Research has been initiated in this area (C.D. Craig, personal communication). Potential technical viability of meadowfoam as an alternative crop for adoption is estimated to be 5 to 10 years away from consideration. Whether it will be an economically viable choice at that time is questionable. Its potential scope is unknown but appears to be limited. Currently, some 20 to 25 growers produce less than 200 acres annually with excess inventory of oil on hand.

STRAW UTILIZATION

Straw removal and utilization or disposal have been essential companions to the viability of alternatives to open-field burning. Straw must be removed for mobile sanitizers, flamers, alternate year burning, and mechanical or chemical methods of disease, pest, and insect control to be effective.

From a technical standpoint, straw can be used as a raw material to make a wide range of products for fiber (paper, particleboard, fuel logs, hydromulch, composted fertilizer, etc.), chemical products (oil, gasoline, plastics, microbial protein, etc.), and livestock feed. Economically, it has been difficult for grass straw to compete in existing markets as a raw material source. Low bulk density of the straw which requires costly densification, high cost transportation, uncertainty of long-term supply, and low volume of supply in fiber markets have made straw non-competitive with other raw materials. The traditional base for making pulp and paper in the Pacific Northwest is wood chips which are cheap, adequate in continuing supply and volume with manufacturing technology adapted to that source and require no storage from rainy weather. ~~Converting to straw would involve major retooling in the wood fiber industry.~~

As a feedstuff for livestock, untreated straw is of poor quality because of low protein and high fiber content. With appropriate treatment, such as ammoniation, the digestibility and palatability of straw can be increased substantially making straw a potential component of maintenance diets for ruminant livestock. Costs of physical and chemical treatment have made the process marginal in an economic sense.

To date less than 20% of annual residue is being used in domestic and export markets as a supplemental livestock feed. During periods of short supply and/or excess demand for forages in U.S. markets, such as experienced during the major drought of 1988, a relatively small quantity of grass straw is marketed. Extended dry weather conditions in the Valley through October permitted more straw to be sold. Japan, the major current market, utilized an estimated 125,000 to 150,000 tons in 1988 for supplemental livestock feed.

THE PUBLIC CONCERN

Research activities involving health, soiling, nuisance, hazards, and aesthetic influences from open-field burning in the Willamette Valley have been extremely limited. Nearly all of such activities have been financially supported by the DEQ Field Burning R&D Program.

Initial work in the early 1970's focused upon air quality and its measurement. From 1971 to 1977, limited surveys of respiratory patients in the Valley and respiratory patients statewide provided inconclusive results relative to health effects.

In 1977 health effects research was given top priority status in the Field Burning R&D Program. Funds were set aside for preliminary studies and for planning a major health effects research project. In doing so it became apparent that research on this issue would require multi-disciplinary research activities and be very costly, the magnitude could easily divert all R&D funds available annually for several years. Consequently, the Field Burning R&D Committee decided to:

1. support preliminary studies based on local data, if possible, to identify evidence that health impacts do indeed exist;
2. follow up such evidence with a planning effort to design a more extensive research effort; and
3. solicit the necessary funding for such an effort and contract the work.

Each of these activities were completed: physician visit and hospital admission surveys in 1980; a field burning health effects workshop in 1986; and a preliminary field burning health effects assessment in 1987. The health effects assessment, conducted to provide quantitative measures of exposures, health effects/risk, and related costs from field burning, slash burning, and residential wood burning, has not been released. A technical review of the assessment raised serious questions concerning the appropriateness of the methodology used and hence conclusions of the study for Willamette Valley conditions.

A 1986 DEQ contracted study provides an initial attempt to assess the importance of air quality through estimation of the amount the public would be willing to pay for improved visibility. No attempt was made to link the study to smoke impact.

In the case of the Willamette Valley grass seed industry, the desired level of environmental quality is made more complex in that a simple inverse trade-off between improved air quality and economic well-being of the industry does not exist. Although known for air pollution, the grass seed industry also provides positive environmental effects through low levels of soil erosion on hillside lands, low levels of dust emissions throughout the year which are more common with other crops and a buffer from urban/industrial development.

STRUCTURAL ADJUSTMENTS TO DATE

Open-field burning has declined from a high of 315,000 acres in 1968 to about 220,000 acres annually during the 1980's. In 1988, 330,000 acres of grass seed were produced in the Valley of which 206,000 acres were thermally treated. An estimated 150,000 acres were field burned and 56,000 acres propane flamed. The remaining 124,000 acres employed other field cultural practices. In general, the net effect to the public has been reduced emissions by more than one-half from reduced acreage burned.

Less obvious grower adjustments have been made. They include changes in thermal sanitation practices to propane, changes in field cultivation practices which substitute for field burning, adjustment among the mix of grass seed species grown both at the farm and industry level, increased use of proprietary varieties, and adjustment to external market forces which have enhanced the industry in recent years.

With annual ryegrass, growers have reduced the acreage planted and made a shift to fall plow-down and reseeding to partially replace field burning. Some straw is removed from the field for disposal by stackburning as a companion practice. On the perennial grasses, especially those grown in the north Valley, a definite increase in straw removal followed by propane flaming has been observed. The volume of straw intended for sale has increased. Several storage units have been built and baling for commercial sale has become more common. During the early 1980's, a definite shift toward proprietary varieties under forward contracting was employed, largely as a mechanism for reducing the risk of low market prices. Some shifting away from this has occurred since 1985 as market prices improved significantly for grass seeds, especially for turf-type tall fescue and perennial ryegrasses resulting in a 23,000 acre increase from 1987 to 1988 for those two grass seed species.

TECHNICAL AND ECONOMIC CONSIDERATIONS FOR FUTURE ADJUSTMENTS

The Willamette Valley grass seed industry may be called upon to make further adjustments in response to the public desire to reduce smoke emissions from open-field burning. Understanding the past provides guidelines of issues to expect when one considers adjustment possibilities for the future.

Important technical and economic factors will influence the ability of the industry to make further adjustments. These include:

1. Ability of the industry to retain its relative economic advantage in the marketplace while responding to cost increasing alternatives to replace open-field burning is unknown. Positive market forces in the 1980's, which provided a measure of industry well being to offset cost increases, may not continue into the 1990's.
2. Incidence of future disease, insect, and weed pests without thermal sanitation is unknown.
3. The impact of straw removal, an important companion to propane flaming, comes at a high cost to growers if little of it is marketable.
4. The role of meadowfoam as a new crop is not expected to have strong economic potential for several years. Low yield and market potential persist as limiting factors.
5. Shifts by growers to crops previously grown are unlikely as their margin of return is very low.
6. Existence of public health effects from thermal sanitation has not been quantified.
7. Extent of public hazard, nuisance, soiling, and aesthetic effects from open burning has not been adequately measured.[3]
8. Ability to conduct required tests using *currently registered* pesticides for disease and weed control to remove EPA label restrictions on use of crop regrowth, straw, or seed screenings for livestock feeding or grazing is uncertain.
9. Ability to conduct necessary tests to obtain EPA registration of *new pesticides* is needed for seed production in the absence of field burning to permit legal access of straw residues to livestock feeding markets.

A VIEW TOWARDS FURTHER ADJUSTMENTS

In considering reduced open-field burning, it is important to examine what alternatives might be considered and what impacts such choices might have. One needs to consider the livelihood of the industry and its individual growers on the one hand, and the general public and its concern about the quality of air it breathes on the other.

[3]Particulate emission (PM 10) quantities are estimable and available for different levels and sources of smoke. They serve largely as a limited proxy for estimating haze level. They should be used in conjunction with meteorological variables under actual conditions as air mixing is an important influencing factor.

Because little substantive research evidence is available to provide measurement estimates on the impacts of improved air quality to the public, currently it is not possible to make direct comparisons between economic losses to grass seed growers and air quality gains to the Oregon public from further reductions in open-field burning. Instead, what is done here is to provide a selected list of possible policy alternatives which simply are ranked in order of increasing improvement in air quality and decreasing economic well being to grass seed growers.

1. Maintain the current field burning program but impose further controls to minimize the risk hazard from open burning that may endanger human lives.
2. Implement negotiable burning rights to grass seed growers.
3. Use public funds for subsidies and expanded R&D on pollution abating technology.
4. Continue with the controlled open burning program but reduce the maximum burned acreage to some lower level with the actual number of acres burned determined by meteorological conditions.
5. Continue with the controlled open burning program but accomplish a reduction in the number of acres burned through an increased per acre burning fee which is of a magnitude large enough to serve as an economic disincentive.
6. Provide a phased reduction in open burned acreage over a set period of time until the practice is eliminated entirely.
7. Eliminate open burning for residue disposal purposes but permit thermal sanitation on a "prescription" basis for disease, weed, and insect control.
8. Eliminate open-field burning entirely.

As the emphasis shifts away from open burning toward greater reliance on propane flaming, production costs would increase accordingly. Increased costs would involve cost of propane flaming and cost for residue removal and disposal. An indirect effect would be reduction in grower fees available for needed smoke management and research and development activities unless alternative mechanisms for funding these activities are identified. Fees generated in policy choice 5 might be used, in part, for such activities.

The discussion of the net impact of further adjustments in grower production practices is complicated by the lack of reliable information on air quality associated with propane flaming and stack burning, practices developed as alternatives to open burning. Preliminary observations suggest that low level emissions from propane flaming may lead to widespread and persistent haze throughout the Valley if the practice gains greater use. Studies are underway to ascertain more precisely the air quality tradeoffs between open burning, propane flaming and stack burning. At issue for policy makers is the impact on air quality from further regulations of post-harvest management practices as they will not provide simple trade-offs in air quality changes.

CHAPTER 1

INTRODUCTION AND BACKGROUND

OREGON'S GRASS SEED INDUSTRY

Oregon is the world's major producer of cool-season forage and turf grass seed and a widely recognized center of expertise in seed production. Most of the acreage is located in the Willamette Valley, the "grass seed capital of the world." Farm gate value of the Valley's 1987 production was $140 million (Miles, 1988). Preliminary data for 1988 show a substantial increase to $190 million. Oregon growers produce essentially all of the U.S. production of annual ryegrass, perennial ryegrass, bentgrass, and fine fescue. Smaller but significant amounts of bluegrass, orchardgrass, and tall fescue are produced. Collectively, Oregon's Willamette Valley produces almost two-thirds of the total U.S. production of cool-season grasses.

Grass seed typically is produced on nearly 800 family farms, averaging 700 acres, with more than 60% of the total labor requirements provided by family members. Seed production of one or more seed species are the major enterprises, with growers using machine technology especially adapted to small seeds. Mild and moist winters with dry summers favoring seed maturation and harvest make the Valley an ideal place to produce high quality seed. Over 360 seed conditioning plants located in the Willamette Valley prepare the seed for market once the harvest operation is complete.

Linn County, with about 156,000 acres of grass seed production in 1987, is the leading grass seed producing county in the state. Linn County produces more than 40% of Oregon grass seed and 75% of the ryegrass produced in the U.S. (Miles, 1988).

Grass seed growers in Linn, Benton, and Lane counties, in the southern Willamette Valley, tend to specialize in grass seed crops because of the extensive area of poorly-drained soils in the region. Most other crops will not survive the winter flooding on these soils.

Grass seed crops are grown on more than 56% of the total harvested cropland in the southern Willamette Valley and 32% of all Willamette Valley counties (Table 1.1) (Miles, 1988).

Annual and perennial ryegrass are adapted to soils in the southern Willamette Valley, but have low net returns per acre. Although draining and supplemental summer irrigation of the soils is technically possible, market conditions and improvement costs generally preclude opportunities for improving soils and producing cereals or intensive fruit and vegetable crops. Availability of contracts for alternate crops is limited.

Significant grass seed production also occurs in Lane, Benton, Polk, Yamhill and Marion counties. Small amounts are produced in Washington and Clackamas counties. Seed farms in Polk, Yamhill, Marion, Clackamas, and Washington counties are smaller and more diversified than those in the south Valley. Soils in these areas are more variable, providing opportunities for a variety of crop alternatives and rotations. Crop choices are definitely limited in the hilly areas where soil erosion can be a problem. Grasses are adapted and provide greater protection against soil erosion than annual cereals or row crops.

Outside the Willamette Valley, small amounts of grass seed are produced in Union, Jefferson, Jackson, Sherman, Malheur, Crook, Douglas, Morrow, and Baker counties.

Table 1.1 Grass seed crop acreage and total crop acreage in the Willamette Valley, 1987

District/County	Total Harvested Cropland	Grass Seed Crops Cropland	Percent of Total Harvested Cropland
	(acres)	(acres)	(percent)
North Valley			
Clackamas	77,805	7,900	10.2
Marion	176,285	49,700	28.2
Multnomah	13,047	90	.7
Polk	109,376	28,150	25.7
Washington	96,035	550	.6
Yamhill	112,900	9,500	8.4
Subtotal	585,448	95,890	16.4
South Valley			
Benton	67,084	28,400	42.3
Lane	83,250	24,880	29.9
Linn	220,593	156,450	70.9
Subtotal	370,927	209,730	56.5
Valley Total	956,375	305,620	32.0

Source: Miles, S.D. 1987 Oregon County and State Agricultural Estimates, Special Report 790, Revised January 1988, Oregon State University Extension Service.

ECONOMIC TRENDS

The past decade has experienced a steadily expanding trend in Oregon's grass seed industry. The increase is attributed largely to an expansion of 95,000 acres (from 235,000 to 330,000 acres), greater use of proprietary varieties that provide market price stability through forward contracts in the U.S. markets and expanded domestic demand for turf-type perennial grasses, especially tall fescue and perennial ryegrass.

Farm gate value of grass seeds produced in Oregon totaled $156 million in 1987, representing 11% of total field crop receipts in the state and 7% of the state's $2 billion gross farm and ranch sales. This is an increase from 1980 when the $81 million in cash farm receipts represented 7% of total field crop receipts and 4.6% of gross farm/ranch sales. Of this amount, $140 million was generated by Valley growers. Cash farm receipts in 1987 from all grass seed production exceeded the value of Oregon's wheat crop which historically has been the number one field crop by value. The value added from processing grass seed is estimated at $34 million. The total effect on the state's economy from sales, using a 2.0 multiplier, is estimated at $364 million. Farm gate value of grass seed in 1988 rose to $211 million, of which $190 million was generated by Valley growers.

Across all grass species grass seed production has shown gains of 15 to 20% over the past decade. The most pronounced has been tall fescue with an increase of 60% largely from turf-type proprietary varieties. Growers have reduced acreage of annual ryegrass and expanded acreage of turf-type tall fescues and perennial ryegrass.

Prices have moved higher in nominal, and in some cases real, terms over the past decade. A major upsurge in prices, linked to the Conservation Reserve Program (CRP) provisions of the 1985 Food Security Act, continued from 1985 through 1987 for orchardgrass and tall fescue as pasture/cover crop grasses. Especially large price increases have occurred with turf-type proprietary tall fescue and perennial ryegrasses in U.S. consumer markets due largely to genetic changes which have expanded the scope of their markets.

Value of production for all grass seed in the Willamette Valley has more than doubled during the past decade with major increases since 1985. However, individual grass seed crops have varied in response to the combined acreage, yield, and price trends. Tall fescue and orchardgrass increased in value throughout the decade. With exception of the 1982 to 1984 period, so did perennial ryegrass. Each of these three grass seed types were used for cover-crop and pasture grass uses. The other three grass seed types (used for lawn and turf purposes) suffered reductions in the value of production during the 1982 to 1984 period as a function of market price, but have since rebounded strongly. Value of production of annual ryegrass has been steady with improved prices offsetting a major decline in acreage.

Proprietary varieties[4] have become an important and dynamic factor in the industry, especially during the past decade. The 1970 Federal Plant Variety Protection Act provided proprietary protection by granting rights to private and public breeders for exclusive propagation and sale of grass seed under private varietal labels in both domestic and foreign markets. Certification records in Oregon indicate that in 1979, 10% of Willamette Valley grass seed acreage was planted to proprietary varieties. By 1987 the acreage had increased to 30%. Proprietary varieties of perennial ryegrass, Kentucky bluegrass, and turf type tall fescue account for 50 to 80% of total acreage of these grass seed types.

MARKETS

Consumer markets for grass seed are specified by lawn and turf use (fine fescues, bentgrass, Kentucky bluegrasses, turf-type tall fescue, and turf-type perennial ryegrass), cover-crop and pasture use (orchardgrass and tall fescue), and multi-purpose use (annual and perennial ryegrass).

Most cool-season grass seed is marketed outside Oregon. Some 75 to 85% is sold in U.S. markets. Domestic markets for lawn and turf grasses are largely in the major urban areas of the U.S. including winter overseeding of lawns in the south. U.S. markets for pasture and cover-crop purposes are dispersed throughout agricultural producing areas and expanded under the 1985 Food Security Act.

Oregon competes with Idaho and Washington in Kentucky bluegrass production and Missouri in orchardgrass production. Field burning is used as a cultural practice in Washington and Idaho bluegrass stands.

Tall fescue is the only cool-season grass seed in which Oregon is not a dominant producer. Missouri produces about 70% of U.S. production of tall fescue, down from 80% in 1978 (F.S. Conklin, personal communication); Oregon captured the increase. Tall fescue and orchardgrass are grown in Missouri primarily for livestock pasture with seed production serving as a secondary enterprise and in which field burning is not employed as a cultural practice. However, Oregon is the largest producer of high-quality certified forage seed of these crops, and the primary producer of turf-type tall fescue.

In spite of expanded acreage and increased yields in Oregon of grass seeds over the past decade, Oregon production as a percentage of U.S. production declined from 73 to 64% (F.S. Conklin, personal communication). Increased U.S. production of tall fescue in Missouri and Kentucky bluegrass in Idaho and Washington outstripped overall Oregon increases in grass seed production through 1987. During this period, the decline in Oregon's annual ryegrass production, which historically accounted for more than one-half of total Oregon grass seed production, was a contributing factor. Since 1986, annual ryegrass acreage has remained relatively constant.

Competition from imports in the U.S. market historically has been very small, accounting for 2 to 3% of U.S. demand. From 1984 to 1987 imports increased from 10 to 40 million pounds due largely to expanded demand, triggered by the CRP program, which could not be met by immediate domestic production increases. Red fescue from Canada and perennial ryegrass from New Zealand accounted for most of

[4] Proprietary varieties are propagated and released by plant breeders and their designees under an exclusive proprietary name. Such varieties are not available to the general public for propagation and release. This licensing arrangement permits holders of such rights to exclusive monopoly development, propagation and distribution rights to use the variety name. Public varieties may be propagated and released by anyone meeting the required certification standards.

the increase. Grass seed production in those areas is largely in conjunction with livestock grazing and/or short rotation with other crops in rotation in which field burning is not used as a cultural practice.

The export market, while somewhat important for all U.S. produced cool-season grass seed, is especially important for bentgrass. Essentially all U.S. produced bentgrass is exported, while 5 to 50% of the remaining cool-season grass species are exported. Principal export markets for lawn and turf grasses are the EEC (European Economic Community), Japan, and Canada. For cover-crop and pasture use grasses the EEC, Japan, Korea, and Argentina are major markets. For the multi-purpose ryegrasses, Japan, Italy, Netherlands, Australia, and Canada are major markets.

International competition in lawn and turf grasses comes from Denmark, West Germany, The Netherlands, and Canada, and in pasture and cover crop grasses from Denmark, Canada, New Zealand, and The Netherlands. Producer subsidies and non-tariff trade barriers in the EEC and Japan serve to restrict trade flow of U.S. grass seed to those markets with high flow years tending to coincide with low production in the EEC.

CHAPTER 2

FIELD BURNING

AN HISTORIC SOLUTION TO A PROBLEM

Open-field burning was introduced in Oregon as a solution for control of certain grass diseases during the mid-1940's (Hardison, 1948) which were threatening the fledgling grass seed industry . The practice was quickly adopted by all growers. In addition to disease control, burning of grass seed crop residue was found to have several other significant benefits which led to its general use in grass seed production in Oregon. The high seed yields and quality associated with a seed production program that included burning has made it possible for Oregon seed producers to compete effectively in national and international markets.

Several major advantages of field burning exist. They are stated succinctly in the next series of paragraphs. Later sections provide further elaboration.

Disease control. The primary reason for initiating field burning of grass seed fields was to control blind seed disease (*Gloeotinia temulenta*) and ergot (*Claviceps purpurea*) (Hardison, 1960). Several other plant diseases were found to be reduced or partially controlled by residue burning.

Residue removal. Grass residue must be removed from perennial grass fields because they are not plowed annually. After harvest, there is a straw volume of three to five tons per acre with a non-uniform distribution across the field. Left undisturbed, this quantity of residue shades developing grasses so severely they either die or grow with low vigor and loss of productivity. Burning is an effective and low cost method of removing grass residue from fields.

Weed control. Market standards allow very limited amounts of weed seed in commercial seed moving in trade. This requires a high level of weed control in seed fields. Weed control involves maintaining a low level of viable weed seeds on the soil surface and thorough removal of residue that can interfere with herbicide activity. Open burning performs both functions very effectively.

Stimulation of seed yield. Post harvest burning changes the plant and soil environment, promoting plant regrowth early in the autumn. Removal of older tillers and early vigorous new growth results in higher seed yields in the subsequent crop year.

Insect control. Field burning of crop residues destroys oviposition sites for some insect pests and controls certain insects such as plant bugs.

Improved genetic purity. Burning destroys shattered crop seed left in the field after harvest. When these seeds are allowed to grow, they represent a second generation and the crop cannot be certified for genetic purity, thus reducing the marketability of the seed.

Nutrient recycling. Ash deposited from burning residue recycles nutrients to the soil. Burning will recycle potassium, magnesium, calcium, and phosphorus. Removing post harvest residue will take these nutrients from the field and increase need for adding these nutrients to the crop as commercial fertilizer.

Decreased nitrogen fertilizer requirement. When annual grass seed straw is plowed down, nitrogen in the soil is immobilized by microbial activity during straw decomposition. Burning straw residue decreases the amount of organic material incorporated and thus the amount of nitrogen immobilized.

Easier crop establishment. Destroying weed seeds and residue on the soil surface eases establishment of the subsequent crop. With burning, annual ryegrass can be planted with little or no tillage, saving fuel and reducing costs. Establishing a small-seeded grass stand requires a good seedbed. The best seedbed can be prepared by disposing of straw prior to tillage.

CREATION OF A NEW PROBLEM

When field burning was started during the 1940's, few if any, public complaints were reported. But as the number of acres burned increased, and especially when fields with green regrowth were burned late in the season or when fields were burned under adverse atmospheric conditions, complaints about smoke increased.

Air Pollution: A Common Property Issue

Smoke discharged into the air is an unwanted residual output from grass seed production. Air is a natural resource used as common property by society for a myriad of activities. Environmental pollution of air, water, and the landscape is largely a by-product of the industrial revolution of the U.S. which has continued for more than a century. The magnitude of its impact upon the public and its realization as a serious issue has emerged only in recent decades. While the environment has a natural capacity to assimilate and break-down some waste materials into desirable or inoffensive elements, a point can be reached at which wastes accumulate in a harmful and/or obnoxious form as population and the level of production increases without a corresponding increase in the effectiveness of the technology used for waste disposal.

Achieving a desired level of environmental quality is a complex problem since the costs, both measurable and unmeasurable, of pollution are borne externally. That is, the persons and firms whose decisions generate the externalities neither bear the costs of the pollution nor have to compensate those who do bear them. While a market economy is equipped to handle market transactions between buyers and sellers of commodities and services, it is not well suited to account for and measure the third party effects (diseconomies) from pollution, a by-product of market transactions.

Policy alternatives devised to control pollution include: direct regulation of input technology and pollution levels, effluent or emission fees to serve as economic disincentives to induce technological change, compensation to injured parties or use of compensation payments to seek alternate means to reduce emissions, and public subsidies of pollution abating technologies to encourage their use. Legislating and administering effective and flexible environmental controls, which are consistent with public desire on the one hand, while encouraging agricultural and industrial efficiency and market competition on the other, is a task of no small magnitude. Trade offs between economic efficiency, market concentration, employment, environmental quality, income distribution, and personal freedoms become the hard choices.

In the case of the Willamette Valley grass seed industry the desired level of environmental quality is made more complex in that a simple inverse trade-off between improved air quality and economic well-being of the industry does not exist. Although known for air pollution, the grass seed industry also provides positive environmental effects on water quality through low levels of soil erosion on hillside lands, lower levels of dust emissions throughout the year which are more common with other crops and a buffer from urban/industrial development.

Smoke Management

Smoke management was the first tool applied to begin addressing the public problem of air pollution from field burning. No systematic effort to manage smoke existed before the 1960's. During the early 1960's, the U.S. Weather Bureau issued public advisories for agricultural burning. These advisories included the degree of atmospheric stability and the likelihood of good smoke dispersal. Farmers interpreted the advisories before arranging their burning programs. Post-harvest burning of grass seed straw was regulated only by local fire districts based on need for fire safety.

The 1967 Oregon Legislature gave the Oregon Sanitary Authority (now the Department of Environmental Quality) advisory power to recommend where field burning was to be done. The 1969 legislature granted the Sanitary Authority the power to limit the amount of field burning on marginal days.

In 1971 the legislature granted permanent authority to the DEQ to enforce and regulate a statewide environmental program, including control over field burning by limiting the amount of burning on marginal days. The Federal Environmental Protection Agency endorsed the Oregon control measures. Meteorological monitoring, daily acreage quotas, and an aerial observer were components of the initial DEQ program. The 1971 legislature also established June 1, 1975 as the date after which field burning would be prohibited. A burning permit system was established with a $0.50 per acre fee assessed.

In the 1973 legislative session, the burning permit fee was increased to $1.00 per acre with an equal amount matched from state funds to be used for research and development, after $0.10 per acre was set aside for operation of the smoke management program. Experience and improved techniques of smoke management reduced the intrusion of smoke into major population centers in western Oregon.

The 1973 law established a five-member committee to direct the R&D program funded by the acreage burning fees. The program was focused primarily toward development of an acceptable mobile field sanitizer. Secondary objectives included effective methods of straw removal from fields to be sanitized and research on uses for grass straw.

The 1975 legislature replaced the June 1, 1975 ban on field burning with a phase-down system scheduled to progressively reduce the allowed field burning from 285,000 acres burned under the 1974 regulation to 50,000 acres in 1978 and adopted a system of increased fees.

The 1977 legislature modified the 1975 phase-down to 195,000 acres and 180,000 acres respectively for maximum open burn limits for 1977 and 1978.

In 1979, the Legislature replaced the phase-down program with a 250,000-acre limitation with authority vested in the DEQ to set daily acreage quotas after 1978 in accordance with state and federal air quality standards. Burning of small grain straw and stubble in the Willamette Valley was prohibited except when a field was being prepared for establishment of a small seeded grass or legume crop. A $3.50 per acre fee was established for burning. Funds were to be used for DEQ smoke management and to support a research program. An advisory committee was established to assist in developing a research program in smoke management, alternative forms of field sanitation, straw utilization, alternative crops, and health effects.

Throughout this period, the limitations on open burning applied only to field burning in the Willamette Valley counties. Areas of central and eastern Oregon were excluded. These areas adopted voluntary burning control programs designed to limit burning on days with atmospheric conditions that restricted smoke dispersal or affected populated areas.

From 1980 through 1987 the smoke management program was conducted by the DEQ and the Oregon Seed Council. The Council was responsible for grower training, radio communication, meteorological evaluation, and operation of the skywatch plane. Following a program review in 1987, most of the Seed Council technical functions in the program were transferred to the Oregon Department of Agriculture in 1988.

The Willamette Valley Field Burning Program provides for direct control of field burning according to prevailing weather conditions and existing air quality. Areas for burning are chosen primarily on the basis of wind direction and atmospheric dispersion or ventilation capacity with the objectives of avoiding direct smoke impact on highly populated areas while minimizing, to the extent possible, ground level concentrations of smoke in other areas. To reduce the possibility of residual smoke problems and nighttime drainage of smoke back into the Valley, significant levels of burning are contemplated only when favorable weather conditions are expected to be sustained.

On the basis of current and forecast weather conditions, the DEQ designates the times, amounts, and places of burning on a continuous basis each day so as to provide for a maximum amount of burning under optimum dispersion conditions. To facilitate geographical control of burning, the Valley is divided into approximately 60 control zones. Burning authorizations are made on a continuous basis to fire district permit agents over a radio network. These burning authorizations include the quantity of burning allowed in specific control zones for specific periods of time.

Continuous aerial and ground based observations of burning progress and smoke drift coupled with frequent updates of weather observations and forecasts are used to tailor burning activity to weather conditions and to avoid serious or prolonged smoke impacts on populated areas. In the event of unfavorable changes in weather or smoke behavior, directories are made by radio to fire district permit agents that may require them to cease or curtail permit issuance and also may require that growers discontinue the lighting of fields. Permit holders are required to monitor the field burning radio frequency at all times during the burning operation and must comply with all directives.

Current Regulations for Field Burning

Field burning regulations have been approved by the federal Environmental Protection Agency (EPA) as complying with federal Clean Air Act requirements. The following is a brief summary of the major regulatory provisions set forth by statute and administrative rule for the Willamette Valley:

1. A maximum of 250,000 acres may be open burned annually in accordance with daily smoke management restrictions. No more than 46,934 acres may be open burned in a single day in the south Valley counties of Linn, Lane, and Benton (under southerly winds).

2. Cereal grain acreage may be open burned only when preparing the field for planting a seed crop the following year.
3. No burning is allowed when the atmospheric mixing height is less than 2,000 feet and average winds are less than 5 knots. Burning also is prohibited in areas which might aggravate downwind pollutant levels projected to exceed federal standards.
4. Burning is limited in any area when relative humidity exceeds 65% under southerly winds and 50% under northerly winds, except for test fires.
5. Burning is limited for up to four consecutive "drying" days following each 0.1 inch rainfall.
6. Burning of acreage in and around major cities, highways and airports is carefully managed to avoid direct intrusions.
7. A "performance standard" is in place for Eugene/Springfield area such that minimum ventilation criteria for burning become more stringent if and when the cumulative hours of smoke impact increase above an allowable level of 14 hours.
8. Civil penalties for illegal field burning generally range from minimum amounts of $500 for burning without registration or permit, $300 for burning at unauthorized times, and $200 for burning without monitoring the field burning radio network. The maximum penalty for each violation if $10,000.
9. Special provisions allow for experimental burning and emergency burning for reasons of economic hardship.
10. Tax credits are available for the use or installation of alternative field sanitation facilities such as propane flamers or equipment used to collect and process straw into marketable products.

Visibility Protection Plan

In 1980, the EPA established rules requiring states to protect visibility in Federal Class I areas. The rule requires states to "develop programs to assure reasonable progress toward meeting the national goal of preventing any future and remedying any existing impairment of visibility in mandatory Class I areas within which impairment results from man-made air pollution." Oregon has 12 Class I areas which consist of 11 wilderness areas (principally along the crest of the Cascades) and Crater Lake National Park.

Control strategies to remedy impairment from field and slash burning were adopted by Oregon's Environmental Control Commission (EQC) on October 24, 1986. With regard to field burning the new regulations took effect in 1987, prohibiting burning on weekends during the July 4 through Labor Day period upwind of the Class I areas. There is an exception for weekend days when there is already natural visibility impairment there such as clouds, fog, or rain. There is also an emergency clause which allows the Director of DEQ to modify the restrictions under unusual and severe hardship conditions. The rules adopted for slash burning are similar. Control strategies will be re-evaluated in 1989.

Current Regulations for Propane Flaming

DEQ regulations formally recognize propane flaming as an approved (less-polluting) alternative to open-field burning. Fields must be properly prepared (i.e., loose straw removed, stubble cut) before propane flaming, and the remaining material cannot sustain an open fire. But once these requirements are met, a grower may conduct propane flaming on any day, in any location, and on any number of acres, providing the DEQ does not prohibit it due to adverse atmospheric conditions or air quality. Propane flaming is exempt from all of the requirements related to registration, permits, and fees which apply to open-field burning. The limited controls on propane flaming, its effectiveness as a field sanitation method, and the increased demand for straw have helped to offset its somewhat higher costs and make it an attractive alternative for a substantial number of growers.

Current rules for propane flaming are as follows:

1. DEQ shall prohibit propane flaming under adverse meteorological or air quality conditions.
2. Propane flaming hours shall be 9 a.m. to one hour before sunset in July and August, and 9 a.m. to one-half hour before sunset in September.

3. Growers shall operate propane flamers in overlapping strips, crosswise to the prevailing wind, beginning along the downwind edge of the field.
4. ~~Propane flamers must be designed such that a) flamer nozzles are no more than 15 inches~~ apart, and b) a heat deflecting hood must extend a minimum of three feet beyond the last row of nozzles.
5. The loose straw must be removed from the field.
6. The remaining field stubble must be chopped or cut close to the ground and removed to the extent practicable.
7. The remaining field residue must not sustain an open fire.
8. A fire permit must be obtained from the fire district.

Additional Restrictions in August 1988

Following the tragic accident on I-5 south of Albany on August 3, 1988, the state imposed an eight day ban on field burning pending a program review. After the review, additional restrictions were placed on burning. One involved the addition of fire safety buffer zones surrounding I-5 and six additional designated major highways. The zones extend as a one-half mile corridor on each side of I-5 and one-quarter mile on each side of the other 6 highways. Within the buffer zones a one-fourth mile wide noncombustible ground surface zone between the field to be burned and the nearest right-of-way of I-5 is required for field burning to be allowed. The ground surface zone is one-eighth mile on the six designated major highways.

A further set of restrictions were implemented affecting all grass seed production in the Valley:

1. All burning in the Valley will be banned when two of the following three conditions exist: temperature of 95°F or above, relative humidity of 30% or below, and wind speed of 15 miles per hour or higher.
2. Twenty-foot noncombustible barriers around the field to be burned are required.
3. Two to four water tank vehicles with specified tank capacities, as pump capacity, and recharge capability determined by field size are required.
4. Radio communication between vehicles at the burn site and a manned station with telephone link to emergency response agencies is required.
5. Staffed fire safety watch at field perimeters prior to igniting and to continue one hour after open flame ceases is required.

Similar rules as listed above shall apply to propane flaming except that the noncombustible barrier around the field to be burned is a 10 foot strip and one or more water tank vehicles with a minimum total capacity of 500 gallons shall be on site.

CHAPTER 3

THE SEARCH FOR SOLUTIONS

The field burning permit fee system initiated in 1971 has continued to the present. The grower fee system has been used to pay the administrative cost of the regulatory smoke management program discussed in the previous chapter and to establish a research and development program to seek viable alternatives to open-field burning. All of the smoke management program and more than 75% of the research and development funds have come from the self-sustaining grower fee program. The smoke management program comprised of the field burning operation, fire district payments, smoke management support services, and lab operations for monitoring and regional enforcement have taken 50 to 60% of total grower fees. This has averaged about $550,000 annually during the past decade.

The research and development expenditures over the past 17 years total nearly $7 million. Current annual R&D activities average from $250,000 to $350,000. Use of those funds by project category are detailed chronologically in Appendix B. Overall dollar allocation was about $1.9 million in search of alternative sanitation measures, $1.5 million for straw utilization, $1.3 million for alternative crops and $300,000 on health effects. Private and public coordination of research and development (R&D) related to field burning has occurred since at least 1968.

From 1968 through 1970 management and R&D advisory was through an Oregon Seed Council Five-Member Research Committee. In 1971 program management and R&D advisory work were separated with hiring of a consulting engineer for program management. R&D management continued with this mode of operation through 1976 (Odell, 1974).

In 1977 the Legislature transferred responsibility for field burning to the DEQ and created a Five-Member Advisory Committee on Field Burning to aid DEQ in conducting the R&D portion of the program.

Three subcommittees were organized in 1977-78 to help the Advisory Committee and DEQ address air quality monitoring, health effects, and R&D planning. Subsequent reorganizations and consolidation of the subcommittees evolved into the single Five-Member Technical Subcommittee which currently serves the Advisory Committee.

The purpose of the DEQ Advisory Committee on Field Burning is to advise and assist the Department of Environmental Quality in the research, development, and application of feasible alternatives to the practice of open-field burning, including but not limited to the following areas (no order of preference):

1. Utilizing and marketing of crop residue.
2. Developing alternate crops.
3. Improving air quality and smoke management.
4. Alternative methods of field sanitization including the economic, agronomic and environmental effects of mobile burners and other methods.
5. Alternative weed, pest, and disease controls.
6. Health effects of open-field burning.

CHAPTER 4

RESEARCH ON ALTERNATIVES TO BURNING

THERMAL SANITATION ALTERNATIVES

Thermal sanitation alternatives to open-field burning developed to date have been in the form of machine sanitizers.

Field sanitizers

Research funds were first directed toward development of a machine to burn residues in 1969. OSU agricultural engineers constructed several designs and ran extensive field tests in cooperation with the Department of Crop Science to evaluate the quality of the thermal treatment at the soil surface and to determine temperature limits so perennial grass crops would not be damaged.

During 1970, two stationary pilot test machines were built and tested. The initial concept was to use the machines for straw disposal as well as field sanitation. However, this approach was modified when tests showed that speed of operation was slowed because of the excessive heat produced by burning all of the straw. Youngberg, Chilcote, and Kirk (1975) found that removing all the straw and leaving only stubble provided enough fuel for field sanitation by machine burning. It was found that the sanitizer provided a more uniform heat treatment than open-field burn, with damage to the crop occurring only when extremely high temperatures were used.

Field experience in 1970, 1971, and 1972 demonstrated the need for a heat resistant firebox liner design. Various materials were tested with little success. Later models tested used a single wall construction, metal shingle design which provided unrestricted natural convective and radiation heat transfer. After more than 200 hours of field operation, inexpensive chromized mild steel and various grades of stainless steel showed little sign of deterioration.

Drawings, specifications, and performance data were supplied to three engineering consulting firms hired by the Field Burning Committee to refine the three basic machines in use in 1973, and to design an improved propane flaming device. Four machines were built by commercial shops incorporating a ceramic liner and single wall construction, with a forced vortex and regenerative burning concept. These were tested during the 1974 burning season.

In evaluating the field sanitizer, agronomists found the most effective burn treatments were made during the mid-summer season when the perennial plants are dormant. Sanitizer treatments late in the season (after the plant's regrowth had been initiated) increased plant mortality and reduced regrowth and seed production as did late open-field burning.

Overall, research indicated that the sanitizer was capable of thorough removal of residue around and on the plant crown over a moderate range of field conditions without serious injury to the plant. Temperatures of more than 1,000°F at the soil surface for short periods were recorded without seriously affecting plant survival and seed yield in the following year.

Sanitizer development was discontinued following a technical and economic evaluation of the machines by the Engineered Systems Division of FMC Corp (FMC Corporation, 1978). The report, commissioned by the DEQ, concluded that because of problems with short machine life, high operating cost, energy use, effective emission control, and slow operating speed, the field sanitizer was not an economical alternative to open-field burning.

Propane Flaming

Propane flamers built for use on mint fields were turned to for consideration in the mid-1970's. Propane flaming resulted in seed yields equal to open-field burning (Chilcote and Youngberg, 1975). Straw and stubble must be removed for this technique to be effective. No attempt was made to evaluate if the temperature developed by propane flaming was sufficient to destroy disease organisms under field conditions. However, studies in annual ryegrass showed that the temperature and duration of propane flaming was not able to destroy many of the weed seeds, whose survival was reflected by an increase in weed infestation.

Cost of propane flaming is influenced by speed of operation and has been shown to range between $32.00 per acre at 1 mph and $8.00 per acre at 4 mph (Youngberg *et al.*, 1984). Increasing the amount of residue allows for faster operating speeds but results in increased emissions. More complete stubble removal in advance of propane flaming requires slower operating speed to achieve good sanitation.

Propane flaming with residue removal as a companion practice is being used by an increasing number of growers, especially in the North Valley. An estimated 56,000 acres were sanitized by propane flaming in 1988 (T.L. Cross, personal communication).

SEED PRODUCTION WITHOUT THERMAL SANITATION

Early studies of seed production without thermal sanitation focused on the effects of non-burning methods, and provided an explanation of the burning effect (Chilcote, *et al.*, 1980). Generally, mechanical removal of the straw reduced seed yield when compared with open burning. Also, weed problems were intensified in both perennial and annual grasses (Chilcote and Youngberg, 1975). However, the extent of loss depended on crop species, soil conditions, and age of stand.

Mechanical Straw Removal

Several mechanical removal techniques have been studied:

1. Raking the straw (leaving remaining stubble intact).
2. Flail-chop removal of a major portion of the straw and stubble.
3. Close clip removal of most stubble and organic material on the soil surface.
4. Soil incorporation of the residue in annual ryegrass production.

An evaluation of six species showed that leaving all of the straw in the field lowered seed yield an average of 48%; raking was little better than no removal (Chilcote and Youngberg, 1975). Flail-chopping to remove additional stubble was somewhat better than raking, suggesting that the greater the degree of residue removal the higher seed yield in the subsequent harvest. The physiological response (plant growth and seed yield) to mechanical residue removal varied with the species, variety, and thoroughness of removal. Early studies showed Chewings fescue, red fescue, and Highland bentgrass usually showed greater need for burning than did bluegrass, perennial ryegrass, and orchardgrass. Researchers also observed that age of stand will influence response to non-burning treatment. In the absence of burning, the yield from older grass stands was reduced more than from young grass stands.

In annual ryegrass, seeding through straw and stubble using specialized drills was not successful. However, stands were established by drilling through stubble following mechanical removal of straw (Chilcote and Youngberg, 1975). Results from a subsequent study investigating residue management and seeding method over five years, found no significant yield difference between annual burning followed by sod seeding, and incorporation of straw residue into the soil prior to seeding (Young, *et al.*, 1984a).

When annual ryegrass fields are not burned, weed control problems increase. Non-selective pre-plant chemical weed control was partially successful in reducing weeds in annual ryegrass. This technique is not effective unless early fall rains occur because it relies on moisture to germinate weed seeds prior to seeding. A herbicide which selectively controls annual grass weeds in annual ryegrass is available but is effective only if crop residues are completely removed mechanically or are incorporated by tillage operations before application of the chemical.

Close-clip Stubble Removal

Complete physical removal of crop residue by close clipping and sweeping was first evaluated in red fescue (Chilcote *et al.*, 1974). Seed yields of the close-clipped and burned treatments were significantly greater than less complete mechanical removal. These data support the hypothesis that the effect of burning on seed yield is due to the elimination of older, non-reproductive tillers and removal of residue, which allows for new tiller development at the soil surface.

Field testing of a prototype machine designed for close clipping and residue removal by vacuum (crew cutting) was shown to be an effective treatment for approximating the physiological response of burning (Youngberg, 1977). However, maintaining seed yield was only partially successful on some species. Stubble and chaff were effectively removed from perennial ryegrass, tall fescue, and orchardgrass. In Kentucky bluegrass the chaff was removed, but some stubble remained. Fine fescues presented a special problem because the stubble left by the windrower lays flat and close to the soil, making it difficult to clean up around the plant crown.

Straw residue must first be removed from the field before close-clip machines can operate, and fields must be smooth and free of ridges to be satisfactorily treated. Rocks presented another serious problem as they were thrown a considerable distance when struck by the cutting knives. This operation causes air pollution with soil and chaff particles released in the air. The residue removed from the field represents a solid waste.

Evaluation of the close-clip technique in a four-year study comparing flail chopping and crew cutting in perennial ryegrass showed no clear advantage for the more complete stubble removal treatment. When compared with annual burning, the average seed yield of non-thermal treatments was 15% less over four years. Results of similar tests in fine fescue and Kentucky bluegrass found a slight advantage for crew cutting when compared to flail chopping. On these two species crew-cutting was capable of maintaining seed yield equal to burning through three years of testing. Thus, some perennial grasses are more tolerant in terms of subsequent seed yield to mechanical removal techniques than others (Young *et al.*, 1984b).

Chemical Treatments

Chemical treatments have the decided disadvantage of requiring EPA registration and approval for use, a costly and time consuming process. Few chemicals currently are approved for use, especially when the straw residue is marketed for livestock feed. Concern about chemicals in groundwater and surface runoff also may restrict their use. An additional factor restricting the role of chemicals is that carbon ash associated with continuous open burning has been found to reduce the effectiveness of chemical pesticides, an issue which might disappear under a no burn regime.

Chemical treatments for pest and disease control were initiated in the early 1980s. Monocarbamide dihydrogensulfate (Enquik^R), a urea-sulfuric acid reaction product applied at 12 to 15 gallons per acre during mid-October, has shown some potential for reducing fall germinating grass seedling (weeds), increased effectiveness of specific herbicides, and accelerating decomposition of old crown growth left at harvest. Results vary with grass species and weather conditions. Additional research is needed to define the role of this product as an alternative for thermal sanitation.

Shorter Crop Rotation

The beneficial effects of burning on plant development and seed yield are greater on older fields than on younger stands. Therefore, a shorter perennial crop rotation may be necessary in perennial grass species if thermal sanitation is restricted. Perennial grass seeds historically have grown up to 10 to 12 years as a single stand without re-establishment. This has been reduced to about five years for proprietary varieties grown under contract. Shortening the rotation appears to decrease the known incidence of disease and pests.

Except for the ryegrasses, spring and late-fall planted grass species do not produce a seed crop during the establishment year. Loss of a year's income every time a new crop is established will become more critical as rotations become shorter. One possible solution is to establish grass seed crops with cereal or other companion crops during the establishment year. Studies with some grass species on well-drained soils have shown that the use of cereal companion crops will provide a cash income during the year of establishment (Appendix D). However, this system has not been evaluated on heavy, wet, clay soils.

Soil Incorporation of Straw in Annual Ryegrass

In establishing annual ryegrass fields it is necessary to chop the straw from the previous crop before plowing it into the soil because whole straw decomposes very slowly. Agronomic trials in 1984 showed that seed yield from open burning and annual incorporation of straw were comparable when 80 pounds of nitrogen per acre was applied in the spring (Jackson and Christensen, 1985). However, the plow down treatment represents a definite increase in production cost. In addition, soil incorporation of weed seed in the residue intensifies weed management problems, increases cost for weed control, and increases the risk of lower product quality in the marketplace. The extent to which diseases can be controlled through tillage is unknown.

ALTERNATING OPEN-FIELD BURNING WITH MECHANICAL REMOVAL

In an attempt to combine the benefit of burning, but reduce the total amount of burning required, studies were conducted alternating one or two years of mechanical straw removal with one year of burning. A reduction in seed yield is realized compared to annual burning, but results were superior to continuous mechanical removal techniques (Chilcote and Youngberg, 1975).

Subsequently, less than annual burning studies investigated the possibility of alternating various combinations of burning and mechanical removal techniques over a period of several years. In perennial ryegrass, alternating burning with mechanical straw and stubble removal through four years produced seed yields averaging 93% of annual burning regardless of whether plots were crew cut or flail chopped during the non-burning year. No deleterious effects on seed yield were reported for fine fescue or bluegrass when averaged over three years (Young, *et al.*, 1984c).

CONTROL OF PESTS AND DISEASES

Over 400 diseases in 63 host species in the United States have been listed for annual and perennial forage grasses and turfgrasses (U.S. Department of Agriculture, 1960). In most years, inocula for many of these pathogens are not present in sufficient amount, or environmental conditions limit disease development. Diseases that have caused frequent loss in Oregon and have been controlled by field burning are listed below.

Disease Control

Blind Seed Disease (Gloeotinia temulenta)

Blind seed was first reported in Oregon on perennial ryegrass and 15 other grass species in 1944 (Fischer, 1944). The disease was believed to have been introduced ca. 1940 in infected seed imported from New Zealand (Hardison, 1948) where the disease was well established (Hyde, 1938). By 1943, 25% of the total perennial ryegrass crop from the Willamette Valley had germination less than 85% as a result of a rapid, epidemic increase in blind seed disease (Hardison, 1948).

Comprehensive disease control studies were conducted in Oregon between 1943 and 1946 (Hardison, 1948). In 1944, a seed inspection and field recommendation program was established. Based on the level of disease determined from seed lot testing, the following controls were suggested for established fields: plow diseased fields; remove light seed from the fields during combining; open-burn as a temporary remedy; prevent heading of perennial ryegrass in pastures until after July; and destroy ryegrass screenings (Hardison, 1948, 1949). Recommendations for new seed fields were to use disease-free seed and to plant seed at least one-half inch deep. Additional recommendations were to plow, prepare good seed beds, and remove the crop after two seed crops.

The few fields that were burned merely for straw removal between 1943 and 1946 were studied; burning was found to provide excellent control of blind seed disease (Hardison, 1948). Following disease control recommendations in 1944 to 1947 reduced the incidence of blind seed in seed inspections. Failure to follow control recommendations in 1947 resulted in an increase in the number of severely diseased fields in 1948 (Hardison, 1949).

In 1948 a few of the perennial ryegrass fields were burned. The burning of perennial ryegrass fields was recommended as a general practice after the 1948 harvest. Blind seed control in 1949 was attributed to removal of light-weight seed and either plowing or burning diseased fields (Hardison, 1957). Burning tall fescue fields was recommended and adopted beginning in 1949.

Field observations (Hardison, 1948) suggested that disease control measures used between 1943 and 1949 were effective in reducing and controlling blind seed disease of perennial and annual ryegrass. Blind seed disease was not thought to be as serious a disease in orchardgrass, bluegrass, or bentgrass as it was in the ryegrasses (Hardison, 1962, 1976, 1980).

Recent studies of straw management practices (crew-cut, bale, and propane flaming) as alternatives to burning have not been evaluated for their effectiveness in managing the incidence of blind seed disease in any grass species. Other methods of disease control such as chemicals have been ineffective in controlling blind seed in the field (Hardison, 1980). Urea-sulfuric acid reaction products (Enquik[R]) have been suggested for control (Hardison, 1987) but additional studies are necessary to evaluate the field efficacy of these materials.

Ergot (Claviceps purpurea and Claviceps spp.)

Ergot is one of the first plant diseases identified by humans. It occurs throughout temperate region countries and over 400 species of grasses are listed as susceptible to ergot (Bovine, 1970). All perennial grasses grown for seed in the Willamette Valley are susceptible to ergot (Hardison, 1962, 1980). Ergot is well recognized as a serious disease, capable of causing nearly total crop loss. Hardison (1980) described ergot as "probably the most serious of the grass seed diseases." The toxic properties of ergot have been known for centuries, and ergot poisoning of humans and animals has been documented in ancient and modern literature (Bovine, 1970).

A disease survey of the Willamette Valley during 1988 by the USDA (S.C. Alderman, personal communication) revealed ergot was widespread throughout the region on wild grasses surrounding seed production fields. These ergot-infected weed grasses are an important source of inoculum (Conners, 1953, 1956; Futrell and Webster, 1966; Harper and Seaman, 1980; Mantle and Shaw, 1977).

Grasses are susceptible to ergot infection only during the flowering period. Mowing or spraying grasses near production fields to prevent or delay development of ergot until after flowering in the seed crop has been cited as an important measure of disease control (Bretag and Merriman, 1981; Campbell and Freisen, 1959). Effective management of ergot also includes planting clean seed, deep planting of seed, rotating crops, and deep plowing (Bretag and Merriman, 1981; Weniger, 1924). Destroying infected fields by deep plowing is especially effective in lowering the effective or viable inoculum in infested fields (Bretag, 1985; Bretag and Merriman, 1981).

Several fungi have been documented as potential biological control agents (Cunfer, 1975; Gay and Shattock, 1980; Hornok and Walcz, 1983; Mower *et al.*, 1975). Conditions most favorable for the activity of hyperparasites are those most favorable for ergot development. However, toxicological and pathological tests need to be carried out before field application of the agents because the antagonists are known to produce chemicals toxic to mammals or to incite plant diseases in grasses or other crops (Mower *et al.*, 1975).

No effective fungicides are commercially available to economically control ergot (Cagas, 1986; Hardison, 1974, 1977a, 1977b). However, urea-sulfuric acid reaction products have been suggested as a means of ergot control (Hardison, 1987). Propane flaming may be inadequate for control of ergot (Hardison, unpublished).

Seed Gall Nematode (Anguina agrostis)

Seed gall nematode was believed to have been introduced into the Pacific Northwest before 1952 in imported seed (Courtney and Howell, 1952). The nematode has caused serious (total) losses of seed crops of creeping and colonial bentgrasses and of fine leaf fescues. Seed gall nematode was reported scattered throughout the Willamette Valley (Jensen, 1961).

Control of the seed gall nematode was evaluated in a comprehensive study by Courtney and Howell (1952). Bentgrasses were found to be especially susceptible to the nematode. They reported that the nematode from bentgrass did not increase on creeping timothy, Chewings fescue, creeping fescue, Kentucky bluegrass, annual bluegrass, velvet grass, and sweet vernal grass. However, Hardison (1946; 1980) and Jensen (1961) report Chewings fescue as very susceptible to seed gall nematode. Severe losses were observed in Chewings fescue seed crops in Clackamas County in the mid-1950's (R. Warren, personal communication).

Control measures for the seed gall nematode included planting nematode-free seed, rotating crops or practicing clean fallow, and preventing movement of galls from infected fields to clean fields. Courtney and Howell (1952) reported that the nematode cannot survive in moist soil for more than one year without a host plant. Apt *et al.* (1960) demonstrated that herbicides used to prevent flowering of bentgrass for one season were effective in breaking the life cycle of the nematode in that crop, but this would result in loss of the seed crop. Burning was cited by Hardison (1980) as providing partial control of the nematode in colonial bentgrass and good control in Chewings and red fescue.

Foliar Diseases

Foliar fungus diseases frequently found in fields include leafspots and stem blights caused by species of *Drechslera* in species of ryegrass (*Lolium* spp.), Kentucky bluegrass (*Poa* spp.), and fescue (*Festuca* spp.); *Rhynchosporium* which causes scald in species of orchardgrass (*Dactylis*), ryegrass and fescue; and *Septoria* which causes blight in species of bluegrass and fescue. The more important rust diseases include stem rust (*Pucciñia graminis*) in perennial ryegrass, tall fescue, orchardgrass and Kentucky bluegrass (*P. pratensis*); stripe rust (*P. striiformis*) in Kentucky bluegrass and orchardgrass; crown rust (*P. coronata*) in tall fescue; and leaf rust (*P. recondita*) in perennial ryegrass and annual ryegrass, timothy and tall fescue. Although field burning destroys much of the current season inocula of these diseases, no quantitative data exist on the effect of burning on disease outbreaks in subsequent crops.

Fungicides have been studied continuously for major foliar disease control since 1944. Most serious foliar pathogens are controlled by fungicide application (Hardison, 1963, 1975; and Welty, 1986, 1987a, 1987b).

Insect Control

Insect pests of grass seed crops can be divided into two groups based on their feeding habits: those that feed on the foliage and those that feed on the crown and roots.

Insect Pest of the Foliage

Aphids, thrips, leafhoppers, stem borers, plant bugs, and certain cutworms use the grass foliage as food or oviposition sites. Plant bugs, thrips, and stem borers feed on grass stems injuring the culm which in turn causes a partial or entirely white, sterile inflorescence. This condition is usually caused by plant bugs which lay their eggs in grass stems. Burning destroys the stems and thereby keeps the plant bug populations in check (Kamm, 1979). Plant bugs can also be controlled by grazing or mechanical removal of crop residue (Kamm, 1971; Kamm and Fuxa, 1977). However, several important insect pests require other control methods to reduce economic loss caused by insects feeding on the foliage.

Insect Pests of the Crown and Roots

Cutworms, billbugs, sod webworms, wireworms, March flies, and symphylans feed in the plant crown or on the roots. In general, crown or soil pests are not directly affected by the heat of field burning and are difficult to control with insecticides. Control of these insects requires multiple tactics in an integrated pest management program.

Billbug and sod webworm populations in orchardgrass seed fields were found to suffer no mortality during field burning (Kamm, unpublished). In 1987 growers reported an apparent failure of certain insecticides to control billbugs. Studies revealed the reduced efficacy was due to adsorption of the insecticide by carbon ash residue from field burning. Efficacy of the insecticide ranged from 95% on fields burned for three years to 15% on fields burned for 12 years. Subsequent tests indicated that activity of chlorpyrifos, diazinon, fonofos, dimethoathe, and fenvalerate was significantly reduced by adsorption on carbon ash when compared with soil treatments without carbon.

Straw residue must be removed from the field for insect control because unburned straw residue remaining in the field harbors certain insects and reduces insecticide activity by intercepting sprays. On the other hand, straw residues might harbor beneficial insects for biological control of insect pests.

Field burning of crop residues destroys oviposition sites of some insects and controls foliar feeding insects such as plant bugs and stem borers. Alternative methods of control by straw removal or properly timed insecticide applications also have been shown to be effective in controlling some insects. Crown- or root-dwelling insects are not directly affected by field burning and ash residue often adsorbs and reduces insecticide efficacy. Multiple control and monitoring programs are necessary to control soil and crown-feeding insect pests.

Weed Control

Weed control in grass seed fields is dependent upon reduction of the potential weed population (weed seeds) and creating the best condition for control of weed seedlings. Field burning affects weed control in grass seed fields primarily by physical destruction of weed seeds, and by changing herbicide behavior resulting from conversion of large quantities of crop residue into carbon ash.

Even a small amount of crop residue remaining after straw is removed has a significant impact on weed control. The effectiveness of propane flaming for weed control after mechanical straw removal has been found to vary greatly with speed of travel and amount of dry residue remaining. Weed seeds often survive propane flaming under conditions designed to minimize cost, time, and smoke production.

Negative Impact of Ash on Weed Control

Herbicides will adsorb to both unburned crop residues on the soil surface and carbon residue left after field burning. In either case, the movement of the herbicide into the soil, where herbicidal activity occurs, is delayed or prevented.

Carbon and ash remaining on the soil surface after open-field burning has been shown to have a negative impact on the effectiveness of many herbicides (G.W. Mueller-Warrant, personal communication). Herbicide labels have generally recommended delay of application until rainfall has washed the carbon residue into the soil. Adsorptivity of the ash once in the soil has not been quantified, but anecdotal evidence suggests that the soil environment in older, annually-burned fields may impair herbicide performance.

Weed Control in the Absence of Burning

When all the residue is left on the field, the straw creates a physical and chemical barrier to herbicides sprayed over the field. Therefore, some type of mechanical residue removal must be practiced for effective weed control.

Methods to control weeds in grass seed fields without open-field burning and after straw removal must be based on certain assumptions and conditions. The severity of both these problems is a function of the amount of residue remaining.

1. The remaining stubble is burned with a propane flamer. The ash residue following propane flaming is less than after an open burn of all straw. While the number of weed and crop seed surviving baling and propane flaming may be greater, improved herbicide performance brought about by reduced ash levels might offset the greater weed population. Under this condition, successful weed control may require little more than minor changes in herbicide practices. However, if propane flaming is not practiced, then weed control becomes a much more difficult problem.

2. Complete absence of burning or propane flaming. Without some burning or flaming, the residue remaining after mechanical straw removal causes two significant problems. First, it acts as a physical and chemical barrier to herbicides sprayed over the field, delays or completely prevents movement into the soil, thus reducing the effective concentration in the soil solution. Using herbicides with higher water solubility and lower affinity for organic matter to minimize the effect of the residue barrier might overcome the barrier effect. However, this action could increase the tendency to more rapidly leach the herbicide through the soil profile into the crop root zone and out of the zone of weed seed germination zone before the end of the growing season. This would also reduce weed control and increase risk of crop injury. Second, residues left on the soil surface create micro-environments favoring rapid weed seed germination. Weeds germinating under these conditions may achieve considerable size and an advanced development stage before herbicides finally reach them. Effectiveness of many herbicides is highly dependent on weed size at time of contact--smaller weeds are more susceptible. Herbicides used for grass seed weed control in western Oregon (atrazine, diuron, ethofumesate, and chlorpropham) require uptake at or before critical weed plant growth development stages.

Additional restriction or complete prohibition of burning or propane flaming reduces the means to control weeds and other pests and will necessitate additional use of pesticides and registration of new ones. The current system for pesticide registration is complex, slow, and expensive. This discourages labeling of chemicals for use on minor crops, such as grasses grown for seed. In order to obtain new registrations to control pests in the absence of burning, funds must be made available to perform the pesticide residue analyses needed for minor crop registration and secure collaboration from the manufacturers.

Basic studies are needed compare the tendency to adsorb herbicides (or the ability to control weeds) between carbon ash left after field burning and various quantities of unburned residues left after mechanical removal of straw.

PLANT BREEDING AND FIELD BURNING

New varieties of forage and turf grass, particularly proprietary varieties, have been released at a high rate during the 1980's (Barker and Kalton, 1988). New varieties have improved forage and turf quality and resistance to plant pests and diseases. However, varieties with high quality or resistance to plant pests have largely been developed in and for the geographic regions where they are used for forage or turf. Usually, diseases and pests in these regions are neither the same nor have the same effect as these problems in the Oregon seed production region. Thus, there is considerable susceptibility to attack by pathogens and insects when the seed crop faces longer exposure because they must remain in the field through physiological maturity.

There has been no forage or turf breeding for development of public varieties by OSU or the USDA-ARS scientists in Oregon in the past decade. Recently many private seed companies have developed active plant breeding programs in the Willamette Valley. Seed yield *per se* has become an important selection criterion resulting in release of varieties with higher seed production potential. This has been particularly pronounced with several turf-type tall fescue and perennial ryegrass varieties which had been adopted rapidly. However, the primary focus of current programs is still on evaluation of varieties and experimental lines developed in and for regions of use outside Oregon.

Breeding of forage or turfgrasses for disease and plant pest resistance during seed production has not been given a high priority because most pests were adequately controlled by cultural practices (including burning and pesticides). Standard plant breeding practices, even in the regions of end-use, have used an annual clean up of residue in selection nurseries and evaluation plots. Selection pressure for low maintenance or no residue management has been used only to a limited extent. In turf species such as Kentucky bluegrass and hard fescue (*Festuca longifolia* Thuill.), selection under low maintenance has resulted in steminess and a decrease in leaves. These traits are opposite to those desired for high turf quality and would not be acceptable in commercial markets.

SEED CERTIFICATION AND FIELD BURNING

Protecting the genetic purity and quality of Oregon grown grass seed of public and proprietary varieties is the purpose of the Oregon Seed Certification Program. Minimum standards for genetic quality in certified seed are established by Federal Seed Law. The number of volunteer plants surviving after harvest of a grass seed crop is a concern for plant breeders, seed contractors, and final consumer because if these plants survive, they alter the genetic purity of the seed harvested. Volunteer plants are eliminated or reduced in the stand by a number of chemical and cultural practices.

Seed producers have experienced problems with volunteer plants when they have not been able to burn after harvest. In annual ryegrass production, for example, volunteers are very common, and the Seed Certification Program has established a tolerance level for volunteers in a certified crop. This standard has been adopted to balance the need to avoid multiple generations in the certified stands against the practical concerns of field production. Burning has historically been the most effective practice used for volunteer control.

Other seed quality concerns associated with reduced field burning include failure to meet standards because of low germination (due to presence of blind seed disease) and higher weed content.

ALTERNATIVE CROPS

Grass seed is grown throughout the Valley on a wide range of soils and topography. The crop alternatives vary with the soil type and topography. Farmers tend to produce higher income crops to the extent that soils, topography and markets allow. Where possible, crops with a higher value than grass seed are grown. Equipment used for seed crop production is used with many other field crops. The net return for grass seed crops relative to other field crops determines shifts among commodities.

Northern Willamette Valley Counties

In the north Valley (Clackamas, Marion, Multnomah, Polk, Washington and Yamhill counties) there is a predominance of well-drained, high quality soil on which many different types of crops can be grown. Grass seed crops comprise only 16% of total harvested cropland in the north Valley. Most new or alternate crops being investigated in Oregon and/or adjoining states require moderate-to-well drained soils. These crops include rapeseed, lupine, fababean, triticale, Chinese milkvetch, and pyrethrum. Many field crops, such as wheat, barley, and oats are grown as government programs permit and prices are favorable.

Southern Willamette Valley Counties

In the south Valley (Benton, Lane, and Linn counties), cropping alternatives are restricted severely by the predominance of poorly-drained Dayton type soils on the Valley floor. These soils have thin, light-colored top soil and a very slowly permeable clay layer at a depth of 16 to 24 inches. Water perched above this restricted layer creates a water table at or near the surface of the soil that may persist for 120 days from November to April. One effect of prolonged saturation is that manganese may be toxic for some agricultural crops. Another effect is that many plants simply cannot survive in the water-logged soils. A third effect is that tillage may be delayed in the spring. Fall harvest operations also can be hampered by poor drainage after an early fall rain.

Prior to the establishment and expansion of the grass seed industry, these poorly drained soils were used for very low return crops such as livestock pasture, spring-sown oats, alsike clover, and vetch. Drainage for these crops was provided by plowing surface furrows through the field.

Production of intensive crops such as tree fruits and nuts and perennial small fruits has been limited as development of irrigation and subsurface drainage systems is required to make them technically feasible. High capital investment for such activities and restricted potential for expansion of markets have historically limited these choices to a few growers.

Some limited tiling and irrigation has been done using federal ASCS (Agricultural Stabilization and Conservation Service) assistance. This has permitted some shifting from annual ryegrass to other grass species such as turf-type tall fescue which tolerates less flooding. The Oregon Legislature in 1983 passed a pollution control tax credit program. Drainage of wetland soils serves as a qualifying activity for the tax credit. Tiling as an Oregon tax credit has not been used by growers as it conflicts directly with the Wetland Conservation (Swamp Buster) provisions of the Food Security Act of 1985 (1985 Federal Farm Bill) in which growers would lose all USDA farm program benefits if sub-surface drainage were conducted on the Dayton type soils on the Valley floor (Appendix C).

Production of grass seed on these soils remains the most profitable and feasible use of this land. In the south Valley where Dayton soils predominate, the 210,000 acres of grass seed crops comprises more than 56% of total harvested cropland. By using surface drainage and species that are tolerant of winter flooding, continued grass seed cropping is possible.

Alternative crops for poorly drained land

Currently, the only known winter annual crop that will tolerate unimproved Dayton-type soil condition is meadowfoam. This is a new crop that has been under investigation in Oregon for more than two decades. Full-scale commercial acreages have been grown, but expanded acreage awaits market improvement and/or development of higher yields.

Meadowfoam (Limnanthes alba Benth.*)*

Meadowfoam is a winter annual plant native to southern Oregon and northern California, adapted to the poorly-drained soils and wet conditions typical of much of the Willamette Valley. As a winter annual, meadowfoam's growing season is slightly shorter than that of grass seed and wheat. Domestication has produced an upright plant with good seed retention and the planting, care, harvesting, and equipment requirements of meadowfoam are entirely compatible with those used to produce grass seed. The amount of leaf and stem material left after harvest is negligible, decays rapidly in the field, and does not require burning or present a residue disposal problem.

The product of the meadowfoam plant is seed containing 25 to 30% oil by weight. The chemical composition of the oil is unique, with high performance properties which may be suited to a variety of commercial and industrial uses. Experimental work on meadowfoam in Oregon was initiated in 1967.

A 1977 feasibility study commissioned by the Pacific Northwest Regional Commission (PNRC) identified oilseeds as promising crops for the region. OSU identified meadowfoam and rapeseed as the most promising oilseeds for the local soils. Bohemia Inc., OSU, and PNRC initiated market development studies in 1978, using oil extracted from 4,000 pounds of meadowfoam seed. DEQ funded 35 acres of meadowfoam plantings in 1979 and 14 acres in 1980 (Jolliff, 1981).

Production costs were found to be comparable to annual ryegrass in one or more studies, although such findings were based on critical assumptions and need further analysis. Production analysis, agronomic and economic feasibility studies were funded through 1982. The value of meadowfoam oil for industrial uses has been variously estimated at $0.75 to $1.00 per pound. Current cost estimates are about $3.00 per pound.

OSU research has focused on understanding environmental factors which limit crop growth and seed yield, and the development of higher yielding cultivars. Agronomic studies on seed production management systems to increase seed yield have included weed and disease control, and soil fertility trials.

In 1984, OSU released the "Mermaid" cultivar of meadowfoam. Farm yields of oil from this variety have been 130 to 300 pounds per acre compared with research yields of 335 to 440 pounds per acre. A new meadowfoam variety selected in 1985 had a 45% higher average seed yield than Mermaid in 1986 to 1988. Its seed also contains approximately 10% more oil than Mermaid. Seed of this new material is being increased in 1988-89. Further advanced selections were made in 1986, 1987, and 1988. Early indications are that oil yield per acre has increased at the rate of 30 to 40 pounds per year. If these trends hold true, oil yields of 500 to 600 pounds per acre could be achieved on research plots by 1990 and available to farmers by approximately 1995 (G.D. Jolliff, personal communication).

In 1984 the Oregon Meadowfoam Growers Association consisting of 20 Willamette Valley grass seed growers was formed. Association growers produced 800 acres in 1985 and 900 acres in 1986. The group has retained a technical marketing consultant to promote the oil to the cosmetic industry, it has secured outside funding from the New Crops Development Board, and initiated a marketing program.

Market development and oil utilization promotion was first conducted through Bohemia Inc., and later through the Meadowfoam Growers Association. Oil samples have been provided to manufacturers and presentations made at trade shows. Cosmetic uses appear to be the most immediately accessible market.

During 1985, a Japanese cosmetic company purchased 10,000 pounds of crude oil and oil samples were sent to several companies in Japan, England, and in the United States for cosmetic research. Basic questions concerning oil processing and refining were studied including research into dehulling, seed pretreatment, mechanical expelling compared to solvent extraction, bleaching, and hydrogenation.

Several companies have explored various uses for the oil; some indicated serious interest, but the major obstacle is the cost of seed and oil production. Production costs are expected to decline with the introduction of improved varieties and development of better production practices.

There is currently a substantial inventory of refined oil and additional seed for planting or pressing to support those companies already interested in meadowfoam oil.

The U.S. Department of Agriculture currently considers meadowfoam one of the five most promising new crops but financial support for continued research is limited.

Pyrethrum (Chrysanthantheum cinerareafolium)

Pyrethrum, a perennial chrysanthemum, is native to areas with warm, dry summers and moderate to cool winters. It prefers deep, well-drained soils, but will respond well on heavier soils provided there is adequate drainage. Pyrethrum is a high input, relatively high return crop which may be adapted to portions of the Willamette Valley; however, because of the drainage requirement, it is not an alternative for the poorly-drained soils.

Pyrethrin is a potent natural insecticide contained in the daisy-like flowers of the pyrethrum plant. There is a well established market for pyrethrin, and the United States is the largest single consumer of the world production. Currently nearly all production is in Kenya where political and agronomic instability have given pyrethrin the reputation of a commodity of unreliable supply.

Pyrethrum production and physiology studies were supported from 1984 to 1986 to examine the potential of growing this specialty crop (Ehrensing and Chilcote, 1985). Results of these studies were not sufficient to support funding of market analyses in 1986, although seed technology work was supported through 1987.

Demand for natural pyrethrin remains strong and preliminary commercial development is currently underway by a private firm.

CHAPTER 5

STRAW UTILIZATION AND MARKETING

Grass straw residue is a by-product of grass seed production. Annual straw production ranges from two to five tons per acre depending upon grass seed species and variety. In the Valley some 1 million tons of residue are produced annually. From a technical standpoint, straw can be used as a raw material to make a wide range of fiber products (paper, particleboard, fuel logs, hydromulch, composted fertilizer), chemical products (oil, gasoline, plastics, microbial protein) and livestock feed products. Economically, it has been difficult for grass straw to compete in existing markets as a raw material source. Low bulk density requiring costly densification, high cost transportation, uncertainty of long-term supply and low volume of supply relative to wood chips in fiber markets have made straw non-competitive with other raw materials. The traditional base for making pulp and paper in the Pacific Northwest is wood chips which are cheap and adequate in continuing supply and volume. Also, manufacturing technology is adapted to that source. Conversion to straw would involve major retooling in the wood fiber industry.

As a feedstuff for livestock, straw in untreated form is of poor quality because of low protein and high fiber content. With appropriate treatment, such as ammoniation, the digestibility and palatability of straw can be increased substantially, making straw a potential component of maintenance diets for ruminants. The costs of physical and chemical treatment historically have made the process marginal in an economic sense. The use of automation in straw handling and storage is increasing the possibility of providing chemical treatment with modest additional cost.

Some grass straw is currently being used in domestic and export markets as a supplemental livestock feed. During periods of short supply and/or excess demand for forages in U.S. markets, such as experienced during the major drought of 1988, some unspecified quantity of grass straw is marketed. The major current market is Japan which utilizes an estimated 125,000 to 150,000 tons annually for supplemental livestock feed.

Straw utilization or disposal has been an essential companion to the economic viability of alternatives to open-field burning. Straw must be removed in order for mobile sanitizers, propane flamers, or other alternate mechanical or chemical methods of disease and pest control to be effective.

Research since 1969 has included the development and demonstration methods of straw and chaff removal, surveys, economic and market studies to identify methods of straw removal and markets for straw, and produce and market development in the areas of feeds, fuels and chemical feedstocks, and fibers.

From 1972 to 1977 Oregon operated a unique *Straw Utilization Center* where prospective products and processes were carried from research level to pilot plant process tests and product preparation for field and market trials in feeds, fibers, and fuels. Straw processing prepared materials for feed trials, fermentation research, and fuel tests. Cubing and processing developments (1972 to 1976) led to Japanese feed contracts of 3,000 tons and 10,000 tons which set relationships for current sales with Japanese trading companies. Fiber processes led to construction of the Grassfiber Inc. hydromulch plant. Equipment and techniques contributed to construction of a straw particleboard plant operated by L. Opel and K. Gorzell.

MARKET STUDIES AND PROMOTIONS

Market and economic studies have included straw removal alternatives (Conklin 1971, 1972; Anderson *et al.*, 1974), pulp and hardboard (Sandwell, 1975), feed exports to Japan (Inoue and Conklin, 1973; Porfily and Conklin, 1973), horse feed (Jacob, 1974), firelogs for fuel (Beelart 1975b; Wells *et al.*, 1979), field burners (Beelart, 1975b; FMC Corporation, 1978), straw uses for fiber (Miles, Jr., 1976b), straw market and technologies including feeds, fuels and fibers (Miles, 1974, 1976a; Miles, Jr., 1976c; Wells *et al.*, 1979), farm scale bale burners (MacKey, 1981), meadowfoam economic potential (Jolliff and Pearson, 1981), mulch (Agricultural Fiber Association, 1986a) and non-burning alternatives (Cornelius, 1983).

Export studies (1972 to 1973) helped describe the Japanese market which stimulated cubing development, but they did not include distribution channels which insulated producers from final consumers until 1980 when straw merchants began visiting Japan. Horse feed studies (Jacob, 1974) identified a potential market. Economic assessments helped detour research from product development in firelogs and also verified engineering assumptions about the potential use of sanitizers. Economic analyses have helped select potential alternatives including straw utilization.

In 1978, the DEQ funded FMC Corporation to reassess the development of mobile field sanitizers and Battelle Pacific Northwest Laboratories to help determine the need for further research in straw markets and technologies (FMC Corporation, 1978; Wells *et al.*, 1979).

Market conditions and market potential for straw products have changed. The volume and accessibility of straw to fiber, feed, and fuel markets have declined. Hydromulch and possibly residential fuels represent the only markets where adequate margin is available for processing straw. Direct sale of bales to mushroom growers, export, mulch, and feed markets are surviving uses. A major consumer, the Salem Mushroom Plant, closed in 1987.

Information about market size, straw potential, sales, and product distribution should be included in more current utilization studies. New market studies could be used to verify current markets, market share, or impact for proposed new areas of research such as residential wood stoves.

Surveys have helped guide assumptions about current levels of straw removal, field treatments and markets (Mikesell, 1973; Miles, 1974; Miles, Jr., 1976a, 1976b, 1976c; Wilson *et al.*, 1983; DEQ, 1985).

Promotions used to communicate straw utilization alternatives and to market straw included OSU field days such as "Grassland 1971," and the Oregon Seed Council tours of Japan with the Governor in 1972 and the State Department of Agriculture in 1979 (Inoue and Conklin, 1973); assembly and demonstration of straw uses and methods at the World Straw Conference, Eugene, Oregon in 1975 (Miles, 1975); and the formation of trade associations such as the Agricultural Fiber Association (AFA) and Environmental Fiber Inc. in 1976. The direct promotion of straw by the Oregon Department of Agriculture (Kileen and Vanderplaat, 1976); cattlemans field day by Agricultural Fiber Association in 1977; and Christmas tree tours (Agricultural Fiber Association, 1986a, 1986b). Several of these promotions have led directly to straw contracts. Others have created temporary high demand for straw. Large plants and projects politically promoted from 1970 to 1980 (pulp, pyrolytic, oil, furfural, steam, fermentation, fuel pellets and insulating board) have not led to increased straw consumption.

Promotional literature or information sheets have been useful to straw and meadowfoam growers when available as circulars and fact sheets from the Oregon Seed Council, DEQ, OSU, or AFA.

STRAW REMOVAL AND HANDLING

Costs and methods to remove straw were evaluated in early OSU research (Conklin, 1971; Anderson *et al.*, 1974). The need to remove straw was an important conclusion of mobile burner development from 1969 to 1971 (Kirk and Bonlie, 1973). A new emphasis was put on straw removal in 1974 when the mobile burner review showed that straw must be removed (Odell *et al.*, 1974). Further importance was given to straw removal during open burning acreage reductions of 1976 to 1977. Straw removal remains a significant cost for all alternatives to open-field burning (Miles, 1976; Cornelius, 1985; Smucker *et al.*, 1984). Rapid field removal of straw is important so that thermal sanitation can be started immediately after harvest when weather conditions are right and risk of straw deterioration from moisture is minimal.

The methods of straw handling and densification are determined by the end use. If no end use exists, the grower chooses the lowest cost option to remove the straw for field-side burning. Several methods to remove the straw from the field including baling, cubing, pelleting, and large stacks or "bread loaves" have been evaluated.

Baling

Baling is done in the form of two-tie low density (80 pound), three-tie high density (100 pound), round (500 pound) and large bales (1,000 pound). Two- or three-tie baling is chosen if the straw will need to be transported and/or stored. The cost of baling ranges from $20 to $30 per ton at a rate of 8 to 10 tons per hour. Various handling and accumulating equipment has been developed to speed up the process of stacking bales, loading and unloading trucks and moving straw in and out of storage.

OSU (1969 to 1971) studied stationary and field densification to replace two-tie bales (6 pound per cubic foot) with cubes (20 pound per cubic foot) (Anderson *et al.*, 1974). By 1972 new commercial systems included three-tie high-tensile wire bales (100 pounds), eight-bale packages. Large round bales, stackwagons, bale stackers, and 56-bale squeeze systems appeared from 1971 to 1976. Three-tie high tensile twine bales (100 pound), large square bales (1,200 pound), and individual compressed bales appeared by 1977.

Stack wagons and large round bales are the preferred grower choice for rapid, low cost field removal where the straw cannot be marketed.

Cubing

Tests were run in 1970 to determine the adaptability of the John Deere hay cuber for cubing grass seed straw. The tests indicated a possibility that ryegrass straw could be cubed when lignin sulfonate or sodium hydroxide is used as a binder. Later, tests were run in a cubing plant set up to do stationary commercial cubing of alfalfa hay and grass seed straw. Although straw was first exported as cubes, current markets are supplied with compressed bales. Cubing and compressing costs are similar ($25 to $55 per ton) with no clear advantage in the market over bales.

Bale Compressor

Several bales were densified and strapped together by Hastro West with 6,000 tons exported from 1972 to 1974. The 1,200-pound bales were strapped with steel and difficult to handle.

Steffen Systems built one of the first single bale compressors for straw export in 1979. Six bale compressors operated in the Willamette Valley in 1986. The largest compresses eight bales at a time into 800 pound bales, which are resawn into individual 70 pound bales.

The most common form of densification now in use is the bale compressor, which compresses a single square bale or a package into about one-third its original size. The need for compressing is generally for transportation cost reduction for straw going into the export market. The compressors are used with large-scale operations in the 7,000 to 10,000 ton size and cost approximately $150,000.

Pelleting

Some uses or markets for straw require further densification. Pelletizing is one form that has advantages in that it produces a flowable material with high bulk density that has good characteristics for use in livestock rations or as a fuel. The drawback is that pelleting is expensive and grass straw is particularly hard on equipment and requires a binder of some type to hold the pellet together.

Storage

Historically, a limiting factor in the handling of straw has been storage. Oregon's rainfall pattern means that about 75% of the straw handled for off-farm end use during a year must be put into storage for later delivery. Some straw can be delivered or shipped directly out of fields and some can be stored under tarps or plastic; the rest must go into permanent storage when delivered for a year-round supply. The usual form of storage is a pole-barn type with metal roof and siding on at least two sides. The cost of such a building is approximately $45,000 for 1,500 ton capacity. Storing straw also increases the cost of delivered straw to $45 to $50 per ton because of the additional handling and storage costs such as insurance.

Recently there has been an increase in construction of on-farm straw storage due largely to expanding markets for straw. Some 20 on-farm storage sheds have been built since 1986, aided by the Oregon Pollution Control Tax Credit initiated by the 1983 Oregon Legislature. Storage sheds qualify for the 25-50% state income tax write-off.

STRAW USES

Animal feed

Feed uses for straw have included feeding trials for beef, dairy cows, lambs and horses; nutritive value surveys; feed processing trials and product development including grinding, defibration, densification, chemical treatment, and fermentation.

Feed trials for winter maintenance from 1967 to 1976 included rations for range cattle (Macy, 1973; Vavra *et al.*, 1973; Phillips *et al.*, 1975; Bedell, 1976; Isley, 1976; Anderson, 1977; Kellums, 1983, 1985; Kellums *et al.*, 1984; Pirelli *et al.*, 1985), and dairy cows (Adams, 1977) in feed market areas of Union, Squaw

Butte, Lakeview, and the Willamette Valley. Straw treatment for livestock maintenance rations included lick tank, a bale supplement injector, and ammoniation. Liquid and dry supplements including alfalfa were used. The DEQ supported reconstruction and testing of a prototype bale supplement injector (Agricultural Fiber Association, 1982) which led to the design and construction of a commercial scale system (Agricultural Fiber Association, 1983a). From 1983 through 1984 straw markets for beef maintenance have been negligible. The 1988 drought saw renewed interest in straw with an unspecified volume shipped to the inter-mountain area for livestock feed.

Beef production trials between 1973 and 1977 were carried out on heifers, calves and steers (Ralston *et al.*, 1966; Ralston and Anderson, 1970; Anderson *et al.*, 1974; Shultz and Ralston, 1973, 1974; Shultz *et al.*, 1984; Church, 1975; Church and Kennick, 1977a, 1977b, 1977c). At the Straw Utilization Center straw was pelleted or cubed or ground as meal and combined with other feedstuffs. These products were ensiled, or treated with alkali such as NaOH or KOH. Straw levels of up to 33 to 37% in mixed rations were determined to maintain adequate production levels (3.1 pound per day) without loss in body condition.

Producing dairy products with straw and seed screenings was investigated at OSU in 1975 using Holstein cows (Adams, 1977). Compared with hay, straw depressed fat and fluid milk production. Depressed fat production also was found when pelleted grass seed screenings made up 50% of a cow's diet (Anderson *et al.*, 1974).

Western Oregon feeder lambs were used to evaluate the metabolism of alkali (NaOH) straw pellets. Carcass weight and feed conversion were measured. Feed conversion of 6 to 20 pound feed per pound gained were obtained when 50 to 65% of the ratio was treated (Anderson and Ralston, 1973; Church and Kennick, 1977a, 1977b, 1977c). A preliminary digestion trial was performed with lambs (Church, 1976). Intake and conversion of ryegrass pellets was sufficient to recommend moderate levels (20 to 30%) of ryegrass straw. Digestion of NaOH-treated straw was better than untreated straw. Cubes were too large and had to be reground to be fed as meal. Eastern Washington trials contributed information about bluegrass straws (Early and Anderson, 1976).

Straw pellets, cubes, and briquettes were fed in horse maintenance trials (Pulse, 1973; Shurg and Pulse, 1974). Digestibility was followed by a horse maintenance trial with cubed rations (Shurg *et al.*, 1978). Horses adapted to up to 50% straw in their rations. All horses showed normal health, no disturbance and trimmer appearance, with a slight gain of body weight. Cubes were range fed to stabled horses for half of their daily diet (Miles, 1976a).

Nutritive value research

Studies between 1971 and 1976 established the quality of grass straw relative to other straws, hays and feedstuffs. Several assay methods included *in vitro* and *in vivo* digestibility, acid detergent fiber, *in vitro* dry matter disappearance (IVDMD) and TSAE (16 hour enzyme) digestibility. A special effort in 1976 led to a comparative study which is the basis for most of the published information (Guggolz *et al.*, 1971; Anderson and Ralston, 1973b; Han *et al.*, 1975; Youngberg and Vough, 1977).

Pesticide residues on straws have received little attention. Restrictions for feeding straw containing pesticide residues have been published (Terriere and Kiigemangi, 1973; Youngberg *et al.*, 1988).

Feed processing

Straw processing by grinding or milling (Groner, 1974a, 1974b), cryogenic grinding (Humphrey, 1975); densification by pelleting, briquetting, and cubing; treatment with alkali (NaOH, KOH) and acids (sulphuric, phosphoric); defibrizing; and semi-solid fermentation have been reported.

Experience at OSU, Brennen Industries, and the Straw Center showed that field cubing was unworkable. Bulk densities of stationary cubes were 16 to 22 pounds per cubic foot. Miles used the Osborn Gear cuber with alkali treatment (NaOH) to densify straw to 40 pounds per cubic foot. The cube had sufficient density, enhanced nutrition and storability for export (Miles, 1976).

Alkali treatments used to increase digestibility of energy in straw included sodium hydroxide, ammonia, and combination of chemical treatment with several reactors (Miles, 1976; Han *et al.*, 1976; Kellums *et al.*, 1984). To increase digestibility, four percent or 80 pounds of alkali are required per ton of straw. Alkali was used to lubricate and bind straw for cubing while preserving fiber length. Ammonia gas (NH_3) enhanced non-protein nitrogen and digestibility at about the same cost as liquid supplement.

Fermentation of straw included the use of straw to absorb runoff from corn silage (Ralston and Anderson, 1970; Keck and McCarthy, 1976), and cultivation of mushrooms and torula yeasts through semi-solid fermentation (Frey, 1973; Anderson, 1974; Han and Anderson, 1975; Han *et al.*, 1976). From 150 to 200 pound of yeast were cultivated, dried and harvested in 30 hours for each ton of straw that was extensively milled and acid hydrolyzed. However, animals rejected most semi-solid fermented products and the cost of fermentation was prohibitive.

Pretreatments for fermentation included hydrolysis with acids, such as sulfuric, phosphoric (Frey, 1973; Grant *et al.*, 1977) and enzymes (Mandels and Gaden, 1976). Changes in nutritive value, digestibility, and composition were documented (Han and Anderson, 1975; Han et al., 1975; Han et al., 1976; Han et al., 1978). Pretreatment by defibrizing straw with a disc refiner showed significant sugar release (Han et al., 1978).

Other hydrolysis and chemical investigations included enzymatic hydrolysis for the production of glucose syrup (Andren *et al.*,, 1975), Quaker Oats search for raw material for furfural (1974 to 1975), sugar extraction (Brady, 1976) and xylitol sugar substitute (Brady, 1976). Straw was too expensive for furfural production. Xylitol was abandoned when linked to cancer.

Livestock feed markets

As with other raw materials, the issue of price of straw relative to other livestock feeds is the overriding consideration. The largest market to date is the export market to Japan. Straw is used primarily as a roughage source for the Japanese dairy industry, where the Japanese find themselves with an abundance of protein sources, (soybean and fish wastes), but little low quality roughage. The market in Japan has grown steadily over the past 10 years with a rapid increase during the past two years when growth from 30,000 tons to 120,000 tons annually occurred. Straw for export is baled, compressed, loaded in containers, and then shipped on deepwater freighters to Japan.

Livestock feed markets exist in the U.S. for straw but primarily as a maintenance feed for dry, nonpregnant cows. Supplemental protein and energy is required for all rations. The more common source is liquid molasses with urea or fish meal as the protein source, but protein blocks also are used. Other straw treatments used to improve digestibility include sodium hydroxide, liquid anhydrous ammonia, and hydrogen peroxide but their expense has prohibited large scale operations.

Pesticide registration for grass seed crops that includes use of straw for livestock feed and in straw aftermath for grazing may become an issue of concern. Testing for pesticide residue may be an important part of the registration process and is expensive. Additional funds from industry or public sources will be needed to complete this process.

Fuels

Fuel research from 1969 to 1986 has been extensive. It has included industrial user trials; product development including grinding, cubing, firelogs, and pelleting; process trials in combustion, pyrolysis, and gasification; market studies; and burner development.

Industrial and institutional burner trials were carried out with major hog fuel consumers including Weyerhauser, Georgia Pacific, Eugene Water and Electric Board (EWEB), University of Oregon, Bohemia and Willamette Industries (Meland, 1973b; Oregon Seed Council 1973; Odell and Miles, 1974; Miles, 1975). Burner manufacturers cooperated in straw fuel tests, including Applied Combustion (Meland, 1973b), Energex, Coen (Odell and Miles, 1974), Turco Industrial Combustion and others (Hughes, 1976; Miles, 1975, 1976a, 1977a, 1977b).

Straw was supplied as pellets, bales, strawdust (less than 1/4 inch diameter) and cubes. Chopped straw was tested as a dryer fuel at Bohemia (Miles, 1975), and as a boiler fuel at several locations, including Withycombe Hall at Oregon State University (Meland, 1973b; Hughes, 1976). The largest test was 2,000 tons of straw supplied by Van Leeuwen Farms to Willamette Industries for boiler fuel in 1980.

Straw requires some special equipment for handling and pollution control. It is more expensive than hogged wood fuel (Miles, 1976a, 1976b, 1978; Miles and Miles, 1979; Wells *et al.*, 1979). In tests to determine the safety of milled straw for fuel the OSU Department of Mechanical Engineering found that ground straw tends to burn in closed containers rather than explode (Hughes, 1976; Miles, 1977b).

Residential straw fuels tested included Weyerhauser Presto logs, Agnew Firelogs, Chip and Saw firelogs and straw pellets (Oregon Seed Council, 1973; Meland, 1973b; Miles, 1976a; Irwin, 1984; Cade, 1986; Traeger, 1986). Firelogs from grass seed straw do not burn well. Growers that produce their own pellets like Venell or Kizer Farms have built their own pellet burners. Traeger Industries has made a commercial furnace available for straw or straw-wood pellets. Fuel cost and smell are major concerns. Straw-fired stove tests have not determined combustion efficiencies or appliance emissions.

Farm scale burner development included a series of furnace designs for bales and chopped straw tested at the Utilization Center (Hughes, 1976; Hughes and Welty, 1976). Bale burners included the adaptation of the rotary path field burner design for stationary farm use (Miles, 1977). Emissions were tested by Rossman (1981). Use of this principle with other crop residues evolved into commercial designs that can be used for straw (Miles, 1979; Sukup, 1982; Ebling *et al*, 1982; Huffman and L'Ecuyer, 1985; Canadian Resourcecon and Miles, 1985). Hughes developed an opposed bale furnace design that became an OSU prototype (Page, 1979). Market studies for DEQ led to development of a water jacket style bale burner which is still in use at the Fraser home near Monmouth (MacKey, 1980; Kirk, 1982, 1984, 1985). Farm scale furnaces for heating or drying have not found a strong demand on grass seed farms.

Oil from straw was investigated in pyrolysis trials by Garret Research (Willard, 1975). Gasification trials included cubes and straw for direct gas conversion in prototype gasifiers by EWEB and others (Miles, 1976; Wilkinson, 1976).

Conversion to synthesis gas for ammonia, urea, or methanol was tested by Battelle (Rohrmann, 1974; Miles, 1976). The feasibility of a commercial straw/refuse-fired ammonia or urea plant was reviewed in 1976 by an interdisciplinary group composed of refuse haulers, seed growers, synthesis gas scientists, consulting engineers, and chemical producers. The group included Battelle Pacific Northwest Laboratories, British Petroleum, W.R. Grace, and Reichhold Chemicals (Miles, 1976). Straw could not compete with imported products.

OSU researchers found that straw added to high protein manures increases biogas production through fermentation (Miles, 1976). Other potential chemical uses of straw were researched and reported by OSU (Oregon State University, 1969; Groner, 1971a; Anderson, *et al*., 1974).

Fuel markets have been monitored and reviewed since 1969 (Miles and Miles, 1979; Wells *et al*., 1979). Straw quoted at a price of $27.50 per ton in 1975 had about the same fuel cost ($2.00 per MMBtu) as oil, but still more than hog fuel or natural gas. Hog fuel in this period rose from $16 per unit ($1.00 per MMBtu) to a peak of $40 per unit ($2.50 per MMBtu) in 1981, equivalent to $37.50 per ton straw.

Hog fuel has returned to a price equal to $15 per ton of straw. This is too low for industrial contracts where straw costs $30 to $45 per ton delivered. Homeowners may be willing to pay $80 to $100 per ton for straw-based pellets or firelogs, if an acceptable product can be produced. But they may not be interested in paying $1,500 for a straw pellet fired furnace. Unless straw as a new product is subsidized to the point of use or energy costs of other products (i.e., electrical and natural gas rates) rise dramatically, straw as a fuel will not be economically feasible.

Fiber

Fiber investigations have included market studies, pilot plant production, and field and market testing of paper, linerboard, particleboard, hardboard and insulating board products, hydromulch and straw mulch, and potting media.

Paper and paperboard market studies were carried out for kraft and fiber processes in general (Sandwell, 1975; Miles, Jr., 1976b, 1976c; Wells *et al*., 1979). Private companies including Crown Zellerbach, Weyerhauser, and Reichhold carried out independent market analyses.

Laboratory pulp and paper studies by OSU (Bublitz, 1974) were followed by pilot plant production at Crown Zellerbach. Product yields, costs and pollution control limited access to paper markets.

Corrugating medium appeared to offer the best potential use for straw fiber compared to fine paper and newsprint. However, the questionable stability of the supply of raw material and relative prices of raw materials favoring wood fibers require considerable changes in technology and relative market prices before straw can become a strong economic contender against wood as a fiber source in pulp, paper, and fiberboard production in the Pacific Northwest where the timber industry provides the existing fiber source.

Nonwoody plant materials such as grass straw and bagasse from sugar cane were the first sources of fiber for paper. They still constitute an important fiber source in parts of the world where woody plants (trees) are not readily available. In the U.S., and the Pacific Northwest in particular, the overriding reason for use of woody plants is economics.

Yields of usable fiber from cereal plants, canes and grasses tend to be much lower than those from wood. Typical straw yields would be 25 to 35% as compared to 48 to 50% from wood. Thus proportionately more straw than wood would have to be collected and transported to the pulp mill to make a ton of fiber.

Straws are generally lower in density than wood, resulting in demand for larger shipping trucks or railcars, larger storage space, and decreased pulping efficiency. Pulping digesters have a fixed volume, and the higher the density of the raw material being used, the greater tonnage output per day, with proportionately lower pulping cost per ton of fiber produced. Low-density raw material costs extra money in every operation, a case for raising straw density. Unfortunately, straw densification itself is costly compared with wood chips which have no such need.

Straw fibers tend to be shorter than woody fibers, thus making weaker paper. Many straws contain bast fiber that is unsuitable for paper making and must be removed. Straw generally contains a higher percentage of inorganic materials (ash) including silica that tend to contaminate process equipment and lower paper quality.

The logistics of straw procurement are unfavorable as compared with those of wood. Straws are available for harvest in a relatively short period of time. Wood can be cut nearly any time in the year if the forests are accessible. A year's supply of straw for a mill would have to be harvested, densified, transported, and put into storage in a month or two, requiring heavy investment in equipment that might lie idle for 10 to 11 months of the year and requiring investment in storage facilities. Wood, by contrast, can be stored in the forests or at mill sites as the occasion demands, and processing machinery can be designed to operate year round. Straw must be dry when densified or putrefaction will quickly set in. It must be stored under shelter from rain for the same reason. Wood is far less susceptible to decay, and it can be stored unprotected for years, if necessary, in either log or chip form with reasonable chance of preservation.

Straws do have some advantages over wood. They contain less lignin (the undesirable portion of wood that must be destroyed to obtain fibers) requiring less drastic and sophisticated pulping methods and can be more readily bleached by simple methods.

Particleboard research at OSU recognized that isocyanate resins made it possible to make a decorative board from straw (Groner, 1971a, 1971b; Groner and Barbour, 1971, 1972a, 1972b; Groner, 1975). Sample boards were sold by the Women for Agriculture. A laboratory press loaned from the Straw Center led to construction of the Meadowwood plant in 1976. Expansion attempts beyond 500 tons per year (1980 to 1983) were unsuccessful (Wilson *et al.*, 1983).

Acoustic and insulation board produced from straw in Europe as "Stramit" was studied and promoted by seed growers until 1973 (Meland, 1970; Jacob, 1973). The Stramit plant in Canada closed. K.H. Industries, the successful producer in Australia, has not been able to establish a market for its "Speedboard," made in Yuba City, California.

Fiber mats were produced for a board overlay product in cooperation with Reichhold Chemical, which supported pilot plant work (Miles, 1976; Razali, 1976; Ayres, 1977). The mats were overlaid and pressed with plywood veneer to make a straw hardboard-plywood structural building panel. Panels made at the Straw Center were weather tested against building standards at Reichhold. The product was ready for the market during a building slump and was abandoned.

Hydromulch was made from straw beginning at OSU in 1974 (Wells *et al.*, 1979). A commercial defibration process was developed and demonstrated at the Straw Utilization Center (1976 to 1977), where 1.5 tons of straw was used for fuel and fiber to produce 1 ton of dry bagged hydromulch for erosion control (Miles, 1976). The product was tested on roadside jobs with commercial contractors (Anderson *et al.*, 1975) and by field and pilot laboratories (Miles, 1976; Kay, 1979, 1983). Pilot plant equipment from the Straw Center was used to start production at Grassfiber Inc., Eugene in 1978. DEQ supported studies to improve product preservation in 1979 (Anderson and Israilides, 1979). Currently, grass fiber straw hydromulch is sold for erosion control to a very limited market of less than 2,000 tons per year at a price of about $125 per ton.

Fiber from hydromulch produced at the Straw Center was tested in molded pulp products such as flower pots (Oregon Seed Council, 1973), as hydromulch (Miles, 1976), as potting media (Brady, 1976; Ticknor, 1977) and as a substrate for yeast fermentation (Han *et al.*, 1978). Grass fiber straw mulch was later used as a specialty mushroom compost at a commercial plant in Salem, and as a horticultural mulch (Agricultural Fibers Association, 1986a).

Straw mulch for erosion control was used by the BLM, Forest Service and Highway Departments between 1973 and 1977. Energy prices depressed road and reclamation programs, which depressed markets for mulch. Straw mulch was tested on Christmas tree farms and hillside crops in 1984 through 1986 (Agricultural Fibers Association, 1986a, 1986b).

Straw bales were tested for direct market vegetable production of lettuce and tomatoes (Mansour, 1984, 1985). The technique is of interest to direct, U-pick, and organic markets.

Potting media trials were carried out with finely-ground strawdust and refined hydromulch fiber in screening tests at the OSU North Willamette Experiment Station (Ticknor, 1977) and in parallel germination trials at the Straw Center (Brady, 1976). Plants such as ivy and azalea responded well to both fiber and finely-ground straw. Quality control in refining eliminated need for herbicides to control volunteer grass seed germination. These results, combined with the need for sawdust mulch substitutes, stimulated the use of straw as mulch for blueberries (Agricultural Fibers Association, 1986b).

Teuffel Industries tested grass straw for their urea formaldehyde resin treated "Strawdust Mix"TM (Ticknor, 1982, 1983). Problems with volunteer grass seed terminated research.

Fiber markets

Straw is not an economically viable source in most U.S. markets. Technical limitations that translate directly into economic disadvantages relative to wood as a fiber source is the major factor. Technology exists to overcome these technical limitations, but at a price that makes straw unattractive. Little information is available today on the pulping characteristics of straws from grasses other than annual and perennial ryegrass. In the long-range view, world-wide demand for fiber in the paper industry may outstrip the supply of wood in the next 50 to 100 years. However, this offers little immediate promise of a market for straws from grasses in the Willamette Valley.

Chemical Extraction

The components of grass straw include cellulose, lignins, pentosans, waxes, oils, and ash. These components can be separated by solvent extraction, oxidation, pyrolysis, and other chemical treatments to produce cellulose acetate, cellulose nitrate and other useful derivatives. Waxes and lignins extracted from straw are similar to those being used industrially. High pressure hydrogenation and destructive distillation of straw yield a combustible gas, an oily liquid, and a carbon residue. Straw is not being used as a commercial source of those products for economic reasons, largely due to the high cost of extraction and low yield relative to other sources.

CHAPTER 6

HEALTH: THE PUBLIC CONCERN

Pollution of the environment emerged as a public concern during the 1960's in the United States. This coincided with public concern in Oregon over smoke emissions from field burning, particularly as it may affect public health. Concerns have come largely from residents of communities which experience smoke intrusions.

The scientific literature offers little definitive information on acute effects or chronic effects from long-term exposure to field burning. Reasons for this include:

1. most of the limited literature on air pollution health effects addresses severe urban pollution events from industrial and automotive emission sources;
2. the relatively temporary and transient nature of field burning smoke intrusions, largely particulate, are not readily comparable to monitoring data for particulate pollutants which are typically present year around at relatively constant levels in large urban and industrial areas;
3. little has been known about how the physical and chemical composition of field burning smoke compares to other sources including vehicles, wood stoves and slash burning emissions; and
4. methods for quantitative exposure and health risk assessment have been slow to develop, and often lack critical information such as dose-response relationships for specific smoke constituents.

R&D activities on health effects provided through the Field Burning Program paid by grower fees has been small. Less than $300,000 have been spent over the past two decades with more than half of it devoted to air quality research from 1969 to 1973. The remaining health effects studies are discussed in this chapter.

REPORT ON RESPIRATORY PATIENTS

Initial health work came from a Eugene physician who reported to the 1971 Legislature on a survey of 10 physicians who saw 201 respiratory patients between July 9 and August 29, 1969. Of these patients, 167 (83%) had a prior respiratory condition and 92 had been seen on more than one occasion for a total of 293 visits. Of these, 152 patients had symptoms of acute coughing, 199 had tightness of the chest, and 84 experienced wheezing and labored breathing. The report stated that 95 patients found it necessary to leave the Valley for relief. It was necessary for 173 patients to purchase medicine and 131 work days were lost. Whether field burning smoke aggravated these pre-existing conditions and to what degree was not determined.

BREATHMOBILE STUDY OF PULMONARY LUNG FUNCTION

From 1972 to 1977 the Oregon Lung Association sponsored lung function tests as part of its five-year Christmas Seal Breathmobile Program. The Breathmobile toured the state offering free spirometric tests to the public. In 1978 the OSU Survey Research Center was funded to conduct a retrospective analysis of this statewide pulmonary lung function data base to detect any glaring dissimilarities in respiratory health between residents of different regions.

For purposes of this study, seven different regions of the state were delineated on a geographical/airshed basis. Included were the southern portion of the Willamette Valley representing a smoke impacted area, the west side of the Valley which is usually free from smoke, Portland, the coastal area, and the regions of central, eastern, and southern Oregon. The following pulmonary functions were evaluated: one second forced expiratory volume; percent of the forced vital capacity expired in the first second; and forced expiratory flow 25 to 75 percent.

As would be expected, respiratory function generally declined with age and increased smoking intensity. For non-smokers, however, there were significant differences between regions. Adjusting for age, sex, and height, residents of the south Willamette Valley, the area representing smoke exposure, had ~~the~~ *highest* ~~average one second forced expiratory~~ values of all the regions, and the difference was statistically significant in every case. The south Valley region also had higher forced expiratory flow values which were statistically better than values for residents of central Oregon, southern Oregon, and the west side of the Willamette Valley. There were no significant differences in the first second forced expiratory values.

Definitive conclusions could not be drawn from this cursory review. Questions regarding the comparability of the test groups, and the effects of regional differences in climatology on respiratory performance could not be addressed. Still no obvious effect on public health could be detected. In fact, residents of the area (south Valley) most frequently exposed to field burning smoke performed better (and presumably had better respiratory health) than residents from all other areas tested.

In 1977 health effects research was given top priority status in the Field Burning R&D Program. Funds were set aside for preliminary studies and for planning a major health effects research project. In so doing it became apparent that research on this issue would require a major and complex undertaking of a multi-disciplinary research nature and be very costly. It could easily divert all of the available R&D funds from other topics. Accordingly, it was decided to:

1. support preliminary studies based on local data if possible, to identify evidence that health impacts do indeed exist;
2. follow up such evidence with a planning effort (i.e., a workshop with selected experts) to design a more extensive research effort, and
3 to solicit the necessary funding for such an effort and contract the work.

The discussion which follows reports on those activities which have been completed.

1980 PHYSICIAN VISIT SURVEY

Questionnaires were made available to patients visiting health clinics in Lebanon (an area affected by smoke) and Corvallis (an area relatively free of smoke). The questionnaires were offered to people seeking medical assistance for any type of respiratory ailment. The questionnaires asked for the following information: date of visit, age, sex, zip code, nature of symptoms, date symptoms began, number of work loss (WLD) days, health status, and exposure to cigarette smoke or other air contaminants.

A total of 164 questionnaires were returned, 137 of these from the Lebanon Clinic. Of the respondents, 59% were women, 21% were smokers, and 45% had been diagnosed as having a chronic respiratory disease or condition. There was fairly even age distribution with regard to symptoms with 80% reporting some upper respiratory symptoms. Symptoms specifically identified were as follows: cough (38%), headache (38%), eye irritation (37%), breathing difficulty (36%), sore throat (34%) congestion (32%), wheezing (23%), sneezing (23%), other (20%), and phlegm (15%).

The survey was intended as a "blind" or objective way to gather local health information, unprejudiced by the participants' personal opinions about field burning. The returned questionnaires, however, contained numerous comments and complaints specifically directed to field burning, suggesting the potential for subjective bias. Therefore, a detailed dose-response analysis or correlation with ambient smoke levels was never performed and no definitive conclusions were attempted.

1980 HOSPITAL ADMISSIONS STUDY

The OSU Survey Research Center conducted a retrospective analysis to determine relationship between smoke "dose" and public health "response" in an area affected by field burning smoke. Admissions into Lebanon Community Hospital during the 1978 and 1979 summer burning seasons, for both respiratory and non-respiratory type ailments were reviewed and compared with smoke data for that area.

Primary and secondary diagnosis codes were selected on the basis of prior studies. In-patient admissions data also included sex, age, and admission and discharge dates. Information on patient smoking status was incomplete and not included in the data base.

Aerometric data considered in this study included continuous nephelometer measurements summarized for each day as 1-hour maximum, 3-hour maximum (average of the highest consecutive three hours), and 24-hour mean. Other data included maximum, minimum, and average daily temperatures and average daytime relative humidity, as recorded at Eugene 30 miles away.

Results of the study indicated no statistical evidence of an effect. No significant differences were observed between respiratory and non-respiratory admissions. There was also no discernible lag effect or delay between a smoke intrusion and a measured response.

1986 FIELD BURNING HEALTH EFFECTS WORKSHOP

A Field Burning Health Effects Workshop sponsored by DEQ and the Advisory Committee on Field Burning was held at Oregon State University to consider alternative approaches to quantitative assessment of the health effects of exposure to field burning smoke.

The difficulties facing health effects studies related to field burning were summarized and discussed. Different approaches to quantitative assessment of health risks related to exposures to particulate air pollution were discussed. One approach utilized correlations between ambient particulate levels and adverse health effects represented by work loss days (WLD) and leisure time reduced activity days (RAD).

Preliminary results suggested the possibility that short term, fine particulate concentrations effects as occur with field burning might be correlated with respiratory related RADs (RRAD). Such morbidity effects have been determined by EPA to be costly to undertake, much more costly than mortality effects associated with cancer incidence and particulate ambient air quality levels. Applying such an approach to the Willamette Valley left several major unanswered issues:

1. whether fine particulate and/or nephelometer data from DEQ field burning or other Willamette Valley monitoring sites could be positively correlated with RRAD from the same area(s), and
2. whether such correlations would remain robust for the brief duration (episodes of a few hours), and seasonal average concentrations which correspond to the principal exposures attributable to field burning.

Another approach suggested the use of prior relevant studies, mathematical models, dose-response, and health-related information to provide for a more thorough and diagnostic approach to the research. Such analysis would need to collect clinical data on health effects, consider lifestyle habits and economic costs to the community as well.

1987 PRELIMINARY FIELD BURNING HEALTH EFFECTS ASSESSMENT

Results of the 1986 Workshop led to initiation of a Preliminary Field Burning Health Effects Assessment in 1987. DEQ contracted an environmental firm to conduct a quantitative assessment of exposures, health effects/risks, and related costs, under typical and worst case conditions, related to field burning, slash burning, and residential wood burning. The study was completed in 1987 and submitted for technical review in 1987. The study has not been released. A technical review of the assessment raised serious questions concerning the appropriateness of the methodology used and conclusions of the study for Willamette Valley conditions.

In summary, to date there is insufficient evidence to ascertain whether or not controlled open-field burning in the Valley has direct and/or indirect health effects.

CHAPTER 7

STRUCTURAL ADJUSTMENTS: ECONOMIC REFLECTIONS AND FUTURE CONSIDERATIONS

DYNAMIC NATURE OF THE VALLEY'S GRASS SEED INDUSTRY

The Willamette Valley grass seed industry has been under pressure for the past 20 years to resolve its field burning problem, a fact well known to Oregonians. Less well known is the dynamic character of that industry, particularly its growers, in adjusting to the need for change. This industry, like many others in the U.S., has had to adjust to reduced pollution levels of concern to a broader public. Some industries in the quest for solutions have simply absorbed the additional costs for pollution control and passed them on to consumers in the form of higher prices. This scenario is not characteristic of agriculture in general nor grass seed production in particular, both of which are perfectly competitive in nature. This means they are price takers in the marketplace with no direct ability to pass on increased costs of pollution control to consumers of grass seed in the form of higher grass seed prices, as the monopolistically competitive firms are able to do. An exception is if the Valley grass seed growers face cost increases collectively and the industry has an adequate comparative economic advantage with competing regions in the marketplace to pass on the cost increases. This issue is unknown. Thus a major concern has prevailed over time concerning the extent to which growers can adjust further to reduced field burning through selection of higher cost alternatives which reduce smoke emissions *and* retain viability as an industry.

A review of the past two decades, and in particular the past decade, reveals an industry which has made considerable adjustments. Open-field burning has declined from 315,000 acres in 1968 to about 220,000 acres annually during the 1980's. In 1988, 330,000 acres of grass seed were produced in the Valley of which 206,000 acres were thermally treated. An estimated 150,000 acres were field burned and 56,000 acres propane flamed. The remaining 124,000 acres were not burned, employing other field cultural practices. In general, the net effect to the public has been reduced emissions by one-half from reduced acreage burned.

Under the current smoke management program, about 75% of total acres burned has occurred within 13 burning days. Total hours of heavy smoke intrusions in metropolitan areas have been reduced from 166 hours in 1981 to 73 hours in 1987 for the entire Valley (1987 DEQ Annual Report on Field Burning). Complaints from individuals citing eye irritation and aggravation of asthma and other illnesses range from 500 to 1,500 per year. A higher proportion of complaints come from urban areas with high populations. Complaint levels correlate poorly with intrusion levels.

The internal adjustments made by growers which have made reduced burning possible while retaining the economic viability of the industry are less obvious. The adjustments have included changes in field cultural practices, changes in thermal sanitation practices, adjustment among the mix of grass seed species grown both at the farm and industry level, and increase in use of proprietary varieties.

Growers have reduced the acres of annual ryegrass produced and have gone, on a portion of the acres remaining, to a fall plow-down and reseeding to replace field burning. Some straw is roadsided as a companion practice. On the perennial grasses, especially those grown in the north Valley, a definite increase in roadsiding the straw followed by propane flaming is observed. An increased volume of straw appears to be intended for sale. Some 20 storage units have been built since 1986. A state pollution control tax credit serves as an incentive for storage construction. Baling for commercial sale is relatively common. During the early 1980's, a definite shift toward proprietary varieties with forward contracting was employed, largely as a mechanism for reducing market price risk. Some shifting away from this has occurred since 1985 as market prices improved significantly and have stayed favorable since then.

HETEROGENEITY OF THE VALLEY'S GRASS SEED INDUSTRY

In discussing internal adjustments it is important to recognize that the industry of some 800 growers is not homogeneous nor is the ability to adjust equal among growers.

Soil conditions and topography vary widely across the Valley and have a major influence upon the nature of grass seed production. Farmers in the southern Willamette Valley (Linn, Benton and Lane counties) tend to specialize in grass seed crops with emphasis upon annual and perennial ryegrass because of the extensive area of poorly-drained soils in which most crops will not survive the winter flooding. Grass seed farmers in Polk, Yamhill, Marion, Clackamas and Washington counties have smaller farm units and are more diversified. Soils are variable, providing opportunities for a variety of crop alternatives and rotations. In the hilly areas where soil erosion is a problem, such as the Silverton Hills, crop choices are more restricted. In those areas farmers specialize in bentgrass and fine fescues, grasses well adapted for erosion control.

Geography is a factor. Grass seed farm location relative to urban population concentrations, major traffic flows, and prevailing winds during the burning season strongly influence whether and when open burning is allowable. The net effect is a wide variation in terms of adjustment alternatives and ability to absorb cost increases associated with those adjustments.

Each grass seed species faces a different market (ranging from export only for bentgrass, to U.S. only for orchardgrass), and serves different market roles ranging from lawn and turf use, pasture and cover-crop use, and multi-purpose use for seed mix blending. Domestic and foreign prices differ markedly among species at a moment in time and over time. Thus relative profitability among species can and does change over time. In general, annual ryegrass has been historically the species with the lowest profit margin. In the marketplace it is most used for winter overseeding of lawns and pastures in the south, and as a filler in grass seed mixes.

ADJUSTMENTS IN CULTURAL PRACTICES INVOLVING THERMAL SANITATION

Some growers are choosing forms of low cost residue removal practices combined with propane flaming for thermal sanitation as a substitute for open-field burning (Appendix D). While this mix of choices is more expensive than open-field burning, it is less costly than other choices or mix of choices. While agronomic research currently is focusing upon non-thermal cropping practices and farming systems, such a focus was begun only since 1980. Some form of thermal sanitation continues as an important cultural practice to dispose of an unmarketable residue and control insect, disease, and weed pests inexpensively.

TECHNICAL AND ECONOMIC CONSIDERATIONS FOR FUTURE ADJUSTMENTS

Competitive and Risky Nature of the Industry

Production of grass seed in the Willamette Valley, like U.S. agriculture generally, is conducted under a perfectly competitive environment in which individual producers are price takers in the marketplace. Market demand is dictated by forces beyond the control of producers. Consumer demand for lawn and turf grasses, especially turf-type proprietary varieties of tall fescue and perennial ryegrass have increased markedly in the 1980's, especially the past five years. This has come largely through the development and release of proprietary varieties which are capturing cool-season turf markets and some warm season grasses markets as well. Additionally, these new turf-type varieties of tall fescue and perennial ryegrass provide significantly and consistantly higher yields of 200 to 300 pounds per acres than their traditional counterpart. The combined higher market price and higher yields have led to phenomenal growth of these species in the Valley. Grass seed producers have shifted away from annual ryegrass and expanded total acreage of grass seed. Supply continues to lag behind demand in this market, a condition which may prevail for another year or two.

The pasture grass market for tall fescue and orchardgrass softened greatly in 1988 with high inventories in the seed trade as the government CRP program comes to an end.

The boom years since 1985 for the industry can be expected to taper off as lagged supply increases catch up with demand. An overshooting of this situation would send market prices tumbling accompanied by major economic stress as occurred in the early 1980's. Slow adjustment by growers to lower prices through downward acreage adjustment would further aggravate the situation.

Unknown Ability of Industry to Absorb Further Cost Increases

Structural adjustments within the Willamette Valley grass seed industry to date have been absorbed almost totally by individual growers through higher production costs. Production costs are an extremely important element in maintaining production efficiency. Increased unit production costs have occurred as growers have shifted from low cost open burning to higher cost alternatives. Improved markets since the mid-1980's have helped offset the increased production costs through higher market prices. Whether further increases in production costs can be absorbed by the industry, without offsetting higher market prices, is unknown.

Historically, the industry has had an economic advantage in the marketplace relative to competing production regions through quality, yield, and cost efficiency advantages. Grass seed contractors, skittish about the future of the Valley's grass seed industry, are searching for alternative producing areas in the U.S. and overseas. Whether such a quest will be successful is unknown. Most other producing regions treat grass seed production as a complementary crop to pasture production for livestock. No analysis of these regions have been made to determine production costs/returns from grass seed/forage production, profitability of grass seed production relative to alternative crop and livestock enterprises in those regions, certification requirements, and seed yields. All of these factors influence the extent to which regions compete with one another in the various grass seed markets.

Physiological Response Differences Among Species to Thermal and Non-Thermal Management

The physiological response of each grass seed species differs widely both under thermal sanitation and non-thermal management alternatives. In other words, the need for burning differs across species and possibly even varieties. Very limited information is currently available in regard to how species might be ranked or given priority for burning. Additional considerations include the thoroughness of mechanical residue removal that is possible on a given field site, and the age of stand. Comparisons between burned and unburned management through previous research have been very limited and under optimal control conditions.

Susceptibility to disease may also determine the necessity of burning on a species by species basis. Ergot is potentially the most serious of the grass seed diseases as all grasses grown for seed are susceptible, and it is widespread throughout the region on wild grasses, which are an important source of inoculum. In perennial ryegrass blind seed disease is the most serious problem; it is also a threat in annual ryegrass, and has been identified in several tall fescue fields. Seed gall nematode has previously caused serious yield loss in seed crops of bentgrass and fine-leaf fescue.

Similar variation by species to affliction from insect pests has also been observed. However, monitoring systems capable of identifying economic levels of impairment from disease or insect scourge have not been developed. Before considering post harvest residue management to be differentiated by particular species, research should evaluate the long term implications of physiological and pest issues.

Unknown Impact of Future Disease, Insect, and Weed Pests Without Thermal Sanitation

Open-field burning as a single operation has played a number of important roles in the production of grass seed. One of them involves pests. The cumulative effect upon seed quality, germination, and yield of reducing thermal sanitation and shifting to less than annual burning and non-thermal practices is unknown. Further, the potential impact of eliminating thermal sanitation entirely in the Valley upon the incidence of pests that affect yield and quality is unknown. Research is now underway to assess these issues. However, short of an outright ban on thermal sanitation, there is no effective way to research the aggregate or industry effect of pests when large acreages of grass seed are not burned. Research on non-thermal sanitation alternatives was initiated in the 1980's when it became apparent that mobile field sanitizers were not an economically viable alternative.

The availability of pesticides for control is very limited and will continue to be further restricted. Concern over pesticide residue in grass straw for livestock and ground water may further limit their use.

Straw Utilization: A Marginal Activity

A very limited market has been found to date for straw residue. Straw must go through costly field removal, transportation, and transformation processes to be used successfully in livestock feed, fiber, fuel, and chemical extraction markets. This makes straw noncompetitive with existing raw materials in those markets, an issue amply tested by R&D activities on straw utilization. At this point perhaps 20% of all straw removed is marketed, mostly in Japan, with some limited U.S. markets during periods of short supply of usual livestock forages. An important implication here is that any additional unburned acres will have little or no potential for straw utilization thus further increasing straw disposal costs for those acres.

Alternative Crops

Crops which are economically superior to grass seed production continue to be elusive. Meadowfoam, a new crop with oil potential in the industrial market, is a prospect but several years away, if ever, from being economically viable in such a market. Potential market size appears to be small, so an unlikely potential crop for the entire Valley.

A number of crops have been grown on grass seed lands. They include small grains, grass pasture for livestock, alsike clover, and vetch. Each of these crops are less intensive in nature and hence less profitable than grass seed.

The Quest for a Solution: To Date Largely a Private Sector Endeavor

Grass seed producers in the Willamette Valley have been the dominant actors in finding economically viable alternatives to open-field burning. Their action has come through use of grower burning fees to fund research and development activities over the past two decades and strong cooperation in making the smoke management program effective. Very limited public funds have been devoted to such activities. The major focus in use of R&D funds has been upon alternative means of thermal sanitation, improved smoke management, crop residue utilization, alternatives to thermal sanitation, and alternative crops. Limited research activity has focused upon public health effects, either through public or Field Burning R&D Program funds.

Public funds have been used for the Pollution Control Tax Credit program initiated by the 1983 Oregon Legislature. Some 20 to 40 grass seed growers have used the tax credit in construction and/or purchase of storage sheds, propane flamers, stack wagons, and associated equipment. The program has provided a 25 to 50% state income tax write-off of capital investment items used in environmental pollution control. The program is being phased down with termination at the end of 1990.

Adverse Public Health Effects Largely Unmeasured

To date, little research has been undertaken to determine the existence of adverse health effects of smoke from field burning under the current smoke management program. This is unfortunate as it is public outcry which has expressed concern over health effects from field burning. Research has not been undertaken to measure the nature and magnitude of such health effects. The transitory nature of field burning, while highly visible during the short burning periods during the summer, is elusive to detection and measurement of incremental health effects. The smoke management program currently in place has contributed to moving smoke to the upper atmosphere and away from urban areas as evidenced by DEQ nephalometer readings and reduced smoke impact hour reportings. As a consequence, it is still unknown whether field burning is or is not the source of substantive health effects. Further, it is unknown whether the full set of smoke emissions in the Valley which includes slash burning, residential wood burning, and open-field burning collectively create a substantive health hazard and the role of field burning as a component.

Public Hazard, Nuisance, and Aesthetic Effects Observed but Largely Unmeasured

It is apparent that field burning can create hazards as evidenced by the August 1988 accident on I-5 near Albany with resulting loss of human lives. Addition of fire safety buffer zones along major Valley highways and strengthening of current smoke management rules were implemented to reduce risk of such a hazard. The extent to which even more stringent rules can serve to minimize or eliminate such hazard is unknown. Some minimal level of fire hazard likely will persist on highway rights-of-way during hot and dry summers as they are grass covered.

A further issue not treated involves nuisance, soiling, and aesthetic effects from field burning. Negative effects upon Oregon's tourist industry, which have been mentioned in public debate, have been limited to a single study contracted by DEQ in 1986. The study provides an initial attempt to estimate the amount Oregonians would be willing to pay for improved visibility. No attempt was made to directly link that to smoke from specific sources (Crocker, 1986).

Research Needs

Significant progress has been made identifying individual factors relating to the complex issue of finding alternatives to open burning. However, many problems remain to be resolved and cannot be resolved without additional resources.

Several methods have been proposed for removing straw residue from perennial grass seed fields and have been tested in experimental trials. Tests have not been conducted under field conditions regarding the effectiveness of these practices to control grass seed diseases or control weeds in the absence of field burning and field flaming.

An integrated research approach is needed to provide definite guidelines for a seed production system for each of the major grass species under Willamette Valley conditions when straw is not burned. Straw handling methods, tillage systems, species, fertilization, disease, insect, weed, and pest variables should be compared. These practices should be molded into competitive production systems.

A study of the seed industry and its ability to compete with other producing regions is needed.

A program for improvement of seed yield in meadowfoam in conjunction with federal resources should be supported. A marketing program for meadowfoam oil should be initiated.

Support is needed to develop an integrated pest management program for grass seed. Such a program would provide both research and extension support for implementation of new technology of pest management to provide long term solutions for pest control.

Support should be provided for registration of pesticides essential for grass seed production to permit livestock feeding.

Support is needed to coordinate on-farm research and conduct an aggressive demonstration trial education program on non-burning alternatives.

CHAPTER 8

A VIEW TOWARDS FURTHER ADJUSTMENTS

Although significant reductions in open-field burning have been realized in the last two decades, public concerns with the hazard effect of field burning resurfaced with the unfortunate series of accidents and subsequent deaths on I-5 near Albany on August 3, 1988. The debate over broader public welfare effects of field burning has also intensified. As a consequence, there is renewed interest in developing grass seed production techniques which are compatible with the welfare of the broader community.

The initial step in addressing this debate is the outlining of a range of policies which may be considered. Next, the implications each choice might have upon all of the relevant groups should be detailed. At stake are the expected benefits and losses resulting from each alternative policy for the grass seed industry and its individual growers on the one hand and the general public concerned with air quality on the other. To date, little substantive research evidence has been provided that quantifies the health impacts from burning. Similarly, while public hazard, nuisance, soiling, and aesthetic effects have been confirmed by observation, their importance has not been measured. It is therefore not possible to quantify the extent that public air quality will be affected by further reductions in open burning.

The discussion of the net impact of further adjustments in grower production practices is complicated by the lack of reliable information on the smoke emissions associated with propane flaming, a practice developed as an alternative to open burning. Preliminary observations suggest that low level emissions from propane flaming may lead to widespread and persistent haze throughout the valley if this practice gains greater use. Studies are underway to ascertain more precisely the air quality tradeoffs between propane flaming and open burning. The treatment of propane flaming within the context of changes in the regulation of thermal sanitation practices remains unclear.

It is unfortunate but true that, given our current state of knowledge, there will be a direct tradeoff between reductions in smoke impact levels and reductions in the profitability of grass seed production, all else equal. At one extreme, unrestricted burning would permit growers to minimize their costs of production and maximize profits but would result in reduced levels of air quality. At the other extreme, the elimination of all thermal sanitation practices would improve air quality levels but would have significant short and long run impacts on the profitability of the industry. In a broader sense the inverse relationship between air quality and the profitability of grass seed production may be an over simplification as current grass seed production practices have favorable environmental impacts when compared to alternatives in areas such as erosion control, levels of dust in the atmosphere, and urban/industrial development.

The current situation which requires growers to register acreage and open burn under the DEQ controlled Smoke Management Program represents an initial effort to weigh the tradeoffs between the conflicting objectives outlined above. In the light of recent events, it is likely that the status quo with regard to burning will be viewed as being at one end of the spectrum of choices with the other alternatives that will receive serious consideration being more restrictive. A selected list of possible alternatives to be considered are listed and briefly discussed below. Increased restrictions on propane flaming may or may not be included for each of these alternatives.

1. Maintain the current field burning program but impose further controls to further reduce the hazard from open burning which may endanger human lives. This policy choice is intended to solely address and reduce the risk of life-threatening accidents. The impact on growers would be geographically focused and limited to those located adjacent to the highways and urban centers. As compared to the current situation, the smoke management program would become more expensive and affected farmers would face increased production costs.

2. Implement negotiable burning rights for grass seed growers. This policy choice involves use or access rights which can be bought and sold in the marketplace among growers. The rights would permit the marketplace to be used to determine the economic importance of open-field burning relative to other choices. Where bans or severe restrictions are placed on burning, the growers can sell their rights or portions thereof, using the proceeds to invest in alternative measures. The current Smoke Management program would not be affected.

3. Use public funds for subsidies and expanded research and development on pollution abating technology and adjustment options. The intent of this policy choice is to expedite the transition toward fewer air polluting activities by seed growers through increased support and assistance from the public sector.

4. Continue with the restricted open burning program but reduce the maximum burned acreage to some lower level with the actual number of acres burned determined by meteorological conditions. Growers in 1988 demonstrated the ability to adjust to a lower level of burning through an increased reliance upon straw removal (often followed by propane flaming), plow-down of residue of annual ryegrass, and other techniques. As the maximum acreage limit is reduced, grower adjustments will become more difficult and costly to accomplish.

5. Continue with the restricted open burning program but accomplish a reduction in the number of acres burned by increasing the per acre fee for burning. The current burning fee of $3.50 does not come close to offsetting the economic advantage to the grower of open burning. Increasing the fee to a level great enough to serve as a disincentive to open burn and shift to other alternatives would simultaneously reduce the number of acres burned and increase or maintain the money generated by the DEQ for research on alternatives to burning. However, availability of effective and economical alternatives is a critical requirement. Several years may be required to construct and field-test equipment.

6. Provide a phased reduction in open burned acreage over a set period of time until the practice is eliminated entirely. The advantage of the deliberate phase-down approach to farmers is that it would provide them with a learning period to incorporate new production technologies. The public, in turn, would realize a gradual reduction in smoke emissions. Adequate time should be allowed for growers to meet contract agreements of two to four year duration.

7. Eliminate open-field burning for residue removal (i.e. for short term economic reasons) but permit the use of thermal sanitation on a "prescriptive" basis in order to control disease, weed, and insect problems. This approach would safeguard the long term productivity of the grass seed industry but would ignore potentially significant short term economic impacts. The key unknowns are cost and effectiveness of the monitoring system, the number of acres burned, and alternative means for residue disposal.

8. Eliminate open-field burning entirely. This approach would be at the extreme end of the spectrum and would provide an abrupt and immediate transition towards the minimization of smoke impacts while simultaneously maximizing the short and long term economic costs and viability risks faced by the industry.

As the emphasis shifts away from open burning toward greater reliance upon mechanical propane flaming and stack burning, production costs would increase accordingly (Appendix D). Increased costs would include propane flaming and residue removal and disposal. An indirect effect would involve reduced grower fees available for needed smoke management and research and development activities unless alternative mechanisms for funding these activities are established as suggested in one of the policy alternatives named above. The air quality effects of propane flaming and stack burning, while unknown, are being researched.

APPENDICES

APPENDIX A

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APPENDIX B

RESEARCH AND DEVELOPMENT PROJECTS ON FIELD BURNING, WILLAMETTE VALLEY, OREGON, 1968-1988

Alternative Sanitation	Straw Utilization	Alternative Crops	Smoke Management	Health Effects	Total Costs
1969					
Mobile Field Sanitizer Prototype Alternate Year Burn Crew-Cutting Residue Incorporation and Stubble Seeding			Emissions from Burning Stubble/ Straw	Air Quality Survey of 200 Respiratory Patients	
$40,000			$130,000	$45,000	$215,000
1970					
Mobile Field Sanitizer Prototype Alternate Year Burn Crew-Cutting Residue Incorporation and Stubble Seeding	Initiate Straw Use Program		Meteorological Conditions Smoke Management Approaches	Air Quality	
$60,000	$30,000		$130,000	$45,000	$265,000
1971					
Field Sanitizer - Testing Alternate Year Burn Crew-Cutting Residue Incorporation and Stubble Seeding Disease/Insect Control	Particle Board - Lab Testing and Pilot Trials Livestock Digestibility Hydrolysis/ Fermentation Chemical Feedstock - Pyrolysis Hydromulch Straw Removal Alternatives - Economics Field and Stationary Cubing and Use of Binders Pelleting	Economic Analysis of Grass Seed Industry/ Alternative Crops	Smoke Management Approaches	Air Quality	

Appendix B, Page 2, Research and Development Projects on Field Burning, Willamette Valley, Oregon, 1968-1988 (continued)

Alternative Sanitation	Straw Utilization	Alternative Crops	Smoke Management	Health Effects	Total Costs
1971 (continued)					
	Baling Bale and Breadloaf Stacking Residue Densification				
$90,000	$234,000	$40,000	$130,000	$45,000	$539,000
1972					
Field Sanitizer - Testing - Manufacturing and Use Crew-Cutting Residue/ Incorporation and Stubble Seeding Stack Burning Disease/Insect Control	Pulp, Paper, Hardboard and Linerboard Potential Japan Market Potential Residue Densification (cubes, superbales, stacking) Beef Maintenance Feeding Trials Digestibility, Pellets, Silage, Alkali Treatment Trials with Sheep and Cattle Hydrolysis/ Fermentation Pellets for Fuel Pyrolysis Furfural Particle Board Pilot Trials Bales for Mulch	Meadowfoam Plot Trials	Climatological Variables	Air Quality	
$226,000	$175,000	$10,000	$130,000	$45,000	$586,000
1973					
Field Sanitizer - Manufacturing and Testing Crew Cutting	Densification Cubing/Binders Feed Processing/ Extrusion NaOH	Meadowfoam Plot Trials	Climatological Variables	Air Quality	

Appendix B, Page 3, Research and Development Projects on Field Burning, Willamette Valley, Oregon, 1968-1988 (continued)

Alternative Sanitation	Straw Utilization	Alternative Crops	Smoke Management	Health Effects	Total Costs
<u>1973</u> (continued)					
Residue Incorporation and Stubble Seeding Stack Burning Disease/Insect Control	Briquettes Pellets and Cubes to Japan Beef Maintenance Feeding Trials (pellets, meal, cubes, NaOH, KOH) Horse Maintenance-Pellets, Briquettes Hydrolysis/Fermentation Pilot Plant Firelogs Pyrolysis Gasification Furfural Bales for Mulch				
$137,000	$153,000	$10,000	$155,000	$40,000	$495,000
<u>1974</u>					
Field Sanitizer - Manufacturing and Testing Crew-Cutting Total Harvest Residue Incorporation and Stubble Seeding Stack Burning Propane Flaming Disease/Insect Control	Densification (bales, chopped, cubed, briquettes, pellets) Feed Markets - Cattle/Horses - US and Japan Superbale Export to Japan Hydrolysis/Fermentation Firelogs Gasification Bales for Mulch	Meadowfoam Plot Trials	Smoke Management Research		
$337,000	$354,000	$10,000	$90,000		$791,000
<u>1975</u>					
Field Sanitizer - Field Use	Densification (bales, chop, strawdust, cube)	Meadowfoam Plot Trials			

Appendix B, Page 4, Research and Development Projects on Field Burning, Willamette Valley, Oregon, 1968-1988 (continued)

Alternative Sanitation	Straw Utilization	Alternative Crops	Smoke Management	Health Effects	Total Costs
1975 (continued)					
Crew-Cutting - Evaluation	Bale Stacking				
	Firelog Market				
Total Harvest - Evaluation	Feed Pellets				
Stack Burning	Feeding Trials/ Supplements/ Dairy Use				
Spray Steam/ Sulfuric Acid After Straw Removal	Feed Processing (NaOH)				
	Hydrolysis/ Fermentation				
	Industrial Burner Trials (ground straw, bales)				
	Furfural				
	Gasification				
	Hydromulch - Pilot Process				
	Bales for Mulch				
		$10,000			NA
1976					
Field Sanitizer - Field Use	Densification (bales, stackers, crewcut, strawdust, cubes)	Meadowfoam Plot Trials			
Stack Burning					
Crew-Cutting	Economics of Fiber Use				
	Feeding Trials (of hydrolyzed straw, pellets, meal, cubes) to Beef, Lambs, Horses				
	Strawdust for Bedding				
	Feed Processing				
	Industrial Burner Trials				
	Gasification				
	Hydrolysis - Sugar Extraction				
	Particle Board - Test and Production				

Appendix B, Page 5, Research and Development Projects on Field Burning, Willamette Valley, Oregon, 1968-1988 (continued)

Alternative Sanitation	Straw Utilization	Alternative Crops	Smoke Management	Health Effects	Total Costs
1976 (continued)					
	Potting Media				
	Bales for Mulch				
		$10,000			NA
1977					
	Particle Board				
	Digestibility				
	Comparative Analysis of Feeding				
	Strawdust for Bedding				
					(Combined with 1978)
1978					
Field Sanitizer - Evaluation	Particle Board	Meadowfoam Seed Trials	Air Quality Surveillance	Health Effects of Burning	
Agronomic Effects of Non-Burn	Hydromulch - Market Analysis		Smoke Management R&D		
	Crew-Cutting				
	Straw Utilization		Emission Testing		
$168,000	$268,500	$14,000	$387,000	$23,000	$860,500
1979					
Sanitizer Evaluation	Battelle Straw Market Analysis	Meadowfoam Seed Production, 35 Acres	Air Quality Impact Studies	Breathmobile Study	
Crew-Cutting/ Less-than-Annual Burning	Mold Inhibition on Hydromulch		Emissions Testing		
			Plume Studies		
Crewcutter Dust Emissions Tests			Application Rapid Ignition		
			Fireline Strip-lighting Method		
			LIRAQ Verification		
$37,000	$37,000		$191,000	$7,000	$272,000
1980					
Crew-Cutting/ Less-than-Annual Burning	AREA's Biomass Burner Feasibility	Meadowfoam Seed Yield Studies	Acreage Validation.	Hospital Admissions Study	

Appendix B, Page 6, Research and Development Projects on Field Burning, Willamette Valley, Oregon, 1968-1988 (continued)

Alternative Sanitation	Straw Utilization	Alternative Crops	Smoke Management	Health Effects	Total Costs
1980 (continued)					
		Meadowfoam Seed Production, 14 Acres Meadowfoam Meal Fermentation	Plume and Fuel Studies FB Emission Factor Review		
$74,000	$4,000	$20,000	$88,000	$5,000	$191,000
1981					
Crew-Cutting/ Less-than-Annual Burning	Bale Injector Bale Burner, Phase I	Meadowfoam Yield Studies - Water stress, fertility, self-pollination	Meteorological Forecasting Study Acreage Validation Study	Diary Study Respiratory Patients	
$76,000	$13,500	$24,000	$50,000	$9,000	$172,500
1982					
Less-than-Annual Burning/ Growth Retardants Chemical Disease Controls Urea-Sulfuric	Bale Injector Straw Feeding Trials Bale Burner, Phase II	Meadowfoam Agronomic Studies - Selection, fertility, fertilization process, photosynthesis - 34 acre production Meadowfoam Oil Utilization - Market development - Oil processing			
$186,000	$62,000	$236,000			$484,000
1983					
Growth Retardants Urea-Sulfuric Tests Propane Flamer	Straw Market Survey Straw Feeding Trials Straw Mulch Tests Straw Bale Vegetable Production	Meadowfoam Agronomic - Nutrients, environmental factors, selection and crossing Meadowfoam Field Trials and Seed Production Meadowfoam Seed Dormancy			
$128,000	$34,500	$192,500			$355,000

Appendix B, Page 7, Research and Development Projects on Field Burning, Willamette Valley, Oregon, 1968-1988 (continued)

Alternative Sanitation	Straw Utilization	Alternative Crops	Smoke Management	Health Effects	Total Costs
<u>1984</u>					
					$355,000
Control Ergot/ Blind Seed Diseases Minimum Till/ Non-Burning Rotation System Economic Analysis Less-than-Annual Burning Urea-Sulfuric Tests	Cooperative Straw Feeding Trials Straw Bale Burner Monitoring Straw Bale Vegetable Production	Meadowfoam Seed Yield Increase - Temperature, fertility, pollination Meadowfoam Field Trials Meadowfoam Seed Dormancy Meadowfoam Market Development Pyrethrum Production and Physiology	(Experimental Evening Burning Tested) (Grower Survey)		
$47,000	$20,000	$163,000			$230,000
<u>1985</u>					
Control Ergot/ Blind Seed Diseases Minimum Till/ Non-Burning Rotation System Urea-Sulfuric Tests	Grass Pellet Heaters Straw Pelletizer	Meadowfoam Yield Increase - Temperature, pollination, yield trials, selection Meadowfoam Field Trials Meadowfoam Seed Technology Pyrethrum Production and Physiology	(Experimental Evening Burning Employed)		
$50,000	$35,000	$136,000			$221,000
<u>1986</u>					
Minimum Till/ Non-Burning Rotation System Decomposition of Crown Growth and Straw Alternate Control of Ergot/Blind Seed Diseases	Straw Pelletizing Evaluation	Meadowfoam Yield Increase Meadowfoam Market Development Meadowfoam Oil Composition and Stability Meadowfoam Seed Technology Pyrethrum Seed Technology	Emissions Sampling of Propane Flaming and Stack Burning	Health Effects Study Evaluation of Field Burning R&D Program	

Appendix B, Page 8, Research and Development Projects on Field Burning, Willamette Valley, Oregon, 1968-1988 (continued)

Alternative Sanitation	Straw Utilization	Alternative Crops	Smoke Management	Health Effects	Total Costs
1986 (continued)					
$39,940	$13,900	$192,521	$39,146	$15,000	$300,500
1987					
Minimum Till/ Non-Burning Rotation System Alternate Control of Ergot/Blind Seed Diseases	Straw Decomposition Tissue and Soil Nutrient Survey	Meadowfoam Market Development Meadowfoam Oil/Seed Yield Increase		Health Effects Peer Review	
$39,489	$46,067	$154,110		$14,825	$255,000
1988					
Minimum Till and Non-Burning System Effect of Soil pH on P Availability and Herbicide Efficacy Distribution/ Severity of Ergot and Blind Seed Disease in Willamette Valley Development of Farming Systems under Non-Burning Management Survey of Propane Flaming Assessment-Impacts of Propane Flaming and Stack Burning Field Burning Training Video	Ryegrass in Pulp and Paper Product Research/ Nonreturnable Strawboard Pallets Straw Decomposition Study	Meadowfoam Oil/Seed Yield Increase Meadowfoam Market Development			
$134,776	$62,154	$120,600			$317,500
Grand Total					
$1,870,205	$1,542,621	$1,342,731	$1,520,146	$293,825	$6,550,000

Source: Oregon Department of Environmental Quality Annual Field Burning Report, 1986 Evaluation of Field Burning R&D Program, Nero and Associates, Inc., and Oregon State University Agricultural Experiment Station files.

APPENDIX C

IMPLICATIONS TO WILLAMETTE VALLEY GRASS SEED PRODUCERS OF THE FOOD SECURITY ACT OF 1985

The Food Security Act of 1985 (1985 Farm Bill) contains two sections which can directly influence a grower's cropping decisions in western Oregon. These sections are entitled Wetland Conservation (Swamp Buster) and Conservation Compliance.

Under the Wetland Conservation provision, soils that are classified as hydric may not be drained (or have drainage improved) in order to allow for annual crop production. Drainage would result in immediate loss of all USDA program benefits such as price and income support programs, federal crop insurance, FmHA loans, CCC storage payment and CRP payments. Annual crops can be grown if no drainage improvements are made.

Under this provision, most grass seed fields on Dayton-type soils in the southern Willamette Valley would be classified as prior converted farmed wetlands. These are wetlands where simple drainage improvements, such as, surface drainage, have made cropping possible. Maintenance of existing drainage systems is allowed under the Food Security Act. Further drainage improvement of such soils would not be allowed and would be considered to be conversion, unless drainage improvement was initiated prior to December 23, 1985. The sub-surface drainage required to raise winter annual crops other than the grass seeds and meadowfoam could not be put in unless the grower was prepared to lose USDA farm program benefits on his/her farm as a whole. Additionally, cost-sharing with the Soil Conservation Service for soil drainage is no longer allowed. The full cost of drainage systems would be borne by the individual grower. Therefore, improvement of Dayton-type soils through drainage would carry a substantial penalty for many growers.

The other provision of the Food Security Act that has potential impact on Willamette Valley growers is the Conservation Compliance Provision. Under this provision, growers with highly erodible soils must develop a conservation plan that is acceptable to the Soil Conservation Service. This plan is to be developed by January 1, 1990 and implemented by January 1, 1995. In many parts of the central Willamette Valley (Silverton Hills, foothill areas, etc.), perennial grass seed crops are included as a part of the conservation plan. Perennial grass seed crops, are a valuable part of conservation plans since soil disturbance is minimized over extended periods of time. The presence of a three to four year stand grass seed crop allows growers to raise other crops such as grains and clovers since average soil erosion over a five to ten year period is below allowed levels. The removal of grass seed crops from rotations or the shortening of crop stand life would negatively impact a grower's ability to comply with soil loss requirements. Non-compliance results in immediate loss of all USDA farm program benefits.

APPENDIX D

FIELD MANAGEMENT OPTIONS FOR PERENNIAL GRASS SEED FIELD

Figure 1. Straw management options in the absence of annual burning for production of perennial ryegrass (forage type) seed crop in the Willamette Valley.

WINDROW → COMBINE			Post harvest management cost per acre: Full cost	Straw removed at no cost
SPREAD STRAW	OPEN BURN (4 t/a)	Labor & fee	$8.90	
		Total	$8.90	
REMOVE ALL STRAW (3 t/a)	PROPANE FLAME (1 t/a)	Propane	$32.00	$32.00
		Straw removal	$37.50	$ 0.00
		Stack burn	$ 0.50	$ 0.00
		Total	$70.00	$32.00
	FLAIL CHOP (Stack hand) (1/2 t/a)	Straw removal	$37.50	0.00
		Flail chop	27.55	27.55
		Stack burn	0.50	0.00
		Total	$65.55	$27.55
	CREW CUT (1 t/a)	Straw removal	$37.50	$ 0.00
		Cut and Vacuum	$36.00	$36.00
		Stack burn	$ 0.50	$ 0.00
		Total	$74.00	$36.00
	CHEMICAL TREATMENT	Enquik (mat. & applic.)	$33.00	$33.00
		Straw removal	$37.50	$ 0.00
		Stack burn	$ 0.50	$ 0.00
		Total	$71.00	$33.00

Source: Miles, 1977; Cornelius, 1985, Youngberg, *et al.*, 1984.

Notes: 1) Estimated yearly crop production cost - $350 per acre; 2) Costs of less than annual burning will be increased as listed above, depending on the treatment method used.

Figure 2. Costs associated with shorter rotation seed production of perennial ryegrass in the Willamette Valley.

		Post harvest management cost per acre	
		Full cost	Straw re-removed at no cost
SHORT ROTATION (2 yr.)	Incr. amortized establishment [1]	$30.00	$30.00
	Straw removal	$37.50	$ 0.00
	Stack burn	$ 0.50	$ 0.00
	Reduced seed yield[2]	$68.00	$68.00
	Total	$136.00	$98.00

[1] Based on $53.30 per year for 4 years = $213.19 ($161.90 + int @ 12%)

[2] Based on 15% yield reduction, 900 pound per a average yield, and price of $0.50 per pound

Figure 3. Straw management options in the absence of annual burning for production of annual ryegrass seed crop in the Willamette Valley.

WINDROW → COMBINE

			Post harvest management cost per acre
→ SPREAD STRAW	OPEN BURN (4- 6 t/a)	Labor & fee	$8.90
		Total	$8.90
→ REMOVE STRAW (2 - 4 t/a)	CHOP & PLOW IN (2 t/a)	Straw removal	$24.00
		Chop Stubble	10.00
		Herbicide	30.00
		Annual Tillage	35.00
		Total	$99.00

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Footnote 16

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Low-Input On-Farm Composting of Grass Straw Residue

in cooperation with the Agricultural Experiment Station, Oregon State University, Corvallis

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Low-Input On-Farm Composting of Grass Straw Residue

in cooperation with the Agricultural Experiment Station,
Oregon State University, Corvallis

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Abstract

Churchill, D.B., W.R. Horwath, L.F. Elliott, and D.M. Bilsland. 1998. Low-Input On-Farm Composting of Grass Straw Residue. U.S. Department of Agriculture, Agricultural Research Service, ARS–142, 32 pp.

In cropping fields of grass seed, straw removal is required to promote tiller growth and reduce pest incidence. In the past, straw removal was done by open field burning, which is being phased out in many regions through legislative mandates. Composting grass residue provides a possible alternative to open field burning in grass seed and other cropping systems in which plant residue waste presents cultural management problems.

Laboratory and field studies showed that composting of grass seed straw with a C:N ratio above 30:1 was feasible without the addition of N or water beyond normal yearly rainfall. Repeated turning with a front-end loader or a straddle-type turner to encourage decomposition reduced the straw volume significantly. Two turns with a flail-type compost turner or four or more turns with a front-end loader during decomposition reduced the bulk straw volume in windrows by 80 percent. More turns reduced the straw bulk by 88 percent and influenced the quality of the end product. The cost of on-farm composting of straw ranges from as low as $47 per hectare ($19 per acre) to more than $62 per hectare ($25 per acre), depending on the equipment used for windrow formation and turning.

This report will be useful to grass seed growers in the Pacific Northwest and to professional and technical workers concerned with recycling farm products.

Keywords: carbon mineralization, composting, crop residue, C:N ratio, decomposition, field composting, microorganisms, perennial ryegrass, straw, straw composting, thermophiles

While supplies last, single copies of this publication may be obtained at no cost from Donald Churchill, USDA–ARS, National Forage Seed Production Research Center, 3450 S.W. Campus Way, Corvallis, OR 97331–7102.

Copies of this publication may be purchased from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161; telephone 703–605–6000.

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Introduction

Grass seed growers in Oregon's Willamette Valley produce 1 million tonnes of crop residue in the form of straw on roughly 150,000 ha of fields used for grass seed production (Young et al. 1993). Removal of this straw has been considered essential to reduce many weed and disease problems and to prevent residues from inhibiting seed production. However, mechanical removal of straw has historically been troublesome and cost prohibitive.

During the 1940s, it was discovered that burning straw in the fields helped maintain profitable yields while controlling weeds, invertebrates, and fungal diseases, and for several decades open field burning was standard practice in the region's grass seed cropping systems. More recently, public concern for the environmental consequences of open field burning led to legislation that severely restricts this practice (Young et al. 1993). Open field burning may be entirely eliminated within the next few years. Without another means of straw removal, increased potential exists for disease, insect, and weed seed problems in grass seed lots. Other forms of disposal in the field, such as shredding and chopping, have been investigated (Young et al. 1993), but none have been entirely satisfactory.

Low-input, on-farm composting of grass seed straw is an alternative to thermal and mechanical residue removal (Churchill et al. 1995). Low-input composting systems have an important role in maintaining and improving soil quality and optimizing nutrient cycling (Hornick et al. 1984). Crop residues are critical components of processes that maintain soil quality and conserve nutrients. Composting is one method of handling crop residues to reduce their volume and render them useful for agriculture.

The main obstacles for perennial ryegrass (*Lolium perenne*) straw decomposition are that the straw residue often has a C:N ratio greater than 50:1 and lignocellulose can comprise over 70 percent of the grass residue by weight (Horwath and Elliott 1996a,b). Previous theory suggests that it is often impractical to compost organic residues with C:N ratios greater than 30:1 (Gouleke 1991). The main purpose of the laboratory and field studies discussed in this publication was to determine whether crop residues such as grass straw (with C:N ratios of 50:1 or greater) can be successfully composted in the field without co-composting them with an additional N source. Chemical, microbial, and environmental changes that occur during composting were also evaluated in these studies.

Decomposition During Composting

Composting is a microbially mediated exothermic process that occurs in an aerobic thermophilic environment (Rynk 1992). Factors such as moisture, temperature, the chemical form of carbon (that is, the level of cellulose, lignins, and so forth), and the form and level of nitrogen are major variables affecting the rate of the process. For the decomposition of perennial ryegrass straw, the magnitude and rate of microbial activity and byproduct production is expected to be slow compared to rates for materials such as food waste or grass clippings.

The initial stages of plant residue decomposition are characterized by the mineralization of labile components, leaving refractory components intact (Reinertsen et al. 1984, Stroo et al. 1989, Kogel-Knabner 1993). In the later stages of decomposition, recalcitrant components, such as lignin, are mineralized. The biodegradation of refractory substances [or substances that associate with refractory substances, such as lignin (that is, lignocellulose) or melanins] is intrinsically limited by their chemical structure—that is, conformational limitations exist between the refractory substance and degradative enzymes. (Haider 1986, Kogel-Knabner 1993). Describing the alteration and degradation of plant components during decomposition is difficult, due to limitations in methodology that make it impossible to distinguish among components or products of plant origin, microbial production, and decomposition (Paul and van Veen 1978).

Four phases (or stages) occur when composting perennial ryegrass in the field (fig. 1). In the first phase of decomposition (the mesophilic phase), the change in the organic C and N content of the substrate is based on the effectiveness of the composting method and determines the maturity of the resultant composted product. The stages of decomposition can be objectively determined by the decrease in C as volume reduction occurs with the metabolic reduction of carbohydrates to CO_2. The stabilization of the substrate to its ultimate humic product generally can be characterized by the C:N ratio.

With sufficient moisture, the second phase of composting occurs (the thermophylic phase). This phase begins in winter and can extend into early spring. For several weeks, little apparent change occurs despite adequate moisture and obvious exothermic activity. This second phase coincides with a period in which the most labile C fraction is consumed by a consortium of thermophiles, but with little effect on the lignocellulose fraction.

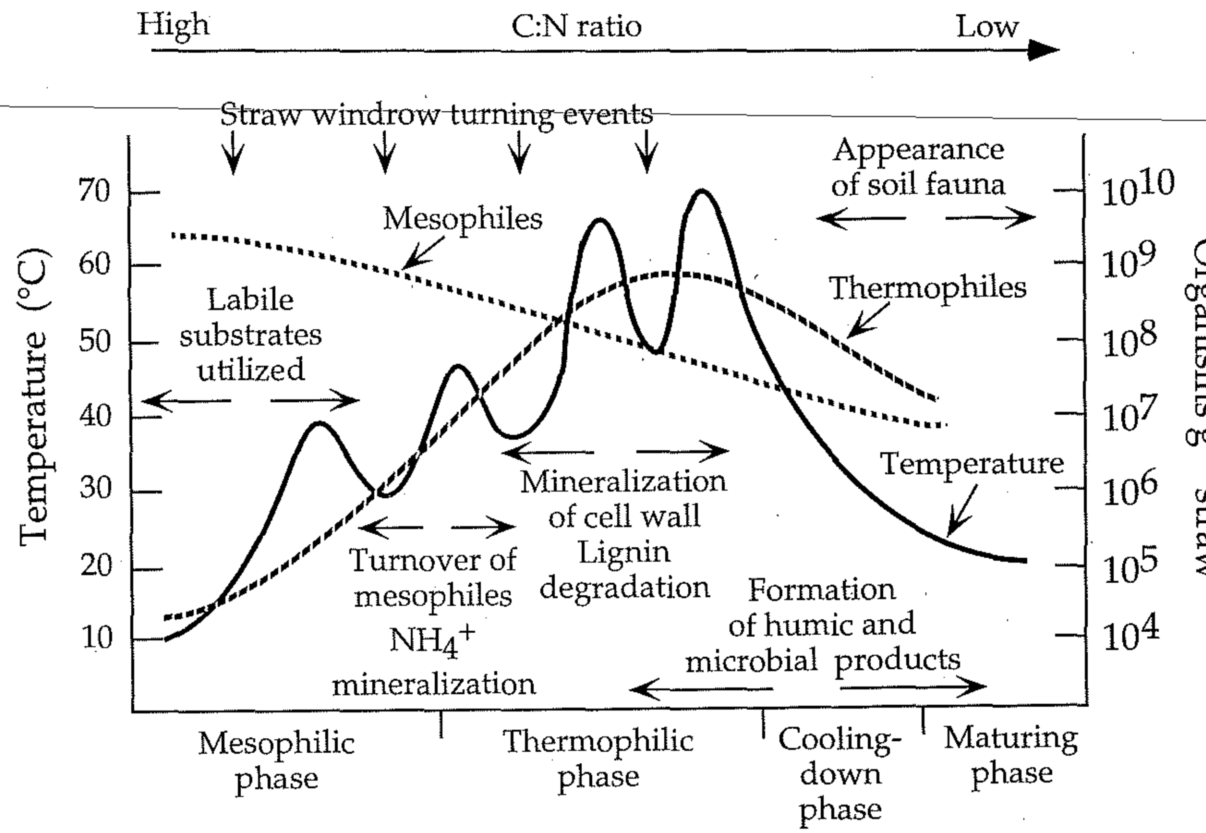


Figure 1. Summary of the four phases of field composting of perennial ryegrass and the main biological and physical characteristics that occur in each phase

The third phase of active composting (the cooling phase) starts with the advent of warmer weather in the spring. Microbiological studies have determined that thermophilic fungi and actinomycetes are instrumental in the degradation of lignin. As the lignocellulose fraction is transformed, the substrate reaches a threshold of decomposition. At this stage there are pronounced changes in the apparent texture, tensile integrity, and color (it darkens) of the substrate. Turnings at this stage cause an increase in decomposition of the straw, resulting in dramatic volume reductions in a matter of 2–4 wk.

The last phase of composting is the curing (or maturing) phase, verified when the C:N ratio reaches 12:1 to 15:1. At this point the compost can be considered "done." Cured compost continues to degrade and lose volume in the field, becoming essentially soil. Turning the substrate further will not generate increased temperatures, but may be useful to prevent saturation and to maintain a friable texture of the compost.

Laboratory and Field Studies on Straw Composting

Laboratory incubations of mature perennial ryegrass straw were conducted at 25 and 50 °C (77 and 122 °F) to simulate mesophilic and thermophilic decomposition. The 50 °C treatment was started at 25 °C for days 1–5, then raised to 50 °C for days 6–25, then lowered to 25 °C for days 26–30, and then raised again to 50 °C for days 31–45. The staggered high-temperature (HT) treatment was imposed to simulate temperature fluctuations that occur during field composting, particularly temperature losses that occur during compost turning. The level of C, H, O, N, lipids, sugars, protein, soluble polysaccharides, cellulose, lignin, CO_2 evolution, microbial biomass, bacteria, fungi, soluble C, and actinomycetes in the straw was measured during the decomposition process (Horwath and Elliott 1996a,b). Straw lignin decomposition was measured by two methods.

Perennial ryegrass straw was also composted in the field, and data from the field were collected and compared with laboratory data. Perennial ryegrass straw was placed in nylon 32-by-32 mesh bags, and the bags were inserted into the compost stacks in the field at various depths. The samples were retrieved and analyzed at intervals during composting. Measurements of bacteria, fungi, actinomycetes, cellulose, xylanase, protease, organic N, lignin, straw lipid, sugars, protein, soluble polysaccharides, and weight loss were made on the straw samples (Horwath and Elliott 1996a,b).

Laboratory Studies

Chemical changes during decomposition

Levels of labile components (C, H, O, and N) of straw residue were monitored in our studies to determine the degree of decomposition. The concentration of C, H, and O in the straw remained similar throughout the 45-day decomposition period in both low-temperature (LT) and high-temperature (HT) treatments (table 1). The content of N in the straw during decomposition decreased from 11.2 g kg^{-1} of straw to 8.6 g kg^{-1} and 7.5 g kg^{-1} of straw in the LT and HT treatments, respectively. The content of C in the straw during degradation decreased by 175.7 g kg^{-1} and 237.1 g kg^{-1} of straw for the LT and HT straw treatments, respectively. The percentage loss of H was similar to the percentage loss of C. The loss of O was 215.8 g kg^{-1} of straw in the LT treatment and 271.6 g kg^{-1} of straw in the HT treatment. The C:N ratio decreased from 40:1 to 32:1 in the LT treatment and to 28:1 in the HT treatment. According to Biddlestone et al. (1987), mature compost C:N ratios vary from 15:1 to 20:1, indicating the decomposed straw in our laboratory study was immature.

The change in straw chemical fractions during decomposition reflects the mineralization of straw components and increases in microbial products (Paul and Clark 1989, Kogel-Knabner, 1993). All the straw components measured decreased during the LT treatment. Cellulose decreased from 562.1 g kg^{-1} of fresh straw to 297.8 g kg^{-1} of straw, representing the largest loss of all the chemical fractions measured (table 2). Lipids increased from 33.1 g kg^{-1} of fresh straw to 38.3 g kg^{-1} of straw on day 7 and then decreased to 23.5 g kg^{-1} of straw after 45 days of incubation at the low temperature. Similarly, soluble polysaccharides increased from 17.1 g kg^{-1} of fresh straw to 21.8 g kg^{-1} of straw on day 3 and then decreased to 10.1 g kg^{-1} of straw. Soluble sugars decreased from 33.0 g kg^{-1} of fresh straw to 6.9 g kg^{-1} of straw. Klason lignin steadily decreased from 121.5 g kg^{-1} of fresh straw to 113.0 g kg^{-1} of straw in the LT treatment. The initial increase in chloroform-soluble material and water-soluble polysaccharides indicates microbial production of membranes and extracellular polysaccharides (Horwath and Elliott 1996b).

Table 1. Mean concentrations of C, H, O, and N and C:N ratio in straw on day 0 and after 45 days of incubation at low temperature (LT) and high temperature (HT)

		Concentration (g kg^{-1})				
Day	Treatment	C	H	O	N	C:N
Undecomposed straw						
0		450.3 (0.7)	68.2 (0.5)	470.3 (0.8)	11.2 (0.4)	40:1
Decomposed straw						
45	LT	468.6 (10.8)	82.6 (2.2)	434.2 (13.3)	14.7 (0.5)	32:1
45	HT	467.3 (17.6)	80.6 (2.5)	435.6 (20.8)	16.5 (0.7)	28:1
Original content remaining after decomposition						
45	LT	274.6 (6.2)	48.4 (1.3)	254.5 (9.1)	8.6 (0.3)	
45	HT	213.2 (8.0)	36.8 (1.2)	198.7 (9.5)	7.5 (0.3)	

Source: Horwath and Elliott (1996b).
Note: Standard deviations are in parentheses.

Table 2. Mean chemical content of straw during decomposition at low and high temperatures

Day	Chemical composition of straw (g kg^{-1}) Lipids	Sugar	Soluble polysaccharides	Cellulose	Lignin
Low-temperature incubation					
1	33.1 (1.8)	33.0 (2.5)	17.1 (1.7)	562.1 (26.2)	121.5 (1.8)
3	33.7 (0.1)	13.3 (0.3)	21.8 (0.2)	542.0 (35.7)	127.9 (6.9)
7	38.3 (1.4)	9.8 (0.6)	19.0 (3.6)	481.9 (7.5)	125.6 (7.6)
12	31.5 (1.4)	8.2 (0.4)	11.4 (1.5)	450.8 (13.6)	125.1 (3.8)
20	26.9 (1.5)	7.3 (1.0)	11.1 (0.8)	381.8 (3.8)	122.2 (1.0)
30	26.4 (1.4)	7.0 (0.9)	8.9 (2.6)	312.9 (11.8)	114.1 (1.8)
45	23.5 (3.5)	6.9 (0.6)	10.1 (1.6)	297.8 (12.7)	113.0 (2.1)
High-temperature incubation					
6	43.7 (1.5)	12.6 (1.0)	13.7 (1.2)	513.8 (23.1)	119.1 (2.3)
8	38.0 (2.5)	7.5 (0.7)	12.3 (0.7)	522.2 (35.8)	119.5 (6.0)
12	35.0 (1.5)	17.9 (3.8)	9.0 (1.1)	315.8 (29.7)	109.1 (2.1)
17	30.4 (2.9)	16.7 (0.8)	8.9 (2.5)	289.0 (40.7)	106.0 (5.6)
25	26.0 (4.1)	11.6 (1.2)	6.2 (0.8)	219.4 (24.0)	102.8 (6.2)
30	25.6 (1.9)	6.1 (1.2)	6.1 (1.2)	185.5 (18.4)	102.4 (8.5)
45	18.7 (1.1)	9.7 (0.9)	5.6 (0.3)	213.8 (9.4)	89.0 (1.7)

Note: Standard deviations are in parentheses.

In the HT treatment, the straw chemical fractions were mineralized more rapidly and to a greater extent than those in the LT treatment (table 2). Cellulose decreased from 562.1 g kg^{-1} of fresh straw to 213.8 g kg^{-1} of straw. Lipids increased from 33.1 g kg^{-1} of fresh straw to 43.7 g kg^{-1} of straw on day 6 and then decreased to 18.7 g kg^{-1} of straw. Soluble sugars decreased from 33.0 g kg^{-1} of fresh straw to 9.7 g kg^{-1} of straw in the HT treatment. Soluble polysaccharides decreased from 17.1 g kg^{-1} of fresh straw to 5.6 g kg^{-1} of straw. Klason lignin decreased from 121.5 g kg^{-1} of fresh straw to 89.0 g kg^{-1} of straw.

Lignin has been reported to be the slowest of all plant components to decompose (Minderman 1968, Aber and Melillo 1991, Kogel-Knabner 1993). The Klason lignin method has been used extensively to determine lignocellulose loss in plant decomposition studies (Kirk and Obst 1988), and many ecological and agricultural field studies have used this method to determine lignin loss because of its simplicity (Kirk and Obst 1988, Aber and Melillo 1991). The Klason lignin method also has been used extensively to determine changes in substrate during composting and mushroom culture (Chang 1967, Flaig 1969, Haider 1969, Tsang et al. 1987).

Lignin C decreased 25 and 39 percent in the LT and HT treatments, respectively, as determined by elemental analysis of the Klason lignin fraction (table 3). This compared with a decline in the lignin fraction of 10 and 29 percent in the LT and HT treatments, respectively, as determined by the Klason lignin method. N in the lignin fraction increased by 12 percent in the LT treatment and 16 percent in the HT treatment (table 3). The loss of lignin H was similar to that of C in both treatments. The mass of O remained similar to that found in undecomposed straw in the HT treatment and increased to 127 percent in the LT treatment. The constant or increased level of O and loss of C and H indicated that the lignin fraction was oxidized during decomposition. Reviews of degradative reactions during lignin decomposition indicate that increases in O content occur through the oxidative splitting of side chains and oxidative ring cleavage to form carboxylic acid groups (Kirk 1971, Flaig et al. 1975, Chang et al. 1980, Crawford 1981, Kirk and Farrell 1987, Kogel-Knabner 1993).

Table 3. Mean change in element concentration in the lignin fraction of low-temperature (LT) and high-temperature (HT) treatments

	Percentage of elements remaining after degradation			
Treatment	C	H	O	N
LT	75.0 (0.4)	75.1 (0.9)	126.5 (5.5)	111.6 (9.2)
HT	61.3 (0.3)	60.0 (0.8)	98.2 (3.7)	116.1 (6.7)

Note: Standard deviations are in parentheses.

The shift in the elemental ratios of the decomposed lignin fraction indicated a greater change than that determined by the Klason method (table 4). The increased N and decreased C contents of the lignin fraction resulted in a reduction in the C:N ratio from 52.9:1 in undecomposed straw to 35.6:1 and 28:1 in the LT and HT treatments, respectively. The C:O ratio decreased from 2.4:1 to 1.4:1 and 1.5:1 in the LT and HT treatments, respectively. The C:H ratio changed little, indicating that the loss of C and H was similar in both treatments. Approximately 6 percent of the original lignin was unaltered in both treatments. The percentage of altered lignin was calculated from the change in element ratios between undegraded lignin and degraded lignin. The increased N content of the decomposed lignin suggests that humic substances are formed during decay of the straw (Flaig et al. 1975, Kogel-Knabner 1993). Other composting studies of straw residues show similar increases of N in the analyzed ligninlike fraction, using the Klason method (Bremner 1954, Flaig 1969, Haider 1969, Hammouda and Adams 1987).

Flaig et al. (1975) and Volk and Loeppert (1982) found that elemental ratios in the decayed lignin fraction closely resembled those of soil organic matter. These findings were similar to those of other studies in which different methods were used to determine lignin degradation in different plant materials (table 5). These other studies indicate that the lignin fraction was both chemically altered and contaminated with microbial products and humic substances. The result is that the lignin elemental ratios become similar to those in soil organic matter.

The composting of plant residues often leads to the accumulation of humic substances (Hammouda and Adams 1987). Horwath and Elliott (1996a,b) showed that the decomposition of lignin C, as determined by the Klason method, was greater in the HT (39 percent) than in the LT (29 percent) treatment. They also showed that the accumulation of nitrogen in the acid insoluble fraction was greater in the HT treatment (2 percent) than in the LT treatment (1.5 percent). Thus decomposition differences between the two temperatures influenced the characteristics and quality of the degradation end products.

The extensive alteration and decomposition of lignin throughout the 45 days of our recent study provides evidence of why grass straw composts successfully in the field without the addition of N to lower the C:N ratio. The results indicate that lignin was degraded concomitantly with the other straw components measured. In earlier studies, Churchill et al. (1993) found that ryegrass volume decreased by 80 percent during 20 wk of field composting. This reduction in volume would not have been possible if it weren't for the breakdown of lignin. The breakdown of lignin likely increases the availability of cell-wall polysaccharide and related compounds for microbial use (fig. 2). The relationships among the formation of humic materials, the alterations in the lignin fraction, and the production of microbial byproducts are poorly understood (Kogel-Knabner 1993). Understanding the degradation of the lignin fraction during plant residue decomposition and composting will lead to practices that can tailor the end product to specific uses and provide insights on the nature and origin of humic substances in soil.

Microbial and soluble C and N

Microbial C was similar (22 mg C g^{-1} of straw) on day 3 in both the LT and HT treatments (HT treatment maintained at 25 °C for the first 5 days) (fig. 3). Microbial C in the LT treatment remained relatively constant for 20 days and then decreased to 8 mg C g^{-1} of straw by day 45. Soluble organic C in the LT treatment was 31 mg C g^{-1} of straw on day 1 and then decreased to 20 mg C g^{-1} of straw by 45 days. The slowly declining level of soluble C indicated that a portion of this C fraction was not readily biodegrad-

Table 4. Element ratios in the lignin fraction of low-temperature (LT) and high-temperature (HT) treatments

Treatment	Mean ratio C:H	Mean ratio C:O	Mean ratio C:N
Day 0	7.8	2.4	52.9
LT	7.8	1.4	35.6
HT	8.0	1.5	28.0

Table 5. Element content of straw before and after lignin degradation

Lignin	Days decomposed	Element content of straw (percent of total)			
		C	H	O	N
Perennial ryegrass*	0	64.02 (4.45)	8.19 (0.62)	26.58 (5.19)	1.21 (0.14)
Perennial ryegrass*	45	53.84 (1.07)	6.90 (0.08)	37.75 (1.06)	1.51 (0.11)
Perennial ryegrass*	45	54.78 (0.66)	6.85 (0.14)	36.41 (0.77)	1.96 (0.11)
Ryegrass†	0	63.10	5.92	30.67	0.54
Ryegrass‡	180	61.15	5.42	32.42	1.75
Ryegrass§	0	62.73	5.64	30.55	0.53
Ryegrass§	180	62.20	5.41	31.30	0.56
Wheat straw‖	0	63.39	5.41	30.98	0.22
	180	60.40	5.66	32.86	1.08

Note: Standard deviations are in parentheses.

* Horwath and Elliott (1996b).
† Freundenberg and Harkin (1964) (cited in Flaig et al. 1975).
‡ Maeder (1960) (cited in Flaig et al. 1975).
§ Flaig (1969).
‖ Flaig et al. (1975).

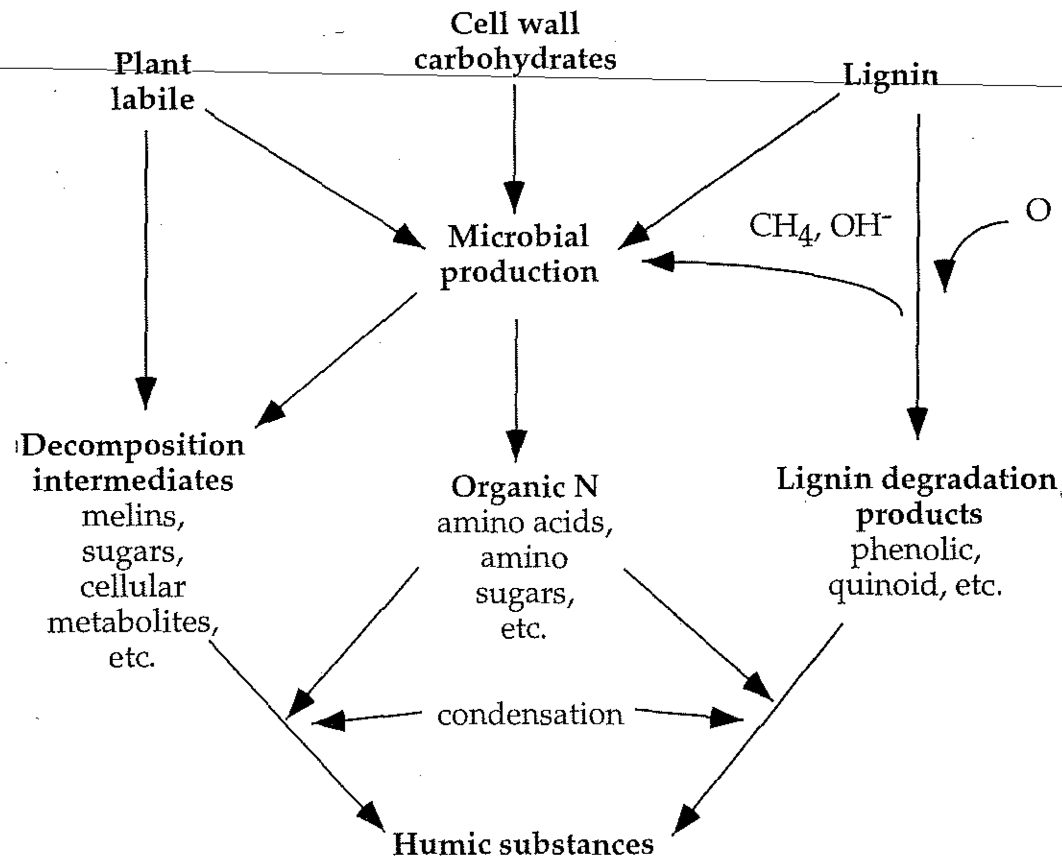


Figure 2. Proposed pathway for lignin degradation and formation of humic substances in decayed ryegrass straw

able. Microbial biomass C and respiration decreased throughout the incubation, supporting the hypothesis that there was no readily available C component.

Microbial C decreased to 4 mg C g^{-1} of straw after the temperature was increased to 50 °C. Microbial C in the HT treatment increased to 14 mg C g^{-1} of straw by day 15, remained constant to day 25, and then decreased to 4 mg C g^{-1} of straw by day 45. Soluble C in the HT treatment gradually increased to 39 mg C g^{-1} of straw after the temperature was increased from 25 to 50 °C and remained above 34 mg C g^{-1} of straw for the remainder of the HT incubation. Soluble C was approximately twice that found in the LT treatment, indicating that a greater proportion of this C fraction remained unavailable for microbial consumption in the HT treatment.

Microbial biomass N increased to 4.0 mg N g^{-1} of straw by day 3 in both the LT and HT treatments (fig. 4). In the LT treatment, microbial biomass N remained unchanged during the next 12 days, decreased to 1.7 mg N g^{-1} of straw by day 30, and increased to 2.8 mg N g^{-1} of straw at the end of the incubation. In the HT treatment, microbial biomass N decreased to less than 1 mg N g^{-1} of straw after the temperature was increased to 50 °C and then gradually increased to 2.1 mg N g^{-1} of straw by the end of the incubation. The increase in microbial N may indicate an accumulation of microbial byproducts, since microbial C decreased rather steadily in both treatments.

Soluble organic N remained below 0.5 mg N g^{-1} of straw in the LT incubation (fig. 4). Conversely, in the HT treatment it increased to 1.2 mg N g^{-1} of straw following the increase in temperature to 50 °C. The increase in soluble organic N during the transition from 25 to 50 °C on day 5 likely indicates the turnover of the mesophilic microbial population. Following the increase in temperature, soluble organic N fell below 0.5 mg N g^{-1} of straw after 20 days and remained constant for the remainder of the HT incubation.

Plating of microorganisms

Levels of bacteria, actinomycetes, and fungi for the LT and HT treatments were measured for the first 30 days of each incubation. In the LT treatment, plate counts of bacteria, actinomycetes, and fungi from the straw stabilized toward the end of the 30-day period at 10^9, 10^8, and 10^7 propagules g^{-1} of straw, respectively

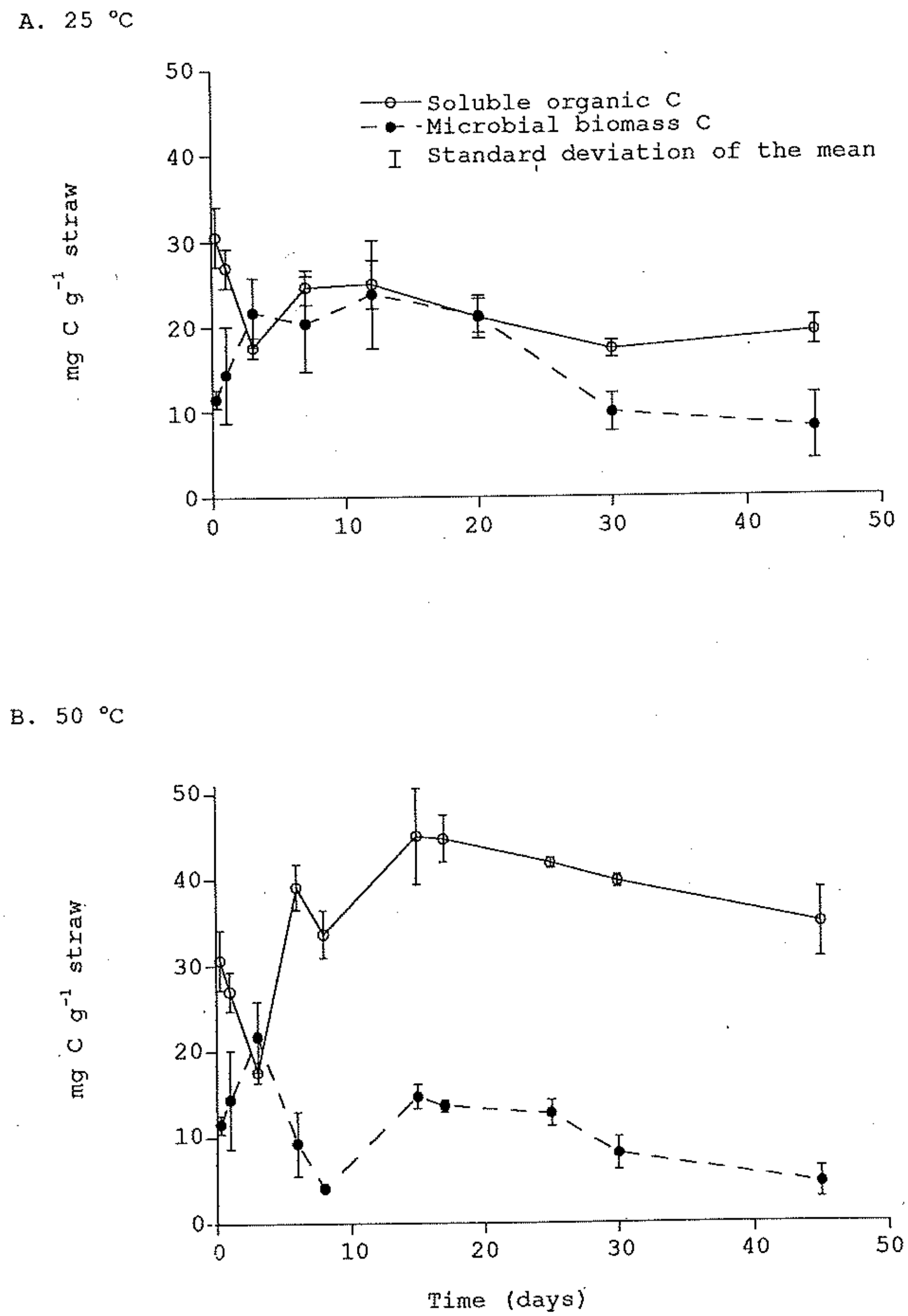


Figure 3. Microbial biomass C and soluble C levels in straw incubated for 45 days at *A*, low temperature (25 °C) and *B*, high temperature (50 °C)

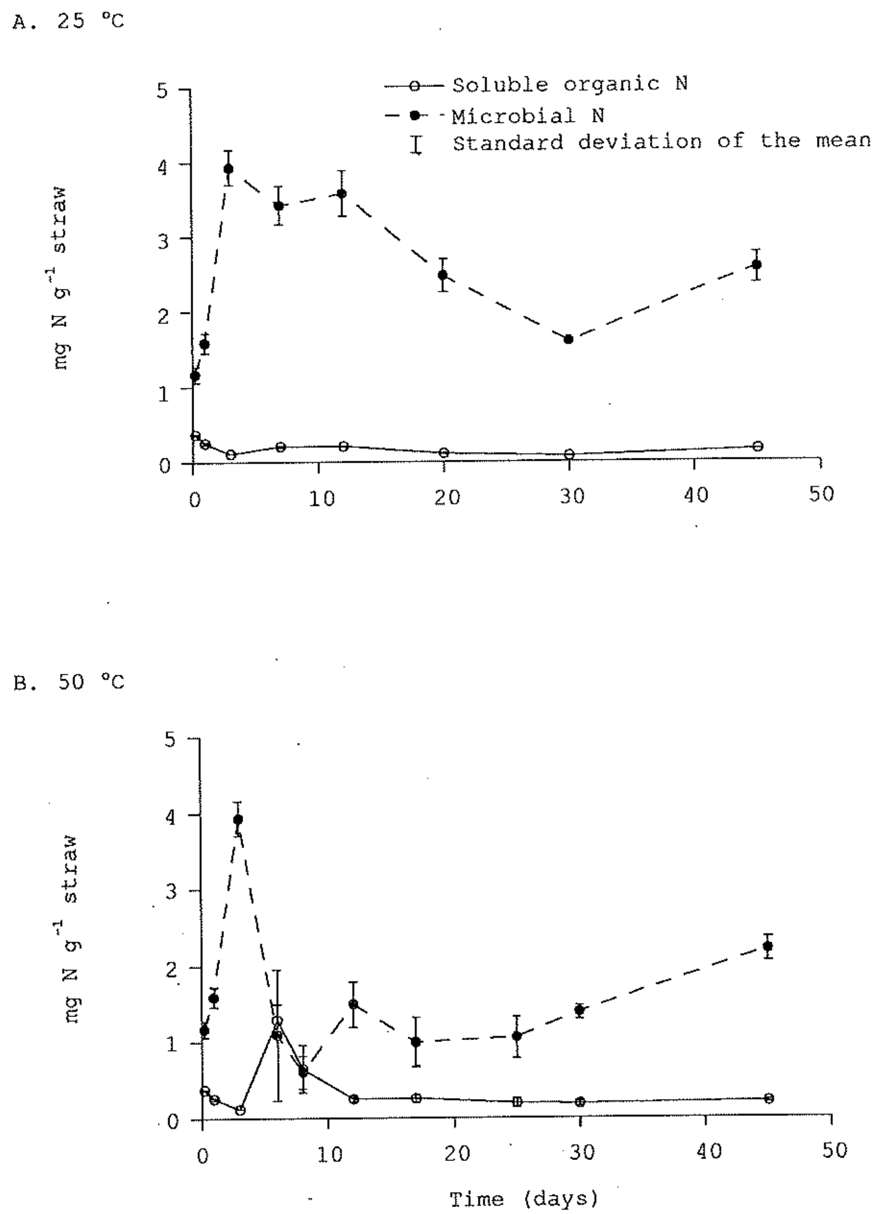


Figure 4. Microbial biomass N and soluble organic N in straw incubated for 45 days at *A*, low temperature (25 °C) and *B*, high temperature (50 °C)

(fig. 5). Actinomycetes and fungi required up to 5 days before plate counts remained constant in the LT treatment. Counts of all organisms except actinomycetes decreased when the temperature was increased from 25 to 50 °C in the HT treatment. Bacteria and fungi decreased an order of magnitude to 10^8 and 10^6 propagules g^{-1} of straw, respectively, in the HT treatment. On day 25, when the temperature was decreased from 50 to 25 °C in the HT treatment, no organisms were detected on agar plates incubated at 25 °C. The lack of microbes indicates that mesophilic organisms did not survive in detectable numbers in the thermophilic environment. The lack of thermophilic organisms at 25 °C also suggests that the organisms were obligate thermophiles.

These results showed that the inoculum potential of grass straw is sufficient to successfully degrade the straw. No additional inoculum was required to facilitate decomposition, and no additional N was needed to lower the combined C:N ratio of the straw substrate. Our initial field studies with grass seed straw composting provided similar results (Churchill et al. 1995). Adequate microbial inoculum in agricultural wastes has been demonstrated in other laboratory and field decomposition studies (Chang and Hudson 1967, Lacey and Dutkiewicz 1976, Lacey 1979, Biddlestone et al. 1987).

C mineralization

The total mineralization of perennial ryegrass straw C was similar at 25 and 50 °C during the 45-day laboratory incubation (46 percent and 52 percent of the total C, respectively). The majority of C mineralized from both of the temperature treatments (LT and HT) occurred by day 20. The addition of N to lower the C:N ratio of the straw decreased C mineralization in both treatments (fig. 6). The results indicate that maximum decomposition occurred without the addition of N.

The similarity in straw C mineralization in the LT and HT treatments without N addition can be explained by relating the C mineralization activity to microbial biomass C (fig. 7). The respiratory quotient (total C mineralized divided by microbial biomass C) for the HT treatment was approximately twice that of the LT treatment. In the HT treatment, the increased C mineralization was associated with respiratory activity, not an increase in the microbial biomass. The thermophiles required less biomass C and N than the mesophiles to decompose approximately twice as much C per unit of microbial biomass.

Successful composting of organic residues is thought to require a C:N ratio of 25:1 to 30:1 or less (Biddlestone et al. 1987). In our studies, however, the addition of N to the straw decreased C mineralization in both the 25 and 50 °C treatments. These data show that the C:N ratio of the straw is not indicative of how well straw will compost. In addition, these results show that additional N is not required to successfully compost grass straw.

The difference in microbial biomass C and N, and similar C mineralization kinetics in the LT and HT treatments indicates that substrate-use efficiency varied under the two temperature treatments. Microbial substrate-use efficiencies can decline in thermophilic regimes in response to increased metabolic rates and cell-maintenance requirements (Amelunxen and Murdock 1978). To accurately assess substrate-use efficiency, a distinction between microbial production and substrate depletion must be determined. Horwath and Elliott (1996a) reported a change in the biochemical fractions of perennial ryegrass straw incubated at 25 and 50 °C. Using their data and the C-mineralization data reported here, a simulation of microbial production and distinction between changes in residue fractions can be estimated by the following equation:

$$C=C_i[1+Y/(100-Y)] \quad [1]$$

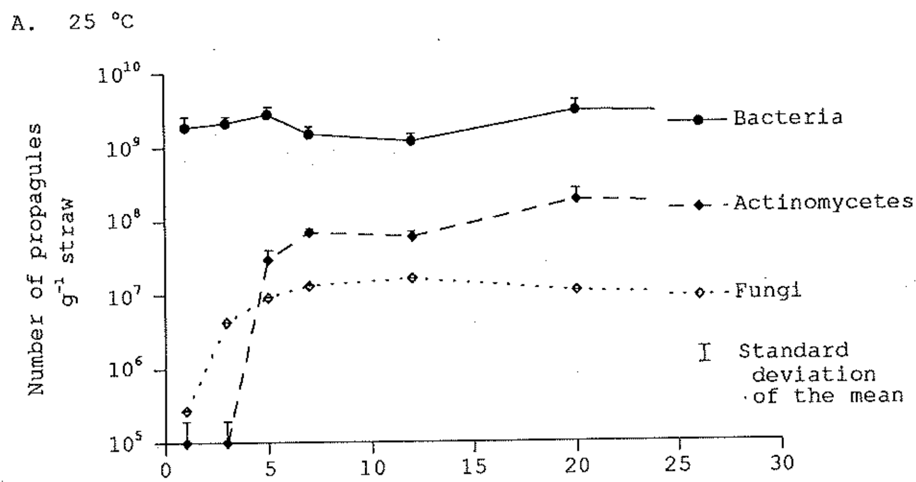
where

C = the amount of substrate decomposed,
C_i = the amount of CO_2–C mineralized, and
Y = the biosynthesis efficiency of the C, expressed as a percentage of the total C used for the production of microbial material (Paul and Clark 1989) (fig. 8).

Straw labile components are estimated to be used in approximately 10–15 days in both the LT and HT treatments. Approximately half of the straw cell-wall components (polysaccharides and lignin) were degraded in the HT treatment during the 45-day incubation (fig. 8). Microbial substrate-use efficiency, on a total straw basis, was 34 percent and 28 percent in the LT and HT treatments, respectively. The difference in microbial biomass size and substrate-use efficiency at 25 and 50 °C may lead to changes in the end products from the decomposition process.

Field Studies

Successful straw composting in the field requires creating an appropriate composting environment with proper moisture, aeration, and substrate nutrients so that thermophilic temperatures can be generated. The proper conditions and higher temperatures are needed to promote the growth of thermophilic bacteria and fungi that consume the straw. The higher temperatures also kill weed seeds, crop disease organisms, and insect pests. During composting, temperature readings



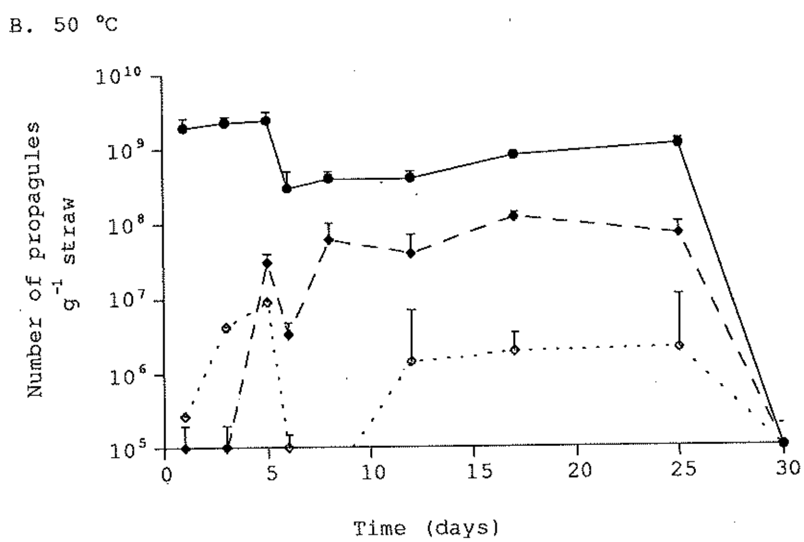
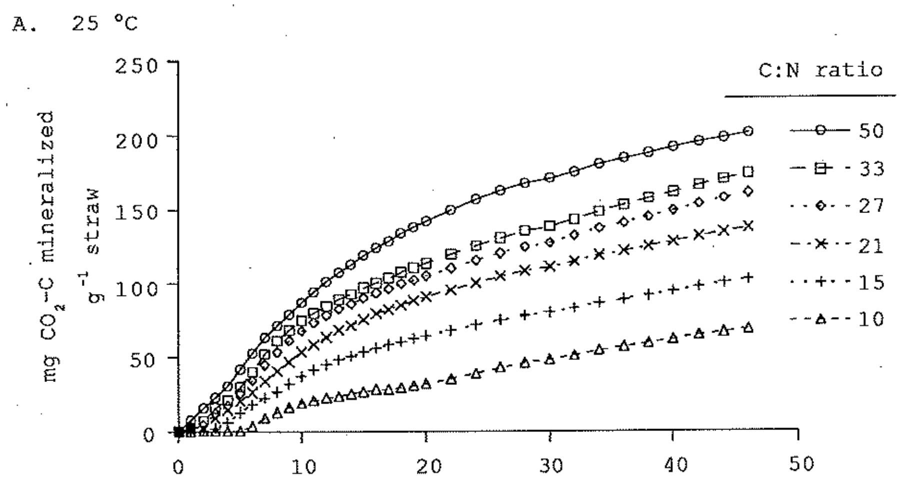


Figure 5. Number of microorganisms in straw (determined by plate count) during the first 30 days of a 45-day incubation at *A*, low temperature (25 °C) and *B*, high temperature (50 °C)



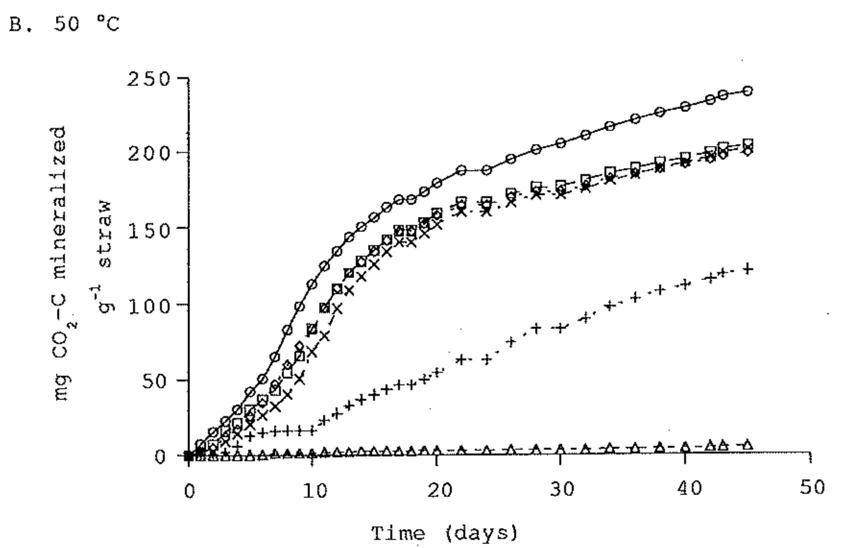


Figure 6. Mineralization of C in straw incubated at *A*, low temperature (25 °C) and *B*, high temperature (50 °C) as influenced by the addition of N during a 45-day laboratory incubation

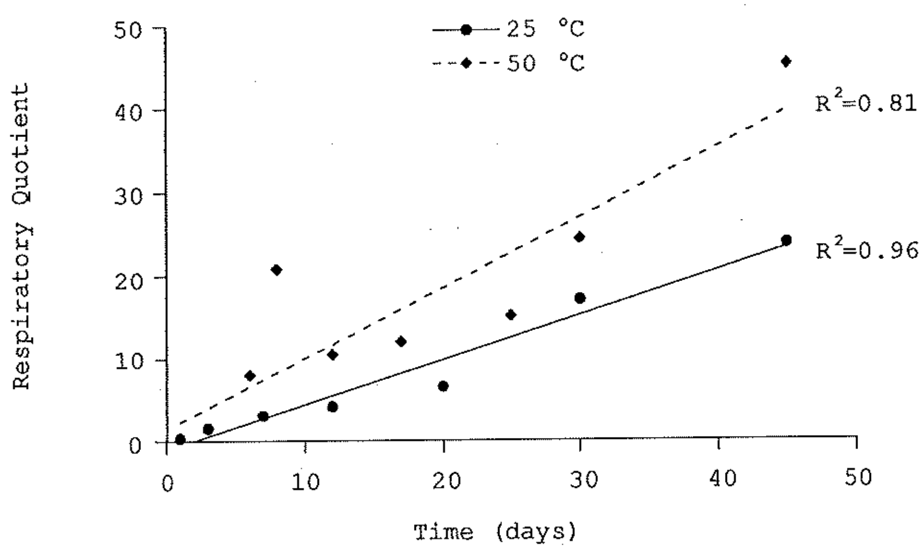


Figure 7. Respiratory quotient (mg CO_2–C g^{-1} straw divided by mg microbial biomass C g^{-1} straw) during a 45-day incubation at low and high temperature

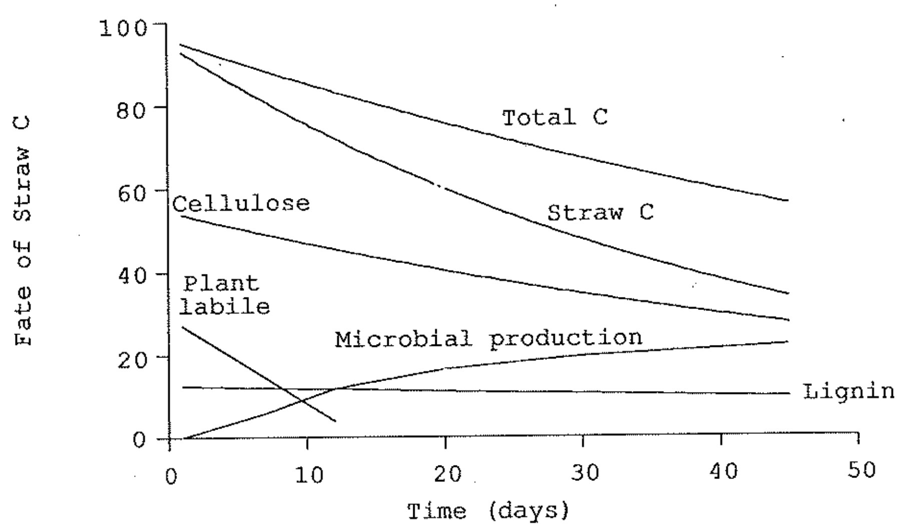


Figure 8. Simulation of microbial C production during a 45-day incubation. Cellulose and lignin degradation were determined at 25 and 50 °C (Horwath and Elliott 1996a,b). Microbial C production can be determined using equation 1.

are normally monitored on a regular basis and used to determine when and how often to turn straw composts.

Practices that alter the composting environment have a large effect on the rate and quality of composting. The field studies performed evaluate some of the effects from straw collection methods, length of straw composted (long straw versus short straw), and the number of times the compost was turned. The compost variables measured include volume reduction, temperature, moisture, and microbial and chemical changes.

Straw collection

Perennial ryegrass straw was used in the field studies. This straw is similar in chemical and physical properties to other grass straws such as those from fescue, orchardgrass, bluegrass, wheat, and rice. The straw was collected using the two most common methods available to the region's seed growers. One method was to rake long straw from the field and form windrows directly after combining. A ground-driven wheel rake and farm-built buck rake (figs. 9 and 10) were used to collect long straw and form windrows. The wheel rake can sweep a swath of 5.5–6 m (18–19.5 ft) on each pass. The wheel and buck rake can rapidly move large amounts of straw.

The other method of straw collection used was to rake, bale, and remove long straw first and then form compost windrows with only the short straw. The short straw was flailed, brushed, and vacuumed from the field using a Rear's Manufacturing Company Flail-vac machine and a John Deere stack wagon (fig. 11). Of all the procedures related to composting grass seed straw, flail vacuuming and removal of straw residues in stack wagons require the greatest equipment expense and the most time [about 2 ha (5 acres) per hr]. Typically, long-straw windrows are loose, are composed almost entirely of straw, and proportionately contain very small amounts of seed and soil. In contrast, short-straw windrows are denser, are composed of finer material, and contain relatively large amounts of soil and seed.

It is desirable to locate compost sites on the perimeter of a field where there is good drainage and easy access for turning equipment during the rainy season. Forming the straw, both long and short, into windrows is recommended to facilitate the operation of turning equipment. An important management variable in the successful composting of straw residue is aerating the material in a timely way by periodic turning. In our study, temperature was monitored to determine optimum turning times. Where product quality and rapid decomposition are factors, accessibility is necessary to enable multiple turnings based on temperature and moisture.

Windrow turning

Dry straw typically has a 10–15 percent moisture content at the end of summer. For composting, the ideal moisture content appears to be in the range of 60–70 percent moisture. After 80–100 mm of accumulated rainfall, windrows should be turned to aerate the pile and mix wet outer material into the interior and expose drier material to the surface. By doing so, the moisture content throughout the compost becomes much more uniform.

Numerous manufacturers produce compost-turning equipment with various mechanical designs. Most of this machinery is designed for the treatment of municipal organic waste solids or agricultural livestock manures. The action of a flail-type turner chops the material into smaller particles and promotes good mixing and aeration. Farm tractors used to power compost-turning machinery and self-propelled turners require a hydrostatic drive or creeper gear to allow maximum power takeoff output at very slow ground speeds. Use of compost-turning machinery is recommended where the quality of finished compost or a rapid rate of composting is an objective. However, straw residues can be successfully turned using a front-end loader (fig. 12). If a front-end loader is used, the compost pile will generally need to be turned more frequently than if a straddle turner (fig. 13) is used, but a front-end loader is effective and costs less. The straddle turner does a more thorough job of turning, thereby opening the material for uptake of water, increasing the temperature, and reducing seed and pest survival with fewer turns.

Experiments to determine the effects of the method of straw collection and number of turns on windrow volume were conducted for two seasons. During the 1992–93 and 1993–94 seasons, short-straw and long-straw windrows were formed in the same perennial ryegrass field. During the first year, turning was done with a Frontier Manufacturing straddle-type turner. In the following year, a tractor-mounted front-end loader was used for turning. Windrow plots of long and short straw were turned zero, two, four, or six times over a 9-mo period between September and June. Timing of turns was based on site access and on having at least 3 wk between consecutive turns, as fields in this region often remain inaccessible for portions of the winter and spring due to wet soil conditions.

Table 6 shows the dates of turning, the number of times the straw compost was turned, and rainfall accumulation in these studies for the 1992–93 and 1993–94 seasons. Because of the anticipated reduction in volume, three side-by-side windrows for each of the four treatments were formed at the beginning of the 1992–93 season. Windrows from the treatments turned two, four, and six times were combined into one large

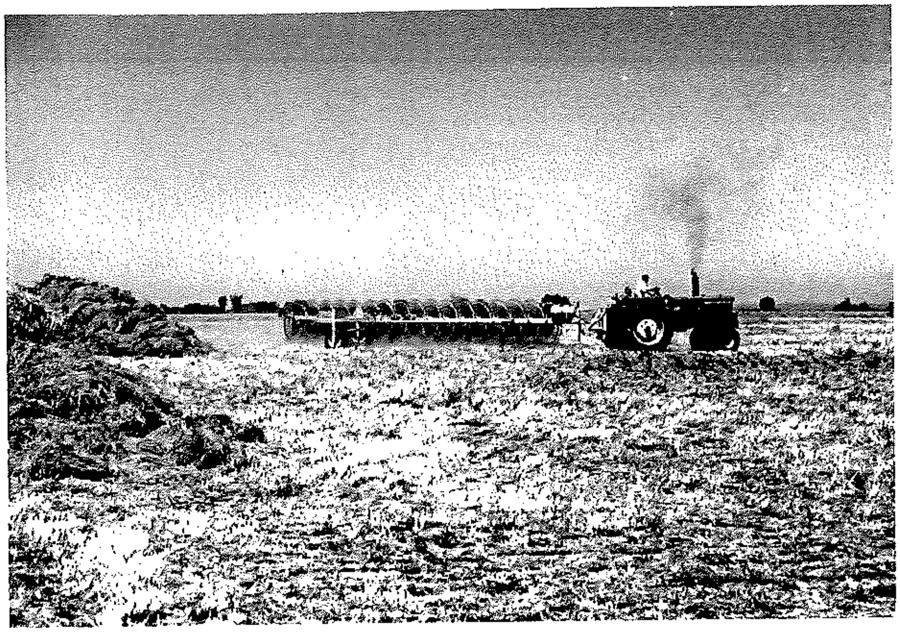


Figure 9. Ground-driven wheel rake

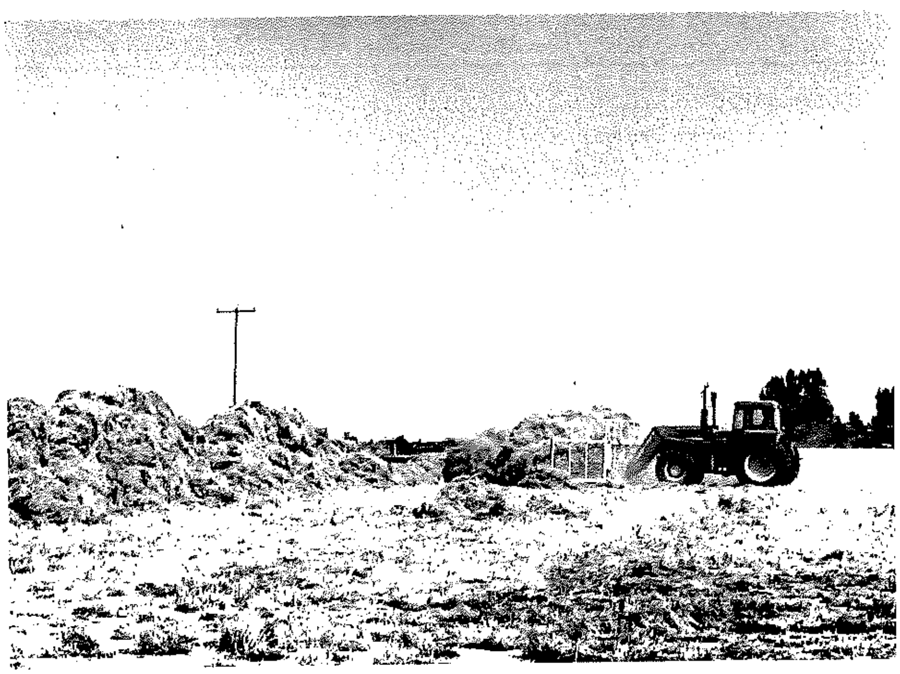


Figure 10. Farm-built buck rake

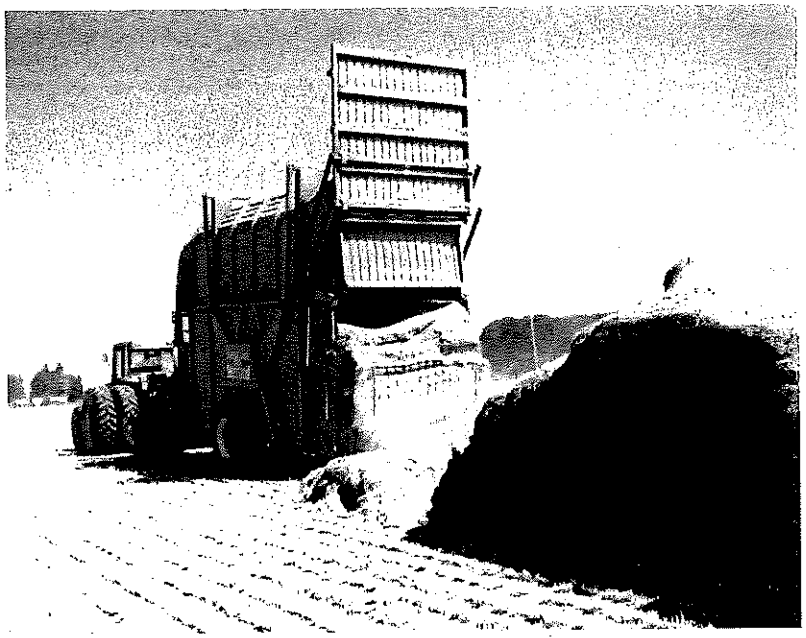


Figure 11. Rear's Manufacturing Company Flail-vac machine and John Deere stack wagon

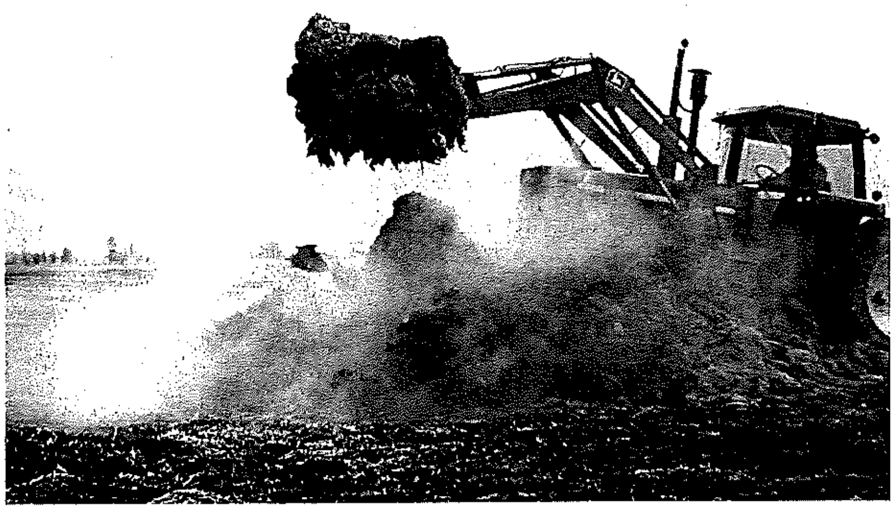


Figure 12. Tractor-mounted front-end loader for turning compost

Figure 13. Straddle turner for turning compost

Table 6. Turning dates, number of turnings, and rainfall accumulation in studies performed in the 1992–93 and 1993–94 seasons

1992–93 Season			1993–94 Season		
Date turned	No. of turnings	Accumulated rainfall (mm) from 8/18/92	Date turned	No. of turnings	Accumulated rainfall (mm) from 8/16/93
10/29/92	2, 4, 6	22	1/13/94	2, 4, 6	227
12/9/92	6	250	1/28/94	4, 6	256
1/13/93*	2, 4, 6	375	3/2/94	6	351
3/11/93	4, 6	511	3/30/94	2, 4, 6	397
4/20/93	6	684	5/3/94	6	467
5/17/93	4, 6	759	6/7/94	4,6	506
6/15/93		887	6/21/94		520

* The three windrows from each turned treatment (but not the 0-turn treatment) were combined into one windrow.

windrow for each treatment on January 13, 1993. During the 1993–94 season, plots turned with a front-end loader did not require combining. Temperature and volume data were collected for each straw type (short vs. long), week (1–33), and number of turns (0–6). Figures 14 and 15 show the volume reductions that occurred during the composting trial with the straddle turner. The reduction in volume in windrow plots of long and short straw was strongly related to the number of turns.

Statistical analysis of the final volume data (after 33 wk) of both types of straw showed a significant difference (p=0.05) between final volumes of compost windrows turned zero times and compost windrows turned two, four, and six times (table 7). However, no significant differences were found between final volumes of windrows turned two, four, or six times.

After the compost was turned with a straddle turner the first year, volume reduction occurred significantly faster in windrows receiving four or six turns than in those receiving zero and two turns. Volume reduction and internal temperatures were significantly (p<0.001) influenced by straw type. Higher internal temperatures and lower volume reduction occurred in windrows formed from shorter straw, probably due to its higher initial density. Volume reduction and internal temperatures were significantly (p<0.001) increased by the number of turns and by the length of time since windrow formation. An analysis of variance of individual straw types also showed significant effects of the number of turns and week on both volume reduction and temperature for short-straw (p<0.001) and long-straw (p<0.001) composts.

In the following year, composts were turned with a front-end loader, and volume reductions in both long-straw and reclipped-straw windrows were estimated to be near 80 percent in windrows turned 4 and 6 times and 50 percent in the unturned windrow. These figures were somewhat lower than those obtained the previous year when a straddle-type turner was used. Four turns with a straddle-type turner were sufficient to thoroughly break down the straw. But six or more turns with a front-end loader were required before the straw was thoroughly broken down. Timing of turning and rainfall events also affected rate of straw breakdown.

Temperature

During composting, it is desirable to maintain the thermophilic activity (in excess of 49 °C) in as much of the material as possible and for as long as possible to promote the most rapid decomposition of substrate and to decrease disease organisms and weed seed survival. In commercial and municipal composting operations, the aim is to sustain temperatures between

Table 7. Percentage of original volume remaining after 33 wk of composting long and short straw

No. of turns	Percent of original volume remaining	
	Long straw	Short straw
0	47	53
2	18	42
4	17	25
6	12	20

54 and 71 °C. Mesophilic organisms present under normal ambient temperatures are overcome by competition with thermophiles at higher temperatures. Temperatures in excess of 77 °C have been measured in composting straw, but this temperature is at the upper limit for thermophiles. Such extremes actually inhibit a more diverse microbial population from being active. When the temperature no longer increases to thermophilic levels after turning, the material has decomposed to the point of no longer providing the substrate and nutrients required to sustain a rapid rate of microbiological activity. At this point the compost is stabilized or "done."

Temperatures exceeding 50 °C were typical in windrow composts and occurred in both the long-straw (LS) and reclipped-straw (RS) treatments (fig. 16). Temperatures of up to 70 °C were observed at depths of greater than 120 cm during windrow composting (Churchill et al. 1995). The RS treatment was turned twice, and the LS treatment was turned four times. The RS treatment achieved higher initial composting temperatures during the first two turns. The temperatures in the LS treatment increased after the last two turns and exceeded those in the RS treatment. The temperature of the control treatment, which was never turned, gradually rose from approximately 10 to 25 °C during the composting period in conjunction with seasonal temperatures. The RS treatment had shorter lengths of straw and therefore a higher bulk density, which may have caused an insulating effect that may explain the differences in temperature between the RS and LS treatments.

The variation in temperature in a single profile can span 20–50 degrees. Turning causes greater substrate uniformity and improves the chance that all material will receive some exposure to the hottest conditions. All of the windrows that were turned exhibited thermophilic temperatures at some point. Figures 17–19 show the average high internal temperatures of long-, short-, and reclipped-straw windrows turned different

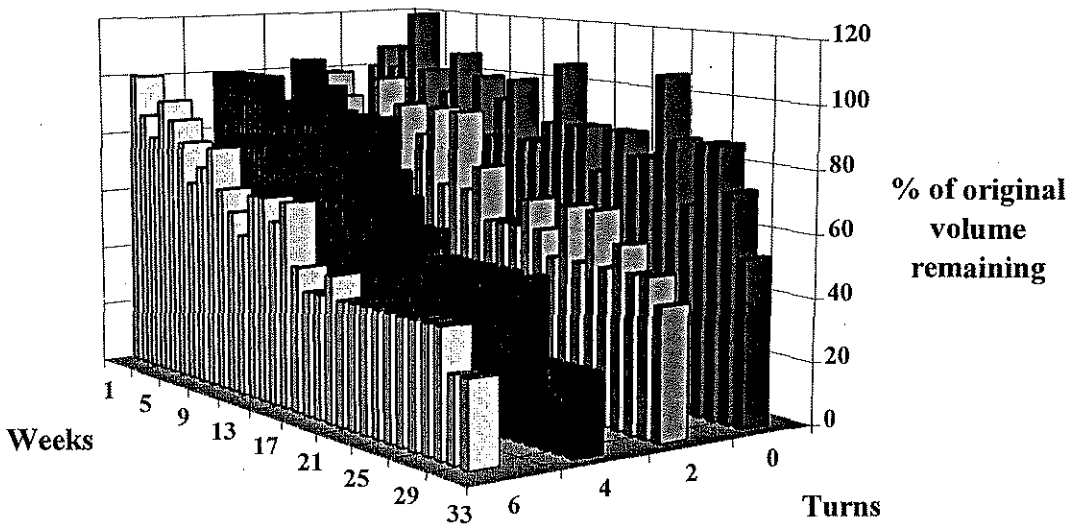


Figure 14. Percentage of original volume remaining in short-straw windrows receiving zero to six turns. Volume measurements over 100 percent were due to additional air space after turning, resulting in a fluffed-up substrate.

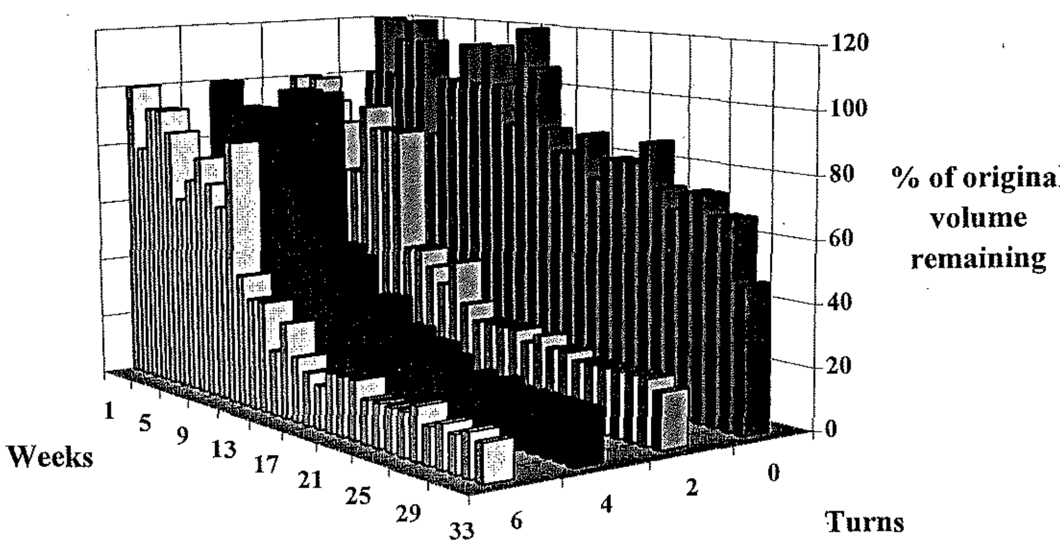


Figure 15. Percentage of original volume remaining in long-straw windrows receiving zero to six turns. Volume measurements over 100 percent were due to additional air space after turning, resulting in a fluffed-up substrate.

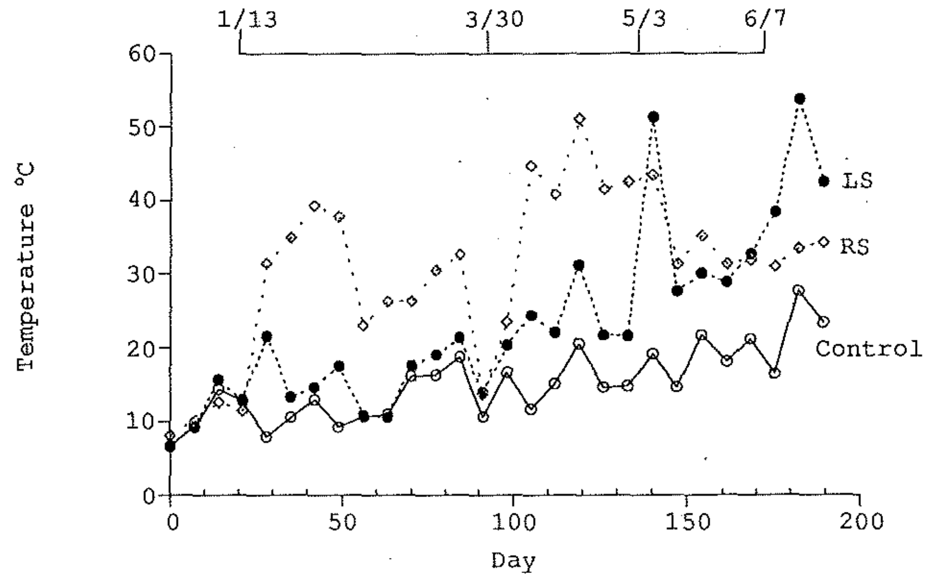


Figure 16. Maximum temperatures in windrow composts from December 19, 1993, to July 28, 1994, for control, long-straw (LS), and reclipped-straw (RS) treatments. Dates (at top) indicate when composts were turned.

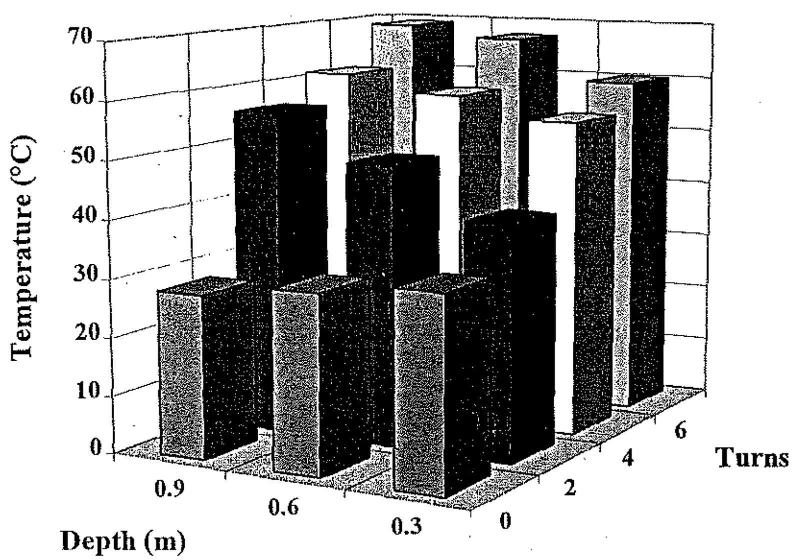


Figure 17. Average high internal temperature of long-straw windrows at different depths with different numbers of turns

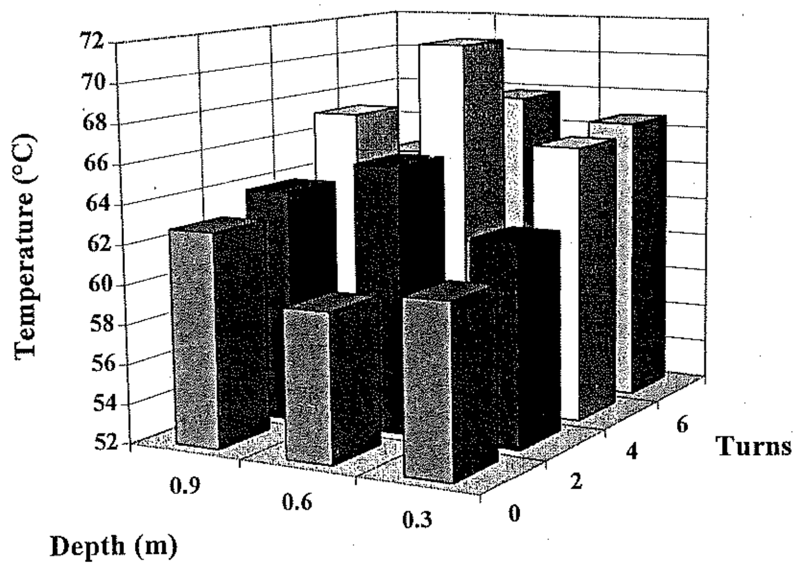


Figure 18. Average high internal temperature of short-straw windrows at different depths with different numbers of turns

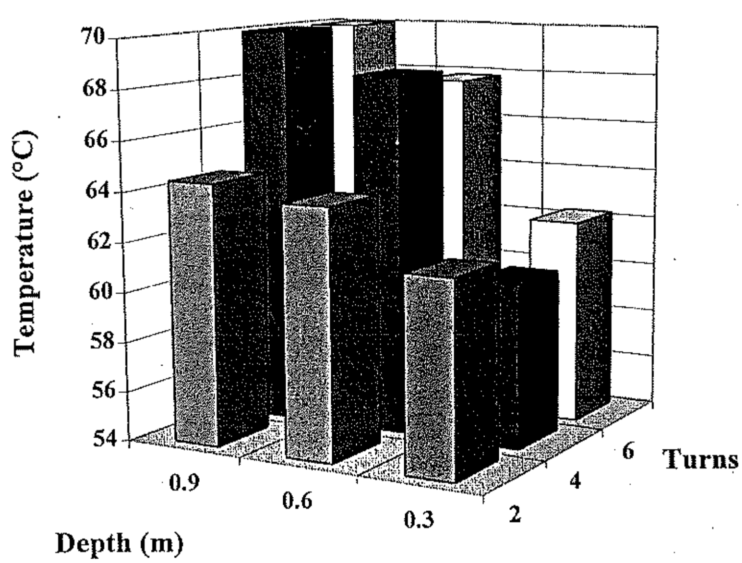


Figure 19. Average high internal temperature of reclipped-straw windrows at different depths with different numbers of turns

numbers of times using a front-end loader. These figures show an increase in temperature for all three types of straw with each additional turn and show that the highest temperatures tend to occur at greater depths. The increased temperatures are conducive to greater microbial activity and further breakdown of straw lignin and cellulose.

Internal temperatures high enough to ensure that all seeds were completely killed were never reached for either type of straw, although temperatures over 49 °C did occur several times. Use of this compost should therefore be limited to instances where the presence of viable crop and weed seed is inconsequential or where volunteer seedlings can be controlled.

Microbiological and chemical changes during field composting

The difference in windrow temperatures, number of turns, and initial C:N ratio among the windrow treatments had little or no effect on the number of culturable mesophilic organisms in the straw (fig. 20). Mesophilic bacteria were present in the largest numbers, attaining densities of 10^8–10^9 colony-forming units (cfu) per g (dry wt) of straw. Mesophilic actinomycetes and fungi were present in numbers between 10^6 and 10^8 cfu per g of straw. During the latter stages of windrow decomposition, as the LS and RS treatments increased in temperature, thermophilic bacteria increased to 10^7–10^8 cfu per g of straw, and thermophilic actinomycetes and fungi increased to 10^5–10^6 cfu per g of straw. In the control treatment (data not shown), thermophilic populations of bacteria, actinomycetes, and fungi remained unchanged at 10^3–10^4 cfu per g of straw, 10^2–10^3 cfu per g of straw, and 10^2–10^3 cfu per g of straw, respectively. The populations of microorganisms in the perennial ryegrass windrows were similar to those observed in wheat and hay composts (Chang 1967, Lacey and Dutkiewicz 1976).

Cellulase, xylanase, and protease activity did not present definable patterns (data not shown). The measurement of potential hydrolytic enzyme activity appears to have limited value in interpreting straw decomposition and completeness or quality of the end product.

Klason lignin increased or remained unchanged in all treatments and depths (data not shown, see Horwath and Elliott 1996a). Elemental analysis of the Klason lignin fraction revealed extensive C loss and accumulation of O and N (table 8) and showed that the lignin fraction was substantially altered. We observed a greater or equal loss of lignin fraction C than in previous laboratory incubations of straw (Horwath and Elliott 1996b). The straw residue in the deep LS treatment lost 55 percent of the original lignin fraction C content (table 8). The loss of lignin fraction C in the other treatments was 16–40 percent of the original lignin C. Deep straw residue samples lost more lignin fraction C than shallow samples for the LS treatment, but depth did not affect lignin fraction C for the RS treatment. The increased loss of the lignin fraction C in both depths of the RS treatment and in the deep straw samples of the LS treatment was associated with higher windrow temperatures, which indicated the importance of thermophiles in lignin degradation.

The increased N content of the lignin fraction was associated with the accumulation of humic substances (Hammouda and Adams 1987). The lignin fraction N content of all treatments increased between 1.5 and 2.4 times the original lignin N content (table 8). Treatment and straw type influenced the amount of N stabilized in the organic fraction. The four-turn LS treatment stabilized more N in organic forms than the control or RS treatments. The differences in the accumulation of lignin fraction N indicated that the treatment conditions affected the production and quality of the composted end product.

The reduced N requirement of the thermophiles shown in these studies is a unique feature of thermophile ecology that enables these organisms to degrade substrates having a high C:N ratio. The N requirement of thermophiles can also be met during the transition between mesophilic and thermophilic environments. During the transition between mesophilic and thermophilic temperatures in laboratory straw incubations, the accumulation of soluble organic N and ammonium occurred (fig. 21). The increase in soluble N and ammonium may occur as a result of the turnover of the mesophilic population. The increase in available N was three times the microbial biomass N content of the thermophilic population and indicates that sufficient N was available for the thermophilic organisms (Horwath and Elliott 1996a).

In the current study, the increase in thermophiles coincides with the gradual increases in windrow temperature in the LS and RS treatments (fig. 16). The turnover of the mesophilic population during thermophilic activity may be an important mechanism that supplies a limited pool of N for thermophilic microorganism activity. The C:N ratio of the final decomposed straw in the deep samples indicates that the windrow composting treatments produced a completed compost (table 9). The LS deep treatment produced material with the lowest C:N ratio (12:1). The RS and control deep treatments had final C:N ratios of 17:1 and 18:1, respectively. The shallow decomposition samples had C:N ratios higher than 20:1, indicating that they were incompletely decomposed.

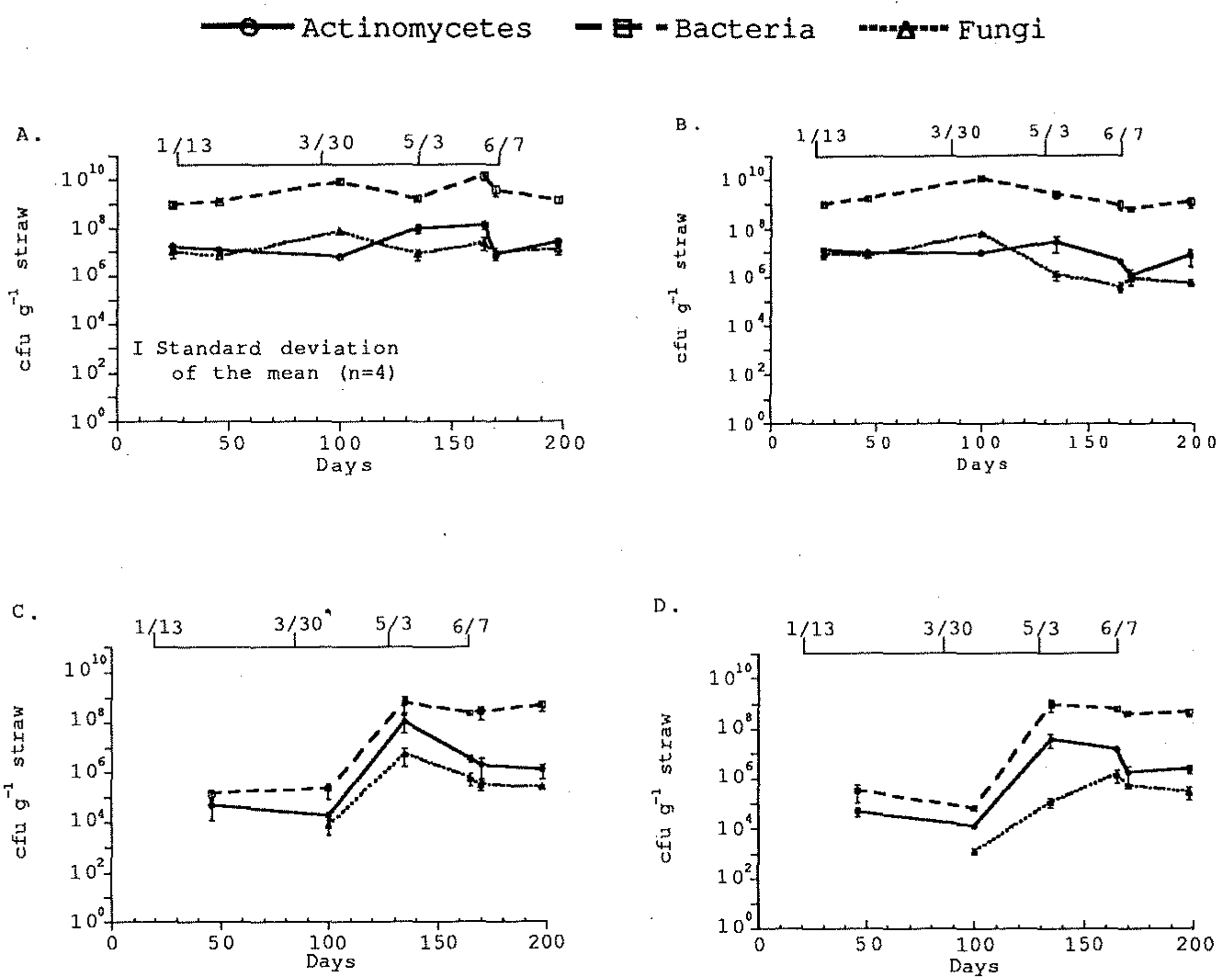


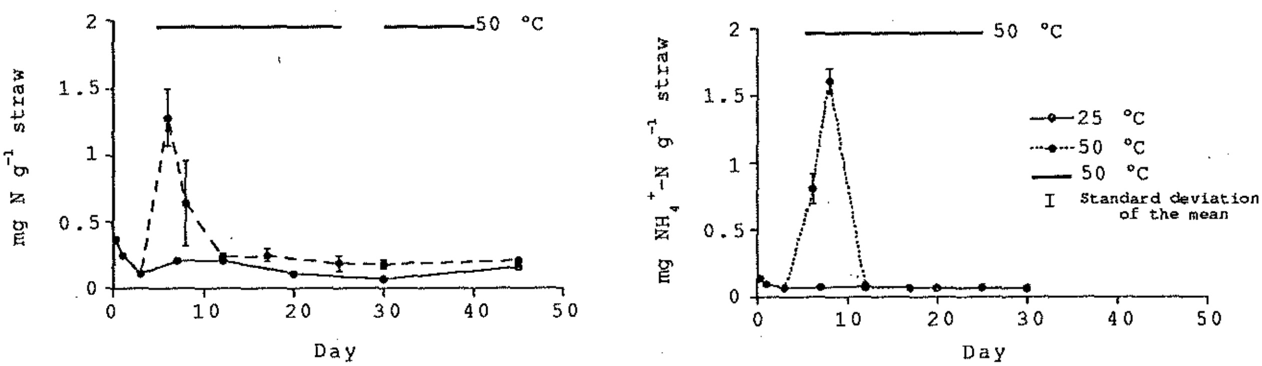
Figure 20. Density of microorganisms [expressed as colony-forming units (cfu)] for the long-straw treatment, including the populations of mesophilic microorganisms in *A*, shallow samples and *B*, deep samples, and populations of thermophilic microorganisms in *C*, shallow samples and *D*, deep samples. Dates indicate when treatments were turned.

Table 8. Percentage of C, H, and O remaining in the lignin fraction after 200 days of decomposition at shallow and deep depths of straw windrow treatments

Treatment	Percent remaining			
	C	H	O	N
Day 0	100	100	100	100
Shallow				
Control	86	82	122	197
LS*	84	83	158	239
RS†	63	54	110	154
Deep				
Control	67	63	115	152
LS	45	42	101	222
RS	60	51	153	187

* Long straw

† Reclipped straw



A. B.

Figure 21. Accumulation of *A*, soluble organic N and *B*, ammonium during laboratory straw incubations

Table 9. Percentage of C and N and the C:N ratio before and after composting control, LS, and RS windrow treatments

Treatment	C (%)	N (%)	C:N ratio
	------------------ Initial values before composting ---------------		
LS windrow straw*†	40.9 (0.5)	0.78 (0.04)	52.6 (3.4)
RS windrow straw†	42.4 (0.2)	0.71 (0.04)	59.7 (2.8)
Straw in nylon bags‡	43.8 (0.2)	0.92 (0.02)	47.7 (0.9)
	-------- Values for straw in nylon bags after composting -------		
Shallow samples			
Control‡	40.9 (0.3)	1.84 (0.16)	24.0 (1.8)
LS‡	41.4 (0.8)	1.94 (0.11)	21.6 (1.4)
RS‡	43.8 (0.7)	1.95 (0.12)	22.7 (1.3)
Deep samples			
Control‡	40.6 (0.4)	2.29 (0.18)	18.0 (1.4)
LS‡	34.6 (0.9)	2.79 (0.12)	12.4 (0.1)
RS‡	40.9 (0.3)	2.35 (0.07)	17.4 (0.6)

Note: Standard errors of the means are shown in parentheses.

* Control windrow straw treatment has same values as LS windrow straw treatment.
† n=3.
‡ n=4.

Composted grass straw as a soil amendment
In these studies, the number of seeds, percent germination, percent N, and C:N ratio of long- and reclipped-straw compost changed as the compost was turned (table 10). Presence of germinable seeds partly dictates the end use of a compost, while C:N ratios indicate compost maturity and the content, form, and fertilizer value of N in the compost. The seed content of both types of compost varied considerably among samples. N content increased in both types of straw while the C:N ratio decreased as the compost matured.

Nutrient levels and availability in composts are typically low when compared to synthetic fertilizers. The value of compost is promoted in terms of its ability to release nutrients over a long period of time and return organic matter to the soil. Because these factors cannot easily be assigned a dollar value, they are generally termed intangible benefits. It is difficult to assign a dollar value to grass straw compost on the basis of its cost of production, as there are so many different methods, combinations of machinery, and potential yields possible from one field and farm operation to the next. Estimates of the nutrient reclamation value and economic worth of grass compost as fertilizer are presented in tables 11 and 12. The data from these tables are averages from three sites on which short straw was composted and two sites on which long straw was composted. The composts were analyzed for levels of N, P, K, Ca, and Mg after 7 mo of composting. Table 11 presents the results in kg of nutrient per dry tonne of compost. Based on the average nutrient content of straw (from table 11) and the average costs of various fertilizer nutrients, the value of grass straw compost is about $18.40 per dry tonne, as summarized in table 12.

Survival of seed and seed disease organisms
Temperatures sufficient to kill seeds were noted in some locations in both types of straw. However, the average internal temperature of the composts was well below the suggested 66 °C necessary for killing all seed. Since windrows created from long straw are of low density, the heat necessary for composting this material is easily lost through cold-air infiltration.

Number of turns, straw length, and internal temperature of the compost affected the survival of all seed species (table 10) and seed disease organisms. Survival decreased as the number of turns increased and as temperatures increased. The high and average temperatures in the compost were affected by the

Table 10. Physical properties of long and reclipped straw receiving different numbers of turns

Straw type and no. of turns	Seeds g^{-1} compost	Germination (%)	Nitrogen (%)	C:N ratio
Long straw				
0 turns	4.07	88.8	0.90	48.62
2 turns	2.87	47.93	1.31	35.29
4 turns	5.98	11.33	—	—
6 turns	—	—	—	—
Reclipped straw				
0 turns	1.43	93.41	0.75	57.37
2 turns	1.18	67.85	1.19	38.18
4 turns	0.68	37.83	—	—
6 turns	—	—	—	—

Table 11. Nutrient content of grass straw compost made from short and long straw

Straw type	Nutrient content (kg $tonne^{-1}$)				
	N	P	K	Ca	Mg
Short	14.4	0.24	7.8	3.7	0.9
Short	16.4	0.34	8.0	4.3	1.4
Short	20.50	0.40	11.6	2.9	1.3
Long	14.6	0.39	15.9	1.5	1.3
Long	12.5	0.08	6.6	1.9	0.5

Table 12. Nutrient content and nutrient value of typical grass straw compost

	N	P	K	Ca	Mg	Total
	---------- Percent ----------					
Nutrient content	1.73	0.03	1.10	0.32	0.13	
	---------- Dollars ----------					
Fertilizer value kg^{-1}	0.53	3.24	0.49	0.05	0.11	
Nutrient value $tonne^{-1}$	10.10	1.07	5.94	1.13	0.16	18.40

number of turns, straw length, depth, and interaction of these variables. Blindseed was most susceptible to turning; none of them survived after two or more turns. Tall fescue seed was most resistant to the effects of turning, with a small percentage surviving six turns in some cases.

Cost Estimates of Field Composting

Total costs for short-straw windrow composting, including preparation and turning, range from \$60 ha^{-1} to over \$80 ha^{-1}. Straw collection with Flail-vac and stack wagon machinery represents \$50–\$55 ha^{-1} of the total costs. Total costs for long-straw composting range from \$47 ha^{-1} to over \$62 ha^{-1}. Straw collection with wheel and buck rake combinations represents about \$30–\$40 ha^{-1} of the total costs. These are estimated values based on field trial observations and farmer interviews (Cross 1992). Per hectare costs are based on the entire acreage from which straw is removed, not the limited area used as the composting site. Actual costs vary with differences in machinery, machinery operator, and weather and field conditions. Field-trial costs for turning compost in 1993–94 with a front-end loader were considerably less than those of the previous season when a straddle-type turner was used.

Conclusion

The extensive alteration and decomposition of lignin and the reduced N requirement of the thermophilic biomass provides evidence for why grass straw successfully composts in the field without the addition of N to lower the C:N ratio. In laboratory studies, it was shown that the breakdown of lignin likely increases the availability of cell-wall polysaccharide and related compounds for microbial use. In the composted straw, the available C was required by thermophiles because of their lower substrate utilization efficiency. The field experiments indicated that ligriolytic wastes can be upgraded to form high-quality organic amendments with low C:N ratios. Treatment and straw quality influenced the final C:N ratio of the straw compost and indicates that straw management can be changed to achieve different-quality end products.

It is evident from the on-farm composting research and from analyzing the characteristics of grass straw compost that it is necessary to aerate compost material by turning. As few as two or three turns can be applied to both short- and long-straw windrows to achieve near-maximum volume reduction. Volume reductions of 80–90 percent can be achieved with relatively low-input when given a timeframe that extends throughout the winter.

The straw-composting methods described serve as an alternative to field burning and traditional on-site residue management techniques that are often associated with residue inhibition and pestilence. These methods can be integrated into a sustainable cropping system. On-farm composting is immediately practicable on grass seed farms that have the straw-handling equipment with which to clear a field of postharvest residue.

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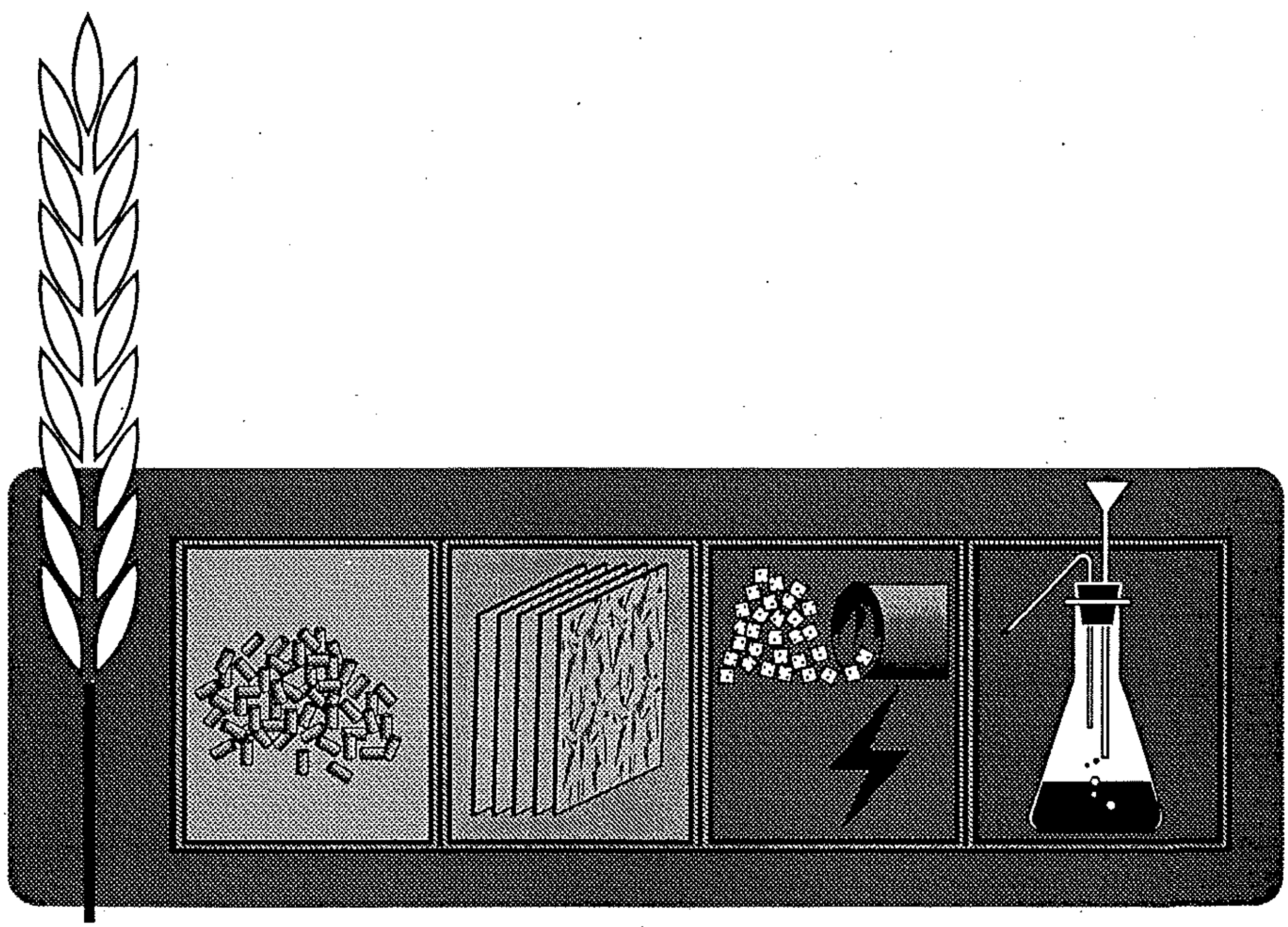
Footnote 16

Opportunities in Grass Straw Utilization



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Preface

This study has been prepared as a reference document for use by the state legislature, industry leaders, private investors, growers, and interested citizenry as a foundation for making informed choices about utilization of Willamette Valley grass seed straw. The study examined existing research in this area to determine what technologies for straw utilization, based on economic and technologic factors of today's marketplace, are most likely to be implemented in the next decade.

The Oregon Economic Development Department (OEDD) was considered as the lead state agency working in cooperation with the Oregon Department of Agriculture (ODA), the Oregon Department of Environmental Quality (DEQ), and the Linn-Benton Regional Strategy. Industry financial support was obtained from the Oregon Seed Council and the grass seed commissions. State funds came from the state Lottery Fund and through grants from the Center for Applied Agricultural Research (CAAR) Board.

This work has built upon the considerable foundation of research done in the area of straw utilization throughout the last two decades and supported by the grass seed industry, state agencies, agricultural associations, individual growers, and private citizens.

Focus

The purpose of this study is to facilitate opportunities for grass straw utilization technologies in the state of Oregon.

Objectives of this study were to 1) determine what technologies could be implemented within the next 10 years to utilize significant amounts of grass seed straw, assuming that open-field burning will be phased down during this time period, and 2) present information so that the parties interested in straw use projects could determine the direction, problems, risks, and benefits of any particular technology.

A 10-year time frame for implementation of viable technologies was assumed.

A 10-year goal towards implementation was established, and represents a realistic appraisal of time to identify technology, obtain political and financial support, provide the first several key projects (with others to follow), and phase down to limited open-field burning as a farming activity. It is difficult to predict how the remaining thermal sanitation techniques (e.g., stack-burning) will survive this 10-year period, but it is assumed these also will be significantly reduced. This emphasizes the importance of having established straw utilization techniques in place.

Several straw utilization alternatives in specific markets were analyzed, along with the assumed economic feasibility, technical factors, and regulatory/social impacts (Table ES-1). These straw uses are the focus of this study and are presented here in order of highest to lowest perceived market value for straw and technical viability. (Further discussion of the alternatives is provided in a later section, Implementation Strategies, of this executive summary.)

The first straw utilization plants, be they for straw processing or burning, could be implemented within 5 of these 10 years. By the end of 10 years, they could be operating on a reliable basis, along with several other new plants. It is assumed that these plants will utilize significant amounts of available straw.

Approach of the Study

This study is based upon a three-phase approach towards implementation of grass straw utilization options. The first stage is this study effort, which examines the current agricultural and economic situation

Table ES-1
Summary of Straw Utilization Technologies

STRAW USE	ECONOMIC FEASIBILITY	TECHNICAL VIABILITY	REGULATORY & SOCIAL
Animal Feed	Current market for straw. Some 150,000 tons exported annually to Japan. Market expansion is uncertain. Domestic market is small and competes with roughage when alfalfa hay is scarce/expensive.	Low bulk density and low feed value require costly preparation for market. Suitable as supplement feed. Endophyte in straw presents new problems as feed source.	Some possible social impacts with transportation. No forseen regulatory impacts.
Pulp & Paper (existing plant)	Attractive potential market. Straw value is highest in this market. Potential volume of straw use is large as a supplement.	Pulping characteristics different for straw than wood. Requires dedicated digester and some modification of existing equipment.	Air, water, noise, land use changes. Social benefits of employment.
Fuel Supplement (existing plant)	Straw can be used as a supplemental fuel at existing facilities. Natural gas may be more competitive than straw or wood.	Should be used in addition to the fuels originally designated for the equipment. Some modification of existing equipment may be required.	Not much change from existing impacts.
Fiberboard (existing plant)	Straw as an extender material or as new product. Potential volume of straw use will be large if enough plants are involved. Straw costs difficult to compete with wood if densification is required.	Straw is implemented differently than wood, and processing will require changes.	Not much change from existing impacts. Social benefit from employment. Public scrutiny of resins and chemicals used, and acceptance of product will be necessary.
Power Plant (new plant)	Straw can be used as a supplemental fuel. Hog fuel costs and availability help straw compete. Potential large use of straw. Changes in PNW power supply will affect rates and plant economics.	Straw creates problems for most combustion equipment with deposits and slagging. Straw preparation and handling is difficult.	Air, water, noise, land use changes. Social benefits of employment. Public scrutiny is expected.
On-Farm Composting	Major "wild card" use of straw. Too preliminary for economic evaluation. Some benefits perceived through improved soil tilth.	Aerobic composting is feasible. Farm level testing is underway. Incorporation into fields not yet developed.	Social benefits to farmer. Limited impacts to environment.

Table ES-1 (continued)

Summary of Straw Utilization Technologies

STRAW USE	ECONOMIC FEASIBILITY	TECHNICAL VIABILITY	REGULATORY & SOCIAL
Home Stove Fuels	Straw costs difficult to compete with wood sources. Potential volume of straw use lower than other options.	Testing has been underway to improve burning properties.	Air quality impacts. Social impacts regarding smoke and airborne chemicals. Social benefits from locally-made products.
Commercial Soil Amendments (hydromulch, potting medium, compost)	Economic feasibility unknown. Hydromulch market potentially large. Potting medium market very small. Compost market unknown. Straw volume use unknown.	Testing underway for commerical composting; only grain straw used in potting medium. Unknown why straw in hydromulch market is not expanding.	Limited impacts to environment.
Chemical Digestion	Markets for products (eg: methane) not commercially established in the PNW. Feasibility of straw use not established in PNW.	Straw conversion into feed most probable. Chemical compound production not past pilot stages.	Air, water, noise, land use changes. Social benefits of employment. Public scrutiny of chemicals used in process.
Pyrolysis/ Gasification	Markets for products (eg: fuels) not commercially established in the PNW. Feasibility of straw use not established in PNW.	Chemical compound production not past pilot stages. Present pilot tests have not become commercial concerns.	Air, water, noise, land use changes. Social benefits of employment. Public scrutiny of chemicals used in process.
Hydrolysis	Markets for products (eg: ethanol) not commercially established in the PNW. Feasibility of straw use not established in PNW	Chemical compound production not past pilot stages. Most testing done with non-straw biomass materials.	Air, water, noise, land use changes. Social benefits of employment. Public scrutiny of chemicals used in process.

of the grass seed growers and identifies technologies that could utilize straw.

The study is based on a three-phased approach of investigation, design, and implementation.

The second phase will follow later with specific plans for preliminary design details of straw use processes. This phase will emphasize straw supply, and straw use technology, a specific choice of sites, permits, and sales contracts. There are, in fact, several particular straw market activities at or near Phase II today, including a straw pulping operation, a potential strawboard plant, straw addition to existing wood-fired boilers, and a potential straw-fired powerplant.

There also are a number of small-scale market uses of straw moving towards Phase II development. While most activities involve private sector sponsorship of a new enterprise, a powerplant activity is one area that will not proceed through Phase II without assistance from public and private agencies.

The third phase will be actual implementation of technology and economics, where projects are financed and constructed. Funding in Phase III will be largely private (developers, third party investors, some grass seed grower interests). This phase will produce bid documents that will also be used to secure final permits, financing, and contracts.

Summary of Grass Straw Utilization Options

There are many potential uses of grass straw in a variety of markets. Several are large users of straw, whereas some markets will not use significant amounts. This study focuses on major users of straw, since implementation of their projects can be more easily identified and supported than many small projects. However, we will discuss in general the uses of straw, without regard to size of project, or its profitability to demonstrate the potential available.

Grass straw has market potential as feed; fiber for pulp products and structural board; fuel for industry, homes, and power generation; agricultural uses such as soil amendments and erosion control; and raw material for chemicals production.

Grass straw first and foremost can be used as a ***feed*** material. In fact, markets exist and straw is currently used as feed both domestically and internationally. Straw is primarily used as a supplement to traditional protein rich feed materials, but straw can also be treated to improve its nutritive value.

Next, straw can be used as a ***fiber*** source. This is particularly significant to a region of the country that already handles millions of tons of wood fiber and wood residue in a variety of product markets. A particularly attractive market is the pulp and paper industry, which obtains a strong product value from the fiber raw materials it uses to produce paper and kraft, cardboard and cardboard liner, as well as other products.

Also predominant in Oregon are ***structural board*** plants producing plywood, particle board, and other types of hardboard and fiberboard.

The millions of tons of fiber used from wood residue in these industries are good candidates for replacement by straw, especially as an extender or bulking agent.

Straw also can be used as a ***fuel*** source. Again, Oregon and the Pacific Northwest are particularly strong in the use of bark and hogged fuel in boilers and dryers that support pulp and paper mills and structural board plants. Huge quantities of materials are needed for these industrial uses, not to mention power generating facilities and other commercial uses of wood as a fuel. Projects could include new plants or retrofit of existing plants (e.g., closed sawmills and hardboard plants).

Straw also has a ***home market*** in regards to use as a fuel. Work done in the 1970s and 1980s confirms that straw can be densified into various forms (e.g., straw cubes, straw logs, or straw pellets) that can be fed into home stoves as a replacement for wood.

In addition, grass straw can be used for on-farm and off-farm ***agricultural uses***, including hydromulch, potting medium, erosion control, and compost. Composting has been field tested this past year and had promising results. Incorporation of compost back to the fields has not been fully evaluated.

Straws from some grass species are particularly suited for specific markets; additional testing will be required.

Finally, grass straw can be used as raw material in ***chemical production*** processes. Work is being done across the country in converting agricultural wastes (biomass) into a variety of chemicals, including alcohol, ethanol, methane, furfural, ammonia, and acetic acid. Processes vary from those that produce fuel gases (pyrolysis and gasification), fuels (hydrolysis and fermentation), and animal feeds (digestion). These processes can be performed at large, industrial type commercial plants or on-farm using small scale equipment and immediate farm use of the products.

Straws from some grass species are particularly suited for specific markets, for example, Forage-type tall fescue, bentgrass, and perennial ryegrass for feed, and annual ryegrass for pulping. However, it is unknown how other varieties may serve the various markets. As the different markets develop, additional testing will be required to determine how straw from different seed types will affect the feed, fuels, chemical, and fiber markets.

Grass Seed Farming in Oregon

Grass Seed Types Planted

Grass seed has been grown in the state of Oregon since the 1920s and 1930s. A significant expansion began in the 1940s, accompanied by open-field burning. By the late 1960s, grass seed farming occupied over 300,000 acres. Today almost 400,000 acres are planted. During the past decade there has been a marked expansion in turf-type tall fescue and perennial ryegrasses. In many areas growers have shifted among grass seed types as well as from other crops.

The steady growth of the grass seed industry in the past 2 decades is not likely to occur in the 1990s, because production could now easily outstrip demand, seed amounts in storage will increase, and prices will drop. Already, declining prices in ryegrass, bluegrass, and other types have been affecting expansion in these areas.

Ryegrass grows well on even the poorest of soils.

The most prevalent grass types grown today in the Willamette Valley are the annual and perennial ryegrasses, representing over 200,000 acres planted in 1990 (Table ES-2). Ryegrass grows well even on the poorest of soils and is one of the easiest types to produce. Next are the fescue varieties, including tall fescue, chewings fescue, and red fescue. These varieties account for over 100,000 acres planted

Total straw production is based upon species and acreage (Table ES-2 and Figure ES-1). Both perennial ryegrass and tall fescue will remain stable in acres planted for the short term, but this may change if seed market demand declines for these types because of economic and supply conditions.

Table ES-2

Total 1990 Statewide Straw Production, Removal, and Export by Grass Type

Grass Seed Types	Acres Planted[1]	Potentially Available Straw (tons)[2]	Current Straw Removed (tons)[3]	Exported for Feed (tons)[4]
Tall fescue	91,510	291,328	206,968	43,345[5]
Annual ryegrass	109,180	272,019	0	0
Perennial ryegrass	108,340	244,266	194,521	106,409
Kentucky bluegrass	25,620	41,205	18,973	544
Orchardgrass	19,950	44,638	29,465	904
Bentgrass, creeping	7,160	15,955	14,096	2,425[6]
Bentgrass, colonial	7,780	9,569	3,794	NA[7]
Hard fescue	2,060	3,605	3,245	NA
Chewings fescue	17,710	2,435	2,361	NA
Red fescue	8,870	1,227	1,416	NA
TOTAL	398,180	926,246	474,839	153,627

[1] Based upon regional data in Table 4-1, which was derived combining data for counties.

[2] Based upon low and high tonnage of maximum potential available straw removed from field, as listed in Table 4-1, Columns 9 and 10.

[3] Based upon low and high tonnage of current grass straw removed from field (roadsided, stack-burned, or marketed), as listed in Table 4-2, Columns 19 and 20.

[4] Based upon Table 6-1.

[5] Includes all types of fescue.

[6] Includes all types of bentgrass.

[7] Not applicable because included in total elsewhere.

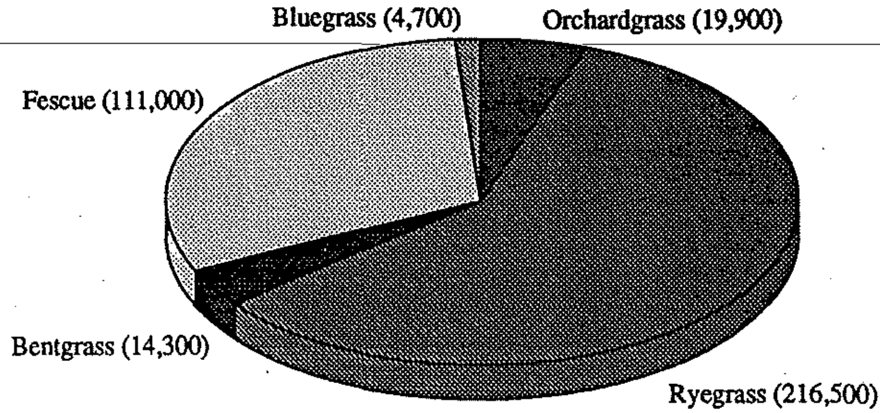

Figure ES-1
1990 Grass Seed Grown in the Willamette Valley by Type (acres)

Orchardgrass represents almost 20,000 acres, bentgrass has about 14,000 acres planted, and Kentucky bluegrass has about 5,000 acres.

A steady trend has developed towards production of proprietary seed varieties. Future varieties may tend to be dwarf or semidwarf, which will affect the amount of straw produced by the length of stem and leaf.

There are some concerns with the proprietary seed varieties.

Two general concerns have been raised about the increase in proprietary grass seed varieties: 1) a narrow genetic base for these seed types makes them more susceptible to disease problems, and 2) phytosanitary (plant cleanliness) requirements for export of straw may become more difficult for the new varieties.

Grass Seed Regions

Most of the grass seed is grown in seven Willamette Valley counties: Lane, Linn, Benton, Polk, Marion, Yamhill, and Clackamas. There is some grass seed production in Washington and Multnomah counties and in eastern Oregon (Jefferson and Union Counties), but the scale is much smaller. For the purposes of this study, four growing regions in the Willamette Valley were identified for analysis: South Valley, Foothills, Marion County Lowlands, and North Valley (Figure ES-2).

The southern Willamette Valley has the most farms over 1,000 acres.

The South Valley region, comprising Lane, Linn, Benton, and southern Polk counties, has the largest proportion of large farms (over 1,000 acres), many of which produce grass seed exclusively. Many farms are managed by fourth and fifth generation growers. Much of the soil is poorly drained, unsuited to most crops other than grass seed. Growers in this region have few if any productive options to grass seed farming.

Nearly all the annual ryegrass is grown in this region, with large amounts of perennial ryegrass and tall fescue as well. Soil types dictate the farming of annual ryegrass and may prohibit the investment cost of shifting to perennial grass seed types. Other seed types include orchardgrass, Kentucky bluegrass, bentgrass, and fescues. Roughly

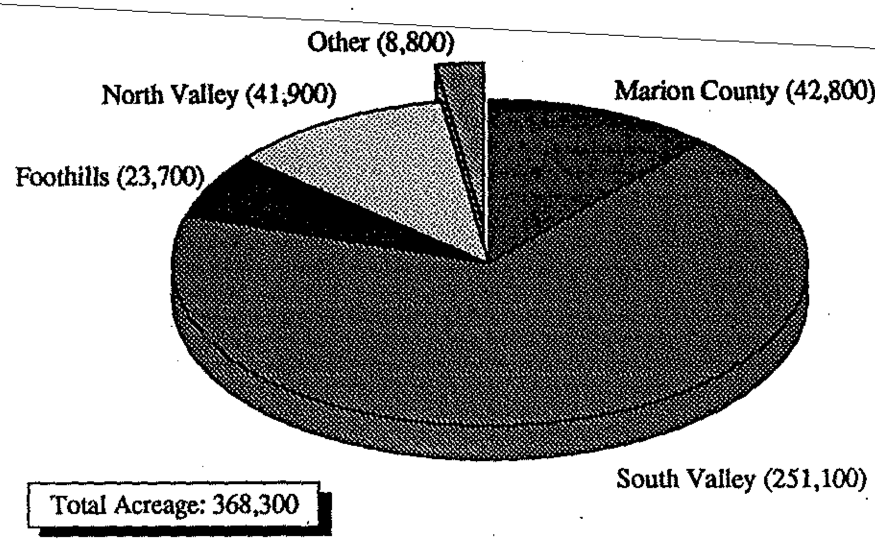

Figure ES-2
1990 Grass Seed Farming in the Willamette Valley by Regional Distribution (acres)

half the region grows proprietary varieties, and the area has seen a shift from wheat and row crops to grass seed as well.

The Foothills region consists of Marion County (Silverton Hills, north Linn, and southern Clackamas Counties). Grass seed growing began here after World War II, particularly with fine fescues and bentgrasses. The area is hilly with shallow soils, and soil erosion has been a historical problem.

Annual rainfall for the region is at least 20 inches greater than on the valley floor, which promotes growth but impacts field burning. Fine-leafed fescues dominate the hill acreage, followed by bentgrass and small amounts of perennial ryegrass and hard fescue.

The Marion County Lowlands region has some of the most productive farmland in Oregon.

The Marion County Lowlands region consists of Marion County bottom and benchland, and includes a small portion of southern Clackamas County. Grass seed production began in the late 1960s, and accounts for one third of total farm acreage in Marion County. Proprietary varieties of tall fescue and perennial ryegrass are the predominant type grown, with smaller amounts of bentgrass, Kentucky bluegrass, and orchardgrass also planted.

This region has some of the most productive—and expensive—farmland in Oregon, with the highest comparable yields available for many crops. Growers here have the greatest number of options available for crops, especially if grass seed markets decline.

The North Valley region consists of Yamhill and northern Polk Counties, and represents the newest growers to grass seed of all regions. About half the total acreage is now planted in grass seed, the remainder being traditional small grain, legume seed, and cannery crops. Land quality is lower than Marion County, with hilly areas in the west that have low water retention capacities (resulting in lower seed and straw yields).

Nearly all grass seed produced in the North Valley is proprietary turf-type tall fescue, perennial ryegrass, and orchardgrass, with some small amounts of fine fescue and bentgrass.

Farming Practices

Straw management practices developed out of significant restrictions and reductions in open-field burning starting in the early 1970s. Traditional open-field burning, which preceded straw management practices, had relatively simple operations and costs, and included the use of straw choppers or spreaders, preparation of fire breaks, and the actual field burn and burn management (fire protection). Today, the grass seed farmer utilizes three processes as part of straw management: straw removal, stubble management, and field sanitation.

Today's grass seed farmers use straw removal, stubble management, and field sanitation to manage straw.

Two options exist for straw removal, each with different equipment and costs. These options are roadsiding and marketing. Roadsiding usually involves temporary storage and/or stack-burning, and includes raking, transport (stack wagon), and baling (round bales or two-tie bales). Straw for market would involve raking and either three-tie bales together with transport (bale stack wagon) or "big bales" together with fork lifts. The bales are then transported via truck to market.

Stubble management consists of various alternatives to remove stubble and residue from the fields and to trim the crowns of plants, thus stimulating seed development for the subsequent year. Alternatives include propane-burning, cutting/clipping, and raking.

Field sanitation is an important and required part of grass seed farming. Sanitation can be implemented either thermally or chemically (herbicides). In the past, farmers tended to utilize thermal sanitation extensively on their fields, but this trend is now changing. For example, 10 years ago 75 to 80 percent of annual ryegrass fields in the South Valley region were open-burned, and today only about 50 percent of the fields are open-burned, with the rest using plowdown techniques .

Today, perennial ryegrass growers in the South Valley region use stubble management techniques for 3 of 4 years in a crop cycle. Open-burning is used in the fourth year for only about 25 percent of perennial ryegrass fields.

The same is true for tall fescue, where only 25 percent of the acreage is open-burned, with the remaining 75 percent subject to stubble management techniques.

Straw Handling

Straw production for 1990 is estimated to be between 1.0 million and 1.2 million tons (Figures ES-3 and ES-4) produced on almost 400,000

Between 800,000 and 1.0 million tons of straw are potentially available for market.

planted acres in the state of Oregon. Of this amount, between 800,000 and 1.0 million tons of straw are potentially available from the fields for market. The largest potential volume of straw is from farms in the southern Willamette Valley, with about 700,000 tons produced.

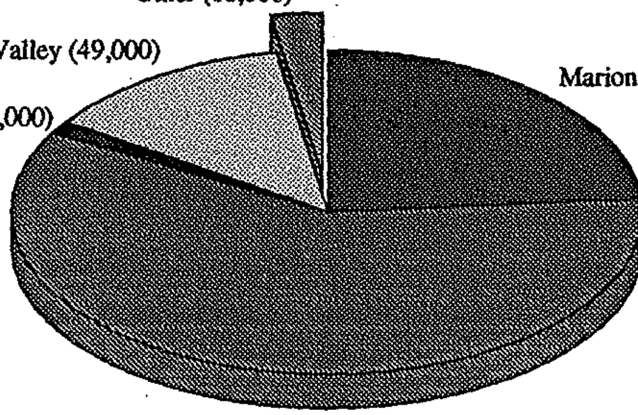

Figure ES-3
1990 Minimum Available Straw Statewide (tons)

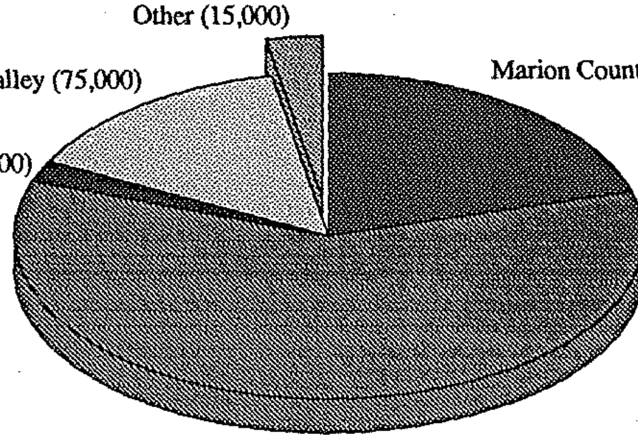

Figure ES-4
1990 Maximum Available Straw Statewide (tons)

In 1990, 156,000 acres were open-burned, and it is estimated that between 60,000 and 80,000 acres were plowed down. The remaining 150,000 to about 175,000 acres had grass straw removed and stack-burned or brought to market. This equates to approximately 150,000 tons of straw for export and between 250,000 and 400,000 tons of straw roadsided and/or stack-burned. Only about 60 percent of the 1990 straw removed is from the southern Willamette Valley, with Marion County and North Valley region producing most of the remainder.

Marketed straw is densified in small bales (100 pounds) or large "super" bales (1,600-2,000 pounds) and shipped to Portland for export as feed. Prior to overseas shipment, the straw is compressed into 5,600-pound blocks.

Nonmarketed straw is densified into round bales or loaves for roadsiding/stack-burning, with some being used for on-farm straw use testing. This form of densification is relatively cost effective, and stack-burns are short and efficient.

Straw brokers exist to a limited degree in the valley. Limited straw storage is available both with the straw brokers and with some individual growers. However, since only 150,000 tons of straw are marketed presently, the amount of storage needed for 800,000 to 1,000,000 tons of potentially available straw would demand significantly more storage be provided. Densifying and baling equipment, needed for straw marketing, must be developed and provided.

Straw as a Byproduct

Straw is a byproduct of grass seed farming, and hence has not commanded economic or agricultural importance in the past. The fact that about 200,000 tons of straw are plowed down and at least 500,000 tons open-burned or stack-burned in 1990 clearly shows that the farmer today continues to dispose of straw rather than market it. If the markets are established for straw use, the farmer must decide whether to plowdown or compost straw for soil amendments, roadside and stack-burn straw for rapid disposal, or gather straw and prepare it for market.

The cost of straw for market is sensitive to the amount of required preparation.

The cost of straw is sensitive to the amount of preparation required for market. Straw that is baled and roadsided costs $12 to $15 per ton. Transportation (150 miles) adds $15 to $25 per ton. Storage of straw adds another $7 to $10 per ton. This places straw costs in the range of $34 to $50 per ton, stored and delivered to market.

Implementation Strategies

This study identifies technologies that satisfy the "10-year goal" for significant grass straw use with processes that are proven to be commercially viable. It has also identified technology that needs more time and development before it can be counted on as a solid market for straw.

Straw for feed is already a successful market with some room for growth.

The first successful market for straw utilization is the export ***feed*** market. This use of straw is proven and can be expanded to other countries. An increased domestic market for straw feed is also a viable option. Technology is available to treat the straw for nutrients, but "raw" straw is already marketable and is successful. Straw can be chemically converted (hydrolyzed) to create a more digestible product as feed. Grass straw has enjoyed a stable export market in recent years, but it is far less stable in domestic markets, depending on supplies and accompanying costs of alfalfa and other forage feed. The problem with endophyte (a fungus that in some cases is toxic to livestock) must be considered for all feed markets.

The cost of wood chips is increasing as supply decreases. Straw can be an alternative fiber source and may command an attractive price.

One potential market is ***pulp and paper***, particularly in cardboard and liner production. Straw has been utilized in Europe for this purpose, and the technology exists to utilize it here in the Northwest. The delivered cost of grass straw is competitive with wood chips, which is the current fiber source. Straw obtains the highest value from this market, since pulp obtains the highest product value from fiber markets.

Pulp mills already handle recycled newsprint and recycled cardboard, and this market could utilize large quantities of straw to replace wood fiber. Production of paper products is less vulnerable to changes in the economy or housing starts as are other wood products industries. The cost for straw-related digestion and handling equipment could be a major capital expense. A new plant, or one that uses only straw to make pulp may not be economically reasonable today. Plants that use existing equipment and blend straw with other materials may be the most feasible.

Straw use as ***supplementary fuel*** in existing heating plants, dryers, and power boilers is also a possible market, and has been demonstrated in several Oregon wood-fired boilers over the years. Technology will support this option only if straw is mixed with wood and other materials to accommodate equipment limitations. In addition, some changes to plant equipment may be unavoidable when handling and firing straw. Some plants are also considering conversion to natural gas fuels from wood; straw cannot easily compete with natural gas costs as a primary or supplemental fuel.

Straw can also be used in ***structural board*** plants as a raw material or "extender" to wood residues. Changes must be made to the manufacturing process in handling and utilizing straw, and the price of wood fiber may have to increase above current levels to economically justify straw use. Also, public acceptance both at the product level and in building codes and standards must be obtained to make this a viable market item. Development of straw processing and use in strawboard and similar products could provide sufficient use of straw to compare with the options listed above. Several plants in Oregon are now considering straw.

The future looks promising for the economics of straw as a fuel source.

The ***powerplant*** market may also be a viable use of grass straw, especially when straw co-fired with other materials. Several straw-fired plants now operate in California and in other parts of the United States, as well as abroad. Technology is available to burn straw (with some unresolved problems), and improvements are continuously being made to improve performance on straw fuels. The economics of a straw-fired powerplant will benefit from changes in the Pacific Northwest power pool, which should help increase power sales rates and hence increase revenues available to the plant.

On-farm composting, while still under development, may be a major use of straw in the near future. It is somewhat unknown what volumes of straw can be processed and incorporated into the fields, but this alternative could divert a large percentage of otherwise available straw from other straw use options. The benefits to soil tilth and perhaps more importantly the independence from straw market conditions to influence straw disposal make this alternative attractive to the farmer.

Most alternatives will take advantage of existing technologies and changing conditions.

Most of these alternatives will take some advantage of existing conditions to help promote the technology and acceptance of straw as a raw material. Pulp mills with appropriate digesters and boilers suitable for firing straw cubes are examples of existing conditions that can be exploited for straw use.

There are many technology areas that will take several years to develop into a commercial enterprise, too long to achieve the "10-year goal" of this study. One such area is the ***chemical production*** market. This technology needs time to develop pilot plants, especially when using straw as the input material, and then commercial scale plants will follow. Also, markets for the products from these plants need to mature, to ensure that consistent financial return is provided to the enterprise.

There are other straw uses that have sufficient technology to produce viable businesses, but the amount of straw used is small, and established markets need to be developed. Included in this category are the ***home fuel*** markets, and ***commercial soil amendments***.

Interestingly enough, all of these straw use processes (home fuels, composting, hydromulching, soil amendments) have been tested and tried for at least the last 10 years, but markets have not grown nor have the number of firms producing these products increased significantly. The amount of straw used in these areas appears to be no more than 50,000 tons per year and is probably much less.

Straw use for on-farm purposes is increasing, especially for plowdown. This will affect the straw supply for other alternatives, but it does provide the farmer with an alternative to field burning.

Regulatory and Social Issues

Social impacts vary for each technology, as do the regulatory implications. Projects implemented at existing plants have positive benefits in terms of land use, social impacts, and jobs. Some straw use alternatives, such as feed or composting, have very limited social impacts. Other alternatives are expected to have much higher impacts to the environment and will experience greater regulatory requirements. These other alternatives will also have higher social rewards in terms of jobs and benefits to the economy.

The public's acceptance of straw utilization technologies is key.

The public has a large role in determining whether straw utilization options are successful. The public must learn to accept straw-based products. Sophisticated utilization systems must be accepted with the understanding that this sophistication will carry with it certain controls and safeguards to the environment.

The use of straw as an extender or supplement to existing processes should not provide many noticeable impacts. Increased employment and the return of operating plants will favor straw use at existing and closed plants. The public will see value in straw use as a sustainable resource.

Public scrutiny is expected to be strongest with technology that deals with chemicals, hazardous waste streams, or clearly visual impacts on the environment. Public participation in the planning, permitting, and siting of new projects will be instrumental in gaining public trust and support.

Market Trends

Various market trends will affect the status of the farmer and the straw produced, just as the farmers' activities also will impact the markets and technology.

For example, expansion of the grass seed market appears to be over. Markets for proprietary varieties, turf-type tall fescue, and perennial ryegrass in particular, have recently become saturated in production volume, and prices have fallen.

The farmers' activities and choices of straw management depend on various markets.

Also, plant breeds will continue to change. Growers will continue to develop proprietary varieties of dwarf and semidwarf types, and this will change the character and volume of straw available.

Straw feed markets and the presence of endophyte will be a continuing concern for growers. Identification and certification of endophyte-free tall fescue and perennial ryegrass varieties will expand as the market demands such information. Specific knowledge of endophyte infestation in all grass seed types will help in stabilizing this market.

The ability to obtain a stable supply of straw will be important to any project. An adequate infrastructure must be created to manage straw inventory, protect it from the elements, and deliver it as needed.

The public's attitude about land use is changing. Many new residents to the state of Oregon view land as a place to live on and not to earn a living from. This view will challenge new projects and reward existing plant sites that are reworked for new technology.

Another very obvious trend is the decline of timber harvest in the Northwest, due to habitat preservation (e.g., the spotted owl), lagging regeneration, and the general shift to the southeast for timber production. Supplies of wood fiber will vary in cost and volume as forest products plants vacillate in response to housing starts. Competition for limited supplies of wood chips and hogged fuel will continue between local mills and out-of-state powerplants.

Dwindling surplus power reserves in the Northwest are now becoming evident. Power production in the region will likely diminish as decisions regarding salmon runs on the Columbia River impact hydropower plants. Also, decisions are pending on how Bonneville Power Authority finances debt, which will affect their wholesale rates for power. Power reserves, now sold to California, have steadily declined and are now predicted to diminish in the mid to late 1990s. New sources of power production will be carefully scrutinized, and traditional types of plants (eg: coal, nuclear, hydropower) are likely to be challenged when proposed.

Revenues for new powerplants should be better in the future.

Power rates will increase as replacement power sources are added to the power pool. Revenues for new powerplants should be better than available today, and power sales contracts will be tied to fuel supplies (including straw supplies) as they impact power production.

On The Horizon

So much work has been done over the years towards straw utilization, yet the situation continues to demand support towards success. It appears that now is the time to unite the public, the legislature, and the grass seed farmer in establishing viable markets for straw use. This effort should include consideration of the farmer's situation, provisions for realistic straw storage and distribution, and favorable support by the public towards straw use projects.

This study is a "snapshot" in time.

It should be recognized that this study is a "snapshot" in time, and that economic and social factors are always changing. The assessments of straw utilization options provided in this study will be affected over time, but the need for action will not.

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1 Introduction

More than 1 million tons of grass straw were generated in 1990.

The Willamette Valley grass seed industry is a major contributor to the agricultural sector of Oregon's economy. Grass seed production is the single largest crop enterprise in the valley, both in terms of acreage and value of crop production. Cool-season turf and forage grass seed has been produced in the Willamette Valley since before World War II. However, disease problems limited the potential for growth in this farming enterprise. Advent of the practice of open-field burning allowed significant expansion of the industry in the 1940s and beyond by providing weed control, sanitation, stimulation of yield in perennials, and convenient straw disposal. The primary production area initially was the southern Willamette Valley, but farming soon expanded to the foothills east of Salem, the benchlands of the central valley, and eventually in the 1980s farther north into Yamhill and Clackamas Counties (Figure 1-1).

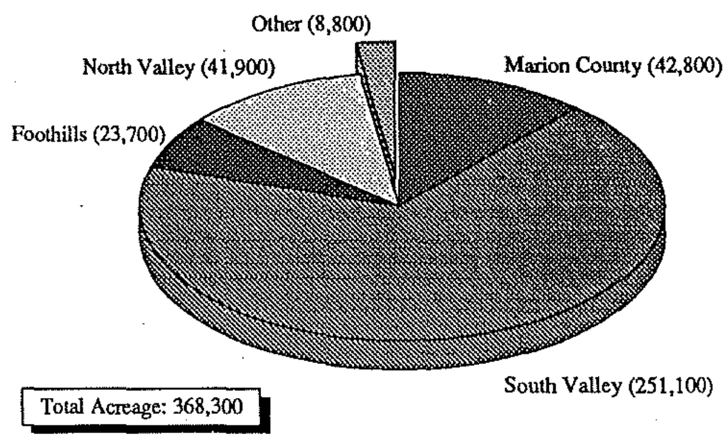

Figure 1-1
1990 Grass Seed Farming in the Willamette Valley by Regional Distribution (acres)

As acreage and seed production grew, the volume of straw disposed of through open-field burning also increased. During this same period, public awareness and concern increased over environmental impacts of smoke intrusion from field burning. The growers' need to remove straw from their fields in a timely fashion, combined with mounting public pressure to reduce smoke intrusion, has again focused attention on the need for straw utilization.

The quantity of straw left after seed harvest is sizeable (Table 1-1). In 1990, more than 1 million tons of grass straw were generated on almost 400,000 acres of land devoted to grass seed production in the State. Less than 160,000 acres (480,000 tons of straw) were open-field burned that year, the smallest amount since the earliest years of practice. Between 60,000 and 80,000 acres (200,000 tons) of annual and perennial grass straw were plowed down. About 150,000 tons of this straw were sold as feed. The remaining straw was roadsided and stack burned.

Table 1-1
Total 1990 Statewide Straw Production, Removal, and Export by Grass Type

Grass Seed Types	Acres Planted[1]	Potentially Available Straw (tons)[2]	Current Straw Removed (tons)[3]	Exported for Feed (tons)[4]
Tall fescue	91,510	291,328	206,968	43,345[5]
Annual ryegrass	109,180	272,019	0	0
Perennial ryegrass	108,340	244,266	194,521	106,409
Kentucky bluegrass	25,620	41,205	18,973	544
Orchardgrass	19,950	44,638	29,465	904
Bentgrass, creeping	7,160	15,955	14,096	2,425[6]
Bentgrass, colonial	7,780	9,569	3,794	NA[7]
Hard fescue	2,060	3,605	3,245	NA
Chewings fescue	17,710	2,435	2,361	NA
Red fescue	8,870	1,227	1,416	NA
TOTAL	398,180	926,246	474,839	153,627

[1] Based upon regional data in Table 4-2, which was derived combining data for counties.

[2] Based upon low and high tonnage of maximum potential available straw removed from field, as listed in Table 4-1, Columns 9 and 10.

[3] Based upon low and high tonnage of current grass straw removed from field (roadsided, stack-burned, or marketed), as listed in Table 4-2, Columns 19 and 20.

[4] Based upon Table 6-1.

[5] Includes all types of fescue.

[6] Includes all types of bentgrass.

[7] Not applicable because included in total elsewhere.

The grass seed varieties grown in the valley are changing. Implementation of Public Law 91-577 (Plant Variety Protection Act) in 1970, which allowed private and public breeders of seed varieties patent rights protection, transformed the structure of the industry. Proprietary varieties expanded both in number and seed volume produced. Until 1970, with the exception of varieties from Europe, nearly all foundation seed used in plant breeding for improved species was propagated by and distributed from public programs as public varieties. Developments by private seed companies have been most pronounced in improved varieties of turf-type perennial ryegrass and tall fescues. This market expansion has resulted in grower acreage expansion, particularly during the past decade, to more than 360,000 acres in 1990 in the Willamette Valley.

Favorable market conditions are emerging for grass straw utilization.

Conditions that have been historically poor for grass straw economics in the fiber, feed, fuels, and chemical products industry also are changing, while Willamette Valley farmers continue to increase their yields of grass seed. More favorable market conditions are emerging for grass straw. For example, timber harvests in the region will be reduced by habitat protection measures and fewer acres of harvest-age timber. This has created a reduced supply of timber products and byproducts, and resulting higher costs for wood fiber resources. In addition, the Pacific Northwest surplus supply of power may be nearing an end, and additional power costs are anticipated. The past few years also have seen an annual export of more than 100,000 tons of grass straw from the Willamette Valley to Japan for cattle feed. While this study was being organized and conducted, world and local events have greatly influenced the economic conditions surrounding straw as a raw material. The economic situation resulting from Iraq's occupation of Kuwait has sharply increased the cost of oil and oil products.

Much research has been conducted to help analyze the opportunities.

Thus, it is very timely to re-examine the opportunities for increased grass straw utilization in Oregon. This report is organized to present information about the current condition of Oregon's grass seed industry, factors affecting the grass straw supply, the feasibility of straw use in specific markets, and future industry conditions and market trends.

A tremendous amount of research and study was conducted throughout the 1970s and 1980s concerning straw use and the grass seed industry. This work was performed by countless individuals, growers, and state agencies in a variety of areas. Of particular note is the pathfinding research conducted during the 1970s by the Field Sanitation Committee. Supported by growers fees, numerous research projects were conducted under the direction of Bill Rose and Tom Miles. Among the studies there were more than 30 dealing with the technical and economic aspects of using straw in a wide range of potential markets. This study was designed to build upon this broad foundation, focusing on specific areas of straw use for the preliminary design and construction efforts that may follow.

After this introductory chapter, the approach to the study, why participants were selected and what were the objectives, is presented in Chapter 2. The next three chapters of this report involve straw availability. They treat the important question of how much straw is produced and available at the farm level for potential market utilization off-farm.

Chapter 3 deals with factors affecting straw supply, limitations in grass seed production, characteristics of the growing regions, and other changes in the industry during the last 10 years.

Chapter 4 provides a tabular view of the amount of existing and potential supply of grass straw. Acreage and straw production tonnage by geographical region and grass seed type is presented for 1990. Current on-farm straw disposal by open-burning and plowdown is specified. Residual acreage and volume of straw removed for market use/roadsiding is shown. Current trends in grass seed production, which could impact straw volume and quality for market, are discussed.

Chapter 5 examines straw removal, stubble management, and field sanitation practices, discussed as sequential and complex postharvest substitutes for open-field burning. Costs of such practices are estimated, including the straw removal component. Experimental on-farm composting of straw composting is described as a possible disposal alternative.

Chapters 6 through 10 examine the range of market potentials for grass straw. Each of the potential markets are assessed using the criteria of technical feasibility, economic viability, and volume of potential straw use. Chapter 6 discusses livestock feed markets for straw. Chapter 7 reviews fiber markets, which include pulp and paper, structural board, erosion control products, and soil amendments. Chapter 8 treats straw in fuel markets, including industrial applications for power and process heat generation, cogeneration systems, and residential stove markets. Chapter 9 discusses the use of straw in a number of chemical processes that produce marketable fuels and other substances.

Chapter 10 outlines the regulatory and social issues influencing straw utilization in the identified markets. Specifically, this chapter discusses the regulatory issues of air, water, noise, and land use, and the social issues of infrastructure, transportation, waste disposal, straw handling, social economies, and social acceptance values. This chapter assumes certain scenarios, without discounting others, for each market area, and discusses what requirements and impacts are involved.

Chapter 11 discusses trends in the grass seed industry and markets for straw utilization, and conclusions that can be drawn from the study.

An executive summary precedes this report (and is available separately) to bring all this information into focus.

Several appendixes are included to supplement the chapters with greater detail or background. Appendix A includes the notes from public meetings held in the valley to discuss straw utilization issues. Appendix B provides 1989 data for the amount of straw produced, removed, and burned, by type, in different regions. Appendix C details manufacturing processes for using straw in various types of structural boards. Appendix D provides low and high performance data calculated for powerplant operation. Appendix E lists Oregon and Washington chemicals manufacturers. Appendix F is an international bibliography of additional sources of information.

2 Approach to the Study

Background

This study began as a collaboration of the grass seed industry and state government to create some specific uses for straw, using demonstrated technology, in facilities located in the Willamette Valley. The Oregon Economic Development Department (OEDD) was considered as the lead state agency, working with other state groups such as the Oregon Department of Agriculture (DOA), Linn-Benton Regional Strategies, and the Oregon Department of Environmental Quality (DEQ). These state agencies secured public funds for this study and have been involved in a material way during its course.

CH2M HILL led the study under OEDD's direction.

CH2M HILL, a firm of consulting engineers, planners, economists, and scientists with headquarters in Corvallis, was approached as the leader of the study, to provide neutrality towards the issues and to provide expertise in the presentation and analysis of the information. Together, CH2M HILL and OEDD fashioned a preliminary approach to the project and set up a budget to finance the effort.

It was decided that the grass seed industry would also provide financial and material support to the study, and that a technical resource was needed to collect and evaluate both the industry situation as well as what specific market opportunities could be identified for grass straw.

Oregon State University served as the technical resource.

Oregon State University (OSU) was selected as that technical resource. OSU's long history of research and support of both the grass seed and forest products industries provided a strong background to draw upon during this study. A 1989 OSU Extension Service publication, titled *Burning Grass Seed Fields in Oregon's Willamette Valley, The Search for Solutions*, was particularly applicable to the study objectives. Industry financial support was obtained from the Oregon Seed Council, an industry supported group that promotes research and development to maintain a viable grass seed industry.

Grower focus groups and public meetings were arranged.

This study did not generate new research in straw use technology. It did use two innovative methods to data gathering, however. The first method was a series of grower focus groups, where growers participated in describing how the industry looked in 1990 and what are the anticipated changes. The second method was a series of public meetings, held in the Eugene, Albany/Corvallis, and Salem areas, where members of the public were divided into discussion groups and challenged to identify markets (and impacts) related to straw utilization.

Approach to Analyzing Market Potentials

An iterative test criterion was used in this study to screen market potential for straw utilization. The process involved a five-phased sequential listing in order of use:

1. Initial technical feasibility
2. Preliminary economic viability
3. Volume of straw demand potential
4. Overall economic viability
5. Social/environmental acceptance criteria

A schematic of the process is presented as Figure 2-1.

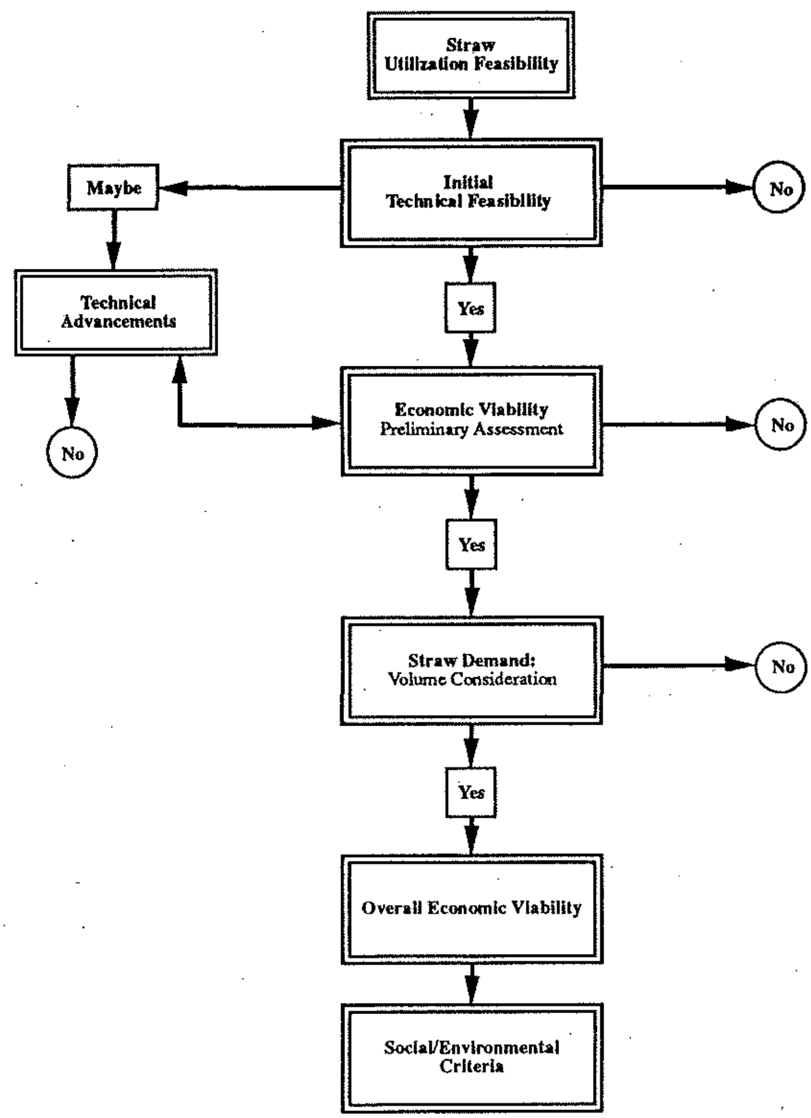

Figure 2-1
Straw Market Test Criteria

Initial Technical Feasibility

Markets that currently used straw or were considering its use were studied.

In looking at market potential for grass straw, this study considers established markets in which it is known that straw is now being used, or is being considered for use, as a raw material. This addresses the fundamental issue that straw usage in industrial processes is known to be technically feasible. This study does not consider markets in which potential straw usage is still in the experimental or developmental stage and will remain so until substantive technical issues precluding its use are overcome.

Thus, initial technical feasibility screening requires that straw can serve as a raw material using known technically operable processes (from somewhere in the world) in producing a commercial product.

This initial screening is done by industry technical expertise.

Preliminary Economic Viability

Straw had to show some probability of competitiveness with other raw materials, that is, economic viability.

The second criterion involves a preliminary assessment of the economic likelihood that market conditions, now or in the near term, will permit grass straw to be economically competitive with raw materials currently being used in existing markets. This is to say that straw must meet a market demand criterion in which it is equal to or less costly than one or more raw materials currently being used, such that it could be given serious consideration as a potential market substitute for current raw materials.

For raw materials being used commercially, the current and near-term expected price is the target of comparison. No substantial market exists for straw in which the straw itself, as a raw material, has a positive value or price. For this analysis, a zero value is inputed for straw roadsided at the farm gate. The additional or incremental costs of any densification required beyond that normally done by growers to roadside the straw but required by the industrial firm, storage costs to provide a continuous supply of straw, and transport costs for delivery of straw to the industrial plant are used to generate an "imputed market price." The "price" is the minimum level of competitiveness required to move straw into commercial channels. Such costs must be incurred to move straw off the farm and into commercial channels. It treats the raw material of straw as a free good, an economic condition comparable to most commercial straw movement currently. To grass seed growers, the situation is one of loss minimization, getting rid of a problem byproduct without incurring further grass seed production costs in shifting to cultural practices that serve as alternatives to open-field burning.

The economic viability criterion precluded straw usage in most commercial markets during the 1970s, but changes in recent market conditions may pose straw in a more favorable economic light.

The first two criteria taken together are not sufficient to assure straw usage in any given market or that the straw utilization problem of the Willamette Valley grass seed industry is resolved. Thus, the three additional criteria are necessarily used.

Volume of Straw Demand Potential

The volume of straw demand needs to be substantial.

Potential volume of demand for straw is an important consideration. Some market uses may have potential for using only small amounts, whereas others such as one or a few powerplants might conceivably use all or nearly all of available total straw supply. Knowledge of this issue is viewed as an important consideration for industrial entities considering straw as a potential raw material.

In cases where volume of potential usage for a given market are determined to be small (e.g., 10,000 tons per year total), no further analysis is made for purposes of this study. Such low-volume utilization potential is viewed as contributing little to resolution of the overall straw utilization problem facing the industry. It should be noted, however, that small-volume straw uses may prove economically viable when pursued in great numbers of installations and should be considered by the small operator.

Overall Economic Viability

Straw may require a price advantage to cover costs of plant modifications.

Although straw use potential may meet the first three criteria, actual adoption of straw in the marketplace may not occur. Physical and chemical properties of grass straw are not identical to other raw materials being used. Modification of existing plant and equipment may be necessary to accommodate straw. The extent to which such modifications or retrofitting are required will influence the capital investment, operating efficiency, and technical modifications for inputting and processing of straw. Thus, straw may require a market price advantage of some magnitude over other raw materials to offset plant modification cost and operating efficiency factors.

Social/Environmental Acceptability Criteria

Social costs and acceptance were also considered.

DEQ, EPA, and other regulatory standards serve as individual and firm proxies for meeting broad social and environmental acceptability criteria established by society. They serve as a mechanism in which individual firms internalize or pay for the environmental equipment and processing costs that reduce or restrict pollution effects to socially acceptable levels as part of the normal cost of doing business. Such costs associated with the addition of straw must be considered in the overall economic viability of utilizing straw as a raw material. This includes the time required to meet the permit process, penalties imposed to current operations if retrofitting requires down time for some portion of the plant, and incremental costs for retrofitting to accommodate straw and adding environmentally required equipment.

3 Factors Affecting Grass Straw Availability

Introduction

During the last decade, several factors have combined to change the cultivation of grass seed in the Willamette Valley. For example, new varieties have been introduced, and acreages have shifted into different plantings. Also, the level of open-field burning has decreased, and new technologies for disposal have been developed and adopted. These factors affect current straw disposal and utilization issues, and will weigh significantly in the potential size of future straw markets.

The grass seed industry has changed in several ways over the last 10 years.

Because no in-depth investigation had been made since the late 1970s (Ryan et al., 1981) of grass seed farming operations, a goal of this study was to identify and quantify today's on-farm practices, production options, market conditions, suitable technologies, and other factors that affect the availability of straw. To gather this information, farmers and specialists in the grass seed industry were brought together in meetings.

Complicating the study is that the history of the grass seed industry and the geography of the Willamette Valley have resulted in considerable differences across the valley in farm sizes and other characteristics affecting grass seed farming. As a result, it becomes important to consider statewide production, and particularly that in the Willamette Valley, in terms of distinct geographic regions.

Regional Distinctions

Four regions, which often cross county boundaries, were proposed for this analysis of grower practices and other factors affecting straw availability:

Grass seed farming is distinctly different in regions of the valley.

- South Valley: Broad benchlands of Lane, Linn, Benton, and southern Polk Counties
- Foothills: Silverton Hills region of Marion, north Linn, and southern Clackamas Counties
- Marion County Lowlands: River bottom and benchlands of Marion County
- North Valley: Yamhill and northern Polk Counties

Although the focus of this study is the Willamette Valley, grass seed production takes place in other parts of the state, but the scale is generally small. In northeastern and central Oregon, approximately

14,000 acres in each of Union and Jefferson Counties are farmed for grass seed. It is important to consider practices and effects in other areas as well for two reasons: first, issues of straw utilization and disposal affect all grass seed production regions; and second, the prevalence of livestock east of the Cascades affords the potential for straw to be used as feed.

Our investigation and subsequent contacts confirmed the appropriateness of the geographic division of the Willamette Valley; conditions and growers were found to be fairly homogeneous within each region and distinctly different from the other regions. For example, farms in the southern part of the valley tend to be larger than those farther north, but those in the north have many more production options. Grass seed types produced in the Silverton Hills of Marion and north Linn Counties are sufficiently different from those in the rest of the valley that production methods (and influences affecting them) are unique. Even the structure of farms west of the Willamette River (north Polk and Yamhill Counties) differ from those on the east side.

Information Gathering and Analysis

For each of the four regions in the valley, a "farm focus group" was devised as a forum to discuss and reach consensus on issues related to grower practices and attitudes in the region. Each focus group consisted of five or six growers, two seed company field agents, and a regional agriculture extension agent. Attempts were made to enlist growers who represented a cross section of farm sizes, produced grass seed types consistent with the area, were considered "leaders" in management, and were familiar with grass seed production in their region.

"Focus groups" provided information on current farming practices.

Focus group meetings were held during the month of September. Meeting notes were sent for review to a 10-person "expert group," consisting of OSU researchers and extension agents, a plant breeder, a seed company field agent, and an economic development specialist, all knowledgeable about grass seed production and the industry. This chapter includes a summary of the detailed information refined by the focus group forum for each region.

Phone discussions with County Extension Agents in Union and Jefferson Counties provided information on practices in these two areas.

Finally, the information gathered also was reviewed by members of the Technical Advisory Committee for this study.

Findings

It is evident that the postharvest practices of grass seed growers across the Willamette Valley and in eastern Oregon vary considerably, even for growers of the same grass seed type. This heterogeneity is indicative of the set of conditions and factors affecting grass straw availability. These factors, summarized below, include soil type and production options, physical limitations, farm size, regulated burning, and market conditions.

Soil Type and Production Options

Production options are limited in some regions.

In overview, predominant grasses grown in the South Valley region include annual ryegrass, perennial ryegrass, and tall fescue; for the Foothills region they are fine fescue, hard fescue, Colonial bentgrass, and perennial ryegrass; for the Marion County Lowlands they are perennial ryegrass and tall fescue; for the North Valley they are tall fescue and perennial ryegrass; for eastern Oregon they are turf-type Kentucky bluegrass, creeping red fescue, turf-type chewings fine fescue, and tall fescue. (See Chapter 4 for specific grass seed acreages by county.)

Seed production has remained important in the southern part of the Willamette Valley (Lane, Linn, Benton, and parts of Polk Counties) and Marion County, both in the foothills and the lowlands. Grass seed types and influences on growers have nevertheless remained distinct in these regions.

Soils in the South Valley region tend to be poorly drained and less productive than elsewhere. They also are not able to effectively produce other crops, either agronomically or economically. Therefore, grass seed producers in the South Valley have few if any productive options besides some leeway in choosing the type or variety of grass seed. Growers are subject to higher risk with respect to grass seed market conditions and external pressures on production (such as limits on open-field burning). As a consequence, a wider range of alternative technologies for straw disposal and disease control are being tested and implemented in the South Valley.

By contrast, the North Valley and Marion County Lowlands regions have better soil conditions and more productive options. Long-term economic conditions affecting the grass seed industry are more apt to be reflected in crop substitution.

During the past decade there has been an expansion of acreage, particularly in turf-type tall fescue and turf-type perennial ryegrass. Shifts have taken place (particularly in the southern valley) out of some grass seed types (annual ryegrass) and into others, but there have also been noted shifts from small grain, vegetables, and legumes to grass seed. This has been most evident in the lowlands of Marion County, and in the new region of northern Polk County, Yamhill County, and to some extent Washington and Clackamas Counties. The year 1990 saw the highest number of acres in production of grass seed ever.

Physical Limitations

The Foothills region stands out as being affected by physical limitations affecting productive capability. Steep slopes can render farming and straw handling equipment and alternative crops unworkable because of unacceptable levels of soil erosion. For the most part, this condition does not affect growers in other areas.

Farm Size

Two primary effects result from the South Valley region having a greater proportion of large farms than the North Valley region. South Valley growers have greater difficulty applying postharvest treatment in a timely fashion, a condition exacerbated when capital-intensive operations are used. However, North Valley growers have higher valued land and require a greater return per acre as a consequence. Thus, the influence of timing affects both areas but for different reasons.

Regulated Burning

Competition for burn permits has led to uncertainty.

While no legislation has been passed since 1978 limiting open-field burning (Conklin et al., 1989), total acres burned annually have declined during the past few years, to about 156,000 in 1990 (Oregon Department of Agriculture, 1990). The number of burn days allowed by the Department of Environmental Quality and by the Oregon Department of Agriculture has decreased while acreage registered for burning has increased. The competition for permits has led to enough uncertainty for growers that many have sought and used alternatives to open-field burning.

The bottleneck for burn permits is exacerbated by the growth in acres of grass seed in production. At the same time, there are yield consequences with leaving straw on the field after harvest. Growers therefore weigh the consequences of waiting for a burn permit with the cost (direct and in terms of future yield penalty) of otherwise removing the straw.

These approaches have not been applied uniformly across the various grass seed types, but rather have led growers to prioritize burning according to agronomic needs, physical limitations, or relative economic value. This has resulted in significant changes in open-field burning for grass seed types across the Willamette Valley:

- Annual ryegrass: 50 percent of acres open-burned now, down from 75 to 80 percent a decade ago, or a decline of some 30-40,000 acres
- Perennial ryegrass: 5 to 25 percent of acres open-burned now, depending upon location (more in the south), down from 10 to 50 percent open-burned a decade ago

- Tall fescue: 25 percent of acres open-burned now, down from 75 to 90 percent open-burned a decade ago (although total tall fescue acres in production has increased)

In each region, and for each grass seed type, alternative approaches are being used in place of open-burning. Straw removal is used in most of these alternatives; as a consequence, straw volume requiring disposal or distribution has increased in proportion higher than the increase in acreage.

Growers in the Marion County Lowlands have very productive lands and higher land costs than elsewhere. The opportunity cost of waiting for a permit may be greatest in this location. As a result, many growers have invested in alternative methods for dealing with the straw, including the building of storage sheds. This investment has allowed growers of perennial ryegrass to export nearly all their straw to Japan. Newer growers in Yamhill and Polk Counties have not made that investment, and while they too have sought alternatives to open-field burning, a higher proportion of their acreage is open-burned.

Straw volume has increased proportionately more than grass seed acreage increases.

The South Valley region has the largest proportion of acreage in annual ryegrass, and much of this is still open-burned. Many growers have shifted their burning allocation to these fields (rather than their perennial grass seeds) because of the higher cost of the alternatives (i.e., plowdown). Even so, a decline in burning of annual ryegrass fields has been noted.

Foothills farmers must consider the consequences of not burning and have chosen a burn priority for the fine fescues. To the extent possible, Colonial bentgrass fields have had straw removed for the feed market.

Market Conditions

The development of new and better varieties of grass seed types, the Federal Conservation Reserve Program and a strong national economy, are factors that led to steady growth of the grass seed industry in Oregon. However, it is unlikely that the next decade will witness a similar expansion for the grass seed industry (Lev, 1990). There is concern among growers and seed companies that production would begin to outstrip demand, stocks would build up, and prices would drop. Declining prices have been affecting some grass seed types (i.e., annual ryegrass, bluegrass, and most forage types), although most others have held steady. Acres in production are remaining stable, as prices for alternative crops remain relatively low.

Expansion in general grass seed demand probably has now ended.

These factors affect the market for and availability of grass straw. Although the near term indicates a stable and abundant supply of straw, declining prices could eventually induce a contraction in production of grass seeds. Any reduction in total acres will be concentrated in the north valley of Polk and Yamhill Counties, where production options remain available.

Despite low prices for annual ryegrass, widespread shifts to other crops or even to perennial grass seed types appears unlikely. Soil types predominant in much of the annual ryegrass country (the South Valley region) are of limited quality for other crops. The return on investment of shifting to perennial grass seed types may be prohibitive.

The export feed market has been an economically viable outlet for straw.

Perennial ryegrass and tall fescue straw supply will remain stable in the short term because of the terms of growing contracts. This could change if seed market conditions (such as declining demand in areas affected by persistent drought), a stagnant national economy, and continued high stocks of seed lead to a fall in prices.

The Japanese feed market has allowed perennial ryegrass growers (primarily in the North Valley region) to have an economically viable outlet for straw. Transportation costs from southern parts of the valley to the Port of Portland are higher. This option is therefore not as accessible to South Valley growers, and they engage in more open-field burning of perennial ryegrass fields.

In eastern Oregon, the high feed quality of Kentucky bluegrass and local livestock production has provided a ready market for straw, encouraging some shift away from open-burning in recent years.

Regional Conditions and Grower Practices

This section summarizes the information collected through the four focus group meetings and two phone conversations. All statements should be considered products of these discussions, unless otherwise cited. Detailed below for each region of the state are the geographic characteristics and general conditions, the practices employed for each type of grass grown, and the role of proprietary varieties.

South Valley

The South Valley region includes the counties of Lane, Linn, Benton, and southern Polk (which is roughly the area south of Highway 22). Grass seed production in the South Valley began with annual ryegrass just after World War II. The region contains a higher proportion of large farms (over 1,000 acres) than elsewhere, many of which exclusively produce grass seed. The longest tenure of seed production is found here, with some farms managed by fourth and fifth generation growers.

South Valley soils are some of the poorest.

The soil quality of the South Valley makes it unique. Broad stretches of Amity and Dayton "Whiteland" soil types make up much of this area, and these soils are characteristically some of the poorest to farm. They are heavy, poorly drained, often flooded during winter, and slow to drain in spring. While they are unsuited to most crops, grass seed (particularly annual ryegrass) produces well, being unharmed by periodic winter flooding.

As a consequence, the South Valley contains nearly all the annual ryegrass fields in the valley, producing some 110,000 acres (Miles, 1990). Next in acreage is perennial ryegrass and tall fescue. Other seed types include orchardgrass, Kentucky bluegrass, and small acreages of bentgrass (Colonial and creeping), chewings fescue, and creeping red fescue.

Roughly half of the South Valley grass seed acreage is planted with proprietary varieties, although very few acres of annual ryegrass are planted with private not public varieties. A general trend has been a shifting of wheat and annual ryegrass acres to perennial grasses, and in the far south (near Junction City) there is a shift out of row crops to grass seed.

Annual Ryegrass

Annual ryegrass production is unique for several reasons. It is a grass seed type that will grow well on even the poorest soil and is one of the easiest grass seeds to produce. It is also the only grass seed type produced in Oregon that is an annual, requiring planting every year. However, annual ryegrass is often considered a grass seed of "last resort" in the market, used as a filler in lawn seed, and is subject to widely fluctuating prices; since 1987, the price received by farmers has ranged from 11 to 25 cents per pound (Mellbye, 1990b).

Only half of annual ryegrass fields are not open-burned.

Decades ago, many South Valley growers produced only annual ryegrass. Today, however, there are fewer growers who produce only annual ryegrass. Most growers of the region are also producing proprietary perennial ryegrass and tall fescue. The trend towards higher proportions of perennial ryegrass and tall fescue continued through the mid-1980s but has since stabilized. This shift away from annual ryegrass, however, is costly, requiring land cleaning from weeds and stand establishment, which in some cases requires leaving land fallow for a year. Nevertheless, seed quality in the valley has improved greatly over the past decade partly because of market demand and the response by growers to improved cultural practices. These practices have cut down the amount of weed seed in the area and have actually reduced the number of winter cleanings needed.

In general, growers use one of two cultural practices for dealing with straw from annual ryegrass fields: open-burning of fields, or plowing the straw into the soil (plowdown). A decade ago, about 75 to 80 percent of annual ryegrass was open-burned, a level influenced by allocated burn quota limits, with the remainder plowed in. At present only about half of this acreage is open-burned. The smaller volume of acreage in the valley, combined with burning restrictions and the need to complete work in a timely manner, have lowered the amount of open-burning. Growers will chop and plowdown the straw once every 3 to 5 years in order to add tilth to the soil and control weeds (especially bentgrass), regardless of burning restrictions.

In the case of plowdown, straw is chopped (flailed) after harvest and plowed directly into the soil. After plowdown, fall rains encourage weed seed germination, and a second harrowing or application of the herbicides Roundup and Nortron or paraquat may be needed for weed control. These practices require an increase in cultural management, equipment, and expense, as compared to open-burning. For example, a 1,500-acre annual ryegrass farm would need to own or rent more tractors to plowdown the acreage than to open-burn in order to complete the work in a timely fashion. Earlier replacement of flail choppers would also be necessary.

Growers will supply straw to market, instead of burning or plowing it, if they are assured of at least recovering their costs.

The effect of plowdown on disease and insects is uncertain. There are cases where continuous plowdown has been practiced for more than a decade with no attributable increase in disease incidence. However, there have been a few incidences of insect damage on annual ryegrass fields (both plowed down and open-burned). Although the cause is not known with certainty, speculation is that it is related to the decrease in open-burning in the valley. Research work currently under way is addressing this and related issues.

As virtually all annual ryegrass straw is open-burned or plowed down, none is currently available for market use. Annual ryegrass straw is considered a poor quality option for livestock feed, but it is the preferred straw of choice in the pulp industry (Biermann, 1990) (see Chapter 7). The willingness of growers to supply straw should a market become available is influenced by three factors:

- Low profit margins, affecting the amount of financial risk they are willing to undertake
- Consistency of a market for their straw, affecting their willingness to undergo the expense of straw removal
- Relative expenses, considering not open-burning and the benefits of improved tilth from plowdown on future production

Therefore, growers would supply straw (i.e., not open-field burn) if they could recover at least the opportunity cost of open-burning ($8 to $10 per acre) or plowing down ($15 to $20 per acre) and if the demand for straw were to remain relatively stable into the future. (Chapter 5 contains details of these costs.)

Perennial Ryegrass

Perennial ryegrass differs from annual ryegrass in that it remains in production for more than one year after planting. Thus, perennial grass straw cannot be plowed into the soil every year, making straw removal and disposal a more critical issue.

Perennial ryegrass fields are usually burned only to establish a new stand--about once every 4 years.

Perennial ryegrass as a species is less tolerant of open-burning than other grass seed types. Consequently, straw typically has been removed and the stubble managed in some form on these fields. However, in the South Valley it appears there is a trend away from some forms of thermal sanitation because of its cost relative to other methods (see Chapter 5).

The usual practices for perennial ryegrass are the following: for 3 years, bale and remove straw, then follow with a stubble management practice for sanitation; in the fourth year open-burn (if possible) or plowdown straw or stubble, and prepare for replanting. Thus, open-burning is practiced on about a quarter of the acreage each year.

South Valley growers have demonstrated considerable innovation with respect to stubble management techniques (after the straw is removed). At least six options are currently being used (Mellbye, 1990a):

- Propane-burn
- Reclip and loaf stubble
- Crewcut with a Rear's vacuum
- Flail chop
- Flail chop and thatch
- Reclip and "rake" with a scratching implement

Each of these practices requires one or more herbicide applications to control volunteer grass and weed seed germination.

Although propane burning has been the dominant practice, the level of propane use has dropped the past 2 years to at most 20 to 25 percent of the fields. Reclip and loafing or crewcutting is practiced now on a majority of fields.

In past years, much straw was simply baled, stacked at the roadside, and burned. Where a market exists for straw, custom operators will often bale and remove straw at no cost to growers. (Growers absorb the cost of any storage facilities, however.) When growers lack storage facilities and a market is not available, custom operators will charge $7 to $15 per ton for storage. Because of a lack of certainty with respect to future markets for straw, it is unclear whether more storage sheds will be built.

Tall Fescue

Compared to other grass seed types, tall fescue is very tolerant to open-burning. However, because it is not tolerant to straw cover, some form of straw removal or thermal sanitation is required very soon after harvest so as to not harm next year's crop yield. Tall fescue's priority ranking for burning has also been influenced by its high profitability over the past several years, although it tolerates herbicide treatment better than perennial ryegrass.

Because tall fescue yields are hurt by straw cover, removal or burning soon after harvest is important.

Roughly 75 percent of the tall fescue acreage in the South Valley has been open-burned in the past, a level influenced by both the Oregon Department of Agriculture burning program and the high number of tall fescue acres. However, in 1990 there was a decided decrease in open-burning, to about 25 percent of the acreage, with the remaining 75 percent under a straw and stubble management program. The cause has been attributed to the prevalence of a favorable hay market. Also important is an apparent change in grower philosophy away from burning and toward baling and stubble management, so as to regain control of their operations rather than wait for a burning permit.

Stubble management options are the same as for perennial ryegrass, with the addition of a limited amount of livestock grazing. There are not enough beef cattle available in the Willamette Valley to make this practice widespread, and grazing can only take place on fields of forage-type varieties because of fungus in turf-type varieties. Cattle are able to graze until November or early December without damaging the stand. (Unlike cattle, sheep will not eat the extra stubble left on the field, so they are not as effective for management purposes.)

Flail chopping is more prevalent than other stubble management practices. It has a lower cost, and it facilitates herbicide penetration to control weed seedlings. It also eliminates fall-formed seed heads that may produce ergot in next year's seed crop. Many other new options now are being tested; their viability as yet is inconclusive.

Straw volume can range from 3 to 6 tons, but it averages about 3-1/2 tons per acre. The wide range is due to seed variety, soil type, and subclimates of areas within the South Valley region. Feed quality for forage-type tall fescue may be better than perennial ryegrass, as long as it is baled very soon after harvest.

An important factor for potential feed markets is the level of endophyte in the straw. Endophyte is a fungus occurring naturally or bred into certain grass seed types and varieties (i.e., tall fescue and perennial ryegrass) to enhance disease and insect resistance, but which is toxic to livestock under certain conditions. The relationship of endophyte to livestock is not fully understood and is the topic of a number of research studies under way across the country.

Role of Proprietary Varieties

A steady trend towards production of proprietary varieties has resulted in three main effects:

- There is greater emphasis in the industry on seed quality, with many contracts requiring that seeds be certified.
- Contract length has shortened to 3 or 4 years.
- The newest varieties of tall fescue tend to be dwarf and semi-dwarf.

There has been a steady trend towards production of proprietary varieties.

The quality emphasis has resulted in wider use of hand roguing (weeding or spraying) in spring by migrant worker crews, where annual ryegrass is rogued out of perennial ryegrass fields, and orchardgrass from tall fescue fields.

An additional effect is an increased prevalence and price spread of as much as 25 cents per pound between standard certified and sod quality grass seeds (although 5 cents is typical). Standard certification by the OSU Seed Certification Office, or "blue tag," provides a mark of quality and assurance to buyers and sellers of seed. Some growers are also able to receive sod quality (premium) certification through a program of the

Oregon Department of Agriculture, and can therefore command a higher market price (Cook, 1990).

The shortened contract periods have allowed seed companies greater flexibility in market production and control of supply when they decide to introduce and phase out varieties.

Finally, the potential shift towards dwarf and semi-dwarf varieties is a result of market demand for characteristics of drought resistance, reduced fertilizer demand, and reduced leaf surface volume (for fewer mowings). This results in a reduction in total straw produced by growers.

Foothills

The Foothills region consists primarily of the Silverton Hills of the eastern Willamette Valley, located in Marion, northern Linn, and southern Clackamas Counties. In this area with a long agricultural history, small grains were produced in abundance prior to World War II, after which grass seed was introduced, especially fine fescues and bentgrasses. These grass seed types were found to be well adapted to the area and their production continues today.

Hilly slopes and wet weather in the Foothills region causes erosion and equipment operating problems.

The land is predominantly hilly with slopes as great as 45 percent, creating unique problems and limitations for agriculture. Erosion historically has been a problem; up to and throughout the 1970s many rotations included a fallow year (with its subsequent erosion incidence). Soils are relatively shallow and erosion can have serious long-term effects upon productivity. In recent years, with the development of new herbicides and no-till practices, continuous grass seed production has emerged as an excellent means of erosion control.

The area qualifies for the federal Sod Buster erosion control program, which specifies that fields be maintained in perennial crops. Sign up with the U.S. Department of Agriculture is required for those participating in other federal programs (such as FHA loans), although an unknown number of growers do not participate.

An additional problem for growers is the difficulty in operating equipment on the steep slopes. Even hillside combines tend to slide and have control problems, particularly on slippery fine fescue fields. Balers and propane burners are confined to shallow slopes.

The climate has important impacts on cultural practices. Annual rainfall in the area is at least 20 inches greater than on the valley floor. When the valley is overcast in summer, often it is misting in the hills. Such a case will cause custom baler operators to cease serving the area, as they are not interested in processing moldy straw.

Permitted burn days for open-field burning often exceeds that for the rest of the valley because the prevailing winds move smoke toward the Cascade Range and away from urban areas. Often this is of little consolation because fields may be too wet to burn. Field size is small (averaging fewer than 50 acres), so when burning is permitted, many small fires are lit and total acres burned is relatively small compared with the South Valley situation.

Fine fescues (chewings and creeping red) dominate the hill acreage, followed by Colonial bentgrass. Some proprietary perennial ryegrass is also produced, but it is limited to the lower slopes in order to accommodate straw densification equipment and propane burners. An unspecified amount of hard fescue also is produced. Turf-type tall fescue has been tried unsuccessfully in the hills; it does not produce well and disposal of its heavy straw load is difficult.

Fine Fescue

Nearly all of the chewings and most of the creeping red fescue produced in the Willamette Valley is confined to the Silverton Hills. Whereas annual bluegrass is a widespread contaminant (weed) in fields in the valley, it is not a serious problem in the hills. The market for fine fescue weakened in the early 1980s, but new long-lived proprietary varieties have led to a rebound in acreage. Between 70 and 85 percent of fine fescue acreage is proprietary.

Fine fescues need a very hot burn to stimulate growth or yields may be half.

Fine fescue is uniformly a grass seed type requiring high priority for thermal sanitation. Fine fescues need a very hot burn to stimulate growth the following year; one grower stated it is analogous to severe pruning of fruit trees to enhance productivity. As a result, there have been very few cultural practice changes in the past 30 years since open-burning has been the dominant practice. If conditions restrict open-burning within a season, fine fescue is burned in preference over bentgrass, perennial ryegrass, and small grains, which would have straw removed from fields. Fine fescue yields may be cut in half if open-burning is not possible.

Burning must take place soon after combining; a late burn reduces yields and seed quality by burning out the crowns. However, limitations of the burning program dictate that no growers produce 100 percent fine fescue. Alternatives to burning have been tried with limited success; the slickness of the straw has meant crewcutters are inclined to beat rather than cut the straw. Fine fescue is also sensitive to alternative cultural practices, where attempts at fall seeding with a nurse crop (e.g., rapeseed) have not been successful.

For certification purposes, winter wheat is often grown in rotation with fine fescue. As well, the life of stand for contracts have shortened for marketing purposes. Stand life, however, is enhanced by the herbicides Poast and Fusilade, which keep the fields free of bentgrass.

Fine fescue straw is currently a nonmarketed commodity; its feed value is considered very poor and no other uses have proven viable.

Hard Fescue

A relatively new type to the foothills, hard fescue is similar in appearance to other fescues; however, the normal practice is to remove the straw from the field and flail and chop as soon after harvest as possible. (Leaving straw on the field even 1 or 2 weeks after harvest decreases yield.) Hard fescue is limited to fields where the full range of equipment can be used. Nearly all acreage is proprietary.

Hard fescue straw has fairly good feed value.

Custom balers are generally used to remove the straw, where straw contracting costs $20 to $25 a ton. If a contractor cannot sell the straw, the cost of baling is shared with the grower. Straw that is sold is for local horse markets, although some was sent to eastern Oregon in 1990 as a result of a hay shortage. Hard fescue has a fairly good feed value and is probably best among the fescues.

Colonial Bentgrass

Virtually all bentgrass produced in the hills is the public variety Highland. The Silverton Hills cannot grow proprietary varieties because of the difficulty in getting certification, where an 18- to 24-month rotation with winter wheat would be necessary to avoid contamination with Highland. Acreage is fairly stable from year to year, although it has been steadily declining since the early 1970s. Turnover is slow, and stand life is essentially infinite.

Colonial bentgrass contrasts to the creeping bentgrasses of the valley, which are primarily proprietary and are not thermally treated.

Colonial bentgrass is usually burned in the fall.

Open-field burning historically has been a common practice, although recently some straw removal for sale in the hay market has also taken place. Nevertheless, burning is desirable at least every other year for sanitation purposes. This has generally not been a problem for two reasons: it is the latest maturing of all seed types, with harvest occurring in September; and straw removal in a timely fashion is not as much of an issue as with other varieties, so simply waiting for a burn permit has been workable. (Burning usually takes place in September or early October.)

Bentgrass straw is of generally high quality for feed, and the potential for sale is tied closely to hay prices.

Perennial Ryegrass

The lower fields and shallow slopes of the foothills are used to produce perennial ryegrass, where equipment can be operated effectively. As a result, these are often the last fields to be open-burned, although a final season open-burn, when possible, is useful for removing residual seed.

The typical practice on perennial ryegrass is to remove the straw and propane-burn the field. Currently, about half the propane burners are owned by growers and the other half is rented. Timeliness and lower priority for burning (relative to the fine fescues) dictates the use of propane burners. Straw removed is baled by custom balers and sold when possible; bales not sold, often because they have been rained upon, are stack-burned.

Marion County Lowlands

This region consists mainly of Marion County bottomland and benchland, and a small portion of southern Clackamas County. Grass seed production began in earnest in the late 1960s on what had been traditional cereal, legume, and vegetable croplands. Some Kentucky bluegrass was produced prior to this time, but is no longer grown. The shift from other crops, including cannery crops, has continued to the extent that grass seed now accounts for about a third of the total acreage in Marion County.

Some of the best farmland in Oregon is in the Marion County Lowlands.

Proprietary varieties of tall fescue and perennial ryegrass dominate the acreage, increasing steadily throughout the last two decades. Smaller acreages of creeping bentgrass, Kentucky bluegrass, and orchardgrass are also grown.

Some of the most productive--and expensive--farmland in Oregon can be found here, with the highest comparable yields for many crops. As a consequence, high investment costs, smaller acreages, high opportunity cost, and a desire for control over risk are of particular importance to these growers and have significant influence on their behavior.

Perennial Ryegrass

A combination of factors affect the choice of cultural practices for perennial ryegrass. It is generally acknowledged that some form of thermal sanitation is beneficial for production. But the existence of a market for straw, the thermal needs of other grass seed types (tall fescue in particular), timeliness requirements, and the possibility of burnout from high temperatures, have resulted in less than 5 percent of perennial ryegrass acreage being open-burned currently. This is down from 10 to 15 percent a decade ago. If there were no burning restrictions and it could take place soon after harvest, most growers would very likely open-burn.

By providing storage sheds for straw, growers have attracted custom balers, who market the straw.

Despite the low level of open-burning, some 90 percent of land remaining in production (i.e., not being replaced) is thermally treated, most of it by propane burning. A major issue influencing the shift to propane burning is the high level of uncertainty in the open-field burning program, and the desire to retain decisionmaking control in the hands of growers. Propane burning is far less restricted and, because yields decline rapidly after harvest if the straw is not removed, some growers feel it becomes worth it to buy a propane burner. Open-burning is occasionally used, however, when replacing the stand of grass.

There is increased emphasis in the past 2 or 3 years on rapid straw removal after harvest and before the fall rains set in. To do so has resulted in higher yields and higher prices for better quality seed produced, important economic considerations for this high-valued grass seed type. With expanded acreages, growers have turned to purchasing balers (both round and square) and stackers, and to building sheds for storage. Those growers with sheds have found that custom baler operators, who handle about three quarters of the perennial ryegrass acreage, are more willing to bale in a timely manner because they are then able to effectively market the straw. It is estimated that about a quarter of the acreage volume is stored in sheds (mostly by larger growers), by far the largest percentage in the valley.

The effect of the shift away from open-burning to propane burning in terms of disease or pests is difficult to assess. Rapid changes and improvements in varieties render meaningless long-term yield comparisons. Rust is now considered a serious problem, with breeding for resistance being explored. Nevertheless, there are about 20 growers who have spent many years keeping fields weed free and may be able to get by without open-burning.

Straw yield is probably higher than elsewhere in the valley. All of the perennial ryegrass straw that is marketed goes to Japan, typically about 50,000 tons of grass straw from Marion County. This is a priority area for export due to its proximity to the Port of Portland and the high concentration of perennial ryegrass grown. More than the amount put in sheds is actually marketed, as some straw is trucked immediately from the field.

Rectangular bales are compressed into 5,600-pound blocks for container loading to Japan.

Marketed straw requires densification in the form of small square bales (100 lb) or large super bales (1,600 to 2,000 lb), which are then commercially compressed into 8- by 8- by 9-1/2-foot bales (using 56 of the small bales) each weighing some 5,600 pounds. These composite bales are loaded into 40-foot containers for shipment to Japan. Virtually no round bales are marketed.

Nonmarketed straw is densified as round bales or in loaves to facilitate roadsiding and subsequent burning; standard square bales and super bales do not burn well as they are too dense. Round bales and loaves burn up well in a couple of hours (roughly twice as fast) and with a minimum of smoke. This form of densification also is less costly than the other alternatives (see Chapter 5).

Tall Fescue

Considerable change in cultural practices has been noted for tall fescue in just the past 5 years. About 90 percent of acreage used to be open-burned, but that level has dropped to about 25 percent. As with perennial ryegrass, operational control is important to growers. Straw removal from the field in a timely manner is even more important with tall fescue than perennial ryegrass, because tall fescue does not tolerate straw cover for long after harvest before reducing next year's yield.

Tall fescue seed demands a price premium over perennial ryegrass.

Tall fescue responds well to thermal sanitation and is less sensitive to burnout. The present price premium over perennial ryegrass demands high quality and hence a priority for thermal sanitation. For fields not open-burned, propane burning is a dominant practice, except for first year stands.

As with perennial ryegrass, rust is becoming a major problem, one that did not exist 4 to 5 years ago. The major courses of action in combating it are chemical spraying and resistance breeding.

Straw volume is considerable, typically more than 4 tons per acre. Cost to growers with their own balers is about $50 per acre. A market for tall fescue is essentially undeveloped, as less than 5 percent is shipped to Japan.

"Recutting" is the harvest of a second crop of hay early in the fall, when some vegetative regrowth has taken place. As the hay is fairly high in protein, some farmers have provided it to the eastern Oregon feed market. However, recutting of stands in early fall is not commonly practiced because future yields are reduced by the process and weather risk increases for baling late in the season. Any recut that takes place is done largely for stand cleansing rather than specifically for the hay market.

Role of Proprietary Varieties

Nearly all perennial ryegrass and tall fescue stands are proprietary. Perennial ryegrass is grown under a 3 to 4 year contract with 3 years typical (yields decline after this time). Tall fescue is generally grown under a 4 year minimum contract, though few contracts extend beyond 5 years. Shortened rotations provide for greater seed company flexibility. The preferred rotation is to reseed to the same variety after the contract is completed. Changing varieties introduces the threat of residual seed sprouts affecting purity of the new variety. As with other locations, seed quality is a major emphasis of contractors, although the judgment of growers is usually regarded in terms of achieving the standards.

There is not much difference in quality or volume of straw among the varieties of perennial ryegrass. For tall fescue, there is some shift towards production of dwarf varieties with resulting lower straw yields but greater palatability as a feed.

North Valley

Farming is diversified in the North Valley region.

The North Valley region consists of Yamhill and northern Polk Counties. This is an area where the shift to grass seed is a relatively new phenomenon, having occurred mostly in just the last 5 years. Historically, production of small grain, legume seed, and cannery crops has dominated. Farmers continue to remain diversified, with about half of their total acreage in grass seed, while maintaining their options (particularly their wheat base) in other crops. However, the effect of highly erodible land (HEL) requirements for federal program compliance may shift acres away from grains. Adequacy of crop production alternatives influences the substitutability of grass seeds.

The quality of land in the North Valley is somewhat lower and more variable than the area east of the Willamette River (Marion County), with hilly areas in the west having lower water retention capacity. The result is somewhat lower seed and straw yields for this area.

Nearly all grass seed produced is proprietary turf-type tall fescue, perennial ryegrass, and orchardgrass, with isolated pockets of fine fescue and bentgrass. Farmers have not yet accumulated the capital for purchase of specialized straw densification and removal machinery or for storage sheds. Storage sheds can cost $3 per square foot. There is a major reliance upon custom operators for straw removal; no Rears vacuum machine is yet owned in the area. This considered, if grass seed prices drop and short-term profitability is threatened, and if grain prices are competitive, they are more inclined than producers elsewhere to shift out of grass seed production.

Tall Fescue

Open-field burning is a common practice on about half the acreage, with straw removed and fields propane burned on the remaining acres. Open-burning is generally preferred to propane burning because of the necessary high-temperature shock treatment required and the better burn of dense and rapid vegetative regrowth. In the absence of burn restrictions, most acres would be open-burned. The thermal needs of the new varieties, however, are unclear.

The demands on growers of open-burn requirements remain a concern. Limited burn days, extreme timing requirements of the grass seed type, field preparations, and fire chief coordination in the area are all major management factors. Hilly areas are usually the first burned because they present straw densification and removal problems.

Distance from population centers presents less concerns with open-burning in the North Valley.

The practice of propane burning is not considered by these growers to be the environmental problem that it is in more concentrated population areas, with its fugitive low-level smoke residual. A lower proportion of grass seed acres, greater use of diversified crop production, and lower population density provide optimism as to its continued use as a management tool.

A small portion of tall fescue straw goes to local and export feed markets, but the existence of endophyte bred into turf-type varieties limits its potential. Most straw not open-burned is usually stack burned. Newer varieties of tall fescue that require more nitrogen fertilizer (according to breeders) and produce more straw add to the straw volume.

Perennial Ryegrass

At most, only 5 percent of perennial ryegrass acreage is open-field burned. Open-burning of wheat stubble and legume aftermath was a common practice in the past. Problems with burnout prompted a considerable shift to propane burning of fields after straw removal.

Current straw removal options include:

- Custom baling for shipping to Japan

- Buck rake (pushing) to roadside and stack burning
- Loaves to roadside and stack burned
- Bale (usually round) and burn
- Bale and sell or give away

Straw volume varies considerably from 1.5 tons per acre in the hills to about 3 tons in the valley.

Endophyte in perennial ryegrass is causing concern (see Chapter 6, Feed Markets). The broader issue of disease potential is unknown and may surface with respect to overseas markets.

Role of Proprietary Varieties

The area is now under 85 percent proprietary and 15 percent public variety contract, with about 4 percent annual proprietary growth in acreage, and no growth in public varieties. Contract lengths have shortened to 3 to 5 years, with an increase in use of rotations with other grass seed types or crops. Where proprietary variety changes within a given seed type occur, a 2 year minimum alternative crop (or seed type) in the rotation is required.

Growing proprietary varieties demands emphasis on quality.

As elsewhere, there is a greater emphasis on seed quality. About half the seed product was blue-tagged (certified) 4 or 5 years ago; presently, 90 to 95 percent, especially turf varieties, are certified. Further management improvements are expected, including irrigation.

In addition, there is a greater emphasis by seed companies on niche marketing. One result of this is the increase in importance of dwarf varieties, which are more drought resistant and require less fertilizer by consumers.

The existence of proprietary varieties has led to a more stable market. Whereas proprietary variety prices have ranged from 45 to 55 cents a pound since the inception of the CRP program, public varieties have ranged from 25 to 98 cents a pound.

Two general concerns have been raised about the nature of proprietary variety production. The narrow genetic base of certain grass seed types makes them susceptible to potentially serious and widespread disease problems. Export market requirements are becoming more stringent, including phytosanitary requirements, an important issue in production of certain grass seed types (Conklin et al., 1989).

Eastern Oregon

Jefferson County

Grass seed has been produced continuously in Jefferson County since the mid-1950s, when mint and grass seed began replacing Ladino clover grown for seed. Presently, some 15,000 acres are in production, with more than 80 percent of that in turf-type Kentucky bluegrass. Other grass seed types include perennial ryegrass, creeping bentgrass, and tall fescue.

About 95 percent of grass seed is grown on contract, and nearly all that is proprietary. There has been a general shift from public varieties in the past 6 or 7 years. Most grass seed acres are irrigated with surface water rather than groundwater. As a consequence, weed transport (e.g., via tailwater) from other fields is a problem that has affected contract lengths.

Open-field burning is common with all grass seed types in eastern Oregon.

Open-field burning is a very prevalent practice on all grass seed types; propane burning takes place on about 30 percent of the fields, depending on the timing of fall rains. Straw may be removed on some fields prior to burning, although no stack burning takes place. Wheat stubble is also open-burned, with some 5,000 acres burned in past years; this has dropped to about 3,000 acres more recently. Mint fields are generally propane burned.

Grass seed following grain is a typical rotation. Grain fields are open-burned just prior to grass establishment; otherwise, the grain stubble is incorporated (grain straw may or may not be removed first).

A grower-financed monitoring and permit program is used for burning. The program monitors weather conditions, with a goal of keeping smoke out of populated areas and a total acreage per day cap. Until last year the program was voluntary, but new county ordinances make compliance mandatory (Jefferson County Commission, 1989). Propane burning also comes under the program, but regulations are less restrictive. Generally, all desired open-burning after harvest can be accommodated under the existing program.

Some straw is removed for the feed market. Last year about half the fields (especially bluegrass) had straw removed and baled; this year it was up to 90 percent. Hay prices have a major impact on whether straw will be removed because there is essentially no other use currently than for feed. About 80 percent of straw removed goes to the central Oregon feed market, which includes the five-county area of Jefferson, Deschutes, Crook, Wheeler, and Wasco. Most of the remainder moves farther east. The quality of straw, particularly the bluegrass, is considered quite good, although the protein content varies from 3 to 7 percent from year to year.

Union County

Most straw removal for feed is sold locally.

Although total acreage of grass seed in Union County is less than 15,000 acres, continuous production has taken place since about 1935, primarily located between La Grande and Imbler. The level of production has fluctuated according to seed prices; nevertheless, there is a core group of growers who have made the necessary investment in the industry to be in it for the long term. Turf-type Kentucky bluegrass, creeping red fescue, turf-type chewings fine fescue, and tall fescue are the main crops. Other crops in Union County include 40,000 acres of wheat; 10-20,000 acres of barley; oats; dry peas; mint; and vegetable seeds.

Kentucky bluegrass and fescues are the main grass seed crops in Union County.

There has been a long history of proprietary production in Union County, and is probably 85 percent of the acreage at present. A higher proportion of public red fescue (Pennlawn) is produced, but only a few acres of public Kentucky bluegrass are grown.

Open-burning is fairly prevalent, particularly in the bluegrass and fine fescue fields, and propane burning takes place on all other fields. Although straw is removed from some fields, no stack burning takes place. About 1,000 acres of wheat are open-burned annually, and mint fields are propane burned. In 1990, approximately 8,000 acres of grass seed was open-burned.

Typical practices begin with an establishment year planting in spring, grazing down by sheep of the growth in the fall (of the establishment year), and seed harvesting the next 3 to 4 years. About 80 percent of grass seed acres are irrigated. After harvest, straw is removed and the field is propane burned or open-burned. In the final year, straw may or may not be burned, and the stubble is beaten and plowed in to break up the sod, followed by a planting of an alternative crop. Grass seed following grain is typical.

A voluntary, grower-financed system monitors and issues burning permits. The program goals are aimed at keeping smoke from La Grande and the nearby Class I Wilderness areas (Union County Field Burning Committee, 1990). In general, smoke dissipates well in this area.

Straw removed from the field is baled and sold for the local livestock market. The market has existed for the past 4 to 5 years, though not as a result of hay prices, selling tall fescue and fine fescue straw. Fine fescue is usually mixed with other hays. The Eastern Oregon Agricultural Research Center, Union Station, is currently conducting feeding trials of tall fescue straw for pregnant cows.

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4 The Supply of Grass Straw

Introduction

A proper accounting of the volume of grass straw produced in Oregon, potentially available for markets, and currently disposed of in various methods, is an important component of understanding and investigating straw utilization. This chapter consists of two main sections: one is focused on straw production and potential availability, and the other on current straw management. These sections are presented in terms of 1990 volumes of straw and acres of grass seed in Oregon, by regions within the state, and by specific grass seed type. (Appendix B has 1989 data.)

The regional divisions follow borders consistent with Willamette Valley and statewide production considerations, as discussed previously in Chapter 3. They include the following:

Willamette Valley:

- South Valley: Lane, Linn, Benton, south Polk Counties
- Marion County Lowlands: River bottoms and lowlands of Marion County
- Foothills: Foothills of Marion, north Linn, south Clackamas Counties
- North Valley: Yamhill, north Polk Counties
- Other Willamette Valley: Washington, Clackamas, Multnomah Counties

Other Oregon:

- Jefferson County
- Union County
- Other areas (all other counties combined)

Straw Production

Table 4-1 displays estimates of straw production in Oregon and maximum potential available for markets or other utilization.

Grass Seed Acres Cultivated

Grass seed type categories and respective acres by geographic region are presented in Columns 1 and 2 of Table 4-1. The 1990 acreage is shown. (See also Figure 4-1.) It is collected and updated by the

Table 4-1
Estimates of Total Grass Straw Production and Maximum Potential Available

REGION (1) GRASS SEED TYPES	ACRES (2) 1990 TOTAL	TOTAL STRAW PRODUCTION — Volume of straw produced (3) (T/acre) Low	(4) (T/acre) High	(5) (Tons) Low	(6) (Tons) High	MAXIMUM POTENTIAL AVAILABLE — Straw removed from field (7) (% of fields) Low	(8) (% of fields) High	(9) (Tons) Low	(10) (Tons) High
SOUTH VALLEY									
- Annual ryegrass	106,500	2.80	3.20	298,200	340,800	75%	90%	223,650	306,720
- Perennial ryegrass	72,900	2.25	2.75	164,025	200,475	75%	95%	123,019	190,451
- Tall fescue	50,500	3.25	3.75	164,125	189,375	75%	90%	123,094	170,438
- Orchardgrass	12,600	2.25	2.75	28,350	34,650	75%	95%	21,263	32,918
- Kentucky bluegrass	2,350	2.00	2.50	4,700	5,875	10%	50%	470	2,938
- Bentgrass, Creeping	2,310	2.00	2.50	4,620	5,775	100%	100%	4,620	5,775
- Chewings fescue	1,500	1.50	2.00	2,250	3,000	5%	10%	113	300
- Bentgrass, Colonial	1,280	1.75	2.00	2,240	2,560	100%	100%	2,240	2,560
- Red fescue	1,150	1.50	2.00	1,725	2,300	5%	10%	86	230
SUBTOTAL	251,090			670,235	784,810			498,554	712,329
MARION COUNTY LOWLANDS									
- Perennial ryegrass	22,500	2.50	2.75	56,250	61,875	100%	100%	56,250	61,875
- Tall fescue	14,500	4.00	4.25	58,000	61,625	90%	100%	52,200	61,625
- Bentgrass, Creeping	3,300	2.00	2.50	6,600	8,250	100%	100%	6,600	8,250
- Kentucky bluegrass	1,400	2.00	2.50	2,800	3,500	10%	50%	280	1,750
- Orchardgrass	800	2.25	2.75	1,800	2,200	90%	100%	1,620	2,200
- Annual ryegrass	250	3.00	3.00	750	750	75%	95%	563	713
SUBTOTAL	42,750			126,200	138,200			117,513	136,413
FOOTHILLS									
- Chewings fescue	12,200	1.50	2.00	18,300	24,400	5%	10%	915	2,440
- Bentgrass, Colonial	5,500	1.75	2.00	9,625	11,000	30%	70%	2,888	7,700
- Red fescue	4,000	1.50	2.00	6,000	8,000	5%	10%	300	800
- Hard fescue	2,000	1.50	2.00	3,000	4,000	100%	100%	3,000	4,000
- Perennial ryegrass	N/A	2.50	3.00			100%	100%		
SUBTOTAL	23,700			36,925	47,400			7,103	14,940
NORTH VALLEY									
- Tall fescue	21,500	3.75	4.00	80,625	86,000	80%	90%	64,500	77,400
- Perennial ryegrass	9,100	2.00	2.50	18,200	22,750	95%	100%	17,290	22,750
- Orchardgrass	6,100	2.25	2.75	13,725	16,775	90%	100%	12,353	16,775
- Annual ryegrass	2,400	3.00	3.00	7,200	7,200	75%	95%	5,400	6,840
- Bentgrass, Colonial	1,000	1.75	2.00	1,750	2,000	100%	100%	1,750	2,000
- Chewings fescue	680	1.50	2.00	1,020	1,360	5%	10%	51	136
- Red fescue	600	1.75	2.00	1,050	1,200	5%	10%	53	120
- Kentucky bluegrass	350	2.00	2.50	700	875	10%	50%	70	438
- Bentgrass, Creeping	200	2.00	2.50	400	500	90%	100%	360	500
SUBTOTAL	41,930			124,670	138,660			101,826	126,959
OTHER WILLAMETTE VALLEY									
- Perennial ryegrass	2,800	2.00	2.50	5,600	7,000	95%	100%	5,320	7,000
- Tall fescue	2,740	3.75	4.00	10,275	10,960	80%	90%	8,220	9,864
- Chewings fescue	1,000	1.50	2.00	1,500	2,000	5%	10%	75	200
- Bentgrass, Creeping	720	2.00	2.50	1,440	1,800	90%	100%	1,296	1,800
- Red fescue	600	1.75	2.00	1,050	1,200	5%	10%	53	120
- Kentucky bluegrass	550	2.00	3.00	1,100	1,650	10%	50%	110	825
- Orchardgrass	400	2.25	2.75	900	1,100	90%	100%	810	1,100
- Annual ryegrass	30	3.00	3.00	90	90	75%	95%	68	86
SUBTOTAL	8,840			21,955	25,800			15,951	20,995
WILLAMETTE VALLEY	368,310			979,985	1,134,870			740,946	1,011,634

Table 4-1(cont'd)
Estimates of Total Grass Straw Production and Maximum Potential Available

REGION (1) GRASS SEED TYPES	ACRES (2) 1990 TOTAL	TOTAL STRAW PRODUCTION — Volume of straw produced (3) (T/acre) Low	(4) (T/acre) High	(5) (Tons) Low	(6) (Tons) High	MAXIMUM POTENTIAL AVAILABLE — Straw removed from field (7) (% of fields) Low	(8) (% of fields) High	(9) (Tons) Low	(10) (Tons) High
JEFFERSON COUNTY									
- Kentucky bluegrass	13,000	2.00	3.00	26,000	39,000	50%	90%	13,000	35,100
- Perennial ryegrass	1,000	2.00	2.50	2,000	2,500	95%	100%	1,900	2,500
- Bentgrass, Creeping	350	2.00	2.50	700	875	90%	100%	630	875
SUBTOTAL	14,350			28,700	42,375			15,530	38,475
UNION COUNTY									
- Kentucky bluegrass	6,940	2.00	3.00	13,880	20,820	50%	90%	6,940	18,738
- Red fescue	2,520	1.50	2.00	3,780	5,040	5%	10%	189	504
- Chewings fescue	1,910	1.50	2.00	2,865	3,820	5%	10%	143	382
- Tall fescue	690	4.00	4.25	2,760	2,933	80%	90%	2,208	2,639
- Hard fescue	60	1.50	2.00	90	120	100%	100%	90	120
- Perennial ryegrass	40	2.00	2.50	80	100	95%	100%	76	100
SUBTOTAL	12,160			23,455	32,833			9,646	22,483
OTHER AREAS									
- Tall fescue	1,580	3.50	4.25	5,530	6,715	80%	90%	4,424	6,044
- Kentucky bluegrass	1,030	2.00	3.00	2,060	3,090	10%	50%	206	1,545
- Chewings fescue	420	1.50	2.00	630	840	5%	10%	32	84
- Bentgrass, Creeping	280	2.00	2.50	560	700	90%	100%	504	700
- Orchardgrass	50	2.25	2.75	113	138	90%	100%	101	138
SUBTOTAL	3,360			8,893	11,483			5,267	8,510
STATEWIDE TOTAL	398,180			1,041,033	1,221,560			771,389	1,081,103

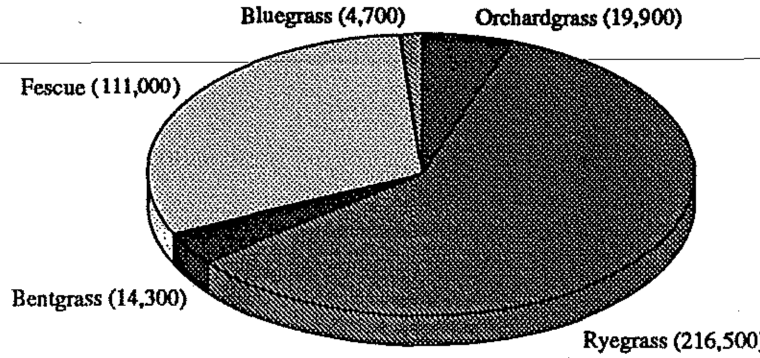

Figure 4-1
1990 Grass Seed Grown in the Willamette Valley by Type (acres)

Economic Information Office, Department of Agricultural and Resource Economics at Oregon State University. This information is obtained by means of an annual survey of Extension agents for each county, and represents the best estimates of acreage available (Miles, 1990).

Acreage for each seed type is allocated into the subregions by combining data for respective counties. The subregion boundaries are the same as the focus group areas specified in Chapter 3.

For those subregions whose boundaries fall within counties, judgment is used with respect to appropriate assignment of grass seed types.

It is difficult to predict what growers will do under entirely new circumstances.

Total Straw Production

Columns 3 through 6 are used to calculate the volume of straw produced in total tonnage. Columns 3 and 4 display estimates of the volume of straw produced per acre. This is obtained by estimating low and high tonnage of straw produced per acre of each seed type. The quantity is the volume of straw produced per acre that could be removed and utilized. It does not include chaff from combining or other dry matter that would not otherwise be considered "straw" for baling.

Estimates of straw production were obtained from the focus groups for annual ryegrass, perennial ryegrass, tall fescue, fine fescue, and red fescue. Estimates for other grass seed types were obtained from Ast Hay Company (1989), and by educated judgment.

Columns 5 and 6 are obtained by multiplying total acres by estimates of per-acre tonnage. Total straw production represents total volume of straw (in tons) that is produced, excluding chaff or other dry matter that cannot be baled.

Maximum Potential Straw Available

Columns 7 through 10 are used to calculate maximum straw potentially available for market use. All straw produced is not necessarily available to be marketed or used. Particular limitations affect a grower's willingness or ability to supply straw, even under seemingly ideal economic conditions.

Of course, there is inherent difficulty in predicting what growers will do under circumstances that have never before existed. This table section attempts to impart the volume of straw that growers would be willing to supply under ideal but realistic economic conditions for straw. As will be detailed below, certain grass seed types impose agronomic, economic, or physical limitations on growers that prevent them from being willing and able to supply all straw produced.

Columns 7 and 8 contain the maximum potential proportion of fields from which straw would be available for use. By grass seed type, these low and high estimates of perceived proportion of acres consider the limitations facing growers.

Limitations in the South Valley for annual ryegrass, perennial ryegrass, tall fescue, and orchardgrass straw are primarily based upon a combination of agronomic and physical limitations; the large quantity of acres involved, coupled with the need to remove straw in a timely manner for agronomic reasons, would require an increase in machinery or machine time in this area. In addition, these fields would probably require an open-burn once every several years for sanitation purposes (this consideration applies to other areas as well).

The physical equipment limitation may not be as severe a problem in the other areas, as farm sizes are smaller. Fine fescue straw (in the foothills) is limited by a physical inability to remove straw from the steeply sloping fields, and by its thermal needs; it appears unlikely that economic conditions would induce necessary technological improvements. Thermal needs would also affect the willingness to supply Kentucky bluegrass straw, although this might be influenced more by the hay market.

Columns 9 and 10 display the potential tonnage of straw available, under ideal market conditions. It is computed by multiplying grass straw tonnage (from Columns 5 and 6) by the percentage of fields with straw removal. This spread, therefore reflects both the production volume range as well as the variation estimate for proportion available.

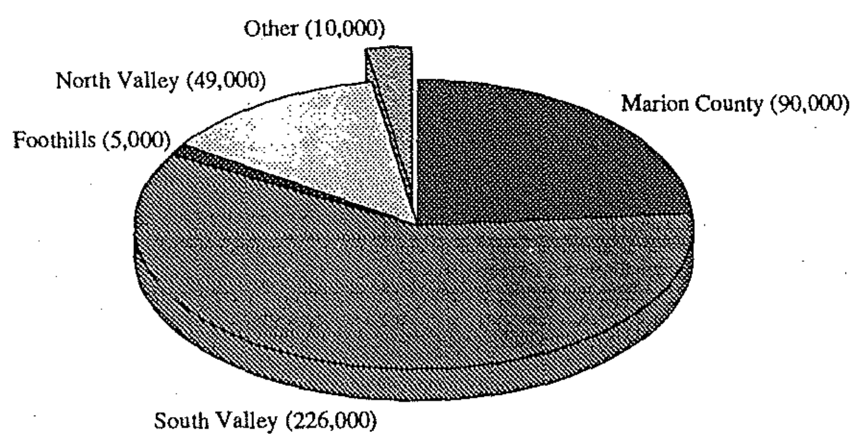

Figure 4-2
1990 Minimum Straw Available Statewide (tons)

Table 4-2
Current (1990) Grass Straw Management (Disposaland Removal)

REGION (1) GRASS SEED TYPES	CURRENT GRASS STRAW DISPOSAL						CURRENT GRASS STRAW REMOVED			
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
	Open field burning				Straw plowdown		Straw removed		Straw volume	
	(% of fields) Low	High	(Acres) Low	(Acres) High	(Acres) Low	(Acres) High	(Acres) Low	(Acres) High	(Tons) Low	(Tons) High
SOUTH VALLEY										
- Annual ryegrass	50%	60%	53,250	63,900	42,600	53,250	0	0	0	0
- Perennial ryegrass	20%	30%	14,580	21,870	6,379	7,290	44,651	51,030	100,465	140,333
- Tall fescue	20%	30%	10,100	15,150	3,535	4,040	31,815	36,360	103,399	136,350
- Orchardgrass	20%	30%	2,520	3,780	1,103	1,260	7,718	8,820	17,364	24,255
- Kentucky bluegrass	80%	95%	1,880	2,233	12	47	106	423	212	1,058
- Bentgrass, Creeping	0%	0%	0	0	289	289	2,021	2,021	4,043	5,053
- Chewings fescue	90%	95%	1,350	1,425	9	19	66	131	98	263
- Bentgrass, Colonial	60%	90%	768	1,152	16	64	112	448	196	896
- Red fescue	90%	95%	1,035	1,093	6	12	52	104	78	207
SUBTOTAL			85,483	110,602	53,948	66,270	86,540	99,337	225,855	308,414
MARION COUNTY LOWLANDS										
- Perennial ryegrass	3%	5%	675	1,125	2,672	2,728	18,703	19,097	46,758	52,516
- Tall fescue	20%	30%	2,900	4,350	1,015	1,160	9,135	10,440	36,540	44,370
- Bentgrass, Creeping	0%	0%	0	0	413	413	2,888	2,888	5,775	7,219
- Kentucky bluegrass	80%	95%	1,120	1,330	7	28	63	252	126	630
- Orchardgrass	20%	30%	160	240	70	80	490	560	1,103	1,540
- Annual ryegrass	40%	60%	100	150	100	150	0	0	0	0
SUBTOTAL			4,955	7,195	4,276	4,559	31,279	33,236	90,301	106,275
FOOTHILLS										
- Chewings fescue	90%	95%	10,980	11,590	76	153	534	1,068	801	2,135
- Bentgrass, Colonial	50%	80%	2,750	4,400	138	344	963	2,406	1,684	4,813
- Red fescue	90%	95%	3,600	3,800	20	40	180	360	270	720
- Hard fescue	0%	0%	0	0	200	200	1,800	1,800	2,700	3,600
- Perennial ryegrass	3%	5%								
SUBTOTAL			17,330	19,790	434	736	3,476	5,634	5,455	11,268
NORTH VALLEY										
- Tall fescue	40%	60%	8,600	12,900	860	1,290	7,740	11,610	29,025	46,440
- Perennial ryegrass	3%	5%	273	455	1,081	1,103	7,564	7,724	15,129	19,309
- Orchardgrass	40%	60%	2,440	3,660	305	458	2,135	3,203	4,804	8,807
- Annual ryegrass	50%	60%	1,200	1,440	960	1,200	0	0	0	0
- Bentgrass, Colonial	100%	100%	1,000	1,000	0	0	0	0	0	0
- Chewings fescue	90%	95%	612	646	4	9	30	60	45	119
- Red fescue	90%	95%	540	570	3	6	27	54	47	108
- Kentucky bluegrass	80%	90%	280	315	4	7	32	63	63	158
- Bentgrass, Creeping	0%	0%	0	0	25	25	175	175	350	438
SUBTOTAL			14,945	20,986	3,241	4,097	17,703	22,888	49,462	75,378
OTHER WILLAMETTE VALLEY										
- Perennial ryegrass	3%	5%	84	140	333	340	2,328	2,377	4,655	5,941
- Tall fescue	40%	60%	1,096	1,644	110	164	986	1,480	3,699	5,918
- Chewings fescue	90%	95%	900	950	6	13	44	88	66	175
- Bentgrass, Creeping	0%	0%	0	0	90	90	630	630	1,260	1,575
- Red fescue	90%	95%	540	570	3	6	27	54	47	108
- Kentucky bluegrass	80%	90%	440	495	6	11	50	99	99	297
- Orchardgrass	40%	60%	160	240	20	30	140	210	315	578
- Annual ryegrass	40%	60%	12	18	12	18	0	0	0	0
SUBTOTAL			3,232	4,057	579	671	4,204	4,937	10,141	14,592
WILLAMETTE VALLEY			125,945	162,630	62,478	76,334	143,202	166,031	381,214	515,926

Table 4-2 (cont'd)
Current (1990) Grass Straw Management (Disposaland Removal)

REGION (1) GRASS SEED TYPES	CURRENT GRASS STRAW DISPOSAL: Open field burning (11) (% of fields) Low	(12) (% of fields) High	(13) (Acres) Low	(14) (Acres) High	Straw plowdown (15) (Acres) Low	(16) (Acres) High	CURRENT GRASS STRAW REMOVED: Straw removed (17) (Acres) Low	(18) (Acres) High	Straw volume (19) (Tons) Low	(20) (Tons) High
JEFFERSON COUNTY										
- Kentucky bluegrass	50%	70%	6,500	9,100	390	650	3,510	5,850	7,020	17,550
- Perennial ryegrass	3%	5%	30	50	119	121	831	849	1,663	2,122
- Bentgrass, Creeping	0%	0%	0	0	44	44	306	306	613	766
SUBTOTAL			6,530	9,150	553	815	4,648	7,005	9,295	20,438
UNION COUNTY										
- Kentucky bluegrass	60%	80%	4,164	5,552	139	278	1,249	2,498	2,498	7,495
- Red fescue	80%	90%	2,016	2,268	25	50	227	454	340	907
- Chewings fescue	80%	90%	1,528	1,719	24	48	167	334	251	669
- Tall fescue	40%	60%	276	414	28	41	248	373	994	1,584
- Hard fescue	0%	0%	0	0	6	6	54	54	81	108
- Perennial ryegrass	3%	5%	1	2	5	5	33	34	67	85
SUBTOTAL			7,985	9,955	226	428	1,979	3,747	4,230	10,847
OTHER AREAS										
- Tall fescue	40%	60%	632	948	63	95	569	853	1,991	3,626
- Kentucky bluegrass	80%	90%	824	927	10	21	93	185	185	556
- Chewings fescue	90%	95%	378	399	3	5	18	37	28	74
- Bentgrass, Creeping	0%	0%	0	0	35	35	245	245	490	613
- Orchardgrass	20%	30%	10	15	4	5	31	35	69	96
SUBTOTAL			1,844	2,289	116	161	956	1,355	2,763	4,965
STATEWIDE TOTAL			142,304	184,024	63,372	77,737	150,784	178,139	397,502	552,176

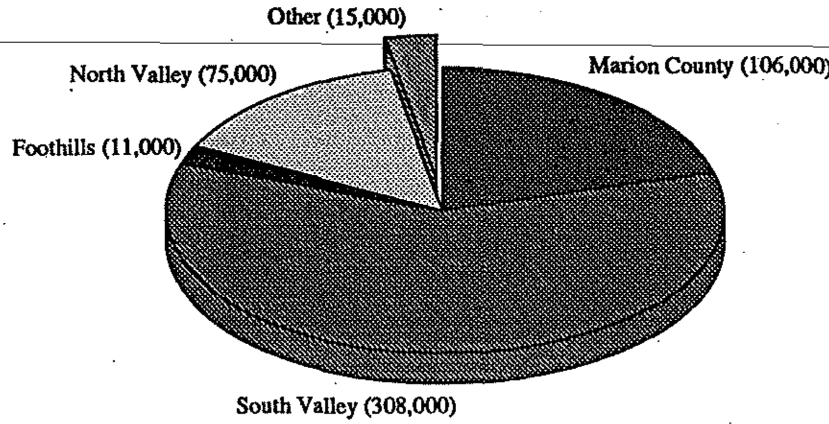

Figure 4-3
1990 Maximum Straw Available Statewide (tons)

Current Straw Management

Table 4-2 displays estimates of current straw management, both in terms of acreage with straw disposed directly on-farm and with straw removed. It presents a "snapshot" of the present situation in Oregon with respect to straw, reflecting current economic conditions, existing markets for straw, and technologies in effect for straw management. The table also gives an indication of the magnitude of the straw disposal and utilization problem. Table 4-2 is presented as an extension of Table 4-1, as indicated by construction of the column numbering sequence.

Current Grass Straw Disposal

Columns 11 through 16 in Table 4-2 contain information about current grass straw disposal in which the straw is neither removed nor available for use. This considers both acres open-burned and those in which straw is plowed into the soil.

The percentage of acres utilizing open-field burning is presented in Columns 11 and 12. These estimates reflect the proportion of fields in which open-field burning takes place. The values were obtained from the focus group meetings for annual ryegrass, perennial ryegrass, tall fescue, creeping bentgrass, colonial bentgrass, fine fescue, and red fescue. Other values were obtained in consultation with Young, Cook, and Jacks (1990). Ranges were used in Table 4-2 to provide a "window of confidence" in acres, although in some cases (colonial bentgrass, Kentucky bluegrass of Union and Jefferson County) the values reflect the effects of hay prices on the willingness to open-burn.

The number of acres open-burned in Columns 13 and 14 are calculated by multiplying acres in Column 2 by estimates in columns 11 and 12.

Estimates of straw plowdown (Columns 15 and 16) include an accounting of acres for which, after harvest, straw is flailed (chopped) and incorporated directly into the soil. With the exception of annual ryegrass, possible plowdown would occur only when a stand is taken out of production. In the case of perennial ryegrass, the stand life is about 3 to 4 years; for tall fescue it is 4 to 5 years (most other grass types are also assumed to fall in this range). However, not all fields have the straw plowed in; in fact, some fraction of fields are open-burned before the stand is removed. It is assumed that half the fields where the stand is removed are plowed in, and half are open-burned or have straw removed.

Virtually no straw is removed from annual ryegrass fields at present.

Annual ryegrass fields are either plowed down or are open-burned, and virtually no straw is removed from fields at present. Plowdown takes place on about half the fields.

Current Grass Straw Removed

The number of acres in which straw densification or removal takes place (Columns 17 and 18) is simply the total acres produced minus the acres open-burned and the acres with straw plowdown. This forms the basis for the estimate of straw currently available and sold, distributed, utilized on farm, or stack burned.

Finally, Columns 19 and 20 display the current volume of straw removed from fields. This estimate is the acres with straw removed times the tonnage per acre of straw produced. The total volume is the current level of straw available in respective regions of Oregon.

Summary and Implications

The largest volume of straw produced is in the southern Willamette Valley, where farms generate from two-thirds to three-quarters of a million tons annually. This is also an area that is able to supply, under ideal economic conditions, a very high proportion and volume of straw. But, as Table 4-2 indicates, less than 60 percent of the current straw volume baled and removed from fields comes from the South Valley. Despite a relatively low amount of open-burning in recent years, at most a half million tons of straw is removed from fields in the Willamette Valley. Yet, certain changes in economic conditions could cause 75 to 90 percent of straw produced to become available for markets.

Open-field burning is prevalent in the South Valley, and more than half of those acres open-burned are in annual ryegrass production, representing the most commonly open-burned grass seed type in Oregon. Tall fescue is next in order of rank with some 25-30,000 acres, followed by perennial ryegrass with about 20,000 acres open-burned.

Annual ryegrass is grown almost exclusively in the southern valley, but perennial ryegrass and tall fescue are produced in many areas. Yet, differences exist across the Willamette Valley with respect to burning of these two grass types. In the South Valley some 20 to 30 percent of

In spite of acreage stability, straw supply by grass type could be variable.

perennial ryegrass acres are open-burned, while very few (less than 5 percent) of these acres to the north receive the same treatment. About a quarter of the tall fescue fields are open-burned in the valley, but about half of those acres in the north are so treated.

Straw plowdown is widespread among those growing annual ryegrass, but a small amount takes place in the perennial grass seed types as well.

Partly as a result of its high productivity of straw, about 45 percent of the straw currently removed from farm fields is tall fescue; a slightly smaller proportion is perennial ryegrass straw. Orchardgrass represents about 7 percent as the next highest volume. Kentucky bluegrass is about 4 to 6 percent of the statewide total, but 70 to 80 percent of that available in eastern Oregon.

The previous chapter contained a discussion of market and other factors affecting the near term future production of grass seed. Projections for the future of grass seed markets have direct implications for the supply of straw. Widespread expansion of grass seed acres over the next decade is unlikely; perennial ryegrass, tall fescue, and annual ryegrass acreage likely will remain relatively stable (see Chapter 3). But despite acreage stability for these three major seed types, straw supply, even in the absence of additional markets, could remain volatile for two reasons:

1. Growers have changed their straw management techniques dramatically during the 1980s, and indications are they will continue to do so in the next decade. This trend has been away from open-field burning and toward plowdown (in the case of annuals) and straw removal (for perennials).
2. The advent of dwarf and semidwarf varieties of grass seed, in market response to consumer preferences, may result in lower straw yields for some varieties of tall fescue and perennial ryegrass.

Although these two factors affect straw availability in opposite directions, it is likely that shifts from open-field burning will increase straw availability more than expansion of dwarf varieties will decrease it during the next decade.

The existence of viable markets for straw could, of course, encourage more straw removal (to a level indicated by "Maximum Potential Available" in Table 4-1). However, it must be stressed that growers produce grass seed and react to grass seed market conditions with respect to acreage in production and selection of varieties. Any straw market that exists would be secondary to their decisions and will not directly affect acreage.

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5 On-Farm Straw Management

Introduction

Straw management is practiced to replace open-field burning.

On-farm straw management by grass seed growers in the Willamette Valley currently entails three major components or processes: straw removal, stubble management, and field sanitation, each of which takes place after seed harvest. The specific field practices involved with each of the post-harvest operations is presented first. New techniques being examined and tested also are described. This is followed with an estimation of costs associated with each practice, taken largely from recent work by Mellbye (1990a, b), and Cross and Mason (1989). The final section discusses a new practice currently under investigation involving on-farm composting of straw for later return to fields as an organic fertilizer.

The development of straw management with its components of straw removal, stubble management, and field sanitation are an outgrowth of significant reduction in open-field burning, which had performed all three functions. Grower dependency upon DEQ burning restrictions and weather uncertainty led to adoption of alternative practices to field burning, particularly during the 1980s. By 1990, total acreage open-burned by growers had been reduced to 159,313 acres (Oregon Department of Agriculture, 1990), the lowest ever in the history of grass seed production, even though the DEQ acreage limitation for burning continues to stand at 250,000 acres.

For traditional open-field burning, the field preparation practices are relatively simple and low cost. The process involves use of a straw chopper or spreader on combines to distribute the straw evenly over the ground, preparation of a border or fire-break around the perimeter of the field to preclude fire spreading to adjacent lands, and straw raking, baling and removal and/or plowing and discing of the straw residue into the ground. The final step involves field ignition and burn management utilizing water tanker crews.

Straw Removal

Systems for Straw Removal

The pusher buck rake system involves raking straw into large in-field windrows followed by pushing of such windrows to roadside in large stacks by a large buck rake mounted on the front-end of a large tractor. The buck rake is manufactured locally or on-farm. Stack disposal by burning is done at a later date. This system is preferred when the straw is roadsided for burning because of its low cost.

The loaf-stack wagon involves a straw pick-up mounted to the front end of a large screened wagon with mechanical unloading capability and pulled by a large tractor.

Huge quantities of straw can be moved with large machinery.

When the wagon is full it is unloaded at the side of the field for disposal by stack burning at a later date. This system tends to be slow but is inexpensive, and loaf stacks usually burn well with little smoke.

Baling is done directly from the combine windrows. In some cases side-delivery rakes are used to produce large windrows. The choice of baler is dictated largely by whether a market end use for the straw exists or whether the straw is to be disposed of by removal from the field, roadsided and stack burned. For disposal, baling into the small 2-tie bales and round bales is generally preferred because of their somewhat lower cost, as shown in Table 5-1. Round bales burn more effectively than stacked 2-tie bales. For 2 and 3-tie bales a bale wagon with mechanical pick-up and stack unloading capability is the predominant means for bale pick-up and roadsiding. For the large round and big bales, front-end loaders and trucks are used. The 3-tie and big bale system, while most expensive, are chosen when the bales are marketed.

A prototype side-delivery rake with 6-foot diameter rotating wheels is in the developmental stage (Rears, 1990). It is being designed to move large quantities of straw into large in-field windrows or to roadside straw rapidly in smaller fields for subsequent stack burning.

Costs of Straw Removal

Cost ranges for removing straw from the fields after harvest are depicted in Table 5-1 using two types of representative farms. A farm producing 300 acres of grass seed serves to represent Marion County Lowlands, North Valley, and Foothill areas of the valley. A farm producing 1,500 acres of grass seed serves to represent South Valley grass seed producers. Capital cost, overhead, and operating cost components used in generating specific machine costs are taken from Mellbye (1990a). Overhead and maintenance cost components of machine costs are influenced by volume of annual use, while the operating cost component is relatively constant on a per acre of use basis. Hence, cost/ton calculations shown on Table 5-1 for the 300-acre size farm are somewhat higher than for the 1,500-acre size farm because of lower annual use (economies of scale). Cost/acre calculations across the two sized farms are influenced both by cost/ton and tonnage of straw removed per acre. Straw yields (and therefore costs) are based on perennial ryegrass production. The 300-acre farm has an estimated 3 tons/acre of straw to be removed while the 1,500-acre farm has 2.2 tons/acre to be removed.

Table 5-1
Itemized Costs of Straw Removal Systems

Choices	Bale or Stack Size	$(Cost/Ton) Acre[1] (Farm Size) 1,500	300	$Cost/Acre[2] (Farm Size) 1,500	300
For Roadsiding/Stack Burning:					
1) Buck Rake	--	--	--	9.06	13.08
2) Loaf-Stack Wagon	1.5 ton	8.78	7.49	19.31	22.47
3) Round Baler	800 lb	7.13	6.90	15.69	20.71
Round Bale Loader		4.90	3.86	10.78	11.59
Subtotal		12.03	10.76	26.46	32.30
4) 2-Tie Baler	65 lb	8.29	7.81	18.23	23.42
Bale Loader/Stacker		4.19	4.43	9.22	13.29
Subtotal		12.48	12.24	27.45	36.71
For Straw Marketing:					
1) 3-Tie Baler	100 lb	9.98	--	21.96	--
Bale Stack Wagon		2.15	--	4.72	--
Custom Bale/Stack		--	15.00	--	45.00[3]
Subtotal		12.13	15.00	26.68	45.00
2) Big Baler (4'x4'x8')	1,200 lb	9.55	--	21.02	--
Truck Fork Lift		3.43	--	7.55	--
Subtotal		12.98	--	28.57	--

Source: Mellbye, 1990a.

[1] Cost variation between 300 and 1,500 acre farms due to hours of annual use for distribution of overhead costs (depreciation, interest, repairs, taxes, insurance). The larger the hours, the lower the unit cost/hour for overhead costs. Operating costs are constant on a cost/ton basis. No costs are shown for 300 acre farm where that equipment typically is not used. One exception is baling with a 3-tie baler, in which case the smaller farm hires a custom baler to do the job. A custom baling rate is specified in that case and includes the combined field operations of raking, baling and stacking the straw.

[2] Machine costs shown in the 300 acre column represent grass seed farms typically found in the mid- to north Valley and in the foothills with an estimated 3 ton straw yield per acre. The 1,500 acre column represents the larger farms typical in the south Valley with an estimated 2.2 ton straw yield per acre. All costs have been converted to costs per acre based on the assumptions of differences in straw yields and hours of use on the two types of farms.

[3] The custom rate is $15/ton.

Stubble Management Systems

Systems for Stubble Management

A number of stubble management systems are used by grass seed growers in the valley after the straw is removed (Table 5-2). The purpose is to remove stubble and residue and to trim the crowns of the plants to stimulate grass seed development for the subsequent year. Some of these systems are still experimental and their effects on future yield are unknown.

Table 5-2
Alternative Stubble Management Systems

1. Propane-burn stubble
2. Re-clip and loaf straw
3. Crew cut (with Rears vacuum)
4. Re-clip and rake
5. Flail-chop
6. Flail-chop and thatch field

Source: Mellbye, 1990b.

Effective stubble management requires companion herbicide treatment.

Each of the systems shown in Table 5-2 requires a companion herbicide treatment to control volunteer grass (weed) seed germination, which occurs after fall rains commence. Details of this sanitation requirement are presented in the next section.

Propane burners pulled by tractors are used to burn the standing stubble, chaff, and residue remaining on the ground after straw is removed. A propane tank is mounted on wheels and connected to a set of burn nozzles attached to large folding booms. The burners are rented from propane gas distributors or owned outright by growers. Propane tanks are provided by gas dealers.

Re-clipping and loafing the straw involves use of a self-propelled swather (same as used prior to combining) to windrow the remaining stubble and residue followed by a loaf stacker to roadside the residue.

Crew cutting involves use of a crew cutting machine built by Rears, which has dual rotary brushes and a flailer mounted to the front of a loaf-stack wagon and pulled by a tractor. The flail cuts very close to the ground cleaning the crown area around each plant while the brushes rotate at high speed providing a partial vacuum that sweeps the ground clean and blows the material into the wagon (Rears, 1990). As a consequence, however, a considerable amount of dust is generated by disturbance of the soil surface. As a significant amount of dirt is drawn in with the residue, the loaves are ill-suited for stack burning (or marketing) but excellent for composting (Conway, 1990).

Reclipping and raking involve cutting the stubble with a swather or mower followed by scratching or raking the soil surface with a newly developed scratching implement pulled by a tractor.

Flail chop involves use of a rotary mower or flail machine pulled by a tractor to clip the stubble very close to the ground and to partly pulverize the remaining limited residue left on the ground after straw removal. The purpose is to prune back the stubble and regrowth, thereby stimulating next year's seed yield and minimize the role of straw residue in impeding the subsequent step of field sanitation by chemicals.

Flail chop and thatching utilize the same step as the previous operation with the addition of a thatching process that cleans and removes old crown growth around each plant. This is accomplished with the addition of a thatching unit attached to a flail machine, or pulled over the field alone after flail chopping.

Costs of Stubble Management

Table 5-3 lists specific components used for field sanitation and their estimated cost. Open-field burning components and their costs also are shown to provide a comparison of the magnitude of cost increases associated with shifts from thermal to non-thermal sanitation. All costs apply to the current year only. No assumptions are made of yield impacts of these methods on next year's crop.

Table 5-3
Itemized Costs of Stubble Management and Field Sanitation Systems

Machine	$ Cost/Acre (Farm Size) 1,500[1]	300[2]	Source
Stubble Management:			
Flail	9.19	11.41	Cross and Mason (1989), Mellbye (1990b)
Swather	10.20	10.20	Cross and Mason (1989), Mellbye (1990b)
Loaf-Stack Wagon	9.67	12.77	Cross and Mason (1989), Mellbye (1990b)
Field Sanitation:			
Open Field Burn [3]			
Labor	0.85	0.97	Cross and Mason (1989)
Water Tanks	1.92	2.18	Cross and Mason (1989)
Border Preparation	1.41	1.59	Cross and Mason (1989)
Burn Fee	3.50	3.50	Cross and Mason (1989)
Subtotal	7.68	8.24	Cross and Mason (1989)
Propaning			
Propane Burner	6.97	9.30	Cross and Mason (1989), Mellbye (1990b)
Propane	12.00	12.00	Mellbye (1990b)
Water Tanks	1.92	2.18	Cross and Mason (1989)
Subtotal	20.89	23.48	Mellbye (1990b)
Crewcutting/Vacuum	18.75	-	Mellbye, Rears (1990)
Thatch Harrow	3.09	3.09	Cross and Mason (1989)
Plow	6.90	6.90	Cross and Mason (1989)
Non-Thermal Sanitation			
Chemicals	23.28	23.28	Cross and Mason (1989)
Sprayer	3.05	3.70	Cross and Mason (1989)
Subtotal	26.33	26.98	Cross and Mason (1989)

[1] Assumed straw yield of 2.2 tons/acre representative of the South Valley.

[2] Assumed straw yield of 3.0 tons/acre representative of the Marion County Lowlands, North Valley, and Foothill areas of the Willamette Valley.

[3] Cost range is based on confidence intervals from a field survey conducted by Cross and Mason (1989) (Table 9, p.16 and Table 11, p. 23).

Field Sanitation

Weeds are controlled with herbicide treatment or propane-burning.

An important and required component of post-harvest straw management by growers involves a field sanitation treatment with selective herbicides to control weed grass seed germination. With both thermal and non-thermal sanitation, one or more fall applications of chemicals are required to control fall weed seed germination.

Spring application of chemicals in some instances also may be required to control grass weeds that germinate during winter.

Table 5-4 lists the most common chemicals used, their application rate and 1989 prices from chemical dealers.

Table 5-4
Application Rates and Prices of Field Sanitation Chemicals

Chemical[1]	Rate per Acre	Price
2,4-D Amine	1 quart	$14.00/gallon
Banvel	1/2 pint	$68.00/gallon
Enquik	15 gallons	$2.00/gallon
Fusilade		$100.00/gallon
Goal	20 oz.	$65.00/gallon
Karmex	2 - 3 pounds	$4.25/pound
Nortron	2/3 gallon	$60.00/gallon
Poast		$110.00/gallon
Sencor	3/4 pound	$25.00/pound

[1] Listing of products by trade name, a common practice, does not imply product endorsement nor discrimination against any products not mentioned.

Source: Cross and Mason, 1989

Chemical costs, including application, reported in Cross and Mason's (1989) study of field sanitation costs were about $26/acre and reported as a cost average of 142 growers. The seriousness of grass weed infestation can easily dictate a wide range of cost around the quoted average.

Economics of Post-Harvest Straw Management

The specific post-harvest straw management operations used in the Willamette Valley depend to a large degree upon the size of the grass seed farm and its location in the valley. Large farms are more common in the southern part while smaller farms are more common in the north valley.

The Marion County Lowlands and North Valley farms are located on soil of generally higher fertility, giving rise to higher straw yields per acre than in the South Valley regions. This situation is described in Appendix B, which details each production region in the valley and its predominant processes of post-harvest straw management. This section estimates the costs per acre of field operations associated with each of the post-harvest straw management practices.

Cost information is obtained primarily from recent analysis of straw removal costs and stubble management costs (Mellbye, 1990a; 1990b) and the Oregon State University Extension Report #703 by Cross and Mason (1989). Additional background information and costs for selected items were obtained from Cenex (1990), Hand (1990), Rears (1990), and Smathers and Willet (1990). The costs of using prototype operational equipment for crewcutting, buck raking, and modified side-delivery rake, while reported here, are relatively high and less well established because of limited use. Their costs are expected to decline over time if usage expands.

Six alternative post-harvest straw management systems are employed by perennial grass seed growers in the valley.

Alternative post-harvest straw management systems used in the valley are presented in economic terms in this section.

The post-harvest practice of flailing the straw on the ground after combining then plowing under all of the straw and stubble now serves as the substitute practice of choice on annual ryegrass to replace open-field burning. Estimated costs associated with this practice are presented in Table 5-5. They are generated from Tables 5-1 and 5-3. A comparison with Table 5-3 showing open-field burning costs indicates that this practice effectively doubles post-harvest management costs to annual ryegrass producers. This situation is confined to South Valley producers. Other systems shown in Table 5-5 are more expensive and are not selected by annual ryegrass producers. It must be remembered that annual ryegrass, because of its extremely low income generating potential, is often considered the "grass seed of last resort" and is confined to South Valley lands where other crops will not grow. The flail/plowdown system is not an option for perennial grass seed growers, whose crop stand is plowed down and replanted only every 4 to 8 years.

Six alternative post-harvest straw management systems are employed by perennial grass seed growers in the valley. A listing of these systems and their estimated costs are shown in Table 5-5. Specific field operation components, their estimated costs, and geographical use preference of each system also are specified. The systems are listed in increasing order of cost/acre. A significant cost component with each system involves the non-thermal sanitation treatment of herbicide application for grass weed seed germination control. Systems 5 and 6 (Table 5-5) are the most costly and each involve propane burning and chemical treatment for weed control as field practices. In recent years, use of these systems has been declining in the South Valley. This is quite likely due, at least in part, to growers shifting to less costly options. Nevertheless, all six systems are used in the South Valley.

It is important to note that Systems 4 and 5 (Table 5-5) for hill lands are limited to the lower and relatively shallower slopes of the foothills. Because steeper slopes dominate the Silverton Hills area, machines and equipment will not function there. Combined with severe erosion potential on these lands, this limits sanitation alternatives to a single choice, that is, open-field burning.

Table 5-5
Itemized Costs of Post-Harvest Straw Management Systems, and by Region

Straw Management Choices	$ Cost/Acre (Farm Size) 1,500	300	Geographical Region: South Valley	Marion Low-Lands	Foot-hills	North Valley
For Annual Ryegrass:						
1) Flail & Plowdown			x			
Flail	9.19	11.41				
Plow	6.90	6.90				
Total	16.09	18.31				
For Perennial Grasses:						
1) Buck Rake & Loaf			x	x		x
Side-Delivery Rake	3.60	3.60				
Buck Rake	9.06	13.08				
Reclip or Flail	18.75	11.41				
Loaf-Stack Wagon	9.67	12.77				
Chemical Treatment	26.33	26.98				
Total	67.41	67.84				
2) Loaf, Flail, & Thatch			x			
Loaf-Stack Wagon (of straw)	19.31	22.47				
Flail	9.19	11.41				
Loaf-Stack Wagon[1] (of residue)	9.67	12.77				
Thatch Harrow	3.09	3.09				
Chemical Treatment	26.33	26.98				
Total	67.59	76.72				
3) Crewcut			x			
Round Baler	15.69	-				
Round Bale Loader	10.78	-				
Crewcut/Vacuum	18.75	-				
Chemical Treatment	26.33	-				
Total	71.55					
4) Reclip & Loaf			x	x	x	
3-Tie Baler	21.96	-				
Bale Wagon	4.72	-				
Custom Bale/Stack	-	45.00				
Reclip with Swather	10.20	10.20				
Loaf-Stack Wagon	9.67	12.77				
Chemical Treatment	26.33	26.98				
Total	72.88	94.95				

(continued)

Table 5-5 (continued)

Straw Management Choices	$ Cost/Acre (Farm Size) 1,500	300	Geographical Region South Valley	Marion Low-Lands	Foot-hills	North Valley
5) Bale and Propane			x	x	x	x
Round Baler	15.69	20.71[1]				
Round Bale Loader	10.78	11.59[1]				
Propaning	20.89	23.48				
Chemical Treatment	26.33	26.98				
Total	73.69	82.76				
6) Bale, Propane & Flail			x	x		
3-Tie Baler	21.96	-				
Load/Stack Bales	4.72	-				
Custom Bale/Stack	-	45.00				
Flail	9.19	11.41				
Propane-Burn	20.89	23.48				
Chemical Treatment	26.33	26.98				
Total	83.09	106.87				

[1] An alternative choice to machine ownership involves custom baling and stacking at $15/ton or $45/acre.

Source: Tables 5-1 and 5-3.

Systems 1, 4, and 5 are used in the Marion County Lowlands. Systems 1 and 4 are used where the straw has little value and is roadsided for ultimate stack burning. System 5, which is more costly, is used when the straw is expected to be marketed.

Systems 1 and 5 are used in the North Valley, with System 5 used where the straw is marketed and System 1 used where the straw is roadsided and stack burned.

Straw Storage

For growers with an existing market for straw, or who invest in the means for marketing straw in the future, the question of storage is crucial. Moisture from fall and winter rains will render straw useless for virtually all markets, so straw must be protected through some form of storage.

The study of Cross and Mason (1989) estimated storage costs to be $13.22 per ton in a pole shed and $14.23 per ton in a metal shed. These costs reflect construction, interest on stored straw, repairs, insurance, and weight loss of 5 percent of the straw. The storage costs reflect 6 months of straw storage per year. A survey of a limited number of growers (17) found average costs per acre of $13.68 to $13.82 for a pole shed, and $27.32 to $28.31 for a metal shed.

Composting

In order for straw to be marketed, its bulkiness requires that straw be densified. Densification, as shown in previous sections, is relatively costly, which has served as a further deterrent to straw's market use potential. An alternative, suggested by some, is to consider on-farm uses for straw. Straw composting and return of the humus as an organic fertilizer is one of such alternatives suggested.

Composting, as the biological reduction of organic wastes to humus, is not new. It is a continuous, universal, and endless process of terrestrial life on our planet. Human involvement in the composting process for organic fertilization dates back to biblical times. Composting, as the basis for organic farming in the U.S., is a post WWII phenomenon, having been overshadowed by major use of chemical fertilizers by U.S. farmers.

An applied research study utilizing state and private funds was conducted this past summer to test the technical feasibility for aerobic composting of grass straw.

The addition of soil and much water to the composting pile speeds decomposition.

Initial Testing

The composting study was conducted using stored grass straw and vacuumed stacks (using a Rears crew cutting machine) on a grass seed farm demonstration site. Some 80 tons of straw in the form of big bales were used initially. The bales were refluffed to simulate straw direct from the field using a commercial compost turner, of which several types are available, and a grower manufactured hay stacking unit. Straw samples were taken to determine the beginning carbon to nitrogen ratio for the demonstration. Successful composting is intended to reduce the ratio from about 70:1 down to 30:1, at which point the straw will release N to the soil when incorporated rather than drawing on available soil nitrogen for decomposition. A 3 percent nitrogen in water solution was added to the stack to serve as a wetting agent and facilitate decomposition.

The process of stack turning and watering continued throughout June with initially poor results. To achieve desired decomposition temperatures of 120 to 170°F for thermophilic bacteria to function, it was found that significant quantities of water and soil incorporated with the straw were important components. Composting continued for 6 weeks with the straw windrow turned nine times.

A second test using two vacuumed stacks began in early July 1990. The stacks came from a Rears vacuum stacker and contained considerable soil with the straw. Again a nitrogen water solution was used. Temperatures rose above 120°F in 5 to 10 days. The stacks were turned every week and water added. Decomposition was completed in about 8 weeks. The experiment with vacuum stacks was much more effective.

The demonstration test was deemed successful. An 80 percent volume reduction of straw occurred in some 8 weeks. The compost product, ready to be returned to the field, was pasteurized adequately by the high temperatures such that no evidence of spurious seed germination remained. Characteristic of aerobic composting, no offensive odors were ever evident. Extremely large volumes of water were required for the experiment.

Future Plans and Assessment

Plans are under way to continue compost experimentation during this winter utilizing natural rainfall, perhaps supplemented with sprinklers to meet the high water requirement for composting.

No economic analysis was conducted on the composting process at this initial testing stage. Preliminary evidence from the researchers conducting the test indicates that operating costs for stack watering, supplemental nitrogen, and turning may be quite low. However, labor and capital costs for equipment involved in stack turning and return of compost to the field by mechanical means were not included. Nor have costs for supplemental irrigation, if needed, been included. Results to date are encouraging enough to warrant continued experimentation this winter.

It is important to note that compost can be incorporated into the soil each year only on annual ryegrass. In the case of perennial grasses, return of compost would likely occur only when a perennial field is plowed down for replanting under a new contract. Laying a thin surface of compost in the fall or winter to a perennial stand has not been evaluated.

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6 Feed Markets

Introduction

Unlike the other three potential market areas for grass straw, the feed market has been utilizing grass straw for some time. This chapter discusses factors affecting the feed market--past, present, and future--for grass straw and presents an economic analysis of the current market.

Current Situation and Trends

Factors that may affect grass straw feed markets include supply, processing, nutrient quality, chemical residues, fungi, and storage. The overriding consideration that determines whether grass straw is used is the relative price of other roughage feeds. If they are high, some straw is purchased as a roughage supplement. Essentially none is used domestically where straw requires processing as a feed because of the cost to value ratio.

Many studies have been conducted on feed uses for straw. They include feeding trials for beef, dairy cows, lambs, and horses; nutritive value surveys; and feed processing trials. In its untreated form, straw as a feedstuff for livestock is of poor quality with low protein and high fiber content, around 30 to 35 percent. In this natural form, grass straw is used primarily as a maintenance diet for overwintering, nonpregnant, mature ruminant animals.

Historically, a domestic market has existed for grass straw as supplemental livestock feed during periods of short supply and/or excess demand for livestock forages (Wells et al., 1979). In Oregon, trucking costs have been an important constraint in limiting the use of Willamette Valley grass straw to the central and eastern areas of the state. In this market, straw is used as a winter maintenance feed for dry, nonpregnant cows. The drought of 1988 in eastern Oregon and Idaho, which has continued through 1990, has brought renewed interest in straw with unspecified quantities shipped to this area for livestock feed (Conklin et al., 1989).

Straw can be treated to improve digestibility and palatability.

Supplemental protein and simple carbohydrates are used with the straw rations, with the more common being urea or fish meal mixed with liquid molasses. Other straw treatments to improve digestability include sodium hydroxide and hydrogen peroxide. Liquid anhydrous ammonia is added for protein, but the expense has prohibited large scale use (Conklin et al., 1989). Processing may include grinding, defibration, densification, chemical treatment, and fermentation (Conklin et al., 1989).

Currently two feed studies are under way, both supported by Linn-Benton Regional Strategy. Their intent is to produce an alternative livestock feed using treated straw. In one study, the straw will be ammoniated, breaking down the lignin surface and thus releasing nutrients with increased palatability and digestibility. The other study will also include ammoniating the straw, but corn juice (a cannery byproduct) will be added to make silage. As these two studies are still in the initial stages of implementation, economic data are not yet available (Miller, 1990). The overriding consideration will be whether the costs of increasing its digestibility and palatability will make it competitive in price with comparable roughage feeds available. To date, essentially none is used domestically when straw requires processing because of cost-to-value ratios.

Over the past 10 years, a feed market for grass straw has developed in Japan, where it is used as a source of roughage in the dairy industry. The largest current commercial use of grass straw is in the export market as a livestock feed in Japan. Straw for export is baled in the field in 2-tie or 3-tie form, hauled to storage or to a central location, compressed into a highly densified form, loaded in containers and then shipped by ocean freighters to Japan. Once it arrives, it is treated with a protein supplement and used as a roughage source in the dairy industry. The Japanese market has adequate protein sources (soybean and fish wastes) but is low in roughage. A similar market may be emerging in Taiwan.

Increased use of herbicides in lieu of burning may reduce the supply of straw for feed.

Agricultural chemicals are used in grass seed production to control weeds, diseases, and insect pests. With recent reductions in field burning, chemical use may be rising, thus increasing the percentage of grass straw with legal restrictions for use as livestock feed (Mellbye, 1990). Publications are available that list the restrictions for feeding straw containing agricultural chemical residues, but this is an area that so far has received little attention. Chemical registration for grass seed crops, which includes the use of straw for livestock feed and grazing, may become an issue of concern (Conklin et al., 1989).

Straw infected with endophyte fungus can be toxic to livestock.

An endophyte is a fungus bred into some turf-type tall fescue and perennial ryegrass varieties to improve their vigor and enhance disease and insect resistance, but which is toxic to livestock under certain conditions (see Chapter 3). Therefore, the presence of endophyte in some grass straw is a factor that may influence its use as a livestock feed. A combination of grazing on or feeding of grass straw infected with high levels of endophyte, as the predominant or only component of the diet, for 1or 2 weeks may result in one of two conditions. Turf-type perennial ryegrass infected with high levels of endophyte can cause an ailment called "ryegrass staggers;" turf-type tall fescue infected with endophyte can result in "foot fescue" (Ballerstedt and Hansen, 1990). Forage-type tall fescue seed and straw produced in Oregon is bred endophyte free. At present, however, no distinction is made in the marketplace between grass straw from these two sources. The relationship of endophyte level to livestock is not fully understood and is the topic of a number of research studies currently under way across the country.

Storage facilities must be available to preserve quality.

One other factor which may influence the use of grass straw as a livestock feed is the number of storage facilities available. Straw for feed must be stored properly to maintain its nutrient levels and availability for seasonal feeding. The greatest volume of grass straw in sheds currently is perennial ryegrass.

In summary, expansion of commercial uses of grass straw in both the domestic and export markets may take place in the future; however, expansion will be directly related to its role as a limited feed substitute for available roughages.

Market Economic Analysis

Demand is directly related to the price of other feed.

The domestic quantity of straw used for livestock feed appears to be directly related to the price of alfalfa hay. In 1990, alfalfa hay prices in Oregon exceeded $110 per ton in some cases, the highest on record (Figure 6-1). Consequently, an apparently large but unspecified volume of Willamette Valley grass straw is being shipped east of the mountains. Estimates range from 5,000 to 20,000 tons being shipped during fall through November 1990, with market quotes at about $10/ton for big bales loaded on the truck. Trucking charges from the Willamette Valley to Central Oregon, with backhaul ranges, from $23 to 25/ton. Without backhaul the rate is about double.

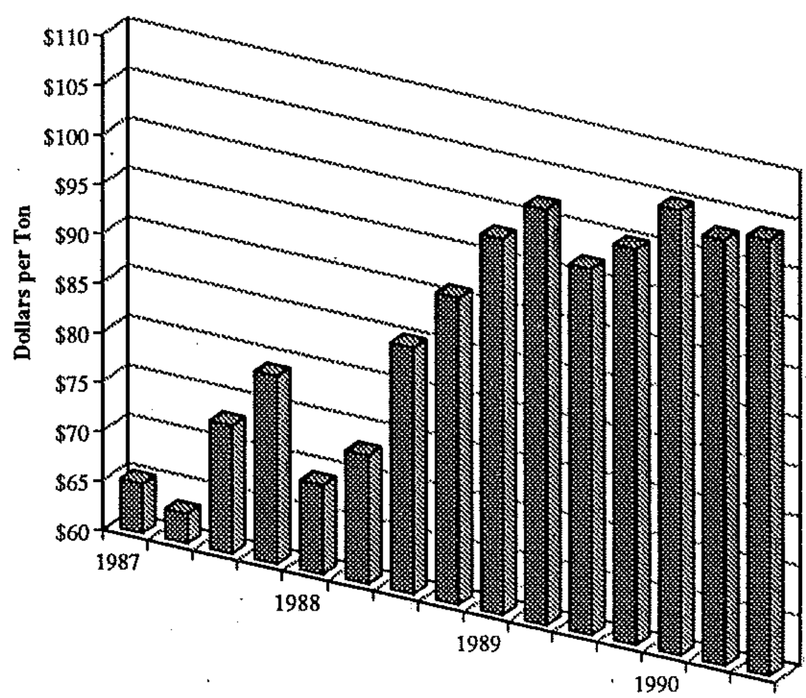

Figure 6-1
Oregon Alfalfa Hay Prices

Table 6-1
Straw Exports from Oregon, 1988-1990 (tons)

Year	Month	Peren. Ryegr.	Fescue	Bent-grass	Orchard-grass	Blue-grass	Oat	Canary-grass	Total
1988	Jan	9,535	623	116	194	0	0	0	10,468
	Feb	8,908	3,064	317	194	735	0	0	13,218
	Mar	7,787	2,762	891	734	1,583	0	0	13,757
	Apr	1,209	1,595	0	579	1,359	0	0	4,742
	May	581	380	190	388	190	0	0	1,729
	June	461	350	0	15	32	0	0	858
	July	1,916	115	0	0	191	0	0	2,222
	Aug	14,235	3,102	0	0	989	0	0	18,326
	Sept	12,340	1,819	0	0	1,227	0	756	16,142
	Oct	13,070	3,434	190	0	377	0	0	17,071
	Nov	14,504	1,694	0	0	0	0	537	16,735
	Dec	13,480	4,167	191	0	386	0	187	18,411
	TOTAL	98,026	23,105	1,895	2,104	7,069	0	1,480	133,679
1989	Jan	11,333	2,445	381	1,158	194	0	0	15,511
	Feb	8,313	3,453	194	386	0	0	0	12,346
	Mar	8,391	2,037	576	0	382	0	0	11,386
	Apr	4,717	2,003	194	0	0	0	0	6,914
	May	6,194	1,674	186	0	180	0	0	8,234
	June	1,580	830	191	0	419	0	0	3,020
	July	4,070	1,938	0	190	0	0	0	6,198
	Aug	3,797	1,813	0	37	0	0	0	5,647
	Sept	3,655	536	0	0	0	0	0	4,191
	Oct	8,640	3,115	309	0	387	0	0	12,451
	Nov	7,657	3,364	467	389	0	0	0	11,877
	Dec	9,687	0	2,794	194	0	0	0	12,675
	TOTAL	78,034	23,208	5,292	2,354	1,562	0	0	110,450
1990	Jan	7,220	1,989	233	194	350	192	0	10,178
	Feb	6,579	2,079	0	194	0	78	0	8,930
	Mar	7,991	1,921	0	0	0	0	0	9,912
	Apr	7,868	1,555	0	389	0	155	0	9,967
	May	7,204	3,333	579	0	0	0	0	11,116
	June	9,394	2,075	117	10	0	65	0	11,661
	July	5,343	4,267	0	0	0	0	0	9,610
	Aug	10,806	6,852	0	117	194	0	0	17,969
	Sept	9,743	4,150	583	0	0	202	0	14,678
	Oct	17,922	6,020	384	0	0	121	0	24,447
	Nov	16,339	9,104	529	0	0	0	0	25,972
	Dec	—	—	—	—	—	—	—	—
Year	To Date								
	TOTAL	106,409	43,345	2,425	904	544	813	0	154,440

The Japanese market has grown steadily over the past 10 years from an annual use of 30,000 tons to its current level of 125,000 to 150,000 tons/ year.

The Asian market for straw feed is growing steadily.

Oregon Department of Agriculture records show 133,679 and 110,450 tons of Willamette Valley grass straw was shipped to Japan in 1988 and 1989, respectively, with the majority being perennial ryegrass and tall fescue (Table 6-1). By November 1990, some 154,440 tons of straw was shipped overseas with one of the larger shipping months still to come. In addition, some 2,400 tons of bentgrass straw was shipped to Taiwan in 1990 as cattle roughage.

The data contained in Table 6-1 are gathered from phytosanitary certificates issued by the U.S. Department of Agriculture. The certification is required by the Japanese government, a requirement not used in the U.S. Table 6-1 understates to a small extent the volume of exports because a small but unspecified portion of total volume is exported without the certificates.

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7 Fiber Markets

Introduction

Four principal market areas exist in the Pacific Northwest for straw fiber. They are pulp and paper products, structural board, erosion control products, and soil amendments. This chapter provides a description of the current technical and economic factors relating to production and sales in those fiber markets. Also provided is an economic appraisal of using straw as an alternative fiber source for selected products in those markets.

Current Situation and Trends

Straw is used in lieu of wood fiber in many parts of the world.

Straw is an important source of fiber in many parts of the world. It is used to produce corrugating medium in Spain, fiberboard in India, and paper in Denmark and China (Chantiny et al., 1990; Conklin et al., 1990). Around the globe, grain and grass straws, rice straw, and bagasse (sugar cane stalks) are used for making an assortment of fiber products because those are the most economical fiber sources available.

In the Pacific Northwest, heartland of U.S. softwood timber production, the historical fiber of choice has been wood rather than straw. The use of wood fiber over straw in this region is due to an abundant, year-round supply. Pacific Northwest fiber consumption for the manufacture of pulped fiber products averaged 10.9 million bone dry tons (bdt) on residual woodchips, 3.7 million bdt of roundwood, and 1.1 million bdt of waste wood (EKONO, 1990).

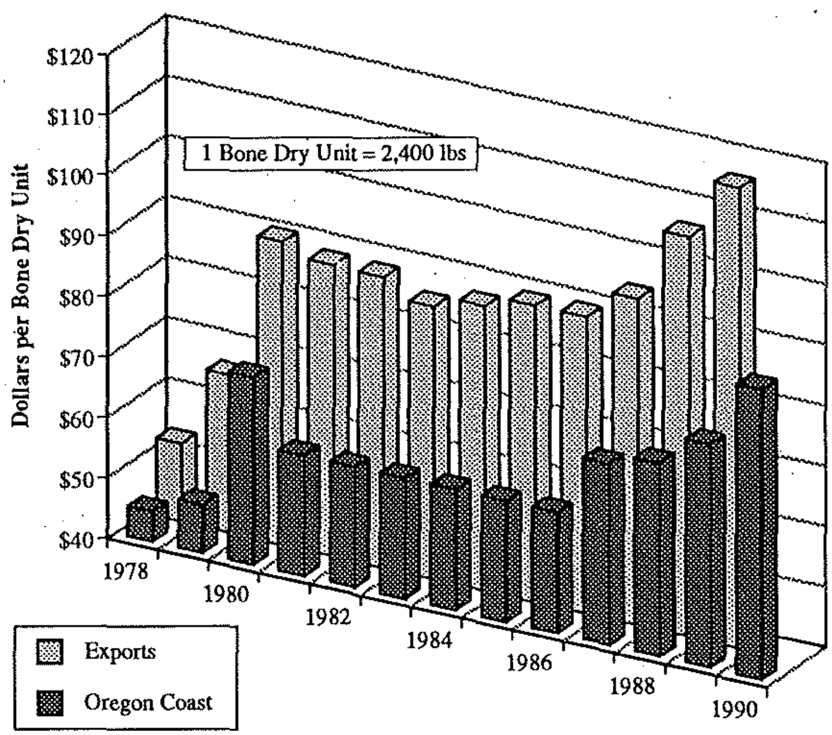
If all valley straw were used for pulp, it would equal only 7 percent of the pulp fiber now used in the Pacific Northwest.

Straw, on the other hand, makes up an extremely small volume of potential fiber compared with wood fiber in the Pacific Northwest. And straw is harvested only during early fall each year, as a by-product of grass seed production. If the entire approximately one million tons of straw available annually were used as a source of pulp fiber in the Pacific Northwest, it would account for no more than 7 percent of the fiber requirement for the manufacture of pulped fiber products in the Pacific Northwest. Thus, at best, the Pacific Northwest pulp/paper industry could view straw as only a supplemental or extender raw material. Other disadvantages of straw are that it requires densification to transport in an economical manner, storage facilities to provide a continuous supply, and protection from inclement weather.

This historic situation in the Pacific Northwest has caused wood fiber prices to have a significant competitive advantage over straw fiber prices. However, recent pressures on the supply of wood fiber, concerns about its long-term availability, and strong domestic and foreign demand for wood fiber products have brought about significant increases in wood fiber prices. Grass straw may now be or soon become economical as a supplement to or partial substitute for wood fiber in several fiber products. This development is discussed further in the following sections concerned with the principal fiber markets.

Pulp and Paper Products

Industry has a renewed interest in using straw for coarse-grade pulp and paper products, such as corrugating medium for cardboard boxes. This is because there is justifiable concern about the future supply and price of hardwood chips, the fiber source commonly used today. There have been significant recent reductions in timber harvest quotas on public lands in the Pacific Northwest. Hardwood log harvesting, a secondary product of timber harvesting but a primary raw material for pulping, likewise has been reduced. The result has been a significant increase in the price of hardwood chips, especially during 1988-89 when prices nearly doubled (Figure 7-1). The situation has been exacerbated by strong export demand for hardwood chips in the Far East.



Source: Charles S. Lewis and Ken Wilson

Figure 7-1
Hardwood Chip Prices (Western Region)

In addition, current reforestation practices attempt to minimize production of alder, maple, and tan oak trees. These trees, a primary source of wood chips, heretofore have been viewed as undesirable species. The result is that these hardwood species have not been renewed at a rate that guarantees future availability at current rates (Chantiny et al., 1990).

Pulp/paper mills in Oregon use both batch digesters, which cook woodchips in individual lots or batches, and continuous digesters, which continually move the raw material being pulped through the digester. Digesters are machines that combine steam under high pressure and chemicals to break down or "cook" woodchips into individual fibers. Most batch digesters in use involve a longer cooking time than that necessary for straw fiber.

Using a wood chip/straw blend with those digesters can create serious and often insurmountable technical difficulties.

An Oregon pulp mill provides a case study.

However, a pulp mill that produces corrugating medium on the Oregon coast provides a possible case study. This mill has expressed interest in the use of grass straw because it is equipped with two digesters: one is a common vertical continuous digester, whereas the other is a horizontal tube continuous digester. Tube digesters are amenable to digesting non-wood fibers and are in use in Europe for pulp/paper production from grass and grain straw. The horizontal tube digester at this mill is used less than 20 days per year. To bring it on line for digesting straw satisfactorily would reduce unit production costs.

At present, the plant uses a 50/50 mix of hardwood chips and recycled old corrugated containers (OCC) to produce corrugating medium. Plant engineers believe a corrugating medium could be produced at the mill by using a 50/30/20 percent mix of OCC, hardwood chips, and grass straw, respectively.

Modification or retrofitting of the existing plant to handle grass straw would appear to be minimal. Waste cardboard (OCC) is delivered to the mill in a 4- by 4- by 4-foot baled form on flatbed semitrailers. The bales are provided as a back-haul from delivery of the finished corrugating medium rolls into California, Nevada and Utah, thus reducing transportation costs. The bales are unloaded and fed through a large repulper (blender) unit. The process bypasses the digester, chemical recovery, washing, and refining process. Grass straw could possibly be fed through the same system after being delivered to the plant in the 4- by 4- by 8-foot big bale and the twine removed. However, it would require going through the horizontal digester before being added to the pulp stock output.

A possible modification to the system might involve spent chemical utilization/disposal. At present, the plant produces sodium sulfate as a byproduct recovered from the pulping process and sold for industrial uses. It is unknown whether spent chemicals from pulping of straw can be converted to a usable byproduct or will require disposal.

Pulp and paper mills will need a continuous supply of straw delivered from storage facilities.

Other questions that need to be addressed concern the type of grass straw and its supply. Previous testing indicates that annual ryegrass straw is the straw of choice because it has pulping characteristics and yields approaching that for hardwood chips (Anderson et al., 1974; Bublitz, 1974; Sandwell, Inc., 1975; Biermann et al., 1989). The mill wants a continuous supply of straw but prefers on-farm storage. Delivery on demand through annual contracts and transport coordination at the plant is preferred.

Preliminary economic analysis indicates that straw can be delivered in a baled form to the coast mill at a price competitive with hardwood chips (Table 7-1). The cost to bale, roadside, and transport a big bale within

Table 7-1

Cost Comparison of Fiber Raw Materials Delivered to a Mill

Raw Materials and Itemizations	Cost Range $	
	Low	High
Hardwood Chips	85	100/bdu
Old Corrugated Containers (OCC)[1]	80	110/ton
Baled Straw (Big Bale)		
Baling and roadsiding[2]	12	15/ton
Storage	7	10/ton
Transport[3] (approximately 150 miles)	15	25/ton
Total Cost	34	50/ton
Conversion from tons to bdu equivalency[4]	47	69/bdu
Adjustment for straw pulping efficiency to be equivalent to wood chips[5]	57	83/bdu

[1] OCC is delivered to the plant in 4- by 4- by 4-foot bales as essentially dry cardboard (moisture content not exceeding 100 percent). Processing into pulp requires only re-pulping (blending and addition of water). The major costly processes of digestion (cooking), chemical recovery, washing, and refining are bypassed. Consequently, while actual cost of remaking corrugating medium from old cardboard is unknown, all of theoverhead and operating costs associated with the process are avoided. This may account for 40 to 50 percent of total cost of a pulp/paper plant. Thus, the total processing cost associated with using OCC may be significantly lower than that of woodchips or straw.

[2] The high end cost for baling and roadsiding represents custom rate.

[3] Transport costs are based on $15/ton delivered within an 80- to 100-mile radius, and $20/ton delivered within a 200-mile radius of the valley.

[4] Conversion from tons to bdu: 2,000 lbs @ 12.5 percent = 1,750 lb bdu; 1,750 lb @ $34 = 2,400 lb @ $47.

[5] Substituting straw for wood chips requires that an efficiency factor for pulping yield be included. Pulp yields are 78 percent for wood chips and 65 percent for straw. Thus, straw is only 83 percent as efficient as wood chips, resulting in the need for additional quantities of straw, to be equivalent to wood chips.

Sources: Chantiny, 1990; Miller, 1990; Warren, 1990; Wilson, 1989.

a 150-mile radius is $27 to $40 per ton. Pulp and paper mills will need a continuous supply of straw delivered from storage facilities.

Straw tonnage must be compared to bone-dry tons of wood fiber.

Storage would add about $7 to $10/ton for a total delivered cost of $34 to $50/ton (Figure 7-2). This cost estimate must be converted to the unit of measure used in the woodchip market, the bone dry unit (bdu), which equals 2,400 lbs at 0 percent moisture content. With this conversion and a pulping efficiency equivalent to wood chips, the cost of delivering baled straw is in the range of $57 to $83 per bdu. Hardwood chips, on the other hand, have been reported in recent markets as high as $85 to $100 per bdu delivered, while 2 years ago OCC reached a high of $140 per ton.

Some 90,000 bdu of hardwood chips are currently used in the plant. For straw to replace 15 to 20 percent of the annual hardwood chip requirement (i.e., 13,500 to 18,000 bdu) and using the conversion factors stated in Table 7-1, some 30,000 to 35,000 tons of grass straw per year could be utilized in this and similar plants.

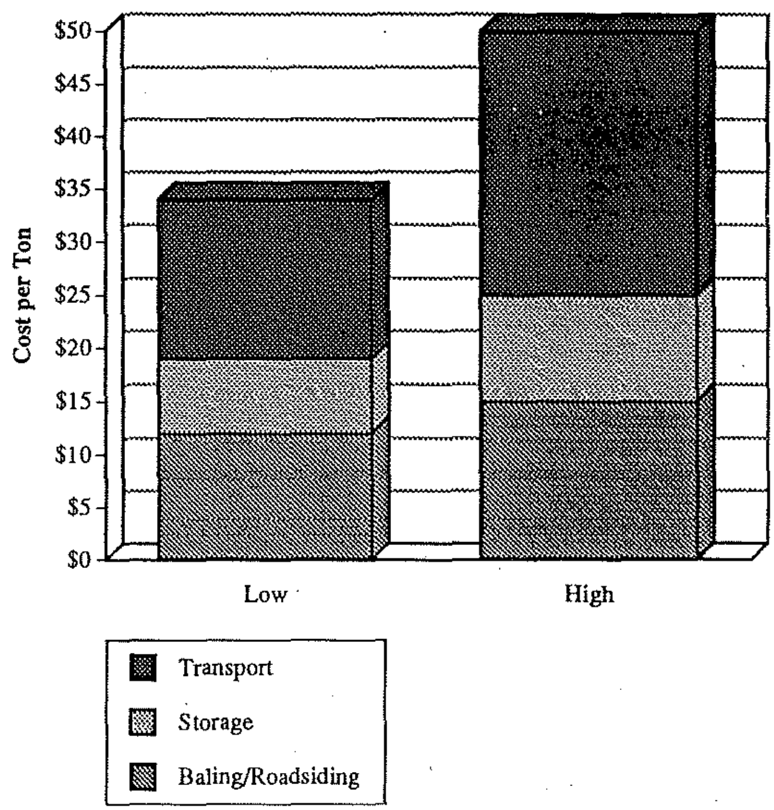


Figure 7-2
Grass Straw to Market Costs

However, for this plant with an existing horizontal digester, a significant capital investment in equipment has been avoided.

The role of straw appears to be that of an extender, that is, to "extend" the utilization of plant and equipment either in the short-term or to be used as a supplemental input on a continuing basis.

Structural Board

Escalating costs of wood fiber will make straw more attractive for structural board.

Grain straws, predominantly from rice and wheat, are currently being used in a number of countries in manufacturing structural (floor, wall, and roof) panelboard-type products on a commercial basis. Manufacturing plants are located in Norway, England, Finland, Bangladesh, India, and Thailand where wood-based products are in short supply. The interior and exterior panelboard is produced dominantly in 4-foot by 8-foot panels (sheets) from 1/4 to 1 inch in thickness. Commercial straw-based structural panelboard is not currently produced in the United States. As a result, strawboard will still have to gain public acceptance as well as meet structural building materials standards appropriate for use in the United States.

In the Pacific Northwest the cost of virgin wood fiber will continue to escalate. This escalation will be driven by the loss of available harvestable public timber. The supply of wood waste is expected to decline further as sawmills and plywood plants cut back in production or close down altogether. The number of Pacific Northwest plywood mills has reduced from 157 to 81 in the past 25 years as the volume of wood production has shifted from the Pacific Northwest to the southeastern United States.

Dwindling supplies of quality logs for making plywood over the past decade has led to the development of alternative structural board products which make use of wood waste from plywood and other wood product processes (e.g., mill ends, sawdust, shavings, and plywood trimmings). Particleboard, fiberboard, and strandboard are examples of alternative structural board products. In some areas of the region, there is already increased competition between panelboard manufacturers and industrial power plants for wood waste residuals. Today, structural panelboard plants in western Oregon are reaching as far out as 150 miles to purchase good quality raw materials. Other new products may be developed by the wood fiber industry in the future to allow them to use lower-quality wood fiber raw materials.

The wood structural board industry is already looking into using other forms of wood-based raw materials. Considerable emphasis has been placed on using paper and paperboard waste materials and urban wood waste from home and construction work which is currently going into landfills (IRU, 1990). Although there are a variety of materials handling and fiber sizing problems for these producers to solve, preliminary tests of these materials indicate that these lignin/cellulose-based materials are suitable for reuse (IRU, 1990). At least one structural board manufacturer in the Pacific Northwest is considering utilizing such wood-based materials.

Structural board plants in western Oregon currently are paying anywhere from $35 to $80 per bdt, averaging between $55 and $65 per bdt, delivered (IRU, 1990). Converting straw at 12.5 percent moisture

(Table 7-1) with a delivered price of $34 to $50 per ton results in a bdt equivalent of $47 to $69 per bdt. Based on these numbers, it appears that straw may be competitive with available wood fiber sources, depending on the additional costs of processing (i.e., bale breaking, size reduction, and storage).

Potential Role for Straw in the Structural Board Market

Straw could replace only 1 percent of expected wood fiber losses from declining timber harvests.

In 1989, the U.S. structural panelboard industry produced over 26.5 billion square feet of product (including plywood panels), on a 3/8-inch-thick, 4-foot-wide by 8-foot-long panel basis, as reported by the American Panel Association. Of that amount, 4.9 billion square feet was from the particleboard and medium-density fiberboard industry (based on a 3/4-inch-thick 4-foot by 8-foot panel). The 11 Oregon structural panelboard plants, who are members of the National Particleboard Association, accounted for over one-fifth of that amount with about 1.2 billion square feet of 3/4-inch-thick panelboard production in 1989.

The issues surrounding the spotted owl and old-growth timber could represent anywhere from a 25 to 45 percent reduction in allowable cut in coming years. If the reduction in available harvest were estimated at 20 percent, and if the residual reduction to the structural board plants in Oregon were half of that amount, this would represent a loss of over 120 million square feet of production. This is equivalent to 7.5 million cubic feet of wood fiber. Using an average of 30 pounds per cubic foot of wood, this means a loss over 112 million tons of dried wood residuals or fiber annually, which would be lost to structural panelboard producers in Oregon. On an average basis, this translates to about a 10 million ton loss per panelboard plant in Oregon.

If the utilization of straw can be determined as an extender to this industry, the 1 million tons of straw fiber available represents about 1 percent of the total wood fiber loss. It would appear that the use of grass straw in the panelboard industry could serve as a supplement to wood fiber in reducing the fiber shortfall, provided public acceptance can be gained and structural standards can be met.

To introduce straw, paper, and paperboard waste or urban wood waste into an existing plant, modification of machine use is necessary. The form the straw is in when it arrives at the manufacturing plant will determine where the material is introduced into the actual process line and to what extent plant and process modifications will be necessary.

Panelboard Products

The structural panelboard industry produces at least eight types of structural board products:

- Plywood
- Particleboard (PB)

- Hardboard
- Medium-density fiberboard (MDF)
- Cement-bonded fiberboard (wet) (CFBW)
- Cement-bonded fiberboard (dry) (CFBD)
- Oriented strandboard (OSB)
- Oriented waferboard (OWB)

Two of the structural boards are not currently produced in western Oregon: oriented strandboard, and oriented waferboard. These two products could face considerable difficulty in fiber orientation and consistency between the larger, heavier wood fibers and those of straw (IRU, 1990). For these reasons, the use of straw has not been considered further for production of OSB and OWB.

The six processes for which plants exist in Oregon and that lend themselves to the utilization of various amounts of grass straw include particleboard, medium-density fiberboard, hardboard, plywood, cement-bonded fiberboard (wet), and cement-bonded fiberboard (dry). It is possible that straw could be used as a fiber source along with wood fibers in any of these structural boards (IRU, 1990).

Appendix C includes process descriptions for six Panel Board Processes.

Modifications to an Existing Facility

The costs associated with modifying an existing plant to utilize straw are difficult to predict. They will be specific to each process as well as to each individual facility. An example of the possible raw material preparation modifications for a particleboard plant to utilize 10 to 20 percent of its fiber needs from straw could consist of equipment requirements that might include the following:

- Straw receiving and storage
- Straw particle sizing to meet the wood residue requirement
- Storage bin
- Straw reduction machine
- Dryer
- Straw flake screen
- Silo for surface material
- Silo for core material
- Weight systems for surface and core
- Resin blenders for surface and core
- Resin preparation and storage
- Additional forming heads
- All necessary ancillary equipment
- All materials handling equipment

The ideal situation would allow the refined particles of straw to be added directly into existing wood fiber storage bins and mixing would occur there. The most probable scenario will be that portions of the stock preparation equipment outlined above will have to be dedicated to the preparation and handling of straw material separately.

Erosion Control Products

Since the late 1970s, grass straw has been utilized in the Willamette Valley to produce a hydromulch and baled forms for erosion control has been extremely limited. Less than 5,000 tons of straw is used for this purpose annually. Because the volume of use is low, this option does little to solve the straw utilization problem in the Willamette Valley. Consequently, investigation of this option beyond that presented below is not anticipated.

Hydromulch

The current market volume for erosion control products using straw is small.

Since the late 1970s, grass straw has been utilized in the Willamette Valley to produce a hydromulch used for erosion control and as a cover for areas recently seeded to a ground cover (Conklin et al., 1989; Miller, 1990). The hydromulch product is sold commercially to applicators whose contractual arrangements vary from residential lawns to roadside application by the State Highway Department as a medium for reseeding grass on cuts and fills (Hopkins, 1990).

The regional market is dominated by a wood-based hydromulch producer in Washington. A single straw-based hydromulch producer operates in Oregon. Straw-based hydromulch has suffered from a lack of product familiarity and tests that demonstrate its performance in comparison with wood-based hydromulch (Wilson et al., 1983). The single Oregon straw-based hydromulch producer has a limited storage capacity and a volume of yearly straw usage of less than 2,000 tons (Wilson et al., 1983; Conklin et al., 1988).

Bales

Other uses of grass straw for erosion control have been limited. Small amounts of straw (in standard and large bales) have been used as sediment retention dams in municipal watersheds; barriers to control erosion on forest slopes, small waterways, and ditch banks; soil stabilizers between Christmas tree rows; and soil retention on roads and railroad rights-of-way, residential and industrial construction sites (Miles, Jr., 1989; Agr. Fiber Association, 1987).

Soil Amendments

Two types of soil amendments have been developed using grass straw as the medium. One is a patented product used as a potting medium in containers for nursery products (Ticknor, 1990). The other is a commercial compost (Lindermann, 1990).

Potting Medium

The potting medium product is produced and sold to wholesale nurseries, and small quantities are bagged and sold retail. The pre-blended mix contains ground straw, peat moss, pumice, and fertilizer (Teufel, 1990). It serves also as a substitute for bark in the landscaping business. The potting mix was developed during the late 1970s as a substitute for bark mulch when sawmills began using more of their bark for fuel during the energy crisis, resulting in an increase in the price of bark mulch.

Production of the mix involves chopping the straw, treating the straw with a urea-based resin, addition of a nitrogen based fertilizer, mixing, cubing the mixture (which sterilizes the product and prepares it for grinding), and then grinding the cubes into a potting mix similar in consistency to bark mulch (Ticknor, 1990).

The potting material has been produced for the past 5 years utilizing some 1,200 tons of wheat straw as the fiber source. Grass straw could be used in lieu of wheat straw. This has not occurred largely because of concern by users of the potential for volunteer grass seeds.

Because the volume of straw used is very low and the problems with consumer acceptance, no further investigation of this alternative for grass straw is anticipated.

Commercial Compost

Straw use for commercial compost is still in the developmental stage, but technology necessary for large-scale production of compost is available on the market. This type of composting system has typically been used in conjunction with wastewater treatment plants to dispose of sludge. The sludge is combined with biomass (e.g., sawdust, urban wood waste, leaves) to aerobically produce a marketable fertilizer. Capacities of these systems often range from a few tons to hundreds of tons per day. Processing time averages 10 to 30 days.

While these systems traditionally have not been designed to handle straw specifically, they have been designed to handle a variety of biomass materials. It may be possible to process straw in these types of systems. If so, the extent to which straw could be used would be dependent on the composting characteristics of grass straw as well as the size of the wastewater facility.

Research is under way on mechanical drum composting machines that rotate and mix the material on a continuing basis to provide the aerobic composting process (Lindermann, 1990). Composting machines slated to be built would use a 10- by 30-foot mixing drum. They are expected to use grass straw, mint sludge, and fish by-products. Input proportions will be determined by field trials expected to be conducted in 1991. Some 15 machines are planned for construction and placement at 3 on-farm sites. Each site is anticipated to produce 1,500 tons of compost every 30 days over a 9-month period, for a total usage of about 40,000 tons of straw annually.

More research is needed concerning composting.

The developmental nature of this alternative requires a wait and see attitude. The volume potential and the costs associated with composting and transporting for commercial use appear as probable limitations. Its potential in contributing to straw utilization is still unknown.

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8 Fuel Markets

Introduction

Biomass fuels are not new. Wood, bark, corn stalks, bagasse (sugar cane residue), rice hulls and straw, and grass straw have all been used as fuel sources in applications ranging from home heating to large industrial powerplants. While the basic technology for utilizing these fuels is available, each fuel has unique characteristics that require modifying the technology to a certain degree.

This chapter examines current technologies for burning grass straw, their relative costs, and the extent to which straw appears to be price competitive with other fuel sources under current market conditions.

Potential energy applications for straw fuel alone or in combination with other fuels will be discussed for:

- Industrial applications
  - Direct process heating systems
  - Steam generating plants
  - Dedicated power production plants
  - Cogeneration systems
- Residential applications
  - Traditional woodstoves
  - Pellet stoves
  - Bale burners

Straw fuel has been tested by several industries and institutions.

Current Situation and Trends

Considerable research has been done in using Willamette Valley straw as fuel. Straw has been tested in a variety of forms and in a variety of applications. The market potential for straw fuels includes both industrial and institutional applications as well as residential use.

For industrial applications, straw fuel testing has been done by several industries and institutions; the longest test was 2,000 tons of straw supplied by Vanleeuwen Farms to Willamette Industries for use as boiler fuel in 1980 (Miles, Jr., 1987). Testing included feeding straw into existing solid fuel boilers in several forms: straight from bales, chopped, chopped and ground, and as cubes. The costs of using straw in each of these forms depends upon the amount of handling, processing, and power required by each process.

For residential applications, straw fuel testing has also been done by several industries (Miles, Jr., 1987). Testing included straw firelogs, straw pellets, and wood/straw mixtures in each of these forms. The fuels were tested in traditional woodstoves and pellet stoves.

The cost and availability of competing fuels determines the demand for straw fuel.

The cost of straw relative to other fuels is the principal factor in determining its use as a fuel. In the northwest, the primary biomass fuel in use is wood waste, a byproduct of the timber industry. Wood waste comes in many forms, including hog fuel (a byproduct of the wood products industry consisting of a mix of bark and other wood residues), chips, and sawdust. It has been used to fire steam generators for many years in both industrial and commercial applications. Approximately 13,400,000 oven dry (OD) tons of these residues are created each year in Oregon, including 5,494,000 OD tons (41 percent) used as fuel for energy (Sifford, 1988).

As the efficiency of the mills improved and as the particle board market developed, less waste was available for fuel. Also, the transition from old growth timber to second and third growth timber and the overall lessening of the raw timber supply have resulted in less waste per tree and fewer trees for processing (Table 8-1). A third factor is that as competition for raw materials increases, many smaller mills lose their ability to compete and drop out of the market. Fewer mills equates to fewer sources of wood waste. Much of the available supply of hog fuel is being drained from Oregon sources to the northern and central California markets at extremely high prices (McHugh, 1990). As the supply shrinks, wood fuel costs will rise and the fuel market will open up to formerly noncompetitive fuels.

Table 8-1
Mill Residue Data

Year	Generated Residue (OD Tons)	Unused Residue (OD Tons)	Unused (%)
1968	15,463,000	2,990,000	19.3
1972	17,122,000	1,463,000	8.5
1976	15,383,000	530,000	3.4
1982	8,991,000	23,000	0.3
1985	13,481,000	75,000	0.5

Source: Funck, 1986; Howard & Ward, 1988 cited in Sifford, 1988

Competition for wood waste is increasing. However, several problems associated with straw continue to work against its competitiveness. Straw is light, yet bulky. Because of its bulkiness, handling the straw is expensive. Transportation costs for straw are quite high relative to other fuel sources. Therefore, the cost to deliver the straw fuel from the source to the point-of-use must also be considered by a potential user.

Also, straw handling and storage at the point of use can be an expensive and labor-intensive part of the processing plant. Multiple types of handling equipment and covered storage areas contribute to the expense.

Another problem with straw results from its combustion characteristics. Straw contains relatively high concentrations of potassium, sodium, and other minerals that have low melting temperatures (on the order of 1,500°F). At combustion temperatures normal for wood fuels (1,800°F to 2,000°F), the minerals soften and melt, creating a glassy slag that can cause significant problems in the combustion equipment. A straw burning facility in California reports that even though their boiler is designed to have low furnace temperatures (1,400°F), there are problems with localized hot spots on the grates of the boiler where the ash is melting, creating a number of smaller slag piles (Sprecher, 1990).

Straw's handling costs and combustion characteristics are two problems to be overcome.

Additional consideration must be given to the emissions from a straw burning facility. Combustion characteristics and residues differ for all fuels. The effects of the residues from straw fuels will need to be analyzed and accounted for by potential users.

Straw Fuel Characteristics

Chemical Analysis

Basic characteristics of fuels are typically given by a proximate and ultimate analysis. These analyses can be given on a dry basis or as-received (wet) basis. Wood fuels are typically 50 percent moisture, whereas straw is typically 15 percent moisture. These analyses can be compared for existing and proposed fuels to assist in predicting available energy, burning characteristics, and potential combustion problems.

Table 8-2 shows the results of these analyses for two typical wood fuels as well as for a typical grass straw.

This table serves as a basic chemical comparison for wood and grass straw. It does not include the specific varieties of grasses found in the Willamette Valley, such as ryegrasses and fescues. A detailed chemical analysis of any straws considered for large-scale fuel use would be necessary to aid in the design and operation of appropriate combustion equipment.

Table 8-2
Typical Fuel Characteristics

Analyses	Western Hemlock[1](%)	Douglas Fir (%)	Bluegrass Straw[2] (%)
Proximate Analysis (Dry Basis)			
Volatile Matter	74.3	73.0	72
Fixed Carbon	24.0	25.8	21
Ash	1.7	1.2	7
Total	100	100	100
Ultimate Analysis (Dry Basis)			
Carbon	51.2	53.0	46.8
Hydrogen	5.8	6.2	6.0
Oxygen	39.2	39.3	37.6
Nitrogen	0.1	0.0	2.3
Sulphur	0.0	0.0	0.3
Ash	3.7	1.5	7.0
Total	100	100	100
Heating Value (Dry, Btu/lb)	8,500	9,200	7,500

[1] Source: Junge, 1975
[2] Source: Fiber Fuels Institute, 1984

Energy Comparison

Using the combustion characteristics of a generic hog fuel and straw fuel, a comparison can be made. This comparison provides an estimate of the cost of straw fuel required to compete with hog fuel on an equivalent energy basis (see Table 8-3 and Figure 8-1). The cost of energy ($/MMBtu) is evenly incremented in the first column of Table 8-3. The second, third, and fourth columns show the required cost of hog fuel, straw fuel, and natural gas, respectively, to provide energy at the corresponding cost listed in the first column.

The cost of natural gas for industry has historically ranged between $0.20 per therm to $0.40 per therm. The cost of hog fuel varies considerably, ranging from negative values (paying to have it hauled away) to upwards of $60 per unit.

Example: In Table 8-3, if we assume hog fuel costs $43/unit (second column), the equivalent cost per unit of energy is $2.50/MMBtu (first column). Thus, straw must be available at about $32/ton or less (third column) and natural gas must be available at $25/100 therms ($0.25/therm) or less (fourth column) to compete favorably with hog fuel.

Table 8-3
Comparison of Boiler Fuels

Energy Cost ($/MMBtu)	Hog Fuel ($/Unit)	Straw Fuel ($/ton)	Nat. Gas ($/100 therm)
0.50	8.60	6.38	5.00
1.00	17.20	12.75	10.00
1.50	25.80	19.13	15.00
2.00	34.40	25.50	20.00
2.50	43.00	31.88	25.00
3.00	51.60	38.25	30.00
3.50	60.20	44.63	35.00
4.00	68.80	51.00	40.00
4.50	77.40	57.38	45.00
5.00	86.00	63.75	50.00
5.50	94.60	70.13	55.00
6.00	103.20	76.50	60.00
6.50	111.80	82.88	65.00
7.00	120.40	89.25	70.00
7.50	129.00	95.63	75.00
8.00	137.60	102.00	80.00

Assumptions	Hog Fuel	Straw Fuel	Natural Gas
Heating Value:	8,600 Btu/lb	7,500 Btu/lb	100,000Btu/therm
Moisture Content:	50 %	15 %	0%
Unit Conversion:	4000lb/unit	2000 lb/ton	--

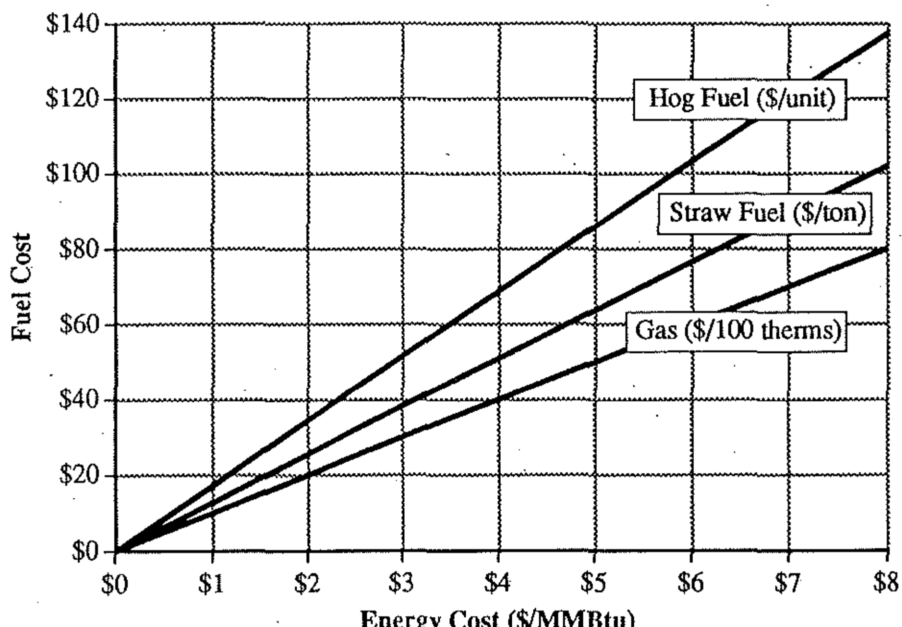

Figure 8-1
Fuel Costs Versus the Cost of Energy

Note that this comparison is only on an equivalent energy basis. The relative ease and efficiency of utilizing the energy in straw is critical for straw to compete in the fuel market. Although hog fuels are more expensive than these competing fuels, it is often produced and used at the same location or is available at a very low cost. At low hog fuel costs, the difference in costs between fuels is small (see Figure 8-1).

The current cost of natural gas ($0.25/therm for special contracts) is considerably lower than either of the other two fuels. This indicates, at least in an energy comparison, that natural gas may be the fuel of choice after hog fuel. The choice of fuels must be made in light of the existing equipment, the type of facility and the use of steam, and the relative costs of conversion to each of the alternative fuels.

Densification

Straw has been densified into pellets and cubes for use in several of the market applications. Densifying straw requires feedstock and final product storage, an important economic consideration.

Straw Pellets

Densification, such as in pellets or cubes, makes straw a more suitable, but expensive fuel.

Grass seed screenings have traditionally been pelletized for use as animal feed. The same pelletizing process has been used to produce a straw fuel pellet. The fuel pellet can then be burned in residential, commercial, or industrial combustion equipment designed to handle solid fuel.

A typical pellet production line requires approximately 500 hp to grind, pelletize, and handle the materials. Pellet production currently costs about $35/ton, not including raw materials and storage costs or profit (Venell Farms, 1990). Table 8-4 includes storage costs to estimate the production costs of pellets.

The estimates in Table 8-4 assume production of 2 tons per hour, labor costs for two people at $10 per hour and one person at $15 per hour, maintenance costs of $10 per ton (Venell Farms, 1990), energy consumption of 150 kWh per ton (Miles, Jr., 1985) at a cost of $0.05 per kWh. The ranges shown indicate a variance of plus or minus about 10 percent to allow for equipment and operation differences.

Table 8-4
Estimated Costs of Pellet Production

Input	Cost Range ($/ton of straw)
Labor	16.00 - 20.00
Maintenance	9.00 - 11.00
Energy Costs	7.00 - 9.00
Storage	6.00 - 8.00
Total	38.00 - 48.00

This cost range for straw corresponds to a range of $51 to $65 per unit of hog fuel (Table 8-3). The above costs do not include any transportation of the fuel.

Based on the average of the above estimates of pellet production, the operating costs of a representative plant were estimated (Table 8-5). The plant would produce 13,000 tons of pellets per year (264 days), operating three shifts per day. There are no packaging costs included based on the assumption that the pellets would be bought on a bulk basis.

Table 8-5
Estimated Annual Operating Costs of a Pellet Plant

Input	Cost $
Labor	222,000
Maintenance & Parts	127,000
Energy Costs	95,000
Storage	89,000
S.L. Depreciation ($200,000, 7 year)	29,000
Overhead	44,000
Total	606,000

By varying the cost of straw as an input into this operation, the resulting production costs can be compared (Table 8-6).

Table 8-6
Effect of Straw Cost on Pelleting Costs

Straw Cost ($/ton)	Operating Cost ($/yr)	Production Cost ($/ton)	($/MMBtu)
0	620,000	48	3.36
10	750,000	58	4.00
20	880,000	68	4.80
30	1,010,000	78	5.50
40	1,140,000	88	6.20
50	1,270,000	98	6.90
60	1,400,000	108	7.60

The pellet production costs (Table 8-6) correspond to hog fuel costs of $60 to $130 per unit (Table 8-3). However, these projections do not include transportation costs to the point of use, which can be significant.

Table 8-6 can be used to make a preliminary economic evaluation of the use of straw pellets as a fuel. For example, using straw at $30 per ton results in a production cost of energy of $5.50 per MMBtu. This dollar value is comparable to paying about $95 per unit of hog fuel or $55 per 100 therms ($0.55 per therm), both of which are much higher than the current market value for these fuels.

Some grass straws are easier to pelletize than others. Perennial ryegrass and bentgrass are difficult to pelletize while tall fescue and annual ryegrass pelletize quite well (Venell Farms, 1990). Annual ryegrass is not usually pelletized because most is either burned or plowed back into the soil.

A number of tests of pellet fuels and stoves were performed in the last two decades through the Oregon Field Burning Committee and the Oregon DEQ (Miles, Jr., 1985). The burn tests resulted in slagging problems as well as increased dust emissions. These problems were reduced by burning pellets that were blended with up to 50 percent wood (Miles, Jr., 1985). Slagging can also be reduced by adding 2 percent kaolin or 6 percent talc (Miles, Jr., 1985). However, the use of blends of materials and additives will increase the cost of production, which must be offset by an increase in performance. As with straw cubes, as the price of hog fuel climbs, the use of straw pellets as a supplement in existing hog fuel boilers may increase.

More research is needed in specific boiler/furnace and fuel handling configurations.

It is clear that straw fuel pellets can be produced, albeit at a significant cost. Additional work needs to be done in the use and marketing of the product. Market development requires consistent performance of pellet burning equipment, justified by long-term testing and documentation. Commercial/industrial applications represent an attractive market in that fewer customers are needed for a given supply of pellets, and the straw would need less processing because it would be sold in larger volumes (Traeger Industries, 1990). However, potential commercial/industrial users of straw fuels need to know how straw pellets perform in different boiler/furnace and fuel handling configurations, and there are no long-term data available to show this.

Previous research indicates that capacity exists for pelletizing approximately 20,000 tons of straw per year in Oregon (Miles, Jr., 1985). Even at full capacity, the straw pellet market would only consume a small portion of the available straw.

Straw Cubes

Straw can be chopped and formed into cubes or briquettes. This densified form of straw is potentially advantageous to several straw markets (e.g., feed and fuel). As a fuel, the straw cube may be burned in residential, commercial, or industrial combustion equipment.

Straw cubes are physically more similar to hog fuel than unprocessed straw and therefore may more easily be introduced into an existing fuel feed system as a supplement to hog fuel. Recent tests burning straw cubes in a hog fuel boiler were positive, with no apparent slagging problems on the grates or tube banks (Schamel, 1990). However, the straw was mixed at 25 percent with hog fuel and the tests were limited to only 2 days. This is not enough time to judge potential long-term effects.

The straw is typically chopped, mixed with a binder, and extruded through a die to form the cubes. Using labor and machinery cost estimates from a cuber manufacturer (Warren & Baerg Mfg., Inc., 1990), the costs were estimated for production of straw cubes (Table 8-7).

The estimates in Table 8-7 assume production of 4 tons per hour, labor costs for six people at $10 per hour, maintenance costs of $5 per ton, and energy consumption of 110 kWh per ton at a cost of $0.05 per kWh. The ranges shown indicate a variance of plus or minus about 10 percent to allow for equipment and operation differences.

Table 8-7
Estimated Costs of Straw Cube Production

Input	Cost Range ($/ton of straw)
Non-Straw Materials	3.00 - 5.00
Labor	13.00 - 17.00
Maintenance Costs	4.00 - 6.00
Energy Costs	4.00 - 6.00
Storage	6.00 - 8.00
Total	30.00 - 42.00

This cost range corresponds to a range of about $43 to $56 per unit of hog fuel (Table 8-3). However, the above costs do not include a cost for straw or any transportation of the fuel.

Based on the average of the above estimates of straw cube production, the operating costs of a representative plant were estimated (Table 8-8). The plant would produce 14,000 tons of straw cubes per year (264 days), operating two shifts per day. There are no packaging costs included with the assumption that the cubes would be bought on a bulk basis.

Table 8-8
Estimated Annual Operating Costs of Cubing

Input	Cost $
Non-Straw Materials	63,000
Labor	238,000
Maintenance & Parts	79,000
Energy Costs	84,000
Storage	111,000
S.L. Depreciation ($500,000, 7 year)	71,000
Overhead	30,000
Total	676,000

By varying the cost of straw as an input into this operation, the costs can be compared (Table 8-9).

Table 8-9
Effect of Straw Cost on Cubing Costs

Straw Cost ($/ton)	Operating Cost ($/yr)	Production Costs ($/ton)	($/MMBtu)
0	676,000	48	3.40
10	834,000	60	4.20
20	993,000	71	5.00
30	1,151,000	82	5.80
40	1,310,000	94	6.60
50	1,468,000	105	7.40
60	1,626,000	116	8.20

These straw cube production costs correspond to hog fuel costs of $58 to $141 per unit (see Table 8-3). However, these projections do not include cube transportation costs to the point of use, which can be significant.

Table 8-9 can be used to make a preliminary economic evaluation of the use of straw cubes as a fuel. For example, using straw at $30 per ton results in a production cost of energy of $5.80 per MMBtu. This dollar value is comparable to paying about $100 per unit of hog fuel or $58 per 100 therms ($0.58 per therm), both of which are much higher than the current market value for these fuels.

Again, the technical feasibility of producing straw cubes is not in question; the problem is to establish the market for them. If hog fuel prices continue to climb, the use of straw cubes as a supplement in existing hog fuel boilers may increase. If the fuels market was able to accept straw cubes as a viable alternative, additional, documented, in-the-field testing may be required.

Quality

Fuel quality must be consistent.

An important consideration of straw fuels is establishing and maintaining fuel quality. Many factors can influence the quality of the fuel: land preparation (e.g., fertilization, weed and pest control), straw removal practices (e.g., inclusion of dirt into the straw), and degradation of the fuel during storage. Whether straw is mixed with other fuels or used alone, the final fuel quality should be consistent with the design and operation of the combustion equipment.

Combustion Technology

The application determines which technology is used for combusting straw fuels. Straw firelogs can be burned in traditional residential woodstoves and fireplaces. Straw pellets can be burned in specialized pellet stoves or in industrial furnaces. Mass burning of straw or straw bales requires combustion equipment designed specifically to accommodate this fuel.

Industrial Technology

There are several applicable equipment types used in combustion on a large-scale basis: grate boilers, suspension burners, and fluidized bed combustors.

Grate Boilers

The floor of biomass-burning furnaces is typically a grate. The grate will have many small holes to allow for introduction of primary (underfire) combustion air to the fuel pile. Combustion air is also distributed above the pile. Some grates are constructed with adjustable slots that allow for control of the amount of combustion air. This feature enables a single grate to burn fuels of various moisture levels. In addition, some grates are water-cooled to minimize corrosion.

Less moisture in the fuel means less excess air is required to maintain combustion. The efficiency of the boiler system improves as the amount of excess air decreases. Wood-fired boilers typically operate at 40 percent to 50 percent excess air. Straw fuels, with their low moisture content, should require a relatively lower percentage of excess air, and hence provide better efficiencies.

After combustion, residue from the fuel is left as ash, which must be removed from the grate. Ash is typically removed manually in smaller boilers, and automatically and continuously in larger, more complex boilers.

Fuel can be spread on the grate by several means (Vranizan et al., 1987):

- Top chute entry: used with coarse, wet fuel
- Spreader stoker: used with wet fuel of uniform size and a minimum amount of fines, often air swept
- Side screw stoker: used with finer-size wet fuel
- Sloping grate: used with a variety of fuels, including municipal solid waste (MSW)

Some of the basic types of boiler stoker combinations include chain-grate stokers, traveling-grate stokers, water-cooled vibrating grate stokers, and reciprocating-grate stokers.

The walls and roof of the furnace are usually built of a refractory or consist of boiler water tubes (often called a water wall). Traditionally, the refractory material has been fire bricks, but today the refractory is usually poured-in-place with castable refractory or is rammed into place using plastic refractory (Vranizan et al., 1987). Cold, wet fuels burn best in furnaces with a large capacity for holding heat (i.e., contain a large amount of refractory). Evaporation of moisture from the fuel is accomplished by radiant heat from the furnace and by the hot combustion gases.

Water wall furnaces are used with dry fuels. The walls and roof are lined with tubes that are either welded together (a membrane wall) or simply situated side-by-side (a tangent wall). The water in the tubes is constantly being heated by the combustion process, primarily by radiant heat from combustion.

Suspension Burners

These types of burners are used for dry fuels of small size and are usually combined with a heat recovery boiler or dryer. The name comes from the fact the combustion of the fuels occurs while the fuel is in suspension; there is no fuel pile and no grate. Sander dust, planer shavings, ground peach pits, and ground straw are examples of candidate fuels for suspension burners. Burners of this type can be divided into at least the following two categories (Vranizan et al., 1987):

- Air/fuel mixing and igniting
- Air/fuel mixing, igniting, and fully combusting

The two burner types are very similar; the only difference is that the first type does not have a furnace. With air/fuel mixing and igniting, the combustion process is completed not in a furnace but in the boiler or heat transfer space. In this type of burner, the combustion of biomass takes a long time to complete. Retention times can be as high as 10 seconds. As a consequence, only very fine fuels are burned in this type of system and relatively large combustion chambers are required (Vranizan et al., 1987).

The second type includes a furnace and typically uses a cyclonic air flow within the furnace to increase the retention time of the fuel. The fuel particles are completely burned before they leave the furnace.

Fluidized-Bed Combustors

There are various types of fluidized bed combustors, including fixed bed, bubbling bed (with or without in-bed tubes), and circulating fluidized bed (with or without an external heat exchanger). Fluidized bed combustors can be operated at atmospheric or elevated pressures.

The bed of a bubbling bed combustor in normal operation resembles the surface of a pot of boiling water. The bed consists of the biomass fuel and a noncombustible or inert material such as silica, sand, alumina, limestone, or ash. This type of system will burn very wet and dirty fuels, but they must first be ground into small particles. Circulating beds have a less confined bed zone, and much of the material is circulated away and returned to the bed.

In the fluidized-bed, the hot sand scrubs past particles of biomass and vice versa, heating the biomass and very effectively wiping away the products of gasification and combustion (Vranizan et al., 1987).

High pressure combustion air forces the bed into turbulence via a large forced-draft fan. The flow of combustion air increases as the demand on the burner increases. As the air flow increases, so does the amount of sand, ash, and carbon that is carried over into the hot gas stream. As a result, there is a limit to the turndown ratio (maximum output/minimum output) of this type of system. The turndown ratio for fluidized-bed combustors is only about 2:1, whereas for most well-designed biomass combustion systems it can be as high as 5:1 (Vranizan et al, 1987).

Combustion temperatures can be held relatively low, preventing the formation of oxides of nitrogen (Vranizan et al., 1987). The lower temperatures could be an advantage when burning fuels such as straw that have the tendency to slag at high combustion temperatures.

A special consideration for using fluidized-bed combustors is the need to monitor and control flue gas quality because of the potential for particulate in the gas stream. Some designs minimize this potential by adding a recirculation system for collecting particulate and sending it back to the bed.

Rotary Systems

A rotary kiln is typically a large refractory-lined, slightly inclined cylinder wherein the fuel is combusted and moved by the rotation of the cylinder. The rotary kiln can be coupled to a traditional heat recovery boiler for steam generation.

A rotary combustor is similar to a rotary kiln but incorporates a water wall into the cylinder instead of refractory. Fuel is fed into the elevated end of the cylinder. It is tumbled and burned as it moves through the waterwall cylinder, discharging into an integral waterwall furnace and boiler section. Rotary combustors are commonly used for mass burning of municipal and industrial wastes in waste-to-energy plants, while rotary kilns are often used to burn hazardous waste materials.

Gasifiers

Gasification is a process by which an appropriate solid or liquid hydrocarbon or organic substance is converted into a gas (Schwieger, 1979). There are three basic types of gasifiers for biomass gasification: fixed-bed, entrained-bed, and fluidized-bed. Although this process is intimately related to the production of chemicals (Chapter 9), the point of the process is actually to produce a gaseous or liquid fuel, not to generate heat directly from the combustion of straw. Often, the gasification process is linked directly to a fixed boiler or similar combustion system for immediate use of the "produced" fuel. The fuel could also be used for power generation or as an export fuel.

A more detailed discussion of gasification and the viability of incorporating straw into this process is presented in Chapter 9, Chemical Markets, of this report.

Residential Technology

Residential applications of straw fuels typically use either a traditional woodstove or fireplace for straw firelogs, a pellet burning for pellets, or small-scale whole-bale burners.

A pellet stove is much like a traditional stand-alone woodstove but has been modified to allow for the fuel feed system. The fuel feed system consists of a small hopper that drops the pellets into an auger feed system. The auger regulates the flow of the pellets into the firepot, where combustion takes place. Combustion air is typically introduced via natural or forced drafts.

The use of this type of stove to burn wood fuel pellets has continued to grow, particularly in the eastern U.S. (Traeger, 1990).

Discussion of Markets

Market utilization of straw as a fuel source requires a number of important considerations. These include the capital costs associated with new construction versus those required for modifications of existing equipment. The volume of straw required and the ability to obtain this volume on a steady basis with a consistent quality must be determined. The cost, supply, and quality of alternative fuels (in terms of both a substitute and supplement for straw) must also be considered since straw will have to be burned in conjunction with other fuels to mitigate combustion problems.

Industrial Applications

Direct Process Heating Systems

One industrial application for straw fuels is burning straw in a fuel cell or some other primary combustion unit for the direct use of the heat of combustion. An example would be drying veneer with exhaust gases from a biomass-fired burner.

There are, however, several considerations for this type of use. Since the grass seed industry at large (and more specifically the farmer) has little need for "process heat," the fuel would have to be hauled to an appropriate facility, incurring a transportation cost that can be high for a fuel as bulky as straw. Additional handling considerations include on-site storage and fuel processing. Direct fire applications must be willing to accept higher ash content in the flue gases. These considerations, in addition to the slagging potential discussed earlier, are the principle hurdles for this type of application.

Straw has a higher ash content than wood fuels.

The most practical use of direct heating would be to incorporate the use of straw fuels into existing systems. Here, too, there may be combustion problems. However, the existing facilities may not be close to the source of the straw; transportation, storage, and handling costs must be considered. If straw were to be incorporated into an industrial process for some other end market (e.g., pulp, fiberboard) then the handling costs could be spread out over more than one production use and the relative cost of straw fuels may not be as restrictive.

The economics of using straw for this application depend primarily on the cost of alternative fuels, additional labor, and equipment costs and can only properly be evaluated given a specific application.

Steam Generating Plants

A second industrial/commercial application for straw fuels is in the generation of steam. Straw could be used in several forms: baled, chopped, pelletized, or cubed. The form of the fuel is dependent on the combustion equipment. Although the general considerations and problems of straw fuels apply to this use, there is some promise for straw fuel use at least as a supplementary fuel for steam generation.

One company recently purchased approximately 25 tons of straw pellets per day for several weeks to supplement its hog fuel supply (Venell Farms, 1990). The pellets were sold for less than half of the cost of production to solve a problem of contaminated feed pellet stock. By mixing the straw pellets with hog fuel (50 percent maximum), the problems of slagging are mitigated. By using a densified straw fuel, the costs of transporting, storage, and handling are minimized, but the processing costs are higher.

By mixing straw pellets with hog fuel, slagging problems are mitigated.

While this is an isolated example of industrial straw fuel use, it does indicate the feasibility of supplementing hog fuel with straw and the willingness on the part of one company to try it.

Operating costs incurred using straw fuels in an existing steam generator depends on the form of the fuel, the fuel and ash handling systems of the steam generator, and the expertise of the plant staff. Existing facilities are more likely to incorporate the use of straw fuels into their system if few modifications are necessary to their operation and equipment.

If extensive modifications are necessary to accommodate the use of straw fuels, conversion to natural gas may very well be considered, because it is a less expensive source of energy (Table 8-3). However, natural gas must be available close to the boiler. If not, and if the local gas utility will not install the required piping, there will be additional costs associated with installing and connecting to a gas pipeline.

Under the current conditions of high hog fuel prices and with the expectations of this trend continuing, and with the affordable cost of natural gas, some hog fuel-fired steam plants are now considering changing their boilers over to natural gas (McHugh, 1990).

Dedicated Power Production Plants

Several agricultural waste-fired powerplants operate in the western United States.

In this application, straw would serve as the sole or primary fuel in the production of electrical power. This type of plant uses a high-pressure boiler to produce steam that drives a condensing turbine-generator set. At present, there are no straw-fired powerplants in the state of Oregon. However, several agricultural waste-fired powerplants operate in the western United States.

One facility in California burns approximately 600 tons of rice hulls and straw per day in a 29-megawatt (MW) dedicated powerplant (Black et al., 1989). The plant is under a long-term contract to sell electricity to the local utility.

Particular attention was required for the fuel firing, ash handling, and heat recovery systems as a result of the abrasive nature of the rice straw and hulls. Strict emissions limits were included as part of the air permit. The two-pass, water-wall furnace uses suspension-fired burners to fire the rice hulls. Natural gas is used as a startup and partial backup fuel. The $54 million cost of the plant resulted in a capital cost of approximately $2,000 per kilowatt (Black et al., 1989).

Another straw/wood burning powerplant in California has been operating since February 1990 but not without problems (Sprecher, 1990). The 15-MW plant was designed to burn 100,000 tons per year of straw (wheat straw from racetrack stables, alfalfa, and Bermuda grass straw) and wood waste in mix of 80 percent straw and 20 percent wood. They have only succeeded in burning a 50/50 mix in the unit. Straw fuel conditions have varied considerably, often arriving at the plant with a significant amount of dirt in the bales. As a result, the boiler is difficult to control.

The basic plant design is a derivative of the other plant discussed above, but this plant uses a traveling grate stoker to fire the fuel. Although the furnace was designed for a temperature of 1,400°F, slagging has occurred, particularly in localized hot spots on the grates as a result of uneven temperature profiles across the grate. The grates are not water-cooled but may be changed over to try to control the slagging. The $65 million cost of the plant resulted in a capital cost of approximately $4,500 per kilowatt (Sprecher, 1990).

It is notable that both plants have experienced difficulty in fuel handling and processing. Additional funding for equipment improvements is being considered to relieve greater-than-anticipated labor costs (staff levels) now required to keep fuel handling equipment operating continuously.

Three other plants (two 12 MW and one 25 MW) in California are using fluidized-bed combustors (atmospheric bubbling beds) to burn a variety of biomass, including rice straw, wheat straw, almond tree prunings and shells, and cotton trash. These plants, too, have fuel handling problems.

All dedicated powerplants must provide a secure fuel supply to satisfy power contracts and investors. Many plants utilize fuel "brokers" to ensure an adequate supply of fuel is provided year-round.

Fuel brokers help ensure an adequate and reliable supply.

Preliminary thermodynamic and economic analyses of a dedicated 20-MW powerplant were done and are included in Appendix D. Two cases were examined: Case 1 used low-end performance and high-end cost data; Case 2 used high-end performance and low-end cost data. This was done to develop some practical limits on the operating costs of this plant. Case 1 represents high operating costs, and Case 2 represents low costs. For each case, a 50/50 mix of straw and hog fuel was used at a cost of $35 per unit. Predicted straw consumption for this 20-MW powerplant ranges from 124,000 tons per year to about 168,000 tons per year. The cost of straw as an input to the process was varied to show the variation in unit production costs of electrical energy (Tables 8-10 and 8-11).

Table 8-10
Case 1 Unit Energy Cost Variation

Straw Cost ($/ton)	Operating Cost ($/yr)	Production Cost ($/kWh)
0	7,449,000	0.052
10	9,134,000	0.064
20	10,819,000	0.076
30	12,504,000	0.088
40	14,189,000	0.100
50	15,874,000	0.112
60	17,559,000	0.124

Table 8-11
Case 2 Unit Energy Cost Variation

Straw Cost ($/ton)	Operating Cost ($/yr)	Production Cost ($/kWh)
0	3,970,000	0.028
10	5,210,000	0.037
20	6,450,000	0.045
30	7,690,000	0.054
40	8,930,000	0.063
50	10,170,000	0.072
60	11,410,000	0.080

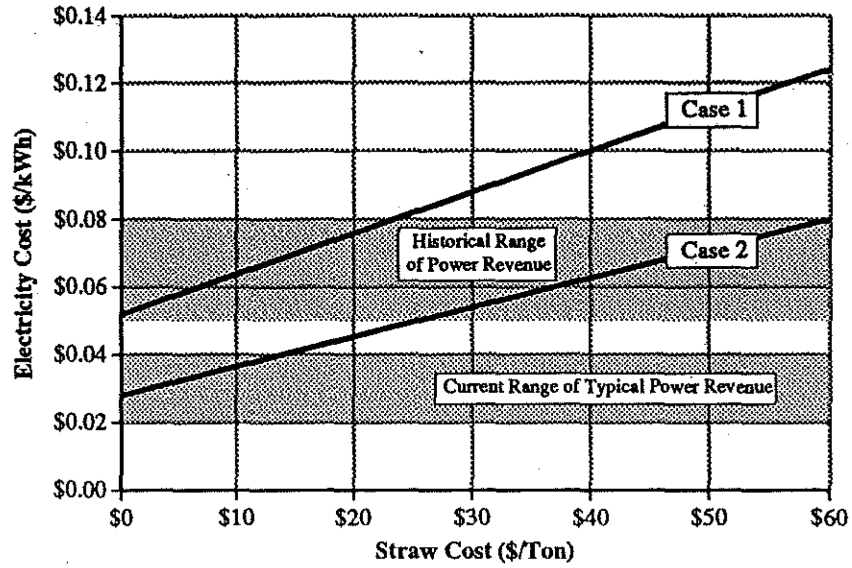

Figure 8-2
Required Power Sales Revenue Versus Straw Cost

Figure 8-2 graphically shows the results of these two cases.As an example, consider that straw is available at the plant for $30 per ton. Just to break even, this plant must be able to sell energy for at least $0.048 per kWh and possibly as high as $0.080 per kWh, depending on its performance.

As a second example, assume that a power sales contract was signed for $0.040 per kWh. The plant, operating under the constraints of Case 2, could support straw costs up to about $20 per ton. Under the constraints of Case 1, the plant could not support any straw costs.

Also shown on Figure 8-2 are two ranges of power sales revenue. The lower range, $0.02 to $0.04 per kWh represents approximate power revenue associated with recent northwest power sales contracts, during times of surplus power. The higher range ($0.05 to $0.08 per kWh) shows approximate power revenue from northwest power sales contracts of 10 to 20 years ago, during times of anticipated power shortages. It is reasonable to expect that given the recent trends in the northwest power supply, the value of generated power may begin to climb back up towards the higher range.

Cogeneration Systems

Cogeneration is the simultaneous generation and use of electricity (or mechanical power) and thermal energy from a single fuel source. The economics of cogeneration are linked directly to the thermal and electric demands of a given power user as well as to the existing fuels currently used to meet those demands. As a result, cogeneration analysis is typically done on the basis of a specific application. The use of straw for cogeneration would likely occur only in an existing facility. While there are currently no cogeneration plants burning straw in Oregon, the same opportunities exist for straw fuel supplements as discussed with respect to steam generation.

Residential Applications

Firelogs

Straw can be used as the source material for production of firelogs and be a product that may compete with wood-based "Presto-logs" and other fireplace or woodstove material in the residential fuel market. Research continues in this area to refine the process of compressing, binding, and combusting straw logs.

It is difficult to produce a straw-only firelog of adequate density.

Straw firelogs are typically produced by running 100-pound bales of straw through a hammermill or chopper to break down the straw into pieces less than 1 inch long. Straw and additional ingredients are metered together, creating a mixture that is then extruded, usually in a piston-type press, to produce a log. Additional ingredients typically include a binder of some kind; chemicals as well as other biomass (paper, wood) have been used as binder for straw.

One difficulty in manufacturing straw firelogs is producing a log of the proper density. High density logs are difficult to burn while low density logs burn well but are difficult to restart (Miles, Jr., 1985). Another problem with burning straw in a residential application is the pungent odor that results (Irwin, 1986).

Both of these problems can be minimized by producing the logs with a mixture of straw and wood. The burning characteristics of the log improve and the odor from burning is dominated by the wood (Irwin, 1986).

Recent testing of combustion in a normal residential woodstove of 10-inch-long, 3-inch diameter firelogs consisting of straw mixed with small amounts of a byproduct from the paper industry resulted in no problem with odor (Miller, 1990). While these results indicate that the odor problem may be solved, the fact remains that odor is a potential problem and can certainly be an important factor in the marketability of the straw log.

The estimates in Table 8-12 assume production of 1.6 tons per hour, one shift per day (7 hours of machine time), 3 pounds per log, 10 percent waste, labor costs for two people at $8 per hour, and maintenance and energy costs of $36 per ton. The ranges shown indicate a variance of plus or minus about 10 percent to allow for equipment and operation differences.

Table 8-12
Estimated Costs of Straw Log Production

Input	Cost Range ($/ton of straw)
Non-Straw Materials	17.00 - 20.00
Labor	10.00 - 13.00
Packaging	8.00 - 10.00
Starter Material	32.00 - 40.00
Machinery O&M and Energy Costs	32.00 - 40.00
Storage	6.00 - 8.00
Total	105.00 - 131.00

Based on the average of the above estimates of straw log production, the operating costs of a representative plant were estimated (Table 8-13). The plant produces 2,700 tons of straw logs per year (264 days), operating one shift per day.

Table 8-13
Estimated Annual Operating Costs of Straw Log Production

Input	Cost $
Raw Straw Processing ($10/ton)	30,000
Non-Straw materials	55,000
Labor	34,000
Packaging	27,000
Starter Material	108,000
O&M, Energy Costs	108,000
Storage	21,000
S.L. Depreciation ($150,000, 7 year)	21,000
Overhead	22,000
Total	426,000

By varying the cost of straw as an input into this operation, the costs can be compared (Table 8-14).

A recent survey of retail prices of five varieties of wood-based firelogs yielded costs per million Btu (MMBtu) ranging from about $7 to $29. Based on these production cost estimates, straw firelogs can be competitive in the market.

The technical feasibility of producing straw logs is not an issue. The biggest hurdle is the development of a straw log market. The product has to be accepted by the public as a wanted commodity. A market test of straw firelogs is to be conducted in January 1991 in the Willamette Valley. The test is to help determine if the public will support this product (in terms of cost and volume) enough to justify a business.

Table 8-14
Effect of Straw Cost on Firelog Costs

Straw Cost ($/ton)	Operating Cost ($/yr)	Production Cost ($/log)	($/MMBtu)
0	426,000	0.26	11.70
10	456,000	0.28	12.50
20	486,000	0.30	13.30
30	516,000	0.32	14.20
40	546,000	0.34	15.00
50	576,000	0.36	15.80
60	606,000	0.37	16.60

Even if straw logs gain a foothold in the Oregon firelog market, their production will not consume a large amount of straw because this market is small and specialized. The non-wax firelog market (in which straw logs will compete) has been estimated at 12,000 to 15,000 tons per year (Irwin, 1986).

The Department of Environmental Quality currently has no restrictions on burning of various types of fuel in wood stoves. Several areas in Oregon (e.g., Medford, Klamath Falls) are affected every winter as the smoke from residential woodstoves lingers close to the ground for long periods of time. One advantage of firelogs is that their moisture content is low, ranging from 8 percent to 14 percent, which allows for a cleaner burn than improperly cured firewood.

However, should an aggressive approach in cultivating the straw firelog market be successful in significantly expanding the market, a potential consideration would be the concentration of new and different emissions from fireplaces and woodstoves within communities.

Pellet Stoves

While the use of pellet stoves to burn wood pellets has increased in the last few years, there are still technical problems associated with the use of straw pellets. Slag and ash problems, as well as smouldering of the straw must still be managed. Combination wood and straw pellets burn well, mitigating the slagging and smouldering potential (Miles, Jr., 1985).

The commercial development of straw-burning pellet stoves has not yet been established but research and testing continues, primarily on an individual basis. Although the economics for wood pellet stoves continue to improve, straw pellets must first overcome their technical problems and then gain acceptance by the market before this market can substantially contribute to straw utilization in western Oregon.

Bale Burners

Newer models of bale burners have significantly reduced emissions.

One method of utilizing straw as fuel would burn the straw as a whole bale in a boiler. This type of system offers the advantage of the least amount of straw processing, thereby minimizing fuel costs. This technology has been developed primarily in the United Kingdom, with considerable improvement in the last 10 years. The systems are small (up to about 30 hp), designed primarily for on-farm or residential applications, and are typically fired on a batch basis although automatic feed systems have been utilized. Most of these systems can also be used to efficiently incinerate wood, paper, cardboard, and other combustibles generated on the farm.Typical on-farm uses include the following:

- General space heating
- Grain dryers
- Greenhouses
- Calf rearing units
- Milking parlors

The modern systems can burn three or more standard bales, or even a big square (Heston type) bale (Teisen, 1990). Most of the systems are of the water jacket design, and use both primary and secondary air systems to control temperature and maximize combustion. Typical efficiencies have improved from about 35 percent to about 65 percent (Teisen, 1990). While smoke emissions were a significant problem with earlier versions of this technology, the newer models are designed to minimize this problem.

Considerations for this type of furnace should include the additional labor of stoking the system (at least twice per day) as well as the advantages of using the straw on-farm or for other markets. In addition, the boilers need regular cleaning out of the combustion residue; once per week on the larger boilers, and once every 2 weeks for the smaller units.

The economics of using one of these burners depend on the costs of alternative fuel(s), additional labor, and equipment costs and can only properly be evaluated given a specific application. Capital costs for these systems range from about $8,000 to $30,000 (Freely, 1987).

Although this type of system may be cost effective in some applications, even a large number in operation would not consume a significant amount of straw.

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9 Chemical Markets

Introduction

The idea of using biomass as a raw material for chemical production is not new to the Northwest. Several chemicals can be obtained from biomass: alcohol, ethanol, hydrogen, methane, furfural, high grade carbon, oils, glucose, xylose, complex sugars, gypsum, ammonia, and acetic acid among others. Although these chemicals are readily available and often marketed, the most common chemicals produced from biomass are ethanol, methane, and oil compounds.

Programs have been in effect for the last 20 years to investigate, pilot, and develop processes that will deliver liquid and gaseous fuels from agricultural and forestry waste. Also included in these studies has been municipal solid waste, which is an abundant resource of a nonagricultural material (U.S. Department of Energy, 1988).

Chemical conversion can produce marketable fuel and coproducts, but the economics are uncertain.

In the Northwest, the Bonneville Power Administration (BPA), under the U.S. Department of Energy (DOE), has led the effort to identify and quantify resources and opportunities for biomass conversion to fuels and other energy sources. Other organizations across the country (e.g., Western Area Power Administration, Tennessee Valley Authority) have also been active in similar efforts, and in fact many of these other regions have begun to demonstrate biomass energy conversion technology.

The conversion of grass straw to a fuel product has not seen rapid support in these organizations, primarily due to the abundance of other materials and the lack of experience in dealing with straw as a resource. Forest and forest products residues are the most common resource presented in the BPA studies, along with agricultural residues (e.g., corn, barley, wheat residue, orchard prunings, vegetable crop residues) and municipal solid waste.

The technology for straw discussed in this chapter is the least likely to pass the test of being commercially demonstrated in the next few years. Therefore, the following information serves to document what will be available in the future, especially if interested firms are willing to develop infant technologies into commercial concerns for straw use.

Current Situation and Trends

The demand for chemicals in the Northwest is not a strong factor for establishing chemical conversion markets. Also, the Northwest is not a major producer of fuels and hence does not attract the chemical conversion market in that sense.

Specific chemical markets for Washington and Oregon can be classified per Standard Industrial Classification (SIC) codes. One such applicable group, Chemicals and Allied Products (Group 28), is shown in Appendix E.

Most of the Oregon industries related to chemical production or use are small, with 111 firms averaging 18 employees per firm. Washington shows somewhat stronger industries, with 139 firms averaging 45 employees per firm. However, this does not represent a strong demand for chemical production, and in fact, most of the chemicals used in these industries are imported from other states.

There is very little oil or gas production in Oregon or Washington, especially oil production. An excellent transportation system provides fuels to the Northwest at reasonable costs; if fuels were produced in the Northwest, they would have to compete with national pricing structures.

Currently, fuel oil averages $1.40/gallon, alcohol averages $1.00/gallon, ethanol averages $1.25/gallon, and natural gas averages $0.60/therm (although lower rates are possible with special purchase agreements). Straw produced fuels must compete with these prices to be marketable.

The conversion processes presented in this chapter can produce coproducts along with fuels that are marketable. However, it has not been demonstrated by research or pilot plant work that these coproducts would sustain a strong enough market price to reliably support the economics from fuel sales with a particular process.

Chemical Conversion Technologies

Straw can be converted three ways: pyrolysis, gasification, and hydrolysis.

A typical pattern for development of chemical processes in this market area consists of the following steps: 1) develop the theoretical process variables and requirements, often using laboratory research, 2) construct a pilot plant to test the theory and establish operating parameters, and 3) invest in a full-scale production plant. With some exceptions, the technology presented in this section is approaching the pilot plant level, especially regarding the use of straw. Many firms estimate that 3 to 5 years will be needed to reach commercial operation after completion of the pilot plant work.

There are three principles that can be applied to convert straw into fuels: pyrolysis, gasification, and hydrolysis. Pyrolysis produces gases, oils, and char in an atmosphere containing less than 20 percent theoretical combustion air. Gasification produces the same products, but in 20 to 50 percent theoretical air and char is usually consumed (Schweiger, 1979). Hydrolysis chemically converts cellulosic materials to glucose and xylose compounds, which is usually followed by a fermentation step to convert these compounds to alcohol or ethanol.

In the real world, technologies are combined to create specific processes. The following sections discuss such combinations of technologies, using the principles mentioned above.

Hydrolysis/Fermentation

One type of fuel production involves hydrolysis and fermentation, processing straw into ethanol and useful coproducts. Three methods of hydrolysis include enzymatic, dilute acid, and concentrated acid techniques. The first method can be a very efficient (as high as 98 percent) conversion process using specially selected enzymes; however, long processing periods (24 hours) and high initial costs have combined to limit the success of this approach.

The second method (dilute acid) has lower conversion efficiency (55 to 65 percent), faster reaction times (10 to 60 seconds), lower operating costs, and is considered more feasible than enzyme hydrolysis. The third method (concentrated acid) has acceptable reaction times (2 hours), very high conversion rates (as high as 97 percent), and reasonable capital and operating costs (if materials such as acid are recycled via a proprietary process).

Estimates have been produced by the Tennessee Valley Authority (TVA) on dilute acid hydrolysis of waste materials to produce ethanol, which is a process that can be used with straw or any cellulosic material.

The dilute acid process begins by mixing waste derived fuels (WDF) with 2 percent sulfuric acid and steam (heating the mixture to 160°C), which causes the cellulose and hemicellulose to convert to glucose and xylose. Liquids are separated and sent to a stripping column where furfural is recovered, and the solids are used as boiler fuel.

After stripping, the liquid is sent to a neutralization tank and mixed with lime. Solids are separated out as gypsum, and the liquid is sent to a fermentation vessel, where the glucose and xylose is converted to ethanol. Solids (stillage) are removed and water is removed from the ethanol in a dehydration column.

A mass balance for the process, based upon one ton of WDF, shows the following (Barrier et al., 1990):

Inputs:	
WDF	2,000 pounds
Acid	80 pounds
Lime	60 pounds
Water	3,000 pounds
Outputs:	
Boiler Fuel	3,000 pounds
Ethanol	200 pounds
Furfural	32 pounds
Gypsum	300 pounds
CO_2	190 pounds

The inputs represent the ideal combination of materials (no wastage), and the outputs also reflect some 1,500 pounds of water recycled plus about 70 pounds of solids (stillage).

On the basis of this mass balance, ethanol production is 10 percent efficient as based upon the input material (WDF).

Energy used (per ton of WDF) in the process is estimated as follows:

Inputs:	
Hydrolysis	1.26 mmBtuh
Stripping	.60 mmBtuh
Distillation	.59 mmBtuh
Total Inputs	2.45 mmBtuh
Outputs:	
Solids combustion	12.8 mmBtuh

Thus, the process is self-sufficient in energy terms, provided uncontrolled losses are reduced or eliminated.

Costs for a dilute acid system have been estimated for this process (Figure 9-1), assuming a 500 ton/day pilot plant capacity, as follows (Barrier et al., 1990):

Equipment	$14.6 million (50% of capital)
Controls	$1.15 million (4%)
Piping	$2.48 million (10%)
Electrical	$0.67 million (2%)
Buildings	$2.6 million (10%)
Land & Improvements	$1.2 million (4%)
Service Facilities	$5.3 million (20%)
Total Capital Costs	$28.0 million
Engineering, Supervision, Construction	$5.4 million (19%)
Contractor's Profit	$1.35 million (5%)
Contingency	$3.40 million (12%)
Total	$38.15 million

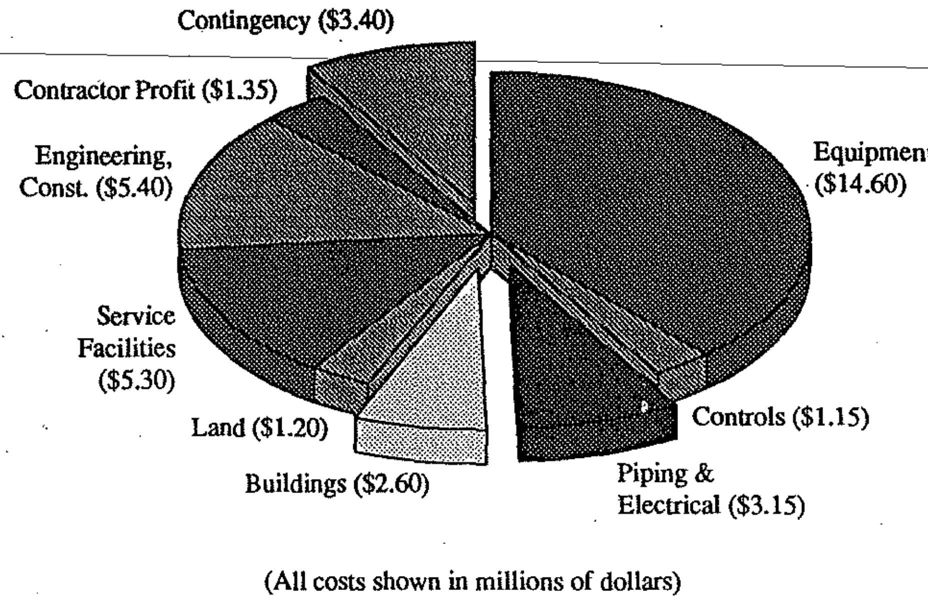

Figure 9-1
Dilute Acid Hydrolysis Project Costs

The following annual operating costs are estimated for this process:

WDF Tipping Fee	<$4.95 million> ($30/ton)
Raw Materials, Utilities, Supplies	$1.50 million
Labor	$1.70 million
Depreciation	$1.85 million (6.7% of capital)
Insurance, Taxes	$0.75 million (3.0%)
Maintenance	$1.50 million (5.5%)
Overhead	$0.85 million (3.0%)
Total Costs	$3.20 million

Assuming 330 days/year production, a 500 ton/day input of WDF that produces 50 tons/day ethanol (about 5.2 million gallons/year), then the following costs can be compared for this process:

Input Material Cost	Operating Cost	Break-even Ethanol Sales Price
Collect $30/ton	$3.20 million	$0.60/gallon
No Fee or Cost	$8.15 million	$1.50/gallon
Pay $30/ton	$13.1 million	$2.50/gallon
Pay $45/ton	$20.5 million	$3.95/gallon

The sales figures above reflect revenues from ethanol only, and do not reflect any profit. However, there are revenues available in the other products, which can approach the same revenue levels as ethanol (at $1.25/gallon):

Input Material Cost ($)	Operating Cost ($)	Coproduct Sales ($)	Break-even Ethanol sales Costs ($)
Collect $30/ton	3.20 million	none required	0.60/gallon
No Fee or Cost	8.15 million	6.0 million	0.40/gallon
Pay $30/ton	13.1 million	6.0 million	1.35/gallon
Pay $45/ton	20.5 million	6.0 million	2.75/gallon

Again, the ethanol and coproduct sales costs are shown without profit. For example, if straw costs $30/ton and coproducts (ethanol, carbon dioxide, furfural, electricity) are sold for $6 million/year, then ethanol sales cost could be $1.35/gallon (about the market price) to break even. Lower straw costs would mean lower ethanol sales costs to break even, or in fact *excess* sales costs for profit. Higher straw costs create unreasonable ($2.75/gallon) ethanol sales costs.

The following revenues are estimated by TVA for this process:

Ethanol	$6.50 million ($1.25/gallon)
Carbon Dioxide	$0.165 million ($10/ton)
Furfural	$2.60 million ($1,000/ton)
Electricity	$2.80 million ($.04/KWH)
Total	$12.05 million

TVA indicates these revenues are discounted for soft coproduct market conditions.

Information on the concentrated acid process indicates that capital costs would be similar to the figures shown above, operating costs would be similar (if acid is recycled), but production rates double that of the dilute acid process. If this production rate were possible on a sustained basis, then the output of a 500-ton pilot plant, generating 100 ton/day ethanol (10.4 million gallons/year) would look like:

Input Material Cost	Operating Cost	Break-even Ethanol Sales Price
Collect $30/ton	$3.20 million	$0.30/gallon
No Fee or Cost	$8.15 million	$0.80/gallon
Pay $30/ton	$13.1 million	$1.25/gallon
Pay $45/ton	$20.5 million	$1.97/gallon

For example, straw costs of $30/ton (without coproduct sales) would require $1.25/gallon sales cost since this process is so efficient. Sales of coproducts would then produce profit. Common straw costs also produce profit, since ethanol sales costs can drop. Higher straw costs continue to produce unreasonable ($1.97/gallon) ethanol sales costs. These figures are dependent on the claim of high yields from the process, without accompanying higher operating costs. With the sales of coproducts included in the revenues, the combination would generate healthy revenues and possible profits.

There are several firms in the Northwest attempting to establish hydrolysis plants using corn, barley, and wheat raw materials (rather than straw). They have not yet established pilot plants and will need several years to establish a commercial business.

Pyrolysis/Gasification

Another method of fuel production is use of a gasifier to produce a combustible gas. This method of conversion dates back before World War II, and perhaps as far back as 100 years. Typical gasification projects have involved wood or coal feed materials, but biomass gasification systems have recently been tested and piloted in Oregon and across the U.S.

This process involves pyrolysis, oxidation, and reduction. The process begins with a dry feed source deliberately dried to remove moisture. Following drying, the feedstock is heated in a reduced oxygen environment (pyrolysis) at temperatures of between 1,400 and 1,600°F. This process liberates gases and volatile hydrocarbons (ketones, alcohols, tars) and creates a residue substance (char) that is mostly carbon.

Following the initial release of gases and hydrocarbons, reduction (or gasification) occurs with the char and carbon dioxide present to produce hydrogen and additional hydrocarbons. Temperatures during this process can range from approximately 1,400 to 2,700°F.

The char produced is burned (oxidized) in many types of gasifier to create heat for the process (drying and pyrolysis stages). The gas produced is typically low in heating value (100 to 300 Btu/cubic foot) and has some moisture present with the gas. Some gasifiers have obtained higher Btu gas, especially those using high carbon fuels (e.g., rubber tires).

There are three general types of gasifiers: fixed-bed, entrained-flow, and fluidized bed.

Fixed-Bed Gasifiers

The simplest type of gasifier is the fixed-bed, updraft type. Fuel is fed at the top of the unit through a rotary air lock, while the gas produced is trapped inside the vessel adjacent to the fuel entry point. Air (or oxygen gas) is introduced at the bottom, and contacts the char to support oxidation and drive the pyrolysis/reduction actions. Drying and pyrolysis of the fuel stock occurs as it descends to the fuel bed and passes through the hot combustion gases. Ash is removed at the bottom of the vessel.

The tars produced with the output gases will condense as the gas cools. If, however, the hot gases are burned before cooling, the tars will also combust and contribute to the energy value of the mixture.

The other type of fixed-bed gasifier is the downdraft gasifier, which attempts to remove tars and oils from the outlet gases. Fuel is fed through a rotary valve near the top of the vessel, and drying/pyrolysis occurs as the fuel drops through the combustion gases. Air (or oxygen gas) is introduced at the lower sidewalls of the vessel using tuyeres, raising the gas temperatures and supporting oxidation. Below this zone is a region of cooler temperatures that supports reduction and helps convert tars into gases. Ash is removed below the reduction zone grate system.

Downdraft gasifiers can be used to generate fuel for internal combustion engines. Downdraft gasifiers are highly sensitive to moisture in the fuel, which must be controlled below 30 percent. Many of the biomass fuel gasifiers in use today are of the fixed-bed type.

Entrained-Flow Gasifiers

The entrained-flow gasifier is a refractory lined vessel that has pulverized feed materials introduced via a series of burners located at the bottom of the vessel. In addition to the feedstock, oxidant (air, oxygen gas) and steam are introduced as well. Steam is used not as an energy source but as a moderator to the oxidant reaction.

These units can be pressurized (up to 350 to 450 psig) or atmospheric, operating at high temperatures (1,000 to 2,700°F) that produce rapid production rates. There are both fixed-bed types and fluidized bed, atmospheric pressure and pressurized units available commercially. Most of these types of gasifiers are currently involved in the conversion of coal to fuel gas.

Fluidized-Bed Gasifiers

This type gasifier is similar in design to fluidized bed combustors. It uses a sand bed zone to support pyrolysis and drying, with reduction occurring at the char materials. Pyrolysis occurs rapidly in this type gasifier, and a greater volume of feed material can be handled than other types of gasifiers.

Fuels must be relatively dry (as with other gasifier types), but operating temperatures are low, approximately 1,400°F, which is below ash fusion temperatures for most materials. Char is removed via a cyclone separator in the exit gas stream and can be collected as an energy product.

A recent project in Oregon was configured as a 5-megawatt (MW) power generating plant, using a fluidized-bed gasifier that produces fuel gas for a 62,000-pph steam boiler. Electricity is generated via a steam turbine-generator and sold to the local utility.

Fuel feed for this particular project is designed for approximately 18,000 pph of lodgepole pine, with an average moisture content of 37.5

percent and an as-received heating value of 6,300 Btu per pound. The fuel is dried to approximately 25 percent moisture before entry into the gasifier, with fuel gas supplied from the gasifier to the wood feed dryer burners.

A firm in Arkansas markets a combination updraft gasifier/combustion system in small sizes (3 MW) for overseas energy production from rice straw. This technology originates from pilot tests run in 1982. The market for these systems is Malaysia, which takes advantage of low labor costs and abundant raw materials (rice straw).

Costs estimated for this 150-tpd process are as follows:

Capital Costs	$550,000
Operating Costs	$1.10 million (included $190,000 labor cost)
Straw Costs	$0.96 million ($18/ton)
Revenue	$2.55 million (electricity, $.10/KWH)
	$0.12 million (ash, $10/ton)

Costs for materials and revenues are shown as projected for the year 2001 (Bailey, 1990).

The development and commercial use of gasifiers for coal feed materials has been slow and dependent on high oil costs. Biomass systems will also depend on high fuel costs to encourage development in the future.

On a commercial scale, fluidized-bed gasifiers will be the most promising that use the present development progress seen in fluidized-bed burners in the power industry.

Recent projects using gasifiers, and specifically fluidized-bed types, have not caused additional plants to be built or new projects started. More demonstration projects will be required in the years to come to provide a clear direction for this technology in a commercial sense.

Other Methods

In addition to the processes described above, two other methods exist that can generate products from straw, both using digestion as the conversion method. These methods include anaerobic digestion and high temperature digestion.

Anaerobic Digestion

Anaerobic and high temperature digestion also can generate products from straw.

Anaerobic biodegradation is a common tool used in municipal sewage systems (as part of solid waste management). One byproduct of this process is biogas, a combination of methane (CH_4), carbon dioxide (CO_2), and other constituents produced by the digestion process. This process is a viable conversion technique for straw into methane, because sewage plants across the state can demonstrate the process for conversion.

The process has certain requirements: bacteria appropriate for the feedstock, the proper environment (e.g., a digester vessel with an anaerobic blanket), and a balanced diet of nutrients. There are three basic stages of anaerobic treatment using three distinct groups of microorganisms.

The first stage uses fermentative bacteria to hydrolyze and ferment complex organic materials, carbohydrates, proteins, and lipids into fatty acids, alcohols, carbon dioxide, hydrogen, ammonia, and sulfides (Walsh et al., 1988).

The second stage involves the consumption of the primary organic products by an acetogenic bacteria, which then produces hydrogen, carbon dioxide, and acetic acid. The third stage utilizes two distinct types of methanogenic bacteria: the first reduces carbon dioxide to methane, and the second decarboxylates acetate to methane and carbon dioxide (Walsh et al., 1988).

Research conducted in the Midwest shows that a wheat straw/manure mixture can be converted into methane (at a rate of 4 cubic feet of gas per pound of volatile solids) in a 100 day fermentation cycle (Hashimoto and Robinson, 1985). Using these figures, a rough estimate can be made of methane production from a ton of straw plus manure:

Gas output = 4 cubic feet gas/lb x 2000 lb/ton x 87% volatile solids

= 6,960 cubic feet gas/ton

In terms of energy, this calculates to

Energy output = 6,960 cubic feet/ton x 600 Btu/cubic foot

= 4.2 mmBtu/ton or 42 therms/ton

Research is being conducted by Oregon State University to determine the corresponding yields from ryegrass and fescue straws with manure. Preliminary results indicate slightly higher yields from these straws (on the order of 5.5 cubic feet gas per pound volatile solids). Although the tests with Willamette valley straw have been small-scale laboratory tests, the results are felt to be representative of pilot plant systems.

Because straw fermentation is not widely practiced, there is little information regarding the modification of traditional digester and fermentation technology to accept and process grass straw. The costs of the few agricultural waste digesters already built have been very sensitive to the economics of scale (i.e., unit production costs decrease with increasing digester size) (Sidibe et al., 1990).

Costs for a typical straw/manure system (40,000 cubic foot digester, 485-kW engine generator, ancillary equipment) would be $1.8 million, with annual costs of $200,000 and revenues of $160,000/year for electric power ($.04/kW) and $500,000 for recovered protein (used as cattlefeed). This would imply a simple payback of about 11 years.

A variation to this process would be the introduction of straw directly into the digester vessels at sewage treatment plants, using the existing bacteria, vessels, and nutrients. Straw would become a bulking agent, providing additional solids for methane generation.

Problems could exist with this concept, however, particularly with material handling into and out of the digester vessels. These vessels are normally designed to receive only liquid sludge mixtures without large amounts of oversized solids. It might be necessary to construct a separate new structure for digesting the straw, adjacent to the existing digesters, with piping that connects them together. This would increase the cost of using straw at the plant and complicate operations.

High-Temperature Digestion

This process is similar to but not the same as the composting process described in Chapter 5, On-Farm Straw Management. Composting involves biological reduction of organic materials to humus, while this form of biomass conversion involves mechanical separation of biomass into principal components: cellulose, hemicellulose, and lignin.

An attractive feature of high-temperature digestion is the ability to develop cattle feed and/or organic chemical feed stocks from crop residues in a relatively short period of time (Daniels, 1990; Masik, 1990). Sources of biomass for this process can be hardwood chips, bagasse, straw, or almost any agricultural or forest waste.

Equipment. One process available today involves a high-pressure digester, which operates at pressures between 150 psig (365°F) and 450 psig (455°F), and is batch fed using a plug feeder and batch emptied through a rotary valve.

The reactor utilizes a screw auger to transport the material in the vessel, timed to agree with the required processing time. The biomass feeder utilizes a reciprocating piston to compact and inject the material against system operating pressures. After processing, the material is discharged as a plug, with accumulated material being compacted before release to a rotary valve and product storage bin.

An auxiliary boiler supplies steam to the process, and biomass supply storage is usually provided with a feed hopper to the plug feeder.

A typical plant might consist of three 5-ton/hour modules, processing 12 percent moisture feedstock for animal feed at an annual rate of 136,000 tons of straw/year. Costs for equipment, materials, and construction are estimated at $12 million (Daniels, 1990) not including land and site improvements.

This process is easily adaptable to fermentation processes (as described above) by following the digested product with a stripping column and fermentation vessel to produce ethanol. This combining of technology, however, is not as advanced commercially as the digester systems.

Products. There are several examples of animal feed products produced using biomass conversion technology. Two products produced are a hardwood chip feed (using aspen or poplar trees) and a bagasse feed using sugarcane. These products contain fiber and carbohydrates but do not contain significant amounts of protein or other essential ingredients required for a balanced feed program. The product is produced in silage form but can be pelletized for improved transport cost (but higher production costs) and ease of use in feed lots.

Tests of these products show that between 10 and 80 percent of the overall feed ration can be supplemented, with typical levels ranging from 10 to 30 percent (Daniels, 1990). Various other tests have been run, combining liquid protein supplements (such as molasses and urea mixtures) and alternate feed materials (e.g., haylage, silage, compound feeds, soybean meal) with the biomass feed products.

Tests were performed on beef cattle, dairy cows, young cattle, and feedlot stock, foreign and domestic herds. Items such as weight gain, feed efficiency (feed weight per weight gain), milk yield, and various metabolism studies were conducted with acceptable results.

The conversion technology involved with digestion has not reached large-scale commercial use at this time. The most viable systems now produce cattle feeds but could be used for ethanol production if fuel prices would support commercial development and production costs.

Trends for the future will follow hydrolysis/fermentation technology successes as they develop after years of pilot work. There will be a market for cattle feeds, but usually as a supplement to traditional "protein balanced" feeds. Energy production from manure/biomass systems is a farm-level activity today and will remain so in the foreseeable future.

On-Farm Chemical Production

Some on-farm chemical production from straw is possible on a small scale.

The technology issues discussed in this section have been reviewed against commercial plants of large scale size and investment. Some discussion of on-farm chemical conversion of straw should be undertaken to understand how this approach compares to commercial projects.

The same risks exist for on-farm projects as for commercial projects: technology is not yet demonstrated for straw use. Further, the necessary technical skills for operating equipment and the source of operating funds may not be available for on-farm projects.

It is possible for an on-farm gasification or hydrolysis system to be used to produce fuels or feeds. For example, a small scale downdraft gasifier could be utilized to power engine-driven farm machinery, with the following considerations:

- Straw material must be dried and chopped
- The process must be continuously attended and maintained
- Capital and operating costs would be high for a small scale system, and replacement energy sources (e.g., electricity, gasoline) relatively cheaper and less labor intensive

If the farmer were interested in marketing products outside of the farm, high temperature digestion (for cattle feed) or some form of hydrolysis/fermentation (to produce fuels) could be used. However, capital, operating, and transportation costs as well as the needed marketing efforts might deter a farmer from this enterprise.

Overall, the farmer may wish to test prototype systems on-farm. However, the farmer should be aware of the preliminary nature of such systems and understand the level of financial and physical support such technology will require. Because straw is a byproduct of the main crop (grass seed), farmers likely will not develop large-scale, on-farm systems, now or in the future.

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10 Regulatory and Social Issues

Introduction

Although research has generated a considerable amount of information about the technology and economics of various market alternatives for straw, this research would be incomplete without examining the regulatory and social implications of such alternatives. Successful straw utilization alternatives must be legally and socially acceptable as well as technically feasible and economically viable for implementation.

Social issues relate to the functioning of our society and concerns raised by various interest groups, such as farmers, environmental activists, exporters, and industrialists. Social issues identified for straw utilization alternatives include health, safety, environment, and economies, and infrastructural systems such as transportation, utilities, energy, and waste disposal. Combined, these issues determine the overall acceptability to our society of an alternative, which can be reflected in political decisions. Therefore, a discussion of the values that drive public and interest group acceptance of proposed alternatives is appropriate as part of the discussion of social issues.

Successful straw utilization alternatives must be legally and socially acceptable.

Regulatory issues relate to the potential application of or compliance with laws that may regulate any aspect of an alternative. Most of these laws relate to land use and environmental quality, including air, water, and noise. Because laws are enacted to reflect the majority's desires regarding social issues, the social implications of some farming and industrial activities are subject to regulation. Thus, it is difficult to totally segregate discussions of regulatory and social implications; some overlap is inevitable.

To clarify the regulatory and social issues that may impact the successful implementation of the straw utilization alternatives (Table 10-1), this chapter includes sections covering:

- Current situation and trends in regulatory and social issues that have provided the impetus for developing straw utilization alternatives
- Identification and overview of the regulatory and social implications that are common to implementation of the alternatives
- Discussion of regulatory and social implications that are specific to each alternative

In this chapter, the discussions of economics focus on the broader economic farm choices that might affect farmers' participation in alternative programs. Also discussed are the basic impacts that each alternative may have on economies within the region, such as construction, transportation, mechanical, manufacturing, energy, and exporting.

Specific alternatives have been defined for discussion in the chapter to allow a focus of issues that would apply to them (Table 10-1). This does not preclude other alternatives from being acceptable or selectable.

There is limited social research available regarding the specific alternatives being considered. Thus, most of the social information in this chapter has been based upon comparisons of the alternatives' facilities with similar operations, experience with similar issues, and one-on-one discussions with potentially affected people.

Table 10-1
Straw Utilization Alternatives

Markets	Alternatives
Fuel	New 20-MW powerplant A straw fuel conversion at an existing facility Home stoves
Chemical	New gasification or hydrolysis plant
Fiber	Modified pulp plant New strawboard plant (using a modified existing plant)
Feed	Raw straw export On-farm densification
Other	On-farm composting or mulching Commercial composting or mulching

Note: Alternatives listed in order of difficulty (most difficult first) with regard to regulatory and social issues.

Current Situation and Trends

In addition to general economic conditions and variable straw export markets, the grass seed industry today is affected by various regulatory and social issues. Principal among these are the regulations pertaining to the quantity and timing of burning, and the social concerns surrounding the environmental and health effects of open-field burning, which have been taken to the political arena.

Regulatory Setting

Field burning is regulated in Oregon to reduce air pollutants. The Oregon Department of Agriculture (DOA) administers a smoke management program for regulating agricultural open-field burning in most of the Willamette Valley. These agencies operate air monitoring networks to assess whether the air is in compliance with health-based ambient air quality standards.

One of the smoke management program tools is to require the grass seed farmer to register all acreage intended for open burn and to obtain burn permits. The smoke management program provides for the daily and hourly control of open-field burning based on prevailing weather conditions.

The DOA designates times, places, and amounts of burning. The Oregon Department of Environmental Quality (DEQ), on the other hand, operates an air monitoring program to detect impacts and enforces burning regulations. The effectiveness of the smoke management program depends on the accuracy of the weather forecasts. Occasional impacts on the public occur.

Although open-field burning is regulated, few regulations apply to stack burning.

The field burning smoke management program, which also finances smoke-related research, is funded by fees collected for burned fields. These fees have increased over the years, and are predicted to increase again in 1991. However, since regulations were first adopted in 1971, the acreage allowed and opportunities for field burning have been getting smaller each year because of weather limits, alternatives chosen by farmers, and by the system involved in choosing which fields to burn when.

Currently, there are few regulations concerned with stack burning, a practice increasingly employed for straw disposal. No uniform method is prescribed to farmers for conducting this type of burn.

Open-field burning is unregulated by statewide and local land-use planning laws. It has been considered a normal farming practice. However, air pollution resulting from open-field burning could be interpreted as being inconsistent with nonspecific air quality and visual resource policies contained in local comprehensive plans.

Social Concerns

Many people are troubled by haze and odor in the air resulting from field burning. There also is much speculation about field burning's effects on public health, even though field burning complies with ambient air quality health standards. Direct evidence of field burning health effects is limited and inconclusive. Over the past 20 years, six studies have been conducted regarding the effects of open-field burning on public health, aesthetics, and general welfare; however, no agreement has been reached about the effects (Conklin et al., 1989). The fact is that the environmental and health effects of open-field burning continue to be the subject of considerable attention and debate, as evidenced by public response in numerous public meetings/workshops, editorials, letters-to-the-editor, and political campaigns.

Social concerns today include haze, odor, health, and traffic safety.

Traffic safety is affected when drifting smoke from open-field burning causes limited visibility on roads. This is at least one acknowledged impact of field burning to public health. Usually, this has not been severe, but the August 1988 multiple car accident on Interstate-5 emphasizes the potential for tragic events caused in large part by burning straw. New field burning regulations have been promulgated that are designed to reduce this potential.

Another method of field sanitation is the mobile field sanitizer, which is a machine that utilizes a traveling burn chamber that burns and heats straw and dirt, and is equipped with controls for smoke release. Production rates of these machines are slow (3 to 6 acres per hour), operating costs are high, and availability is limited.

Currently, many grass seed farmers bale straw for stack burning and alternative uses. The practice of stack burning is now heavily used as a means of disposal. Between 250,000 and 400,000 tons of straw were stack burned in 1990. If the public focuses on stack burning restrictions, as a followup to open-field burning restrictions, farmers will realize significant impacts on their operations.

Baling and bale-transport impact roadway capacities. Baling machinery often must be moved between fields via county and state roadways. Transporting the bales, to on-farm or other storage locations and points of export or use, requires use of county, state, and interstate roadways. This activity affects roadway use by:

- Causing traffic delay due to slower acceleration rates and lower speeds of trucks and farm machinery
- Increasing localized impacts to environmental elements such as noise sensitivity and straw blowing off trucks
- Decreasing forward visibility by size of trucks hauling straw and machinery
- Increasing the overall traffic on roadways

During 1990, approximately 150,000 tons of straw were transported over Oregon roadways for export use alone. This figure does not include straw (or straw products) transported for use as livestock bedding, feed, fuel, or other uses. The effects of this increased traffic on roadway capacities have not been analyzed, nor have any specific examples of problems been widely reported.

Because many people in the general public hold a negative view about open-field burning, there are political pressures to ban or more severely restrict this form of field sanitation. However, many people in the farming community feel that the public does not adequately understand the effects that halting or significantly curtailing field burning will have on the grass seed industry and regional economy. This is a source of concern to the farmers who have pride in their economic contributions to the region and who desire some certainty in applying cultural practices.

In addition, many farmers feel that political factions and state agencies responsible for promulgating and/or implementing open-field burning regulations are prone to respond to vocal environmental opposition to field burning. The result has been a sense in the grass seed farming community that their industry receives less than equitable consideration in the problem. The farming community wants a balanced consideration of facts concerning the environmental and economic effects.

General Issues Surrounding Straw Utilization Alternatives

A summary of the regulatory and social issues relating to the identified straw utilization alternatives (Tables 10-2 through 10-6) are provided at the end of this chapter. When weighing alternatives, evaluations of these common characteristics, and those specific to an alternative (presented later), should be compared to those associated with open-field burning.

Regulatory Issues

Several of the alternatives will have associated regulatory issues, such as potential impacts to air sheds, water quality, and noise levels.

Air

Air, water, and noise are environmental concerns subject to regulation.

Air Contaminant Discharge Permits (ACDP) will be required for any of the alternatives with new or modified industrial facilities. The permitting process could require between 12 and 18 months, depending on the scale and location of the proposed facility and the pollution discharges. As part of the permitting process, detailed information on the processes, emission sources, emission rates, and proposed air pollution control equipment must be submitted for agency review.

Onsite material handling and over-the-road truck transportation aspects are expected to have similar air quality impacts for all alternatives. Removal of straw from the fields generates dust or particulate emissions. Air quality impacts of particulate emissions (i.e., dust) will be the greatest for workers. The Occupational Safety and Health Administration (OSHA) regulations for worker exposure to dust permit 10 milligrams per cubic meter for 8 hour exposures. However, this situation exists today for farmers, and the impacts of straw utilization alternatives may not be noticeable above the current levels.

Water

Many of the straw utilization alternatives involve industrial operations that will have wastewater discharges. The type of approval/permit needed for the industrial facility will depend on where the wastewater is discharged. If wastewater were discharged into a surface water stream or river, a National Pollutant Discharge Elimination System (NPDES) permit would be needed. The DEQ issues these permits; permit application review could require up to 24 months, depending on the scale of the facility and discharges. The level of treatment required and the concentration of pollutants allowed in the discharge will depend on the capacity of the receiving water to accept the discharge.

If the wastewater were discharged to a sewer system, approval from the sewerage agency would be required. Pretreatment of the industrial wastewater may be required by the agency. Flow rate, pH, and temperature are commonly regulated parameters.

Noise

Noise control in Oregon is under the jurisdiction of the DEQ. The DEQ regulations control statistical noise levels, impulse noise levels, and discrete frequency noise levels. The allowable statistical noise levels for new industries are shown in Table 10-7. The human ear is less sensitive to sounds in the low- and high-frequency ranges than to mid-frequency sounds.

The allowable increase in the L_{10} and L_{50} noise levels is limited to 10 decibels acoustic (dBA) over existing levels for all direct and indirect noise sources. Impulse noise levels are limited to 100 dB during the day (7 a.m. to 10 p.m.) and 80 dB at night (10 p.m. to 7 a.m.).

Discrete frequency limitations are designed to control screeching, squealing, humming, or rumbling type noises. The purpose of these regulations is to prevent noise that is not too loud overall but is very annoying because it is concentrated at one high or low pitch. The DEQ noise regulations are applied at noise sensitive properties (residences, schools, churches, hospitals, and libraries).

Table 10-7
Noise Source Standards for New and Existing Industry Allowable Statistical Noise Levels in any One Hour

Statistical Level	Daytime Limit (7 a.m. - 10 p.m.) (dBA)	Nighttime Limit (10 p.m. - 7 a.m.) (dBA)
L_{50}	55	50
L_{10}	60	55
L_{1}	75	60

The use of loaders and tractors on existing agricultural properties would be a typical farming activity and is not expected to significantly change the existing noise at those sites. However, pelletizers, choppers, and similar farm-level straw processing equipment could impact present noise levels and be viewed as beyond "normal" agricultural noise generations.

The trucking of straw or a processed product to an offsite facility could potentially generate significant truck traffic volumes where they currently do not exist. Truck traffic will be subject to the DEQ 10-dBA increase limitations for the L_{10} and L_{50} statistical levels. On quiet rural highways, truck volume increases do not have to be large to cause existing L_{10} levels to be exceeded. Mitigation of truck traffic noise would typically be accomplished by limiting the number of trucks using a particular road. Another alternative is to provide noise barrier walls for impacted sensitive properties. This will be very costly if a large number of roadways is involved.

Land Use

Land use laws may impact the siting of some facilities.

The possible local land use permit requirements are extensive, depending on the particular site characteristics and the local jurisdiction's land use ordinances.

Land acquisition, environmental studies, and agency/public review of permit applications can easily require 18 to 24 months for major facilities. Overall time requirements and sequencing for permit application reviews would probably be less for modifying facilities than for new ones. General time requirements for land use-related permit application reviews include:

- Local Land Use Permits (no appeals)
  - Site Plan or Comprehensive Plan Compatibility Reviews: 3 weeks
  - Conditional Use Permit: 2 to 3 months
  - Expansion of Nonconforming Use: 2 months
  - Zone Change, Comprehensive Plan Amendment, Statewide Planning Goal Exception: 3 months
- Oregon Water Resources Department
  - Water Appropriation Permit: Minimum 6 months

Commercial operations may be permitted as conditional uses in exclusive farm use (EFU) zones. Three Oregon court cases have helped to define the criteria for determining if a use is a commercial use in these zones: Craven vs Jackson County; Earl vs McCarthy; and Balin vs Klamath County. Many counties use "rules-of-thumb" for determining commercial uses that may be granted conditional use permits in EFU zones when:

- The activity is directly serving local agriculture
- A product developed by the activity is sold on the commercial market
- At least 50 percent of the agricultural material that results in a product is operator-owned

- The scale, appearance, and impacts of the activity are more commercial than industrial

These rules-of-thumb are hereafter referred to as the agricultural commercial use conditions. Activities that will not meet the agricultural commercial use conditions probably will not be permitted in an EFU zone. A zone change, comprehensive plan map amendment, and exception to Statewide Planning Goal 3 will probably be required for siting a facility in an EFU zone when other feasible sites are unavailable.

Counties can exercise discretion in defining the use and the resulting permitting requirements because "local area" is not clearly defined, and the boundary between industrial and commercial activity remains unclear.

In siting an alternative, several potential "fatal flaw" criteria should be considered, including:

- Wetlands
- Air quality
- Visual quality
- Floodways
- Water supply sources
- Parks
- Populated areas
- Airports
- Cultural resources
- Significant wildlife habitat and threatened or endangered species
- Significant mineral resources

Local jurisdictions will require building permits and will conduct building inspections, including fire and life safety reviews for large industrial facilities. Local building permit plan reviews can be expected to require 2 months for large industrial facilities, and less time for smaller operations.

In most counties, however, building permits are not required for constructing straw storage structures used solely for storing straw on farms outside city boundaries. Agricultural Building Authorizations, including a site plan to assure compliance with zoning regulations, will be required by local jurisdictions.

Social Issues

Social issues that are common to all the alternatives are related to infrastructure and acceptance values. A discussion of these is provided below.

Infrastructure

Infrastructure includes transportation, utilities, energy, and waste disposal.

Infrastructure includes functional systems of society such as transportation, utilities, energy, and waste disposal. Transportation is most common to the alternatives because most will require baling and transport of large amounts of straw. Waste disposal also will be a prevalent concern.

Transportation. Generally, straw is currently hauled by tractor-trailer trucks using low-deck, 40- and 24-foot double trailers capable of carrying between 22 and 25 tons of straw. Because of the geographically widespread distribution of grass seed fields, this report assumes that the trucking industry will continue to be the primary means of transporting straw. The railroad system may provide a feasible straw transportation alternative for long or large volume hauls. A detailed feasibility analysis of railroad transport should be addressed if a short-listed alternative involves possible long hauls of straw.

The regional and localized impacts to the existing transportation network capacity and traffic safety that should be assessed for each alternative include:

- Increased overall weight load on roadways
- Increased truck traffic
- Increased localized straw blow-off from trucks.
- Municipal roadway use restrictions that may limit use to certain arterial, or use by types of vehicles (e.g., waste, or ash, disposal trucks and double-trailer vehicles)
- Increased noise impacts

An example of these impacts was seen recently at a powerplant in California, where straw deliveries were temporarily halted by the highway patrol due to a nuisance caused by straw blowing off trucks. Tarping was required, which increases labor significantly.

Waste Disposal. The huge volume of straw waste generated by grass seed production, juxtaposed to the national concern for reducing the waste streams to landfills and the rise in disposal fees, renders landfilling of raw straw an impractical and particularly politically sensitive alternative to solving the problem. Disposing of raw straw at existing or straw-dedicated landfills will only redirect public attention concerning the effects of the straw disposal problem from air pollution concerns of field burning to the land and water impacts of landfills.

Whereas disposal of raw straw in landfills is considered an infeasible alternative to open-field burning, many of the alternatives will, nonetheless, potentially require addressing the following situations:

- Portions of loose or stored straw could decompose to an unusable extent and would need to be disposed of in landfills
- Landfills may need to accommodate ash, sludge, and other wastes generated by alternatives Disposal issues that may need to be addressed include:
- Availability and capacities of existing landfills
- Ability to establish new onsite or offsite landfill(s) to accommodate the wastes generated by the alternatives, considering availability of land and permitting requirements

Economies

The amount of straw storage facilities available today is small; there is capacity for export straw feed, plus some additional small amounts for

The implementation of straw utilization alternatives will impact several related economies.

farm uses. Most of the alternatives will require additional straw storage structures, hauling, gathering, and baling equipment, which will provide more jobs in these industry areas. Currently, a small percentage of straw is stored in on-farm storage structures; however, some straw handlers have constructed or use their own structures or lease other storage facilities.

In California, straw utilization facilities employ straw brokers as agents to supply straw; these agents often provide storage as part of their service. Farmers will also continue to provide storage, and this activity will need to increase as market demand for straw increases.

The demand for additional straw storage space, particularly in areas near points of use or export, may affect lease rates. The regional impacts associated with building more straw storage sheds will depend upon:

- Availability of land and suitable locations
- Sources of financing and ownership of storage facilities, including cooperative arrangements and third-party ownerships
- Additional employment opportunities and economic gains

Alternative straw uses will create additional economic activity in the trucking industry. Significantly larger amounts of straw will be transported to processing facilities and commercial markets instead of being burned on the farm. However, straw that is now trucked to Portland for shipment to overseas markets might instead be transported to a processing facility if that proves to be a higher valued use of this material.

The economic activity in the shipping industry could change. Locally this economic activity will include port handling of straw and ships transporting the straw.

There generally will be a proportional increase in local employment opportunities (e.g., construction, operations, maintenance) as the scale of each alternative increases.

Each of the options could generate both additional revenues and costs for the farmers. The general economic effects will depend on the selected option providing a positive net return (or reduced loss of revenue) to the farmer, cost savings (or losses) compared to current practices, or avoidance of further restrictions on their practices that could further increase their costs of operation.

Grass seed growers who build straw storage structures may be eligible for a Pollution Control Tax Credit for each structure. The main criteria are that the structure must be designed and sized only for straw storage and is used primarily for this purpose.

Acceptance Values

The alternative to open-field burning will affect the whole agricultural industry with interests in grass seed production. This includes grass seed farmers, equipment sales businesses, and straw handlers-brokers, among

Grass seed farmers have several needs, values, feelings, and expectations that alternatives must include.

others. This represents a sociocultural segment of our society with diverse values and attitudes towards resolution of the issue.

In choosing an alternative, grass seed farmers have identified several needs, values, feelings, and expectations that should be considered, including:

- Getting the straw off their fields in a timely manner that permits them to prepare the fields efficiently
- Use of straw that is socially, economically, and environmentally sound
- Avoid solving one problem by creating another that ultimately could reflect poorly on the grass seed industry
- Farming health and safety, while often not considered as a criteria for choosing an alternative, may be a concern, particularly for straw handling operations where increased exposure to dust or dangerous equipment may be an issue

Important social variables that have not been explicitly addressed include:

- Sustainability and cohesion of the farming community—how will an alternative affect the number of grass seed operations and their interrelationships?
- Farming culture—how will increasing the farmer's opportunities to become involved in new markets be balanced with his/her desire to maintain economic independence and comfort with the level of business management required to operate the farm?
- How will farming occupational patterns change?
- Will the alternative(s) affect farming regions differently?

An assessment of public values and attitudes is critical at an early stage of implementation.

An assessment of public values and attitudes would identify the concerns and expectations that should be addressed in identifying an alternative. The assessment would also assist in developing a public involvement/relations program that addresses critical public issues relating to the problem and allows members of the public to identify all their concerns as part of the process.

Any straw use alternative should consider all those communities affected commensurate with the level of the effect. Success, in the sense that the affected and potentially affected publics are reasonably satisfied with the solution, demands that the public be involved in the selection and development of an alternative.

The Oregon legislature represents all affected publics. Understanding and addressing the political and legislative issues concerning all of the alternatives are critical to a successful resolution of the open-field burning problem. This understanding can be achieved by:

- Identifying populations and their political districts that will be affected by an alternative
- Researching the district's historical voting or opinion trends on similar environmental/resource issues

- Defining issues about which residents are concerned
- Identifying specific legislative measures that could assist in the implementation of an alternative

The social issues discussed above can serve as the foundation for developing an assessment of straw utilization alternatives, and as important items to be considered in developing a public involvement/relations program.

Issues Specific to Each Alternative

This section presents a discussion of the regulatory and social issues that are specific to each alternative. The alternatives for each market (Table 10-1) are discussed in the order of difficulty of implementing them (most difficult first) with regard to the issues presented.

Introduction to Fuel Alternatives

Alternatives considered in this chapter for the fuel markets include a new 20-megawatt (MW) powerplant, straw fuel conversion at an existing facility, and home stoves. Regulatory and social issues specific to each are presented after this introductory section, which discusses elements common to each.

The sectors of the local economy, besides the grass seed growers, that will be directly impacted by the use of straw as a fuel source for an existing industrial plant, a large-scale powerplant, or in home stoves are expected to be the trucking, electric utility, and the straw handlers and gatherers. Other sectors of the economy will also be impacted because of the indirect and induced effects of these direct economic impacts.

If the straw needs to be processed prior to its use as a fuel source, such facilities will need to be constructed and operated for that purpose. This may create some employment and income impacts.

Additional energy production in the powerplant or industrial plant will reduce the amount of energy that will need to be generated at other facilities. Some employment will be created by the construction and operation of the new plant. Employment impacts will depend on whether the straw was being used in a new facility, or whether the straw will simply replace another fuel source in an existing facility.

Use of straw in wood stoves could reduce the usage of wood and other materials in wood stoves and/or reduce the demand for other heating supplies (i.e., gas, oil, and electricity). The employment impacts of the reduced demand for energy from other suppliers will depend on the magnitude of the reduction in demand for those energy or fuel sources.

Under current energy development programs, alternative energy facilities may sell the power they generate to utilities at a predetermined rate.

This rate is the avoided cost the utility would incur to generate that power at a new powerplant. This allows the power generator to sell the power at rates that are somewhat greater than the current market rates for purchased power. The value of these rates is critical to the economics of this alternative.

New Straw-Dedicated Powerplant

We assume that a new 20-MW electrical generating facility would be constructed in the Willamette Valley. This facility would use straw as the primary fuel, but would probably use another fuel source (e.g., natural gas, hog-fuel, municipal solid waste, or urban wood waste) as well.

While there are no major powerplants in Oregon using straw as a primary fuel source, comparable data can be obtained from biomass (wood residue) fired powerplants, agricultural residue plants, or waste-to-energy facilities in Oregon and outside the state. For example, several plants in California uses rice hulls and straw for generating electricity. In addition, several waste-to-energy facilities are in operation throughout the U.S. from which comparable information can be derived concerning economic, social, and regulatory impacts.

Regulatory Issues

Air. The sources of air pollution at a powerplant will include the combustion units, fuel handling equipment, onsite mobile equipment, fugitive dust, and traffic exhaust. Air pollutants from these sources will primarily include particulate matter (PM), nitrogen oxides (NO_x), carbon monoxide (CO), and volatile organic compounds (VOC). If the straw fuel is supplemented with oil, coal, or other sulfur containing compounds, sulfur dioxides (SO_2) could also be generated in the combustion unit. Pesticide residues may also be on some of the straw.

High efficiency combustion units should provide effective control on reducing potential emissions of VOC and pesticide combustion products. Dry scrubbers, electrostatic precipitators, or baghouses will probably be needed to reduce PM emissions from a CO combustion unit. Small baghouses or water spray systems may be needed to control other PM sources at a powerplant.

The level of air pollution control required for a powerplant will depend on the site location, the impacted areas, and the regulatory limits triggered by the emissions. Emission offsets for PM or VOC may be needed if the project has significant impacts to particulate or ozone nonattainment areas.

Water. Powerplants require significant quantities of water, especially for cooling tower operations. The quantity and rate of water discharged will vary depending on the plant design. The site location and plant design will influence the type of permitting required for the facility.

Uses of the straw fuel in existing industrial facilities may or may not affect the quantity or quality of wastewater generated at the facilities. If changes occur, modifications to the wastewater permits may be required.

Noise. Powerplants are significant noise sources. The primary individual noise sources are forced draft and induced draft fans and cooling towers. Pollution control equipment, ancillary sources (e.g., pump motors and compressors), and onsite mobile equipment can be contributing secondary sources. Locations that already have industrial development of some type will provide a less restrictive environment in terms of the allowable noise increases. Typical mitigation will consist of enclosures and silencers on stationary sources, good mufflers on mobile sources and, berms or noise walls.

Land Use. The acreage required for a dedicated 20-MW powerplant will depend on the size of the main facility, scale house, straw storage, ash storage, air pollution control equipment, wastewater treatment facilities, parking, setback and landscaping buffers, and other land uses. A 28-MW facility in California is sited on an approximately 40-acre parcel, of which approximately 5 acres is used for storing 5,000 tons of uncovered straw (or about 2.5 percent of its yearly fuel-straw requirements). Generalized siting requirements will include:

- Nearby electrical power transmission line
- Close access to major transportation routes, with existing means of access
- Twenty to 40 acres of land
- Access to water with low dissolved solids
- Stream or river wastewater discharge
- Distance from population center
- Reasonable proximity to the straw source
- Absence of particulate and/or ozone nonattainment area
- Availability and location of suitable ash disposal landfills

The land-use permitting procedures will require addressing and resolving any significant impacts to critical resources prior to issuing any permit.

A critical concern will be the classification of the waste ash and the availability, capability, and capacity of nearby landfills to accommodate the ash, or ability to establish onsite disposal. Classification of the ash as a hazardous waste will complicate the disposal issue and the choice, siting, and operation of a powerplant. Other concerns will include chlorine use and sludge handling (from storage pits and onsite treatment systems).

An onsite landfill for ash disposal will require a considerably greater amount of land, environmental analysis, and permitting review particularly by the DEQ and the local planning agency. An onsite landfill will likely prompt a higher level of local land use permit requirement, such as an exception to the Statewide Land Use Planning Goals, or, minimally, greater scrutiny of environmental impacts through the permit review process.

It can be expected that counties and cities will permit a major power generation facility only after holding public hearings. Permits would be obtained through a variety of application review procedures, including:

- Conditional use permits: These will be required in county agricultural (ORS 215.213(2)(c)) and some forestry zones, some city industrial zones, and probably county industrial zones in Urban Growth Boundaries. The emphasis during review will be on the facility's compatibility with surrounding resource uses and impacts to the environment. Given the scale of the development, applications will require substantial environmental studies.
- Industrial site plan reviews and plan policy reviews: These may be required in some city industrial zones. The review will focus on the facility's conformance to environmental and design performance standards, including landscape, setback, traffic patterns, parking, and other nuisance abatement measures.
- Comprehensive plan amendments and zone change/statewide land use planning goal exceptions: This procedure may be required in certain forestry zones, and should be used as a last resort if other properties are unavailable.

The Oregon Department of Energy (DOE) requires a site certificate prior to constructing an "energy recovery facility" that will produce over 50 MW. The site certificate review process requires detailed studies and a public hearing.

A 20-MW powerplant could require approximately 75,000 to 150,000 gallons of water per day. A water appropriation permit issued by the Oregon Water Resources Department (OWRD) will be required. The application must show compliance with local land use laws, availability of water, and consistency with the OWRD Water Basin Plan that applies to the basin in which the facility will be constructed. It should be expected that the OWRD might require a public hearing on issuance of the permit, which will probably require minimally 6 months.

A powerplant will involve environmental research, design work, and permit application reviews that could require 18 to 24 months.

Social Issues

Infrastructure. A 20-MW powerplant probably will require between 15 and 30 truckloads of baled straw daily, generating 30 to 60 vehicle trips per day. Approximately 100 vehicle trips will be generated each day from straw delivery trucks, waste ash disposal trucks, employee cars, and miscellaneous business traffic.

The powerplant will require connection to an existing electrical transmission line. Proximity to the line will be an important siting criterion to minimize costs and environmental impacts. Local conditional use permits may be required for a transmission line that is not accommodated on the site. Proximity to an existing natural gas pipeline may be an important siting criteria if this fuel source were used.

Economies. Trucking, electric utility, and straw storage and handling are sectors of the local economy that will be directly impacted by the use of straw as a fuel source. Other sectors of the economy will also be impacted because of the indirect and induced effects of these direct economic impacts. Some employment will be created by the construction and operation of a new plant. Straw storage facilities also will have to be constructed to ensure a reliable supply of fuel.

If the straw needs to be processed prior to its use as a fuel source, such facilities will need to be constructed and operated for that purpose. This may create some employment and income impacts.

Additional energy production in the powerplant will reduce the amount of energy that will need to be generated at other facilities; although, with the power demands predicted for the Pacific Northwest, a reduction in output at other facilities is unlikely.

Under current energy development programs, alternative energy facilities may sell the power they generate to utilities at a predetermined rate. This rate is the avoided cost the utility would incur to generate that power at a new powerplant of their own. This allows the power generator to sell the power at rates that are somewhat greater than the current market rates for purchased power.

Acceptance Values. Construction, operation, and monitoring of almost any powerplant will be of public concern, and care should be given to account for that concern. The construction and initial operation of a 28-MW powerplant in California generated little public comment, probably because the facility was not located near high density populations areas. However, recent environmental problems have developed with the ash generated at the plant, creating an increased public concern about the facility.

It can be expected that siting and operation of a 20-MW powerplant will be resisted if it were proposed near residences or if the haul route were through residential areas.

Fuel Conversion at Existing Facility

It is assumed that an existing industrial boiler, or a powerplant, could be modified to burn straw in the Willamette Valley, central Oregon, or on the Oregon coast region. Candidate plants could include sawmills, plywood mills, electric generating utilities, university and city central plants (such as those in Eugene).

Regulatory Issues

Air. Industrial uses of straw fuel may include steam generation in existing boilers or the production of heat for use in wood dryers. The air permit at the existing facility must be modified to allow the use of a new fuel or the addition of equipment. Air pollution sources and pollutant types are generally the same as a new powerplant. New air pollution control equipment may be needed to comply with the 1990 Clean Air Act. Site location can make a difference on the level of air pollution control required.

Water. The water requirements and impacts of a fuel-converted operation will be similar to those discussed for a new powerplant, although the scales will depend on the size of the facility.

Noise. The noise impacts will be similar to those discussed for a new powerplant; however, the existing industrial development will provide a less restrictive environment in terms of the allowable noise increases.

Land Use. A straw-fueled facility will require a significant area if straw is stockpiled onsite. Particular siting criteria will include:

- An existing facility that could be technologically, financially, and economically modified to use straw-fuel
- Sufficient land for stockpiled straw

Local land use permits that may be required for the modification of a facility to add biomass energy production include:

- Permitted Outright: This will apply to facilities located in properly zoned industrial areas in which plant expansion will not require major modifications to locally approved site plans
- Conditional Use Permits: Will be required for facilities in industrial and resource zones that required expansion of site area and/or sale of generated power where it was not previously sold.

Cogeneration facilities that have been permitted by local land use agencies during the last 10 years have generally not experienced extensive regulatory reviews. For example, the conditional use permit granted for a cogeneration facility in Douglas County did not directly address transportation issues. However, the cumulative effects of a series of straw use facilities developed as part of a regional program could highlight the traffic impacts and could result in increased attention to a broader range of issues.

A water appropriation permit, or a modification to an existing permit, will be required for water used in operation of this type of facility. A public hearing might be required by the OWRD if the water use issues are sensitive or complex. At least 6 months will be required for OWRD review.

Social Issues

Infrastructure. Considerations for a straw-fuel facility conversion include:

- Near-site effects to transportation system capacity and safety
- Impacts of increased truck traffic
- The role (if any) of railroad systems for transporting straw to distant facilities

Ash disposal methods might be the same as for existing boiler ash, but could be influenced by changes in the ash content and classification resulting from burning straw. The volume of ash generated may increase relative to the current fuel used to fire the industrial boiler and/or added energy generating capacity.

Economies. Trucking, electric utility, and straw storage and handling are sectors of the local economy that will be directly impacted by the use of straw as a fuel source. Other sectors of the economy will also be impacted due to indirect and induced effects of these direct economic impacts. Straw storage facilities also will have to be constructed to ensure a reliable supply of fuel.

If the straw needs to be processed prior to its use as a fuel source, such facilities will need to be constructed and operated for that purpose. This may create some employment and income impacts. Employment impacts will be slight if straw were used to replace another fuel source in an existing facility.

Additional energy production in the industrial plant will reduce the amount of energy that will need to be generated for other facilities.

Under current energy development programs, alternative energy (cogeneration) facilities may sell the power they generate to utilities at a predetermined rate. This rate is the avoided cost the utility will incur to generate that power at a new powerplant of their own. This allows the power generator to sell the power at rates that are somewhat greater than the current market rates for purchased power.

Acceptance Values. Because this alternative involves a modification of an existing high impact facility located in an industrial area suited for this use, the level of public objection to an expanded facility should be less than for a new powerplant.

Home Stoves

It is assumed that pelletized straw would be used for use in home stoves, although bale burners, straw logs, or cubed straw use would also apply. Straw would be processed on-farm prior to sale.

Regulatory Issues

Air. Air permits are not required for using straw fuel in residential heating stoves; although, some local governments do regulate wood stove use (e.g., Jackson County), and this trend may be increasing. The types of air pollutants from a stove include particulates and smoke. Odor can be a problem with slow-burn stoves. Because of the reduced efficiency of a stove relative to an industrial combustion unit and because direct air pollution control equipment is not used on stoves, the amount of air pollution per ton of straw fuel will be greater for a stove than for a powerplant. Air quality impacts from residential stoves are harder to manage and control than powerplant impacts and could be greater from a regional air quality prospective.

Water. Residential use of straw fuel probably will not have water quality impacts.

Noise. Individual home stoves will not be a significant noise source. Delivery of straw pellets to individual homes will not be a significant noise source. The trucking and on-site bulk handling common to all the uses will apply to home stoves.

Land Use. Home stove use is unregulated by land use laws. Local comprehensive plans, however, may indirectly address air quality impacts caused by home stove smoke. These impacts might be addressed through locally issued building or stove permit performance standards.

The agricultural commercial use conditions could apply for on-farm structures involved in storage of pellet fuels using at least 51 percent on-farm straw in exclusive farm use agricultural zones.

Social Issues

Infrastructure. The transportation facility requirements of using straw for home stove use, and the effects of the industry on the facilities, will depend on:

- The number of facilities producing straw pellets for sale
- The number of process phases through which the straw must be handled
- Location of ports for export of pellets if they are marketed outside the region

Home stove use of straw pellets will generate a considerable amount of ash, the initial disposal of which will be left to the user. Disposal of home stove ash is currently largely unregulated. Ash disposal currently is done mostly on the user's property, or by placing it in garbage cans. Nonpoint source controls over ash disposal could be a concern if significant amounts of ash were deposited on home properties. A significant contribution to the municipal waste flow could result if many users deposit stove ash into garbage cans.

Economies. Use of straw in wood stoves could reduce the usage of wood and other materials in wood stoves and/or reduce the demand for other heating supplies (i.e., gas, oil, and electricity). The employment impacts of the reduced demand for energy from other suppliers will depend on the magnitude of the reduction in demand for those energy or fuel sources. If the straw needs to be processed prior to its use as a fuel source, such facilities will need to be constructed and operated for that purpose. This may create some employment and income impacts.

Acceptance Values. Oregon consumers might appreciate using another locally produced material for home heating purposes. Additionally, increased ease in handling the fuel over wood might be favored by the public. However, concerns about the effects of possibly increased air pollution caused by unregulated home stove use, as well as concerns with global warming and the ozone layer, could offset the appreciation values locally. The unknown economic variables of this alternative (e.g., market acceptance of straw pellets, market region, etc.), make an assessment of the social values relating to this alternative difficult to assess.

Chemical Production plant

It is assumed that a new chemical production plant (e.g., gasification or hydrolysis) would be similar to the scale and requirements typical of a pulp or paper mill.

Regulatory Issues

Air. A large new chemical production plant will consist of reactor vessels, tanks, boilers, piping, and power generating equipment. The types of air pollutants will depend on the specific processes used, chemicals used, and types of supplementary fuel used. An air permit will be required. The level of air pollution control will depend on the quantities of pollutants and site location.

Water. Wastewater could be generated in significant quantities in a new chemical plant. The process will dictate the quantity and character of wastewater discharged. The site location and receiving stream (river or sewer) will dictate what permitting approvals will be required.

Noise. A chemical production facility could have significant noise sources. Typical noise sources will include electric motors and bulk handling equipment. This type of plant should require much less noise control than a powerplant.

Land Use. The acreage requirements are similar to existing industrial resin/binder production plants, such as those located in Medford or White City. The following siting criteria will apply to a chemical plant:

- Fairly large parcel of land
- Near major transportation routes
- Industrial zone
- Distance from population center

It can be expected that all jurisdictions in Oregon will permit a chemical production plant only in lands zoned for heavy-industry uses. The type of land-use permit application review will depend on the characteristics of permitted and conditionally permitted uses allowed in the industry zone; however, it can be assumed that public hearings will be required in conjunction with a detailed site development plan review.

The water requirements of a chemical production plant will depend on its operating requirements, as discussed for powerplants. An OWRD water appropriation permit will be required to develop new water systems for use in this industrial process.

Of all the alternatives, a new chemical production plant will probably involve the greatest complexity and amount of time with respect to land use and environmental permitting. Environmental research, design work, and permit application reviews could be expected to require 18 to 24 months.

Social Issues

Infrastructure. Transportation and utility considerations will be similar to those discussed for a powerplant. Energy consumption could be significant.

Waste Disposal. Most waste streams are minimized or sold as coproducts. Disposal options may include landfill, land application, or incineration. If the amounts of materials requiring disposal are significant, there likely would be strong public objections.

Economies. The impacts to economies from constructing a large plant for producing chemicals from straw could be very similar to the impacts of using the straw for fuel. However, as an exception to this, there could be direct impacts on the sectors of the economy involved in use of chemicals rather than the production of energy. The impacts of the two issues will differ primarily because of (1) the size of their operations and their associated resource demands, (2) the potential returns to the owners of each plant, (3) the location of the plant, and (4) the economic returns to grass seed growers.

Acceptance Values. Basically, the same social values discussed for a powerplant could be expected to apply to a chemical plant. A significant difference could lie in the public attitudes toward production and transport of toxic chemicals or residues.

Pulp Mill

We assume that an existing pulp mill would be modified to accommodate straw as a source of pulp. A pulp mill could also use straw for energy production or steam used in the facility's operation. Should power production also be considered by the pulp mill operators, the previous discussion of issues related to straw as a fuel for existing facilities could apply. Should a new plant be considered, then the issues related to chemical plants would apply.

Regulatory Issues

Air. Air pollutant emissions from a pulp plant modified to use grass straw will be generated from the pulping process equipment vents, chemical handling, and recovery operations. The types of air pollutants will depend on the chemicals used in the process. A new fiber line at an existing pulp mill will require that the air permit for the mill be modified to include the new equipment. Equipment typically used to control these emission sources are scrubbers.

Water. Pulping operations tend to use large quantities of water. The used water is treated in on-site wastewater treatment plants and discharged into surface waters. The NPDES permit for an existing pulp mill may need to be modified if the quantity and character of the permitted discharge changes with the addition of a new fiber line. The use of different chemicals in the pulping process may alter the types of water pollutant discharges.

Noise. A pulping plant can be a significant noise source depending on the specific equipment used. Typical noise sources will be pump motors, fans, and boilers as well as mobile sources, such as loaders. It is anticipated that modifications for straw use will not impact the existing noise sources, unless special processing equipment for the straw were installed and a noticeable effect were produced on current noise conditions.

Land Use. Of all the large-scale structural alternatives, expanding an existing heavy industry facility involves the least regulatory land-use review. Existing facilities are usually consistent with land-use zones, and on-site operational expansions are usually permitted outright or require only administrative review of site plans. It should be reiterated, however, that commercial sale of energy may trigger land-use regulatory review similar to that discussed for powerplants.

Generally, the land-use permit reviews required for powerplants will apply to pulp mill expansion. Environmental impacts or circumstances that might trigger more complex land-use permit application review include:

- Substantial impacts to local transportation facilities
- Expansion of the industrial site to accommodate straw storage. The significance of this issue could increase if the expansion involves improperly zoned land, development of a new commercial energy industry, and/or impacts to critical natural or cultural resources
- Expansion of a nonconforming facility

A modification to an existing water appropriation permit will be required if the plant modification and subsequent operations required additional water.

The overall time requirements and complexity of the environmental and land-use permitting process for a modification to a pulp plant will be expected to be similar to the modified straw-fuel facility alternative.

Social Issues

Infrastructure. The impacts to transportation facilities resulting from a pulp mill expansion will be similar to those discussed for a powerplant, depending on the capacity and location of the expansion.

Solid wastes generated by pulp mills primarily consist of wastewater sludges. Some sludges have odors; therefore, sludges are often disposed of in landfills or combusted in incinerators or boilers to produce energy.

Economies. Trucking, railroad, and straw storage and handling are sectors of the local economy that will experience additional activity if straw were used as a fiber source. However, this increased activity could be partially offset by reduced trucking of wood residue, which straw will replace. Other sectors of the economy will also be impacted due to indirect and induced effects of these direct economic impacts.

Impacts on the grass seed industry are expected to be minimal unless the volume of straw used is significant.

Acceptance Values. Using straw for pulp production could help offset the economic and social impacts that reductions in the timber supply will have on the pulp industry. Expansion of an existing plant should be less objected to than new facilities. The public would have to accept pulp products made from straw, especially if product appearance were affected.

Strawboard Plant

Under this scenario, a new strawboard plant is developed by modifying an existing fiberboard plant to use straw with or without wood fiber. More than one facility is assumed.

Regulatory Issues

Air. Air permits will be required for a strawboard plant. Site location may influence the permitting and air pollution control requirements. The sources and types of air pollutants will depend on the specific design of the manufacturing process and chemicals used. Power generation combustion units or natural gas-fired driers will generate PM, NOx, CO, and VOC emissions. Chemicals used in the binders may volatilize as air pollutants. Air pollution control equipment may be required if the quantities of emissions are significant.

Water. A strawboard plant will have similar water issues as a pulp mill, except the quantities of water and types of constituents in the wastewater should be less severe. The type permitting (NPDES or sewer) and treatment requirements will depend on the site location.

Noise. A strawboard plant could potentially be a significant noise source depending on the specific equipment used. Typical noise sources will be pump motors and fans, and mobile sources, such as loaders. Similar siting and mitigation considerations apply as for powerplants.

Land Use. The acreage that a strawboard plant will require is unknown. However, numerous plywood and particleboard mills in Oregon can serve as comparative facilities for siting studies. Specific siting criteria will probably involve:

- Industrial zoning
- Proximity to truck and/or railroad facilities
- Distance from residences

All jurisdictions would consider placement of a strawboard plant in an industrial facility requiring urban level industrial services such as sewer and wastewater treatment facilities and power utilities. Because a strawboard plant will use agricultural byproducts, some county jurisdictions might consider a strawboard plant a commercial activity in conjunction with an agricultural use, which is generally permitted by state law in agricultural zones as a conditional use. However, two factors greatly influence this approach:

1. The agricultural commercial use conditions will apply.
2. An Oregon Supreme Court ruling (1000 Friends of Oregon vs LCDC/Curry County - SC S31859) suggests that developments requiring urban level services should be located in incorporated areas or within Urban Growth Boundaries around cities.

Large strawboard plants will probably need to be sited in industrial zones in or near cities.

Therefore, large strawboard plants will probably need to be sited in industrial zones in or near cities. Land use permits/reviews required include:

- Permitted Outright: This will probably apply in most city or county heavy industry zones, provided other environmental permits were obtained. Certain light industry zones may accommodate facilities with limited indoor straw-storage. A large amount of outdoor or indoor straw storage could increase the complexity of the land use permit review that will be required.
- Conditional Use: This could apply to small strawboard plants using largely operator-owned straw in an agricultural zone.
- Site Plan Review: Site plan review and comprehensive plan compatibility review may not be required for modification of an existing fiberboard plant if spatial use and impacts were not significantly different. The review will focus on the facility's conformance with environmental and design performance standards, including landscape, setback, traffic pattern, parking, and other nuisance abatement measures.

A water appropriation permit issued by the OWRD may be required for a strawboard plant, depending on the manufacturing requirements and availability of municipal water.

Social Issues

Infrastructure. Transport of straw for a strawboard plant will involve impacts similar to those identified for a powerplant or chemical plant, depending on the size of the facility.

Provisions will be necessary for solid waste issues created by a strawboard plant.

Economies. Trucking, railroad, and straw storage and handling are sectors of the local economy that will experience additional activity if straw were used as a fiber source. However, this increased activity could be partially offset by reduced trucking of wood residue, which straw would replace. Other sectors of the economy will also be impacted due to indirect and induced effects of these direct economic impacts.

Some direct employment and income will be created. However, the production of strawboard could change the amount of employment and income generated in the production of competing building materials. Consumers might benefit from the competition generated by the alternatives.

Impacts on the grass seed industry are expected to be minimal unless the volume of straw used is significant.

Acceptance Values. Closed plywood plants serve as facilities that could be refitted for producing strawboard. The socioeconomic values of potentially using closed plywood mills in the Willamette Valley are obvious:

- The up-front capital investments can be significantly reduced provided the facilities could be modified
- An unemployed labor force may already exist that will require little retraining

Expansion of an existing plant should be less objectionable than new facilities. However, straw products would have to be found acceptable in the marketplace, construction industry, and building codes.

Feed

This alternative involves the increased use of straw bales or densified straw for cattle feed, a market that already exists in Oregon. Straw would be densified using either in-field, on-farm, or local commercial densification facilities. More than one facility is assumed.

Regulatory Issues

Air. Air quality impacts will be similar to all alternatives and will involve dust from material handling and vehicle emissions from transportation.

Water. Water quality impacts will not be expected from operations handling straw for feed.

Noise. Baling and trucking straw will have the general impacts discussed for all alternatives. If straw were pelletized for feed prior to transportation, noise level increases on the individual farms could be significant.

Land Use. This alternative generally requires less industrial processing than the fuel, fiber, and chemical alternatives. Subsequently, land use impacts and land use regulations are expected to be less complex. Land use regulations will apply to siting and operation of a network of storage and/or densification facilities. Related land use permits and reviews for these feed-related facilities could include the following:

- Permitted Outright: This could apply to storage facilities and operation of portable densification machinery in exclusive farm use agricultural zones; and, storage and densification facilities in most medium to heavy industrial zones.
- Conditional Use: This could include fixed densification facilities in agricultural zones in which the agricultural commercial use conditions could apply.

Social Issues

Infrastructure. Impacts to the roadway network of cities housing major export terminals could be significantly impacted by a substantially expanded baled-straw export alternative. Impacts will probably first affect Portland, where the existing export market is centered, but might later affect other coastal ports or railroad terminals if foreign or domestic straw-feed markets are substantially expanded.

Economies. Trucking, straw storage and handling, and grass seed industries are the sectors of the local economy that are expected to be directly impacted by the increased use of straw as an animal feed source. Other sectors of the economy will also be impacted due to indirect and induced effects of these direct economic impacts.

Increased straw use as a feed source could create additional activity in the trucking industry as more of the straw, that is currently being burned, could be transported to the feed lots or to Portland for shipment to Japan or other overseas markets.

Use of straw will decrease the demand for other high-fiber feeds and roughage.

The increased use of grass straw for shipment overseas will also increase the number of straw storage facilities and the amount of straw handling activities, either baling or densifying the straw.

The impact on the grass seed industry will depend on whether increased use of the straw for feed will increase or decrease the economic returns to grass seed growers. In addition, if only certain varieties of grass straw could be used as feed, then some change in the grass seed mix could occur.

Acceptance Values. Farmers have noted that on-farm densification of new straw shipments could involve additional mechanical operations that will increase the potential for employee injuries for which the operator will be responsible. Otherwise, the farmer is well qualified and prepared for this change in the feed market area.

Composting and Mulching

The other alternatives considered in this chapter are composting and mulching. Commercial composting and mulching of straw from numerous grass seed farms and on-farm composting are considered here.

Regulatory Issues

Air. In the case of on-site reuse and composting or mulching, potential odor impacts from decomposition gasses may be the most important air quality issue. These impacts will increase for commercial composting operations. The impacts are largely unregulated except through discretionary local nuisance abatement ordinances. Proper handling practices and holding times will minimize impacts.

Water. Leachate from composting operations, particularly large-scale commercial facilities, could have significant impacts on groundwater and/or surface water quality. It will be important to coordinate siting, construction, and operation of a facility with the Oregon Water Resources Department to identify local aquifer and well characteristics, and the DEQ to identify an appropriate leachate barrier construction, maintenance, and monitoring program.

Noise. Composting or mulching of straw could involve the use of choppers, windrowing machinery, diesel engines, and loaders. These types of operations imitate existing farming equipment, and their impacts are felt to be negligible.

Land Use. Important siting criteria for commercial composting or mulching facilities include:

- Water availability and location
- Appropriate drainage or topography
- Depth to the water table (to avoid contamination by leachate)

Non-commercial, on-farm composting operations are clearly permitted outright in EFU zones. The agricultural commercial use conditions will apply to a commercial composting operations, depending on the amount of owner-operated straw used.

Water appropriation permits may be required for composting operations, particularly for commercial facilities.

Overall, this alternative will probably require the least complex environmental and land-use permit review of all of the alternatives.

Social Issues

Infrastructure. On-farm composting operations will involve minimal changes to transportation facilities; volumes of materials transported will be quite small. The transportation impacts resulting from a commercial composting or mulching operation, or series of facilities, will be similar to those described for the feed alternatives.

If the grass straw were completely utilized in this alternative (i.e., returned to the soil), solid waste would not be generated. However, unused, partially decomposed straw disposal may be required at some times.

Economies. Commercial composting and mulching will involve similar impacts as those identified for feed alternatives.

The nonfarm economic impacts of composting the straw or using the straw for mulch are expected to be relatively small.

Acceptance Values. Grass seed farmers will be concerned that the effort invested in on-farm composting will be compensated for by the benefits to on-farm soil fertility or by revenues from commercial operations. Many farmers are cautious about the practicality of integrating large-scale, space consuming composting operations on their farms, especially on land that could otherwise grow grass seed. This would be balanced, however, by the land made available from present day fire-breaks provided as part of field burning requirements. The farmer would realize overall benefits from timing of straw removal/processing and storage benefits from composting.

Table 10-2
Summary of Air Quality Issues

MARKET ALTERNATIVE	AIR QUALITY: Impacts & Considerations	AIR QUALITY: Permitting & Complexity
Fuel		
New 20-Megawatt Power Plant	High Emissions levels, types of pollutants	High New ACDP 12 to 18 months
Fuel Conversion	Medium - Low Depends on existing fuel(s)	Medium Modified ACDP
Home Stoves	High Uncontrolled emissions, odor potential	Medium - Low Building installation permits help control pollution
Chemical		
Production Plant	Medium - High Emissions levels, types of pollutants	High New ACDP 12 to 18 months
Fiber		
Modified Pulp Mill	Medium - Low Depending on differences in pollutants	Medium Modified ACDP
Strawboard Plant	Medium - High Emissions quality, quantity	Medium - High New ACDP 12 to 18 months
Feed	Medium - Low Trucks, dust	None
Other		
Composting & Mulching	Low - Medium Possible odor problems	None

Table 10-3
Summary of Water Quality Issues

MARKET ALTERNATIVE	WATER QUALITY Impacts & Considerations	WATER QUALITY Permitting & Complexity
Fuel		
New 20-Megawatt Power Plant	High Discharge volume and rate	High NPDES Up to 24 months
Fuel Conversion	Medium - High Depends on scales of facility	Medium - High Modified NPDES possible
Home Stoves	Low - Medium Depends on point/non-point impacts from uncontrolled ash disposal	Low If processing requires no water discharges
Chemical		
Production Plant	High Discharge volume, rate, and quality	High NPDES Up to 24 months
Fiber		
Modified Pulp Mill	Medium - High Discharge volume, rate, and quality	Medium - High Modified NPDES possible
Strawboard Plant	Low - Medium Discharge quality	Low - Medium Modified NPDES possible or sewer discharge
Feed	Low - None	None
Other		
Composting & Mulching	Medium - High Leachate control	None for on-farm, unknown for commercial

Table 10-4
Summary of Noise Issues

MARKET ALTERNATIVE	NOISE * Impacts & Mitigation Complexity
Fuel	
New 20-Megawatt Power Plant	High DEQ regulations
Fuel Conversion	Low With few changes to facility
Home Stoves	Low - Medium Local densification impacts
Chemical	
Production Plant	Medium - High DEQ regulations
Fiber	
Modified Pulp Mill	Low - Medium Depending on modifications to existing machinery
Strawboard Plant	Medium - High DEQ Regulations
Feed	Low - Medium Local densification impacts
Other	
Composting & Mulching	Low Similar to normal farm machinery

* Noise impacts are regulated by standards and require no permits.

Table 10-5
Summary of Land Use Issues

MARKET ALTERNATIVE	LAND USE			
	Land Acquisition Considerations	Environmental Studies: Likelihood & Complexity	Permitting Complexity *	Water Appropriation Complexity
Fuel				
New 20-Megawatt Power Plant	High 20 to 40 acres, location	High	High Public review very likely because of impacts, sensitivity	High 75,000 to 150,000 gpd of low dissolved solids
Fuel Conversion	Medium Possibility for storage & handling	Medium	Low Public review possible if new land required	Medium - High Depending on original fuel source
Home Stoves	Low Possibility for densification facility	Low	Low Possibility for densification facility	Low
Chemical				
Production Plant	High 20 to 40 acres, location	High	High Public review very likely because of impacts, sensitivity	Medium - High
Fiber				
Modified Pulp Mill	Medium - Low Possibly, for added storage & handling acreage	Medium - Low Possibly, for added storage & handling acreage	Medium - Low Public review possible if new land is needed	Low - Medium Possibly modified
Strawboard Plant	High - Low Depending on new vs. modified, and storage needed	Medium Depending on new vs. modified, and storage needed	Medium Public review possible if a new facility is built	Unknown
Feed	Low Possible for stationary pelletizing facility	Low	Low	Low
Other				
Composting & Mulching	None - Medium Depending on farm vs. commercial use	Low	Low	Medium - High If private, may require additional applications

* All new facilities, except storage sheds, will require building permits and probably fire and life safety review.

Table 10-6
Summary of Social Issues

MARKET ALTERNATIVE	SOCIAL ISSUES			
	Infrastructure *	**Waste Disposal**	**Economies**	**Acceptance Values**
Fuel				
New 20-Megawatt Power Plant	High Point specific; possible hazardous waste hauling	High Large volumes, potential hazardous classification, location problems	High Pollution Control Tax Credits, job opportunities	High New point-specific impacts
Fuel Conversion	High Possible urban impacts and/or hauling	High	Low Pollution Control Tax Credits	Medium - Low Use of existing facility lessens concern
Home Stoves	Medium - Low	Low - Medium Uncontrolled; ash disposal can be mitigated through education	Low - Medium Job opportunities	Low - Medium Ease in handling, air pollution concern, local product
Chemical				
Production Plant	High - Medium Point specific; possible hazardous waste hauling	High Large volumes, potential hazardous classification; location problems	High Pollution Control Tax Credits, job opportunities	High Unknown, new, point-specific impacts
Fiber				
Modified Pulp Mill	High - Low depending on how existing fiber is delivered	Low - Medium Use of sludge in fuels or disposal	Low - Medium depending on the degree of expansion	Medium - Low Use of existing facility lessens concern
Strawboard Plant	Medium - Low	Medium	Medium - High Could reduce loss of jobs in plywood sector	Medium - Low New vs. modified, proximity to populations
Feed	Medium - High Possible impacts on truck, rail, and ship traffic	Low	High - Low Depending on markets	Low
Other				
Composting & Mulching	Low - Medium Possible increase in transport of new product	Low Probable, unless classified as solid waste	Low	Low Land requirements, local concern about odor

* All alternatives, except on-farm composting, would involve about the same number of straw hauling vehicle trips if fully developed on a programmatic basis. Impacts would have to be studied on a project-by-project basis.

11 Trends and Conclusions

Because straw is a byproduct of grass seed production, its market utilization (supply) is affected by the economics (supply and demand) of the grass seed commodity market. That is, the elements of supply and demand affect grass seed straw but only indirectly as they apply to grass seed. The extent of activity in markets specific to straw utilization depends quite often on the value of straw as a substitute raw material, as well as the value of the end-use product.

Risks and uncertainties are associated with the development of most markets.

As with any market, there are risks and uncertainties involved. Volume requirements and the need for stability of the raw material in terms of quality and supply are fundamental considerations for any consumer. The greatest risk is for the small user who will suffer from economies of scale and also must compete with large users for the raw materials.

Trends become evident and conclusions can be drawn from the study.

Several trends in grass seed and straw utilization markets become apparent from this study, and several conclusions can be made, as enumerated below:

1. The supply of straw will remain generally stable, even as demand grows in developing straw markets. There is a strong base of grass seed production.
2. The ability to obtain a stable straw supply of consistent quality will be an important consideration of any market developer.
3. The expansion of the grass seed market has been substantial in the last decade. However, the expansion has saturated the seed market and prices have fallen. As a result, further expansion has been curtailed through reduced production contracts.
4. Although the total grass seed acreage has stabilized somewhat, there will continue to be some acreage adjustments between grass seed types in response to the seed markets. Nevertheless, utilizations with preferences for specific straw types will experience a generally stable supply.
5. Growers will continue to develop proprietary varieties of dwarf and semi-dwarf types that have less stem than typical varieties. This shift will directly affect the volume and quality of straw.
6. The amount of straw plowed down on annual and perennial grass seed fields has gone from practically none 10 years ago to more than 200,000 tons in 1990. While this practice started as an on-farm disposal technique, growers have since detected improved tilth of their grass seed fields. However, concerns exist about increases in disease problems. The benefit from this on-farm utilization of straw will have to be weighed against any advantages of market utilization.

7. Straw availability for markets will vary with geography and demand intensity, in terms of both the location of the straw supply as well as the location of the market.
8. The quality of grass straw is dependent on its source seed type, the method used for its removal from the field, and the type of storage provided.
9. The value of straw will depend on the availability of competing byproducts (e.g., wood residues) and the end-use product.
10. The use and control of endophytes will continue to be a concern to the growers. Improved identification and certification programs for endophyte-free tall fescue and perennial ryegrass varieties will develop and expand in response to feed market demands for such information, both domestically and overseas.
11. The timber supply will continue to decline in the Pacific Northwest for several years as a result of increased habitat protection, lagging regeneration, and the general shift of timber production to the southeastern United States.
12. Supply and cost of wood residues and other wood wastes will continue to fluctuate as the wood products industry follows the demand for new housing. While the current recession may cause a decline in such activities, this may be offset by the continuing strong demand for wood products from overseas.
13. As the prices of traditional raw wood fiber materials continue to increase, the use of alternative wood waste materials and other fiber sources will increase in the pulp and paper and structural panelboard industries.
14. Competition for both hog fuel and wood chips will continue between local wood products plants and out-of-state fiber demands.
15. Demand for power, in general, will increase beyond surplus levels in the Pacific Northwest. Additional limitations will be felt as policy decisions regarding salmon runs on the Columbia River affect hydropower plants. Power rates will rise as the need for additional power increases.
16. People will continue to move to Oregon to enjoy our healthy environment. Most will move into an urban environment where land is viewed as a place to live on and not as a place from which to earn a living. This attitude will affect land use issues associated with any straw market under consideration.
17. The increasing environmental awareness of the general public will be a key issue for any market developer. Increased scrutiny from the public of potential environmental impacts should be anticipated.
18. Public concern will continue about air quality (contamination and odor), wastewater discharge and cleanup, noise levels, process byproduct utilization or disposal, and transportation impacts (increased emissions and volume of traffic).

19. Implementation of a straw utilization technology will be more acceptable to the public if it can take advantage of an existing facility and/or site.

20. Market development implies job opportunities. Increases in employment will improve local economies and be viewed as a benefit by the public.

Appendix A

Public Meeting Comments

As part of the investigation of potential straw utilization technology and markets, a series of three public meetings was held. The meetings were held to serve two purposes: inform the audience about the scope of the study and its purpose, and solicit input from the audience with respect to additional uses of straw and issues that should be included in the study. A professional facilitator was used to ensure that during each meeting, sufficient time was allotted for each purpose, and especially to make sure every attendee had the opportunity to express ideas and concerns.

Each meeting began with an explanation of the study by CH2M HILL and Oregon State University. The facilitator divided the audience into groups. Each group was then asked to identify any ideas and issues that should be included in the study. The groups then reassembled for a summary of the discussions of each group.

For each of the three meetings, the straw use ideas of each group were categorized according to market (i.e., feed, fuel, fiber, chemical, and other) and the impacts/concerns associated with the utilization idea. The following pages list the input received during the public meetings.

Eugene - 10/16/90

Group 1

Market		Impacts
Fuels:	Central Power Plant Home market (firelogs)	Emissions, efficiency, transport Storage, retrofit costs
Fiber:	Strawboard (decorative) Paper making Paper	Farmer incentive to cooperate Market demand, cost of storage Resins, chemicals
Feed:	Fiber from seed (screenings)	
Chemical:	Methanol Ethanol Methane gas	
Other:	Composting Other crops Bedding material Mulch (landscaping) Soil amendment	Public awareness of study results

Eugene (continued)

Group 2

Market		Impacts
Fuel:	Ethanol Methanol Bulk fuel for power plant	Transportation & handling Limited supply
Fiber:	Straw particle board	Tax credits for entrepreneurs
Other:	Mushroom media On-farm composting In-vessel composting Assist current projects (regional strategies)	

Albany/Corvallis - 10/17/90

Group 1

Market		Impacts
Feed:	Animal feed	Endophyte
Fuel:	Cogeneration Home use	Storage, transportation, supply Cost to gather, siting, EIS
Fiber:	Paper Strawboard (decorative, structural)	Cost of facilities
Chemical:	Chemicals	
Other:	Mulch Soil amendments	

Group 2

Market		Impacts
Fuels:	Power plant fuel Pellets for home heating Firelogs	Storage, steady supply, emissions Plant costs, transportation Silica in ash
Feed:	Straw feed	Pesticide residue
Fiber:	Building materials (straw "chip" board) Pulp - for paper and cardboard	 Volume of supply, economics
Chemical:	Ethanol	
Other:	Composting Expand export market Chemical sanitation & disposal Microwave sanitation Straw dust mulch	Availability of water Pest & disease control Nutrient replacement

Group 3

Market		Impacts
Fiber:	Market for second quality straw Silage Feed lot opportunities Pulp for paper Kitty litter Packaging material	

Albany/Corvallis (continued)

Chemical:	On-farm methane generator	
Other:	Composting with sewage sludge Composting with paper sludge Multiple solutions	 Dioxin problems

Group 4

Market		Impacts
Fiber:	Strawboard Packing material Insulation Building material (concrete/straw) Straw twine Paper	
Feed:	Animal feed	
Fuel:	Steam (power) Use existing plant boilers (Halsey)	
Chemical:	Pyrolysis Methane	
Other:	Composting Technology transfer Erosion control	

Group 5

Market		Impacts
Fuel:	Home heating (firelogs) Straw/hog fuel in boiler	Pollution, transportation
Fiber:	Insulation Particle board Brick Pulp - paper, textiles Paper	 Delivery, supply
Feed:	Export/domestic Fiber (screenings)	Contamination, insects
Chemical:	Gasification (methanol)	
Other:	Compost (on-farm, central) Mulching	

Salem - 10/18/90

Group 1

Market		Impacts
Fuel:	Presto logs, pellets 50/50 wood/straw in boilers Small power plants	Emissions, smoke, odor Straw supply declining Better match to straw supply
Feed:	Expand existing export market Domestic feed (E. Oregon)	Pesticide residue
Other:	On-farm use (composting) On-farm heating, drying	Traffic impacts if off-farm

Salem (continued)

Group 2

Market		Impacts
Fuel:	Cogeneration	Competing costs
Feed:	Animal feed	Transportation costs
Fiber:	Strawboard Pulp	Environmental impacts
Other:	Compost Mushroom plants	Technology problems

Group 4

Market		Impacts
Fiber:	Pulp (textiles) Paper Building materials (structural) Insulation Strawboard (decorative)	Increased raw material cost Increase straw storage costs
Fuel:	Pellets, cubes, logs Power generation (water, freon cycles)	Emissions, silica in ash Transportation
Feed:	Animal feed	
Chemical:	Ethanol, methane Pyrolysis	 High capital costs
Other:	On-farm composting Mulches (roadside, garden)	

Group 5

Market		Impacts
Feed:	Animal feed (blue grass)	Pesticide residue
Fuel:	Straw log	
Fiber:	Fiberboard	
Chemical:	Ethanol	
Other:	Maximum economic benefit, or maximum straw utilization?	

Appendix B

Table B-1
1989 Estimates of Total Grass Straw Production and Maximum Potential Available

REGION (1) GRASS SEED TYPES	ACRES (2) 1989 TOTAL	TOTAL STRAW PRODUCTION — Volume of straw produced (3) (T/acre) Low	(4) (T/acre) High	(5) (Tons) Low	(6) (Tons) High	MAXIMUM POTENTIAL AVAILABLE — Straw removed from field (7) (% of fields) Low	(8) (% of fields) High	(9) (Tons) Low	(10) (Tons) High
SOUTH VALLEY									
- Annual ryegrass	109,900	2.80	3.20	307,720	351,680	75%	90%	230,790	316,512
- Perennial ryegrass	71,800	2.25	2.75	161,550	197,450	75%	95%	121,163	187,578
- Tall fescue	46,400	3.25	3.75	150,800	174,000	75%	90%	113,100	156,600
- Orchardgrass	13,030	2.25	2.75	29,318	35,833	75%	95%	21,988	34,041
- Kentucky bluegrass	5,930	2.00	2.50	11,860	14,825	10%	50%	1,186	7,413
- Bentgrass, Colonial	3,950	1.75	2.00	6,913	7,900	100%	100%	6,913	7,900
- Bentgrass, Creeping	2,000	2.00	2.50	4,000	5,000	100%	100%	4,000	5,000
- Chewings fescue	1,650	1.50	2.00	2,475	3,300	5%	10%	124	330
- Red fescue	1,250	1.50	2.00	1,875	2,500	5%	10%	94	250
SUBTOTAL	255,910			676,510	792,488			499,357	715,623
MARION COUNTY LOWLANDS									
- Perennial ryegrass	22,000	2.50	2.75	55,000	60,500	100%	100%	55,000	60,500
- Tall fescue	14,500	4.00	4.25	58,000	61,625	90%	100%	52,200	61,625
- Bentgrass, Creeping	2,500	2.00	2.50	5,000	6,250	100%	100%	5,000	6,250
- Kentucky bluegrass	2,000	2.00	2.50	4,000	5,000	10%	50%	400	2,500
- Orchardgrass	1,600	2.25	2.75	3,600	4,400	90%	100%	3,240	4,400
- Annual ryegrass	400	3.00	3.00	1,200	1,200	75%	95%	900	1,140
SUBTOTAL	43,000			126,800	138,975			116,740	136,415
FOOTHILLS									
- Chewings fescue	10,500	1.50	2.00	15,750	21,000	5%	10%	788	2,100
- Bentgrass, Colonial	5,900	1.75	2.00	10,325	11,800	30%	70%	3,098	8,260
- Red fescue	5,500	1.50	2.00	8,250	11,000	5%	10%	413	1,100
- Hard fescue	2,000	1.50	2.00	3,000	4,000	100%	100%	3,000	4,000
- Perennial ryegrass	N/A	2.50	3.00			100%	100%		
SUBTOTAL	23,900			37,325	47,800			7,298	15,460
NORTH VALLEY									
- Tall fescue	19,500	3.75	4.00	73,125	78,000	80%	90%	58,500	70,200
- Perennial ryegrass	8,500	2.00	2.50	17,000	21,250	95%	100%	16,150	21,250
- Orchardgrass	7,000	2.25	2.75	15,750	19,250	90%	100%	14,175	19,250
- Annual ryegrass	1,500	3.00	3.00	4,500	4,500	75%	95%	3,375	4,275
- Bentgrass, Colonial	850	1.75	2.00	1,488	1,700	100%	100%	1,488	1,700
- Chewings fescue	780	1.50	2.00	1,170	1,560	5%	10%	59	156
- Red fescue	650	1.75	2.00	1,138	1,300	5%	10%	57	130
- Kentucky bluegrass	450	2.00	2.50	900	1,125	10%	50%	90	563
- Bentgrass, Creeping	200	2.00	2.50	400	500	90%	100%	360	500
SUBTOTAL	39,430			115,470	129,185			94,253	118,024
OTHER WILLAMETTE VALLEY									
- Tall fescue	3,400	3.75	4.00	12,750	13,600	80%	90%	10,200	12,240
- Perennial ryegrass	2,650	2.00	2.50	5,300	6,625	95%	100%	5,035	6,625
- Chewings fescue	1,500	1.50	2.00	2,250	3,000	5%	10%	113	300
- Red fescue	1,040	1.75	2.00	1,820	2,080	5%	10%	91	208
- Orchardgrass	710	2.25	2.75	1,598	1,953	90%	100%	1,438	1,953
- Bentgrass, Creeping	700	2.00	2.50	1,400	1,750	90%	100%	1,260	1,750
- Kentucky bluegrass	550	2.00	3.00	1,100	1,650	10%	50%	110	825
- Annual ryegrass	200	3.00	3.00	600	600	75%	95%	450	570
SUBTOTAL	10,750			26,818	31,258			18,696	24,471
WILLAMETTE VALLEY	372,990			982,923	1,139,705			736,343	1,009,992

Table B-1 (cont'd)
1989 Estimates of Total Grass Straw Production and Maximum Potential Available

REGION (1) GRASS SEED TYPES	ACRES (2) 1989 TOTAL	----- TOTAL STRAW PRODUCTION ----- ------- Volume of straw produced ------				MAXIMUM POTENTIAL AVAILABLE ---------- Straw removed from field ----------			
		(3) (T/acre) Low	(4) (T/acre High	(5) (Tons) Low	(6) (Tons) High	(7) (% of fields) Low	(8) High	(9) (Tons) Low	(10) (Tons) High
JEFFERSON COUNTY									
- Kentucky bluegrass	12,600	2.00	3.00	25,200	37,800	50%	90%	12,600	34,020
- Perennial ryegrass	1,000	2.00	2.50	2,000	2,500	95%	100%	1,900	2,500
- Bentgrass, Creeping	400	2.00	2.50	800	1,000	90%	100%	720	1,000
SUBTOTAL	14,000			28,000	41,300			15,220	37,520
UNION COUNTY									
- Kentucky bluegrass	8,440	2.00	3.00	16,880	25,320	50%	90%	8,440	22,788
- Red fescue	2,690	1.50	2.00	4,035	5,380	5%	10%	202	538
- Chewings fescue	1,930	1.50	2.00	2,895	3,860	5%	10%	145	386
- Tall fescue	590	4.00	4.25	2,360	2,508	80%	90%	1,888	2,257
- Hard fescue	60	1.50	2.00	90	120	100%	100%	90	120
- Perennial ryegrass	50	2.00	2.50	100	125	95%	100%	95	125
SUBTOTAL	13,760			26,360	37,313			10,860	26,214
OTHER AREAS									
- Kentucky bluegrass	870	2.00	3.00	1,740	2,610	10%	50%	174	1,305
- Tall fescue	610	3.50	4.25	2,135	2,593	80%	90%	1,708	2,333
- Chewings fescue	420	1.50	2.00	630	840	5%	10%	32	84
- Bentgrass, Creeping	170	2.00	2.50	340	425	90%	100%	306	425
- Orchardgrass	50	2.25	2.75	113	138	90%	100%	101	138
SUBTOTAL	2,120			4,958	6,605			2,321	4,285
STATEWIDE TOTAL	402,870			1,042,240	1,224,923			764,744	1,078,010

Table B-2
1989 Grass Straw Management (Disposal and Removal)

REGION	CURRENT GRASS STRAW DISPOSAL						CURRENT GRASS STRAW REMOVED			
(1)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
GRASS SEED TYPES	Open field burning				Straw plowdown		Straw removed		Straw volume	
	(% of fields) Low	High	(Acres) Low	(Acres) High	(Acres) Low	(Acres) High	(Acres) Low	(Acres) High	(Tons) Low	(Tons) High
SOUTH VALLEY										
- Annual ryegrass	50%	60%	54,950	65,940	43,960	54,950	0	0	0	0
- Perennial ryegrass	20%	30%	14,360	21,540	6,283	7,180	43,978	50,260	98,949	138,215
- Tall fescue	20%	30%	9,280	13,920	3,248	3,712	29,232	33,408	95,004	125,280
- Orchardgrass	20%	30%	2,606	3,909	1,140	1,303	7,981	9,121	17,957	25,083
- Kentucky bluegrass	80%	95%	4,744	5,634	30	119	267	1,067	534	2,669
- Bentgrass, Colonial	60%	90%	2,370	3,555	49	198	346	1,383	605	2,765
- Bentgrass, Creeping	0%	0%	0	0	250	250	1,750	1,750	3,500	4,375
- Chewings fescue	90%	95%	1,485	1,568	10	21	72	144	108	289
- Red fescue	90%	95%	1,125	1,188	6	13	56	113	84	225
SUBTOTAL			90,920	117,253	54,976	67,744	83,681	97,246	216,742	298,900
MARION COUNTY LOWLANDS										
- Perennial ryegrass	3%	5%	660	1,100	2,613	2,668	18,288	18,673	45,719	51,349
- Tall fescue	20%	30%	2,900	4,350	1,015	1,160	9,135	10,440	36,540	44,370
- Bentgrass, Creeping	0%	0%	0	0	313	313	2,188	2,188	4,375	5,469
- Kentucky bluegrass	80%	95%	1,600	1,900	10	40	90	360	180	900
- Orchardgrass	20%	30%	320	480	140	160	980	1,120	2,205	3,080
- Annual ryegrass	40%	60%	160	240	160	240	0	0	0	0
SUBTOTAL			5,640	8,070	4,250	4,580	30,680	32,780	89,019	105,168
FOOTHILLS										
- Chewings fescue	90%	95%	9,450	9,975	66	131	459	919	689	1,838
- Bentgrass, Colonial	50%	80%	2,950	4,720	148	369	1,033	2,581	1,807	5,163
- Red fescue	90%	95%	4,950	5,225	28	55	248	495	371	990
- Hard fescue	0%	0%	0	0	200	200	1,800	1,800	2,700	3,600
- Perennial ryegrass	3%	5%								
SUBTOTAL			17,350	19,920	441	755	3,539	5,795	5,567	11,590
NORTH VALLEY										
- Tall fescue	40%	60%	7,800	11,700	780	1,170	7,020	10,530	26,325	42,120
- Perennial ryegrass	3%	5%	255	425	1,009	1,031	7,066	7,214	14,131	18,036
- Orchardgrass	40%	60%	2,800	4,200	350	525	2,450	3,675	5,513	10,106
- Annual ryegrass	50%	60%	750	900	600	750	0	0	0	0
- Bentgrass, Colonial	100%	100%	850	850	0	0	0	0	0	0
- Chewings fescue	90%	95%	702	741	5	10	34	68	51	137
- Red fescue	90%	95%	585	618	3	7	29	59	51	117
- Kentucky bluegrass	80%	90%	360	405	5	9	41	81	81	203
- Bentgrass, Creeping	0%	0%	0	0	25	25	175	175	350	438
SUBTOTAL			14,102	19,839	2,777	3,526	16,815	21,802	46,502	71,156
OTHER WILLAMETTE VALLEY										
- Tall fescue	40%	60%	1,360	2,040	136	204	1,224	1,836	4,590	7,344
- Perennial ryegrass	3%	5%	80	133	315	321	2,203	2,249	4,406	5,623
- Chewings fescue	90%	95%	1,350	1,425	9	19	66	131	98	263
- Red fescue	90%	95%	936	988	5	10	47	94	82	187
- Orchardgrass	40%	60%	284	426	36	53	249	373	559	1,025
- Bentgrass, Creeping	0%	0%	0	0	88	88	613	613	1,225	1,531
- Kentucky bluegrass	80%	90%	440	495	6	11	50	99	99	297
- Annual ryegrass	40%	60%	80	120	80	120	0	0	0	0
SUBTOTAL			4,530	5,627	674	826	4,450	5,394	11,059	16,270
WILLAMETTE VALLEY			132,542	170,708	63,118	77,431	139,165	163,017	368,889	503,084

Table B-2 (cont'd)
1989 Grass Straw Management (Disposal and Removal)

REGION (1) GRASS SEED TYPES	CURRENT GRASS STRAW DISPOSAL (11) Open field burning (% of fields) Low	(12) High	(13) (Acres) Low	(14) (Acres) High	(15) Straw plowdown (Acres) Low	(16) (Acres) High	CURRENT GRASS STRAW REMOVED (17) Straw removed (Acres) Low	(18) (Acres) High	(19) Straw volume (Tons) Low	(20) (Tons) High
JEFFERSON COUNTY										
- Kentucky bluegrass	50%	70%	6,300	8,820	378	630	3,402	5,670	6,804	17,010
- Perennial ryegrass	3%	5%	30	50	119	121	831	849	1,663	2,122
- Bentgrass, Creeping	0%	0%	0	0	50	50	350	350	700	875
SUBTOTAL			6,330	8,870	547	801	4,583	6,869	9,167	20,007
UNION COUNTY										
- Kentucky bluegrass	60%	80%	5,064	6,752	169	338	1,519	3,038	3,038	9,115
- Red fescue	80%	90%	2,152	2,421	27	54	242	484	363	968
- Chewings fescue	80%	90%	1,544	1,737	24	48	169	338	253	676
- Tall fescue	40%	60%	236	354	24	35	212	319	850	1,354
- Hard fescue	0%	0%	0	0	6	6	54	54	81	108
- Perennial ryegrass	3%	5%	2	3	6	6	42	42	83	106
SUBTOTAL			8,998	11,267	255	487	2,238	4,275	4,669	12,327
OTHER AREAS										
- Kentucky bluegrass	80%	90%	696	783	9	17	78	157	157	470
- Tall fescue	40%	60%	244	366	24	37	220	329	769	1,400
- Chewings fescue	90%	95%	378	399	3	5	18	37	28	74
- Bentgrass, Creeping	0%	0%	0	0	21	21	149	149	298	372
- Orchardgrass	20%	30%	10	15	4	5	31	35	69	96
SUBTOTAL			1,328	1,563	61	86	496	707	1,319	2,411
STATEWIDE TOTAL			149,197	192,407	63,981	78,805	146,482	174,868	384,043	537,829

Appendix C

Strawboard Manufacturing Processes

The following descriptions and diagrams show where straw could be added and suggest a similar preparation to the straw that the wood goes through. Duplication of equipment may be necessary in areas where straw is considered as an expander to existing wood fiber. In such cases, both types of materials may require separate preparation.

Four issues are important in reviewing the drawings. First, the drawings were developed to depict one possibility for the insertion of straw into existing process lines, should it be possible to include straw as an expander for that particular process line. Second, no two plants are identical even when producing the same product. Third, the drawings are for reference only, to depict the steps a panelboard manufacturer may have to go through to ensure a quality product. Any particular plant is likely to be somewhat different. Fourth, it is possible for the straw to enter the production line at more than one place and in more than one physical form. These are technical questions to be answered with plant-specific investigation.

Market acceptance of strawboard has been a problem.

The following process descriptions for each of these products are taken from the 1990 International Resources Unlimited report.

Straw Particleboard

Straw particleboard using 100 percent wheat straw is being manufactured commercially in England. The operational plant is designed for use in Third World countries with relatively low capital investment, low operating and maintenance requirements, and is somewhat labor intensive. Such a plant would likely require special equipment for preparing the straw to operate in Western Oregon. This would include equipment for the breaking of bales, as well as fiberizing and storage of the ground materials.

Straw particleboard was successfully test produced in the 1970s (Conklin et al., 1989). Commercial production has never been attained. There may be problems of market acceptance of a 100 percent straw panelboard similar to those faced by oriented strandboard when it was first introduced. However, with major price increases for wood fiber raw materials, there is renewed interest within the hardboard industry in western Oregon in producing a straw-based particleboard or incorporating straw with wood fibers in existing hardboard plants.

The basic operation for a particleboard process follows. Drawings D-001A and D-001 depict this process with and without the use of straw, respectively.

The raw material (e.g., logs, straw) is conveyed into a size reduction machine. The chipped or chopped raw material is pneumatically conveyed to the dosing bin. From there, the material is regulated into a universal reduction machine or shredder. The shredded material is then conveyed to a dryer where the particles are dried prior to transport to a flaker screen. The top screen in the flaker takes the larger particles and deposits them in the core material storage silo. A second screen takes out the finer particles which are then conveyed to the surface material storage silo.

The raw materials (both core and surface) then travel to the flake weight scales for batch weighing. The materials are then mixed with resin in the resin blenders and are sent to the material forming station where the mat preforming takes place. The mat is preformed on a cull plate and the plate is conveyed to the multi-opening hydraulic press where pressure and heat is applied.

Straw can be best used as a supplement fiber.

After pressing, the mats are conveyed to a cooling wheel where they are removed from the plates and allowed to cool. Final processing includes trimming, sanding, inspection, grading, and stacking prior to shipment.

Medium-Density Fiberboard

In this process, it is estimated that up to 20 percent grass straw (by weight) can be used to supplement the wood fiber presently being used (IRU, 1990).

The basic operation for an MDF process follows. Drawings D-002A and D-002 depict this process with and without the use of straw, respectively.

The raw material is initially loaded into storage bins. It is then conveyed to a rock and metal separator and back to a second set of storage bins. The material is then sent to the digester where the fiber is broken down prior to the addition of wax to the material. The mixture then proceeds to the ribbon feeder which feeds the fiber through the steam heating coils to reduce its moisture content.

A belt conveyor takes the dried fiber to the fiber bin and then to a weight belt conveyor. The weight of the material signals the resin system to add the proper amount of resin to the fiber material in the resin blender. Next, the fiber is further reduced in size and conveyed to the forming machine where it is formed into mats. The mats are cut to length and trimmed. The mats are then conveyed to the multi-opening hydraulic press where pressure and heat is applied. From the press the boards proceed to the final trim saws and panel saws and are transferred into storage prior to shipment.

Hardboard

In this process, it is estimated that up to 20 percent grass straw (by weight) can be used to supplement the wood fiber presently being used (IRU, 1990).

The basic operation for a hardboard process follows. Drawings D-003A and D-003 depict this process with and without the use of straw, respectively.

The raw materials are conveyed from storage to a vibrating screen. From the screen they travel to the chip silo from which they are metered into the rotary feeders and on into the digester. From the digester they are conveyed to the refiner where further reduction in particle size takes place. Here, wet stock from the agitated stock chest is added. The material is then pumped to the board formers where the mat is laid on a wet mat conveyor. The mat then passes through the wet press and then the wet saw. The mats are then sent to the hydraulic press where pressure and heat are applied.

From the press the boards travel into the board dryer wherein air is circulated to remove moisture and cool the board. The board is removed from the dryer and sent to the trim line. The trimmed board is then inspected prior to sanding. The final product is stored or shipped directly.

Straw could be used as a core material.

Plywood

As stated earlier, dwindling log supplies generated substitute wood-fiber structural boards as substitutes for plywood. A further plywood "extender" might be the use of a thin straw particleboard which could be used as core material in a plywood panel. This would require the existence of a straw particleboard manufacturing plant capable of producing thin panels, similar to veneer, as the core material to the plywood panel. It is estimated that 50 to 65 percent of the material going into the plywood board could be made up of grass strawboard for core material (IRU, 1990). However, problems of incorporating grass core board into the lay up process of veneer will need to be investigated as will strength tests of the final product for industry acceptance.

The basic operation for a plywood process follows. Drawings D-004A and D-004 depict this process with and without the use of straw, respectively.

Raw logs are transferred from a conveyor to an automatic XY-charger for automatic positioning prior to peeling. The logs are then peeled in the lathe producing veneer. The veneer is then clipped to length and sorted. Next, moisture is removed from the veneer as it moves through a veneer dryer. The final section of the dryer allows the veneer to cool down prior to removal from the dryer. It is then graded into face and core sheets prior to use in the lay-up machine.

Through a series of glue stations, glue is applied to both sides of the core sheets and to the inside of each face sheet. It is at this point in the process where straw particleboard core sheets could be utilized. The straw sheets would be fed into the glue line as necessary. The number of core sheets depends on the desired thickness of the plywood panel. From the glue line the plywood travels to the stacker. A fork lift loads the panels into a prepressing machine. The panels are then conveyed into a multi-opening press where heat and pressure is applied. From the press, the panels are trimmed and sanded, ready for storage or shipment.

Cement-Bonded Fiberboard (Wet)

This process has been used worldwide for many years and can utilize straw as a primary or secondary fiber (IRU, 1990). Historically, straw has been used to supplement asbestos or glass fibers in fiberboard plants in Eastern Europe. In Russia, straw has been used as the primary material (2:1 or 3:1 cement to straw, by weight) but the resulting boards were of low quality in strength, surface characteristics, and composition (IRU, 1990). Fiberboard and bricks manufactured in Central Africa with a 5:1 ratio of straw were of good quality as were light standards and utility/telephone poles produced in East Germany, also using a 5:1 ratio of straw (IRU, 1990).

Straw can be used as a primary or secondary fiber in cement-bonded fiberboard.

This process has the possibility of replacing up to approximately 30 percent (by weight) of the wood fiber currently used with straw fiber (IRU, 1990).

The basic operation for a CFBW process follows. Drawings D-005A and D-005 depict this process with and without the use of straw, respectively.

Raw materials enter the particle generator where size reduction takes place. The particles are transferred to a dryer for moisture removal and then into a screening process. The coarse material, used for the core of the board, is removed to one mixing bin and the fine material, used for the face material, is removed to another mixing bin. In these two bins, chemicals and cement are added.

The material is then transferred to the mat forming station where the back, core, and surface layers are assembled, forming a mat. The mats are then loaded into a prepressing machine, then conveyed into a multi-opening press where heat and pressure is applied. From the press, the mats are transferred on a cooling conveyor to the final processing area. The boards are trimmed, sanded, and graded prior to stacking, packaging and storage or shipment.

Cement-Bonded Fiberboard (Dry)

This process can also utilize straw as a primary or secondary fiber. In Finland, product integrity tests are underway to utilize Oregon ryegrass straw as an extender in dry cement-bonded fiberboard wherein some 20 to 30 percent of the panel (by weight) would be straw (IRU, 1990).

The basic operation for a CFBD process follows. Drawings D-006A and D-006 depict this process with and without the use of straw, respectively.

Wood chips are delivered from the chip hopper and are conveyed to a chip screen where the particles are sorted, allowing the small pieces to pass on to the chip bin and sending the large ones back for further size reduction. The small chips are then conveyed into a knife-ring flaker. At this point, straw would enter the process.

Grass straw and chips from the flaker would be sent through a hammermill knife for further size reduction. The particles are then conveyed into a wet flake bin before being dried in the flake dryer. The material is then sent to another screen for further size separation. The small particles continue into the dry flake bin and metering silos. The larger ones are recycled.

The material is then mixed with cement, paint, and lime prior to being weighed and distributed into a forming station, where the board is formed. The boards are loaded

into a press which uses CO_2 to speed up the setting and curing of the product. The product is then cleaned and trimmed prior to storage.

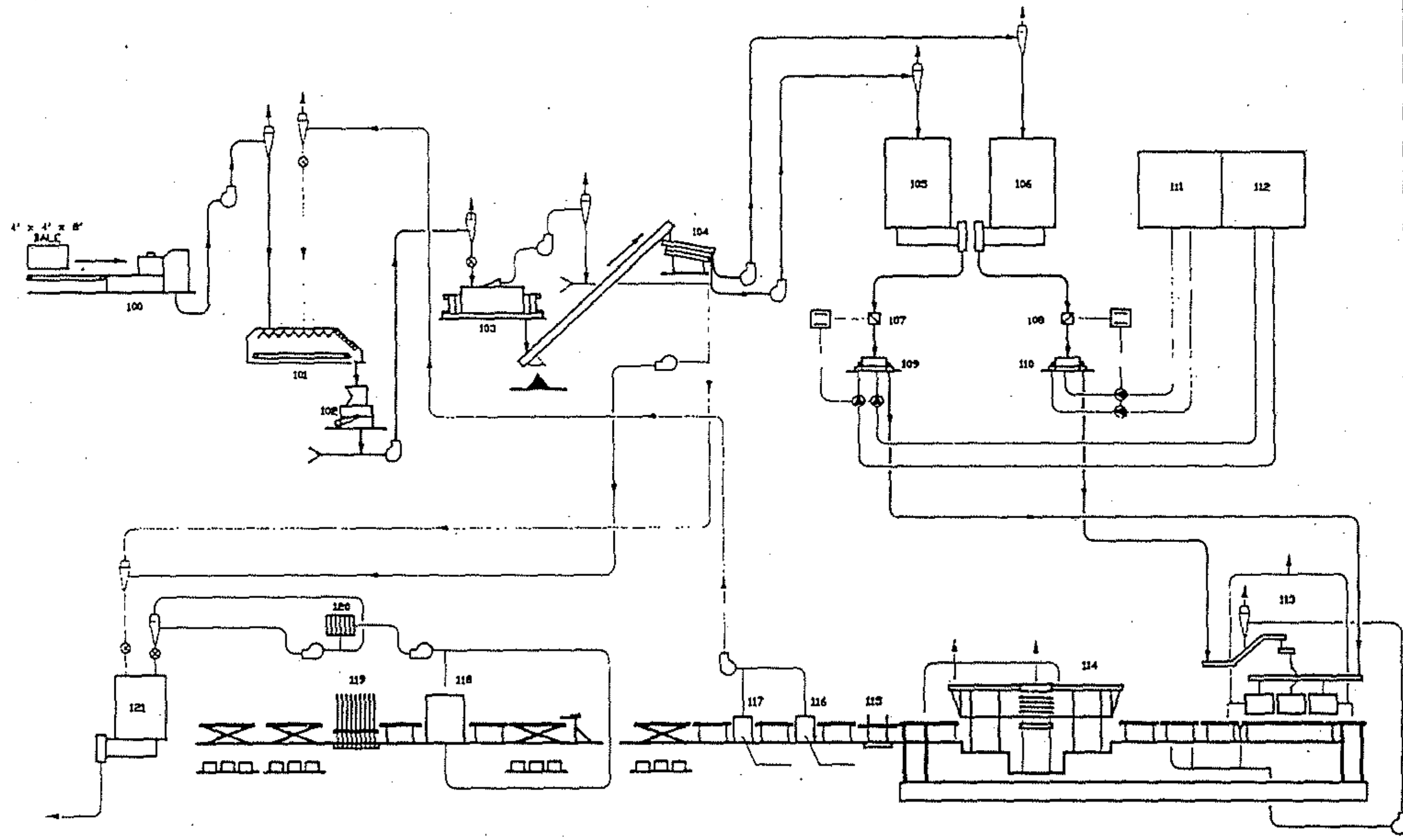


	DIAGRAM NUMBER KEY
100	BALE BREAKER
101	DOSING BIN
102	UNIVERSAL REDUCTION MACHINE
103	DRYER
104	FLAKE SCREEN
105	SILO-SURFACE
106	SILO-CORE
107	FLAKE WEIGHT SCALE
108	FLAKE WEIGHT SCALE
109	RESIN BLENDER
110	RESIN BLENDER
111	RESIN PREP. UNIT
112	RESIN PREP. UNIT
113	MATERIAL FORMING STATION
114	MULTI-OPENING HYD. PRESS
115	COOLING WHEEL
116	TRIM SAW
117	TRIM SAW
118	SANDING MACHINE
119	BOARD INSPECTION TURNER
120	DUST FILTER
121	SILO

CLIENT
OREGON STATE UNIVERSITY
CORVALLIS, OREGON

DRAWING TITLE
PARTICLEBOARD
FLOW DIAGRAM

DRAWING NO.
D-001A

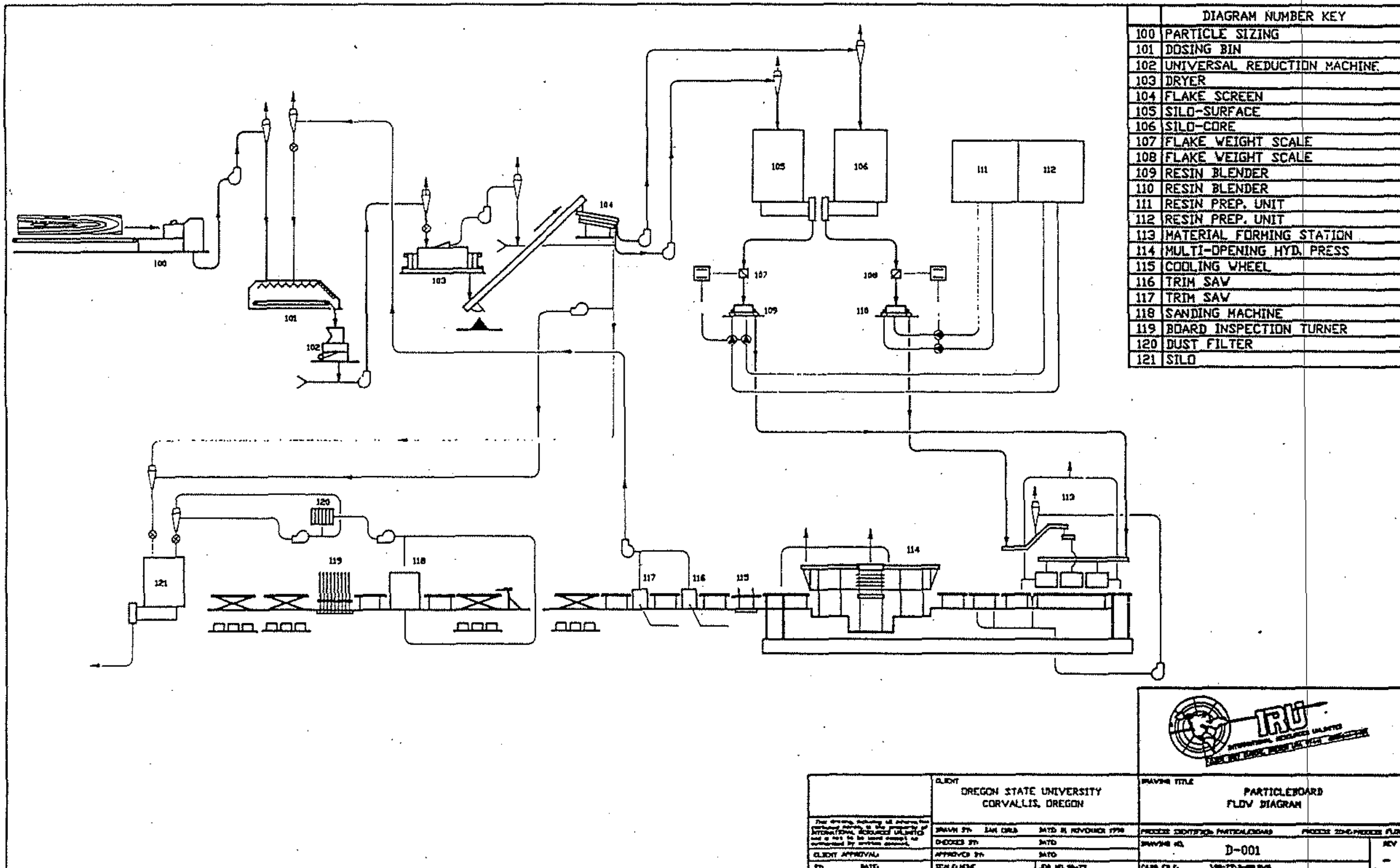
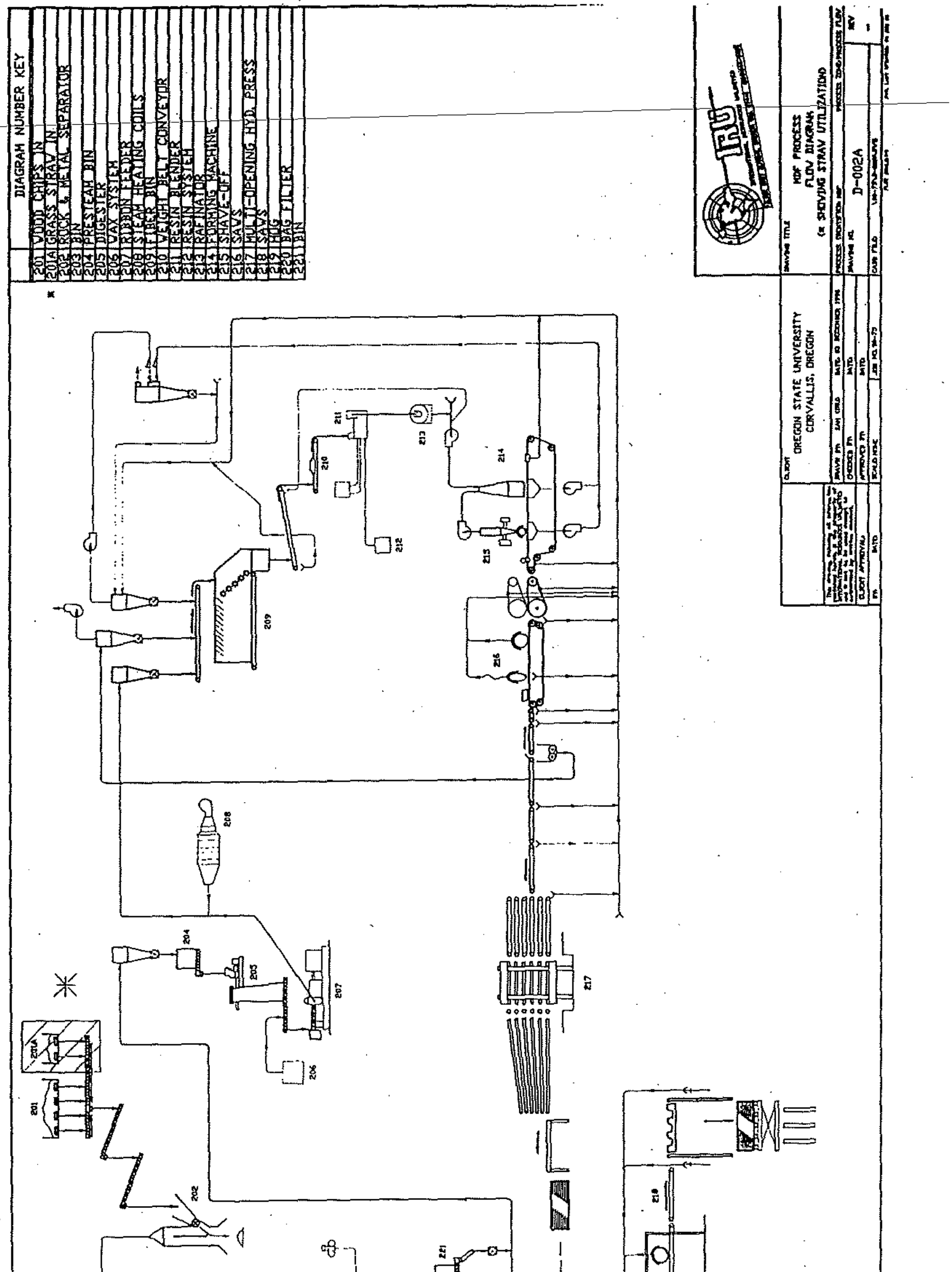


DIAGRAM NUMBER KEY
100 PARTICLE SIZING
101 DOSING BIN
102 UNIVERSAL REDUCTION MACHINE
103 DRYER
104 FLAKE SCREEN
105 SILO-SURFACE
106 SILO-CORE
107 FLAKE WEIGHT SCALE
108 FLAKE WEIGHT SCALE
109 RESIN BLENDER
110 RESIN BLENDER
111 RESIN PREP. UNIT
112 RESIN PREP. UNIT
113 MATERIAL FORMING STATION
114 MULTI-OPENING HYD. PRESS
115 COOLING WHEEL
116 TRIM SAW
117 TRIM SAW
118 SANDING MACHINE
119 BOARD INSPECTION TURNER
120 DUST FILTER
121 SILO
IRU
CLIENT
OREGON STATE UNIVERSITY
CORVALLIS, OREGON
DRAWING TITLE
PARTICLEBOARD
FLOW DIAGRAM
CLIENT APPROVAL
DRAWING NO.
D-001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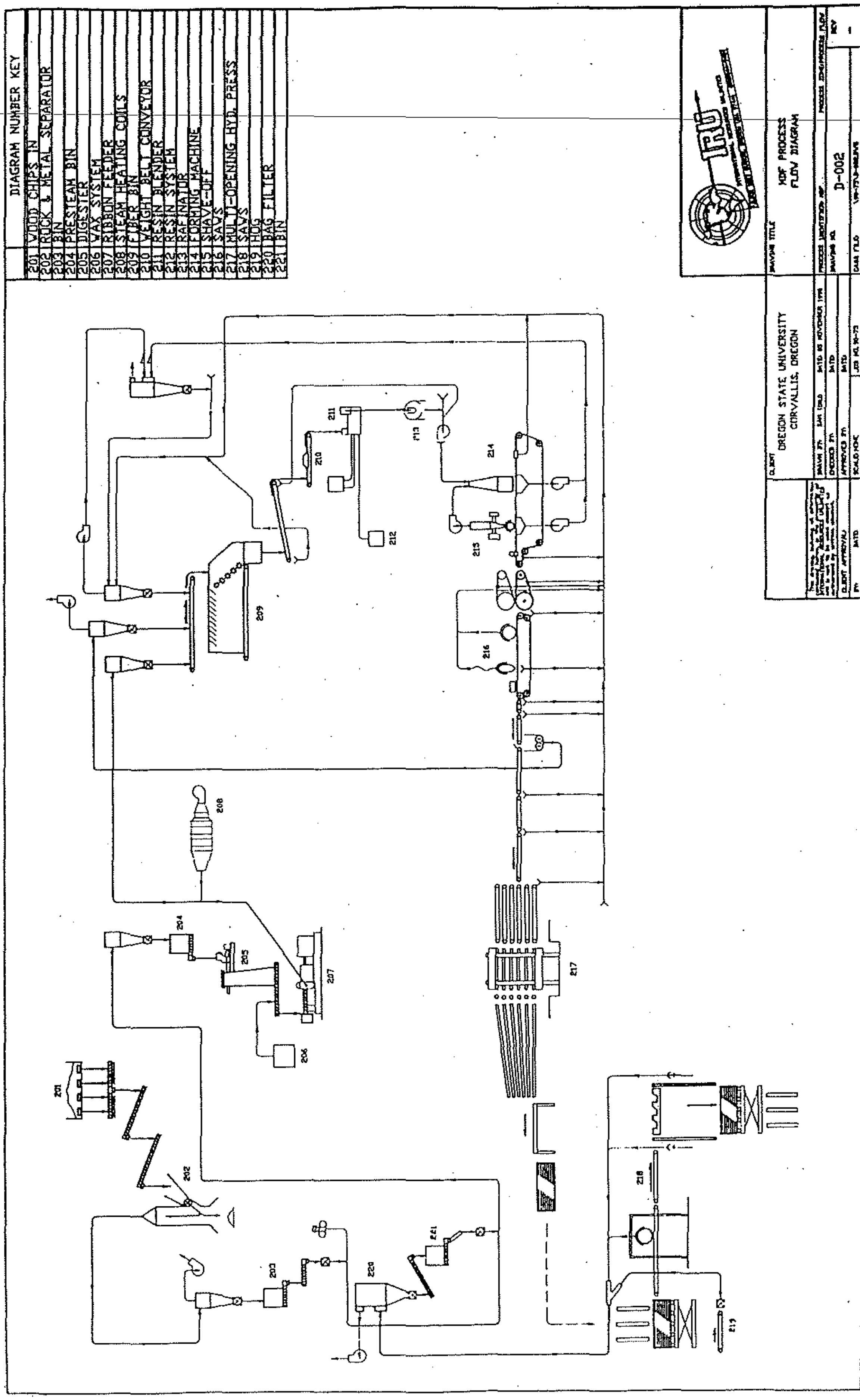
201 WOOD CHIPS IN
201A GRASS STRAW IN
202 ROCK & METAL SEPARATOR
203 BIN
204 PRESTEAM BIN
205 DIGESTER
206 WAX SYSTEM
207 RIBBON FEEDER
208 STEAM HEATING COILS
209 FIBER BIN
210 WEIGH BELT CONVEYOR
211 RESIN BLENDER
212 RESIN SYSTEM
213 RAFINATOR
214 FORMING MACHINE
215 SHAVE-OFF
216 SAWS
217 MULTI-OPENING HYD. PRESS
218 SAWS
219 HOG
220 BAG FILTER
221 BIN
MDF PROCESS
FLOW DIAGRAM
(W SHOWING STRAW UTILIZATION)
D-002A
OREGON STATE UNIVERSITY
CORVALLIS, OREGON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204 PRESTEAM BIN
205 DIGESTER
206 WAX SYSTEM
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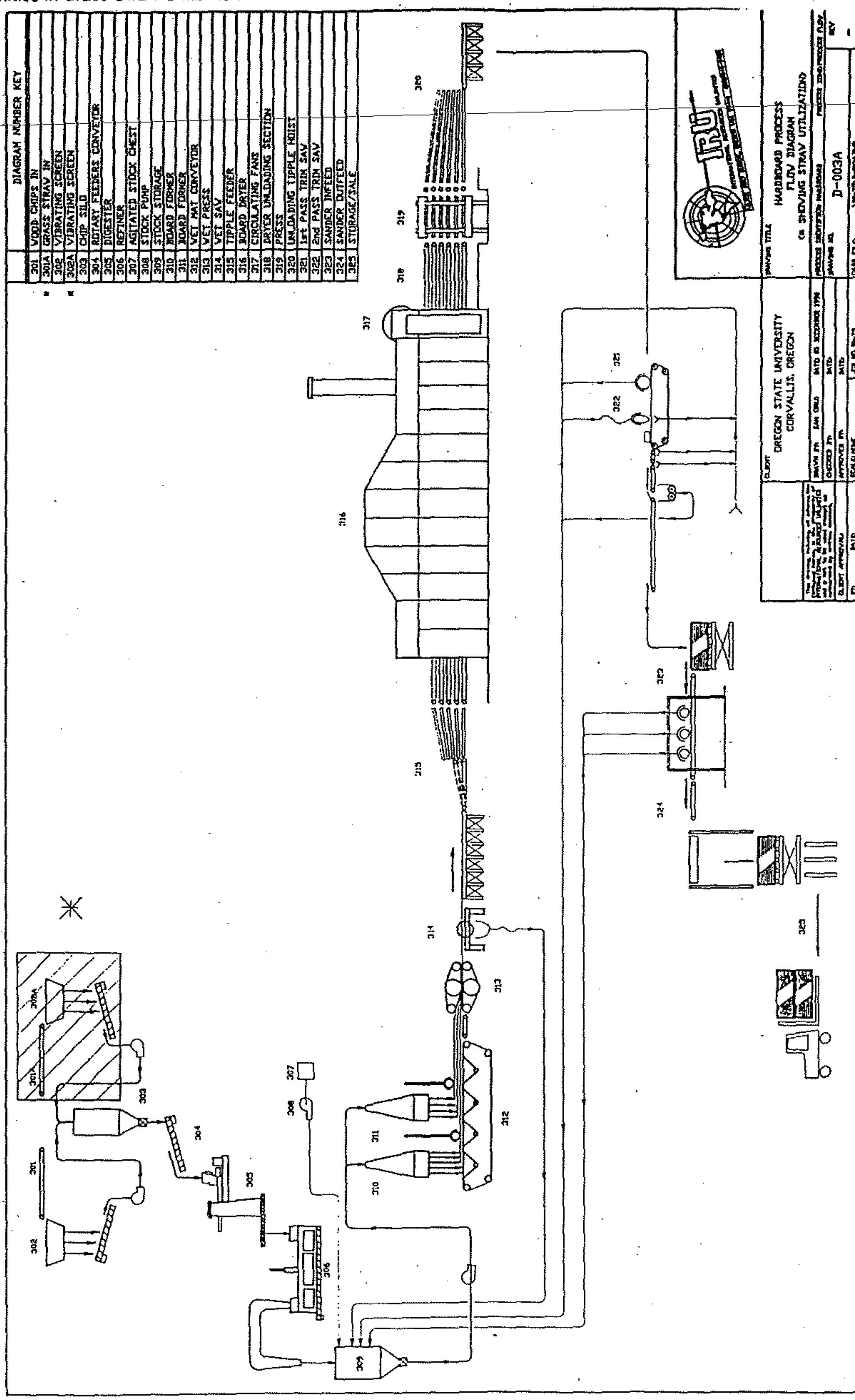
208 STEAM HEATING COILS
209 FIBER BIN
210 WEIGH BELT CONVEYOR
211 RESIN BLENDER
212 RESIN SYSTEM
213 RAFINATOR
214 FORMING MACHINE
215 SHAVE-OFF
216 SAVS
217 MULTI-OPENING HYD. PRESS
218 SAVS
219 HOG
220 BAG FILTER
221 BIN
OREGON STATE UNIVERSITY
CORVALLIS, OREGON
MDF PROCESS
FLOW DIAGRAM
D-002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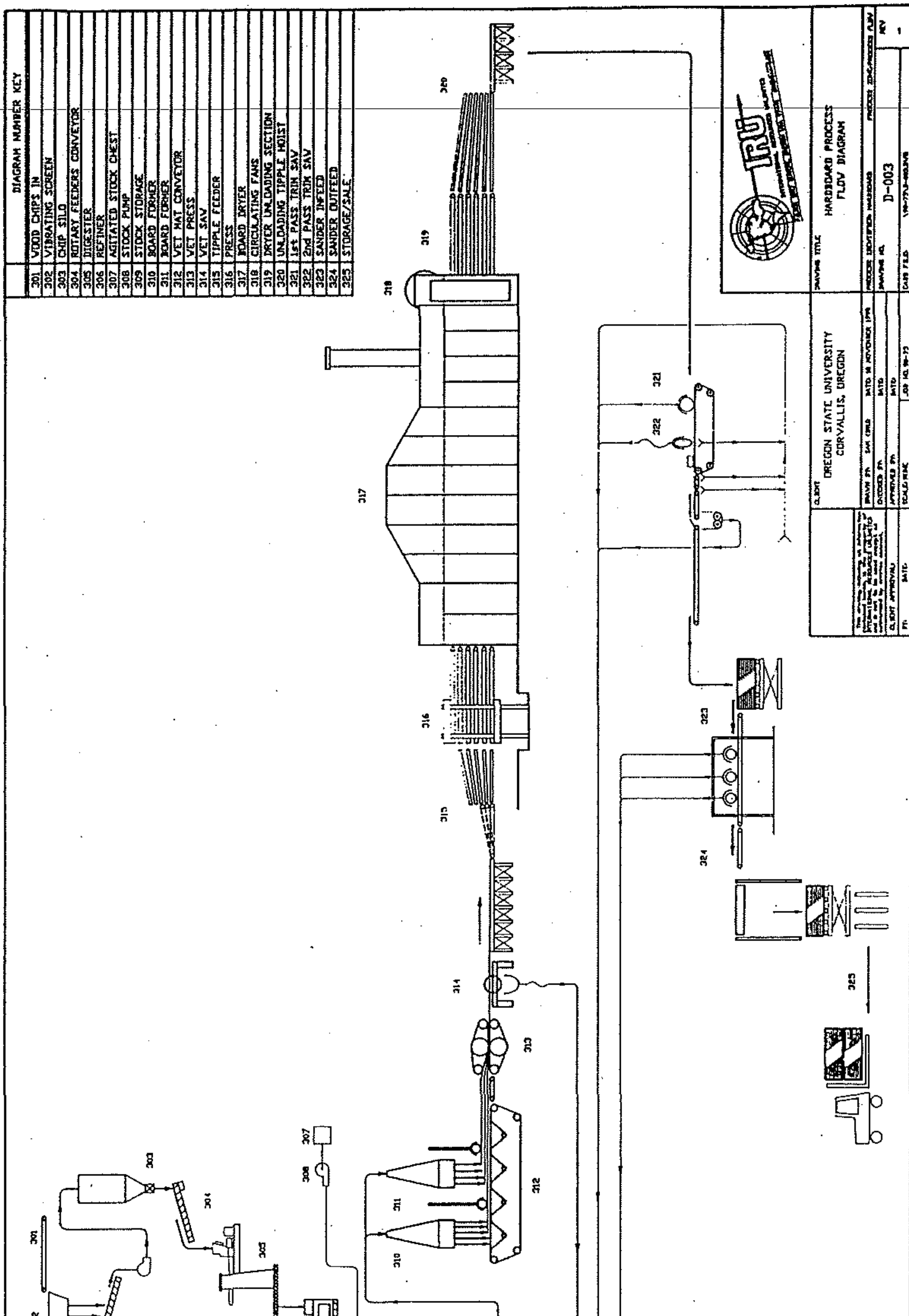
301A GRASS STRAW IN
302 VIBRATING SCREEN
302A VIBRATING SCREEN
303 CHIP SILO
304 ROTARY FEEDERS CONVEYOR
305 DIGESTER
306 REFINER
307 AGITATED STOCK CHEST
308 STOCK PUMP
309 STOCK STORAGE
310 BOARD FORMER
311 BOARD FORMER
312 WET MAT CONVEYOR
313 WET PRESS
314 WET SAW
315 TIPPLE FEEDER
316 BOARD DRYER
317 CIRCULATING FANS
318 DRYER UNLOADING SECTION
319 PRESS
320 UNLOADING TIPPLE HOIST
321 1st PASS TRIM SAW
322 2nd PASS TRIM SAW
323 SANDER INFEED
324 SANDER OUTFEED
325 STORAGE/SALE
OREGON STATE UNIVERSITY
CORVALLIS, OREGON
HARDBOARD PROCESS
FLOW DIAGRAM
SHOWING STRAW UTILIZATION
D-003A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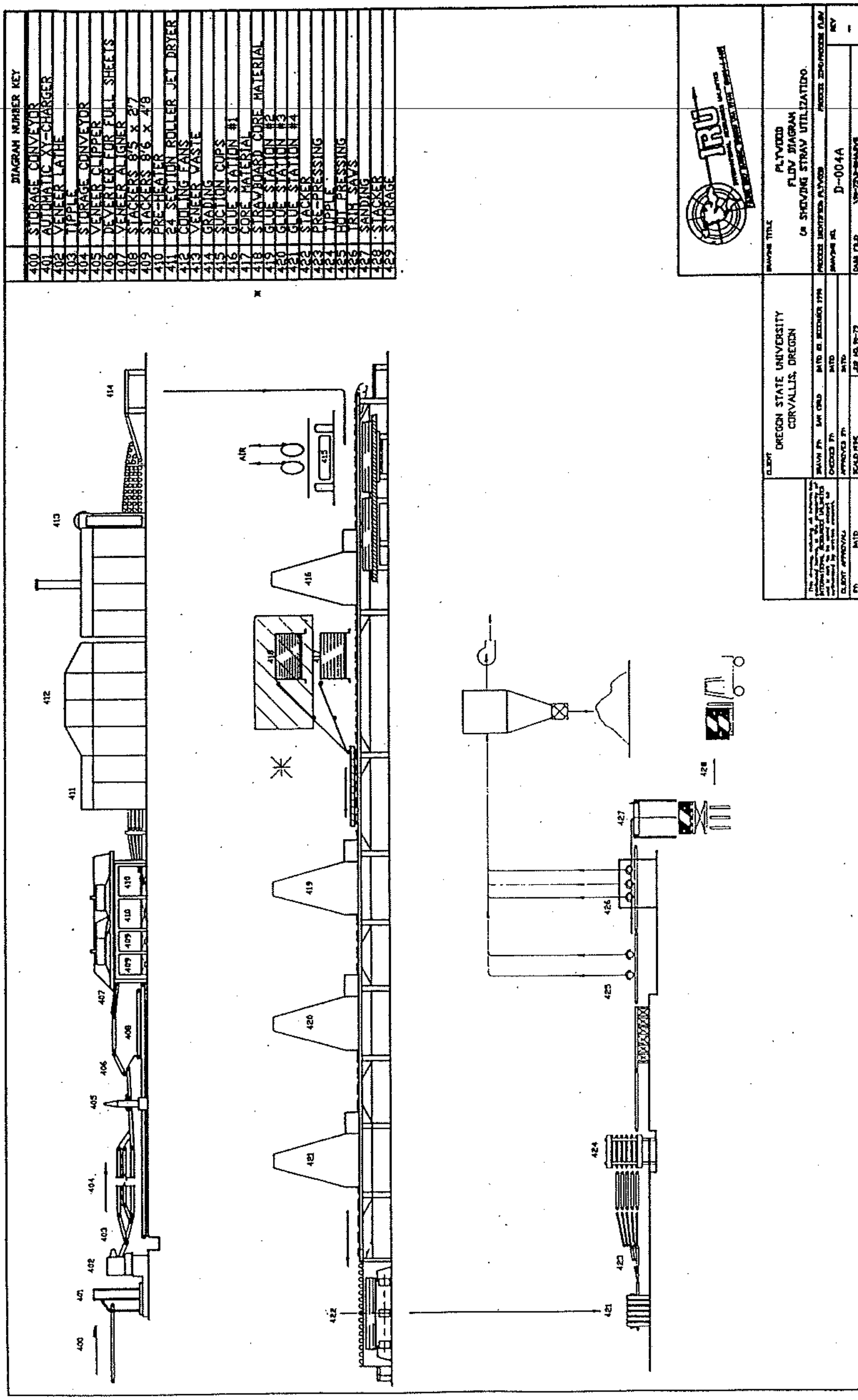
303 CHIP SILO
304 ROTARY FEEDERS CONVEYOR
305 DIGESTER
306 REFINER
307 AGITATED STOCK CHEST
308 STOCK PUMP
309 STOCK STORAGE
310 BOARD FORMER
311 BOARD FORMER
312 WET MAT CONVEYOR
313 WET PRESS
314 WET SAW
315 TIPPLE FEEDER
316 PRESS
317 BOARD DRYER
318 CIRCULATING FANS
319 DRYER UNLOADING SECTION
320 UNLOADING TIPPLE HOIST
321 1st PASS TRIM SAW
322 2nd PASS TRIM SAW
323 SANDER INFEED
324 SANDER OUTFEED
325 STORAGE/SALE
HARDBOARD PROCESS
FLOW DIAGRAM
OREGON STATE UNIVERSITY
CORVALLIS, OREGON
D-003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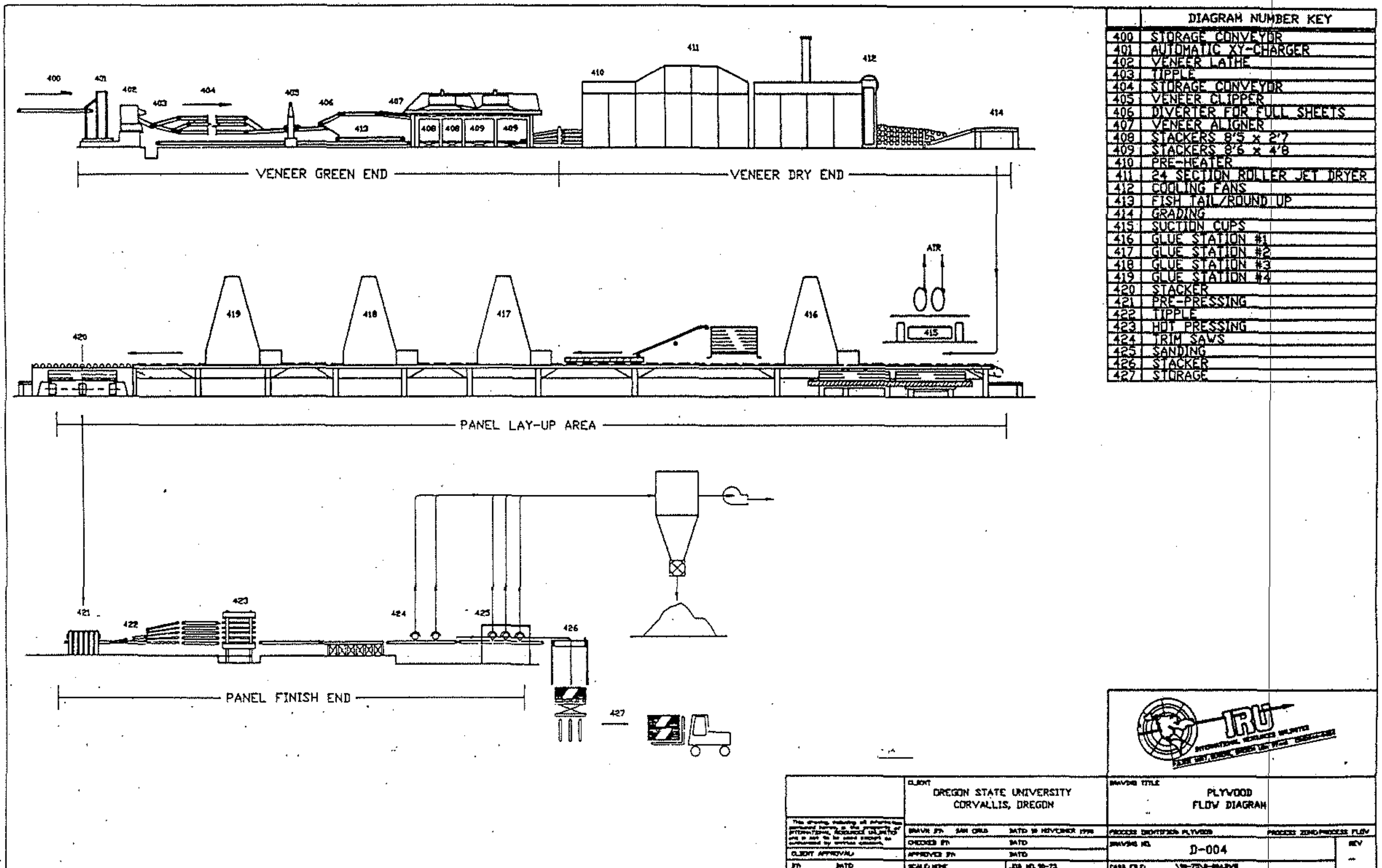
401 AUTOMATIC XY-CHARGER
402 VENEER LATHE
403 TIPPLE
404 STORAGE CONVEYOR
405 VENEER CLIPPER
406 DEVERTER FOR FULL SHEETS
407 VENEER ALIGNER
408 STACKERS 8'5 X 27
409 STACKERS 8'5 X 4'8
410 PRE-HEATER
411 24 SECTION ROLLER JET DRYER
412 COOLING FANS
413 VENEER WASTE
414 GRADING
415 SUCTION CUPS
416 GLUE STATION #1
417 CORE MATERIAL
418 STRAWBOARD CORE MATERIAL
419 GLUE STATION #2
420 GLUE STATION #3
421 GLUE STATION #4
422 STACKER
423 PRE-PRESSING
424 TIPPLE
425 HOT PRESSING
426 TRIM SAWS
427 SANDING
428 STACKER
429 STORAGE
AIR
OREGON STATE UNIVERSITY
CORVALLIS, OREGON
PLYWOOD
FLOW DIAGRAM
ON SHOWING STRAW UTILIZATION
D-004A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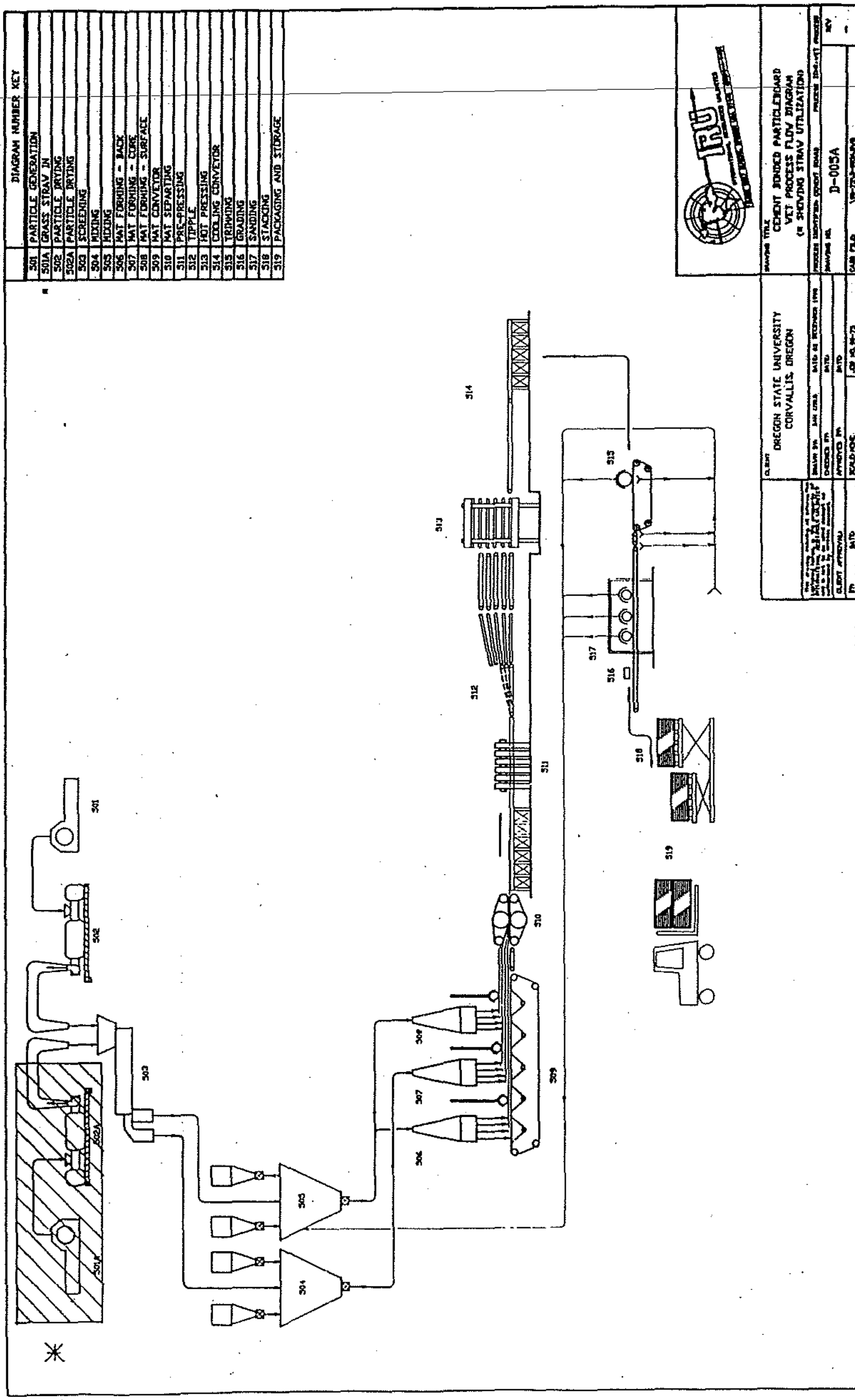
401 AUTOMATIC XY-CHARGER
402 VENEER LATHE
403 TIPPLE
404 STORAGE CONVEYOR
405 VENEER CLIPPER
406 DIVERTER FOR FULL SHEETS
407 VENEER ALIGNER
408 STACKERS 8'5 x 2'7
409 STACKERS 8'6 x 4'8
410 PRE-HEATER
411 24 SECTION ROLLER JET DRYER
412 COOLING FANS
413 FISH TAIL/ROUND UP
414 GRADING
415 SUCTION CUPS
416 GLUE STATION #1
417 GLUE STATION #2
418 GLUE STATION #3
419 GLUE STATION #4
420 STACKER
421 PRE-PRESSING
422 TIPPLE
423 HOT PRESSING
424 TRIM SAWS
425 SANDING
426 STACKER
427 STORAGE
VENEER GREEN END
VENEER DRY END
AIR
PANEL LAY-UP AREA
PANEL FINISH END
IRU
OREGON STATE UNIVERSITY
CORVALLIS, OREGON
PLYWOOD
FLOW DIAGRAM
D-004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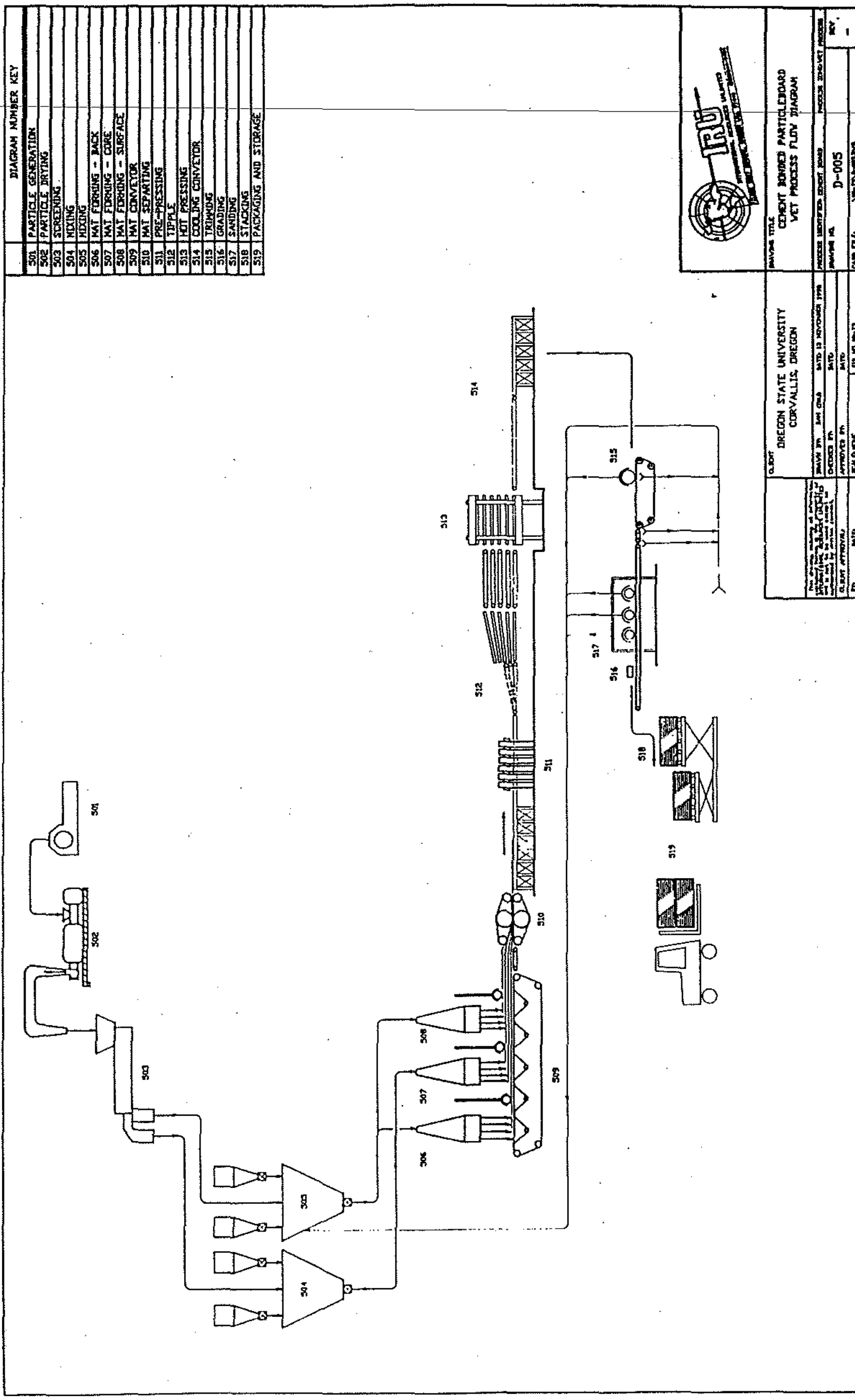
501A GRASS STRAW IN
502 PARTICLE DRYING
502A PARTICLE DRYING
503 SCREENING
504 MIXING
505 MIXING
506 MAT FORMING - BACK
507 MAT FORMING - CORE
508 MAT FORMING - SURFACE
509 MAT CONVEYOR
510 MAT SEPARATING
511 PRE-PRESSING
512 TIPPLE
513 HOT PRESSING
514 COOLING CONVEYOR
515 TRIMMING
516 GRADING
517 SANDING
518 STACKING
519 PACKAGING AND STORAGE
OREGON STATE UNIVERSITY
CORVALLIS, OREGON
CEMENT BONDED PARTICLEBOARD
WET PROCESS FLOW DIAGRAM
(* SHOWING STRAW UTILIZATION)
D-005A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505 MIXING
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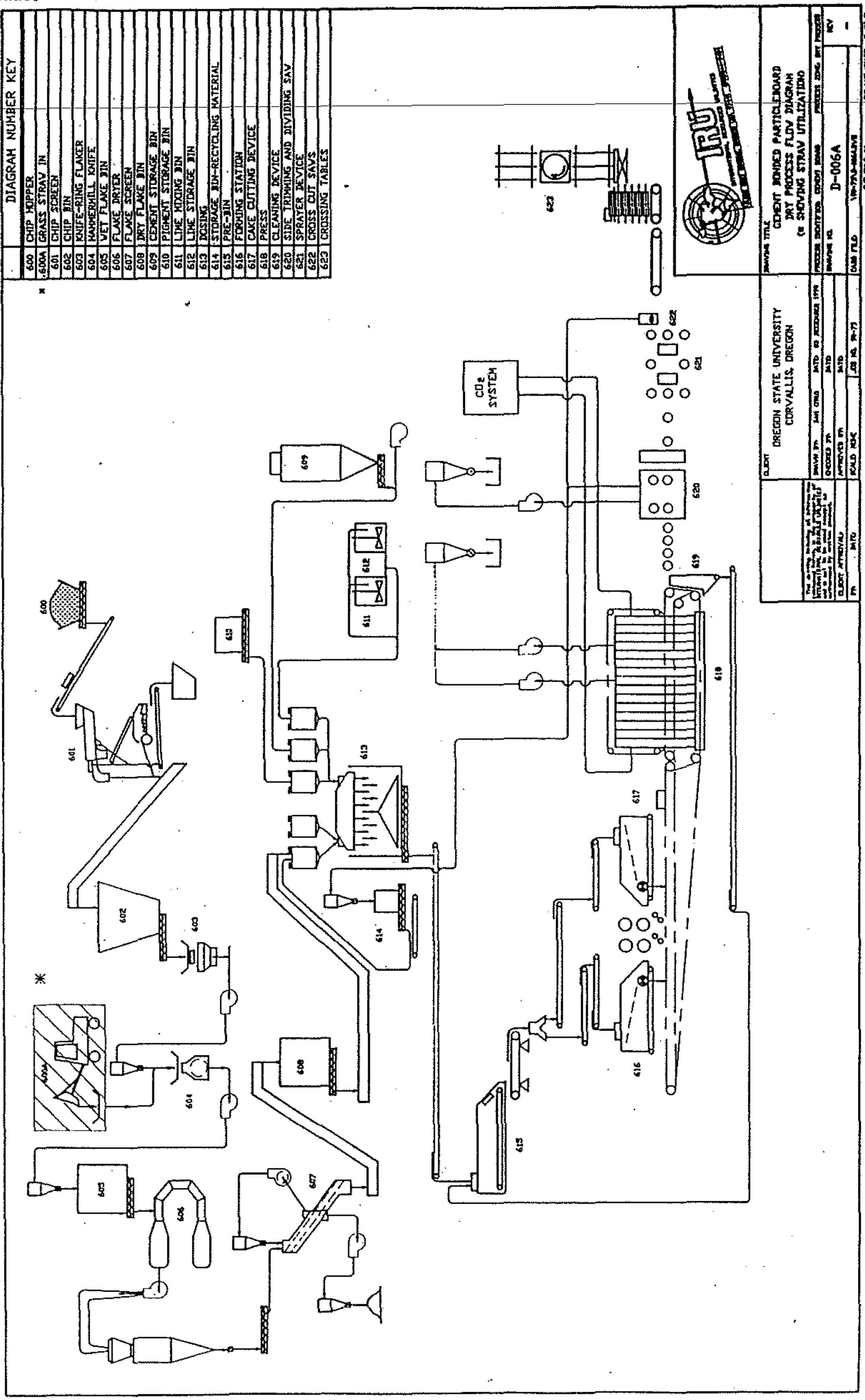
508 MAT FORMING - SURFACE
509 MAT CONVEYOR
510 MAT SEPARTING
511 PRE-PRESSING
512 TIPPLE
513 HOT PRESSING
514 COOLING CONVEYOR
515 TRIMMING
516 GRADING
517 SANDING
518 STACKING
519 PACKAGING AND STORAGE
CLIENT
OREGON STATE UNIVERSITY
CORVALLIS, OREGON
DRAWING TITLE
CEMENT BONDED PARTICLEBOARD
WET PROCESS FLOW DIAGRAM
DRAWING NO.
D-005
REV.
-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600A GRASS STRAW IN
601 CHIP SCREEN
602 CHIP BIN
603 KNIFE-RING FLAKER
604 HAMMERMILL KNIFE
605 WET FLAKE BIN
606 FLAKE DRYER
607 FLAKE SCREEN
608 DRY FLAKE BIN
609 CEMENT STORAGE BIN
610 PIGMENT STORAGE BIN
611 LIME MIXING BIN
612 LIME STORAGE BIN
613 DOSING
614 STORAGE BIN-RECYCLING MATERIAL
615 PRE-BIN
616 FORMING STATION
617 CAKE CUTTING DEVICE
618 PRESS
619 CLEANING DEVICE
620 SIDE TRIMMING AND DIVIDING SAW
621 SPRAYER DEVICE
622 CROSS CUT SAWS
623 CROSSING TABLES
CO2 SYSTEM
OREGON STATE UNIVERSITY
CORVALLIS, OREGON
CEMENT BONDED PARTICLEBOARD
DRY PROCESS FLOW DIAGRAM
(W SHOWING STRAW UTILIZATION)
D-006A

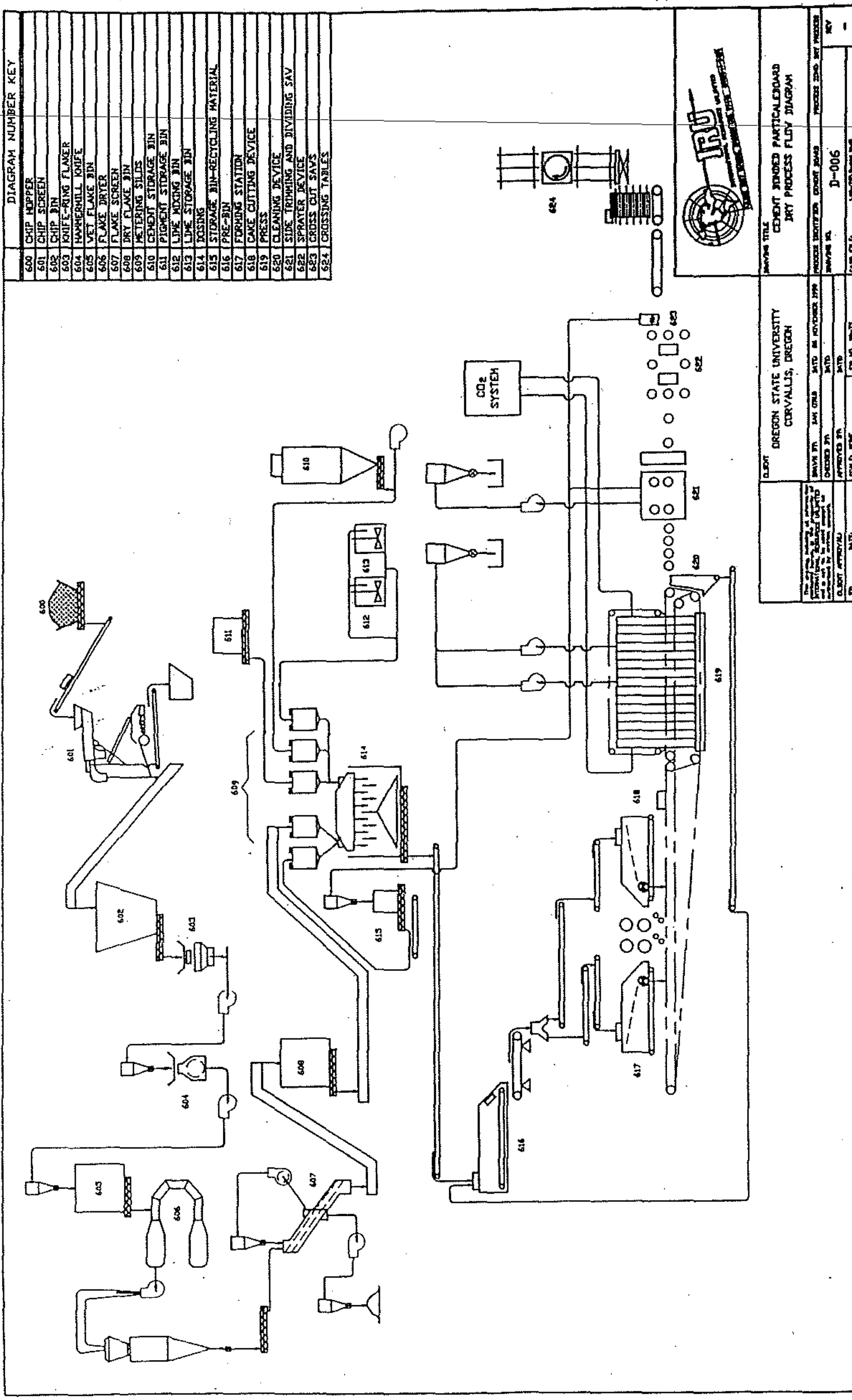
DIAGRAM NUMBER KEY
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601 CHIP SCREEN
602 CHIP BIN
603 KNIFE-RING FLAKER
604 HAMMERMILL KNIFE
605 WET FLAKE BIN
606 FLAKE DRYER
607 FLAKE SCREEN
608 DRY FLAKE BIN
609 METERING SILOS
610 CEMENT STORAGE BIN
611 PIGMENT STORAGE BIN
612 LIME MIXING BIN
613 LIME STORAGE BIN
614 DOSING
615 STORAGE BIN-RECYCLING MATERIAL
616 PRE-BIN
617 FORMING STATION
618 CAKE CUTTING DEVICE
619 PRESS
620 CLEANING DEVICE
621 SIDE TRIMMING AND DIVIDING SAW
622 SPRAYER DEVICE
623 CROSS CUT SAWS
624 CROSSING TABLES
CO2 SYSTEM
OREGON STATE UNIVERSITY
CORVALLIS, OREGON
CEMENT BONDED PARTICALBOARD
DRY PROCESS FLOW DIAGRAM
D-006

Appendix D

Powerplant Calculations

Inputs/Outputs	Case 1: Low Performance	Case 2: High Performance
Straw (20% moisture):	7,500 Btu/lb	7,500 Btu/lb
Hog Fuel (50% moisture):	8,600 Btu/lb	8,600 Btu/lb
Fuel Mix:	1:1, Straw:Wood	1:1, Straw:Wood
Straw Fuel Costs:	$0/ton	$0/ton
Wood Fuel Costs:	$20/unit	$20/unit
Boiler Efficiency:	60%	70%
Steam Pressure:	600 psia	600 psia
Steam Temperature:	600°F	600°F
Steam Enthalpy:	1,290 Btu/lb	1,290 Btu/lb
Feedwater Enthalpy:	170 Btu/lb	170 Btu/lb
Turbine Exhaust Pressure:	2" Hg abs.	2" Hg abs.
Ideal Turbine Exhaust Enthalpy:	856 Btu/lb	856 Btu/lb
Theoretical Steam Rate:	7.86 lb/kWh	7.86 lb/kWh
Turbine Efficiency:	60%	70%
Actual Steam Rate:	13.11 lb/kWh	11.23 lb/kWh
Actual Heat Rate:	14,680 Btu/kWh	12,582 Btu/kWh
Powerplant Size:	20 MW	20 MW
Plant Unit Cost:	$4,500/kW	$3,000/kW
Annual Operating Hours:	7,884 hrs/yr	7,884 hrs/yr
Fuel Flow:	337,000 tons/yr	248,000 tons/yr
Straw Fuel Consumption:	168,500 tons/yr	124,000 tons/yr
Wood Fuel Consumption:	168,500 tons/yr	124,000 tons/yr
Plant Capital Costs:	$90,000,000	$60,000,000
O&M Costs:	$4,500,000/yr[1]	$1,800,000/yr[2]
Straw Fuel Costs:	$0/yr	$0/yr
Wood Fuel Costs:	$1,685,000/yr	$1,240,000/yr
Net Electricity Production:	141,912,000 kWh/yr	141,912,000 kWh/yr

[1]Five percent capital cost.

[2]Three percent capital cost.

Appendix E

Oregon and Washington Chemicals Manufacturers

Oregon	Number of Firms	Average Number of Employees
2812 Alkalies and Chlorine	1	10
2813 Industrial Gases	4	5
2819 Industrial Inorganic Chemicals	2	10
2821 Plastics Materials & Resins	12	25
2822 Synthetic Rubber	2	20
2823 Cellulosic Manmade Fibers	1	10
2841 Soap and Detergents	8	20
2842 Polishes & Sanitation Goods	9	15
2844 Perfumes, Cosmetics	7	10
2851 Paints & Allied Products	18	40
2865 Cyclic Crudes & Intermediates	2	20
2869 Industrial Organic Chemicals	2	10
2873 Nitrogenous Fertilizers	4	25
2879 Agricultural Chemicals	5	40
2891 Adhesives & Sealants	13	25
2893 Printing Ink	6	15
2895 Carbon Black	1	10
2899 Chemical Preparations	14	15
Total	111	
Average	18	

Source: Directory of Oregon Manufacturers, State of Oregon Economic Development Department, 1989-1990.

Washington	Number of Firms	Average Number of Employees
2812 Alkalies and Chlorine	2	165
2813 Industrial Gases	8	25
2819 Industrial Inorganic Chemicals	7	45
2821 Plastics Materials & Resins	59	45
2822 Synthetic Rubber	2	25
2841 Soap and Detergents	1	25
2842 Polishes & Sanitation Goods	7	15
2851 Paints & Allied Products	18	35
2869 Industrial Organic Chemicals	6	70
2873 Nitrogenous Fertilizers	9	85
2879 Agricultural Chemicals	3	5
2891 Adhesives & Sealants	5	25
2892 Explosives	1	50
2893 Printing Ink	4	20
2899 Chemical Preparations	7	35
Total	139	
Average	45	

Source: Washington Manufacturers Register, Washington State Department of Trade and Economic Development, 1991.

Appendix F

International Bibliography

The following is a list of publications which were not used in writing this report, but could be viewed as additional references providing information on topics related to straw utilization. The list was generated from an international agricultural database and contains citations from 1984 to present. References have been divided into two sections depending on their subject matter relative to the report.

Related to Chapters 1-5

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Footnote 17

468A.550 Definitions for ORS 468A.555 to 468A.620 and 468A.992. (1) As used in ORS 468A.555 to 468A.620 and 468A.992:

(a) "Research and development of alternatives to field burning" includes, but is not limited to, projects concerned with cultural practices for producing grass seed without field burning, environmental impacts of alternative seed production methods, straw marketing and utilization and alternative crops.

(b) "Smoke management" means the daily control of the conducting of open field burning to such times and places and in such amounts so as to provide for the escape of smoke and particulate matter therefrom into the atmosphere with minimal intrusion into cities and minimal impact on public health and in such a manner that under existing meteorological conditions a maximum number of acres registered can be burned in a minimum number of days without substantial impairment of air quality.

(c) "Smoke management program" means a plan or system for smoke management. A smoke management program shall include, but not be limited to, provisions for:

(A) Annual inventorying and registering, prior to the burning season, of agricultural fields for open field burning;

(B) Preparation and issuance of open field burning permits by affected governmental agencies;

(C) Gathering and disseminating regional and sectional meteorological conditions on a daily or hourly basis;

(D) Scheduling times, places and amounts of agricultural fields that may be open burned daily or hourly, based on meteorological conditions during the burning season;

(E) Conducting surveillance and gathering and disseminating information on a daily or more frequent basis;

(F) Effective communications between affected personnel during the burning season; and

(G) Employment of personnel to conduct the program.

(2) As used in this section, "open field burning" does not include propane flaming of mint stubble or stack or pile burning of residue from Christmas trees, as defined in ORS 571.505. [Formerly 468.453; 1997 c.473 §3; 1999 c.439 §2; 2001 c.70 §1]

468A.555 Policy to reduce open field burning. The Legislative Assembly declares it to be the public policy of this state to reduce the practice of open field burning while developing and providing alternative methods of field sanitization and alternative methods of utilizing and marketing crop residues. [1991 c.920 §3]

468A.560 Applicability of open field burning, propane flaming and stack and pile burning statutes. (1) Except for the fee imposed under ORS 468A.615 (1)(c), the provisions of ORS 468A.550 to 468A.620 and 468A.992 shall apply only to open field burning, propane flaming and stack or pile

Footnote 18, 20
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Conservation Service, or its successor agency, the Agricultural Stabilization Commission, the state Soil and Water Conservation Commission and other interested agencies. The Department of Environmental Quality shall advise the commission in the promulgation of such rules. The commission must review and show on the record the recommendations of the department in promulgating such rules.

(4) No regional air quality control authority shall have authority to regulate burning of perennial grass seed crops, annual grass seed crops and grain crops. *

(5) Any amendments to the State Implementation Plan prepared by the state pursuant to the federal Clean Air Act, as enacted by Congress, December 31, 1970, and as amended by Congress August 7, 1977, and November 15, 1990, and Acts amendatory thereto shall be only of such sufficiency as to gain approval of the amendment by the United States Environmental Protection Agency and shall not include rules promulgated by the commission pursuant to subsection (1) of this section not necessary for attainment of national ambient air quality standards. [Formerly 468.460; 1997 c.249 §163]

* SIP Do not update

468A.597 Duty to dispose of straw. Unless otherwise specifically agreed by the parties, after straw is removed from the fields of the grower, the responsibility for the further disposition of the straw, including burning or disposal, shall be upon the person who bales or removes the straw. [1993 c.414 §2]

468A.600 Standards of practice and performance. The Environmental Quality Commission shall establish standards of practice and performance for open field burning, propane flaming, stack or pile burning and certified alternative methods to open field burning. [1991 c.920 §10]

Has DOA done this?

468A.605 Duties of Department of Environmental Quality. The Department of Environmental Quality, in coordinating efforts under ORS 468.140, 468.150, 468A.020, 468A.555 to 468A.620 and 468A.992, shall:

(1) Enforce all field burning rules adopted by the Environmental Quality Commission and all related statutes; and

(2) Monitor and prevent unlawful field burning. [1991 c.920 §11; 1995 c.358 §4]

468A.610 Reduction in acreage to be open burned, propane flamed or stack or pile burned. (1) Except as provided under ORS 468A.620, no person shall open burn or cause to be open burned, propane flamed or stack or pile burned in the counties specified in ORS 468A.595 (2), perennial or annual grass seed crop or cereal grain crop residue, unless the acreage has been registered under ORS 468A.615 and the permits required by ORS 468A.575, 476.380 and 478.960 have been obtained.

(2) The maximum total registered acreage allowed to be open burned per year pursuant to subsection (1) of this section shall be:

(a) For 1991, 180,000 acres.

Footnote 10, an 22-24

(b) ~~For 1992 and 1993, 140,000 acres.~~

(c) For 1994 and 1995, 120,000 acres.

(d) For 1996 and 1997, 100,000 acres.

(e) For 1998 and thereafter, 40,000 acres. 40,000 open

(3) The maximum total acreage allowed to be propane flamed under subsection (1) of this section shall be:

(a) In 1991 through 1997, 75,000 acres per year; and

(b) In 1998 and thereafter, 37,500 acres per year may be propane flamed. 37,500 propane

(4)(a) After January 1, 1998, fields shall be prepared for propane flaming by removing all loose straw or vacuuming or prepared using other techniques approved by rule by the Environmental Quality Commission.

(b) After January 1, 1998, propane equipment shall satisfy best available technology. – Has this been done?

(5) Notwithstanding the limitations set forth in subsection (2) of this section, in 1991 and thereafter, a maximum of 25,000 acres of steep terrain and species identified by the Director of Agriculture by rule may be open burned and shall not be included in the maximum total permitted acreage. 25,000 open-steep

(6) Acreage registered to be open burned under this section may be propane flamed at the registrant's discretion without reregistering the acreage. 102,000 total acres

(7) In the event of the registration of more than the maximum allowable acres for open burning in the counties specified in ORS 468A.595 (2), after 1996, the commission, after consultation with the State Department of Agriculture, by rule or order may assign priority of permits based on soil characteristics, the crop type, terrain or drainage. → Priorities

(8) Permits shall be issued and burning shall be allowed for the maximum acreage specified in subsection (2) of this section unless:

(a) The daily determination of suitability of meteorological conditions, regional or local air quality conditions or other burning conditions requires that a maximum number of acres not be burned on a given day; or

(b) The commission finds after hearing that other reasonable and economically feasible, environmentally acceptable alternatives to the practice of annual open field burning have been developed. *

(9) Upon a finding of extreme danger to public health or safety, the commission may order temporary emergency cessation of all open field burning, propane flaming or stack or pile burning in any area of the counties listed in ORS 468A.595 (2). *

(10) The commission shall act on any application for a permit under ORS 468A.575 within 60 days of registration and receipt of the fee required under ORS 468A.615. The commission may order

Footnote 18, 20
22-24

emergency cessation of open field burning at any time. Any other decision required under this section must be made by the commission on or before June 1 of each year. [1991 c.920 §12; 1995 c.358 §5]

468A.615 Registration of acreage to be burned; fees. (1)(a) On or before April 1 of each year, the grower of a grass seed crop shall register with the county court or board of county commissioners, the fire chief of a rural fire protection district, the designated representative of the fire chief or other responsible persons the number of acres to be open burned or propane flamed in the remainder of the year. At the time of registration, the Department of Environmental Quality shall collect a nonrefundable fee of $2 per acre registered to be sanitized by open burning or $1 per acre to be sanitized by propane flaming. The department may contract with counties and rural fire protection districts or other responsible persons for the collection of the fees which shall be forwarded to the department. Any person registering after April 1 of each year shall pay an additional fee of $1 per acre registered if the late registration is due to the fault of the late registrant or one under the control of the late registrant. Late registrations must be approved by the department. Copies of the registration form shall be forwarded to the department. The required registration must be made and the fee paid before a permit shall be issued under ORS 468A.575.

(b) Except as provided in paragraph (d) of this subsection, the department shall collect a fee in accordance with paragraph (c) of this subsection for issuing a permit for open burning, propane flaming or stack or pile burning of perennial or annual grass seed crop or cereal grain crop residue under ORS 468A.555 to 468A.620 and 468A.992. The department may contract with counties and rural fire protection districts or other responsible persons for the collection of the fees which shall be forwarded to the department.

(c) The fee required under paragraph (b) of this subsection shall be paid within 10 days after a permit is issued and shall be:

(A) $8 per acre of crop sanitized by open burning in the counties specified in ORS 468A.595 (2);

(B) $4 per acre of perennial or annual grass seed crop sanitized by open burning in any county not specified in ORS 468A.595 (2);

(C) $2 per acre of crop sanitized by propane flaming;

(D) For acreage from which 100 percent of the straw is removed and burned in stacks or piles:

(i) $2 per acre from January 1, 1992, to December 31, 1997;

(ii) $4 per acre in 1998;

(iii) $6 per acre in 1999;

(iv) $8 per acre in 2000; and

(v) $10 per acre in 2001 and thereafter; and

So, now, it's changed to open ban in A.595 counties'

(E) For acreage from which less than 100 percent of the straw is removed and burned in stacks or piles, the same per acre as the fee imposed under subparagraph (D) of this paragraph, but with a

Footnote 14

468A.590 Duties of Department of Agriculture. Pursuant to the memorandum of understanding established under ORS 468A.585, the State Department of Agriculture:

(1) Shall:

(a) Conduct the smoke management program established by rule by the Environmental Quality Commission as it pertains to open field burning, propane flaming and stack or pile burning.

(b) Aid fire districts and permit agents in carrying out their responsibilities for administering field sanitization programs.

(c) Subject to available funding, conduct a program for the research and development of alternatives to field burning.

(2) May:

(a) Enter into contracts with public and private agencies to carry out the purposes set forth in subsection (1) of this section;

(b) Obtain patents in the name of the State of Oregon and assign such rights therein as the State Department of Agriculture considers appropriate;

(c) Employ personnel to carry out the duties assigned to it; and

(d) Sell and dispose of all surplus property of the State Department of Agriculture related to smoke management, including but not limited to straw-based products produced or manufactured by the State Department of Agriculture. [1991 c.920 §9; 2001 c.70 §3]

468A.595 Commission rules to regulate burning pursuant to ORS 468A.610. In order to regulate open field burning pursuant to ORS 468A.610:

(1) In such areas of the state and for such periods of time as it considers necessary to carry out the policy of ORS 468A.010, the Environmental Quality Commission by rule may prohibit, restrict or limit classes, types and extent and amount of burning for perennial grass seed crops, annual grass seed crops and grain crops. EQC can prohibit

(2) In addition to but not in lieu of the provisions of ORS 468A.610 and of any other rule adopted under subsection (1) of this section, the commission shall adopt rules for Multnomah, Washington, Clackamas, Marion, Polk, Yamhill, Linn, Benton and Lane Counties, which provide for a more rapid phased reduction by certain permit areas, depending on particular local air quality conditions and soil characteristics, the extent, type or amount of open field burning of perennial grass seed crops, annual grass seed crops and grain crops and the availability of alternative methods of field sanitation and straw utilization and disposal. more rapid phased reduction

(3) Before promulgating rules pursuant to subsections (1) and (2) of this section, the commission shall consult with Oregon State University and may consult with the United States Natural Resources

Footnote 19

Conservation Service, or its successor agency, the Agricultural Stabilization Commission, the state Soil and Water Conservation Commission and other interested agencies. The Department of Environmental Quality shall advise the commission in the promulgation of such rules. The commission must review and show on the record the recommendations of the department in promulgating such rules.

(4) No regional air quality control authority shall have authority to regulate burning of perennial grass seed crops, annual grass seed crops and grain crops. *

(5) Any amendments to the State Implementation Plan prepared by the state pursuant to the federal Clean Air Act, as enacted by Congress, December 31, 1970, and as amended by Congress August 7, 1977, and November 15, 1990, and Acts amendatory thereto shall be only of such sufficiency as to gain approval of the amendment by the United States Environmental Protection Agency and shall not include rules promulgated by the commission pursuant to subsection (1) of this section not necessary for attainment of national ambient air quality standards. [Formerly 468.460; 1997 c.249 §163] * SIP Do not update

468A.597 Duty to dispose of straw. Unless otherwise specifically agreed by the parties, after straw is removed from the fields of the grower, the responsibility for the further disposition of the straw, including burning or disposal, shall be upon the person who bales or removes the straw. [1993 c.414 §2]

468A.600 Standards of practice and performance. The Environmental Quality Commission shall establish standards of practice and performance for open field burning, propane flaming, stack or pile burning and certified alternative methods to open field burning. [1991 c.920 §10] Has DOA done this?

468A.605 Duties of Department of Environmental Quality. The Department of Environmental Quality, in coordinating efforts under ORS 468.140, 468.150, 468A.020, 468A.555 to 468A.620 and 468A.992, shall:

(1) Enforce all field burning rules adopted by the Environmental Quality Commission and all related statutes; and

(2) Monitor and prevent unlawful field burning. [1991 c.920 §11; 1995 c.358 §4]

468A.610 Reduction in acreage to be open burned, propane flamed or stack or pile burned. (1) Except as provided under ORS 468A.620, no person shall open burn or cause to be open burned, propane flamed or stack or pile burned in the counties specified in ORS 468A.595 (2), perennial or annual grass seed crop or cereal grain crop residue, unless the acreage has been registered under ORS 468A.615 and the permits required by ORS 468A.575, 476.380 and 478.960 have been obtained.

(2) The maximum total registered acreage allowed to be open burned per year pursuant to subsection (1) of this section shall be:

(a) For 1991, 180,000 acres.

Foot note 25

From: Dixie Maurer-clemons
To: dwmonk@oregontoxics.org
Cc: prton@comcast.net
Sent: Thursday, March 01, 2007 12:27 AM
Subject: field burning

I am a life long resident of the Willamette Valley and from a family that now has 6 generations who have been raised in the southern end of the valley.
My strikingly beautiful mother suffered a bout with Bell's Palsy one summer when she was in her mid-thirties. After much therapy and many trips to a specialist in Portland her face was no longer distorted. The following summer it returned much to her distress; as it did the third summer. The fourth year she realized that it returned during the field burning season. In those days Eugene literally sat in a dark cloud of smoke on many days. In spite of the lessening of smoke intrusions into the south end of the valley due to legislation in following years, mother became more and more sensitive to the smoke. Finally, she was driven out of her home for several weeks each summer in order to avoid a return of palsy every summer. She always hoped to see an end to field burning in the valley. She died in 2001 without seeing that occur and still having to leave her home and the valley in her last summer due to several days of discomfort.
I have never known whether it was the smoke itself or the chemicals in the smoke that caused mother's problem; but I know that field burning was the source.
Please do what needs to be done to stop this practice. I know it is not necessary for good grass seed farming practices. There are other ways to achieve the same result without endangering the health of everyone who lives in the southern end of the valley.
Thank you for your attention.

Sincerely,

Dixie Maurer
339 W. 22nd Ave.
Eugene, Or 97405

Phone: (541) 343-3028

Foot note 26

From: George & Maxine Kovarik
To: OTA
Sent: Tuesday, February 27, 2007 3:19 PM
Subject: Field Burning

OTA, This letter is to give my support to banning the practice of field burning in Oregon. I live on the Marcola Road side of the Coburg Hills, at the Hill road, Donna Road intersection. The smoke boils up over the hills and makes it's way downward on into the valley. It was so bad this last fall, that I could'nt read the phone book to locate a phone number, to call in a complaint. My eyes burned so badly, and tears poured down my face,

messed up my eyeglasses, so I could barely see. This was inside my house. I live on just under an acre, smoke was so bad at times I could barely see my back fence. I also suffer severe allergy problems all year long. This smoke worsens this condition, to the point I have difficulty breathing. Also covers every thing with sooty particles from the burned material in the fields. I have utmost sympathy for those afflicted with asthma, COPD, and other respiratory problems. With our short summers, it is an absolute shame, that people are driven inside, to try to escape the smoke and related discomfort it brings us. This was not a single occasion, it was many days the winds did'nt do what they were supposed to. It is way past time we put an end to this. I don't have a lot of years left. I would like to be able to go out into my yard, and enjoy the last good days of summer and fall. Thank You, so much for representing my thoughts about this serious issue. Maxine Kovarik 91127 Hill Road Springfield, Oregon 97478.

Foot note 27

March 2, 2007
Dear State Legislators:

I have lived in the Willamette Valley since 1960. I graduated high school in Cottage Grove in 1962 and married in 1963 and worked at the Pacific NW Bell telephone company downtown Eugene. I can remember many times of coming out of work during my lunch hour and after work and it being smokey and it was as thick as the fog at the Oregon Coast. I also remember the horrible day that Governor Tom McCall was on the news because you couldn't see 10 feet in front of your face in downtown Eugene. I had taken my child to the cinema and walked out and thought main street of Eugene must be on fire as the smoke was so thick.
We then moved to the Mohawk Valley and put in a swimming pool. The smoke would drift over the Coburg hills right towards our house and pool. Their would be 2 – 4 inch long pieces of black straw heading right for our bright shiny blue pool and of course it would leave a black smear like someone had taken a black marker and wrote on the pool. We called and complained and of course nothing was ever done.
The smoke was diverted toward Eugene, or west or east but heaven forbid never North toward Salem.
I also remember the young college student who was living with us and his family lived in Hillsboro and he was headed home when the 7 car pileup happened. I was almost hysterical waiting for a phone call from him or his mother who was watching the scene unfold live on television both of us praying he was not in that mess on the freeway. He wasn't thank God.
I thought at the time maybe this will finally be the end of this – maybe God actually stepped in to signal to the people in Salem to show the legislators that it is killing people slowly but tragically all at once.
It slowed a little but not much.
We moved to Creswell and built a new home and this last summer were dismayed at the actually straw that floated in our neighbor hood. This time the pieces were 8 – 10" long. I called the number in the book to complain and the young man who answered said, "Lady, we don't have anyone for Creswell, you will have to find out who represents your district and contact them by writing a letter. So since 1960 to 2007 which is 47 years I and my

family have suffered so the grass seed farmer could get richer. Meanwhile the rest of us have just had to live with it. It is like being next to someone smoking a cigarette – second hand smoking kills or don't any Legislators read the science about the smoke. I believe it is past time for this to stop and take care of our earth – has any of you read "An Inconvenient Truth"? I suggest it become mandatory reading for every Legislator and every grass seed farmer. It is now a new century and certainly time to find a way to help the grass seed industry find a more viable way to control disease without killing the rest of us.

Sincerely
Penny Spencer
644 Creswood Drive
Creswell, OR 97426
541-895-9858

Foot note 28

From: dorothyblueeyes
To: dwmonk@oregontoxics.org
Sent: Saturday, February 24, 2007 7:50 PM
Subject: The Past of My Family In the Valley,and Grass Seed Burning here.

Dear Sir: Thank you for being concerned about the noses and sinuses of the people of Willamette Valley. My family has lived here for about 50 years, my dad built our house during the 50's,and planted all the trees,and we had orchards in back. My poor dad, who has always had sinus trouble, was made so miserable, by all the grass seed burning of the farmers, every summer, that he was sick, and got bloody sinuses all the time. I remember his handkerchiefs always being stained with blood.

Now, I know that he probably had sinus infections all the time, from the burning of seed,and stuff burning in Willamette Valley, (we are in Eugene, on river Rd.)but he never went to a doctor for it,he just put up with it,and was always blowing his nose. I was not so lucky; I got sinus infections,and hay fever, from the grass burning, and all the lumber mills burning all the time. I pretty much have chronic sinusitus,and I get a sinus infection every once in a while.

Even living in California did not help it any, for some years, when i was working,as they also have a lot of pollen. But the burning of seeds,and grass,and agricultural burning here, was always much worse,and it made my poor dad who had the "River Rd. Watchmaker" and small jewelry business, on River Rd., miserable all the years we lived here. He did not have the option of moving, or leaving and going someplace else,his home, place, and his small business was right here. It's not so easy to just leave a business,and move away cause the air is bad. He had a family to support, for a long time,and my sister and I went to the University of Oregon, finally, too,while we were living at home.

Because I was born here, in Eugene,and grew up with all that grass seed burning,and all that bad agricultrual burning every summer, I started out with a bad sinus, just growing up here. I have to use nasal sprays, special ones,and antihistimines, all the time, every day, to help the bad condition, which is very inflamed,and also I have to regularly "decongest" my sinus, by using a bronchial steamer almost every day,to loosen up the congestion more easily. (I cannot take pill decongestants.)

Summer should be very nice, here, in Oregon, but it is often Hell for all of us, cause we cannot BREATHE here, cause of all the grass seed burning,and agricultural burning. People tell me,it is illegal for the farmers to burn grass seed,and they get PAID TO NOT BURN IT,BUT THEY DO IT ANYHOW, cause there is no law, or money, to stop them from doing it.

If you can put any "teeth" in any laws, or legislation, to stop all this grass seed burning,and the farmers from burning all their agricultural stuff, during the whole summer, in an enclosed valley, you would be helping all of us,and the ghost of my dad would probably be very happy too. He was a good gardener,and he loved Oregon,and I hate to think how he suffered, just cause of the bad air,when this could be such a wonderful place to live.

Thank you, sincerely, Dorothy H. Bucher, jr., of 2980 River Rd., Eugene, Oregon 97404 at bucher1045@comcast.net 541-463-7605.

Footnote 29

From: "Pam Perryman" <pam@bobwhitman.com>
To: <dwmonk@oregontoxics.org>
Sent: Saturday, February 10, 2007 3:51 PM
Subject: field burning testimony

> Dear Oregon State Legislator.
>
> I have a medical diagnosis of exercised-induced asthma. I never had
> it until I moved here in 1972 when field burning was more prevalent
> than today. When there is particulate matter in the air from field
> burning smoke, I get wheezy and it is difficult to walk. I have to
> stay inside. My eyes sting as well. 34 years later, I still get
> wheezy when the field burning smoke blows into town. I called LRAPA
> to complain this year, and I called at least once before about 2-3
> years ago, but the official complaints I filed do not reflect the
> frequency of my problem -- it happens with every smoke intrusion.
>
> I realize that the farmers and the state have been working to
> minimize the smoke intrusions, but you can't predict which way the
> wind will really blow. That's the problem with field burning smoke.
> You can't plan your day around it.

> When I was a student teacher in Junction City in 1974, I had a
> student whose father was a grass seed farmer. She told me, "We can't
> make money if we don't burn our fields." I told here, "But I can't
> make money if I can't breathe!"
>
> Please pass legislation ending field burning. There are other ways to
> remove grass straw and weed seeds from the field; I only have one way
> to get air into my lungs.
>
> Pam Perryman
> 3025 Neslo Lane
> Eugene, OR 97405

Footnote 30

Original Message -----
From: RGates7390@aol.com
To: DWMONK@oregontoxics.org
Sent: Thursday, February 01, 2007 12:03 PM
Subject: FIELD BURNING

DEAR OREGON LEGISLATORS

EVERY YEAR THE SMOKE ROLLS ACROSS THE COBURG HILLS FROM FIELD BURNING AND IWE BOTH HAVE TROUBLE BREATHING AND HAVE HEADACHES AND NOSE BLEEDS. THIS WAS ESPECIALLY BAD THREE DIFFERENT TIMES LAST SUMMER/FALL. WE CALLED EACH TIME AND COMPLAINED, BUT NEVER HAD A CALL BACK.
WE HAVE LIVED AND PUT UP WITH THIS THE LAST 35 YEARS AND ENOUGH ALREADY
THE SMOKE IN OUR VALLEY SEEMS TO HAVE GOTTEN WORSE AS THEY HAVE TRIED TO KEEP THE SMOKE FROM THE EUGENE/SPRINGFIELD AREA. WE LIVE IN THE MOHAWK VALLEY AND THE ASH AND PARTICULATE COVER OUR CARS, DECK AND THE CLEAN CLOTHES HANGING ON THE LINE (YES, WE TRY TO OUTGUESS THE BURNERS AND HANG THE CLOTHES OUT TO DRY). NOT ONLY IS THIS UNNECESSARY, BUT A HEALTH ISSUE. LAST SUMMER COMING FROM PORTLAND BETWEEN ALBANY AND EUGENE THE SMOKE WAS THICK AND TRAFFIC HAD TO SLOW AND HAD TO HAVE THEIR LIGHTS ON. WE WONDERED IF WE WOULD BE REAR-ENDED. WHY DO THE FARMERS GET PAID A SUBSIDY FROM THE GOVERNMENT AND STILL BURN THEIR FIELDS?

RONALD and DORIS GATES
90429 SHADOWS DR.
SPRINGFIELD, OR. 97478

541-747-8667
RGATES7390@AOL.COM

Footnote 31

----- Original Message -----
From: Victoria Whitman
To: dwmonk@oregontoxics.org
Sent: Thursday, February 08, 2007 11:00 PM
Subject: Field burning

Dear Oregon State Legislators;

For me field burning is a horrible problem. I am allergic to both smoke and pollen, and with exposure I can go into an asthma attack. My condition is not daily asthma but smoke and allergy triggered asthma. This is the medical diagnosis.

When I have an attack I get a swollen face, I have trouble breathing, I get wheezy, and I get sinus headaches that do not just disappear when the smoke does. I am very fatigued. Attacks weaken my immune system. Attacks trigger migraines as well. I cannot function normally; ike with anyone who is very ill. I get spacey, disoriented, having trouble tracking what I'm doing and even conversing. It really levels me. My husband can notice when I'm on the verge of an incident because I begin to blacken underneath my eyes due to the lack of oxygen. He worries about me driving, although he knows I try not to when I feel badly. I have to stay inside, preferably in a place with airconditioning and filters. I did buy a car with a hepa allergy filter to help with this problem, but still often feel it would just be better not to drive. Being a realtor, this can make doing my job very difficult.

You would not know any of this to look at me. When I am not having or recovering from an attack I look like a healthy, young, energetic person with a successful career. I am active in the community, volunteer, love the outdoors - especially hiking, and live a full life. I am not considered a "wimp" nor am I easily dissuaded from doing the things I love.

I have been treated for this condition for years, but I was feeling my treatment regimen and quality of life were not satisfactory. So, last fall, I spent three weeks in Denver at National Jewish Hospital, the hospital ranked #1 the past 9 years in the USA for asthma and allergies. They did multiple tests, and confirmed the connection between my smoke and pollen allergies and my asthma. They also confirmed that I do not have daily asthma, nor excercise induced asthma. ONLY ALLERGY INDUCED ASTHMA - which is often triggered by smoke burning. This three-week stay cost me $24,000. And that's just the medical bills, not the hotels and food. My insurance originally tried to deny my claim, but eventually they paid what my policy was written for.

One thing I know now after the visit to this clinic and getting a more precise diagnosis is that many people with asthma are overmedicated. Most people see their family practicioner for asthma, and because asthma can kill you, these doctors, for liability reasons, prescribe lots of medications. But all these medications have side effects. I know, bacuse I've taken many of them. Over time they can actually weaken your lungs, making a person's asthma worse.

I am a real estate salesperson. The smoke has had serious imapcts on my job. Last summer during the field burning season I missed a part of the working day for one entire month. I'd have to go home. I couldn't drive clients around to look at property because I felt so bad that I did not think it was safe to be driving. I continue working during the field burning season until I absolutely can't, becasue I'm self-employed, and when I don't work, I don't get paid. And here I am, sick from the smoke and trying to convince my clients how wonderful it is to live in Eugene!

I've often treid to leave town for the weekend to get away from the smoke, but that also means leaving work (and the rest of my life). I can't just do that any time. And there isn't any warning about when the smoke will hit. Even when the news tries to send out warnings, who can predict the weather (and wind!) with that much accuracy?

Field burning has also had negative impacts on my personal life. It's very hard on my family life when I'm sick and irritable for much of the summer.

I called LRAPA about three times last year to complain. Even though I've lived here 15 years, I didn't call before that because I was unaware there was someone to complain to.

I love living in Oregon and Eugene. I have a family, friends and a successful career. I do not want to leave, but do consider it due to my health. Ending field burning could substantially improve my ability to manage my health and make me feel far more comfortable with living here.

Sincerely,

Victoria Whitman

"I appreciate your business and referrals!"
http://whitman.mywindermere.com

Footnote 32

msn® Hotmail®

From : Jeff Wyman <jwyman44@comcast.net>
Sent : Thursday, March 8, 2007 8:15 PM
To : banfieldburning@hotmail.com
Subject : Letter of support

Dear Oregon State Legislators,

My wife and I have lived in Eugene for four years now, and we truly love it. Lane County is a wonderful area in all respects: culturally, physically, and environmentally. However, there's one notable exception that is an issue of grave concern to me, and that is the annual burning of grass seed fields in the Southern Willamette Valley every August and September. It's bad enough that, for a couple of months every year, our lovely area looks like Los Angeles. We caution our out of town friends not to visit us in August because, frankly, it's embarrassing. What I can't live with is the health hazard this pollution creates for many of us. My wife has spent days in bed with severe headaches; my lungs burn and sometimes I have trouble breathing. Our energy is sluggish and our eyes are bloodshot - every year at this time.

My family's health problems are small compared to the thousands of Oregon citizens who suffer from asthma, other respiratory diseases, and heart conditions. These people are incapacitated by exposure to field burning smoke, and, in many cases, their very lives are in danger. Please do whatever you can to support Rep. Paul Holvey's House Bill #3000 to ban field burning, so we can enjoy the quality of life in our state that we should have.

Sincerely,

Jeff Wyman
2966 Riverview St.
Eugene, OR 97403
email: jwyman44@comcast.net

Footnote 33

msn Hotmail®

banfieldburning@hotmail.com Printed: Wednesday, April 4, 2007 2:10 PM

From : Berrien, Hewitt <HBerrien@peacehealth.org>
Sent : Wednesday, March 7, 2007 9:19 AM
To : banfieldburning@hotmail.com
Subject : stop the burning

I moved with my young family to Eugene a little less than 15 years ago. Both of us now have asthma and must broncho-dialate daily, often more than once, with steroid medications. Our children have intermittent bouts with bronchial and nasal congestion, commonly during the latter part of summers. None of us had any health problems before moving here. My wife and I both work in the healthcare fields and fail to understand how this practice of field-burning could be permitted to go on for so many years. We are confident in our perception that the reason for its sanction is largely related to big money and political clout. What's new in the present era? We are tired of the lack of "pull" the commonwealth have in it; on all levels. May our individual wills, framed in this small email message, carry the "winds of the commonwealth" back into the face of all those responsible for the fires and the unnecessary suffering of others. Just say NO to field-burning!!!

Hewitt and Patricia Berrien

Footnote 34

msn® Hotmail®

banfieldburning@hotmail.com Printed: Wednesday, April 4, 2007 2:01 PM

From : RAG <sublimey2u@wbcable.net>
Sent : Sunday, April 1, 2007 10:24 PM
To : banfieldburning@hotmail.com
Subject : Choking smoke

My wife is an Asthma sufferer and it is disgusting that she should have to breath in this crap.

I have found black ash in our local park and our back yard as big as my fist.

There is no need for this habit to continue, it belongs with the Model T Ford, along with backyard burning..

We are sick and tired of these selfish grass seed farmers, who obviously don't give a damn about the public's health and welfare, or for that matter there own families health.

The time is long overdue in putting a permanent lid on field burning, I don't give a damn if their families have been doing it for decades. Put a stop to it now.

I sincerely hope the Salem crowd have not only the will, but the guts to face up to these grass burning yokels.

It is time to sow the seed of a very upset general public.

Yours truly,

R Gunn. East Marion County.

Footnote 35

From : Terry Sitton <serpico52us@yahoo.com>

Sent : Wednesday, April 4, 2007 12:02 PM

To : Holly Higgins <banfieldburning@hotmail.com>

Subject : Re: Please Support Banning Field Burning April 6 in Salem

To Whom it may concern.

I have lived in Sweet Home for nearly 14 years now. 10 years ago my docter told me in order to better my health I would need to purchase a second home over at the coast. One reason the smoke from field burning. Field burning was a big concern to him. I can get liver damage from the smoke if I take in to much. There are days when I see it coming over the hills and I must rush to shut all the windows asap or it will invelope inside my home. It still can get in to a degree even with the windows closed. There is a gentleman that I call in Salem to ask if they are going to burn etc. and he has been very polite and I thank him. If I know a heavy burn is coming I will leave the valley and head over to the coast asap which is called now! It puts myself in a frantic situation. One of the problems to of the burns is it can be up to 90 degress out and I am unable to open up the windows at night when one so needs to cool ones home. We in Sweet Home and nearby areas are targeted so Eugene and Salem etc. can be spared. My guess all combined 50,000 people are affected and more. It is time to consider stopping field burning and let those live a longer healthier life please.

Sincerely,

Terry Sitton

Footnote 36

House Health Committee Testimony
Re: Field Burning and HB 3000
April 6, 2007

Dear Members of the Health Committee:

My name is Steve Nielsen and I live in Mill City, thirty miles east of here in the beautiful North Santiam Canyon. I come before you today on behalf of my family and the citizens of the canyon in full support of House Bill 3000 and would like to thank Representative Holvey for bringing it forward for us to discuss today.

I have been an Oregon resident for eighteen years and have lived in the Canyon for eight of those years. Each summer, our health, along with the beauty, peace and serenity of our area is assaulted by harmful field burning smoke on a daily basis in August and September. This outdated and harmful practice eliminates the many reasons people choose to live here in the first place.

First and foremost is the impact that field burning has on public health. I know the medical research has been or will be presented to you, but field burning smoke is very dangerous, especially for children, the elderly and anyone who suffers from asthma. As a result, there are many residents in our area that are literally held hostage in their own homes on field burning days because they either can't breathe and/or can't see due to burning and irritated eyes.

This issue has affected my family personally as well. My wife and two youngest sons became ill last August and went to our doctor to be checked. They were diagnosed with bronchitis and irritant related asthmatic symptoms, which the doctor firmly believed was a direct result of the field burning smoke. In my wife's case, she had never suffered from any symptoms of asthma prior to being exposed to this dangerous smoke.

It offends me that we are essentially tagged as 'expendable' and thrown to 'slaughter' since those of us east of the burns make up less of the population than those west of the burns. I wonder what the reaction would be if burning was allowed when the wind blows from the east? We are respectful, law abiding taxpayers just like those in the densely populated areas and deserve equal air quality rights. It is worth mentioning that the smoke was so heavy one day last August that it set off the fire alarm in our high school building.

Please support House Bill 3000 for the health of all Oregonians. It's time for this dangerous and outdated practice to stop. I recognize that grass seed farming is important to our economy, but I feel that there are healthier alternatives to choose from. I truly want their businesses to succeed, but only in a way that is healthy for the thousands of Oregonians who are suffering unfairly by the current practice. Thank you for your time and attention to this matter.

Sincerely,

Steve Nielsen
Mill City Resident
Supporter of House Bill 3000

Footnote 37

msn Hotmail®

From : Glen and Rhoda Love <rglove@uoregon.edu>

Sent : Sunday, March 18, 2007 11:39 AM

To : banfieldburning@hotmail.com

As Eugene residents since 1965, we both have been adversely affected by fieldburning smoke through the years. We deeply resent having to hole up inside when the smoke drifts in to ruin a lovely day. Fieldburning is an affront to everyone's health and quality of life. If other western states can ban it, why should we continue to be subjected to it. We remember the deaths from a huge pile-up on I-5 caused by field-burning smoke. We have fled to the mountains to escape the smoke, only to have it blow into the mountains and ruin the beautiful days there. We remember the day that Steve Prefontaine coughed up blood after running in a big track meet in Eugene while fieldburning smoke was thick in the air of Hayward Field. (If Eugene is to be the running capital of the world, we cannot have bad air. And that does not just apply to the days of track meets, but to the everyday life of the many who are already here, or will come here to live, and enjoy our reputation as a clean and healthy place to live and work and enjoy the outdoors.)

The Willamette Valley populace should not have to breathe the garbage from the grass-seed-growing operations. Why should we do this so that these operations can enjoy a financial advantage over growers in other states who are not permitted to torch their fields. It is time to bring Oregon farming methods into the twenty-first century, as other neighboring states have done. No more open-field burning.

Sincerely,

Glen and Rhoda Love,
Eugene, Oregon

Footnote 38

FILE

Estimates of the Benefits and Costs From Reductions in Grass Seed Field Burning

June 1997*

*Revised publication version. The version contains format edits and copy edits to the "Estimates" report dated January 7, 1997. Both versions are available for review. No substantive changes were made from the January 7, 1997 version.

Report Summary

On March 29, 1996, the Department of Ecology issued an emergency ruling that called for a one-third reduction in the number of acres of field and turf grasses that could be burned in Washington in 1996. A permanent rule requiring an additional one-third reduction in 1997 is currently being considered. Specifically, the proposed rule would modify WAC 173-430, to require "burning of field and turf grasses for seed in 1997 and thereafter (until approved alternatives become available) be limited to no more than the larger of one-third of the number of acres permitted to burn in 1995 or in grass seed production on May 1, 1996. This report presents information on the probable economic benefits and costs that would result from a limitation on grass seed field burning and a consequent reduction in grass smoke.

Benefits and Costs

We estimate that probable benefits of the proposed reduction in grass seed field burning will exceed probable costs. Our best estimate of probable benefits is **$8.4 million** per year and our best estimate of probable costs is **$5.6 million** per year. Both costs and benefits include uncertainty so we estimated ranges for the probable values. We estimate total probable benefits between $6.6 and $10.2 million and total probable costs between $3.9 million and $7.9 million. There is considerable overlap in these ranges, but in our estimation the probable benefits are greater than the probable costs. Our estimates compare the pre-rule situation with the reduction of burning on two-thirds of bluegrass acreage.

Probable economic costs of the proposed rule stem from the limitation on grass seed field burning. Limitations on grass seed field burning reduces returns for grass seed farmers. Farm losses may come from reduced bluegrass yields, increased costs, or the reduced returns from an alternative crop. Besides these direct farm income losses, costs include environmental costs due to increases in soil loss from wind and water erosion, losses in the seed processing sector, and losses in jobs and income in the wider community. Other costs include emotional costs to those who lose jobs or suffer business losses, potential changes in farm accident rates due to changes in farm practices, and the costs of administering the program. The largest share of the cost is incurred by the grass-seed production sector.

The largest potential benefit of the proposed rule is improved air quality from reduced smoke emissions. Epidemiological evidence has established a clear link between small airborne particles and health, particularly for an at-risk population comprising people with existing cardio-pulmonary conditions such as asthma, emphysema, chronic bronchitis or heart disease.[1]

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[1]There is also some speculation that the higher rate of asthma found in Spokane compared to other regions may be due to the higher levels of particulate pollution in the Spokane area. Since this possibility is still speculative it was not counted in the study. Recent work at Eastern Washington University also indicates a possible link between smoke from field burning and cancer.

Additional benefits from the proposed rule include the benefits of traffic accident reductions, enhanced recreational opportunities, reduced dirt and nuisance effects from smoke particles, and the aesthetic effects of improved visibility.

In our studies we constructed some greatly higher cost estimates and some significantly lower cost estimates. Likewise we generated some significantly lower benefit estimates and some vastly higher benefit estimates compared to those reported above. However, these higher and lower cost and benefit estimates were based on less dependable estimation procedures or on unrealistic premises and were therefore not reported as part of the probable range. Those interested are directed to the detailed and technical reports.

The basic results of our study are described in the following summary. The larger report details how the estimates of probable benefits and costs were estimated. A series of technical appendices contain the detailed studies that generated the data leading to the benefit and cost estimates.

Estimated Costs

Since there is uncertainty about the impact of the proposed rule, our estimation of probable costs began by examining a number of possible scenarios for the impact of the rule. The final estimated range for economic costs was based on two scenarios that represent the likely outcomes of the rule. A final, best estimate was based on the most realistic features of these two benchmark scenarios.[2]

Cost estimates were based on an estimate of a little over 60,000 acres of planted bluegrass. We used past burn permits, conservation plans filed with the Farm Service Agency, and processor information about seed volume to estimate this acreage. Since the rule permits continued burning on one-third of the acreage until suitable non-burn technologies are certified, our estimates are based on the two-thirds or about 40,000 acres affected by the rule.

Table one shows the breakdown of the costs for each scenario. This table shows the estimated costs for the alternative version of the rule that includes a 5 percent exemption for land that is deemed extraordinarily difficult to cultivate using alternative (non-burn) technologies and a provision allowing growers to trade burn permits within local jurisdictions. Under this rule, fields that were certified by a conservation official as being extraordinarily difficult to cultivate would be given an exemption--with exemptions limited to 5 percent of the fields.. In other words, burning would be allowed on at least 33 percent and as much as 38 percent of a farmer's fields depending on field conditions.

[2]We calculated costs for about a dozen different scenarios. Many of these scenarios were calculated to test the impact of particular effects by taking them to an extreme; for example the loss of all affected grass acres. These different scenarios generated costs ranging from about $1.4 million to as much as $14 million--a tenfold difference. However, the range of estimates on the scenarios considered probable are those given above.

Adoption of the alternative version of the rule reduced costs by about $300,000 on the best cost estimate compared to the rule version that includes no exemption. (Analysis of the basic version of the rule can be found in the full report and the technical appendices.) This rule will also reduce benefits, but our benefits estimates were not finely tuned enough to estimate the value of this variation of the rule.

The benefits from trading were not explicitly estimated due to lack of appropriate data. The benefits of trading are that, once the overall desired limit on burning is set, farmers are able to increase efficiency--"fine-tuning" their farming by using burned bluegrass on the fields most productive under burning. Since we modeled farms in only two broad classes, irrigated and dryland, we were not able to capture the efficiencies that result from shifting burning from one field to another with different productivity and farming cost characteristics. We therefore expect costs lower than those reported here under the alternative version of the rule. In principle, the trading provision will not decrease benefits because it does not change the overall level of burning. However, in practice it is possible that some fields will be burnt that would otherwise not be burned. For instance, if a farmer had most of his bluegrass fields in a rotation (establishment, "take-out" year) where he did not need to burn, he might sell his permit and thereby increase the total burn.

It is also important to note that the impact of the trading provision will depend, among other things, on the scope of area for the rule. If permits were tradable across all of eastern Washington, it is likely that irrigated farmers would sell permits to dryland farmers, especially those in the Spokane area. Such a version of the rule would reduce the benefits of the rule, perhaps substantially. It is therefore assumed here that trading will be within local jurisdictions only.

Rotational Burn Cost Scenario

The estimate of total costs of a little under $4 million for the lower end of the probable cost range is based on an assumption that farmers will innovatively adapt to the rule change. We used a scenario of rotational burning to represent this innovation.

Burning is used in bluegrass farming primarily to remove residue--straw and thatch. If residue is not burned it must be removed some other way, generally by mechanically raking and bundling; otherwise seed yields will be drastically reduced. Even with mechanical raking and disposal of the residue, many studies show a yield penalty compared to burning. Our analysis assumes such a yield penalty. Therefore, use of non-burn technologies affects farm returns through both lower yields and higher costs compared to annual burning.

Under rotational burning of bluegrass fields, farmers would burn all bluegrass acres, but burn each field only every other year. Non-burn technologies would be employed in the alternate year. Because of the reduced yields and increased costs of mechanical residue removal, we

Table 1: The Probable Costs

Cost component	Cost estimates ($1000s) Rotation Scenario	Half-out scenario	Most probable scenario
Farm costs	$3,000	$5,120	$3,548
(No. jobs lost)	(+3)	(21)	(0)
Environmental costs	$0	$270	$270
Processing costs	$0	$477	$369
(No. jobs lost)	(0)	(9)	(0)
Economic impact costs	$552	$1,098	$586
(No. jobs lost)	(18)	(19)	(18)
Other costs	$388	$944	$790
TOTAL COSTS	$3,940	$7,909	$5,562

estimate that farmers and farm workers would lose about $3 million of income compared to pre-rule circumstances. While substantial, these losses are lower than the farm losses that would occur under most alternative scenarios we analyzed.

By using rotational burning, bluegrass acreage can be maintained at pre-rule levels. In a six year rotation farmers burn two times or one-third of the time. The reason that farmers can burn only two of six years in a rotation instead of three of six years is that fields are not burned in the establishment year. We also assumed that fields are not burned in the last ("take-out") year. Under current conditions some farmers like to burn in the last year, but this burn is for disease and weed control rather than for enhancing yields. So, in a six year rotation farmers would burn the third and fifth years and use non-burn residue removal in the second and fourth years. (A table in the full report shows the rotation more clearly.)

Some land is not suitable for non-burn technology and so would have to be burned every year or go out of bluegrass (for example, because it is too steep). However, the 5 percent exemption and the trading provision of this version of the rule should permit continued bluegrass cultivation on all acreage in this scenario.

Because bluegrass acreage is not reduced in this scenario, there are no environmental costs. Bluegrass reduces wind and water erosion compared to alternatives like wheat and is often recommended as part of conservation rotations. Also, since bluegrass seed production is reduced minimally, processors are not affected.

We also estimated impacts on the rest of the economy due to the "ripple" effects from reduced spending by farmers and workers in the bluegrass sector. We estimate these impacts at $552,000 in the rotational burning case. Generally, benefit cost studies do not count the indirect loss of jobs and the ripple effect of lost income in the rest of the economy. It is usually assumed that this secondary lost business and jobs will be made up elsewhere in the economy. However, in this case the comments at hearings and the results of the survey we conducted (primarily for our contingent valuation estimate of benefits) made it clear that people were concerned about the potential economic impact on the local economy of any losses to the bluegrass seed industry. We therefore examined these impacts more closely than is customary. We used a regional economic impact model to analyze the probable community economic impacts. Input-output estimates are biased upwards because they assume all job losses or business income losses are permanent. Our economic impact cost estimates are therefore adjusted to account for the rate at which lost jobs and business are made up by economic activity elsewhere. We used relatively high estimates of these "ripple" impact costs.

The rotational burning scenario is an example of the kind of innovation that may follow adoption of the burn rule. Other innovations might include better mechanical thatch removal and the development of seed varieties that maintain high yields under non-burn cultivation methods. Past experience indicates that it is highly likely that the agricultural industry will find an innovative way to adapt to the rule change so we place a high probability on this scenario. (See, e.g., Moore and Villarejo.) However, it will also take time for such innovations to be developed and shorter term losses are likely to be greater than those portrayed in this innovative technology scenario.

Half-Out Scenario

The estimate of about **$7.9 million** for the high end of the range of probable costs is based on the assumption that no change is made from currently available technology and current farm practices. We should be clear that this is not the highest cost we explored but the high end of what we estimate to be the range of probable costs[3]. In the half-out scenario we assume that farmers respond to the rule change using only current technology and farming practices. Current technology includes the machinery now developed for thatch removal and the current seed stocks. This estimate is also based on the current cost of non-burn technology for straw removal and a prediction of little or no increase in bluegrass seed prices even if production falls.

These assumptions are cautious. It is possible that the price of machinery for non-burn residue removal will fall somewhat when machinery is produced in larger quantities, and it is probable that some improvements in machinery will be made. It is likely that seed varieties optimized for non-burning cultivation will be developed. Also, it is very likely that grass seed prices will rise if supply is reduced. There are also emerging industries that would create a market for bluegrass straw, thereby reducing the cost of straw removal, and perhaps even generating a payment for the straw. Since any straw market is still speculative, we have made the assumption that there is no market for bluegrass straw (although we studied the potential impacts of such a market). In short, we assume none of these potentially mitigating developments in our half-out scenario which is why we consider it the top end of the probable cost range.

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[3] For instance, we analyzed the impact if all of the affected bluegrass acres (two-thirds of the total) go out of production and all job and income losses are permanent in one of the scenarios of our input-output model. While it is possible that all of the irrigated farms could switch out of bluegrass, it is very unlikely that all dryland fields will be switched to other crops. It is also very unlikely that all those who lose jobs will never again be employed.

The half-out scenario also assumes that most of the lost bluegrass acreage would go into wheat while a small proportion goes out of production altogether. For dryland fields this is the most likely outcome, but for irrigated fields there are more profitable alternatives than wheat, so this estimate is probably a bit high. Overall, we estimate that the bluegrass farm sector would lose about $5.1 million in lost farm returns and lost jobs in these circumstances.

In this scenario we estimate substantial lost bluegrass acreage in Washington--about 20,000 out of an estimated 60,000 total acres. We estimate that about half the affected bluegrass acres will move to an alternative use and half will stay in bluegrass production using non-burn technology. (This means that two-thirds of the original acreage will remain in bluegrass.) Switching one-third of the land from bluegrass to wheat will create environmental costs of about $270,000. It also means that the processing industry will suffer losses due to reduced bluegrass supply--though some or all of this might be made up by bluegrass seed planted elsewhere. We assumed about half would be replaced. The processing industry will suffer income and job losses of about $477,000.

We also estimate that the rest of the economy would suffer economic losses of about $1.1 million of lost jobs and business income. These are secondary losses due to lost purchases by the bluegrass production and processing sectors. They were estimated with the input-output model and account for re-employment using the same assumptions as for the rotational burn scenario.

Other costs include the cost of some bluegrass smoke which will be shifted to residents of northern Idaho as more production is moved into Idaho. We counted $324,000 in damages from the shifted smoke. The shifted cost estimate was based on the fact that these households would not get the full amount of the benefits from the adoption in the rule. Specifically, we calculated that half the lost grass-seed production would be replaced by Idaho grown grass-seed and that half of that would be grown in the Coeur d'Alene area.

We also included $160,000 in administrative costs. We added an extra margin of 5 percent on potential job and business losses to account for the emotional costs of these losses--about $460,000 in this scenario.

Another potential cost is the change in accident rates for farmers as they change production practices. We found no data on changes in accidents rates on which to build a cost estimate. However, we did make an illustrative calculation of the possible actuarial costs of any increases in accidents. Although any specific accident may have high medical and emotional costs, we found the potential monetary value of such costs low compared to the other costs, based on the probability of an accident in any given year.

Most Probable Cost Scenario

The above two scenarios bracket what we think are probable costs. Some innovative scenario like the rotational scenario is highly probable, but its actual nature is unknown so the cost estimates are imprecise. On the other hand, the estimate based on the half-out scenario is likely to be a bit high, but the costs are based on what is known to be feasible under current technology and farming practices. The half-out scenario is probably a good representation of what will happen in the short run while the industry adjusts to new conditions. However, a more likely estimate of costs after a year or two of adjustment can be obtained. We estimated a most probable impact based on using cautious, but more realistic assumptions from the two bracketing scenarios.

We believe that the most realistic assumption is that the bluegrass industry would adapt to a large degree but that some bluegrass production would nonetheless be lost. It is also probable that there would be some increase in bluegrass seed prices but, to be cautious, we assume none. To approximate the most likely outcome, we constructed a scenario in which half of the affected acreage (20,000 acres) switches out of bluegrass, but the acreage remaining in bluegrass (40,000 acres) adopts an innovative technology like the rotational burning cultural practice.

For this scenario we estimate total probable costs of about $5.6 million. The cost breakdown (Table 1) follows the same patterns explained for the other two cost scenarios. Direct farm income and job costs are a little higher than for the rotational burn scenario at $3.5 million. This estimate includes environmental costs which are the same as for the half-out scenario at $270,000. It also includes impacts on the processing sector of about $369,000 since some seed production is lost. Impacts on the general economy are about $586,000 in lost job and business income with the same assumptions about the rate at which lost jobs and business are replaced in the economy. Costs of shifted smoke, program administration, and emotional losses for lost jobs and income total $790,000.

Economic Benefits

We estimate probable benefits of the rule at between $6.6 to $10.2 million. Our most reliable estimate is that benefits will be about **$8.4 million.** This is a reliable, but cautious estimate of benefits. For instance, using an alternative, less dependable estimation technique, we estimate potential benefits of between $9 and $18 million. While these estimates are less reliable than the primary estimate, they suggest that it is unlikely that the primary estimate is overstated.

Willingness to Pay--Survey Estimates

Our principal estimation method is based on directly estimating the value of smoke reduction from the point of view of the average household in the affected area. This method estimates combined health and non-health benefits. To estimate this value we conducted a scientific, random sample survey of households in Spokane, other affected areas of Eastern Washington, and parts of Northern Idaho. We obtained 1,561 completed surveys. We used a standard economic valuation technique called the contingent valuation method. In the contingent valuation method households are asked how much they would be willing to pay (WTP) for implementation of the rule to reduce smoke from bluegrass seed field burning. To get reliable estimates survey respondents were asked to imagine they were voting in a referendum about whether to approve and pay for the smoke reduction program--the proposed rule. The willingness to pay estimate for the sample is then extrapolated to the overall population of the area.

Our best estimate of $8.4 million in benefits is based on this technique. The range around the estimate is based on the margin of error in extrapolating the benefit value from the sample population to the total population. Our use of a relatively large sample (1,561 households) compared to many studies of this type helps to minimize this margin of error.

Epidemiological-Economic Estimates

The alternative benefits estimation method uses an indirect method based only on potential health benefits. This is a two step procedure based on combining epidemiological and economic techniques. We first estimate the potential exposure of the affected population and the resulting probable change in medical and mortality impacts due to the improvements in air quality using the results of epidemiological studies. There is a large epidemiological literature documenting the health effects of small airborne particles. Particles from combustion processes appear to have larger health impacts than ordinary dust particles. The potential impacts of reduced particles include reduced medical costs, reduced loss of wages due to lost work, reduced "pain and suffering" and, most importantly, reduced mortality.[4] Once the potential improvements are identified, monetary values are estimated. The monetary values for impacts like asthma attacks are obtained from standardized values based on previous economic studies. We estimated benefits of between $9 and $18 million using this two step procedure.

The estimates based on this epidemiological-economic approach are imprecise. We lack detailed information on how the smoke reduced by the rule would reduce the exposure of the affected population. We had to use general estimates of this exposure, since the detailed monitoring and smoke modeling necessary to determine exposures have not been done. More detailed exposure knowledge would allow us to make more precise estimates of the health effects because we have very good information on the effects of particulate exposure from the extensive epidemiological literature on the impacts of airborne particles on human health. However, we had to use available estimates of the smoke exposure, which means these health cost estimates are imprecise.[5]

It is interesting to note, however, that the estimate of health benefits from reducing smoke actually exceeds the willingness-to-pay estimate. This is a paradox because the WTP estimate is supposed to include both health and non-health benefits. There are several reasons for this apparent paradox. One has been mentioned; the epidemiological-economic estimates of health benefits are imprecise.

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[4] The health effects of exposure to other constituents of smoke (such as volatile gases) were not estimated. Moreover the possibility that long term exposure to smoke and particles may increase the rate of asthma or of lung cancer were not used because reliable epidemiological estimates are not available.

[5] Another source of variance in the estimates is the assumed cost of mortality. The cost of mortality is the major component of benefits in this approach. We used medium to low estimates for the cost of mortality.

A second reason that the WTP estimate may be lower than the health based estimate is that many respondents did not like the fact that the proposed rule to reduce smoke would impose a burden on local farmers. They, therefore, discounted the value they were willing to pay for the program to account for this negative impact. This can be seen especially outside the Spokane and North Idaho areas. While the majority of households in Spokane and Northern Idaho favor the proposed rule, the majority of residents in other areas of Eastern Washington oppose the rule. Moreover, statistical analysis showed that those who felt the proposed rule would impose a burden on agriculture were more likely to oppose the proposed rule. These results imply that the willingness to pay for the smoke production is a net value: that is, the value of the benefits of smoke reduction to households reduced by a penalty or cost for the burdens of the program.

Finally, a third reason that the WTP estimate is low is that it measures benefits only from a private perspective. This means that, in evaluating their costs, households consider their costs for, say, hospitalization, but not the cost paid by insurance, other businesses, or government programs. This means that the survey based WTP benefit estimate is likely to be understated because it does not include costs to general businesses and the public. Thus, losses to the recreation industry in Northern Idaho are not included, though the cost of lost recreation days to the individual are included. The health exposure based estimates are also understated because they do not include non-health benefits at all. Therefore, the primary estimate of benefits is a conservative estimate.

Compensation Based Estimate

Besides the willingness to pay and epidemiological-economic estimates, a third estimate of benefits could be made based on the assumption that the population affected by smoke has the right to be free of smoke. If they have the right to be free of smoke they should not have to pay to get reduced smoke, they should be compensated for any damages caused by continued burning. This approach produces much larger estimates of the value of smoke reduction, over $30 million.

We put less emphasis on these estimates than the other two benefits estimates for conceptual and practical reasons. Conceptually, the question of whether it is the right of farmers to burn their fields or the right of local residents to clean air that should be paramount is a legal and moral question beyond the scope of this study. However, the main reason we put less emphasis on this estimate is that the method used for estimation of compensation is unreliable. We used the same survey to estimate compensation as we did for willingness to pay. However the compensation value is based on a very small number of respondents making it hard to generalize to the whole population, and respondent reporting patterns are less stable for compensation questions giving rise to a great range of individual value estimates. Most economists and government agencies disallow compensation estimates for these practical reasons. For instance, the National Oceanic and Atmospheric Administration disallows compensation estimates based on the recommendations of a blue ribbon panel of economists.

Footnote 38

Estimates of the Benefits and Costs from Reductions in Grass Seed Field Burning

Project Report

December 27, 1996

Submitted to:

Washington Department of Ecology
Air Quality Program
P.O. Box 47600
Olympia WA 98504-7600

Submitted by:

David Holland, Kathleen Painter, R. Douglas Scott,
Philip Wandschneider, David Willis[1]

Department of Agricultural Economics
Washington State University
Pullman, Washington

Report prepared under terms of Inter-agency Agreement No. C9600164.

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[1]Wandschneider (Principal Investigator, Ph.D.) is an associate professor; Holland (Investigator, Ph.D.) is professors, and Painter (Investigator, Ph.D.), Scott (Investigator, Ph.D.), and Willis (Investigator, Ph.D.) are Research Associates at Washington State University. Herb Hinman (Professor, Ph.D.) and Eric Schuck (Research Assistant, M.A.) also helped in portions of this research.

Revised publication version. The version contains format edits and copy edits to the "Estimates" report dated January 7, 1997. Both versions are available for review. No substantive changes were made from the January 7, 1997 version.

Introduction: Purpose and Limitations of the Study

On March 29, 1996, the Department of Ecology issued an emergency ruling that called for a one-third reduction in the number of acres of field and turf grasses that could be burned in Washington in 1996. A permanent rule requiring an additional one-third reduction in 1997 is currently being considered. Specifically the proposed rule would modify WAC 173-430 to require burning of field and turf grasses for seed in 1997 and thereafter (until approved alternatives become available) be limited to no more than the larger of one-third of the number of acres permitted to burn in 1995 or in grass seed production on May 1, 1996. This report presents information on the probable economic benefits and costs that would result from a limitation on grass seed field burning and a consequent reduction in grass smoke.

Study Method

The purpose of an economic benefit-cost analysis is to provide a systematic and comprehensive comparison of the positive and negative impacts of a proposed program (e.g., the proposed burn reduction rule). Aside from the legal requirement, the economic evaluation will help understand what is being sacrificed to attain the goals of the program. Often all of the impacts (positive and negative) are not understood without a systematic analysis. Moreover, a systematic accounting puts into perspective the individual benefits and costs, which when considered one at a time may be misleading about the desirability of the project. Finally, the economic evaluation is also likely to illuminate methods for mitigating some of the potential sacrifices.

A list of impacts includes financial costs to farmers and grass seed processors, environmental losses from increased erosion, and losses to the general economy. Benefits include improvements in the health of people with lung and heart conditions, reductions in human lives lost, improvements in the aesthetics of air quality, and increases in recreational activities because of the improved environmental conditions.

The economic evaluation method uses monetary equivalents to put all effects into one common denominator. While using monetary equivalents is sometimes offensive to some people, it does provide a comprehensive and standardized valuation system by which all effects can be compared. Nonetheless, it would be asking too much of economic analysis to claim that economic values capture all the value of some specific impact. Thus, an individual human life is priceless--and so is a great work of art or a pristine environment. Moral and aesthetic judgements cannot be reduced to economic values, but economic evaluation is useful for comparing all benefits and costs.

Unless stated otherwise, this analysis employs the general conventions of benefit-cost analysis. Benefit-cost analysis counts costs and benefits from the national perspective to whomsoever they accrue. One implication of these assumptions is that environmental costs are counted even though they are not incurred directly by farmers. Another implication is that costs to residents of Idaho and other states as well as to Washington residents should be counted if the Washington rule affects them.

The two central concepts used to create the consistent valuation scheme is that economic costs are opportunity costs (e.g., the medical cost of treating smoke induced illness is the lost opportunity to use those medical resources to treat other illnesses) and that economic values are the price that people would be willing to pay for a (increment of a) desired item or prices they would be willing to accept as compensation (sell) for an item or service that is lost. (See Carruthers, *Ecology Economics Resource Book* for further discussion.)

Input-Output Analysis

Generally, benefit-cost studies do not count the indirect loss of jobs and the ripple effect of lost income in the rest of the economy. It is usually assumed that secondary lost business and jobs will be made up elsewhere in the economy. However, in this case the comments at hearings and in the survey we conducted made it clear that people were concerned about the potential economic impact on the local economy of any losses to the bluegrass seed industry. Therefore, we examined secondary impacts more closely than is customary.

In benefit-cost analysis, these secondary costs are usually not counted because it is assumed that the value of the lost production is captured by the loss in the output of the good, valued at its selling price. Benefit-cost (B/C) analysis is based on two assumptions. The first assumption is that the economy is at full employment. This means that all labor, capital, and land is being used for some productive activity. Second, the standard benefit-cost study assumes that factors are flexible and mobile. Each factor has a back-up use--an opportunity cost. If it were not employed in its present use, it could be employed elsewhere, at almost the same level of productivity.

Based on this full employment (flexible factor assumption) most benefit-cost analyses assume that any labor or capital thrown out of work will instantly find itself re-employed. Under this assumption as one reduces sales at the local supermarket and restaurant, offsetting increases in sales are occurring at another community's supermarket and restaurant as the released laborers and capital equipment go elsewhere.

In contrast, the input-output (I/O) assumption is that any factor that is thrown out of production will stay out of production. Suppose reduced bluegrass production means reduced income to community farmers leading to lower sales at the local fast food place which leads to firing of a local high school teenager. In the input-output framework the teenager never gets another job--at least in the region of the input-output analysis. In the framework of benefit-cost analysis, the teenager is hired the instant he walks out the door of his old employment. Obviously neither assumption is very realistic. The total input-output impact overestimates the impact; the standard benefit-cost assumption underestimates the impact. The actual impact will vary depending upon the rate of re-employment. The rate of re-employment will depend on the flexibility of the resource and the vigor of the economy in generating new opportunities. Re-employment will be faster in good economic times than bad.

There are other differences between the input-output approach and benefit-cost analysis. For instance, I/O analysis looks at the overall impact on economic activity, whereas B/C analysis views economic impacts through the normative lens of benefits and costs. Input-output analysis also traces only market transactions and so does not capture "external effects" like the impact of changes in soil productivity, water quality and air quality which are typically incorporated into benefit-cost analysis. In this study we use the input-output results within the framework of benefit-cost analysis.[1]

Decision Criteria

Another point to remember in interpreting the economic evaluation results is that economic evaluation methods are but one way of evaluating policy options. Other methods include voting and the legal-judicial process. Economic evaluation is simply a method to provide information on relative tradeoffs: what must be sacrificed in terms of things people value in order to implement policy A or project B. It may be that economic tradeoffs are overruled by other values as determined by legal rights or the democratic decision process.

Limitations of Economic Evaluation

Economic evaluation is not a precise discipline. Although one will typically find very specific numeric estimates of values in economic evaluation studies, a great deal of inherent uncertainty always underlies these very exact numeric estimates. In this study, we too have generated exact numeric estimates, but we have generated a range of such estimates to reflect the underlying uncertainty in the estimates.

There are two principle sources of imprecision in estimating economic values. First, estimates of benefits and costs are based on predictions of future impacts. Predicting the future is necessarily uncertain. We have approached this task by generating a number of possible future scenarios and then judging which scenarios are most likely. Reasonable people may disagree with our predictions. We have presented the material which we used to generate scenarios so that those who differ might build alternative scenarios using their best judgement of what the future will be like.

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[1]In the input-output study we looked only at losses to the Washington economy. This is a reasonable approximation to the national losses provided that most changes in the processing industry occur in Washington. In fact a large part of the processing industry is located in Idaho. It may be that losses in Washington are offset by gains in Idaho (or someplace else like Oregon). In this case an approximation of national effects can be gained by using the low impact assumption for the Washington economy impacts.

The second major source of uncertainty in economic evaluation lies in the nature of values themselves. Economic value judgements, like other human value judgements, do not reflect some physical characteristic of nature that can be precisely measured. Values reflect subjective mental states. Economic estimates can be somewhat misleading because they can be presented with numeric precision down to the last decimal place. Indeed, when we investigate specific scenarios under specific value assumptions we take care to make sure our numeric calculations are exact. This numeric exactitude serves to maintain consistency and rigor. But ultimately all values rest on the unknowable inner experience of individuals. Even market prices, the talisman of economic values, are fuzzy; they change with changing income, tastes, and other shifts in circumstances.

Fortunately, the legislative mandate is not to estimate the exact benefits and cost of the proposed policy. Rather it is to estimate probable benefits and costs of the policy. Our estimates of probable benefits and costs follow.

Probable Cost Estimates

Introduction and Scenarios

We estimated probable costs of $5.6 million with a probable range from about $3.9 to $7.9 million. In this section we describe how we estimated these costs. The detailed studies on which these estimates were built are describe in the attached technical appendices.

Probable economic costs of the proposed rule stem from the limitation on grass seed field burning. Limitations on grass seed field burning reduces returns for grass seed farmers. Farm losses may come from reduced bluegrass yields, increased costs, or the reduced returns from an alternative crop. Besides these direct farm income losses, costs include environmental costs due to increases in soil loss from wind and water erosion, losses in the seed processing sector, and losses in jobs and income in the wider community. Other costs include emotional costs to those who lose jobs or suffer business losses, potential changes in farm accident rates due to changes in farm practices, and the costs of administering the program.

Our estimation of costs was based on two major sub-studies: one estimating changes in farm level costs and returns and environmental costs (Painter, Technical Report B), and the other study estimating the impacts that reduced farm production and spending would have on the rest of the economy, particularly the seed processing industry (Holland and Willis, Technical Report A). These studies are described in more detail in separate appendices.

Since there is uncertainty about the impact of the proposed rule, our estimation of probable costs began by examining a number of possible scenarios for the impact of the rule. We began with three scenarios in which bluegrass was replaced on all the affected acres (two-third of the total), half the affected acres (one-third total), and none of the affected acres. In preliminary studies these were termed the high, medium, and low impact scenarios based simply on the number of acres affected. Analysis of the total loss and no loss (high and low impact) scenarios can be found in the technical reports. Our final cost estimates were based on the medium impact or half-out scenario.

Beginning with these baseline scenarios we also explored a number of additional scenarios. In some scenarios prices changed to reflect the impact of reduced supply. In other scenarios markets were assumed to have emerged for grass straw. In still others the impact of changing farm technologies was examined. A totally separate cost estimate was derived from survey data. From these scenarios a wide range of possible cost impacts emerged. Our potential cost estimates ranged as low as $1.4 million to as high as $14 million. However, many of these scenarios were unrealistic--but useful for examining specific impacts. We chose two scenarios as most representative of the likely outcome of the proposed rule and these set the probable range of costs. A final, best estimate was based on the most realistic features of these two benchmark scenarios. We describe these scenarios next.

Half-Out Scenario

For what became the high end of our probable cost range we used the scenario in which one-half of the affected acres are switched from bluegrass production into alternative land uses.[2] This outcome would imply significant environmental costs because about 20,000 acres is switched from bluegrass into alternative rotations or out of production altogether. This outcome would also cause economic losses in the processing industry unless the grass seed were replaced by production from other areas. We assume some replacement--which mitigates some of the economic damages but also means that the costs of smoke are shifted to other areas.

We adopted this "medium" or half-out scenario as one representation of probable costs because our farm analysis showed it to be a likely outcome. In irrigated areas farmers have profitable alternatives to blue grass so that they are likely to change crops as the costs of bluegrass production increase. Our estimates are that about one-third of bluegrass is from irrigated acreage. Farmers in dryland areas have fewer good alternatives. Therefore, many of them are likely to keep most of their blue grass in production even if they have to use more expensive non-burning technologies. Assuming that some of the dryland bluegrass acreage will move to other land uses, the half-out scenario appears to be a likely outcome under current technology. Moreover, price sensitivity analysis confirms this judgement. Reduced bluegrass production will lead to higher prices unless that production is replaced. A modest increase of five percent will make it profitable to keep more than half of the blue grass in production even using current high cost non-burning residue removal technology. The cost we report here is based on the assumption of no price impacts.

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[2]In preliminary studies this was called a medium impact or moderate cost scenario because it was halfway between the extremes of all affected fields switching out of bluegrass on the one hand and none of the fields switching to alternative uses on the other.

Rotational Burning Scenario

Past evidence suggests that farmers and the agricultural industry often adapt creatively to new conditions. Economists logic suggests that when prices and conditions change, producers and consumers change their behaviors. Experience and ex-post studies have shown that farmers are usually better adapters than researchers give them credit for. Often the yield and economic impacts predicted by researchers do not emerge because of innovation by farmers and the farm supply industry (Moore and Villarejo).

We modeled a scenario in which behavior changed in response to adoption of the proposed rule. We used a rotational burning scenario to represent such innovative behavior. In rotational burning farmers burn their bluegrass fields every other year. This works out to two years in a six year rotation when non-burning in the establishment and final year of harvest are taken into account. Table 2 shows how such a rotational pattern would work. The fields are divided into six areas--one for each year of rotation including the establishment year. In practice the transition to rotational burning may involve some yield losses or need to burn additional acres in the first year if permits were available through trade or exemption. The reason for the potential yield losses is that, based on past history, some fields may be due to be brought out of rotation sooner than scheduled according to the table below. For instance, in the extreme case a farmer might have had all his bluegrass in the final year of a rotation just before the rule took effect. All his fields would look like field one on our chart. He would have to make some adjustments (either keep a field in an extra year, or burn out of sequence) in order to get his fields into the rotational sequence.

Table 2. Rotational Burning

Year	Field 1	Field 2	Field 3	Field 4	Field 5	Field 6
1	establish	non-burn	**burn**	non-burn	**burn**	non-burn
2	non-burn	establish	non-burn	**burn**	non-burn	**burn**
3	**burn**	non-burn	establish	non-burn	**burn**	non-burn
4	non-burn	**burn**	non-burn	establish	non-burn	**burn**
5	**burn**	non-burn	**burn**	non-burn	establish	non-burn
6	non-burn	**burn**	non-burn	**burn**	non-burn	establish
7	new crop	non-burn	**burn**	non-burn	**burn**	non-burn
etc.	etc.	etc.	etc.	etc.	etc.	etc.

Rotational burning has the benefit of avoiding the sharp yield declines of the later years of the rotation. It also allows the farmers to keep their fields in bluegrass for longer so that they can recoup the establishment costs when no harvest is produced. So, in the rotational burning scenario yields decline (we estimate 30 percent in each of the two years preceded by non-burn residue removal for an average of about 12 percent over the five years of production) but very little bluegrass acreage is lost. Therefore, environmental impacts and effects on jobs and the processing industry are minimal.

Most Probable Cost Scenario

The above two scenarios bracket what we think are probable costs. Some innovative scenario like the rotational burning scenario is highly probable, but its actual nature is unknown. Therefore, the cost estimates are imprecise. On the other hand, the half-out scenario is more exact because the costs are based on what is known to be feasible under current technology and farming practices. However, the cost estimate based on the half-out scenario is also probably an overestimate because some kind of adjustment will take place. Since the half-out scenario is based on a continuation of current trends with only the increased cost of residue removal, it is probably a good representation of what will happen in the short run while the industry adjusts to new conditions. However, the most realistic assumption for the medium and longer term is that the bluegrass industry will adapt to a large degree, but that some bluegrass production will be lost nonetheless. It is also probable that there will be some increase in bluegrass seed prices but, to be cautious, we assume none.

To approximate the most likely outcome we estimated a scenario in which half of the affected acreage switches out of bluegrass, but the acreage remaining in bluegrass adopts an innovative technology like the rotational burning cultural practice. This scenario is built up from pieces of other scenarios we modeled and reported in the technical reports. It does not appear as a separate scenario in the technical reports.

In summary, our final estimates are based on three scenarios. One scenario continues production of bluegrass in all areas but at reduced yields (an average of about 12 percent lower over the six-year rotation) under innovative management systems. A second scenario assumes that one half of the affected blue grass goes out of production and land moves to other uses. (One-half of two-thirds means that one-third of the original total of about 60,000 acres will go out of bluegrass production). The most likely estimate is based on adoption of innovative farm practices, but with a loss of one half the affected acres so that environmental and processor and other economic impacts remain.

Table 3 and 4 show our calculations of probable costs. Table 3 shows estimates of the three scenarios under the baseline rule and Table 4 shows estimates including the exemption and trading version of the rule. (The final results shown in Table 1 in the Summary are essentially a condensed version of Table 4.) Table 4 shows the estimated costs for the alternative version of the rule that includes a 5 percent exemption for land that is deemed extraordinarily difficult to cultivate using alternative (non-burn) technologies and a provision allowing growers to trade burn permits within local jurisdictions. Under this rule, fields that were certified by a conservation official as being extraordinarily difficult to cultivate would be given an exemption--with exemptions limited to 5 percent of the fields. Adoption of the alternative version of the rule reduced costs by about $300,000 on the best cost estimate compared to versions of the rule that include no exemption. (Analysis of the basic version of the rule can be found in the full report

Table 3. Base Rule Cost Estimates ($1000s)

Cost Category	Rotational Burn Scenario			Half-out Scenario			Best estimate			Comments
	Direct Costs	Potential Costs	**Estimated Costs**	Direct Costs	Potential Costs	**Estimated Costs**	Direct Costs	Potential Costs	**Estimated Costs**	
1. Farm level costs:										
Lost income	$3,030	$3,030	**$3,030**	$5,150	$5,150	**$5,150**	$3,51 0	$3,510	**$3,510**	**100% productivity loss**
Lost employment	$0	$0	**$0**		$340	**$170**		$340	**$170**	50% job loss
2. Environmental cost:										
Soil loss, clean-up, AQ & WQ	$30	$30	**$30**	$300	$300	**$300**	$300	$300	**$300**	$15/acre lost bluegrass
3. Direct processing										
Lost income	$0	$0	**$0**		$300	**$270**		$230	**$207**	90% lost productivity
Lost employment	$0	$0	**$0**		$480	**$240**		$370	**$185**	50% job loss
4. Rest of the economy:										
Lost income		$600	**$360**		$1,300	**$780**		$660	**$396**	60% productivity loss
Lost employment		$960	**$192**		$2,110	**$422**		$1,350	**$270**	20% job loss
5. Other costs:										
Shifted smoke costs	$0	$0	**$0**	$324	$324	**$324**	$324	$324	**$324**	
Administrative costs			**$160**			**$160**			**$160**	two FTEs
Emotional losses			**$230**			**$484**			**$323**	5% penalty
TOTALS	$3,060	$4,620	**$4,002**	$5,790	$10,320	**$8,292**	$4,15 0	$7,100	**$5,857**	

Table 4. Alternate Rule Cost Estimates ($1000s)

Cost Category	Rotation scenario Direct Costs	Rotation scenario Potential Costs	Rotation scenario **Estimated Costs**	Half out scenario Direct Costs	Half out scenario Potential Costs	Half out scenario **Estimated Costs**	Best estimate Direct Costs	Best estimate Potential Costs	Best estimate **Estimated Costs**	Comments
1. Farm level costs:										
Lost income	$3,000	$3,000	**$3,000**	$4,960	$4,960	**$4,960**	$3,385	$3,385	**$3,385**	100% productivity loss
Lost farm employment	$0	$0	**$0**		$320	**$160**		$325	**$163**	50% job loss
2. Environmental cost:										
Soil loss, Clean-up, A & WE	$0	$0	**$0**	$300	$300	**$270**	$300	$300	**$270**	$15/acre lost bluegrass
3. Direct processing										
Lost income	$0	$0	**$0**		$280	**$252**		$215	**$194**	90% productivity loss
Lost employment	$0	$0	**$0**		$450	**$225**		$350	**$175**	50% job loss
4. Economic costs in the rest of the economy:										
Lost income		$600	**$360**		$1,150	**$690**		$540	**$324**	60% productivity loss
Lost employment		$960	**$192**		$2,040	**$408**		$1,310	**$262**	20% job loss
5. Other costs										
Shifted smoke costs	$0	$0	**$0**	$324	$324	**$324**	$340	$324	**$324**	
Administrative costs	$160	$160	**$160**	$160	$160	**$160**	$160	$160	**$160**	Two FTEs
Emotional losses			**$228**			**$460**			**$306**	5% emotional loss penalty
TOTALS	$3,160	$4,720	**$3,940**	$5,760	$10,000	**$7,909**	$4,185	$6,925	**$5,562**	

and the technical appendices.) This rule will also reduce benefits, but our benefits estimates were not finely tuned enough to estimate the value of this variation of the rule.

The benefits from trading were not explicitly estimated due to lack of appropriate data. The benefits of trading are that, once the overall desired limit on burning is set, farmers are able to increase efficiency--"fine-tuning" their farming by using burned bluegrass on the fields most productive under burning. Since we modeled farms in only two broad classes, irrigated and dryland, we were not able to capture the efficiencies that result from shifting burning from one field to another with different productivity and farming cost characteristics. We therefore expect costs lower than those reported here under the alternative version of the rule. In principle the trading provision will not decrease benefits because it does not change the overall level of burning. However, in practice it is possible that some fields will be burnt that would otherwise not be burned. For instance, if a farmer had most of his bluegrass fields in a rotation (establishment, "take-out" year) where he did not need to burn he might sell his permit and thereby increase the total burn.

It is also important to note that the impact of the trading permit will depend, among other things, on the scope of area for the rule. If permits were tradable across all of eastern Washington it is likely that irrigated farmers would sell permits to dryland farmers, especially those in the Spokane area. Such a version of the rule would reduce the benefits of the rule, perhaps substantially. It is therefore assumed here that trading will be within local jurisdictions only. (We could estimate the cost reductions of trades from irrigated fields to dryland fields since we modeled them separately. We didn't estimate these cost reductions because of the assumption of local trading only.)

Direct Farm Costs

Direct farm level losses comprise the majority of the losses in all three scenarios. Direct farm losses are calculated as reductions in returns to management, capital, and land.[3] (See Technical Report B for details.) The cost of variable inputs, capital, and labor are subtracted from revenues. These returns may be distributed as profits to farm operators, rents to landlords, mortgage payments, or taxes.

The basic cost of any reduction in allowable grass seed field burning is the cost of lost farm level production. Our primary method for estimating farm level financial costs was the farm budget approach. Budgets were based on the history of farm budget research done at WSU, particularly bluegrass budgets based upon a multi-state research project entitled "Bluegrass Seed Production Without Open Field Burning" currently underway at Washington State University, the University of Idaho and Oregon State University on non-burning methods for producing both dryland and irrigated Kentucky bluegrass (STEEP project #PSES 061-K534). Enterprise budgets for

[3]These are called economic rents or quasi-rents (producer surplus) in economic jargon.

producing common and proprietary varieties of Kentucky bluegrass were developed in close coordination with growers for both irrigated and dryland production (Hinman, personal communication). Budgeting of the costs for the new technologies which would be used to replace burning was based on the best available equipment costs, but such costs could change when the machinery goes into production. (Usually mass production of equipment leads to lower prices. In this case it may be that the equipment is so specialized it never gets mass produced.)

Typical yields were determined using results of three years of on-farm field trials as well as input from growers. The bluegrass price is based on the 1991-1995 average price and the typical differential for proprietary varieties.

The total cost will depend on the bluegrass seed acreage affected. The exact acreage of bluegrass currently under cultivation is unknown. There are about 40,000 acres permitted for burning. Washington Agricultural statistics also reports about 40,000 acres of bluegrass. However, these official figures appear to be underestimates. By using the higher of the acreage from 1996 burn permits or the amount of acreage reported in bluegrass acreage as part of conservation plans we could document about 54,000 acres. However, information from seed processors indicates that there may be even higher acreage. We based a final estimate of acreage on the documented 54,000 acres adjusted upwards based on the information from processors. We have used 60,000 acres of planted bluegrass in this study. Although this is more acreage than we can document, it is more consistent with the information from seed processors than lower estimates would be.

Farm budget analysis was done separately for irrigated and dryland farms due to a large number of differences between the two farming systems. Irrigated farms are generally on more level ground, have more consistent yields, and usually use proprietary seeds which often command a price premium. Dryland bluegrass farm systems are often on the steeper, more erodible and more difficult to farm ground, and have more erratic yields and generally use common bluegrass. The results of the two separate estimates were then combined for the total estimates.

As noted above, a wide variety of scenarios about the future were budgeted. (See technical report.) Table 5 summarizes some of the key farm budget scenarios estimated. The first budget (A) is a somewhat simplified budget designed to be consistent with the input-output analysis.

Half-Lost Scenario

The half out, fixed price scenario (A) is the basis for our estimates of the high range of probable costs. In this scenario a total of approximately one-third of the land remains in burned bluegrass, one-third goes to wheat, and one-third goes to non-burn technology bluegrass (compared to the

Table 5. Farm Returns

Scenario/Estimate	Lost Grass Acres	Lost Farm Returns Base Rule	Alternative Rule
A. Half-out scenario (fixed prices, wheat replace bluegrass)	20,000	$5,533	$5,143
B. Flex price, flex rotation scenario (price up 5%, best crop replaces bluegrass)	27,333	$4,267	$3,835
C. Rotational burning scenario	0	$2,997	NA
D. Other scenarios			
D1. Rot burn + $15 subsidy	0	$2,671	NA
D2. Rot burn + straw market	0	$2,128	NA
D3. Rot burn + subsidy + mkt	0	$1,803	NA

original, pre-rule situation). Also 10 percent of the one-third that goes out of bluegrass, (3 percent of the total) is idled altogether. Although this idled land will probably be used for pasture it is assumed to generate no net returns. Returns to farms drop for three reasons. Costs of non-burn technologies are higher; returns to land in wheat are lower than returns to bluegrass (idled land brings no net returns); and yields in non-burn bluegrass are lower. The cost increase in no-burn bluegrass is due to the higher costs of mechanical thatch removal and the costs of straw disposal. (See technical report for details.)

This half-out scenario is unrealistic in two ways. Irrigated bluegrass farmers are modeled as switching to wheat rather than to their most profitable rotations. (For dryland farmers wheat is generally the most profitable rotation.) It was also assumed that prices would not change in order to be consistent with input-output modeling. However, indications are that bluegrass is price responsive (Folwell). If supply declined, prices would increase. This would increase returns to the remaining bluegrass and would attract some of the lost acreage back into bluegrass production. Indeed this is a more realistic outcome we have modeled as the flexible prices scenario (B).

Although the half-out scenario is unrealistic, it was chosen to represent the higher range of potential farm costs because of its consistency with the input-output model. It also produces production estimates that are consistent with a more realistic model in which irrigated farmers switch to their next most profitable crops and bluegrass prices rise a modest 5 percent. However, the price increase and opportunity to use the best rotation in the best rotation, flex price scenario (B) reduce farm losses by about $1 million compared to our base scenario--indicating that we are

are probably overestimating costs somewhat. This is one reason we designate the base half lost scenario to be the high end of the probable costs.

In preliminary studies we examined alternative assumptions about the direct impact on farmers of reducing bluegrass acreage. In one scenario farmers are assumed to continue to grow the same quantity of bluegrass as before the rule, but the affected two-third acres will all be produced using alternative, non-burn technology. In another fixed price, wheat rotation scenario we examined what happens if all the affected acres (two-third of total) go out of bluegrass production. These scenarios allowed us to test the impact on the economy and the processing sector of the extreme assumptions of no lost acreage or all affected acres lost. See the technical report for details.

In the next farm budget (B) we test the effect of price changes and allow farmers to choose the best alternative rotations. This and similar scenarios we explored are more realistic at the farm level because they are based on what farmers could do to make the highest possible profit (or lowest losses) in each case. In these scenarios the high costs of alternative, non-burn thatch/straw removal tends to drive production of bluegrass out. However, research shows that bluegrass prices are quite sensitive to changes in supply (Folwell et al). Reductions in bluegrass production will induce higher prices which in turn will attract some farmers back into production. How much of a price reaction there will be depends on how much reductions in Washington bluegrass is replaced by bluegrass elsewhere. Based on the history of grass burning restrictions in Oregon and the increasing attention the Environmental Protection Agency is giving to particulate pollution, it is highly probable that areas outside Washington will also be subject to restrictions on burning which will prevent other areas from replacing all Washington bluegrass.

In addition to the 5 percent price increase we examined scenarios using a 15 percent price increase and no increase in price together with flexibility in choosing the best rotation. See the technical report for details. As noted above, returns to farmers improve compared to the case when they were forced to switch to wheat and prices remained constant. It is possible that a sufficient price rise would compensate farmers for the higher cost of using non-burn technology. In the 15 percent price rise scenario (discussed in technical report) irrigated farms actually gain relative to the pre-rule situation, though dryland farms still lose and overall farm losses are reduced to about $2.3 million.

The next scenario, C, is the rotational burn, adaptation scenario described above. We examine the possibility that farmers would creatively adapt to the burn regulation and determine efficient and profitable ways to farm.

A final group of scenarios (D) examined some possibilities for mitigating farm losses. For instance, the financial impacts on farmers might be mitigated if markets for bluegrass straw appeared or if the costs of straw removal were compensated by the public sector. The budgets in section D illustrate the impacts of the possibility that a market for bluegrass straw would develop or that subsidies would be provided to bluegrass farmers to compensate for their losses. We did not include these mitigating features in any of our final estimates, but the data indicates that farm losses can be reduced by up to about $1 million.

Agricultural Job Losses

Returning to tables 3 and 4, we next examine losses to agricultural labor. Tables 3 and 4 show potential and estimated costs of job losses. As discussed above, Benefit Cost studies usually do not count the secondary loss of jobs and the ripple effect of lost income in the rest of the economy.[4] However, in this case we used a regional economic impact model to include probable job and business losses in our analysis.

We used the input-output model (see appendix) to estimate potential losses of jobs in the farm sector. The input-output model estimates potential job loss. The number of jobs lost is a potential rather than an actual job loss because the model assumes all those who lose employment at one farm will never get a job the rest of their life (or more accurately, the rest of the model life). The actual job loss depends on how many and how quickly those who lose jobs are re-employed. Records for unemployment compensation claims from the Washington Employment Security Division show that most farm workers who lose jobs are re-employed fairly quickly. However, much of this quick re-employment reflects the large short-term work in agriculture. We assume that some of the lost jobs are going to be for the more permanent "hired hand." Since workers in rural communities tend to be more place bound and the job market more restricted we assume that 50 percent of workers remain permanently unemployed.

Note also, that the job losses counted in the model are net losses. The model calculates the number of jobs lost in switching out of bluegrass and the number gained jobs gained from replacing bluegrass with say, wheat production. Thus, if a farm replaces bluegrass with wheat and keeps the same level of hired labor it will show up as no change in jobs.

We estimated no change in employment in the rotational burning scenario. If anything, the use of non-burn technology might add some employment to the bluegrass sector though our model picked up none. In the half out and most probable scenarios we estimate some net job loss. If about half of these workers find jobs, then the economy will suffer a loss of about $170,000 due to these lost agricultural jobs in both scenarios.

Environmental Costs

Returning to Tables 3 and 4, the next category is environmental costs. Bluegrass is used as a cover crop to prevent soil erosion. Replacing bluegrass with other crops will generally increase

[4]See also discussion below concerning economic impacts and the input-output technical report appendix.

soil erosion (both water based and wind erosion) although in irrigated areas bluegrass may sometimes be replaced with alfalfa, another good ground cover. Farmers bear some of these costs in the form of reduced future productivity and costs of cleaning up on-farm ditches. Other costs are incurred by the local community including the cost of cleanig sediment from ditches and the environmental impacts of lower air and water quality.

Environmental costs are shown in Table 6 with the affected acreage for the three probable estimate scenarios. Environmental costs were estimated separately for irrigated and dryland areas.

Table 6. Environmental Costs

Scenario/ estimate	Lost Bluegrass (Acres)	Environmental Costs ($1,000s)
Rotation scenario		
Base rule	2,000	$30
Alternative rule	0	$0
Half-out scenario		
Base rule	20,000	$300
Alternative rule	18,000	$270
Best estim. scenario		
Base rule	20,000	$300
Alternative rule	18,000	$270

Environmental costs for dryland areas were estimated as the sum of costs for cleaning-up dirt due to increased off-site run-off from eroding fields; a value for impacts on water quality; and a value for the potential for lost future production due to the loss in soil from increased erosion. Only the clean-up costs for ditches has a market value, the other environmental costs are non-monetarized. Estimation of non-monetarized values require specialized techniques such as the survey based valuation technique we used in this study to estimate benefits of reduced smoke. Since additional non-market studies were beyond the time and resources of this study we used environmental values from other studies. Most studies measuring the value of erosion control have used a value between $1 and $5 per ton of top soil eroded. We used $5 per ton of erosion, a value on the high end of those found in the literature. Based on an average of 3 tons per acre of erosion from dryland wheat, we estimate environmental costs of $15 per acre in Spokane county and we have used the same figure elsewhere. See the technical appendix for more details on these calculations.

In the irrigated areas, wind erosion is the major environmental concern. Wind erosion is extremely variable, depending on location and crop cover. In some cases bluegrass might be replaced by alfalfa which would cause little or no change in wind erosion. However, fields switched to other crops may experience quite large increases in soil loss, since wind erosion varies from 4 to 21 tons per acre for Columbia Basin row crop rotations. But we have no concrete data on what change in erosion will come from switching out of bluegrass. We also have no values for the per acre or per ton value of the wind erosion. In the absence of any specific information on wind erosion quantities or values we used the same $15 per acre for environmental losses in the irrigated areas as we used in the dryland areas.

Tables 3, 4, and 6 show that environmental costs are minimal for the rotational burn scenario because the bluegrass industry keeps about the same amount of land in bluegrass. In the half-out and best estimate scenarios about 20,000 acres of bluegrass are lost leading to environmental damages of about $300,000 in the base rule. For the alternative rule allowing exemption and trading 18,000 acres are lost for a cost of $270,000.

Direct Processor Costs

The next two cost items in Tables 3 and 4 are the economic costs to the processor industry due to the reduced supply of bluegrass seed. Tables 7 and 8 show the economic impact effects to the farm sector, processors and the rest of the economy in isolation for ease of reference and comparison to the data in the summary and technical reports. The potential cost numbers are what appear in the technical appendix describing the input-output models. The summary of the estimated costs for each category are what appears in the summary report.

Lost production will mean reduced supply of raw materials for seed processors. The impact on seed processors will depend on whether or not the reduced supply of raw material can be made up from other sources. We assumed that about half of lost seed supply would be made up by other sources.

In the rotational burning scenario the bluegrass seed processing industry suffers no direct losses because bluegrass production is maintained at almost the same levels as before the rule. In the half out and best estimate scenarios, losses will result from any reduced supply to the processing industry.

Table 7. Base Rule Economic Impact Estimates ($1000s)

Cost Category	Rotation Scenario		Half-out scenario		Best estimate		Comments
	Potential Costs	**Estimated Costs**	Potential Costs	**Estimated Costs**	Potential Costs	**Estimated Costs**	
1. Farm level costs:							
Lost farm income	$3,030	$3,030	$5,150	$5,150	$3,510	$3,510	100% of direct costs
Lost employment	$0	$0	$340	$170	$340	$170	50% job loss
Sub-total	$3,030	$3,030	$5,490	$5320	$3850	$3680	
2. Processing sector							
Lost processor income	$0	$0	$300	$270	$230	$207	90% lost productivity
Lost employment	$0	$0	$480	$240	$370	$185	50% job loss
Sub-total	$0	$0	$780	$510	$600	$392	
3. Rest of the economy:							
Lost business income	$600	$360	$1,300	$780	$660	$396	60% loss productivity
Lost employment	$960	$192	$2,110	$422	$1,350	$270	20% permanent job loss
Sub-total	$1560	$552	$3,410	$1,202	$2,010	$666	
TOTALS	$4,590	$3,582	$9,680	$7,032	$6,460	$4,738	

Table 8. Alternate Rule Economic Impact Estimates ($1000s)

Cost Category	Rotation Scenario		Half-out Scenario		Best Estimate		Comments
	Potential Costs	**Estimated Costs**	Potential Costs	**Estimated Costs**	Potential Costs	**Estimated Costs**	
1. Farm level costs:							
Lost farm income	$3,000	$3,000	$4,960	$4,960	$3,385	$3,385	100% of direct costs
Lost employment	$0	$0	$320	$160	$325	$163	50% job loss
Sub-total	$3,000	$3,000	$5,280	$5,120	$3,710	$3,548	
2. Processing sector							
Lost processor income	$0	$0	$280	$252	$215	$194	90% lost productivity
Lost employment	$0	$0	$450	$225	$350	$175	50% job loss
Sub-total	$0	$0	$730	$477	$565	$369	
3. Costs in the rest of the economy:							
Lost bus. income	$600	$360	$1,150	$690	$540	$324	60% loss productivity
Lost employment	$960	$192	$2,040	$408	$1,310	$262	20% job loss
Sub-total	$1,560	$552	$3,190	$1098	$1,850	$586	
TOTALS	$4,560	$3,552	$9,200	$6,695	$6,125	$4,503	

Impacts to the processing industry fall in the class of things that are not generally counted in benefit-cost analysis. It is generally assumed that the value of the loss in production is fully captured by the loss in the output of the good, valued at its selling price. However, if the processing plant and associated jobs lost are not re-employed, than the opportunity cost of losing the productivity of these resources should be counted according to economic logic. We therefore calculated potential losses to the processor industry and workers. Enterprise budgets were calculated for processors using the same kind of assumptions as are used in the farm enterprise budgets. These enterprise budgets are used as the basis for calculating direct losses to processors. Additional details can be found in the economic impact technical report.

In economic terms losses of business capital should be counted as quasi-rents, that is, lost returns to a fixed factor as long as the factor would have had a viable economic life. Worn out, depreciated, or obsolete equipment has no economic value and so cannot be "lost."[5] In an industry like grass-seed processing, the equipment is specialized and has a long lifetime. Therefore, we counted a fairly high proportion of the lost potential returns to processors as economic losses. If one assumes that the grass-seed processing plant has a useful life of about 15 to 20 years and one looks at effects in the medium term, than the grass seed plant still has most of its economic life left. We assume 90 percent. We assumed that labor in the processing industry is like labor in the farm sector and that 50 percent would be re-employed--leaving an estimated cost of 50 percent of the potential job costs.

Impacts on the processing industry also depend on how much of the seed supply can be replaced. Our estimates are based on the assumption that the seed processors are able to replace about half of the lost Washington seed from other sources, most likely bluegrass farmers in Idaho.

The losses also depend on which version of the rule is adopted. The more flexible alternative version of the rule would mean that less supply is lost to the industry. In the alternative rule, half-out scenario the seed processing sector potential losses are about $280,000 in lost returns to capital and management and $450,000 in lost employment. Using the 90 percent and 50 percent medium term unemployment assumptions the result is estimated losses of $252,000 and $225,000 for income and job losses. Estimated losses are $194,000 and $175,000 for the best estimate scenario.

Other (General) Economic Costs

The reduced economic activity in the bluegrass growing and processing sectors can lead to reduced economic activity elsewhere. Total (potential) impacts of a change in final demand include the "ripple" effects of spending in the economy as well as the direct effect on the target

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[5]The fact that obsolete equipment cannot be counted as losing business is part of the justification for the usual benefit cost practice of not counting ripple impacts. In the long run all capital must be replaced. Therefore, if one counts costs only after all economic adjustments have taken place, costs to capital disappear--new equipment and new industries would have to be formed as the economy changes anyway.

industry. Each industry buys supplies from other industries and pays its employees and shareholders. A change in bluegrass production and processing industries' sales will result in changes in what they buy from other industries (called indirect effects).

The reduced income to farmers, farm laborers and landlords will also mean lower spending at the local supermarket and restaurant (called induced effects). The owners and laborers of the firms have lower household incomes leading to fewer purchases in the consumer markets. The "ripple" or secondary economic effects (indirect and induced) may be made up by compensating growth in other parts of the local economy. Or there may be permanent reductions in the local economy which are, however, partly offset by increases in the economies of other regions.

In our cost estimates for the general economy we assume 80 percent of the labor released because of bluegrass production will be rehired, and 20 percent will remain unemployed. Capital is less flexible than labor. We assume that 60 percent of the capital in the general economy remains unemployed. In the general economy, business turnover is more rapid than in a specialized industry like grass seed. We use the 60 percent loss figure in the general economy to reflect both the greater flexibility of business opportunities and the shorter useful life of investments. In the general economy a five or six year useful life is common. We based our 60 percent loss on a medium term which includes about three years of lost capital productivity out of a typical business investment life of five years. In a longer run analysis--six or more years from the rule implementation, most businesses will have adjusted or have been replaced in the normal pattern of economic change. In such a longer run we would count business losses at zero.

We count potential impacts of $1.56 million and estimated impacts of $552,000 in the rotational burning scenario divided between losses in returns to capital (business profits) and lost income due to lost jobs. In the half out scenario $3.19 million in potential impact are divided between $1.15 million in lost business income and $2.04 million in lost jobs. Adjusting for re-employment brings an estimate of about $690,000 in lost business income and $408,000 in lost jobs. The potential impacts for the best estimate scenario are about $1.85 million and the estimated impacts are $324,000 in lost business income and $262,000 in lost jobs for a total of $586,000.

Other Costs

An additional cost is due to the shifting of smoke damages if part of the lost production of bluegrass is made up by bluegrass seed produced elsewhere. We assumed that about half of the lost bluegrass seed will be replaced by Idaho farmers and that about half of that will be replaced in the Coeur d'Alene area. Therefore the benefits these areas will receive from reduced smoke from Spokane county growers will be partly offset by increases in smoke from local growers who step in to fill the demand for seed.

Another cost is the lost utility or "pain and suffering" of people who lose a job or suffer business losses. While in principle such losses should be included, they are, however, rarely included in economic analyses due to the lack of reliable data. We found no data relevant to the current study. To partly compensate, we added a penalty of 5 percent of job and business losses to account for the emotional costs of the proposed rule. We added this to the "potential" jobs and income losses to include even those who, for instance, lose a job and then get rehired fairly quickly. We also used high end estimates of job loss and business losses. For instance, in the general economy of Washington the current unemployment rate is about 5 percent. We assumed that 20 percent and 50 percent of general and local labor respectively would remain unemployed.

Another cost is for administration of the rule. We included $160,000 in administrative costs in all scenarios based on personal communication with the Department of Ecology. This amount is based on an estimated two FTE (Full Time Equivalent) including overhead and associated costs. This presumes about one full time person and another FTE of periodic effort by other personnel (for example, six people working for two months would be one FTE).

Another potential cost is the change in accident rates for farmers as they change production practices. Farming is a high risk occupation and changing practices would change accident rates. However, we found no concrete data on which to base costs of this change. We looked at accident reports, but could not find a pattern we could apply to the expected changes in farming practices so this potential cost remains unquantified. Conceptually, it could be measured as the increase in health, accidental death and dismemberment (AD&D) and, especially, long term disability insurance costs to farmers from the change in production processes. In summary, although any specific accident may have high medical and emotional costs, we found the potential monetary value of such costs low compared to the other costs, based on actuarial (insurance costs from changes in the probability of an accident) calculations.

For illustrative purposes we examined the change in disability insurance costs for a 50 year old farmer with a net income of $50,000 per year. Such a farmer might pay about $2,300 per year premium for coverage of $33,000 of his or her income (the insurance companies generally do not insure the full income of farmers). This premium includes a surcharge of about 25 percent over a standard premium to reflect the extra riskiness of farming. Suppose the change in bluegrass farming practices increased the risks of farming by nearly 40 percent--that would work out to an increase of 10 percent in the annual disability premium. Calculating 200 farmers at 10 percent of $2,300 per year, one comes up with an estimate of $46,000 per year for the actuarial value of the increase in risk from changing farming practices. We did not include this figure in our estimates because we did not have the data to estimate the actual change in risks. The purpose of the illustration is to show that the change in risk has a relatively small actuarial value.

WTP (Survey-Based) Cost Estimate

In general, cost estimates assume a compensation perspective--what amount of income would be required to replace the income lost by farmers or processors.[6] A completely different way to estimate costs would be to ask those who might be injured by a reduction in bluegrass field burning how much they would pay to retain the right to burn bluegrass seed fields. This is exactly analogous to the approach used on the benefit side to estimate total benefits by survey. Economists expect that willingness-to-pay value estimates will be lower than compensation perspective estimates. People are limited by their incomes in how much they can pay, but they may accept any amount. However, in the case of market valued impacts the difference between WTP and compensation perspective estimates is usually small.

We did derive a direct willingness to pay estimate for the amount that people would pay to avoid having restrictions imposed on grass field burning. We included a question in the survey instrument. (The survey instrument was principally designed to estimate the benefits to improved air quality from reduced burning.) We asked those who opposed the proposed rule to reduce burning what they would pay to continue to allow burning. For concreteness we suggested that the payment would go into a fund for compensating those who could show they were harmed by grass field smoke. This question was asked of farmers and non-farm opponents alike.[7]

We obtained a value of about $1.4 million for total costs from this approach. In principle this is what the right to continue to burn is worth to those who wish to keep that right, but our estimate is a very unstable and imprecise value for a variety of reasons. First, very few of the main affected party, bluegrass seed growers, appeared in the survey. (The survey respondents were selected randomly and there are relatively few farmer operators, and specifically, bluegrass farmers in the total population of eastern Washington and northern Idaho.) Also, the overall number of people who offered to pay for continued burning was very small. These small numbers makes it very unreliable to generalize our value to the overall population.

Another factor is that the way we asked this willingness-to-pay question encouraged people to answer in terms of what the thought might be the "right" amount for a contribution to pay for the damages caused by the burning instead of what the right to continue burning is worth to their household. Some people may not have been paying for the continuation of burning -- but making a donation to a group whom they felt obligated to help. Thus, this group of respondents is actually revealing what they think they should pay as there fair share for the damage from

[6]This contrasts with the benefits estimates which were largely based on a willingness-to-pay perspective--the amount of income that people would pay to receive some benefit or avoid some harm

[7]Bluegrass farmers have an obvious personal incentive to pay for the continuation of the open burn, "the right to burn." Presumably non-farmers are paying partly in solidarity with farmers, partly because they want to reduce the general regulatory environment, and partly for humanitarian reasons discussed in the subsequent paragraph.

grass field burning rather than what it is worth to them to have the open burning policy continued.

Probable Economic Benefits

We estimate probable benefits of the rule at between 6.6 to 10.2 million dollars. Our most reliable estimate is that benefits will be about 8.4 million dollars. This is a reliable, but cautious estimate of benefits. For instance, using an alternative, less dependable estimation technique, we estimate potential benefits of between 9 million and 18 million dollars. While these estimates are less reliable than the primary estimate, they suggest that it is unlikely that the primary estimate is overstated.

The largest potential benefit of the proposed rule is improved air quality from reduced smoke emissions. Epidemiological evidence has established a clear link between small airborne particles and health, particularly for an at-risk population comprising people with existing cardio-pulmonary conditions such as asthma, emphysema, chronic bronchitis or heart disease.[8] Additional benefits from the proposed rule include the benefits of traffic accident reductions, enhanced recreational opportunities, reduced dirt and nuisance effects from smoke particles, and the aesthetic effects of improved atmospheric conditions.

Contingent Valuation--Willingness to Pay Estimates

Our principal estimation method is based on directly estimating the value of smoke reduction from the point of view of the average household in the affected area. This method estimates combined health and non-health benefits since households are asked for one value for smoke reduction regardless of the reasons they may wish to have smoke reduced.

To estimate this value we used a standard economic valuation technique called the contingent valuation method. In the contingent valuation method households are asked how much they would be willing to pay (WTP) for implementation of the rule to reduce smoke from bluegrass seed field burning. To get reliable estimates, survey respondents were asked to imagine they were voting in a referendum about whether to approve and pay for the smoke reduction program--the proposed rule. The willingness to pay estimate for the sample is then extrapolated to the overall population of the area.

To obtain this contingent valuation estimate we conducted a scientific telephone survey of a random sample of households in the affected area. Households were randomly selected from

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[8]There is also some speculation that the higher rate of asthma found in Spokane compared to other regions may be due to the higher levels of particulate pollution in the Spokane area. Since this possibility is still speculative it was not counted in the study.

telephone directory data banks. The goal of the study was to complete 1,500 interviews comprising two subsamples: (1) 750 completed interviews in Spokane County, and (2) 750 interviews covering other affected areas in Eastern Washington and Kootenai and Bonner Counties in Northern Idaho. The Social Survey Research Unit at the University of Idaho administered the survey. We obtained 1,561 completed surveys.

The questionnaire (contained in a separate technical appendix that can be obtained upon request) contained:

- a section for identifying primary farm operators and asking questions about farm operations and use of field burning as an agricultural practice;
- a section with questions about respondents' perceptions of general air quality and environmental policy;
- a section with questions regarding the health status of household members; this section had follow-up questions for households containing anyone with a chronic respiratory or cardiac condition;
- a section which described the proposed rule to reduce smoke from the burning of bluegrass fields; follow-up questions were asked about perceived benefits or concerns about the rule;
- a section describing the proposed rule and asking the value questions;
- a section with demographic questions (age, income, etc.).

A sequence of questions were used to describe the rule and then elicit the value for measuring the household benefits due to the proposed rule. Respondents were first asked whether they favor or oppose the proposed rule. All respondents, including those in Northern Idaho, were told that the rule only affects smoke from bluegrass fields in Washington. Responses to the referendum question are given in Table 7. It is important to note that this survey was not designed as a voter survey. These survey results do not predict how a popular vote on the proposed rule would actually turn out, although they do give some indication of popular sentiment. Voter surveys include questions designed to predict who would actually vote and have other differences from the survey we conducted.

We also did a statistical analysis of the referendum data to analyze what factors disposed people to oppose or to favor the rule. We analyzed only data from the survey so there may be other factors beyond the scope of the survey which influence opinions on this issue. The model shows that those respondents who favored the rule placed greater importance on:

- health risks to their own household,
- health risks of other households,
- the nuisance caused by smoke and,
- the degree grass smoke contributes to air pollution.

Table 7. Results of Revised Vote Count on the Referendum to Reduce Smoke*

Response	Spokane Co.	Eastern WA	No Idaho	Row Total
Favor Program	374	232	110	716
	(50.1)	(38.9)	(50.2)	(45.9)
Against Program	302	300	80	682
	(40.5)	(50.3)	(36.5)	(43.7)
Other Responses	70	64	29	163
	(9.4)	(10.8)	(13.2)	(10.4)
Column Total	746	596	219	1561
	(47.8)	(38.2)	(14.0)	(100.0)

* Numbers in parenthesis are column percents except Column Total which are row percents.

Respondents who opposed the rule felt the rule

- singled farmers out,
- placed financial burdens on farmers,
- overstated the health benefits, and
- lacked importance compared to other issues.

Also, those with higher incomes tended to vote for the program while residents of Eastern Washington outside Spokane tended to vote against the rule. Details about this analysis can be found in the appendix.

Respondents who favored the rule or who were not sure were than asked whether they would pay to have the rule implemented. (Those who did not favor the rule were asked if they would be willing to pay to continue to allow burning; see earlier discussion.) Also those who would not pay were asked further questions to determine if they truly viewed the rule as having zero value or if they were "protesting." Some people object to the idea of expressing their preference as a monetary value. Others believe that "the polluter should pay." Such respondents clearly have a positive value, but they will not reveal it directly. We used statistical means to estimate values for the "missing values" of people who just did not know how much they would be willing to pay, and for the "protest" zeros. (See Mitchell and Carson for discussion of this problem.)

Our best estimate of $8.4 million in benefits is based on this technique. The range around the estimate is based on the margin of error in extrapolating the benefit value from the sample population to the total population. Our use of a relatively large sample (1561 households) compared to many studies of this type helps to minimize this margin of error.

Epidemiological-Economic Estimates

The alternative benefits estimation method uses an indirect method based only on potential health benefits. This is a two step procedure based on combining epidemiological and economic techniques. We first estimate the potential exposure of the affected population and the resulting probable change in medical and mortality impacts due to the improvements in air quality using the results of epidemiological studies. There is a large epidemiological literature documenting the health effects of small airborne particles. Particles from combustion processes appear to have larger health impacts than ordinary dust particles. The potential impacts of fewer dust particles include: reduced medical costs, reduced loss of wages due to lost work, reduced "pain and suffering" and, most importantly, reduced mortality.[9] Once the potential improvements are identified, they are valued using monetary values. The monetary values for impacts like asthma attacks are obtained from standardized values based on a large number of economic studies. We estimated benefits of between $9 and $18 million using this two step procedure.

However, the estimates based on this epidemiological-economic approach are imprecise. We lack detailed information on how the smoke reduced by the rule would reduce the exposure of the affected population. We had to use general estimates of this exposure since the detailed monitoring and smoke modeling necessary to determine exposures have not been done. More detailed exposure knowledge would allow us to make more precise estimates of the health effects because we have very good information on the effects of particulate exposure from the extensive epidemiological literature on the impacts of airborne particles on human health. However, we had to use available estimates of the smoke exposure which means these health cost estimates are imprecise.[10]

It is interesting to note, however, that the estimate of health benefits from reducing smoke actually exceeds the willingness-to-pay estimate. This is a paradox because the WTP estimate is supposed to include both health and non-health benefits. There are several reasons for this apparent paradox. One has been mentioned; the health benefits estimates are imprecise.

A second reason that the WTP estimate may be lower than the health based estimate is that many respondents did not like the fact that the proposed rule to reduce smoke would impose a burden on local farmers. They therefore discounted the value they were willing to pay for the program to account for this negative impact. This can be seen especially outside the Spokane and North Idaho areas. While the majority of households in Spokane and Northern Idaho favor the proposed rule, the majority of residents in other areas of Eastern Washington oppose the rule.

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[9]The health effects of exposure to other constituents of smoke (such as volatile gases) were not estimated. Moreover the possibility that long term exposure to smoke and particles may increase the rate of asthma or of lung cancer were not used because reliable epidemiological estimates are not available.

[10]Another source of variance in the estimates is the assumed cost of mortality. The cost of mortality is the major component of benefits in this approach. We used medium to low estimates for the cost of mortality.

These results imply that the willingness to pay for the smoke production is a net value: it is the value of the benefits of smoke reduction to households less a penalty or cost for the burdens of the program.

Finally, a third reason that the WTP estimate is low is that it measures benefits only from a private perspective. This means that, in evaluating their costs, households consider their costs for, say, hospitalization, but not the cost paid by insurance or government programs. This means that the survey based WTP benefit estimate is likely to be understated because it does not include costs to general businesses and the public. Thus, losses to the recreation industry in Northern Idaho are not included, though the cost of lost recreation days to the individual are included. The health exposure based estimates are also understated because they do not include non-health benefits at all.

Non-Health Benefits

As noted above, the WTP benefits estimate in principle captures health and non-health benefits. In a preliminary review of existing information we explored information on benefits from improved visibility, reduced dust and nuisance, and increased recreational opportunities. Due to the limited time and resources and the inclusiveness of the contingent valuation WTP estimate we did not conduct any original research on these issues. Our preliminary studies indicated that these benefits are relatively small compared to the health effects.

Compensation Based Estimate

Besides the willingness to pay and epidemiological-economic estimates, a third estimate of benefits could be made based on the special assumption that the population affected by smoke has the right to be free of smoke. If they have the right to be free of smoke, they should not have to pay to get reduced smoke, they should be compensated for any damages caused by continued burning. This approach produces much larger estimates of the value of smoke reduction, about $18 to $30 million.

We put less emphasis on these estimates than the other two benefits estimates for conceptual and practical reasons. Conceptually, the question of whether it is the right of farmers to burn their fields or the right of local residents to clean air that should be paramount is a legal and moral question beyond the scope of this study. However, the main reason we put less emphasis on this estimate is that the method used for estimation of compensation is unreliable. We used the same survey to estimate compensation as we did for willingness to pay. However the compensation value is based on a very small number of respondents making it hard to generalize to the whole population, and respondent reporting patterns are less stable for compensation questions giving rise to a great range of individual value estimates. Most economists and government agencies disallow compensation estimates for these practical reasons. For instance, the National Oceanic and Atmospheric Administration disallows compensation estimates based on the recommendations of a blue ribbon panel of economists.

APPENDIX A

THE ECONOMIC IMPACT OF A LIMIT ON GRASS SEED FIELD BURNING: THE WASHINGTON ECONOMY

Technical Report

Submitted to:

Washington State Department of Ecology
Air Quality Program
P.O. Box 47600
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Revised publication version. The version contains format edits and copy edits to the "Estimates" report dated January 7, 1997. Both versions are available for review. No substantive changes were made from the January 7, 1997 version.

Introduction

The purpose of this report is to provide an analysis of the economic impact of reducing grass seed field burning in Washington. The estimates of economic impact summarized in this report were subsequently used to estimate the "economic costs" in the benefit-cost analysis of reduced field burning. The analysis applies specifically to the production and processing of Kentucky Bluegrass grass seed. Many other species of grass seed are produced in Washington, but it is only Kentucky Bluegrass that is critically dependent on field burning as part of the production practice. The tasks associated with this analysis are: (1) to estimate the expected changes in industry supply, income, and employment for both the grass seed growers and the grass seed processing industry; (2) estimate the total effect on economy-wide supply, income, and employment stemming from the direct effects on growers and processors.

The analysis in part (1) relies on farm enterprise budgets that show grass seed yields and production costs under current technology with burning and under future expected technology without burning. These budgets were developed by agricultural economists at Washington State University working in collaboration with other agricultural scientists and grass seed growers. Also important were enterprise budgets representing the grass seed processing industry. The direct economic impact of the limit on grass seed field burning was derived from information contained in the enterprise budgets representing production costs for growers and processors.

The analysis in part (2) as summarized in this document, relies on an input-output model of the Washington economy. The model was constructed from the IMPLAN data system and represents the Washington economy in 1993.[1] The industry accounts in the original model were modified based on the enterprise budget information previously described, in order to more accurately depict the grass seed production and processing industries. The resulting model is able to more accurately capture the direct effect of the field burning restriction on grass seed growers and processors. This is important since accurate economic impact analysis depends mainly on a correctly specified direct effect.

The remainder of this report is organized as follows: (1) the grass seed industry is reviewed in terms of basic structure of the industry and its economic contribution to the Washington economy; (2) the economic impact section reviews the economic assumptions that characterize economic impact analysis and discusses each of the scenarios that characterize possible adjustment of the grass seed industry to the two thirds reduction in grass seed acreage burned; (3) the final section presents the results of the economic impact analysis in terms of the overall cost to the Washington economy of the limit on grass seed field burning.

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[1]IMPLAN is a input-output modeling system that was developed to facilitate the construction of regional input-output models. The IMPLAN data base designed to be used with Micro IMPLAN, an economic estimation tool. The IMPLAN system is the product of MIG, Inc. a firm in Minneapolis, Minnesota.

The Structure and Economic Importance of the Grass Seed Industry

The Kentucky Bluegrass seed industry in Washington has two parts. The growers who produce the seed and the firms that process the grass seed. The grass seed processors buy the uncleaned seed, clean it, sort it, and bag it; and then market the seed to wholesalers, nurseries, and other downstream users. (For a good discussion of the Kentucky Bluegrass growing and processing sectors, see the July 26, 1996 Huckell/Weinman report to the State Department of Ecology.) The purpose of this description is to add to and elaborate on that discussion.

Roughly, 34,500 acres of Kentucky Bluegrass were permitted to burn in 1995, but an industry source estimated total production at 57,000 acres. A recent estimate of acres in production in 1996 (the first year of the burning limitation) places production acres at 60,220 (Painter, 1996) which corresponds closely with the industry estimate of 57,000 acres. This comprehensive figure provided by Painter is the estimate that we use in the following description and analysis.

Assuming **60,220** acres of Kentucky Bluegrass production at an average yield of 530 pounds of clean seed per planted acre results in **31.8** million pounds of total Bluegrass seed production in Washington in 1995 (Table 1). The 530 pound average includes the zero yield in the establishment year. Recent years have seen the development of proprietary varieties of Bluegrass that exhibit special qualities of color, texture, etc., and an increasing portion of the Bluegrass acreage in Washington is allocated to the proprietary varieties. Just how much Washington production is of the common variety and how much is proprietary is not clear from available public sources of agricultural data. The question is important because nearly all proprietary grass seed is grown on irrigated land and involves different yields, product prices, and production techniques than common grass seed which tends to be produced mainly on non-irrigated or dryland.

Based on informal discussions with grass seed processors in Washington and Idaho, we estimate that approximately 35 percent of total grass seed acreage is proprietary and, thus, involves irrigated production practices. (The corresponding Huckel/Weinman estimate was 20 percent.) For practical purposes this means that we assume that 35 percent of Washington Kentucky Bluegrass production (proprietary varieties) is produced under irrigated technology, with the remaining portion of production (common Bluegrass seed) produced under dryland technology.

Accordingly, the total sales value of the Bluegrass production in Washington in 1995 valued at the farm gate is approximately **$22,220,000** (Table 1). The income (employee compensation plus returns to operator labor, land, and management) is estimated as **$11,570,000**. Not all of this seed is processed in Washington. A major processor of grass seed is located in Northern Idaho and our estimate is that about 30 percent of Washington Bluegrass seed supply is exported from the state in unprocessed form (Table 1). This is important regarding the economic impact analysis, because processing income is not generated in Washington from the exported seed.

By the same token, not all the Bluegrass seed that is processed in Washington is produced in Washington. Idaho is an important producer of Bluegrass seed that is imported into Washington for processing. Our estimate is that approximately 25 percent (7,354,000 lbs) of the Bluegrass seed processed in Washington is imported into Washington from other states (Table 1). The amount of imported (from outside Washington) grass seed supply is important to the economic impact analysis. Imported grass seed supply will not be directly affected by the grass seed field burning reduction, but it does generate processor income in Washington. Washington grass seed processors may be able to obtain additional supply from imported sources (Idaho, Oregon) if Washington Bluegrass seed production were to decline.

The processing of Kentucky Bluegrass seed in Washington is estimated to generate **$30,710,000** in total sales of processed grass seed. Income (total returns to labor and capital) from processing is estimated to be **$6,250,000**, with employee compensation accounting for 62 percent of processing income. The direct employment including full time and part time jobs is estimated at **146** jobs.[2] The growing of proprietary Bluegrass seed generates an estimated **$3,400,000** in income and generates **101** full and part time jobs. Common Bluegrass seed production is responsible for **$8,170,000** in Washington State income and **170** jobs (Table 1).

Table 1. Economic Aspects of the Kentucky Bluegrass Industry in Washington

Description	Irrigated Production	Dryland Production	Seed Processing
Acreage	21,077	39,143	--
Total Production (lbs)	11,297,272	20,550,075	--
Washington Production Processed in Washington (lbs)	5,937,272	16,350,075	22,287,347
Washington Production Exported (lbs)	5,360,000	4,200,000	--
Seed imported for Washington processing (lbs)	--	--	7,354,825
Value of Total Output (Sales) MM ($)	8.25	13.97	30.71
Value of Income MM ($)	3.40	8.17	6.25
Employee Compensation MM ($)	1.18	0.76	3.86
Number of Jobs (including proprietors)	101	170	146

[2]The employment data in the input-output model measure jobs in terms of full time and part time employment.

The Economic Impact Analysis: Ground Rules and Assumptions

To understand the implications of the economic impact analysis it is useful to review the economic assumptions of this study. The impact analysis utilizes a demand driven input-output economic model. In input-output analysis, supply is assumed to always respond to changes in aggregate demand, where economic supply (measured as the value of output of each sector) is a function of exogenous variables representing final demand (e.g. investment demand, government demand, and export demand).

The supply of every good or service is assumed to be produced with constant returns to scale production technology. All primary factors of production are assumed to be characterized by perfectly elastic supply functions and all primary factors are assumed to be perfectly mobile. As a result of these collective assumptions, the supply curve of every good or service produced in the economy is perfectly elastic with marginal cost of output equal to average cost of output. In the language of welfare economics, there is no producer surplus because all supply curves are perfectly elastic. Likewise, since output prices are fixed there is no measure of consumer surplus.

In an input-output analysis, changes in regional well being are measured as changes in the payments to the primary factors of production (gross regional product) or as changes in household income for regional households. (For additional discussion on the regional household income measure, see the Appendix).

The economic impact analysis is known as comparative statics. In the analysis, the economy is assumed to be in economic equilibrium (baseline). Some sort of an economic shock (a change in public policy) is introduced which disturbs the equilibrium and the economy adjusts to a new equilibrium. The impact of the economic shock is measured by comparing the new equilibrium outcome to the original (baseline) equilibrium.

In the analysis of a new economic constraint such as a limit on grass seed field burning, a comparison of the baseline with the new equilibrium will necessarily indicate some loss of jobs and income to the Washington economy. What happens at the national level is another matter and becomes the basis for translating the results of the economic impact analysis into estimates of economic cost. It is possible (although unlikely) that the unemployed (from the point of view of the Washington economy) capital and labor would fail to find re-employment. In this case, the loss in Washington income is identical to the loss in national income and the income loss from the economic impact analysis is equal to social cost. However, it is also possible (although unlikely) that the unemployed labor and capital would find employment at the same return they received in the baseline Washington economy. In this case, the loss in Washington income would be offset by a gain in the rest of country income. The level of total national income would be unaffected and the social cost of the policy would be zero. And, of course, it is possible that the loss in Washington income would be only partially made up by employment of primary factors outside of Washington. Then some of the loss in Washington income would also depress the national income and this reduction in national income would indicate the total economic cost of the policy.

In practical terms, the figures from the economic impact analysis were adjusted in the final cost estimates to reflect the expected re-employment of capital and labor throughout the economy. The adjusted figures represent the total economic cost of the policy. These estimates can be found in the summary and main reports.

The Washington input-output model represents the production and consumption decisions in the economy as a system of simultaneous linear equations. The model represents all goods and service producing sectors in the economy. In the model constructed for this study, 59 separate industries were identified.

The input-output model is a Type II model. This means that the ripple effect captured in the model consists of both an inter-industry effect (indirect) and a household-consumption (induced) effect. In other words, in response to a demand shock (direct effect) the economy is assumed to adjust by changing supply. The equilibrium change in supply across all industries is captured by the direct, indirect, and induced effects. The ripple effect in a Type II model is the sum of the indirect effect and the induced effect. The direct effect is measured by changes in the directly affected industry. In the case of a reduction in grass field burning, the direct effect would be the change in productive inputs, the change in yields, and the change in grower income. The indirect effect would be measured by all other industries change in output and income in response to grass growers changes in production practices. The induced effect is the change in household spending induced by the change in grower income that stems from the reduction in burning. Thus, the total economic impact of a given economic shock as the economy adjusts from the old to a new equilibrium will consist of the sum of the direct, indirect, and induced effects.

Finally, it should be noted that the limit on grass seed field burning does not fit nicely into the conventional demand driven assumptions of the input-output model. (Yet, the input-output model was the only general equilibrium model available, given the study deadline constraint.) There is not a clear connection between the given policy shock and the associated change in a set of exogenous model variables. The burning constraint affects primarily grass seed production and grass seed processing, yet we must capture the economic impact of this policy constraint in a model in which all the exogenous variables are demand variables. To deal with this problem, we constructed a set of "industry adjustment scenarios" that, based on our best judgement, capture the full range of likely grass seed industry adjustments to the limitation on grass seed field burning. These scenarios are then used to structure the economic impact analysis in which supply shocks to the grass growers and processors are simulated as demand shocks in the input-output model. For a more complete discussion of this procedure see Petrovich and Ching (1978) or Lee, Blakeslee, and Butcher (1976).

GRASS SEED SCENARIOS

Three possible scenarios are developed to capture the range of industry adjustment to the grass seed field burning limit. In the **"least costly"** or low impact scenario, growers are able to find alternatives to field burning that allow grass seed production to continue to compete for land labor and capital. In this scenario, seed production costs are increased and yields are slightly reduced (see budget data). Processors are able to make up for the small reduction in Washington grass seed production attributable to the lower yields associated with the field burning limit by increasing imports of seed to process. In the **"most costly"** or high impact scenario, growers are unable to find alternatives to field burning on two-thirds of their grass seed acreage. They must plant less profitable wheat on the grass seed acreage previously burned. In this scenario, irrigated wheat replaces grass seed production on all lost irrigated grass seed acreage, but only 90 percent of the previously burned dryland grass seed acreage is converted to dryland wheat. Ten percent of dryland grass seed acreage is assumed to be too steep to be planted to dryland wheat. Furthermore, Washington grass seed processors are assumed to be unable to find alternative sources of grass seed supply from imported sources which reduces the Washington processing level in response to decreased Bluegrass seed production in Washington. Finally, we have the **"moderate cost"** scenario. This scenario is called the "half-out" scenario in the final report because about half of the grass production is lost. In this scenario, growers switch some of their grass seed acreage to wheat while experiencing a reduction in grass seed yield and an increase in production cost in their remaining non-burn acreage. Grass seed processors are able to replace some of the lost Washington seed production with increased imports, but not all. A more complete description of the assumptions associated with each scenario is presented in the next section. These scenarios were designed to capture the range of potential impacts for analytic purposes rather than to represent the probable range of impacts of implementation of the rule.

Least Costly (Low Impact) Scenario

Growers find a way to produce grass seed that allows the crop to compete for labor and land. Processing plant production levels are unaffected.

Grower Impact

- Per-acre yield slightly decreases.
- Per-acre costs moderately increase.
- Net effect is to reduce Washington Bluegrass grower returns to land, labor, and capital (reduces value added).
- Assumes that grass seed continues to be produced on the impacted acreage using mechanical residue control.

Processor Impact

- In-state processors are able to compensate for reduced production levels by finding additional sources of supply. Therefore, processor economic impact is zero.

Most Costly (High Impact) Scenario

All grass acreage affected by the 2/3 reduction in burn acreage is forced out of production. Processors are directly impacted because alternative grass seed supplies cannot be found to substitute for the decreased output levels attributable to the burn ban.

Grower Impact

- 90 percent of lost dryland grass acreage into wheat rotation.
- 10 percent of lost dryland grass acreage out of production (land too steep to plant to wheat).
- 100 percent of irrigated grass acreage goes into irrigated wheat rotation.
- Wheat assumed to replace grass seed on impacted acres.

Processor Impact

- In-state processors have no additional supply to compensate for banned burn acreage. Assumes that reduced grass seed production affects in-state and out-of-state processors in proportion to their absorption of Washington supply.

Moderate Cost (Half-Out) Scenario

Assumes one of three things happen to acreage impacted by the 2/3 reduction in permitted burn acreage: 1) a portion of the acreage will be switched to a wheat rotation; 2) some dryland acreage will go out of agricultural production; and 3) and some grass acreage will be produced using mechanical residue management techniques which have lower average yields and higher per-acre production cost. Washington processors are assumed to be able to partially offset a portion of the production decrease resulting from reduced planted acres and/or reduced yields on mechanically managed acres by developing alternative sources of supply from outside the state.

Grower Impact

- Produce 50 percent of impacted grass acreage (dryland and irrigated) under mechanical residue management techniques (crewcut vacuum). Relative to burned acreage, results in a small reduction in average yields and higher per-acre production cost.

- Convert 40 percent of the remaining affected dryland acreage to a less profitable wheat rotation. The rest of the dryland acreage, 10 percent, goes out of production (land is too steep to put in an alternative crop).

- Convert the other 50 percent of the remaining affected irrigated grass acreage to irrigated wheat acreage.

<u>Processor Impact</u>

- In-state processors are assumed to compensate for 50 percent of the state level reduction in grass seed supply by finding out-of-state suppliers (Oregon and Idaho).

Table 2 summarizes each of the scenarios to be analyzed.

Results--Direct Effects

Low Cost (Low Impact) Scenario

As a preface to the results discussion, it is useful to review the assumptions that underpin the analysis. The economic impact analysis for each scenario should be viewed as the result of an intermediate run adjustment. That is, growers are assumed to have had time to adjust to the burning limitation and grass seed processors have had time to adjust to grower changes in production. All sectors in the economy adjust to the new equilibrium using the same production recipe. (All production functions for all industries except grass seed growers are assumed unchanged.) What this means is that a given change in industry output will be accompanied by a change in all inputs purchased by that industry in the same proportion. This is consistent with the adjustment process assumed to generate indirect and induced effects in the regional input-output model. Given the fixed proportion assumptions built into the input-output model, the economic results from such a model are usually viewed as the upper limit of changes that would characterize the more flexible real world economy.

In the low cost scenario, grass seed processors are not directly affected. The reduction in grower production is made up by imported grass seed by the processors. Grass seed producers continue to produce grass on the same acreage as before, but receive less yield, less gross revenue, and have higher costs. The main economic impact in this scenario is a reduction in grower income. The direct effect is a reduction in total grower income of $5,400,000 (Table 3). However, grower employee compensation (wage payments) increases slightly under the non-burn technology because it is more labor intensive than the baseline burn technology.

Table 2. Scenarios to be Investigated and Underlying Technical and Behavioral Assumptions for Grass Seed Study

	Scenario		
Economic Agent	Low Cost	Moderate Cost	High Cost
Grower	Per-acre yields slightly decrease under mechanical residue control. Per-acre production costs are higher.	Produce 50 percent of impacted acreage under mechanical residue management (crewcut vacuum). Slightly higher production costs and slightly lower per acre yields. Switch 40 percent of affected dryland acreage to a less profitable wheat rotation. Of affected dryland acreage, 10 percent goes out of production as land is too steep to be farmed in another rotation.	90 percent impacted dryland grass seed acreage goes into a less profitable wheat rotation. 10 percent of impacted dryland grass seed acreage goes out of agricultural production. 100 percent of impacted irrigated grass seed acreage goes into irrigated wheat rotation
Processor	No economic cost. Any decreased in-state production is compensated for by new sources of grass seed supply.	In-state processors are able to find additional sources of grass seed production (either in-state or out-of-state producers) for 50 percent of the lost in-state production.	In-state processors are unable to find any additional supply sources to substitute for the lost in-state production.

Table 3. Direct Employment, Sales, and Income Effects of Proposed Limitation on Grass Seed Field Burning

Direct Policy Impact	Employment	Sales (millions $'s)	Total Labor and Capital Income (millions $'s)	Employee Compensation (millions $'s)
Grower (Includes grass and wheat)				
Low Cost Scenario	+3	-0.41	-5.40	+0.024
Half-Out Scenario	-46	-3.08	-5.49	-0.342
High Cost Scenario	-86	-5.62	-5.58	-0.707
Processor				
Low Cost Scenario	0	0.00	0.00	0.000
Half-Out Scenario	-18	-3.84	-0.78	-0.483
High Cost Scenario	-72	-15.07	-3.07	-1.899

High Cost Scenario

In this scenario, grower acreage of Bluegrass is reduced by two thirds, all lost irrigated acreage and 90 percent of dryland grass seed acreage is shifted into a corresponding irrigated or dryland wheat rotation (10 percent of the land used for dryland grass seed production is idled). Processor output is reduced by 2/3 of the lost in-state production going to in-state processors. Grass seed processors are assumed to reduce input purchases and employment in proportion to the reduction in Washington produced grass seed output.

The direct reduction in processor sales is estimated to be $15,070,000. The associated reduction in processor income is $3,070,000 and the reduction in processor jobs is 72 (Table 3). The direct change in grower income reflects some of the formerly burned land going out of production with the rest of the formerly burned land being converted to a wheat rotation. The direct reduction in grower income is estimated to be $5,580,000. The direct employment loss (the difference between the loss of employment in grass seed production and the gain in employment from increased wheat production) is 86 jobs which translates into $707,000 of forgone employee compensation.

Moderate (Half-Out) Scenario

In this scenario, growers continue to grow Bluegrass seed using mechanical methods of residue removal on 50 percent of their impacted acres and switch the other 50 percent of the impacted acres to a wheat rotation. Grass seed produced on the impacted acres is characterized by higher cost and lower yields. Washington Bluegrass processors are able to find imported seed to replace 50 percent of lost Washington grower Bluegrass output that would have been processed in state.

The direct reduction in processor sales is estimated to be $3,840,000. The associated reduction in processor income is $780,000 and the reduction in processor jobs is 18 (Table 3). The direct reduction in grower income is estimated to be $5,490,000. The direct change in grower employment is 46 jobs as wheat is less labor intensive than grass seed production.

Discussion of Results

Grower direct income impacts are of the same order of magnitude under all scenarios. This comes from the assumption that growers will not idle land affected by the burning limitation, but even in the high cost scenario, grow an alternative crop (wheat). Processors, on the other hand, experience a wide range of direct income impacts across the range of scenarios. The range of processor direct income effect is driven by the assumption of availability of imported grass seed supply. In the low cost scenario, processors are assumed to totally replace the reduction in Washington production with imported supply so their production is unaffected. In the high cost scenario, processors are assumed to be unable to replace any of the lost Washington grass seed production. The assumption about processor capital is different than it is for grower land. If it becomes unprofitable to grow grass seed, the grower is assumed to switch to an alternative crop. If the processor has no grass seed to process, there is no alternative use for that capital.

Results--Total (Direct, Indirect, and Induced) Impacts

It should be noted that all total impacts are economy-wide for the Washington economy. For example, the loss in income under the low cost scenario is estimated to be a loss of $8,030,000 (Table 4). This includes the loss associated with the directly affected industries (growers and grass seed processors) from Table 3 plus the loss in income from all other industries in the Washington economy that stems from the direct impact. In the high cost scenario, the total impact on the Washington economy is estimated to be a loss of $13,990,000 in income and a loss of 316 jobs (Table 4). The moderate cost scenario is characterized by a loss of $9,690,000 in income and 168 jobs.

Table 4. Total Economic Impact (Employment, Sales, and Income) of Proposed Limitation on Grass Seed Field Burning on the Washington Economy

Total Policy Impact	Employment	Sales (millions $'s)	Income (millions $'s)	Employee Compensation (millions $'s)
Low Cost Scenario	-89	-4.46	-8.03	-1.57
Half-Out Scenario	-168	-12.24	-9.69	-2.93
High Cost Scenario	-316	-29.37	-13.99	-5.95

Discussion of Results

The relatively small direct employment effect (Table 3) in the low cost scenario becomes a more significant total economic impact at the state level (Table 4). This result is largely explained by the loss in direct income associated with the low cost scenario. The ripple effect (induced) stemming from the loss in grower income results in loss of household spending, which causes the loss in jobs in the goods and services sectors that serve households. As noted previously, all total economic impacts should be viewed as the result of a very inflexible adjustment process.

Sensitivity Analysis of the Half-Out (Moderate Cost) Scenario

Given the large and relatively constant direct income loss incurred by grass seed growers under each scenario, sensitivity analysis was performed on the most likely moderate cost scenario to examine how sensitive the income loss estimates were to the assumptions governing the reduced burn production technology and policy implementation. The first modification considered was a change to the reduced burn production technology. The reduced burn technology production function was changed to increase both the average yield on planted acreage and the number of years the grass seed stand remains in production, relative to the moderate cost scenario. This new production function was developed by Painter (1996) and is based upon Canode and Law's research (1977). Under the modified production function, grass seed acreage is only burned every other year. Even though average annual yields are higher and production cost is lower than for the baseline moderate cost scenario, the modified average annual yields are 9 percent less than they are under the pre-ban burn technology and average annual production costs remain higher than they are in the absence of the burn limitation policy.

The second modification considered, is consistent with the proposed legislation that allows an impacted grower " . . . to request an exemption for extraordinary circumstances on 5 percent of the acreage in production on May 1, 1996." Discussion with representatives from the Washington State Department of Ecology (Calkins) revealed that it was likely an exemption that would be granted to those growers who could verify that currently grown grass seed acreage would be left idle under the proposed ban, because the acreage was unsuited for any alternative agricultural activity. Thus, any acreage idled under the moderate cost scenario is assumed to remain in grass seed production, provided the idled acreage does not exceed 5 percent limitation on exempt baseline acreage.

Results--Direct Effects

The impact of the two modifications to the half-out (moderate cost) scenario are compared to the original (baseline) moderate cost scenario in Table 5. Employment levels and employee compensation are relatively unaffected by the two modifications at the grower level. However, grower loss in total labor and capital income is 30 percent less under the alternative burn/production technology than the baseline moderate cost. This primarily results from amortizing the establishment year over the longer grass seed stand life which reduces average annual per-acre production cost. The higher yields associated with the alternative burn technology also contributes to lower grower income and sales losses. The direct sales and income losses are also less under the 5 percent exemption scenario, but the loss reduction is much smaller than when adopting the more efficient production technology.

Processor sale and income levels are also less adversely impacted with both modifications to the moderate cost scenario. Both scenario modifications increase grower production which, in turn, increase the level of processor throughput over the baseline moderate cost levels. Similar to growers, processors benefit more from adopting the alternative technology than the 5 percent exemption because the aggregate grass seed production level is greater when the alternative technology is used. As shown in Table 5, processor employment and employee compensation levels are only minimally affected by these changes to the baseline half-out (moderate cost) scenario.

Results--Total (Direct, Indirect, and Induced) Impacts

Similar to the direct effect findings, the reduction in total income is less for the alternative burn technology than for the 5 percent exemption policy. As reported in Table 6, the total reduction in lost labor and capital income is two-thirds as much under the alternative burn technology compared to the baseline moderate, half-out cost scenario. Lost sales are nearly 28 percent less with the alternative technology. The 5 percent exemption also reduces the total economic burden imposed on the Washington State economy, but to a much smaller degree than the adoption of a new rotational burning technology.

Table 5. Direct Employment, Sales, and Income Effects of Proposed Limitation on Grass Seed Field Burning: Three Moderate Case Scenarios

Direct Policy Impact	Employment	Sales (millions $'s)	Total Labor and Capital Income (millions $'s)	Employee Compensation (millions $'s)
Grower (Includes grass and wheat)				
Half-Out Scenario Baseline Assumptions	-46	-3.08	-5.49	-0.34
Half-Out Scenario Rotational Burn	-40	-2.58	-3.85	-0.34
Half-Out Scenario 5% Exemption	-42	-2.67	-5.28	-0.32
Processor				
Half-Out Scenario Baseline Assumptions	-18	-3.84	-0.78	-0.48
Half-Out Scenario Rotational Burn	-14	-2.95	-0.60	-0.37
Half-Out Scenario 5% Exemption	-17	-3.59	-0.73	-0.45

Table 6. Total Economic Impact (Employment, Sales, and Income) of Proposed Limitation on Grass Seed Field Burning on the Washington Economy: Three Alternative "Half-Out" Scenarios

Total Policy Impact	Employment	Sales (millions $'s)	Total Labor and Capital Income (millions $'s)	Employee Compensation (millions $'s)
Half-Out Scenario Baseline Assumptions	-168	-12.24	-9.69	-2.93
Half-Out Scenario Rotational Burn	-123	-8.83	-6.46	-2.06
Half-Out Scenario 5% Exemption	-153	-11.09	-9.20	-2.81

Policy Implications

The sensitivity analysis revealed that the economic cost of the burn limit can be reduced if it is possible to adopt technologies that require burning of grass seed acreage on an alternate year basis. (The long-run viability of this technology is still untested on farms.) If this technology is viable over the long-run, per-acre average annual production costs are less than they are under the half-out, moderate cost scenario and average annual yield is slightly higher on all acreage in production (the sum of harvested and establishment acreage). While the 5 percent burn exemption helps to mitigate both grower and processor costs, mitigation was limited to about 10 percent of the costs imposed under the baseline moderate cost scenario. Thus, it is inappropriate for either growers and/or processors to anticipate significant financial relief from the 5 percent burn exemption under the half-out, moderate cost scenario.

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ADDENDUM TO TECHNICAL REPORT, APPENDIX A

One of the interesting features of the input-output model constructed for this study is its income distribution capability. The model makes the standard fixed proportion assumptions regarding the distribution of factor income to institutions including households. Factor payments made by industries in Washington are tracked to their ultimate destination in Washington households, non-Washington households, governments or firms.[3] Households are assumed to pay direct taxes, save, and consume in fixed proportions according to their position in the size distribution of income.

Households are ranked according to their position in the size distribution of household income. Household income is measured before federal income taxes, but after transfers such as social security payments. Three classes of household income are identified. Low income households (less than $20,000); medium income households ($20,000 to $40,000); and high income households (greater than $40,000). According to the 1990 Census of Population, roughly, 30 percent of Washington households were in the low income class, 32 percent were in the medium class, and 38 percent were in the highest class.

As a result of the income distribution feature of the input-output model, it is possible to estimate not only how a given economic policy will change payments to the primary factors of production as noted in Tables 3-6, but also how before-tax income of Washington households will change. In addition, we can measure how that change in household income will be distributed between low, medium, and high income households in Washington.

For example, consider the low cost scenario. The total change in household income to Washington households is estimated to be a loss of $7.24 million. This is the total economic impact of the policy as it it relates to changes in income received by Washington households. The distribution of that income change is estimated to be a loss of $.21 million to low income households, $1.16 million to medium income households, and $5.44 to high income households (Appendix Table 1.) Of the loss in household income, 75 percent accrues to high income households. This is mainly a function of the fact that much of the loss of factor income is in the form of proprietor (sole ownership business) income, and this form of income payment is largely claimed by households in the high income group.

The same interpretation applies to the figures for the other scenarios in Appendix Table 1. Perhaps the major point to emerge from these figures is that regardless of the scenario, most of

[3]Some of the income paid to the primary factors of production is not received by Washington households. Some of the income is retained by firms for future investment. Some of the income is paid to state and federal governments in the form of factor taxes (social insurance contributions etc.). Some of the factor income is paid to claimants who live outside Washington. And, finally, some of the income is paid to the federal government by firms in the form of corporate income taxes.

the loss in household income in Washington stemming from the limit on the burning of grass seed fields falls upon the high income households in Washington.

Appendix Table 1. Changes in Washington Household Income and the Distribution of Income

Scenario	Change in Total Household Income $MM	Change for Low ($0-19,999) Income Households $MM	Change for Mid. ($20,000-39,999) Income Households $MM	Change for High ($> 40,000) Income Households $MM
Low Cost	-7.24*	-0.21	-1.16	-5.44
Moderate Cost	-8.56	-0.26	-1.91	-6.38
High Cost	-12.05	-0.39	-2.77	-8.89
Moderate Cost Alternative Burn	-5.71	-0.18	-1.28	-4.25
Moderate Cost 5% Exemption	-8.04	-0.25	-1.80	-6.00

*The reader may note the different income estimates for the Low Cost Scenario in Table 4. and Appendix Table 1. In Table 4, the income measure is total factor income. In Appendix Table 1, the income measure is total household income. Some factor income "leaks" out of the household payment stream as it is distributed to households (see footnote 3).

APPENDIX B

Estimates of Farm and Environmental Costs of Increased Restrictions on Grass Seed Field Burning

Technical Report

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Submitted to:

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Revised publication version. The version contains format edits and copy edits to the "Estimates" report dated January 7, 1997. Both versions are available for review. No substantive changes were made from the January 7, 1997 version.

Introduction

Bluegrass production is a risky business, both agronomically and economically. Bluegrass yields are highly sensitive to environmental conditions. In dryland areas yields may vary between 100 and 1,000 pounds per acre due to weather variations alone. Bluegrass can also be difficult to establish. Prices are sensitive to supplies in this relatively small industry, and can fluctuate greatly from year to year. In addition, there are a large number of bluegrass varieties with different characteristics, making it difficult to make generalizations about the industry.

Air quality concerns from open field burning are not new. In the late 1960s, these concerns prompted a large research project conducted by Washington State University beginning in 1968. Research into practical non-burning methods were conducted by Washington State University at six sites over a period of seven years. A summary of the study stated that removal of primary residue by baling reduced yields an average of 32 percent in the second seed crop, 46 percent in the third crop, and 60 percent in older stands compared to open field burning (Canode and Law, 1977). More thorough removal of stubble beyond simply baling primary residue increased yields, but the costs of removing this secondary residue were often greater than could be justified by the increase in yield. Machine burning of stubble and thatch at high temperatures after straw removal appeared to be the best alternative to open burning of residue. Yields from this procedure compared favorably with open field burning. The development of a burning machine has been problematic, however. Another approach examined the practice of open field burning after the second seed crop but not after the first seed crop. Yields for the third year were essentially the same as burning after each crop.

In 1974, the Washington State Legislature amended the Washington Clean Air Act to give the Department of Ecology jurisdiction over emissions from open field burning of the grass seed industry. At that time, the Department of Ecology adopted guidelines to 1) minimize the adverse effects on grass field burning on Washington air quality; 2) provide for implementation of research to find practical alternatives to grass burning, and 3) provide interim regulation of grass burning until practical alternatives were found. Bluegrass industry opposition to the burning ban prevented any further action on the issue of open field burning. Two decades later, public pressure has once again mounted in opposition to open field burning.

The rest of this paper is organized as follows. We first present an analysis of farm level economic impacts of the proposed field burning limitation. Next we analyze the environmental impacts of the proposed limitation. We then present an integrated analysis of farm costs and environmental costs consistent with the analysis of processor and general economic impacts reported in another technical report (Holland and Willis).

Farm-Level Economic Impacts of the Proposed Open Field Burning Limitation

This analysis builds upon a multi-state research project entitled "Bluegrass Seed Production Without Open Field Burning" currently underway at Washington State University, the University of Idaho and Oregon State University on non-burning methods for producing both dryland and irrigated Kentucky bluegrass (STEEP project #PSES 061-K534). Enterprise budgets for producing common and proprietary varieties of Kentucky bluegrass were developed in close coordination with growers for both irrigated and dryland production (Hinman, personal communication). Typical yields were determined using results of three years of on-farm field trials as well as input from growers. The bluegrass price is based on the 1991-1995 average price and the typical differential for proprietary varieties.

Scenarios

Table 1 presents average production costs, yield, revenue, and returns to land and management for various bluegrass production methods for irrigated and dryland areas. These figures are averaged over the life of the stand, including the establishment year. Although bluegrass is typically produced as part of a longer rotation, this study examines the production of bluegrass alone since it is an industry-level rather than a farm-level study. In any case, information on every farm and its proportion of bluegrass to other crops on their farm would have been extremely difficult to obtain. Thus, all cost figures in Table 1 reflect the fact that, during the establishment year, there is no crop nor need for residue removal through burning or non-burning methods.

Yields

Starting with the base line scenario for irrigated production, yields are 670 pounds per acre for each year of production in the burn scenario (scenario one). In the second scenario, yields are assumed to be 670, 574, 670, 574, and 670 pounds per acre in years two through six. In this scenario the stand is burned twice in six years, or one-third of the time, after every second year of seed production. For scenario three, yield is 670 pounds per acre the first year and 574 pounds the second year. Stubble is removed mechanically after the first harvest. In all rotations, both irrigated and dryland, the bluegrass stand is chemically killed in the last year.

In the dryland region, yield is 600 pounds per acre for every year in the burn scenario. In scenario two, the yield alternates between 600 and 480 pounds per year, with the larger yield in the first year and in subsequent years following field burning. For scenario three, the yield is 600 pounds in the first year and 480 in the second year.

Table 1. Average Returns to Land and Management to Bluegrass Production, Including Various Burning Scenarios, and Typical Non-bluegrass Crop Rotations by Area ($/ac/year)

	Years in Rotation	Prod. Costs	Yield	Revenue	Returns to Land and Management
		($/A)	(lbs./A)	($/A)	($/A)
Irrigated Areas					
1. Burn residue	5	325	536	456	131
2. Burn every 2nd year	6	349	526	447	98
a) $15/acre subsidy for residue removal	6	344	526	447	103
b) market for straw	6	336	526	447	111
c) both a) and b)	6	331	526	447	116
3. Mechanical residue removal	3	331	415	353	22
a) $15/acre subsidy for residue removal	3	326	415	353	27
b) market for straw	3	317	415	353	35
c) both a) and b)	3	312	415	353	40
4. Other crop rotations	7	varies	varies	varies	96
Dryland Areas					
1. Burn residue	8	220	525	420	200
2. Burn every 2nd year	6	242	460	368	126
a) $15/acre subsidy for residue removal	6	237	460	368	131
b) market for straw	6	229	460	368	139
c) both a) and b)	6	224	460	368	144
3. Mechanical residue removal	3	247	360	288	41
a) $15/acre subsidy for residue removal	3	233	360	288	46
b) market for straw	3	242	360	288	55
c) both a) and b)	3	228	360	288	60
4. Other crop rotations	4	varies	varies	varies	28

NOTE: Price assumptions are $0.80 per pound for common bluegrass (CBG) and $0.85 per pound for proprietary bluegrass (PBG).

Returns

Per acre returns to land and management for bluegrass production are highest for the burn residue scenario in both irrigated and dryland production (Table 1). In the irrigated areas, returns for bluegrass production with burned residue average 50 percent higher than the "other crop rotations" scenario. In the dryland areas, returns for other crop rotations average just one-eighth of the returns under burned bluegrass. The "other crop rotations" scenarios represent average returns over a typical crop rotation cycle for irrigated and dryland areas. For irrigated production, this represents four years of alfalfa followed by one year each of potatoes, grain corn, and winter wheat. In the dryland regions, a rotation of small grains is used. This regional difference indicates that farmers in the irrigated areas have much better alternatives to bluegrass production than those in the dryland areas.

When fields are not burned following harvest, other methods for removing grass stubble must be used in order to maintain a good crop yield for the following year. Table 1 shows the large drop in expected returns under the mechanical residue removal scenarios in both regions. Mechanical residue removal consists of cutting, baling and stacking the primary residue (straw), which is estimated to be a $40 per acre operation. A crewcut vacuum is used to remove the secondary residue for a cost of $30 per acre based on custom rates for this operation. There is no charge included for disposal of either the primary or secondary residue. Ideally, the grower could recoup some of the expenses from residue removal if there were a local market for the straw. Assumptions a) through c) in Table 1 show how markets or subsidies for this residue would impact returns to land and management. In a), a $15 subsidy covers half the cost of the crewcut vacuum operation. In b), a market for straw is available which is assumed to just cover the $40 cost of harvesting it. In c), both a) and b) occur, so mechanical residue removal costs total $15 per acre. Despite this large decline in income using non-burn methods, dryland farmers would still earn more using these methods than growing alternative crops under the assumptions used in this study. However, non-burn methods may not be feasible on dryland areas that are too steep to bale.

Scenario 2 in Table 1 describes a bluegrass rotation in which burning takes place after every second seed crop. This rotation is based on experimental work by Canode and Law showing bluegrass yields after burning the second crop that were the same as burning after every crop. If farmers burned their fields after every second year of production, they could burn just one-third of their base over a six-year cycle in the following manner: Year 1, establishment; year 2, mechanical residue removal; year 3, burn stubble; year 4, mechanical residue removal; year 5, burn stubble; year 6, take out crop. At first, this may mean burning more than one-third in one year and less than one-third in another year until the rotational cycles were established to burn one-third of the acreage each year. A longer cycle of eight years with burning in three of those years would result in 37.5 percent of the total acreage being burned. Growers would either need to obtain the extra burning percentage through trading, if allowed or to reduce their bluegrass acreage if they were to use an eight-year rotation. An eight-year rotation would increase average net returns by approximately 11 percent under current prices over a six-year rotation.

Returns for burning every second year of production are much higher than mechanical residue removal alone, as the rotation is longer and costs are lower than the non-burning rotations which tend to become uneconomical after just two crops. In the original study, results indicated that burning after the second year of production would reduce yields in the second year by 30 percent, assuming removal of primary residue only (Canode and Law). Here we have assumed removal of both primary and secondary residue with yield reductions in the second year based on these practices. Plot data show yield declines of 15 percent in irrigated areas and 20 percent in dryland areas following the first year of mechanical residue removal of both primary and secondary residue. Under these assumptions, returns would decline by 22 percent in the irrigated areas for the burn-every-other-year scenario compared to the pre-rule burn residue scenario, and 28 percent in the dryland areas.

If there is a market for the bluegrass straw that would make baling primary residue a break-even proposition, returns would decline by 13 percent in the irrigated areas and 21 percent in the dryland areas. A $15 per acre subsidy on the secondary residue removal costs combined with a straw market would result in 10 percent and 18 percent reductions in net returns relative to returns under open field burning. These results are contingent upon the assumption that stands would remain viable with every-other-year burning.

Several proposed projects for using bluegrass straw are under study. These include biomass recycling, a paper manufacturing plant, and a plant for producing wood from straw. Estimated costs for removing and storing residue for the biomass recycling project would be about the same as item c) in Table 1, or $15 per acre. Costs for residue removal under the assumption that there is a bluegrass straw market for the paper or pulpwood plants would be similar to costs in item b, or $30 per acre. While these plants may offer more than a break-even price for the straw, transportation costs to the plant might use up any profit. The impact of these assumptions on net returns can be seen in Table 1.

Environmental Impacts of a Change in Bluegrass Acreage

The environmental impact of a change in bluegrass acreage will be highly dependent upon the specific area affected and what is grown in its place. Environmental damage such as water quality degradation is dependent upon factors such as field steepness, soil type, precipitation, location of waterways, and specific farming practices. Bluegrass is an excellent crop for preventing soil and wind erosion and the environmental damage that accompanies it. Dollar estimates of damage are based upon erosion estimates for bluegrass and for the typical alternative rotation in the dryland and irrigated areas.

The erosion impact of replacing bluegrass production with alternative crop rotations was estimated to be an additional 1.5 tons/acre of sheet and rill erosion, 0.5 ton of concentrated flow erosion, and 1 ton/acre of wind erosion based on a study by the Spokane County Natural Resource Conservation Service entitled Water Quality Benefits of Bluegrass in Spokane County. No erosion is predicted to occur under bluegrass production. While it is difficult to place an accurate value on damage to air, water, and soil quality, it is important to acknowledge these impacts and attempt to estimate their value. Most studies measuring the value of erosion control have used a value between $1 and $5 per ton of soil lost (Ribaudo, 1989; Dailey, 1994; Forster and Abrahim, 1985). Ribaudo's estimates of total downstream impacts are widely used in valuing erosion damage; his estimate for the Pacific region including Washington State is $3.05 per ton of erosion (1995 dollars). On-site erosion damage is estimated as an additional $1.50 per acre of bluegrass removed from production (Painter et al., 1995) Wind erosion damage has not been quantified in this format. For this study, an estimate of $5/ton is used to account for all water erosion-related damage for a total erosion impact of $15/acre. While this estimate is based on Spokane County erosion estimates, most dryland bluegrass is produced in this area. A more accurate value might be obtained with a detailed study of the bluegrass terrain in Washington State, but this was not possible within the time frame of this study.

Environmental impacts of reduced bluegrass acreage will be quite different for dryland and irrigated bluegrass production. In the irrigated bluegrass areas, wind erosion is the major environmental concern. The Tri-Cities and Spokane both fail to meet federal air quality standards due to PM-10 emissions from time to time. The cover that bluegrass production provides over winter provides excellent protection from wind erosion. Given the wide range of wind erosion estimates and the nature of wind events, it is difficult to predict an average figure for bluegrass production compared to the typical alternative rotation. Wind erosion values may range from 4 to 21 tons per acre for a typical rotation in the Columbia Basin, depending on the location, soil type, farming practices, and wind characteristics (Crowse, personal communication). The correct value to use for this study depends upon the crops chosen to replace bluegrass. If alfalfa is grown instead of bluegrass, erosion impacts will be very small. If a typical corn, wheat, and potatoes rotation is substituted for bluegrass production, erosion impacts will be much greater. However, wind erosion savings of at least 3 tons per acre of bluegrass will be observed across most of the irrigated areas, with much larger savings in some regions like the Horse Heaven Hills. For this reason, a $15 per acre value (3 tons at $5/ton damage) for bluegrass production compared to the typical alternative rotation was used for irrigated land.

Estimations of Economic and Environmental Impacts of Rule Change by Region and Scenario

Table 2 presents changes in regional bluegrass acreage for four scenarios using current prices. These results are slightly simplified in order to fit the needs of the input-output model of the bluegrass processing industry in Washington State. The first scenario, the pre-rule situation, assumes burning 100 percent of bluegrass residue on 60,220 acres in Washington State. Irrigated acres represent 35 percent or 21,077 acres while the remaining 39,143 acres are under dryland production.

The exact acreage of bluegrass currently under cultivation is unknown. There are about 40,000 acres permitted for burning. Washington Agricultural Statistics also reports about 40,000 acres of bluegrass. However, these official figures appear to be underestimates. By using the higher of the acreage from 1996 burn permits or the amount of acreage reported in bluegrass acreage as part of conservation plans we could document about 54,000 acres. However, information from seed processors indicates that there may be even higher acreage. We based a final estimate of acreage on the documented 54,000 acres adjusted upwards based on the information from processors. We have used 60,220 acres of planted bluegrass in this study. Although this is more acreage than we can document, it is more consistent with the information from seed processors than lower estimates would be.

Table 2. Returns to Land and Management for Irrigated and Dryland Bluegrass Production for Fixed Price Scenarios: High, Medium, and Low Impact by Extent of Grass Acreage Retained (Used for Input-Output Model of the Bluegrass Processing Industry)

	Returns to Land & Management			Change from Pre-rule	Environ. Impact	Net Change
	($/ac)	(%)	($1000)	($1000)	($1000)	($1000)
Pre-rule:						
Irrigated						
BG burned	131	100	2754	0	0	0
Dryland						
BG burned	200	100	7817	0	0	0
Total			10571	**0**	0	**0**
High Impact:						
Irrigated						
BG burned	131	33	909			
BG nonburn	22	0	0			
BG to wheat	87	67	1227			
BG to idle		0				
Subtotal			2136	-618	-213	-831
Dryland						
BG burned	200	33	2580			
BG nonburn	41	0	0			
BG to wheat	22	60	523			
BG to idle		7	0			
Subtotal			3102	-4715	-393	-5107
Total			**5238**	-5333	-605	**-5938**
Medium Impact:						
Irrigated						
BG burned	131	33	909			
BG nonburn	22	33	152			
BG to wheat	87	33	604			
BG to idle		0	0			
Subtotal			1665	-1089	-105	-1194
Dryland						
BG burned	200	33	2580			
BG nonburn	41	33	533			
BG to wheat	22	30	261			
BG to idle		3	0			
Subtotal			3374	-4443	-195	-4638
Total			**5039**	-5532	-300	**-5832**
Low Impact:						
Irrigated						
BG burned	131	33	909			
BG nonburn	22	67	308			
BG to wheat	87	00	0			
BG to idle		00	0			
Subtotal			1217	-1537	0	-1537
Dryland						
BG burned	200	33	2580			
BG nonburn	41	67	1083			
BG to wheat	22	0	0			
BG to idle		0	0			
Subtotal			3662	-4155	0	-4155
Total			**4879**	-5692	0	**-5692**

Price assumptions are $0.80 per pound for common bluegrass (CBG), $0.85 per pound for proprietary bluegrass (PBG), and $4.00 per bushel for wheat.

Total income at current (five-year average) prices of $.80 per pound for common bluegrass and $0.85 per pound for proprietary varieties is $10.5 million. A simplifying assumption is made that proprietary bluegrass is grown by irrigated producers while dryland producers raise common bluegrass. The next scenario is the high impact situation in which all acres affected by the burning ban on two-thirds of the production base are planted to wheat. In the dryland areas, 10 percent of the two-thirds affected acreage, or approximately 7 percent, is left idle because it is unsuitable for wheat production. The economic impact of switching the affected acreage to wheat is a drop in farm income of $5.3 million, plus another $600,000 in lost environmental benefits.

In the medium impact (half-out) scenario, farmers in both irrigated and dryland areas are assumed to plant half of the affected acreage (33 percent) to wheat, leaving the remaining acreage in bluegrass production using non-burning methods. In the dryland areas, one-tenth of the land or 0.03 percent is assumed to be left idle. This scenario reduces farm income by $5.5 million and incurs an additional $300,000 in environmental costs.

The last scenario is a **low impact scenario** in terms of total bluegrass acreage in that farmers are assumed to continue to grow bluegrass but use non-burning methods on the affected acreage. This scenario has the largest impact on farm income of $5.8 million but has no additional costs in terms of environmental damages. It is surprising that the impact of the three scenarios under the new rule actually have fairly close values in terms of total change in farm income and environmental benefits. The per acre cost of the rule is nearly $100 per acre of bluegrass originally in production under all three scenarios. These choices are obviously not very satisfactory for bluegrass producers.

Bluegrass is a relatively small industry with the bulk of its production in the Inland Pacific Northwest. Prices tend to be quite volatile in response to supply and demand changes. The proposed burning ban on two-thirds of bluegrass acreage in this state could have a large impact on price, depending on how much acreage is put into production outside the state and whether similar burning regulations are imposed in other states as well.

Price Impact Scenario

Table 3 shows the impact of two levels of price changes on per acre and region-wide returns. The pre-rule scenario is identical to that in Table 2. In the **high impact flexible rotation scenario,** it is assumed that the price does not increase in response to the rule as production moves to areas outside Washington State. In this scenario, farmers use alternative crop rotations on the affected acreage, except 10 percent of the acreage impacted by the ban in the dryland area which is left idle. The difference between this scenario and the high impact scenario in the previous table is that the farmer is assumed to use an alternative crop rotation rather than replacing bluegrass with wheat. This is slightly more realistic but it was too complicated to use in the input-output model of the processing industry. Under these assumptions, economic impacts are slightly smaller

Table 3. Returns to Land and Management for Irrigated and Dryland Bluegrass Production Based on Economic, Geographic, and Political Factors, Prices Allowed to Vary

	Returns to Land & Management			Change from Pre-rule	Environ. Impact	Net Change
	($/ac)	(%)	($1000)	($1000)	($1000)	($1000)
Pre-rule:						
Irrigated						
BG burned	131	100	2754	0	0	0
Dryland						
BG burned	200	100	7817	0	0	0
Total			10572	0	0	0
High Impact Flex Rotation:						
Irrigated						
BG burned	131	33	909			
BG nonburn	22	0				
BG to alt. rotation	96	67	1361			
BG to idle		0				
Subtotal			2270	-484	-213	-697
Dryland						
BG burned	200	33	2580			
BG nonburn	41	0	0			
BG to alt. rotation	28	60	662			
BG to idle		7	0			
Subtotal			3242	-4575	-393	-4969
Total			**5512**	-5059	-606	**-5666**
Medium Impact Flex Rotation:*						
Irrigated						
BG burned	153	33	1067			
BG nonburn	39	0	0			
BG to alt. crop rotation	96	67	1361			
BG to idle		0	0			
Subtotal			2428	-326	-212	-538
Dryland						
BG burned	221	33	2851			
BG nonburn	56	34	730			
BG to alt. crop rotation	28	27	296			
BG to idle		07	0			
Subtotal			3877	-3940	-198	-4139
Total			**6305**	-4266	-410	**-4677**
Low Impact; High Price:						
Irrigated						
BG burned	199	33	1384			
BG nonburn	75	50	787			
BG to alt. crop rotation	96	17	345			
BG to idle		0	0			
Subtotal			2516	-238	-54	-292
Dryland						
BG burned	263	33	3393			
BG nonburn	84	53	1752			
BG to alt. crop rotation	28	7	77			
BG to idle		7	0			
Subtotal			5223	-2594	-82	-2675
Total			**7739**	-2832	-136	**-2968**

NOTE: Price assumptions are $0.80 per pound for common bluegrass (CBG) and $0.85 per pound for proprietary bluegrass (PBG) under the Pre-rule and High Impact scenarios, $0.84/lb for CBG and $0.89/lb for PBG (a 5 percent increase) under the Medium Impact scenario, and $0.92/lb for CBG and $0.98/lb for PBG (a 15 percent increase) under the Low Impact scenario. Grain prices are assumed to be $4 per bushel for wheat and $88 per ton for barley.

*Signifies "Most Realistic Estimate"

while environmental impacts remain the same as in the previous table for a total impact of $5.7 million or $94 per acre of bluegrass currently in production.

The medium impact flexible price scenario in this table represents a "best-estimate" case given the current state of technology for non-burn methods. In this scenario, prices are assumed to increase by 5 percent in response to the regulation. Although there may well be an increase in out-of-state bluegrass acreage, it is assumed these areas will not quite make up the lost Washington acreage. In addition, out-of-state growers may also face some regulations or increased costs in the near future, so this small increase in price was justified. Of course, the actual price response is impossible to predict and will have a very large impact on farmer response to this regulation.

Under this best estimate or medium impact scenario, the two-thirds acreage affected by the ban is planted to alternative crop rotations in the irrigated areas. Per acre returns under non-burn production are not competitive with alternative crop rotations at $39 per acre compared to $96 per acre for alternatives to bluegrass. In the dryland areas, the per acre returns for non-burn methods was higher than the returns under alternative crop rotations at $56 compared to $28. Because of difficulties associated with non-burn methods on steep hillsides common to the dryland bluegrass producing region, it was assumed that half of the affected acreage (33 percent) would remain in bluegrass with non-burn methods, 10 percent of the affected acreage (7 percent of total) would be left idle, and the remaining 27 percent would be placed in alternative crop rotations. The economic impact of this scenario is $4.3 million, with an additional $410,000 in environmental impacts for a total impact of $4.7 million or $78 per acre of bluegrass currently in production.

The final scenario predicts impacts with a larger price increase of 15 percent, which may well be the case if other states impose burning restrictions on bluegrass production as well. With higher returns for bluegrass production, it is assumed that approximately half of the total pre-rule bluegrass acreage would go to non-burning techniques in both the irrigated and dryland areas. Returns are still somewhat higher for alternative crop rotations in the irrigated areas, so the remaining 17 percent of original bluegrass acreage in that region is assumed to convert to alternative crop rotations. In the dryland areas, 10 percent of the affected acreage would be idled and the remaining 10 percent would go to alternative crop rotations due to problems with non-burning techniques on steep ground. The economic impact of this higher bluegrass price scenario is a drop in farm income of $2.8 million and another $136,000 in environmental costs for a total impact of just under $3 million or approximately $50 per acre of bluegrass originally in production.

Rotational Burning Scenarios

A final set of scenarios in which fields are burned following every second year of production as outlined earlier is presented in Table 4. Experimental results showed that yields following a burn after the second year were virtually identical to yields in fields that are burned every year (Canode and Law). If the expense of establishing a bluegrass field can be amortized over a longer rotation, production costs will be dramatically reduced. In addition, if non-burning residue

Table 4. Returns to Land and Management for Irrigated and Dryland Bluegrass Production with Burning Fields Every Second Year of Production for a Total of 33 percent of Irrigated Acreage and 37.5 percent of Dryland Acreage

	Returns to Land & Management			Env. Impact	Net Change
	($/ac)	(%)	($1000)	($1000)	($1000)
Pre-rule:					
Irrigated					
BG burned	131	100	2754	0	0
Dryland					
BG burned	200	100	7817	0	0
Total			10572	0	0
Rotational Burning:					
Irrigated					
BG burn every 2nd year	98	100	2067	0	-687
a) $15/acre subsidy on removal costs	103	100	2172	0	-582
b) market for straw	111	100	2348	0	-406
c) both a) and b)	117	100	2454	0	-301
Dryland					
BG burn every 2nd year	141	100	5507	0	-2309
a) $15/acre subsidy on removal costs	146	100	5728	0	-2089
b) market for straw	156	100	6095	0	-1722
c) both a) and b)	161	100	6315	0	-1502
Total Acreage					
BG burn every 2nd year					**-2997**
a) $15/acre subsidy on removal costs					**-2671**
b) market for straw					**-2128**
c) both a) and b)					**-1803**

Price assumptions are $0.80 per pound for common bluegrass (CBG) and $0.85 per pound for proprietary bluegrass (PBG).

removal techniques, currently estimated to cost $70 per acre, are required only every other year, costs will decline. Various scenarios are presented assuming a $15 per acre subsidy toward residue removal costs (a), the existence of a straw market that completely covers the costs of baling and stacking the primary residue (b), and both scenarios combined (c). There are no environmental costs to the rotational burning scenarios as all bluegrass is assumed to remain in production. Prices remain at the current level for the same reason. In reality, there may be some acreage in the dryland areas that are too steep to use these techniques, but that is not considered here. The net economic impacts for rotational burning across both regions range from $3 million without any subsidies or markets for straw to $1.8 million with a $15 per acre subsidy for straw removal and a market for straw. While these scenarios may only be realistic for a certain percentage of the original bluegrass acreage in production, it is obvious from the per acre returns in the second column that rotational burning is much more likely to be competitive with alternatives to bluegrass production than non-burning methods, and would decrease the environmental impacts of a loss in bluegrass acreage.

Impact of 5 Percent Exemption on Dryland Acreage

Table 5 presents the impacts of a proposed 5 percent exemption on the two-thirds burning ban on dryland acreage. Assuming there are extraordinary circumstances such as field terrain that is too steep for non-burning residue removal methods, farmers may be allowed to burn up to 38 percent rather than 33 percent of their acreage. This exemption must be certified by an agronomic professional. For the fixed price scenarios in Table 2, the region-wide economic and environmental impacts of this exemption if it is used by all dryland producers would be an increase in total returns of $390,000 plus $29,000 additional environmental benefits for a total of $419,000 (Table 5). In Table 3, prices were allowed to vary across the high, medium, and low impact scenarios. The high impact scenario uses the same prices as Table 2, resulting in the same total region-wide impact. Bluegrass prices are assumed to rise 5 percent for the medium impact flex price scenario and 15 percent for the low impact high price scenario, which increases total returns to $432,000 and $543,000, respectively, for the two scenarios. Total environmental impacts are the same for all scenarios at $29,000. The total impact for these two scenarios are $461,000 and $543,000. Thus, the 5 percent exemption would have a significant positive impact on net returns as well as the environment if widely used across the dryland areas.

Table 5. Economic and Environmental Impacts of a 5 Percent Exemption on Dryland Acreage on High, Medium, and Low Impact Scenarios

Scenario	Change in Total Returns ($1000/yr)	Change in Env. Impacts ($1000/yr)	Total Impact ($1000/yr)
Fixed Price Scenarios (Table 2)			
High, Medium & Low Impacts	390	29	419
Varying Price Scenarios (Table 3)			
High Impact, Flex Rotation	390	29	419
Medium Impact, Flex Price	432	29	461
Low Impact, High Price	543	29	543

Impact of Proposed Trading of Burning Permits

Tradeable permits are used in air pollution control to decrease the economic burden on polluters. Some industrial plants may prefer to buy a permit than to invest in new technologies such as scrubbers. Other plants may prefer to invest in non-polluting technology and sell some of their permits to pollute. Within one airshed, this type of trading should result in the desired level of air pollution control while allowing individual companies to choose the best strategy for their particular situation.

This concept could be used several ways under the proposed regulation for reducing burned bluegrass acreage to two-thirds of current production. If farmers were allowed to trade permits within one airshed, farmers wishing to continue burning bluegrass at higher levels than permitted under the proposed regulation could buy permits from farmers who decided to quit growing bluegrass, and both parties should be better off.

The reduction in costs from trading were not explicitly estimated due to lack of appropriate data. The benefits of trading are that, once the overall desired limit on burning is set, farmers are able to increase efficiency--"fine-tuning" their farming by using burned bluegrass on the fields most productive under burning. Since we modeled farms in only two broad classes, irrigated and dryland, we were not able to capture the efficiencies that result from shifting burning from one field to another with different productivity and farming cost characteristics. In principle, the trading provision will not change the overall level of burning. However, in practice it is possible that some fields will be burnt that would otherwise not be burned. For instance, if a farmer had most of his bluegrass fields in a rotation (establishment, "take-out" year) where he did not need to burn, he might sell his permit and thereby increase the total burn.

It is also important to note that the impact of the trading provision will depend, among other things, on the scope of area for the rule. If permits were tradable across all of eastern Washington, it is likely that irrigated farmers would sell permits to dryland farmers, especially those in the Spokane area. Such a version of the rule would reduce the benefits of the rule, perhaps substantially. It is therefore assumed here that trading will be within local jurisdictions only. Another approach might be to encourage farmers in an area with air pollution problems and large centers of population to sell their permits to farmers in areas without these characteristics. If all costs of production had to be paid, including externalities such as health impacts on the surrounding population, bluegrass production would naturally move to areas with lower total costs of production. However, the high concentration of producers in Spokane County would undoubtedly be adversely affected and thus this solution would be politically unpopular. Also, as population increases over the years, the problem may simply repeat itself elsewhere.

What is needed for this bluegrass burning situation is a silver bullet that would allow economical production of bluegrass with non-burning methods. The environmental benefits from production of this perennial could then be maintained without the air pollution problem. In the absence of a solution, measures such as allowing burning every second year of production, provision or subsidization of residue removal equipment, and assistance with development of markets for straw would help reduce the economic burden on growers.

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Appendix C

Estimates of Benefits from Reductions in Grass Seed Field Burning

Technical Report

by

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Report prepared for Washington Department of Ecology under terms of Inter-agency Agreement No. C9600164.

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INTRODUCTION

On March 29, 1996, the Department of Ecology issued an emergency ruling that called for a one-third reduction in the number of acres of field and turf grasses that could be burned in Washington in 1996. A permanent rule requiring an additional one-third reduction in 1997 is currently being considered. The proposed rule would modify WAC 173-430, to require "burning of field and turf grasses for seed in 1997 and thereafter (until approved alternatives become available) be limited to no more than one-third of the number of acres in grass seed production on May 1, 1996." State law requires that a benefit-cost analysis examine the economic impact of the permanent rule be completed for such a proposed rule. This report presents the analysis measuring the economic benefits that would be gained under the proposed rule.

The largest potential benefit of the proposed rule is improved air quality from reduced smoke emissions. Epidemiological evidence has established a clear link between small air-born particles and health, particularly for an at-risk population comprising people with existing cardio-pulmonary conditions such as asthma, emphysema, chronic bronchitis or heart disease.[1] Additional benefits from the proposed rule include the benefits of traffic accident reductions, enhanced recreational opportunities, reduced dirt and nuisance effects from smoke particles, and the aesthetic effects of improved visibility.

The primary component of this section of the report presents the results of a contingent valuation survey that was conducted between July and September of 1996. The following discussion will describe the analysis of the survey data that was used to calculate the potential benefits. The population surveyed comprised the residents of Eastern Washington in counties where bluegrass is grown and the residents of two counties in Idaho that are also affected by smoke from bluegrass field burning.

A secondary component of this benefits analysis considers evidence from epidemiology studies and from studies on the economics of health improvements. A final section reports information on the incidence of respiratory and cardiac problems gathered from the contingent valuation survey which can be used to provide some additional rough estimates of the costs that exposure to smoke burning has on area residents.

BENEFIT ESTIMATES FROM CONTINGENT VALUATION SURVEY

Characteristics and Disposition of Survey Sample

A survey instrument was developed by researchers at the Department of Agricultural Economics at Washington State University to measure the household benefits of reducing smoke from grass

[1] There is also some speculation that the higher rate of asthma found in Spokane compared to other regions may be due to the higher levels of particulate pollution in the Spokane area. Since this possibility is still speculative it was not counted in the study.

burning. The survey is described below. It was designed to elicit information on attitudes and values toward smoke from grass field burning, data on health status, demographic information, and other information, described below, needed to estimate economic value. The Social Survey Research Unit at the University of Idaho administered the survey.

The sampling frame used for this study included all listed telephone directory numbers in the study area. By using listed directory numbers the addresses of households are also obtained. This permitted us to send an advance letter to the household notifying them about the study. The sample of telephone numbers for this study was obtained from Survey Sampling, Inc. of Westport, Connecticut, a sampling firm that maintains current lists of telephone directories for the nation. The initial sample contained 3,000 households. Households were randomly selected from telephone directory data banks maintained by Survey Sampling. The goal of the study was to complete 1,500 interviews comprising two subsamples: (1) 750 completed interviews in Spokane County, and (2) 750 interviews covering other affected areas in Eastern Washington and Kootenai and Bonner Counties in Northern Idaho.

A pretest of the questionnaire was conducted between July 18, 1996 and July 24, 1996. A total of 76 pretest interviews were conducted. Interviews using the final form of the questionnaire began on July 25, 1996. A total of 1,561 interviews were completed. Interviews were completed by September 9, 1996. Table 1 presents the percentage of permitted bluegrass acres in each county along with projected household population counts for each county in the sample.[2]

The response ratio (completes / completes + refusals + did not reach) for the survey is 71 percent. The overall cooperation ratio (completes / completes + refusals) is 77 percent. The dispositions of the sample by region is presented in Table 2.

Development of Contingent Valuation Questionnaire

The contingent valuation method (CVM) is a survey based method for eliciting economic values. It works by simulating a market for an environmental amenity or other public good. Respondents are asked to treat the environmental good like a commodity that they might have to pay for--either in a real market or through taxes or fees for government services. Respondents are asked to place a value on a change in the amount or in the quality of a commodity that is expected to result from an environmental policy. In this way, CVM provides economic information about the value of environmental goods or services that do not have any monetary values associated with their use in consumption or production. In the case of a public good like clean air, a voting referendum model is used for further realism. Respondents are asked whether they would approve, and pay for, a program to obtain the desired public good (such as cleaner

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[2]Permitted bluegrass acres is an undercount of actual acres in production due to under-reporting. See technical appendix on farm costs for updating of acreage.

Table 1. Number of Household in Sample with Number of Permitted Grass Acres by County

County	Percentage of Permitted* Grass Acres	Number of Households (Sample Frame)	Number of Households (Population)	Percentage of Households
Lincoln	3	3,845	3,958	1.1
Grant	1	14,682	22,963	6.6
Adams	6	3,636	5,045	1.5
Whitman	11	9,933	13,987	4.0
Benton	4	23,440	50,276	14.5
Franklin	2	7,875	13,707	4.0
Walla Walla	3	12,645	19,131	5.5
Columbia	1	1,192	1,689	0.5
Garfield	4	931	907	0.3
Asotin	1	5,345	8,059	2.3
Spokane	64	158,373	158,373	45.7
Total Washington	100	315,088	298,096	86.0
Kootenai	NA	21,819	35,437	10.2
Bonner	NA	9,627	13,001	3.8
Total Northern Idaho	NA	31,446	48,438	14.0
Grand Total		199,360	346,534	100.0

*. Permitted acres are about 40,000. We estimate actual planted acres at about 60,000.

air) In this case the environmental improvement or "public good" is a reduction of grass seed field smoke. The method is called Contingent Valuation because the value elicited from the respondent depends or is contingent upon the hypothetical scenario described in the survey instrument.

There are three basic parts to the design of a Contingent Valuation Method (CVM) survey (Mitchell and Carson, 1989):

1. A detailed description of the good(s) being valued and the hypothetical circumstances under which it is made available to the respondent.

2. Questions which elicit the respondent's willingness-to-pay for a change in provision or willingness-to-accept to forgo a change for the good being valued.

3. Questions concerning the demographics and characteristics of the respondents including the extent to which the good in question relates to their household (in this case we asked ,questions concerning farm operations, attitudes toward air pollution, and health questions to determine if the household was in the at-risk group.

Table 2. Disposition of Sample by Region

Dispositions	Eastern WA	Spokane	Idaho
Completed interviews	596	746	219
Refusals	133	252	57
Ineligibles:			
Duplicate Households	3	5	3
Deceased	11	17	2
Business/Govt tel no.	9	18	9
Language problem	54	51	14
Rings Wrong HH/no listing	156	220	55
Illness	25	43	4
Moved out of area	29	51	24
TOTAL INELIGIBLE	287	405	111
Did not reach	71	96	22
TOTAL	1,090	1,500	410
RESPONSE RATE (completes/completes+refusals+did not reach)	74.5%	68.2%	73.5%
COOPERATION RATE (completes/completes+refusals)	81.8%	74.8%	79.4%

More specifically, the questionnaire (available in a separate technical appendix and available by request) contained:

- a section for identifying primary farm operators and asking questions about farm operations and use of field burning as an agricultural practice;
- a section with questions about respondents' perceptions of general air quality and environmental policy;
- a section with questions about the health status of household members and whether any members suffer any major or minor symptoms due to smoke from field burning; the section contained follow-up questions for respondents whose household contained anyone with a chronic respiratory or cardiac condition;
- a section describing the proposed rule to reduce smoke from the burning of bluegrass fields; follow-up questions were asked about perceived benefits or concerns about the rule;

- a section describing the proposed rule, asking whether or not respondents favor the rule (using a referendum format) and asking the value questions; two formats--an opened-end format for one quarter of the sample and a discrete-choice with follow-up format for the rest of the sample) were asked;[3]
- a section with demographic questions (age, income, etc.).

Calculation of the Benefits

A sequence of questions were used to establish the background and then elicit the value for measuring the household benefits due to the proposed rule. First, respondents were given a referendum asking whether they favor or oppose the proposed rule to reduce the number of acres burned by Washington bluegrass producers by two-thirds by 1997. All respondents, including those in Northern Idaho, were told that the rule only affects smoke from bluegrass fields in Washington. Responses to the referendum question are given in Table 3.

Table 3. Results of Revised Vote Count on the Referendum to Reduce Smoke*

Response	Spokane Co.	Eastern WA	No Idaho	Row Total
Favor Program	374 (50.1)	232 (38.9)	110 (50.2)	716 (45.9)
Against Program	302 (40.5)	300 (50.3)	80 (36.5)	682 (43.7)
Would Not Vote	14 (1.9)	7 (1.2)	4 (1.8)	25 (1.6)
Depends on Cost	2 (0.3)	0 (0.0)	0 (0.0)	2 (0.1)
Not sure/No Opinion	48 (6.4)	45 (7.6)	21 (9.59)	114 (7.3)
No Answer	6 (0.8)	12 (2.0)	4 (1.8)	22 (1.4)
Column Total	746 (47.8)	596 (38.2)	219 (14.0)	1561 (100.0)

* Numbers in parenthesis are column percents except Column Total which are row percents.

[3] An opened-ended question directly asks the respondent how much they would pay to receive the benefits of the rule. A discrete choice question asks the respondent if they would pay a set amount (e.g. $25) to get the rule. With a follow-up questions, those that agreed to make the level of payment are asked the maximum amount they would pay, while thus that would not pay the set amount are asked what amount, if any, they would pay.

It is important to note that this survey was not designed as a voter survey. These survey results do not predict how a popular vote on the proposed rule would actually turn out, although they do give some indication of popular sentiment. Voter surveys include questions designed to predict who would actually vote and have other differences from the survey we conducted. Our purpose was to elicit how much the rule was worth to people, not whether it would be approved in a general election referendum.

There were two adjustments made in the voting data. First, respondents who indicated that a program to reduce smoke produced no benefits for the own household were asked if they would vote for the program if it helped other households besides their own. A total of 12 respondents favored the program if it helped others. Second, respondents who indicated that they would not vote for the program either because (1) they did not want to vote, (2) it would depend on costs, (3) they were not sure or had no opinion, or (4) they would not answer, were asked if they would pay anything to get the benefits of the program. Sixty-six of the respondents who voted in these categories indicated they would pay something for the program. The responses of the respondents were recoded to indicate that they favor the program since they indicated they would pay something for it.

Using the revised vote count, the rule is favored by a majority in Spokane County (50 percent in favor with 40 percent against) and Northern Idaho (50 percent in favor with 37 percent against). In Eastern Washington, a majority of respondents oppose the rule (39 percent in favor with 50 percent against).

In order to determine how the vote reflects the combined preferences of Washington residents and also of the entire region represented in the sample, responses from Table 3 were weighted to obtain a fair representation. Table 4 presents the weighted results of vote of just Washington residents. Here, the vote count of Eastern Washington residents is weighted upward by a factor of 1.25 in order to balance the number of households between each region so they can be compared. No further adjustment is needed since both Spokane County and the other counties comprising the Eastern Washington portion of the sample contain roughly the same number of households.

For the Washington state region, slightly less than 45 percent of the households voted in favor of the program while slightly more than 45 percent voted against the program. In view of these results, residents of Washington are evenly split on their support for the rule.

The voting responses were also weighted to determine the outcome for the entire study region. Votes were adjusted in each of the three subsamples in order to give each households the appropriate weight based on the number of households in each of the three regions. The results of this region vote can be found in Table 5. Overall, the program is favored by a slim majority of 45.1 percent while 44.6 percent of the households in the region voted against the program.

Table 4. Results of Weighted (Representative) Preferences on the Referendum to Reduce Smoke for Washington Residents Only*

Response	Spokane Co.	Eastern WA	Washington Total
Favor Program	374 (50.1)	290 (38.9)	664 (44.5)
Against Program	302 (40.5)	375 (50.3)	677 (45.4)
Would Not Vote	14 (1.9)	8.8 (1.2)	25 (1.5)
Depends on Cost	2 (0.3)	0 (0.0)	2 (0.1)
Not sure/No Opinion	48 (6.4)	56.25 (7.6)	114 (7.0)
No Answer	6 (0.8)	15 (2.0)	22 (1.4)
Column Total	746	745	1491 (100.0)

* Numbers in parenthesis are column percents except Column Total which are row percents.

Table 5. Results of Revised Vote Count on the Referendum to Reduce Smoke For Entire Region[1]

Response	Spokane Co.[2]	Eastern WA[2]	No Idaho[2]	Region Total
Favor Program	357.7 (50.1)	274.8 (38.9)	71.15 (50.2)	703.6 (45.1
Against Program	288.8 (40.5)	355.4 (50.3)	51.7 (36.5)	695.9 (44.6
Would Not Vote	13.4 (1.9)	8.3 (1.2)	2.6 (1.8)	24.2 (1.6)
Depends on Cost	1.9 (0.3)	0 (0.0)	0 (0.0)	1.9 (0.1)
Not sure/No Opinion	45.9 (6.4)	53.3 (7.6)	13.6 (9.6)	112.8 (7.3)
No Answer	5.7 (0.8)	14.2 (2.0)	2.6 (1.8)	22.5 (1.4)
Column Total	713.4 (45.7)	706 (45.2)	141.7 (9.1)	1561 (100.0)

[1]Numbers in parenthesis are column percents except Column Total which are row percents.
[2]Weights for each region are 0.96 for Spokane County, 1.18 for Eastern Washington, and 0.65 for Northern Idaho.

To understand the motivations behind the responses to the referendum question, a statistical model was used to analyze possible factors in determining why respondents voted the way they did. We analyzed only data from the survey so there may be other factors beyond the scope of the survey which influence opinions on this issue. We used a logit statistical model to analyze the survey data. The logit model is used to predict yes-no responses and similar qualitative dependent variables (See statistics or econometrics text such as Greene). The logit model predicts the relative proportion of the population which will vote yes or no. The logit model also adjusts for the fact that one does not want to predict that fewer than zero or more than 100 percent of the votes are yes or no.

Table 6 presents the definitions of the variables from the survey that were used in the logit model. Eleven different variables were tested to determine if they were factors in explaining why respondents voted the way they did. These included responses to how respondents ranked health risk, the benefit to reducing health risks to other households, and the nuisance smoke is to their household; and also responses to concerns about the program including causing financial burdens to farmers, overstating the health benefits of reducing smoke, and giving more importance to dealing with other issues like crime and funding education.

The results of the logit analysis can be found in Table 7. The estimated coefficients from the logit model are not directly interpretable. However, the signs on the coefficients indicate whether responses to the variable is a factor in explaining why the respondent voted for the rule. A positive coefficient indicates that, on average, responses to the variable resulted in a greater probability of voting for the program. The chi-squared statistic indicates whether the effect is statistically valid.

The model shows that those respondents who favored the rule placed greater importance on:

- health risks to their own household (HEATHR),
- health risks of other households (ODEATH),
- the nuisance caused by smoke (NUISSM), and
- the degree grass smoke contributes to air pollution (FACT_6).

Respondents who did not favor the rule felt the rule

- singled farmers out (FARMCAUB),
- placed financial burdens on farmers (FARMERB),
- overstated the health benefits (HEALTHOB),
- lacked importance compared to other issues (OTHISSUB), and
- infringed on farmers right to farm (FARMITB).

Also, those with higher incomes tended to vote for the program while residents of Eastern Washington outside Spokane tended to vote against the rule. All the variables in the model are significant at the at the .01 level except EWASH which is not quite significant at the .05 level

Table 6. Definition of Variables Used in Statistical (Logit) Model

Label	Question
HOWVOTE (Dependent Variable)	Suppose you were asked to vote on this smoke reduction program reducing the acres farmers can burn by 2/3 of past levels by 1997. Would you vote for or against the program? (1=favor, 0=against + would not vote + depends on how much it costs + not sure or no opinion + no answer)
EWASH	Resident of Eastern Washington (1=Yes, 0=No)
HEALTHR	Given the health status of people in YOUR household, how much of a health risk does smoke from field burning pose for your household? (1=an extreme risk, 2=serious, 3=moderate, 4=slight, or 5=no risk)
ODEATH	Would reducing the health risks of smoke from grass field burning to other outside of your household be a (1) great, (2) moderate, (3) slight, or (4) no benefit.
NUISSM	Overall, how much of a nuisance is grass field smoke for you and your household? (1=great nuisance, 2=moderate, 3=slight, or 4=not a nuisance)
FARMERB	Regulations on grass burning may put additional financial burdens on farmers. (1=strongly agree, 2=somewhat agree, 3=somewhat disagree, or 4=strongly disagree)
HEALTHOB	Those who favor regulations on burning exaggerate the health problems caused by smoke. (1=strongly agree, 2=somewhat agree, 3=somewhat disagree, 4=strongly disagree)
FARMCAUB	Farmers are being unfairly singled out for causing air pollution. (1=strongly agree, 2=somewhat agree, 3=somewhat disagree, or 4=strongly disagree)
OTHISSUB	There are more important issues than air quality like controlling crime and funding education. (1=strongly agree, 2=somewhat agree, 3=somewhat disagree, or 4=strongly disagree)
FARMRITB	Farmers have a right to farm their land as they best see fit. (1=strongly agree, 2=somewhat agree, 3=somewhat disagree, or 4=strongly disagree)
FACT_6	To what extent do you think smoke from grass field burning contributes to air pollution. (1=major, 2=moderate, 3=minor, or 4=insignificant contributor)
INCOME 1995	Total household income before taxes for 1995. (1=less than $10,000, 2=$10,000-$20,000, 3=$20,000-$30,000, 4=$30,000-$40,000, 5=$40,000 to $60,000, 6=$60,000-$80,000, 7=over $80,0000)

Table 7. Results of Logit Model

Variable	Results*	
EWASH	- 0.31	(0.0522)
HEALTHR	0.30	(0.0056)
ODEATH	0.48	(0.0001)
NUISSM	0.46	(0.0001)
FARMERB	- 0.39	(0.0001)
HEALTHOB	- 0.31	(0.0001)
FARMCAUB	- 0.19	(0.0020)
OTHISSUB	- 0.13	(0.0483)
FARMRITB	- 0.26	(0.0001)
FACT_6	0.27	(0.0022)
INCOME 1995	0.11	(0.0296)

*Chi-squared probability values for the test of significance for individual variables are in parenthesis.

One limitation to the logit model is that the analysis could only be conducted on 1,467 observations. Ninety-four cases were not asked the questions about health risks or about concerns with the rule. In order to keep the duration of the interview down, farmer operators who were asked other questions about their farm operation. So the logit analysis is based mostly on the non-farm population.

Calculating Willingness-to-Pay Estimates from Contingent Valuation Survey

Respondents voting in favor of the rule or who indicated that (1) they would not vote, (2) their vote would depend on cost, (3) they were not sure or no opinion, or (4) they had no answer, were asked follow-up questions concerning how much their household would be willing to pay to get the benefits of the rule. (Those who did not favor the rule were asked if they would be willing to pay to continue to allow burning; see earlier discussion.) Those respondents that voted against the rule were asked follow-up questions to determine if they were either "true" zero values or if they were protesting against the idea of paying for the rule or against the referendum format.[4]

Information on willingness-to-pay (WTP) for the program was collected using two different types of question formats. A quarter of the sample was given the open-ended question format which just simply asks the respondent how much they would pay for the program. An alternative

[4]A protest vote or a protest zero value is one where the respondents objects to being asked to pay for a rule for several reasons including: (1) respondents feel polluters should pay for the rule, (2) respondents may object to the payment vehicle (in this case increase taxes) as inappropriate, or (3) respondents may want a reduction in smoke but dislike the approach taken to reduce it.

format called discrete choice was used for the remaining three-quarters of the sample. Here, respondents are asked if they would pay some set amount for the program. For this survey, the set amounts were $10, $20, $25, $30, $40, $50, $75, $100, $150, and $200.[5] These amounts were chosen based on the distribution of opened-ended responses from earlier interviews. The amounts were chosen to represent approximately equal proportions of the population. For each respondent, the set amount was randomly selected. If respondents agreed to pay the amount, a follow-up question asked the maximum amount the respondent would pay. If the respondent declined to pay the set amount, a follow-up question asked what amount, if any, the respondent would pay for the program. The responses to the follow-up questions in the discreet choice format were combined with the responses from the open-ended responses to form one continuous measure of WTP for the entire sample. This combined set of responses is used as the basis for WTP estimates in this report.

Table 8 shows the average WTP values for those who expressed a positive value, by each region. The table shows the number of positive responses, the percentage of positive responses within each region, and the standard error about the mean.

Table 8. Means for Positive WTP Value Responses

Region	% of Sample	Mean	Std Error
Spokane County (N=246)	33	$49.39	3.49
Eastern WA (N=138)	23	$54.12	4.43
Northern Idaho (N=70)	32	$81.35	18.15

Row one of Table 9 shows the aggregate WTP values for the proposed rule based on the mean WTP for all initial positive value responses. The mean values are then extrapolated to the total regional population based on the proportions of the sample that gave a positive WTP. However, this estimate represents a low estimate of the economic benefits of the proposed rule.

The reason the estimate in row one is low is that it assumes that all the respondents who did not exactly know their WTP had a zero value for the program. However, some respondents will have a positive value for the program but be unable or unwilling ("protest zeros") to express it. The other calculations in Table 9 account for households that could not provide explicit economic values using several different methods of imputing value for these "missing values." Imputing WTP values for these "don't know" households is an important calculation because follow-up responses indicate these households may have some value to the program. (See, e.g., Mitchell and Carson for an extensive discussion of this issue.) Explanations for these missing value observations include:

[5]These amounts were chosen based on the distribution of open-ended responses from the pretest interviews. Once chosen, each amount was randomly assigned to each interview in order to get an equal number of responses at each bid level.

Table 9. Aggregated WTP Benefits With Different Estimators

Type of Estimate	Mean Estimate ($ Millions)	Range[1] ($ Millions)
1. Low Estimate: Mean of Positive Responses Only (n=454)	5.4	4.3 to 6.4
2. Moderate Estimate: Positive and Missing Value Estimate using Mean of Positive and Zero Value Cases for Missing Value Estimate (n=770)	7.4	5.9 to 9.0
3. High Estimate: Positive and Missing Value Estimate using Mean of Positive Value Cases Only (n=770)	9.2	7.3 to 11.0
4. Best Estimate: Positive and Missing Value Estimate using OLS estimates for Missing Cases (N=770)	8.4	6.6 to 10.2

[1]Range based on 95 percent confidence interval based on two standard errors of the mean.

- respondents are protesting against paying because they feel polluters should pay for the damage,
- respondents would like to improve air quality but do not trust the government to properly implement the rule, or
- respondents are not able to provide any value information without being provided more information about the program
- respondents can't or won't express their value in monetary terms.

In all, there are 316 observations that can be considered either protests or not sure households.

Three alternative approaches to imputing value to missing households were used. One approach was to give these missing households the mean values based on all households with positive values. These calculations represent a high estimate and can be found at row 3 in Table 9. In the high case, we essentially assume that the "don't know" households are like those that offered positive values. In the conservative approach (row 1), we assume that "don't know" households are like those who have zero value. A more moderate approach would impute a value based on a combined mean calculated from all positive value households and those households with "true" zero values. Aggregations based on these means can be found at row 2 in Table 9.

Finally, the last approach uses values for missing households that have been statistically predicted. We used ordinary least squares (OLS) regression models to predict these "missing values." These models use key relationships from other variables in the survey to explain how much a household is willing-to-pay for a reduction in smoke. Based on these quantifiable relationships, predicted values for missing households can be estimated based on their responses to variables in the OLS model (the models used are presented in a separate technical appendix, along with the questionnaire, that can be obtained by request). The assumption is that the responses to other variables in the questionnaire by households that did not give a value is similar to the responses of households that did provide values.

The use of both the mean of positive values and mean from predicted values (for missing cases) are presented in row 4 of Table 9. This estimate represents our best estimate for the amount households are willing to pay for the smoke reduction program since the use of models to predict WTP is the best method for filling in "missing values." (See, for example, Mitchell and Carson.) The range around the estimate is based on the margin of error in extrapolating the benefit value from the sample population to the total population. Our use of a relatively large sample (1561 households) compared to many studies of this type helps to minimize this margin of error.

Compensation Measure of Benefits

An alternative measure of the economic benefits of a smoke reduction program can come from an additional compensation value question. The "compensation question" asked respondents how much their household should be compensated in the absence of a smoke reduction rule. In the compensation question households are asked how much they must be compensated to "sell" their right to the the effects of the proposed rule (cleaner air), rather than how much they would pay to get the rule implemented. It is based on the assumption that the population affected by smoke has the right to be free of smoke. If they have the right to be free of smoke they should not have to pay to get reduced smoke, they should be compensated for any damages caused by continued burning. This approach produces much larger estimates of the value of smoke reduction. The compensation question was asked of all respondents except primary farm operators and those who voted against the program and agreed to pay to allow continued burning.

Table 10 shows the distribution of the 104 respondents who said they should be compensated. Table 11 presents the mean compensation values and the aggregated value by region. Fifty-six respondents did give an amount they would require for compensation.

Overall, extrapolating the compensation value to the entire region gives a total value of approximately $328 million based on positive responses given to the compensation question. In addition to those who indicated how much compensation they needed to allow burning to continue, an additional 48 respondents wanted compensation for burning to continue but did not place a value on the compensation because they were not sure or needed more information before they could give an amount. If the mean of the compensation values from those who did give a value is used as a measure for these missing households, the overall level of compensation would be $543.3 million.

Table 10. Number of Households Wanting Compensation By Region[1]

Region	Household Wanting Compensation
Spokane County	56 (9.61)
Eastern Washington	26 (5.95)
Northern Idaho	22 (13.10)
Total	104 (8.75)

[1]All numbers in parenthesis show the percentage of those wanting compensation in each region. The parenthesis for the total row shows the percentage of those wanting compensation for the entire sample.

Table 11. Means for Compensation Value Responses*

Region	% of Sample with Postive	Mean	Total Value (millions)	Percent of Sample including Missing Value Household	Total Value Including Missing value Households (millions $)
Spokane County (Positive n=35; Missing n=21)	4.7 (7430)	$39,282	$291.87	7.5 (11,878)	466.6
Eastern WA (Positive n=12; Missing n=14)	2.0 (3155)	$11,212	$ 35.37	4.3 (6739)	75.6
Northern Idaho (Positive n=11; Missing n=11)	5.0 (1579)	$ 359	$ 0.57	10.0 (3145)	1.1
TOTAL			$327.81		543.3

* Numbers in Parenthesis are the number of households represented by the sample for each region.

Compensation measures are not often used in economic valuation studies partly due to the wide range of values respondents report. In this study, the range of values given for compensation was from $10 to $1.3 million. A better estimator of required compensation for continued burning at 100 percent is a "trimmed mean." (Mitchell and Carson) A trimmed mean is based on discarding the extreme lowest values and the extreme highest values and calculating the mean based on the remaining observations. Table 12 provides a calculation of an aggregate compensation value using a trimmed mean. Throwing out the three lowest observations ($10, $15, and $20) and the three highest values ($50,000; $100,000; and $1.3 million) produces means that are less influenced by extremely large values.

Table 12. "Trimmed" Mean Estimates of Compensation Value Responses*

Region	% of Sample	Mean	Total Value (millions)	% of Sample Including Missing Value Households	Total Value Including Missing Value Households (millions $)
Spokane County (Positive n=35; Missing n=21)	4.7 (7430)	$ 886	$ 6.4	7.5 (11,878)	10.5
Eastern WA (Positive n=12; Missing n=14)	2.0 (3155)	$ 3,836	$10.8	4.3 (6735)	25.8
Northern Idaho (Positive n=11; Missing n=11)	5.0 (1579)	$ 393	$ 0.6	10.0 (3145)	1.2
TOTAL			$ 17.8		37.5

* Numbers in Parenthesis are the number of households represented by the sample for each region.

Based on the trimmed mean as an estimator of compensation values, the aggregate compensation value is $17.8 million for those willing to express a monetary value. If this value is expanded to include missing value observations, the level of compensation increases to $31 million.

Conceptually, the question of whether it is the right of farmers to burn their fields or the right of local residents to clean air that should be paramount is a legal and moral question beyond the scope of this study. This right should determine whether willingness to pay or compensation is used to estimate benefits. However, the compensation estimate is unreliable. The compensation value is based on a very small number of respondents so that extending the estimate to the whole population requires a very large confidence interval--range of estimate of the error. Moreover, as noted in the discussion of trimmed means respondent reporting patterns are less stable for compensation questions because they are characterized by a great range of individual value estimates. Most economists and government agencies disallow compensation estimates for these practical reasons. For instance, the National Oceanic and Atmospheric Administration disallows compensation estimates based on the recommendations of a blue ribbon panel of economists.

Conclusions

Results from the survey indicated a range of potential values that can be realized from the proposed smoke reduction rule. Estimated benefits range from a low of $5.3 million (based on willingness-to-pay) to a possible $31 million in benefits (base on willingness-to-accept compensation using a trimmed mean). Our best estimate accounting for most of the potential willingness-to-pay is $8.4 million with a range of $6.6 to $10.2 million. The range is based on the confidence interval of the estimate--the potential error in extrapolating the estimate based on the sample to the entire population. We used a relatively large sample size to minimize this error.

The willingness to pay estimate using contingent valuation captures most of the total value of the proposed rule. However, there are several reasons that WTP estimate may not include all benefits. One reason is that many respondents did not like the fact that the proposed rule to reduce smoke would impose a burden on local farmers. They therefore discounted the value they were willing to pay for the program to account for this negative impact. This can be seen especially outside the Spokane and North Idaho areas. While the majority of households in Spokane and Northern Idaho favor the proposed rule, the majority of residents in other areas of Eastern Washington oppose the rule. These results imply that the willingness to pay for the smoke production is a net value: it is the value of the benefits of smoke reduction to households less a penalty or cost for the burdens of the program.

Another reason the WTP estimate is low is that it measures benefits only from a private perspective. This means that, in evaluating their costs, households consider their costs for, say, hospitalization, but not the cost paid by insurance or government programs. This means that the survey based WTP benefit estimate is likely to be understated because it does not include costs to general businesses and the public. Thus, losses to the recreation industry in Northern Idaho are not included, though the cost of lost recreation days to the individual are included. The health exposure based estimates which follow are also understated because they do not include non-health benefits at all.

Health Related Benefits of Reducing Particulate Pollution

To supplement the benefit estimates from the contingent valuation survey, this section presents estimates of the health benefits of reducing smoke from agricultural field burning based on secondary sources. This analysis is based on extensive data in the epidemiological literature on the impacts of airborne particles on human health. We have used a standard approach of first determining exposure estimates and assigning health impacts based on the epidemiological literature. Once health impacts are estimated, economic impacts are assessed based on results from general studies in the literature. See Freeman for an account of this approach.

A useful example of the epidemiological-economic approach to air pollution can be found in *Dollars and Cents: The Economic and Health Benefits of Potential Particulate Matter Reductions in the United States*, a report prepared by Lauraine G. Chestnut of Hagler Baily Consulting, Inc. for the American Lung Association. The Chestnut reference provides a synthesis of available epidemiology studies. It then combines these results with potential economic values for improving air quality to make estimates of the economic benefits of reducing particulate pollution to the PM_{10} standard established by the state of California. The Chestnut report includes daily health risk relationships between particulate pollution and number of indicators of public health. These relationships were adapted to provide estimates of the health benefits gained from the elimination of grass smoke.

Analysis of the health benefits from reducing the particulate pollution from grass smoke in Eastern Washington requires the following assumptions. In most cases we used assumptions that produce a conservative estimate of health benefits.

1. The analysis considers only how grass burning increases the background level of daily particulate pollution levels and not include direct plume effects. During the burning season (from August 1 to September 30), ambient PM_{10} levels can increase up to ten micrograms per cubic meter in Spokane County (source: Spokane County Air Pollution Control Authority), nine micrograms per cubic meter in Benton county (source: Benton County Clean Air Authority) and five micrograms per cubic meter in Kootenai County (source: Idaho Division of Environmental Quality). While PM_{10} levels in a plume of smoke can reach between 150 to 300 micrograms per cubic meter during burning and for one or two hours immediately afterward, there is not enough information to evaluate the health effect of these plumes. Generating such information would require a model to estimate exposures that was well beyond the time and resource constraints of this study. Therefore, we analyze here only the effect of the increase in background level particulate during the burn season. Therefore, this analysis will only provide a lower bound or base level estimate of the health benefits of reduce burning for Eastern Washington.

2. The Lung Association report provides a range of estimates (a low, central, and high) of the relative risks that the general population faces from particulate pollution exposure. Also, a range is provided for the economic values associated with each health effect. Eastern Washington is likely to differ in both the characteristics of its population and in its economic values from other parts of the country. Thus, it is reported that Spokane has twice the national level incidence of asthma which will mean that its population is more at risk than is typical. On the economic side, Spokane has a lower household income which usually produces lower economic values. We have used the central estimates of health related risks and the central value economic estimates for this analysis. This assumes that everyone in the

population faces the same health risks, which is clearly not the case, but the central is a good approximation for the purposes of this report without better data to adjust the figures.

3. Because the burn season lasts only 60 days, only the health effects for which daily incidence rates could be found were evaluated. These include: the effects of reducing premature mortality, respiratory hospital admissions, emergency room visits, restricted activity days, asthma symptom day, and acute respiratory symptoms day. Other effects have annual incidence rates which would have required some method for apportioning the annual figures to a shorter season. These include health effects such as bronchitis episodes.

Health Outcomes

To conduct this analysis, we assume that the measurements of particulate levels from Benton County as representative of particulate levels for the counties in Eastern Washington where bluegrass is grown. Likewise, we assume that the measurements of particulate levels in Kootenai County in Idaho is representative of levels in Bonner County . Table 13 presents a summary of the concentration response relationships (the expected health outcomes for a given population based on a dose or exposure to particulate) that are used to measure the health effects of particulate pollution in the region.

Table 13. Human Health Effects Associated with PM_{10}

Health Effect Category	Concentration-Response
Daily mortality risk factors given a 1 mg/m³ change in daily PM_{10} concentration. Various sources: Including Pope, et al. (1995), and Dockery, et al. (1993).	C 3.3×10^{-8}
Respiratory hospital admissions (RHAs) daily risk factors given a 1 mg/m³ change in PM_{10} concentration. Source: Pope (1991)	C 3.3×10^{-8}
Emergency room visits (ERVs) daily risk factors given a 1 mg/m³ change in daily PM_{10} concentration. Sources: Samet, et al. (1981)	C 6.5×10^{-7}
Asthma symptom days (ASDs) daily risk factors given a 1 mg/m³ change in daily PM_{10} concentration. Sources: Whittemore and Korn (1980), Ostro, et al. (1991)	For population with asthma (4.7% of population)[6] C 1.6×10^{-4}
Restricted activity days (RADs) daily risk factors given a 1 mg/m³ change in daily PM_{10} concentration. Sources: Ostro (1987), Ostro and Rothschild (1989)	For population aged 18 years and over: C 1.6×10^{-4}
Days with acute respiratory symptoms (ARSs) daily risk factors given a 1 mg/m³ change in daily PM_{10} concentration. Source: Krupnick, et al. (1990)	C 4.6×10^{-4}

[6] Spokane has a rate of asthma (10 percent) which is higher than the national average. For these calculations, the higher rate was use for Spokane County while 4.7 percent was used everywhere else.

Calculating the effect on daily mortality of a 10 microgram per cubic meter increase in particulate matter in Spokane County will illustrate how these relationships are used. The general form of the formula is given as:[7]

(1) $3.3 * 10^{-8} * (\Delta PM_j) * (\text{Population})$

Taking the relative risk of daily mortality and multiplying it by both the daily change in particulate (ΔPM_j = 10 micrograms per cubic meter) and the 1995 population estimate of Spokane County yield the following expression:

(2) $3.3 * 10^{-8} * 10 * 401{,}200 = 0.132$

which is the expected increase in daily mortality for Spokane County from a 10 microgram per cubic meter increase in PM_{10}. Multiplying by 0.1.32 by 60 days gives an increase of 8 deaths that are due to the increase in PM_{10} over the entire burning season. The remaining health outcomes are calculated in the same way.

Valuation of Health Effects

Once the health outcome is identified, the outcome is multiplied by the associated dollar value found in Table 14 to provide an estimate of the economic benefit to be gained if particulate from grass smoke is eliminated. The dollar values from the various economic studies are adjusted to first quarter 1995 dollars.

Of special note is the value of a statistical life estimate that is used to value premature mortality. While the value of an individual life (or death) is immeasurable, value can and is placed on changes in risk of death. To illustrate, people drive cars, enter certain occupations, and engage in other activities that have differing risks associated with them. Based on the different value that people place on risks, a value for a statistical life can be calculated. It is not a value for a life per se, but a value placed on the increase in likelihood that one additional person will die. The figure selected for this analysis is $4.5 million per statistical life as recommended in the *Ecology Economics Resource Book* (Carruthers). However, this figure has been adjusted downward given that approximately 85 percent of premature deaths from particulate pollution are 65 or older (Chestnut, 1995, p. 5-9). Since the willingness-to-pay for mortality risks is less for those over 65, Chestnut recommends adjusting the "value of a statistical life" estimates downward by 30 percent.

[7] Note that the incidence rate is applied to the whole population, not just the at-risk population for Spokane. The incidence rates are already adjusted for the proportion of the general population which is at risk for the particular health effect.

Table 14. Summary of Selected Monetary Values for Various Health Effects

Health Effect	Estimate per Incident (1Q95$)	Primary Source	Type of Estimate[1]
Premature mortality (VSL)	3.15 mil.	Viscusi, et al. 1992	WTP
Respiratory hospital admission	15,000	Krupnick and Cropper (1989)	Adjusted COI
Emergency room visit	500	Rowe, et al. (1986)	Adjusted COI
Restricted activity day	60	Loehman, et al. (1979)	WTP & Adjusted COI
Asthma symptom day	36	Rowe and Chestnut (1986)	WTP
Acute respiratory symptom day	12	Loehman, et al. (1979) Tolley, et al. (1986)	WTP

[1] WTP = Contingent valuation WTP estimate.
Adjusted COI = COI x 2 to approximate WTP.

The estimates for respiratory hospital admissions, and emergency room visits are from studies that actually measure the cost of illness (COI) associated with each service. Chestnut (1995, p. B-8) recommends multiplying COI estimates by 2 in order to get a better estimate of WTP for benefit-cost analysis.

Table 15 presents the total damage estimate from all particulate pollution above background levels during the length of the burn season for the entire region. It is estimated that the increase in background levels of PM_{10} during August and September each year results in $54 million in health effects. The most significant health effect is the $50 million in economic loss due to 16 premature deaths that can occur during the burn season.

Since the value in the Table 15 shows damage from airborne particulates from all sources, the figures must be adjusted to determine the benefit of reducing the particulate due to burning bluegrass seed fields. If smoke from the burning of bluegrass fields accounts for between one-quarter and one-half of the particulate level increases during the burn season, then the total economic loss due to grass smoke ranges from 13.6 to 27.2 million dollars. Since the proposed rule would reduce smoke from bluegrass field burning by two-thirds, the benefits of the rule would range from 9.1 to 18.2 million dollars (two-thirds of 13.6 and 27.2).

Table 15. Economic Costs of Increasing Particulate Levels During Burn Season

Health Effect	Spokane Co. (10 mg/m³)	Eastern WA (9 mg/m³)	NO Idaho (5 mg/m³)	Dollar Value	Total $
Premature Death	8	7	1	3,150,000	50,400,000
Respiratory Hospital Admissions	8	7	1	15,000	240,000
Emergency Room Visits	156	134	24	500	157,000
Asthma Symptom Days	3,851	1,554	278	36	204,588
Restricted Activity Days	26,960	23,148	4,141	60	3,254,940
Acute Respiratory Symptoms	110,731	95,075	17,010	12	222,816
TOTAL					$ 54,479,344

INCIDENCE OF ILLNESS DUE TO SMOKE: SURVEY RESULTS

To better understand the public health impact of exposure to smoke from field burning, the contingent valuation questionnaire also gathered information on area residents who have chronic respiratory or heart conditions. Because of the difficulty respondents may have in identifying the source of smoke (wheat stubble versus grass fields), the questions were designed to measure behavior in responses to smoke from any field burning. Therefore, not all behaviors are the result of being exposed to smoke from the burning of bluegrass fields, but should be interpreted in the broader context of all field burning. This analysis is consistent with the previous section where exposures to the regions population were based on increased particulate pollution levels observed during the summer months of August and September.

The survey contained a series of questions on the last time any member of the household with a chronic respiratory or heart condition sought additional medical care outside of their regularly scheduled checkups. If so, the respondents were asked about their condition, what additional medical services they used, what symptoms they experienced, and if their symptoms could be caused by smoke. Of the 1,561 interviews completed, 253 households (16.2 percent of the sample) have a member with a chronic respiratory or heart condition. Table 16 shows the distribution of the number of households that have a member with a chronic condition by region.

Table 16. Number and Percentage of Households with Chronic Condition

Region	Number of Households	Percentage of Sample
Spokane County	123	16.5
Eastern Washington	90	15.1
Northern Idaho	40	18.3
Overall Sample	253	16.2

Based on information from this section of the survey, a profile of the potential health impacts was constructed for those individuals whose symptoms may be caused by smoke from outdoor field burning. Of the 253 households that contained someone with a chronic respiratory or heart condition, 69 of these (4.4 percent of the total sample) stated that their symptoms can be caused by exposure to smoke from field burning (47 of this identified the source of smoke as coming from the burning of bluegrass fields). Table 17 contains a listing of the chronic respiratory conditions for these households. The most frequently reported condition is asthma (50 total), with 39 households having asthma only and an additional eleven households having asthma with some other condition.

These households were asked about the last time additional medical care, outside of their normal checkups, was needed by someone in their household. Of these 69 respondents, 95 percent have experienced at least one episode where additional medical care was needed to treat their symptoms between 1992 and 1996. Table 18 summarizes the services used. The variety of services range from doctor visits to admission to the hospital. A majority of the households used more than one service. Forty chronic cases had to visit a doctor, while 19 visited an emergency room (ER) or a minor ER clinic, and 10 were admitted to a hospital.

Using the economic information from Table 10, the economic loss of the ten hospital admissions is $150,000 while the economic loss of 19 emergency room visits are $9,000.

Valuation of Symptoms Requiring Additional Medical Treatment

Table 19 contains a summary of the various symptoms experienced by household members with a chronic respiratory or heart disease. Using secondary information, an economic value can be place on reducing just one incidence of each symptom. Economic values used are in 1991 dollars. These values range from $17 to avoid an episode where breathing is difficult to $65 to avoid one headache.

Table 17. Chronic Respiratory Conditions for Those Households Reporting Symptoms Caused by Smoke

Condition	Number of Households
Asthma	39
Asthma and Sinusitis	1
Asthma and Chronic Bronchitis	2
Asthma, Chronic Bronchitis, Sinusitis	2
Asthma and Emphysema	4
Asthma, Emphysema, Chronic Bronchitis	1
Asthma, Emphysema, Sinusitis	1
Emphysema and Chronic Bronchitis	1
Emphysema, Chronic Bronchitis, Sinusitis	1
Emphysema	1
Chronic Bronchitis	4
Sinusitis	2
Lung Cancer and Angina	1
Other Lung or Heart Problems	9
TOTAL	69

Table 18. Additional Medical Services Used Treating Symptoms

Services Used	Frequency
Emergency Room/Minor ER Visit	19
Visit Doctor	40
Check into Hospital	10
Home Visit by Doctor	4
Visit by Nurse Practitioner	5
Additional Medication	28
Purchase Additional Oxygen	8
Visit a Lung Specialist	1

Table 19. Valuation of Symptoms Experienced the Last Time Additional Medical Case Was Needed by Households Reporting Symptoms Caused by Smoke

Symptoms	Frequency of Symptom	Unit Value (1991 $)	Total Value
Chest Pains	9	$ 22[1]	$ 198
Bronchial Spasm	10	$ 30[1]	$ 300
Asthma Episode	32	$ 45[2]	$1440
Difficulty Breathing	46	$ 17[1]	$ 782
Coughing Spell	22	$ 25[2]	$ 550
Sinuses	13	$ 45[2]	$ 585
Throat Congestion	6	$ 35[2]	$ 210
Itching Eyes	2	$ 35[2]	$ 70
Headache	3	$ 65[2]	$ 195
High Blood Pressure	1	N/A	N/A
Total Dollar Value			$4330

[1]Source: Dickie et. al. (1987)--Values adjusted to 1991 dollars.
[2]Source: Tolley et. al. (1994)

Based on the symptoms experienced the last time additional medical treatment was needed, the total economic value of avoiding one incidence of these symptoms is $4,330.[8] This value is an upper bound for total value for it should be weighted by the frequency of exposure to smoke from field burning in any year. However, if each household does experience these symptoms just once a burn season, then this value would reflect the economic loss due to one exposure to smoke from field burning.

Table 20 presents the aggregated regional economic damage of suffering one incidence of these symptoms. With 346,534 households represented by the sample, the number of households with chronic conditions (4.4 percent) is 15,247. Multiplying these chronic households by $4,330

[8]$4,330 is the value for the 69 households producing an average of $62.75 per household per incident (June 1997).

Table 20. Value of Symptoms When Additional Treatment was Needed

Total Households	Households with Chronic Conditions	$ Value of Symptoms	Total Economic Value
346,534	15,247	$4,330	$66 million
Revised, June 1997	per household	$63	$960 thousand

yields a total value of $66 million.[9] Caution must be exercised when interpreting this number for it represents the economic loss to individuals suffering symptoms that can be caused by one incidence of exposure to smoke, mostly occurring between 1992 and 1996. This number represents an aggregate of the economic damage accrued over this time period.

The survey did not collect information on the frequency of exposure to smoke that required additional medical care. However, the value above is still substantial. It should be noted that 61 percent of the households (n=42) suffering symptoms due to smoke from field burning identified the source of smoke they are exposed to as coming from bluegrass field burning.

Expenditures to Mitigate Minor Symptoms

Additional economic information on expenditures to mitigate minor symptoms were also collected in the contingent valuation survey. Respondents were asked if smoke from field burning ever caused someone in their household to suffer symptoms such as stuffy nose, watery eyes, coughing, headache, and mild bronchitis. A total of 613 respondents (39.27 percent of sample) said that they do suffer minor symptoms from smoke from field burning. These respondents (along with 43 respondents who answered that they were not sure) were further asked how likely would it be that someone in their household would purchase any medication to treat these minor symptoms. Overall, 224 respondents said they were very likely, 115 said somewhat likely, and 65 said somewhat unlikely that they would buy medication to treat these symptoms. This group was further asked how much money they would spend each time they suffered these symptoms due to smoke from field burning. Table 21 shows the average amount spent per household within each region and the aggregated total amount spent by region.

Overall, residents in the region are estimated to spend $2.6 million to treat minor symptoms each time they are exposed to smoke from field burning.

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[9]Revised calculation (June 1997 edition). The original value per incident calculation omitted a term. The correct calculation of (346,534 households) * (0.44) * $4330/69 yields a value of $957,000 per "incident." A value for the burning season would depend on how many "incidents" there were.

Table 21. Expenditures For Mitigating Minor Symptoms by Region

Region	% of Sample	Mean	Total Value (millions $)
Spokane County (n=160)	21	$38.5	$1.308
Eastern WA (n=88)	15	$46.1	$1.081
Northern Idaho (n=47)	21	$35.5	$0.234

CONCLUSIONS

The various analysis of potential benefits to reducing grass smoke yield a range of potential values. From the contingent valuation survey, the best estimate of willingness-to-pay to get the benefits of the proposed rule is $8.4 million with a range of $6.6 to $10.2 million. The best estimate of the value of compensation (also from the contingent valuation survey) is $31 million if values are imputed to missing observations.

Results for analysis using dose-response relationships and economic values from other studies indicate a potential economic loss of $54 million due to rising particulate levels in the region during the burn season. If grass smoke accounts for between one-quarter and one-half of the particulate levels, the economic benefits of the proposed rule range from approximately $9 to $18 million.

Analysis of the incidence of symptoms indicates that as much as $60 million in economic damage occurred from 1992 to 1996 to individuals that had to seek additional medical care due to exposure to smoke.[10] Although this estimate is a broader measure of the economic loss due to all smoke from field burning, it represents the potential economic impact on those households in the region that are at risk to exposure to smoke from field burning. Additionally, it is estimated that households in the region can spend up to $2.6 million to mitigate the minor symptoms each time they are exposed to smoke from field burning.

[10]Correction, June 1997. The correct cost of symptoms estimate is about $1 million per "incident." The number of "incidents" per season is unknown.

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Footnote 39

RCW 70.94.656

Open burning of grasses grown for seed — Alternatives — Studies — Deposit of permit fees in special grass seed burning account — Procedures — Limitations — Report.

It is hereby declared to be the policy of this state that strong efforts should be made to minimize adverse effects on air quality from the open burning of field and turf grasses grown for seed. To such end this section is intended to promote the development of economical and practical alternate agricultural practices to such burning, and to provide for interim regulation of such burning until practical alternates are found.

(1) The department shall approve of a study or studies for the exploration and identification of economical and practical alternate agricultural practices to the open burning of field and turf grasses grown for seed. Any study conducted pursuant to this section shall be conducted by Washington State University. The university may not charge more than eight percent for administrative overhead. Prior to the issuance of any permit for such burning under RCW 70.94.650, there shall be collected a fee not to exceed one dollar per acre of crop to be burned. Any such fees received by any authority shall be transferred to the department of ecology. The department of ecology shall deposit all such acreage fees in a special grass seed burning research account, hereby created, in the state treasury.

(2) The department shall allocate moneys annually from this account for the support of any approved study or studies as provided for in subsection (1) of this section. Whenever the department of ecology shall conclude that sufficient reasonably available alternates to open burning have been developed, and at such time as all costs of any studies have been paid, the grass seed burning research account shall be dissolved, and any money remaining therein shall revert to the general fund. The fee collected under subsection (1) of this section shall constitute the research portion of fees required under RCW 70.94.650 for open burning of grass grown for seed.

(3) Whenever on the basis of information available to it, the department after public hearings have been conducted wherein testimony will be received and considered from interested parties wishing to testify shall conclude that any procedure, program, technique, or device constitutes a practical alternate agricultural practice to the open burning of field or turf grasses grown for seed, the department shall, by order, certify approval of such alternate. Thereafter, in any case which any such approved alternate is reasonably available, the open burning of field and turf grasses grown for seed shall be disallowed and no permit shall issue therefor.

(4) Until approved alternates become available, the department or the authority may limit

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the number of acres on a pro rata basis among those affected for which permits to burn will be issued in order to effectively control emissions from this source.

(5) Permits issued for burning of field and turf grasses may be conditioned to minimize emissions insofar as practical, including denial of permission to burn during periods of adverse meteorological conditions.

(6) By November 1, 1996, and every two years thereafter until grass seed burning is prohibited, Washington State University may prepare a brief report assessing the potential of the university's research to result in economical and practical alternatives to grass seed burning.

[1998 c 245 § 130; 1995 c 261 § 1; 1991 sp.s. c 13 § 28; 1991 c 199 § 413; 1990 c 113 § 1; 1985 c 57 § 69; 1973 1st ex.s. c 193 § 7.]

Notes:

Effective dates -- Severability -- 1991 sp.s. c 13: See notes following RCW 18.08.240.

Finding -- 1991 c 199: See note following RCW 70.94.011.

Effective date -- 1985 c 57: See note following RCW 18.04.105.

Grass burning research advisory committee: Chapter 43.21E RCW.

Footnote 39

WAC 173-430-045

Alternatives to burning field and/or turf grasses grown for seed.

(1) When is open burning of field and turf grasses grown for seed prohibited?

The Washington Clean Air Act prohibits open burning of field and turf grasses grown for seed whenever ecology has concluded, through a process spelled out in the act, that any procedure, program, technique, or device constitutes a practical alternate agricultural practice to open burning, and that alternate is reasonably available.

(2) Has ecology certified practical alternatives to open burning of field or turf grasses grown for seed?

Yes. Ecology concludes that mechanical residue management constitutes a practical alternate agricultural practice to the open burning of field and/or turf grasses grown for seed. Mechanical residue management means removing, including arranging for removal of, the residue using nonthermal, mechanical techniques including, but not limited to: Tilling, swathing, chopping, baling, flailing, mowing, raking, and other substantially similar nonthermal, mechanical techniques. Ecology further concludes that mechanical residue management is practical throughout all phases of seed production including:

(a) When the field is planted (establishment);

(b) When the field is producing seed (harvest years);

(c) When the field is prepared for replanting (tear-out).

(3) Are the alternatives to open burning that have been certified by ecology reasonably available?

Ecology concludes that mechanical residue management is reasonably available throughout the state wherever baling can be used. Baling is the process of gathering the residue and moving it off the field. Typically, a machine known as a "baler" is used to gather and bundle residue that is already cut.

Based on this conclusion, the open burning of field and/or turf grasses grown for seed is prohibited except as described in subsection (4) of this section. This rule does not require the use of any particular practice or technique. A farmer may use any alternate practice that does not involve field burning.

(4) Under what circumstances may open burning of field or turf grasses grown for seed be allowed?

(a) Where a farmer establishes that mechanical residue management is not reasonably available on specific portions of a field under specific production conditions due to slope. In a request for a waiver, a farmer must certify in writing to ecology or local air authority the following:

(i) Baling is not reasonably available due to slope. A farmer must explain why baling is not reasonably available, referring to specific facts supporting this belief. Unacceptable facts include, but are not limited to, general statements about burning as a tool for the routine control of weed and disease, for seed propagation purposes, or as a less costly alternative to mechanical residue management. A farmer may use statements from three separate businesses providing baling services as part of their commercial operation to support the belief that baling is not reasonably available due to slope. In the statements, the businesses must certify that they are independent from the farmer and have no financial interest in the farmer's operation;

(ii) Current harvest practices have not diminished the ability to use mechanical residue management;

(iii) Field production is after the first harvest season and prior to the fourth harvest season;

(iv) The ground or portions of the field have not been burned three years in a row in the three years preceding the request for a waiver;

(v) The ground or portions of the field will remain, without replanting, in grass production at least through the next harvest season following burning;

(vi) Residue from any neighboring fields or portions of fields under the control of the farmer will be removed prior to burning and reasonable precautions will be taken to prevent fire from spreading to areas where burning is not allowed; and

(vii) Adjustments in field rotations and locations cannot be made at any time during the rotational cycle and could not have been made when planted to allow the use of mechanical residue management techniques.

(b) Where a farmer establishes that extreme conditions exist. Ecology or a local air authority, at their discretion, may grant a request for a waiver for extreme conditions. The farmer must certify in writing the following:

(i) Why mechanical residue management is not reasonably available, referring to specific facts supporting this belief. Unacceptable facts include, but are not limited to, general statements about burning as a tool for the routine control of weed and disease, for seed propagation purposes, or as a less costly alternative to mechanical residue management;

(ii) He/she did not cause or create the condition to purposefully avoid using mechanical residue management techniques;

(iii) Field production is after the first harvest season and prior to the fourth harvest season;

(iv) The ground or portions of the field have not been burned three years in a row in the three years preceding the request for a waiver;

(v) The field will remain, without replanting, in grass production at least through the next harvest season following burning;

(vi) Residue from any neighboring fields or portions of fields under the control of the farmer will be removed prior to burning and that reasonable precautions will be taken to prevent fire from spreading to areas where burning is not allowed; and

(vii) Adjustments in field rotations and locations cannot be made at any time during the rotational cycle, and could not have been made when planted to allow the use of mechanical residue management techniques.

(c) Where a farmer demonstrates to ecology or local air authority that his/her small agricultural operation is eligible for mitigation.

For 1998 only, ecology or a local air authority may allow burning on a small agricultural operation. A small agricultural operation owner has a gross 1997 revenue from all agricultural operations of less than $300,000. A farmer must show information of sufficient quantity and quality to ecology or a local air authority to establish gross revenue from agricultural operations. A small farm owner may burn current acreage up to 25% of 1997 acreage burned under a valid permit. Fields taken out of production after the 1997 harvest season and in 1998 cannot be counted in the determination of 1997 acreage burned for the purpose of eligible burn acreage.

(d) Where a request for a waiver is approved under (a), (b), and (c) of this subsection, the following additional limitations also apply:

Total burn acreage must not exceed 1/3 of a farmer's acreage in production on May 1, 1996. Permits issued pursuant to (a), (b), or (c) of this subsection are not eligible for the permit trading program identified in WAC 173-430-040.

(5) What is the process for a farmer to request a waiver for circumstances described in subsection (4) of this section?

(a) A farmer submits a request for a waiver.

Sixty days prior to the planned burn date, a farmer must submit in writing a request to ecology or a local air authority. In the request, the farmer must identify the circumstances and meet the specific requirements of subsection (4)(a), (b), and/or (c) of this section. Ecology or the local air authority may require the request to be submitted on a form or in a format provided by ecology or the local air authority.

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(b) Ecology or local air authority evaluates the request for a waiver.

Upon receiving a request for a waiver, ecology or the local air authority will determine if the necessary documents and information provided is complete enough to evaluate the request. If incomplete, ecology or local air authority will advise the farmer and suspend further evaluation until the request for a waiver is complete. The documents and information identified as necessary to complete the request must be delivered to ecology or the local air authority at least thirty days prior to burning. Once a request for a waiver is deemed complete, ecology or the local air authority will evaluate the request and decide whether the burning waiver is appropriate. As part of the evaluation, ecology or the local air may conduct an on-site inspection.

If ecology or local air authority denies a request for a waiver, the reasons will be provided to the farmer in writing. If approved, ecology or the local air authority will notify the farmer by convenient means. Ecology will also notify the appropriate delegated authority.

(c) The farmer applies for an agricultural burning permit.

If ecology or local air authority approves a request for a waiver, the farmer must complete a permit application and pay the fee as described in WAC 173-430-040. A delegated authority must receive written authorization from ecology that a waiver has been approved prior to processing a permit application.

[Statutory Authority: RCW 70.94.656. 98-12-016 (Order 97-45), § 173-430-045, filed 5/26/98, effective 6/26/98.]

Footnote 40, 41

Westlaw.

Safe Air for Everyone v. U.S. E.P.A.
C.A.9,2007.

United States Court of Appeals,Ninth Circuit.
SAFE AIR FOR EVERYONE; American Lung Association of Idaho; Noël Sturgeon, Petitioners,
v.
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY; Stephen L. Johnson, Administrator of the United States Environmental Protection Agency; Elin D. Miller,[FN*] Regional Administrator of the United States Environmental Protection Agency, Region X, Respondents,

FN* Elin D. Miller is substituted for her predecessor as Regional Administrator of the United States Environmental Protection Agency. Fed. R.App. P. 43(c)(2).

State of Idaho, Intervenor.
No. 05-75269.

Argued and Submitted Nov. 15, 2006.
Filed Jan. 30, 2007.

Background: Environmental group petitioned for review of Environmental Protection Agency (EPA) order that approved amendment to state implementation plan (SIP) to permit open burning in agricultural fields.

Holding: The Court of Appeals, Berzon, Circuit Judge, held that the plain meaning of the SIP in banning open burning in agricultural fields was controlling on EPA, despite legislative history of Idaho provisions related to agricultural burning and smoke management, various reports and plans prepared by the state, and various agreements signed by it.

Petition granted; remanded.
West Headnotes

[1] Environmental Law 149E 683

149E Environmental Law
149EXIII Judicial Review or Intervention
149Ek677 Scope of Inquiry on Review of Administrative Decision
149Ek683 k. Air Pollution. Most Cited Cases
The Court of Appeals reviews the Environmental Protection Agency's (EPA) decision to approve state implementation plan (SIP) amendments under the "arbitrary, capricious, or otherwise not in accordance with law" standard of the Administrative Procedure Act (APA). 5 U.S.C.A. § 706(2)(A); Clean Air Act, § 110, 42 U.S.C.A. § 7410.

[2] Environmental Law 149E 258

149E Environmental Law
149EVI Air Pollution
149Ek257 Implementation of Federal Standards
149Ek258 k. In General. Most Cited Cases
In interpreting a state implementation plan (SIP), courts begin with a look toward the plain meaning of the plan and stop there if the language is clear. Clean Air Act, § 110, 42 U.S.C.A. § 7410.

[3] Environmental Law 149E 272

149E Environmental Law
149EVI Air Pollution
149Ek266 Particular Sources of Pollution
149Ek272 k. Waste Disposal Facilities; Incineration. Most Cited Cases
Plain meaning of state implementation plan (SIP) that banned open burning in agricultural fields was controlling on Environmental Protection Agency (EPA) at time of decision to approve amendment to allow field burning, despite legislative history of Idaho provisions related to agricultural burning and smoke management, various reports and plans prepared by the state, and various agreements signed

by it; published notices that accompanied the consideration or adoption of previous SIPs established no intent concerning field burning, EPA's purported intent to allow field burning was demonstrated, if at all, only through informal materials such as letters and presentations and its silent acquiescence when approving certain antipollution strategies submitted by Idaho, and although Idaho lawmakers and regulators made their intentions toward field burning known through more formal actions, none of these measures were referenced in the published materials that accompanied adoption of the earlier SIPs. Clean Air Act, § 110, 42 U.S.C.A. § 7410.

[4] Environmental Law 149E 258

149E Environmental Law
149EVI Air Pollution
149Ek257 Implementation of Federal Standards
149Ek258 k. In General. Most Cited Cases

State implementation plan (SIP) became federal law, not state law, once the Environmental Protection Agency (EPA) approved it, and it could not be changed unless and until the EPA approved any change. Clean Air Act, § 110, 42 U.S.C.A. § 7410.

[5] Environmental Law 149E 258

149E Environmental Law
149EVI Air Pollution
149Ek257 Implementation of Federal Standards
149Ek258 k. In General. Most Cited Cases

A state's interpretation of the regulations incorporated into state implementation plan (SIP), even if binding as a matter of state law, is not directly dispositive of the meaning of the SIP since it becomes federal law once approved by the Environmental Protection Agency (EPA). Clean Air Act, § 110, 42 U.S.C.A. § 7410.

[6] Administrative Law and Procedure 15A 412.1

15A Administrative Law and Procedure
15AIV Powers and Proceedings of Administrative Agencies, Officers and Agents
15AIV(C) Rules and Regulations
15Ak412 Construction
15Ak412.1 k. In General. Most Cited Cases

As a general interpretative principle, the plain meaning of a regulation governs.

[7] Administrative Law and Procedure 15A 413

15A Administrative Law and Procedure
15AIV Powers and Proceedings of Administrative Agencies, Officers and Agents
15AIV(C) Rules and Regulations
15Ak412 Construction
15Ak413 k. Administrative Construction. Most Cited Cases

Other interpretative materials, such as the agency's own interpretation of the regulation, should not be considered when the regulation has a plain meaning.

[8] Administrative Law and Procedure 15A 412.1

15A Administrative Law and Procedure
15AIV Powers and Proceedings of Administrative Agencies, Officers and Agents
15AIV(C) Rules and Regulations
15Ak412 Construction
15Ak412.1 k. In General. Most Cited Cases

The plain language of a regulation will not control if clearly expressed administrative intent is to the contrary or if such plain meaning would lead to absurd results.

[9] Administrative Law and Procedure 15A 409

15A Administrative Law and Procedure
15AIV Powers and Proceedings of Administrative Agencies, Officers and Agents
15AIV(C) Rules and Regulations
15Ak407 Publication or Notice After Adoption
15Ak409 k. Sufficiency. Most Cited Cases

Although clearly expressed intent of regulators can overcome the plain meaning of a regulation, the notice provisions of the Administrative Procedure Act (APA) require that some indication of the regulatory intent that overcomes plain language must be referenced in the published notices that accompanied the rulemaking process; otherwise, interested parties would not have the meaningful opportunity to comment on proposed regulations that the APA contemplates because they would have had no way of knowing what was actually proposed. 5 U.S.C.A. § § 552(a)(1), 553(b, c).

[10] Environmental Law 149E 258

149E Environmental Law
149EVI Air Pollution
149Ek257 Implementation of Federal Standards
149Ek258 k. In General. Most Cited Cases
State implementation plans (SIPs) are interpreted based on their plain meaning when such a meaning is apparent, not absurd, and not contradicted by the manifest intent of the Environmental Protection Agency (EPA), as expressed in the promulgating documents available to the public. Clean Air Act, § 110, 42 U.S.C.A. § 7410.

[11] Environmental Law 149E 683

149E Environmental Law
149EXIII Judicial Review or Intervention
149Ek677 Scope of Inquiry on Review of Administrative Decision
149Ek683 k. Air Pollution. Most Cited Cases
Court of Appeals on review of Environmental Protection Agency (EPA) decision to approve amendment to state implementation plan (SIP) to permit open burning in agricultural fields could not review whether approval would weaken prior SIP and violate Clean Air Act (CAA), where the EPA based the action under review on its erroneous belief that the preexisting SIP did not ban agricultural burning. Clean Air Act, § 110(*l*), 42 U.S.C.A. § 7410(*l*).

[12] Environmental Law 149E 678

149E Environmental Law
149EXIII Judicial Review or Intervention
149Ek677 Scope of Inquiry on Review of Administrative Decision
149Ek678 k. In General. Most Cited Cases
The Court of Appeals must review the Environmental Protection Agency's (EPA) actions based on the grounds upon which the record discloses that its action was based; this principle means that the Court can only uphold EPA's action on the basis articulated by the agency itself, but it also means the Court must remand to the agency for additional investigation or explanation when the agency's analysis is incomplete after its flawed basis is removed.

David S. Baron, Earthjustice, Washington, D.C., for the petitioners.
Paul Cirino, Environmental Defense Section, U.S. Department of Justice, Washington, D.C., for the respondents.
Lisa J. Kronberg, Deputy Attorney General, Idaho Department of Environmental Quality, Boise, ID, for the intervenor.

On Petition for Review of an Order of the Environmental Protection Agency.

Before: ARTHUR L. ALARCÓN, PAMELA ANN RYMER, and MARSHA S. BERZON, Circuit Judges.
BERZON, Circuit Judge:
The Clean Air Act ("CAA" or "the Act"), 42 U.S.C. § § 7401-7671q, authorizes the creation of air quality standards for a number***1099** of pollutants, including particulate matter produced as a byproduct of burning. To implement these standards, the Act establishes a system of State Implementation Plans ("SIPs"), whereby states submit, subject to the United States Environmental Protection Agency's ("EPA") review and approval, proposed methods for maintaining air quality. Once approved by EPA these plans "[h]av [e] 'the force and effect of federal law.' " *Trs. for Alaska v. Fink,* 17 F.3d 1209, 1210 n. 3 (9th Cir.1994) (quoting *Union Elec. Co. v. EPA,* 515 F.2d 206, 211 (8th Cir.1975), *aff'd,* 427 U.S. 246, 96 S.Ct. 2518, 49 L.Ed.2d 474 (1976)).

In this case, we are presented with a preexisting SIP containing language that prohibits open burning generally and contains no exception allowing farmers to burn the residue left in their fields after harvesting their crops. Petitioner, Safe Air for Everyone ("SAFE"), challenges EPA's decision to approve an amendment to that SIP authorizing such burning. SAFE argues that certain CAA provisions which prohibit amending SIPs so that they interfere with meeting air quality standards forbid EPA's action, at least absent further analysis of field burning's impact on Idaho's air quality; EPA maintains that its approval of the amendment does not contravene any CAA provisions.

We hold that as it presently stands, EPA's approval is legally unsustainable. EPA grounded its approval of this amendment on the premise that the preexisting Idaho SIP did not ban field burning, so that the amendment only clarified what was already the case. This view of the preexisting SIP is one with which we cannot agree. Because our review of an administrative agency's decision begins and ends with the reasoning that the agency relied upon in making that decision, *see* SEC v. Chenery Corp., 318 U.S. 80, 87, 63 S.Ct. 454, 87 L.Ed. 626 (1943); *Ctr. for Biological Diversity v. Kempthorne*, 466 F.3d 1098, 1103-04 (9th Cir.2006), we grant the petition for review and remand for EPA's reconsideration of SAFE's objections under a correct understanding of the preexisting Idaho SIP.

The current treatment of field burning in the Idaho SIP came about as the result of a thirty-five-year regulatory evolution. After reviewing the factual administrative record, we first explain the regulatory process established by the CAA and then trace the development of the current SIP provisions related to field burning in Idaho. We then closely examine how the preexisting Idaho SIP treated field burning prior to 2005, when EPA approved an amendment to the SIP that explicitly authorized the practice. Finally, we explain why our interpretation of the SIP as it existed at the time of the 2005 amendment resolves this case and requires that we grant the petition for review and remand for further proceedings.

I.

A.

Open burning of agricultural fields is a common practice in Idaho, particularly among bluegrass farmers in the northern portion of the state. Those farmers maintain that burning the grass residue improves the productivity of their fields and has certain environmental benefits, views with which the Idaho legislature has expressed agreement. *See* IDAHO CODE ANN. § 22-4801 (2006) ("The legislature finds that the current knowledge and technology support the practice of burning crop residue to control disease, weeds, pests, and to enhance crop rotations.... The legislature finds that due to the climate, soils, and crop rotations unique to north Idaho counties, crop residue burning ***1100** is a prevalent agricultural practice and that there is an environmental benefit to protecting water quality from the growing of certain crops in environmentally sensitive areas."); *Safe Air for Everyone v. Meyer*, 373 F.3d 1035, 1043-47 (9th Cir.2004) (recognizing that "the Growers realize farming benefits from reusing grass residue in the process of open burning").

Despite these attested benefits, the administrative record establishes that such field burning is also a source of particulate matter that contributes to air pollution. SAFE submitted evidence indicating that the burning of agricultural fields in Idaho creates significant air quality problems. That evidence documents: (1) that clouds of smoke cover large portions of rural Idaho and surrounding states during burning season; (2) that area doctors believe that this smoke has had particularly severe health consequences for individuals with respiratory ailments; (3) that some individuals with such ailments have fled their homes during burning season to avoid the smoke; and (4) that a coroner's report linked at least one fatality to field burning. EPA has recognized that substantial pollution and health problems are created by the practice. *See* EPA, AGRICULTURAL BURNING: EPA MAKES NORTHWEST FIELD BURNING A TOP PRIORITY 2 (2000) ("[F]ield burning can cause serious environmental and health effects.... Scientific studies-along with thousands of complaints-indicate that smoke is unhealthy.... Exposure to fine particles, either alone or combined with other air pollutants, has been linked to difficulty in breathing, aggravated asthma, increased emergency room visits and hospital admissions, and, in some cases, premature deaths.").

B.

Under the CAA, EPA has the authority to issue national air quality standards setting the maximum allowable concentration of a given pollutant. 42 U.S.C. § 7409(a).[FN1] Using this authority, EPA has issued limits for particulate matter. 40 C.F.R. § § 50.6, 50.7.

FN1. All citations to the United States Code refer to the 2000 edition, unless noted otherwise.

To assure that such air quality standards are met, the CAA establishes a system heavily dependant upon state participation. *See* 42 U.S.C. § 7407(a) ("Each State shall have the primary responsibility for assuring air quality within the entire geographic area comprising such State ...."); *see generally* Train v.

Natural Res. Def. Council, 421 U.S. 60, 64-70, 95 S.Ct. 1470, 43 L.Ed.2d 731 (1975). As a central aspect of this system, states promulgate SIPs that "provide[ ] for implementation, maintenance, and enforcement" of the CAA's air quality standards within the state. 42 U.S.C. § 7410(a)(1). Although states retain significant flexibility in establishing the details of these plans, the CAA, and EPA regulations, outline many required features. *Id.* § 7410(a)(2)-(6); 40 C.F.R. pt. 51. Among them is the mandate that state plans provide for regular revisions to reflect evolving air quality conditions and standards. 42 U.S.C. § 7410(a)(2)(H). These revisions need not be wholesale recastings of SIPs; instead, the CAA allows the states to submit, and EPA to review, piecemeal amendments dealing with discrete SIP provisions, leaving most of the plan untouched. *See* *Hall v. U.S. EPA,* 273 F.3d 1146, 1159-60 (9th Cir.2001).

Before a SIP becomes effective, EPA must determine that it meets the CAA's requirements. 42 U.S.C. § 7410(k)(3). EPA must also approve plan amendments and "shall not approve a revision of a plan ***1101** if the revision would interfere with any applicable requirement concerning attainment and reasonable further progress ... or any other applicable requirement of [the CAA]." *Id.* § 7410(*l*).

C.

Idaho, like every other state, was first required to submit a SIP to EPA within thirteen months of the Act's 1970 passage. *See* *Train,* 421 U.S. at 65, 95 S.Ct. 1470. The original Idaho SIP was approved by EPA in May 1972. Approval and Promulgation of Implementation Plans, 37 Fed.Reg. 10,842, 10,861 (May 31, 1972). A provision on open burning was among the Idaho state regulations incorporated into that SIP: "No person shall allow, suffer, cause or permit any open burning operation which does not fall into at least one of the categories of Section 3." Field burning was included in the types of burning allowed by Section 3, but with significant limitations:

The open burning of plant life grown on the premises in the course of any agricultural, forestry, or land clearing operation may be permitted when it can be shown that such burning is necessary and that no fire or traffic hazard will occur. Convenience of disposal is not of itself a valid necessity for burning.

1. It shall be the responsibility of any person conducting such burning to make every reasonable effort to burn only when weather conditions are conducive to a good smoke dissipation and only when an economical and reasonable alternate method of disposal is not available.
2. When such alternate method is made available, it shall be put into use within a reasonable time.
3. Any person conducting an agricultural, forestry, or land clearing burning operation similar to an operation carried out by a governmental agency shall follow the rules and procedures of the agency with regard to minimizing air pollution.
4. When such burning creates air pollution or a public nuisance, additional restrictions may be imposed to minimize the effect upon the environment.

Section 3 also allowed eight other categories of open burning: food preparation and recreational fires; weed control fires; fires for firefighting training; industrial flares; residential solid waste disposal fires in rural areas; disposal site fires; junked motor vehicle fires; and orchard fires.[FN2]

> FN2. In 1982, EPA approved amendments to Idaho's SIP that incorporated Idaho's recodified air pollution regulations. *See* Approval and Promulgation of Implementation Plans, 47 Fed.Reg. 32,530, 32,531 (July 28, 1982). Those recodified regulations maintained the identical substantive language of the open burning regulations incorporated into the 1972 SIP, including the limited permission for field burning and permission for eight other categories of fires.

In 1993, EPA approved amendments to the Idaho SIP that substantially changed the open burning provisions. *See* Approval and Promulgation of Implementation Plans, 58 Fed.Reg. 39,445, 39,446 (July 23, 1993) (noting that in Idaho's submission, "the existing Rules for Control of Open Burning and Categories of Allowable Burning were revised extensively" and that "[t]hese new and revised provisions for open burning comply with EPA's general requirements for SIP control strategies" (citations omitted)). These SIP provisions, incorporating section 01.01151.04(a) of Idaho air pollution regulations in effect on December 31, 1991, contained a general prohibition on open air burning:

***1102** *No person* shall allow, suffer, cause or permit any open burning operation *unless it is a category of open burning set forth in Section 01.01153* and does not include any of the following materials:

i. Garbage;
ii. Dead animals or parts thereof;

iii. Junked motor vehicles or any materials resulting from a salvage operation;
iv. Tires or other rubber materials or products;
v. Plastics;
vi. Asphalt or composition roofing or any other asphaltic material or product;
vii. Tar, tar paper, waste or heavy petroleum products, or paints;
viii. Lumber or timbers treated with preservatives;
ix. Trade wastes except as allowed in Section 01.01153;
x. Insulated wire;
xi. Pathogenic wastes; or
xii. Hazardous wastes.

(Emphases added). The revised regulation incorporated into the SIP listed categories of allowable burning that no longer included field burning. Instead, that list retained seven of the nine categories of permitted fires included in the 1972 SIP regulations-food preparation and recreational fires, weed control fires, fires for firefighting training, industrial flares, residential solid waste disposal fires in rural areas, disposal site fires, and orchard fires; omitted two categories of permitted fires from the 1972 list-junked motor vehicle fires and agricultural fires; and added three new categories of permitted fires-prescribed burning, dangerous material fires, and infectious waste burning.

In 2003, EPA approved another set of Idaho SIP amendments. Those amendments incorporated updated versions of Idaho regulations. This round of revisions, however, updated the open burning regulations only to reflect a recodification. *See* Approval and Promulgation of Implementation Plans, 68 Fed.Reg. 2217, 2218 (Jan. 16, 2003) ("[S]ince EPA last approved the Idaho SIP in 1993, Idaho has revised nearly every section of its air quality rules to some degree. Many of these amendments have been editorial and are renumberings, changes to citations for cross-referenced rules or statutes, changes in terminology, or grammatical corrections."). The substantive language of the incorporated provisions on open burning was identical to the language approved in the 1993 SIP.

That 2005 rulemaking approved amendments to the SIP that added field burning as an eleventh category of allowed burning. The relevant provision, incorporating section 58.01.01.617 of the Idaho Administrative Code in effect on March 21, 2003, states: "The open burning of crop residue on fields where the crops were grown is an allowable form of open burning if conducted in accordance with the Smoke Management and Crop Residue Disposal Act and the rules promulgated pursuant thereto." (Citations omitted). Although Idaho first enacted statutes dealing with field burning in 1985 and amended them in 1986, 1999, and 2003, *see* Act of March 12, 1985, ch. 248, 1985 Idaho Sess. Laws 580 (codified as amended at IDAHO CODE A NN. § § 22-4801 to -4804 (2006)), the SIP amendment approved by EPA in 2005 was the first explicit reference to those statutes in the SIP, *see* Approval and Promulgation of Air Quality Implementation Plan ("Final SIP"), 70 Fed.Reg. 39,658, 39,659 (July 11, 2005) (noting that the field burning legislation "was not [previously] specifically submitted to EPA as a SIP revision").FN3

FN3. Although Idaho's field burning statute was referenced in a 1993 report submitted to EPA detailing Idaho's strategy for bringing one portion of the state into attainment with particulate matter pollution standards, that strategy did not purport to alter the provisions of Idaho's statewide SIP, which contains the language banning field burning.

***1103** [1] SAFE submitted comments to EPA during the 2005 rulemaking process and now challenges EPA's approval of the amendment permitting field burning in this court. We have jurisdiction over SAFE's challenge to this 2005 rulemaking under 42 U.S.C. § 7607(b)(1). This court reviews EPA's decision to approve SIP amendments under the "arbitrary, capricious, or otherwise not in accordance with law" standard of the Administrative Procedure Act ("APA"). *Hall,* 273 F.3d at 1155; *see* 5 U.S.C. § 706(2)(A).

II.

A.

As detailed above, Idaho's 2003 SIP mandated that "[*n*]*o person* shall allow, suffer, cause or permit any open burning operation *unless it is a category of open burning set forth* " in ten specified sections that "establish categories of open burning that are allowed when done according to the prescribed conditions." (Emphases added). Those ten sections cover: "Recreational and Warming Fires"; "Weed Control Fires" for "abatement along fence lines, canal banks, and ditch banks"; "Training Fires" for firefighting training; "Industrial Flares"; "Residential Solid

Waste Disposal Fires"; "Landfill Disposal Site Fires"; "Orchard Fires"; "Prescribed Burning" for fire management purposes; "Dangerous Material Fires"; and "Infectious Waste Burning." Field burning does not fit into any of these categories. EPA so acknowledged during the 2005 rulemaking proceedings. *See* Final SIP, 70 Fed.Reg. at 39,659 ("EPA recognizes the rule language ... does not, on its face, appear to identify crop residue as a category of allowed burning"); *id.* at 39,660 n. 1 (noting EPA's agreement with SAFE that field burning does not come within the "prescribed burning" exception). Nor is it debatable that field burning is an "open burning operation" covered by the SIP's expansive mandatory terms.

In short, given the SIP's broad prohibition and the absence of any pertinent exception, the plain meaning of the SIP, in the clearest of terms, prohibits field burning. *Cf. Craft v. Nat'l Park Serv.,* 34 F.3d 918, 922 (9th Cir.1994) ("[T]he regulation by its terms clearly prohibits appellants' activities. With two exceptions, the regulation prohibits 'dredg[ing] or otherwise alter[ing] the seabed in any way.' ... There can be no question but that this language prohibits the excavation activities in which appellants were engaged." (second and third alterations in original) (quoting 15 C.F.R. § 935.7(a)(2)(iii) (1994))).

[2] In interpreting a SIP, we begin with a look toward the plain meaning of the plan and stop there if the language is clear. This much is clear from *Bayview Hunters Point Community Advocates v. Metropolitan Transportation Commission (BHPCA*), 366 F.3d 692 (9th Cir.2004), a leading case in this court in which the meaning of a SIP was at stake. In considering the SIP for the San Francisco Bay Area related to transit ridership, *BHPCA* began by observing that "[w]e start with the plain language of [the SIP]. 'A regulation should be construed to give effect to the natural and plain meaning of its words,' " and then noted that "[t]he expected ridership increase was never described as anything more than a 'target.' " *Id.* at 698 (quoting *Crown Pac. v. Occupational Safety & Health Review Comm'n,* 197 F.3d 1036, 1038 (9th Cir.1999)). Because the plan did "not, on its ***1104** face, require a ridership increase of 15%," we held "[t]hat by its plain language [the SIP] does not establish a mandatory requirement to increase transit ridership by a specified percentage weighs heavily against the conclusion that such an obligation can be imposed based upon [the SIP]." *Id.* (internal quotation mark omitted); *see also Idaho Conservation League v. Boer,* 362 F.Supp.2d 1211, 1216 (D.Idaho 2004) (refusing to defer to a state environmental agency's interpretation that "cannot be reconciled with the plain language of the regulations" included in the SIP); *United States v. Gen. Dynamics Corp.,* 755 F.Supp. 720, 723 (N.D.Tex.1991) ("The [Texas state agency's] interpretation of the Texas SIP to allow plantwide averaging is unreasonable, because it contradicts specific language of the SIP...."); *Citizens for a Better Env't v. Deukmejian,* 731 F.Supp. 1448, 1454-55 (N.D.Cal.1990) (refusing to credit evidence that the provisions of a SIP did not make a binding commitment when the SIP included "unequivocal[ ]" phrasing). Applying that same methodology here, we would quite readily conclude that the pre-2005 Idaho SIP did not permit field burning.

B.

[3] EPA, however, assumed during the 2005 rulemaking proceedings that this clear-as-day prohibition of field burning does not resolve the meaning of the SIP as it existed as of the 2005 proceedings. Instead, the agency considered Idaho's "intent" in drafting the SIP, conducting "an examination of the State's overall approach to field burning" and "consider[ing] such things as the legislative history of Idaho's provisions related to agricultural burning and smoke management," various reports and plans prepared by the State, and various agreements signed by the State. Final SIP, 70 Fed.Reg. at 39,659. EPA also noted that its own past actions "indicate[ ] that EPA understood agricultural burning to be allowed in Idaho and that the SIP does not prohibit it." FN4 *Id.* at 39,660. EPA did not, however, justify or explain this approach to interpreting a SIP, and the approach cannot be reconciled with the role of SIPs in the federal regulatory scheme.FN5

FN4. None of these past actions, however, purported to interpret the relevant SIP provisions. Thus, there is no agency interpretation to which courts must afford deference on the determinative question in this case.

FN5. Nor is there any indication that EPA has previously taken a position on the proper way to interpret a SIP. Given this vacuum, the case also does not implicate agency deference considerations on this key conceptual issue.

Interpreting a similar state implementation plan scheme under the Clean Water Act,[FN6] the Supreme Court held that the Clean Water Act "effectively incorporates into federal law those state-law standards the Agency reasonably determines to be 'applicable.' In such a situation, then, state water quality standards-promulgated by the States with substantial guidance from the EPA and approved by the Agency-are part of the federal law of water pollution control." ***1105***Arkansas v. Oklahoma,* 503 U.S. 91, 110, 112 S.Ct. 1046, 117 L.Ed.2d 239 (1992) (footnote omitted). Similarly, a SIP, once approved by EPA, has "the force and effect of federal law." *Trs. for Alaska,* 17 F.3d at 1210 n. 3 (quoting *Union Elec.,* 515 F.2d at 211) (internal quotation marks omitted). In accord with this general proposition, a state may not unilaterally alter the legal commitments of its SIP once EPA approves the plan. *See* 42 U.S.C. § 7416 ("[I]f an emission standard or limitation is in effect under an applicable implementation plan ... such State or political subdivision may not adopt or enforce any emission standard or limitation which is less stringent than the standard or limitation under such plan ...."); *Gen. Motors Corp. v. United States,* 496 U.S. 530, 540, 110 S.Ct. 2528, 110 L.Ed.2d 480 (1990) ("There can be little or no doubt that the existing SIP remains the 'applicable implementation plan' even after the State has submitted a proposed revision.").

FN6. Under the Clean Water Act,
"water quality standards" are, in general, promulgated by the States and establish the desired condition of a waterway.... [T]he Act requires, *inter alia,* that state authorities periodically review water quality standards and secure the EPA's approval of any revisions in the standards. If the EPA recommends changes to the standards and the State fails to comply with that recommendation, the Act authorizes the EPA to promulgate water quality standards for the State.
Arkansas v. Oklahoma, 503 U.S. 91, 101, 112 S.Ct. 1046, 117 L.Ed.2d 239 (1992) (citing 33 U.S.C. § 1313).

[4][5] Thus, the SIP became *federal* law, not *state* law, once EPA approved it, and could not be changed unless and until EPA approved any change. Consequently, the state's interpretation of the regulations incorporated into the SIP, even if binding as a matter of state law, is not directly dispositive of the meaning of the SIP.

[6][7] Accordingly, we look to the standards governing the interpretation of federal regulations. As a general interpretative principle, "the plain meaning of a regulation governs." *Wards Cove Packing Corp. v. Nat'l Marine Fisheries Serv.,* 307 F.3d 1214, 1219 (9th Cir.2002). Other interpretative materials, such as the agency's own interpretation of the regulation, should not be considered when the regulation has a plain meaning. *See id.* (citing *Christensen v. Harris County,* 529 U.S. 576, 588, 120 S.Ct. 1655, 146 L.Ed.2d 621 (2000)); *see also Roberto v. Dep't of the Navy,* 440 F.3d 1341, 1350 (Fed.Cir.2006) ("If the regulatory language is clear and unambiguous, the inquiry ends with the plain meaning.").

[8][9] The plain language of a regulation, however, will not control if "clearly expressed [administrative] intent is to the contrary or [if] such plain meaning would lead to absurd results." *Dyer v. United States,* 832 F.2d 1062, 1066 (9th Cir.1987).[FN7] Although "clearly expressed ... intent" of regulators therefore could overcome the plain meaning of a regulation, *see id.,* we have never considered how definitely and in what form such intent must be expressed. Doing so now, we conclude that the notice requirements of the APA, 5 U.S.C. § § 552(a)(1), 553(b),[FN8] requires that ***1106** some indication of the regulatory intent that overcomes plain language must be referenced in the published notices that accompanied the rulemaking process. Otherwise, interested parties would not have the meaningful opportunity to comment on proposed regulations that the APA contemplates, *id.* § 553(c),[FN9] because they would have had no way of knowing what was actually proposed. For, as the D.C. Circuit has observed:

FN7. *Dyer* uses the term "legislative intent," but then inquires into the intent of the promulgating executive agency, not that of Congress. 832 F.2d at 1066. That focus makes sense, so, for clarity, we use "administrative intent."

FN8. As pertinent here, these requirements provide:
Each agency shall separately state and currently publish in the Federal Register for the guidance of the public

...

(D) substantive rules of general applicability adopted as authorized by law, and statements of general policy or

interpretations of general applicability formulated and adopted by the agency; and
(E) each amendment, revision, or repeal of the foregoing.
Except to the extent that a person has actual and timely notice of the terms thereof, a person may not in any manner be required to resort to, or be adversely affected by, a matter required to be published in the Federal Register and not so published. For the purpose of this paragraph, matter reasonably available to the class of persons affected thereby is deemed published in the Federal Register when incorporated by reference therein with the approval of the Director of the Federal Register.
5 U.S.C. § 552(a)(1).
General notice of proposed rule making shall be published in the Federal Register, unless persons subject thereto are named and either personally served or otherwise have actual notice thereof in accordance with law. The notice shall include-
(1) a statement of the time, place, and nature of public rule making proceedings;
(2) reference to the legal authority under which the rule is proposed; and
(3) either the terms or substance of the proposed rule or a description of the subjects and issues involved....
Id. § 553(b).

FN9. That provision mandates:
After notice required by this section, the agency shall give interested persons an opportunity to participate in the rule making through submission of written data, views, or arguments with or without opportunity for oral presentation. After consideration of the relevant matter presented, the agency shall incorporate in the rules adopted a concise general statement of their basis and purpose. When rules are required by statute to be made on the record after opportunity for an agency hearing, sections 556 and 557 of this title apply instead of this subsection.
5 U.S.C. § 553(c). This opportunity for comment applies to SIP revisions. *Ober v. U.S. EPA*, 84 F.3d 304, 312 (9th Cir.1996).

Courts' reliance on the "plain meaning" rule in this setting [of interpreting administrative regulations] is not a product of some fetishistic attraction to legal "formalism." In order to infuse a measure of public accountability into administrative practices, the APA mandates that agencies provide interested parties notice and an opportunity for comment before promulgating rules of general applicability. This right to participate in the rulemaking process can be meaningfully exercised, however, only if the public can understand proposed rules as meaning what they appear to say. Moreover, if permitted to adopt unforeseen interpretations, agencies could constructively amend their regulations while evading their duty to engage in notice and comment procedures. As applied to agency regulations, then, the plain meaning doctrine is an interpretive norm essential to perfecting the scheme of administrative governance established by the APA.
....
... To protect the integrity of [the APA's required] procedures, we cannot permit an agency to rely on its unexpressed intentions to trump the ordinary import of its regulatory language.

Exportal Ltda. v. United States, 902 F.2d 45, 50-51 (D.C.Cir.1990) (citations and emphases omitted).

Such a mode of interpretation is particularly sensible under the CAA, which requires that judicial challenges be filed within sixty days of a SIP's approval. 42 U.S.C. § 7607(b)(1). If an agency can promulgate a regulation with plain language that dictates one meaning but later interpret it according to an intent indicated neither in the regulatory language nor in the promulgation documents, parties may depend on the plain meaning of the regulation in deciding not to launch a challenge within the prescribed time limit. If, later, the agency relies on an undisclosed intended meaning, interested parties might be foreclosed from challenging the regulation, contrary to the statutory permission to launch such challenges.[FN10]

FN10. When review is sought "based solely on grounds arising after such sixtieth day," the CAA also allows for the challenge to be "filed within sixty days after such grounds arise." 42 U.S.C. § 7607(b). We take no position on whether EPA's reliance on its previously undisclosed intent in approving a SIP could constitute "grounds arising after such sixtieth day."

***1107** Here, following the plain language prohibiting field burning in Idaho's 2003 SIP does not produce "absurd results" or contravene the pertinent administrative history. *See Dyer*, 832 F.2d at 1066. As the administrative record of air quality and health problems created by field burning demonstrates, it is far from patently inconceivable that the federal air pollution law covering Idaho would ban a significant source of the state's particulate pollution. Indeed, one of Idaho's neighbors has enacted a broad ban, except in limited circumstances, on the open burning on farms that produce grass seed. *See* WASH. ADMIN. CODE 173-430-045 (2006). So the interpretation of the 2003 SIP mandated by its plain language is not absurd at all, much less sufficiently absurd to justify departure from a plain words interpretation. *See* *Crooks v. Harrelson,* 282 U.S. 55, 60, 51 S.Ct. 49, 75 L.Ed. 156 (1930) ("[T]o justify a departure from the letter of the law upon that ground, the absurdity must be so gross as to shock the general moral or common sense.").

Likewise, no administrative intent expressed in an appropriate way contradicts the plain meaning of the SIP: None of the published notices that accompanied the consideration or adoption of Idaho's previous SIPs established any intent concerning field burning. Instead, EPA's purported intent to allow field burning in Idaho is demonstrated, if at all, only through informal materials such as letters and presentations and its silent acquiescence when approving certain antipollution strategies submitted by Idaho.[FN11] Although Idaho lawmakers and regulators made their intentions toward field burning known through more formal actions, such as enacting legislation and regulations allowing field burning, none of these measures were referenced in the published materials that accompanied adoption of the earlier SIPs.

FN11. EPA cites its approval of an area-specific plan that referenced Idaho's field burning statute, *see supra* note 3, to demonstrate that it understood prior to 2005 that field burning was not banned in Idaho. Final SIP, 70 Fed.Reg. at 39,660. EPA, however, did not refer to the provisions on field burning when explaining its decision to approve that strategy. *See* Approval and Promulgation of Sandpoint, Idaho, Air Quality Implementation Plan, 67 Fed.Reg. 43,006 (June 26, 2002).

C.

For the first time on appeal, EPA proffers two additional reasons we should not rely on the plain meaning of the 2003 and earlier SIPs. We owe no deference to these *post hoc* litigating positions, adopted by counsel for EPA. *See* *Bowen v. Georgetown Univ. Hosp.,* 488 U.S. 204, 212, 109 S.Ct. 468, 102 L.Ed.2d 493 (1988) ("[W]e have declined to give deference to an agency counsel's interpretation of a statute where the agency itself has articulated no position on the question...."). We do not find EPA's arguments persuasive.

EPA argues, first, that giving effect to the plain meaning of a SIP contrary to the true intent of state policymakers would violate case law prohibiting EPA from enacting more stringent SIP provisions than those proposed by the state. *See* *Riverside Cement Co. v. Thomas,* 843 F.2d 1246, 1247-48 (9th Cir.1988) (holding that EPA's approval of a SIP after removing a proviso submitted by the state was arbitrary and capricious); ***1108***Bethlehem Steel Corp. v. Gorsuch,* 742 F.2d 1028, 1035-36 (7th Cir.1984) (holding the CAA's partial approval provision did not allow EPA to make a SIP stricter); *cf.* *Train,* 421 U.S. at 79, 95 S.Ct. 1470 ("[S]o long as the ultimate effect of a State's choice of emission limitations is compliance with the national standards for ambient air, the State is at liberty to adopt whatever mix of emission limitations it deems best suited to its particular situation."); *Hall,* 273 F.3d at 1153 ("By virtue of the States' roles in devising a strategy and adopting an implementation plan, ... '[i]t is to the States that the Act assigns initial and primary responsibility for deciding what emissions reductions will be required from which sources.' " (alteration in original) (quoting *Whitman v. Am. Trucking Ass'ns, Inc.,* 531 U.S. 457, 470, 121 S.Ct. 903, 149 L.Ed.2d 1 (2001))). Those decisions, however, interpreted the CAA's provisions concerning the authority of EPA to approve or deny SIPs. They are not relevant to the task presently before the court-interpreting SIP language that *was* originally proposed by the state. As to that endeavor, requiring states to express their intent understandably when submitting proposed SIPs in no way detracts from states' critical role in devising the strategy to be used in achieving the requisite air quality standards.

Second, EPA argues that crediting the SIP's plain meaning would contradict case law prohibiting EPA from approving SIPs based on "an elusive and illusory measure." *Riverside Cement,* 843 F.2d at 1248. In *Riverside Cement,* EPA approved a SIP that contained a provision that explicitly stated its operation was "contingent upon the results of ongoing factfinding." *Id.* at 1247 (internal quotation mark omitted). Because that provision, by its own terms, might never have become effective, the court held EPA could not rely on that provision in determining whether the SIP met the CAA's pollution reduction requirements. *Id.* at 1248. In this case, by contrast, nothing on the face of Idaho's SIP suggests that the field burning prohibition is in any way contingent or indefinite. The plan is therefore not illusory under our case law. Moreover, by relying on a SIP's explicit language to find it illusory, *Riverside Cement* supports our broader conclusion that the plain meaning of a SIP controls.

* * *

[10] In sum, we hold that SIPs are interpreted based on their plain meaning when such a meaning is apparent, not absurd, and not contradicted by the manifest intent of EPA, as expressed in the promulgating documents available to the public. Because the prohibitory language of the preexisting Idaho SIP plainly applies to field burning, federal law banned field burning in Idaho prior to EPA's 2005 approval of the SIP amendment.

III.

[11] In commenting to EPA about Idaho's proposed amendment to the SIP, SAFE maintained that its approval would weaken the prior SIP and thereby violate sections 110(*l*) and 193 of the CAA. Section 110(*l*) provides that EPA "shall not approve a revision of a [SIP] if the revision would interfere with any applicable requirement concerning attainment and reasonable further progress ... or any other applicable requirement of this chapter." 42 U.S.C. § 7410(*l*). Section 193 provides that "[n]o control requirement in effect, or required to be adopted by an order, settlement agreement, or plan in effect before November 15, 1990, in any area which is a nonattainment area for any air pollutant may be modified after November 15, 1990, in any manner unless the modification insures equivalent or greater emission reductions of such air pollutant." *Id.* § 7515. ***1109** In its 2005 approval of the amendment, EPA denied the amendment contravened either of these statutes. Final SIP, 70 Fed.Reg. at 39,659-60. SAFE now challenges those determinations. We do not reach those broad statutory challenges, except to hold that EPA's reasoning in rejecting them cannot be squared with our interpretation of Idaho's pre-2005 SIPs.

As we have explained, EPA's decision to approve the 2005 amendment to Idaho's SIP rested on the fundamental premise that "EPA does not believe that Idaho's *existing SIP* when viewed in its entirety prohibits the burning of crop residue." *Id.* at 39,659 (emphasis added). EPA relied on this premise in rejecting SAFE's claims under sections 110(*l*) and 193. *See id.* at 39,660 ("The proposed SIP revision is merely a clarification *of the existing SIP* and does not change or otherwise relax an existing control measure and therefore will not interfere with any applicable requirements concerning attainment and reasonable further progress or other applicable requirement of the Act. EPA believes that the requirement of section 110(*l*) is satisfied." (emphasis added)); *id.* ("In sum, EPA believes that approving the proposed SIP revision does not change or alter the *existing SIP* in Idaho which does not prohibit burning of crop residue.... Therefore, the requirements of section 193 of the Act are satisfied." (emphasis added)). Moreover, EPA has continued to rely on the same logic in its brief to this court: "In approving [the 2005] amendment to Idaho's SIP, EPA understood it to be a clarification of *existing* state law and the *SIP,* governing open burning of crop residue. EPA's action to approve Idaho's SIP revision request *therefore* did not relax Idaho's *pre-existing SIP* with respect to open burning of crop residue, or any control requirements in the SIP that had been in effect before November 15, 1990." (Emphases added).

[12] We must review the EPA's actions based on the "grounds ... upon which the record discloses that its action was based." *Chenery,* 318 U.S. at 87, 63 S.Ct. 454; *see also Ctr. for Biological Diversity,* 466 F.3d at 1103-04. On one hand, that principle means that we can only uphold EPA's action "on the basis articulated by the agency itself." *Motor Vehicle Mfrs. Ass'n of the U.S., Inc. v. State Farm Mut. Auto. Ins. Co.,* 463 U.S. 29, 50, 103 S.Ct. 2856, 77 L.Ed.2d 443 (1983). On the other hand, it also means we must "remand to the agency for additional investigation or explanation" when the agency's analysis is incomplete after its flawed basis is removed. *INS v. Ventura,* 537 U.S. 12, 16, 123 S.Ct. 353, 154 L.Ed.2d 272 (2002) (per curiam) (quoting *Fla. Power & Light Co. v. Lorion,* 470 U.S. 729, 744, 105 S.Ct. 1598, 84 L.Ed.2d 643 (1985) (internal quotation mark omitted)). The record demonstrates that because EPA based the action under review on its belief that the preexisting SIP did not ban agricultural burning, the agency did not address the question whether the 2005 amendment, if indeed a change, contravened the statutory requirements. We therefore cannot reach that question either.

We have held EPA's conclusion that the preexisting SIP did not ban field burning legally erroneous. Because that flawed premise is fundamental to EPA's determination that it did not contravene sections 110(*l*) or 193 of the CAA by approving the 2005 SIP, EPA's outcome on those statutory interpretation questions is "arbitrary, capricious, or otherwise not in accordance with law" for the purposes of our review. *Hall*, 273 F.3d at 1155. We therefore grant SAFE's petition and remand to EPA for its consideration of Idaho's proposed amendment as a change in the preexisting ***1110** SIP, rather than as simply a "clarification" of it. Final SIP, 70 Fed.Reg. at 39,660. Accordingly, we have no reason to interpret the meaning of either CAA provision relied upon by SAFE but will instead allow EPA the first opportunity to apply those provisions, this time in accord with the understanding that the preexisting SIP bans field burning while the proposed amendment clearly allows, and regulates, the practice.

Petition for Review GRANTED; REMANDED to EPA.

C.A.9,2007.
Safe Air for Everyone v. U.S. E.P.A.
475 F.3d 1096, 63 ERC 1897, 07 Cal. Daily Op. Serv. 1043

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PUBLIC COMMENT PERIOD INFORMATION
to
ENVIRONMENTAL QUALITY COMMISSION
regarding Lane County petition to ban field burning
Presented by
Dave Nelson, Executive Secretary
Oregon Seed Council
June 22, 2007

Chair Hampton, members of the Commission I am Dave Nelson, Executive Secretary of the Oregon Seed Council, a position I have held since 1977. Prior to joining the Seed Council I was Executive Vice President of the Oregon Farm Bureau from 1969 through 1975.

Field burning is not a new issue and has been debated by the Oregon Legislature since 1967. The Legislature heard the same petition by Lane County legislators during the current session and consciously decided not to make further modifications in the current program. As a matter of fact two bills were presented to the legislature and both failed to gain support.

Field burning is the most heavily regulated agricultural practices in the country. Today less than 10% of the land producing grass seed is burned. Field burning has been reduced from 320,000 acres in 1972 to less than 50,000 acres today.

I have prepared some background information for you and your staff.

Background

Grass Seed Production & Marketing information page 3

Air Quality Regulation - Standards

EPA establishes standards to protect human health and to protect livability page 4

Willamette Valley Air Quality

Air Quality in relation to EPA Standards to protect health page 9 of pages 6 - 10

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Health Effects

Impact Data - ODA Report - description heavy, medium and light page18

Oregon Asthma Surveillance Summary Report page 21 - 23

Field Burning by month: July 2,793 page 23
August 36,455
September 8,360 (6,932 on 9/08)

University of Washington study of students at Pullman, Washington. page 24 - 28

Online Surveys

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Thank you for the opportunity to testify HB 3000, it is critically important to all agriculture. We urge you to move it to the Committee on Agriculture and Natural Resources.

OREGON SEED INDUSTRY - FACT SHEET

Prepared by
The Oregon Seed Council - 503-585-1157

Grass Seed Industry ~~The term "seed industry" generally refers to production and marketing of cool grass~~ seeds in the state of Oregon. Cool season grasses are those adapted to the temperate climates of the world and includes six major species.

Species Species include Annual and Perennial Ryegrass, Tall Fescue, Fine Fescue, Orchardgrass, Bluegrass, and Bentgrass. Warm season grass include Bermuda grass, St Augustine grass, Zoyzia, etc.

Number of Growers There are about 1,500 grass seed growers in Oregon. The majority of grass seed is produced in the 9 Willamette Valley Counties. Other areas with significant acreage are Jefferson, Jackson, Union, Morrow and Umatilla Counties. Grass Seed is also produced in much smaller amounts in Washington, and Idaho.

Number of Companies There are approximately 55 wholesale seed companies marketing grass seed.

Acreage Grass seed is produced on nearly 530,000 acres; 485,000 acres in the Willamette Valley, the rest in Jefferson, Jackson, Union, Morrow, Umatilla, and Klamath Counties.

Production In 2006 Oregon produced and marketed 788 million pounds of grass seed.

World Use The total demand for cool season grass seed is about 1.3 billion pounds annually.

Value of Production Agricultural crops are valued in various ways. The "farm gate" value is what the grower received for the seed. In 2006 the "farm gate" value was over $454 million. Grass seed companies added about 30% or $135 million in research, production and marketing services bringing the total value to over $590 million.

Where Sold Nearly all of the grass seed produced in Oregon is sold outside of the state. It is estimated that only 1-2% of the grass seed produced in Oregon is needed here for new lawns and pastures.

Export Approximately 12-15% of the grass seed produced in Oregon is exported. Major buyers include Europe, Pacific rim countries, South American countries, African countries, New Zealand and Australia, Canada and China. In total, grass seed is exported to about 60 countries.

Why Oregon Oregon has a unique combination of cool moist winters and dry warm summers that are ideal for grass seed production. A high percentage of soils in the Willamette Valley are well suited to growing grass and of limited value for producing other crops. Using Oregon's natural advantages, grass seed growers have learned to produce very high quality seed cheaper than competitors.

Economic Economic impact refers to the ripple effect of new money coming into an economy; how many times the dollar changes hands. Agricultural crops have an economic multiplier of about 3. That is a new dollar will result in about $3 worth of total economic activity. Using 3 as the multiplier, the seed industries economic impact is $1.77 billion (3 X $590 million).

National Ambient Air Quality Standards (NAAQS)

The Clean Air Act, which was last amended in 1990, requires EPA to set **National Ambient Air Quality Standards** (40 CFR part 50) for pollutants considered harmful to public health and the environment. The Clean Air Act established two types of national air quality standards. ***Primary standards*** set limits to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly. ***Secondary standards*** set limits to protect public welfare, including protection against decreased visibility, damage to animals, crops, vegetation, and buildings.

The EPA Office of Air Quality Planning and Standards (OAQPS) has set National Ambient Air Quality Standards for six principal pollutants, which are called "criteria" pollutants. They are listed below. Units of measure for the standards are parts per million (ppm) by volume, milligrams per cubic meter of air (mg/m^3), and micrograms per cubic meter of air ($\mu g/m^3$).

National Ambient Air Quality Standards

Pollutant	Primary Stds.	Averaging Times	Secondary Stds.
Carbon Monoxide	9 ppm ($10\ mg/m^3$)	8-hour(1)	None
	35 ppm ($40\ mg/m^3$)	1-hour(1)	None
Lead	$1.5\ \mu g/m^3$	Quarterly Average	Same as Primary
Nitrogen Dioxide	0.053 ppm ($100\ \mu g/m^3$)	Annual (Arithmetic Mean)	Same as Primary
Particulate Matter (PM_{10})	Revoked(2)	Annual(2) (Arith. Mean)	
	$150\ \mu g/m^3$	24-hour(3)	
Particulate Matter ($PM_{2.5}$)	$15.0\ \mu g/m^3$	Annual(4) (Arith. Mean)	Same as Primary
	$35\ \mu g/m^3$	24-hour(5)	
Ozone	0.08 ppm	8-hour(6)	Same as Primary
	0.12 ppm	1-hour(7) (Applies only in limited areas)	Same as Primary
Sulfur Oxides	0.03 ppm	Annual (Arith. Mean)	-------
	0.14 ppm	24-hour(1)	-------
	-------	3-hour(1)	0.5 ppm ($1300\ \mu g/m^3$)

(1) Not to be exceeded more than once per year.

(2) Due to a lack of evidence linking health problems to long-term exposure to coarse particle pollution, the agency revoked the annual PM_{10} standard in 2006 (effective December 17, 2006).

(3) Not to be exceeded more than once per year on average over 3 years.

(4) To attain this standard, the 3-year average of the weighted annual mean $PM_{2.5}$ concentrations from single or multiple community-oriented monitors must not exceed 15.0 $\mu g/m^3$.

(5) To attain this standard, the 3-year average of the 98th percentile of 24-hour concentrations at each population-oriented monitor within an area must not exceed 35 $\mu g/m^3$ (effective December 17, 2006).

(6) To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.08 ppm.

(7) (a) The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is ≤ 1, as determined by appendix H.
(b) As of June 15, 2005 EPA revoked the 1-hour ozone standard in all areas except the fourteen 8-hour ozone nonattainment Early Action Compact (EAC) Areas.

October 20, 2006

Honorable Representative Paul Holvey
PO box 51048,
Eugene, OR, 97405

RE: Field Burning

Dear Representative Holvey:

Thank you for your request about field burning in the Willamette Valley. I have enclosed some information that I hope will be informative and help place field burning emissions in context with other sources of particulate pollution in the Valley.

Figure 1 below shows our estimate of 2002 particulate emissions (PM10) in the Willamette Valley during the June-September field burning season. As you can see, field burning emissions represent approximately two percent of total particulate emissions in the Valley during this time period. Because field burning emissions reflect a short term, seasonal activity, they represent less than one percent of total annual particulate emissions. The majority of particulate emissions during the summer are from air borne dust, primarily from motor vehicle travel on unpaved roads. Occasional, short term particulate sources such a field burning or prescribed forest burning can have adverse heath impacts on the public, especially sensitive groups like asthmatics. However, these sources do not generally contribute to violations of national ambient air quality health standards. The Oregon Smoke Management Program is designed to minimize the public's exposure to smoke impacts from field and prescribed forestry burning.

Figure 2 shows our estimate of 2002 particulate emissions (PM10) in the Willamette Valley during the winter season (December-February) when Oregon is most likely to violate the federal particulate health standard. Emissions from woodstoves, open burning, industrial activity and other sources combine with poor wintertime ventilation to increase particulate levels and can jeopardize compliance with standards. Recently, EPA tightened the national ambient air quality standard for fine particulate by lowering the acceptable daily level from 65 ug/m^3 to 35 ug/m^3. This will put a number of Oregon communities at risk of violating the new standards. The PM10 information in figure 2 includes both fine and coarse particles, with residential wood combustion being mainly fine particulate and fugitive dust being mainly coarse particulate. One of DEQ's priorities will be to help communities avoid violations of the new federal fine particulate health standard by reducing emissions from old woodstoves. Toward that end, DEQ intends to propose legislation in 2007 called *Heart Smart* to help further reduce particulate pollution from old woodstoves.

Figures 3 and 4 are examples of daily fine particulate levels measured in the ambient air for an entire year. Figure 3 is for the city of Eugene/Springfield, Figure 4 is for Corvallis. The charts illustrate that summertime air quality is quite good, and that particulate pollution is much higher in the winter. It also shows that there can be occasional, short term episodes of higher particulate levels in the summer. Table 1 below shows the highest particulate values measured over a nine year period (1997-2005) for the cities of Albany, Carus, Corvallis, Eugene, Salem, Sweet Home, Lyons, and Lebanon. In the summer, the highest measured values in these communities averaged about 31 ug/m^3 where as the highest wintertime values for these communities averages about 50 ug/m^3.

As noted above, seasonal activities like field or prescribed forestry burning can cause elevated particulate levels. But because of their short-term, seasonal nature, they are not likely to jeopardize compliance with federal air quality health standards.

Figure 1: Willamette Valley Particulate Emissions 2002 (Field Burning Season)

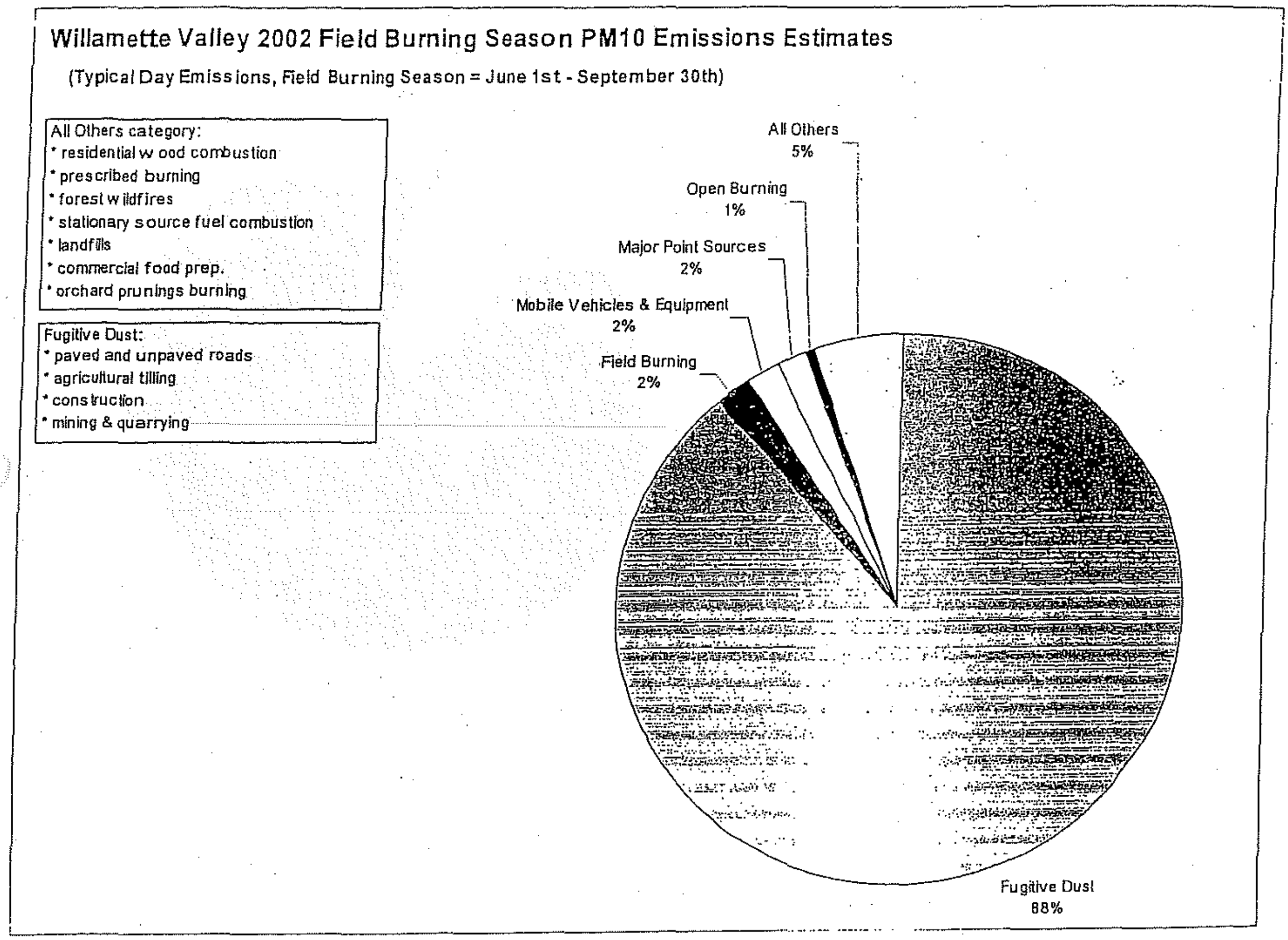


Figure 2

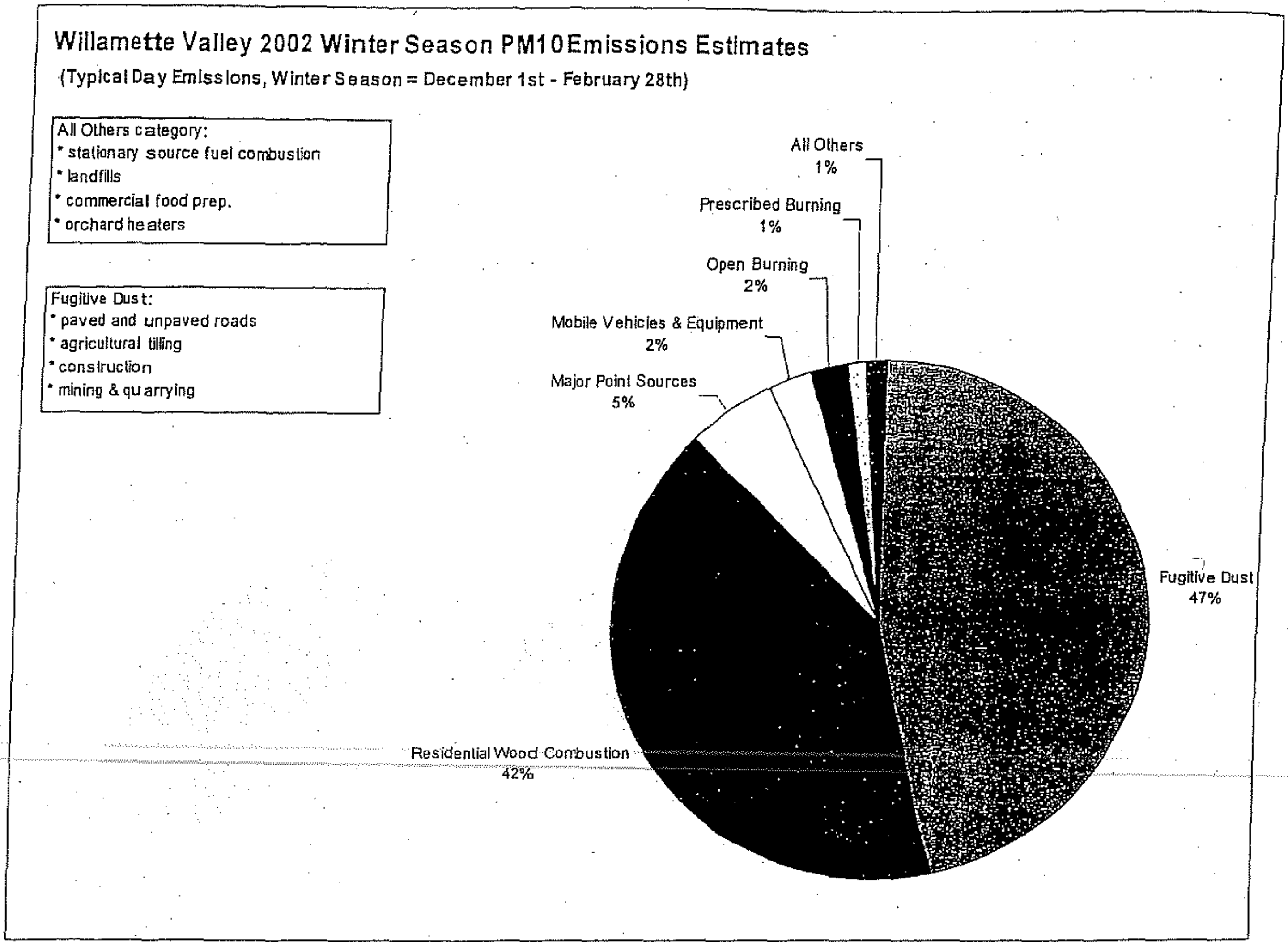
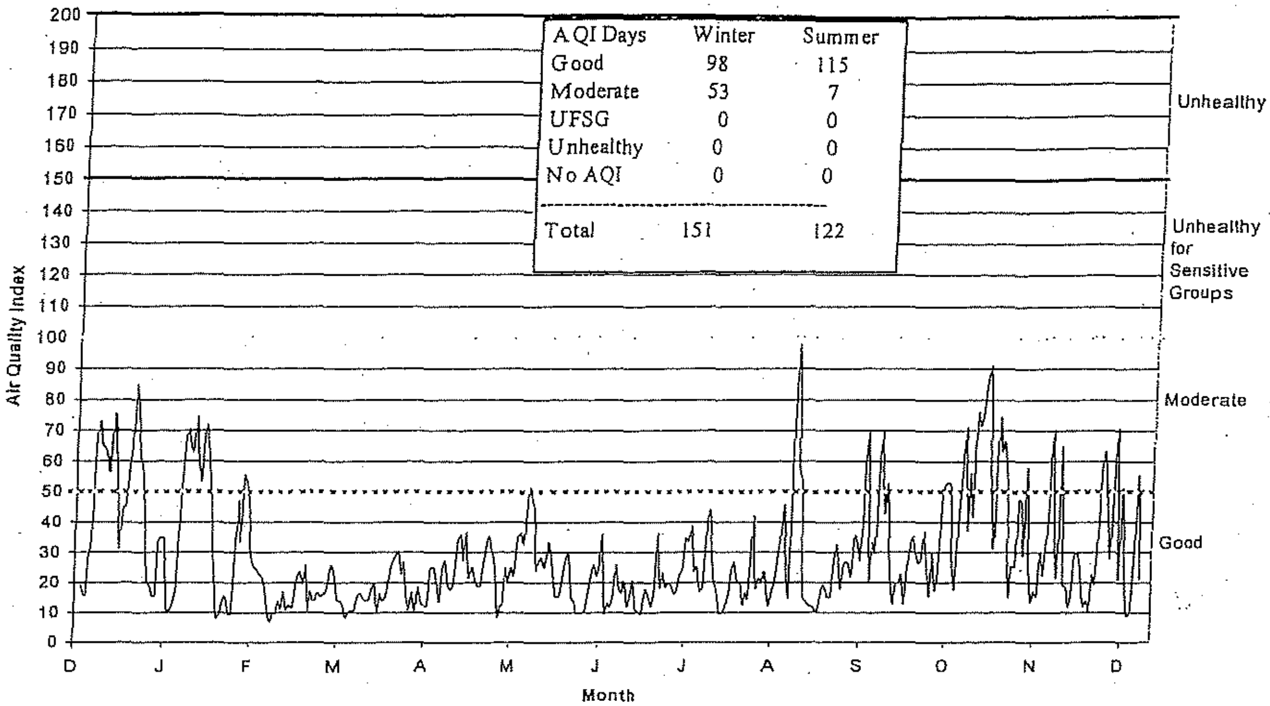

Willamette Valley 2002 Winter Season PM10Emissions Estimates
(Typical Day Emissions, Winter Season = December 1st - February 28th)
All Others category:
* stationary source fuel combustion
* landfills
* commercial food prep.
* orchard heaters
Fugitive Dust:
* paved and unpaved roads
* agricultural tilling
* construction
* mining & quarrying
All Others 1%
Prescribed Burning 1%
Open Burning 2%
Mobile Vehicles & Equipment 2%
Major Point Sources 5%
Fugitive Dust 47%
Residential Wood Combustion 42%

Figure 3

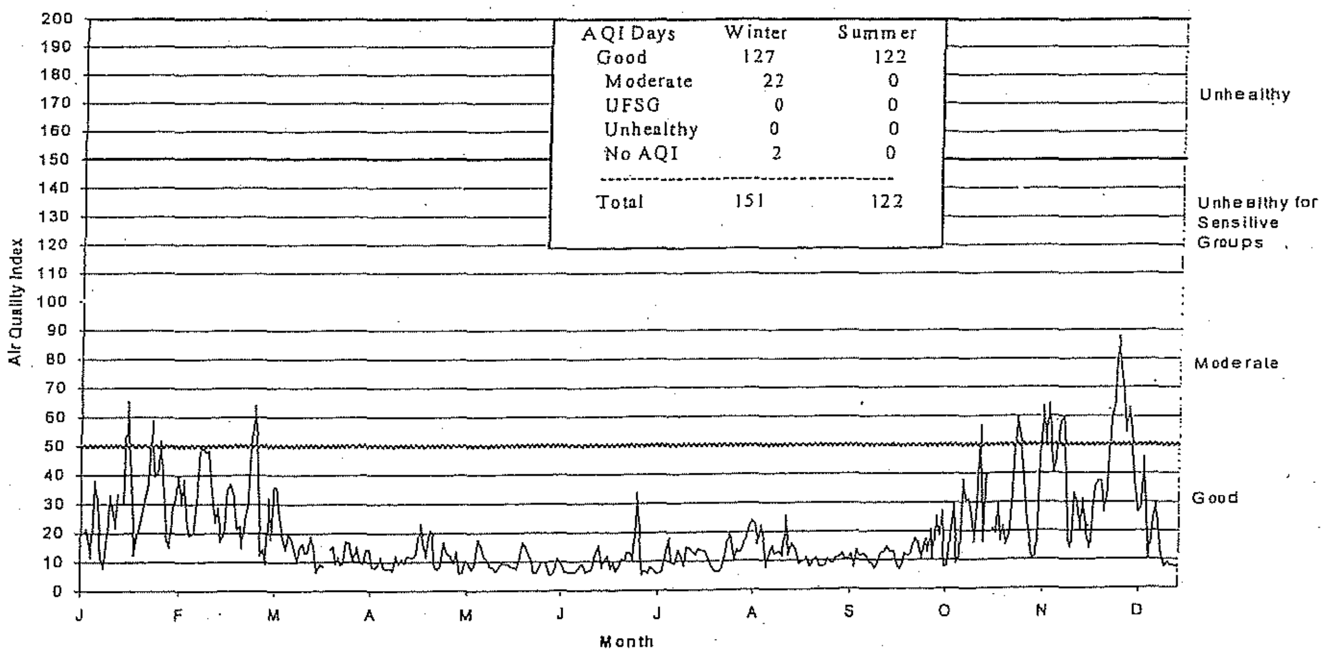
2003 Eugene / Springfield Air Quality Index (based on PM2.5)



Winter Oct 1- Feb 31, Summer June 1 -Sept 30

Figure 4

2005 Corvallis Air Quality Index (based on $PM_{2.5}$)



Winter Oct 1- Feb 31, Summer June 1 -Sept 30

Table 1: Highest measured particulate levels measured in each listed community (1997-2005)

	Summer			**Winter**		
Community	Date	Highest Measured PM2.5 (ug/m^3)	Air Quality Index (AQI)	Date	Highest Measured PM2.5 (ug/m^3)	Air Quality Index (AQI)
Albany	9/24/04	22	Moderate	12/11/05	57	UFSG
Carus	9/3/03	26	Moderate	11/7/04	41	UFSG
Corvallis	9/3/03	43	UFSG (Unhealthy for Sensitive Groups)	12/11/05	37	Moderate
Eugene 1	8/19/02	30	Moderate	10/20/97	49	UFSG
Eugene 2	9/3/03	37	Moderate	11/18/00	55	UFSG
Salem	9/3/03	29	Moderate	1/5/99	58	UFSG
Sweet Home	9/2/03	30	Moderate	Monitoring summer only	NA	
Lyons	9/3/03	33	Moderate	Monitoring summer only	NA	
Lebanon	9/2/03	34	Moderate	Monitoring summer only	NA	

I hope this information meets your request. If you have further questions about the field burning program, please feel free to call Brian Finneran of my staff at (503) 229-6278, or Nick Chambers at the Oregon Department of Agriculture at (503) 986-4701.

Sincerely,

David Collier
Air Quality Planning Manager

gtp/DC
Cc:
Greg Aldrich, Andy Ginsburg, Brian Finneran, Gerry Preston, Cheryll Hutchens, Kerri Nelson, Merlyn Hough (LRAPA) and John Byers (ODA)

Oregon
Department
of Agriculture

SUMMARY OF THE 2006 FIELD BURNING SEASON

Oregon Department of Agriculture
Natural Resources Division
Smoke Management Program

NATURAL RESOURCES DIVISION
OREGON

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Salem, OR 97301-2532
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In compliance with the Americans with Disabilities Act, this publication will be made available in alternate formats upon request.
TTY: 503-986-4762

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December 2006

The information provided in this report is accurate as of 12/31/06.

SUMMARY OF THE 2006 FIELD BURNING SEASON

Prepared By

The Oregon Department of Agriculture
Natural Resources Division
Smoke Management Program

1. Introduction

This summary is prepared at the close of each burn season by the Oregon Department of Agriculture (ODA) Smoke Management Program staff to report the statistics of each field burning season.

2. Weather Discussion

Weather in the Willamette Valley presents a multitude of challenges to operating the Smoke Management Program. Predicting weather patterns that will take smoke up, out, and away from populated areas is an inexact science. Rapidly changing winds, lower than expected mixing heights (the height of smoke rise), unpredictable smoke down mixing, and inefficient field ignition procedures executed by growers can all contribute to a given burn day's potential for smoke impacts.

Early June was rather wet (see Figure 1), which slowed maturation of the grass seed crops causing harvest to begin a bit later than usual. In late June and early July growers were occupied with combining late maturing crops. Even so, ODA was able to orchestrate a modicum of burning in mid-July by working with individual growers who were able to prepare fields quickly for burning after harvest.

There were a few very hot days during late June and July (see Figure 2) which caused State Fire Marshall (SFM) fire-safety rules* to come into effect. This precluded burning of any kind during those days. The high temperature chart for the summer shows August and early September cyclically varying between warm and cool temperatures. These transitions from warm to cool were usually "marine pushes," which allowed for widespread burning opportunities at relatively regular intervals throughout the month.

The summer of 2006 did not have persistent low-level inversions as have been prevalent in previous summers. However, there was a dominant north wind pattern which precluded field burning on many days.

In 2006, the heaviest recorded number of smoke impact hours occurred on the evening of August 8th and morning of August 9th. On August 8th, on-shore pressure gradients were predicted and pilot balloon readings indicated a favorable west wind direction for field burning. Upper air

* SFM rules preclude burning on days in which any two of the following three criteria exist in the Willamette Valley: (1) temperature of 95° F or greater, (2) 30% relative humidity or less, and (3) 15 mph or greater surface winds.

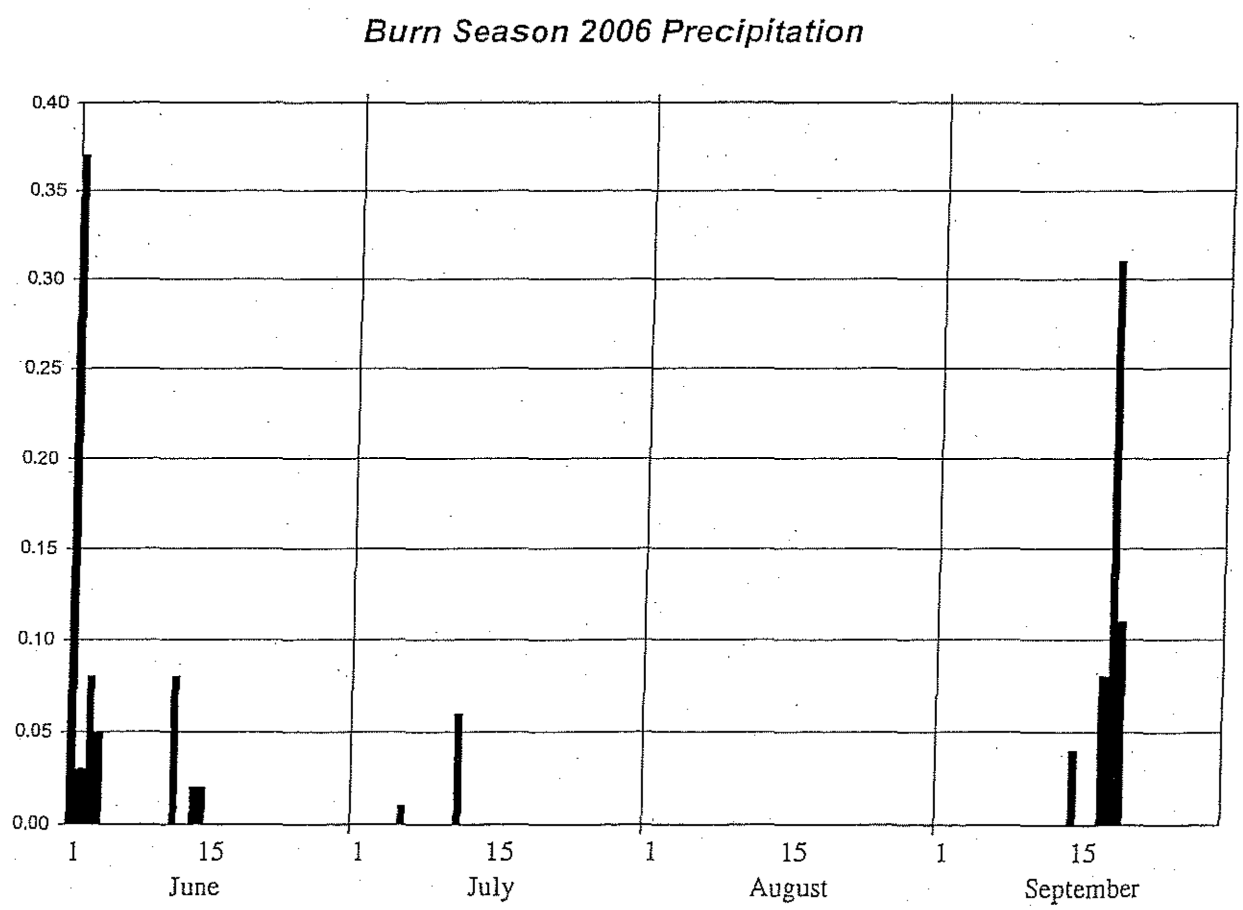
The information provided in this report is accurate as of 12/31/06.

charts revealed a minor short wave over northern California moving northeastward. However, it appeared that this short wave was far enough away that it would have no impact on smoke movement out of the Willamette Valley. Nearly 8,500 acres were burned on August 8th.

Unfortunately, as the short wave impulse moved northeast it altered the pressure pattern across the Cascades. Subsidence (sinking air motion) behind the axis of the trough caused a rapid rise in pressures in central Oregon. This collapsed the pressure gradient across the Cascades causing the smoke to "hang up" in the Cascades and associated foothills. As a result, the nephelometer at Lyons recorded 13 hours of smoke impact (8 hours light and 5 hours moderate). During the same period, the Sweet Home nephelometer recorded 1 hour of light impact.

ODA continues to refine techniques to identify individual fields and geographic locations which can be burned under specific weather conditions that are not conducive to large scale field burning yet can be used for limited localized burning. The addition of a third theodolite in 2006 allowed ODA to conduct mobile pilot balloon (pibal) readings in more areas throughout the Valley. A pibal is used to collect information about wind speeds and directions through the atmosphere from the surface to approximately 10,000 feet.

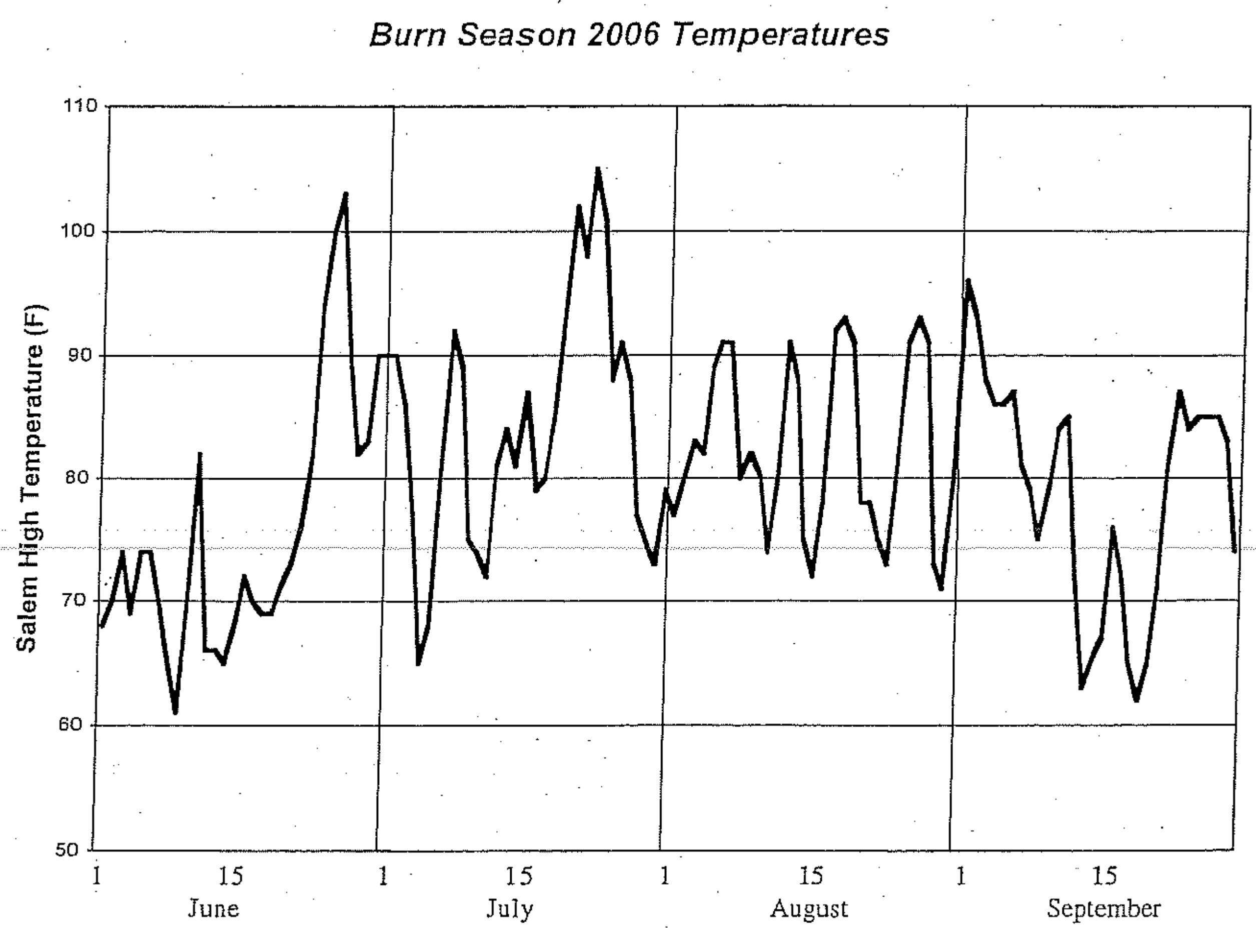
Figure 1



On August 25th, pibals were conducted on the west side of the Willamette Valley to confirm easterly winds aloft. These rare easterly winds are not suited for large-scale open field burning, but are very suitable for burning fields on the west side of the Valley. After east wind

confirmation, ODA authorized field burning on the west side of the Valley, expecting smoke to travel out over the relatively unpopulated coast range. Almost 1,700 acres were burned on the west side on the 25th. Unfortunately, one 62-acre field burn north of Corvallis was not ignited with "rapid ignition" techniques and produced a large amount of ground smoke. As such, this smoke did not rise into the easterly wind layer. Instead, it drifted southward on surface winds producing one hour of heavy smoke impact, and an inordinate number of complaint calls from Corvallis and some communities to the south.

Figure 2



3. Four-Day Burn Percentage

During the 2006 field-burning season, 56% of all the acreage open field burned occurred over 4 days. This compares with 53% of all acreage burned over 4 days in 2005. The chart below outlines the 2006 figures.

Tues. 8/8/06	Thu. 8/10/06	Mon. 8/28/06	Fri. 9/8/06	**4 Day Total**	**Percent**
8,412	5,275	7,018	6,932	27,637	56%

4. Registered Acres

Open field burning and propane flaming acreage pre-registration began on March 17th and continued through April 1st. The chart below shows the breakdown of acres registered by type, the statutory limitation of each type, and the final allocation of each type as imposed by the statutory limitation.

Type	**Limitation**	**Acres Registered**	**Allocation**
Regular	40,000	96,962	41%
Identified Species	22,000	16,294	100%
Steep Terrain	3,000	1,041	100%
Propane Flame	37,500	2,439	100%

<u>Definitions</u>

Type: Open Field Burning

- **Regular:** Perennial or annual grass seed, or cereal grain residue.
- **Identified Species:** Research has identified some species of grass seed that cannot be profitably produced without thermal sanitation. These identified species are Chewings Fescue, Creeping Red Fescue, and Highland Bentgrass.
- **Steep Terrain:** Locations in the Willamette Valley where grass seed is grown, but because of the steepness of the terrain, it is extremely difficult to apply alternatives to open field burning.

Type: Propane Flaming

- The process of sanitizing (burning) regular and identified species fields with a propane flamer; a mobile, fire-producing, sanitation device.

5. Open Field Burning

In the 2006 field burn season, a total of 114,297 acres were registered for open field burning compared to 114,299 in 2005. Registration included 96,962 acres of regular, 16,294 acres of identified species, and 1,041 acres of steep terrain. Regular registration exceeded the legislatively mandated limitation of 40,000 acres; therefore, the regular open field burning allocation rate for 2006 was 41%. The allocation rate for identified species and steep terrain for 2006 was 100%.

The information provided in this report is accurate as of 12/31/06.

A total of 49,017 acres were open field burned during the 2006 burn season (34,971 regular limitation, 13,375 identified species, and 671 steep terrain). By comparison, a total of 49,225 acres were burned in 2005, 49,553 acres in 2004, 50,437 acres in 2003, and 51,374 acres in 2002.

2006 Open Field Burning by Crop

Species	Burned (acres)	% Of Total
Annual Ryegrass	27,640	56.39%
Chewings Fescue	8,714	17.78%
Perennial Ryegrass	4,867	9.93%
Creeping Red Fescue	3,824	7.80%
Tall Fescue	1,649	3.36%
Cereal Grain	970	1.98%
Highland Bentgrass	837	1.71%
Orchardgrass	299	0.61%
Fine Fescue	217	0.44%
TOTAL	**49,017**	**100%**

6. Propane Flaming

The maximum allowable acreage to be propane flamed is 37,500 acres (as set by the 1995 Oregon Legislature). In 2006 growers registered 2,439 acres of fields to be propane flamed and burned 1,466 of those registered acres. This compares to 1,631 acres propane flamed in 2005, 1,067 acres in 2004, 1,602 acres in 2003, and 1,582 acres in 2002.

2006 Propane Flame Burning by Crop

Species	Burned (acres)	% Of Total
Creeping Red Fescue	653	44.54%
Perennial Ryegrass	351	23.94%
Chewings Fescue	242	16.51%
Cereal Grain	100	6.82%
Kentucky Bluegrass	85	5.80%
Tall Fescue	35	2.39%
Highland Bentgrass	0	0%
Orchardgrass	0	0%
Fine Fescue	0	0%
TOTAL	**1,466**	**100%**

7. Stack Burning

Stack burning does not have an imposed acreage limitation, nor is registration required. Growers are obligated to secure a stack burning permit containing the responsible party's name, location of the burn, and acreage represented by the accumulated residue prior to ignition. The stack burning season lasts from April 1st to March 31st of the following year. As of October 31, 2006, growers had stack burned 1,061 acres since April 1, 2006. Previous years are as follows:

The information provided in this report is accurate as of 12/31/06.

Historical Stack Burn Statistics

Year	Interim – October 31st	Final – March 31st
2006-2007	1,061	N/A
2005-2006	1,366	1,692
2004-2005	1,667	1,864
2003-2004	1211	1,636
2002-2003	616	1018

8. Total Thermal Residue Management

The chart below shows the figures for total thermal residue management, including stack-burning acreages.

Burn Type	2006	2005	2004	2003	2002
Open Field Burning	49,017	49,225	49,553	50,437	51,374
Propane Flaming	1,466	1,631	1,067	1,602	1,582
Stack Burning†	1,399	1,692	1,864	1,636	1,018
Total	**51,882**	**52,548**	**52,484**	**53,675**	**53,974**

9. Enforcement

The 2006 burn season marked the tenth year that the department has performed the enforcement function of the Smoke Management Program (as stipulated under a Memorandum of Understanding with the Oregon Department of Environmental Quality, Pursuant to Oregon Revised Statutes 468A.585).

There were 5 enforcement contacts during the 2006 season (as of October 31, 2006). This compares with 17 enforcement contacts during the 2005 season, 21 contacts in 2004, 2 contacts in 2003, 11 contacts in 2002, and 10 contacts in 2001.

Of the 5 enforcement contacts in 2006, all of them resulted in letters of warning; none resulted in notices of non-compliance, and none resulted in civil penalty assessments.

10. Smoke Impacts

It is the goal of the ODA Smoke Management Program, with the cooperation of the Willamette Valley growers, to reduce or eliminate smoke impacts in populated areas.

The combination of accurate weather prediction for burning, ODA field personnel observations, and grower experience all contribute to alleviate smoke impacts. However, smoke impacts still occur. Unexpected wind shifts, rapidly changing mixing heights, rapidly decreasing transport

† Estimated Total Stack Burn Acreage (April 1, 2006 – March 31, 2007)

The information provided in this report is accurate as of 12/31/06.

wind speeds and directions, other meteorological factors and inefficient lighting techniques all contribute to the occurrence of impacts.

Smoke intrusions attributable to open field burning occurred on 7 days in 2006. Previous years totals included 15 days in 2005, 10 days in 2004, 9 days in 2003, and 9 days in 2002.

The number of hours of recorded smoke impact[‡] in cities monitored for smoke in 2006 are outlined below.

2006 Open Field Burning Impacts

Date	Acres Burned	Impact Hours			Location
		Heavy	Moderate	Light	
8-Aug	8,412		5	8	Lyons
8-Aug	8,412			1	Sweet Home
15-Aug	107			1	Sweet Home
21-Aug	3,833		2		Lyons
21-Aug	3,833			1	Sweet Home
23-Aug	1,097			1	Lyons
25-Aug	1,699	1			Corvallis
28-Aug	6,915		1		Lyons
28-Aug	6,915		1		Sweet Home
8-Sep	6,932			2	Lyons
8-Sep	6,932		2	2	Sweet Home

11. Complaints

Open field burning complaints received from Willamette Valley residents by the Smoke Management Program[§] totaled 1,182 during the 2006 field-burning season. This compares with 1,106 complaints received for the 2005 season, 475 in 2004, 206 in 2003, 705 in 2002, and 608 in 2001.

[‡] As defined in Oregon Administrative Rule (OAR) 603-077-105, cumulative hours of smoke impact result in hourly nephelometer measurements that exceed 1.8×10^{-4} b-scat above the average prior 3-hour background levels. For the purposes of this report, "heavy" hours of smoke impact are 5.0×10^{-4} b-scat or more above background (equivalent to visual range of 5 miles or less), "moderate" hours of smoke impact are 1.8×10^{-4} to 5.0×10^{-4} b-scat above background (equivalent to visual range of 12 miles or less), and "light" hours of smoke impact are 1.0×10^{-4} to 1.8×10^{-4} b-scat above the background. "Light" hours of smoke impact were not recorded prior to the 1999 season. The terms "light," "moderate," and "heavy," as used in relation to smoke impacts, are not defined in OAR, but are used by ODA to quantify the level of smoke impact on residents of the Willamette Valley. Nephelometers are located in Portland, Eugene, Springfield, Sweet Home, Lyons, Corvallis, Salem, and Carus.

[§] Complaints received by the Lane Regional Air Protection Agency (LRAPA) are forwarded on to ODA at the end of every week during the field burning season. Those complaints are also included in the total presented in this report.

The information provided in this report is accurate as of 12/31/06.

2006 Open Field Burning Complaints by City

Albany	8	Noti	17
Brownsville	10	Portland Metro	0
Corvallis	75	Salem/Keizer	16
Cottage Grove/Lorane	13	Scio	3
Creswell	27	Silverton	7
Eugene	275	Springfield	65
Harrisburg	16	Stayton	19
Junction City/Monroe	49	Sublimity	6
Lebanon	59	Sweet Home	36
Lyons/Mehama	11	Veneta/Elmira	107
Mill City/Gates	27	Other	160
Mohawk Valley	131	Unknown	45
		Total	**1,182**

Breakdown of 2006 Open Field Burning Complaint Calls**

ODA tracks the number of complaint calls by individuals to determine the amount of repeat callers. Information is recorded by ODA in order to prevent the results from being skewed by multiple calls from one individual.

Number of People	Times Called	Number of Complaints
649	1	649
100	2	200
24	3	72
10	4	40
7	5	35
2	6	12
3	7	21
1	8	8
1	10	10
1	12	12
1	16	16
107	Unknown	107
	Total	**1,182**

** Chart outlines the number of individuals and how many times they called. For example; 3 people called 7 times each for a total of 21 complaints. 107 callers chose not to provide identifying information and, therefore, it is unknown if those callers called multiple times.

The information provided in this report is accurate as of 12/31/06.

5 Year Historical Comparative Open Field Burning Data

Season	2006	2005	2004	2003	2002
Acres Registered[††]	116,328	114,299	91,933	83,695	79,679
Acres Burned	49,017	49,225	49,553	50,437	51,374
Most burned in one day	8,412	9,311	10,252	8,617	9,994
Burn days accounting for 75% of total acres	7	10	7	9	6
Weekend burn days allowed	0	0	1	0	0
Number of Burn Days[‡‡]					
300 – 999 acres burned	15	15	8	11	2
1,000 – 4,999 acres burned	5	10	5	8	8
5,000 – 9,999 acres burned	4	2	3	3	4
10,000 or greater burned	0	0	1	0	0
Total Burn Days	**24**	**27**	**17**	**22**	**14**
Smoke Impact Hours total/heavy/mod/light(#days)[§§]	**2006**	**2005**	**2004**	**2003**	**2002**
Portland	0/0/0/0	0/0/0/0	0/0/0/0	0/0/0/0	0/0/0/0
Salem	0/0/0/0	0/0/0/0	0/0/0/0	0/0/0/0	0/0/0/0
Corvallis	1/1/0/0	0/0/0/0	0/0/0/0	0/0/0/0	0/0/0/0
Carus	0/0/0/0	0/0/0/0	1/0/1/1(1)	0/0/0/0	0/0/0/0
Lyons	8/0/8/11(5)	14/0/14/25(14)	5/1/4/5(5)	4/0/4/10(6)	3/0/3/11(4)
Sweet Home	3/0/3/5(5)	0/0/0/1(1)	2/0/2/9/(4)	2/0/2/2(3)	5/0/5/16(4)
Eugene	0/0/0/0	1/0/1/1(2)	0/0/0/0	0/0/0/0	0/0/0/0
Springfield	0/0/0/0	4/0/4/3/(3)	0/0/0/0	0/0/0/0	0/0/0/1(1)
Total (day total is of individual days not of days at each location)	**12/1/11/16(7)**	**19/0/19/30(15)**	**8/1/7/15/(10)**	**6/0/6/12(9)**	**8/0/8/28(9)**

[††] All registered regular, identified species, and steep terrain open field-burning acres plus registered propane acres.

[‡‡] Days with less than 300 acres burned are not counted as open field burning days.

[§§] As defined in Oregon Administrative Rule (OAR), total hours of impact include hourly nephelometer measurements exceeding 1.8×10^{-4} b-scat above prior 3-hour background. For the purposes of this report, "heavy" hours of smoke impact are 5.0×10^{-4} b-scat or more above background (equivalent to visual range of 5 miles or less), "moderate" hours of smoke impact are 1.8×10^{-4} to 5.0×10^{-4} b-scat above background (equivalent to visual range of 12 miles or less), and "light" hours of smoke impact are 1.0×10^{-4} to 1.8×10^{-4} b-scat above the background. "Light" hours of smoke impact were not recorded prior to the 1999 season. The terms "light," "moderate," and "heavy," as used in relation to smoke impacts, are not defined in OAR, but are used by ODA to quantify the level of smoke impact on residents of the Willamette Valley. Nephelometers are located in Portland, Eugene, Springfield, Sweet Home, Lyons, Corvallis, Salem, and Carus.

The information provided in this report is accurate as of 12/31/06.

Oregon Asthma Surveillance Summary Report

March 2007

Oregon Asthma Program
Office of Disease Prevention and Epidemiology
Public Health Services
Oregon Department of Human Services

21

Oregon Asthma Program

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Debi Livengood, Administrative Assistant, Asthma Program

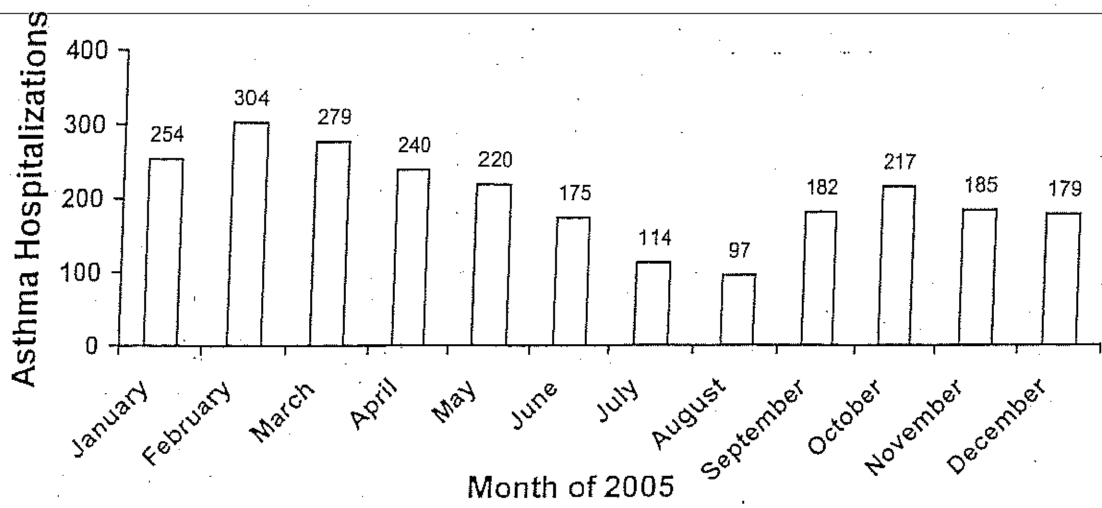
Sara Beth Weiner, MSW, MPH, CDC Public Health Prevention Service, Asthma Program

For more information contact:

Oregon Asthma Program
Department of Human Services
800 NE Oregon Street, Suite 730
Portland, OR 97232-2162
Phone: (971) 673-0984 Fax: (971) 673-0994
Email: asthma.ohd@state.or.us
Web site: www.healthoregon.org/asthma

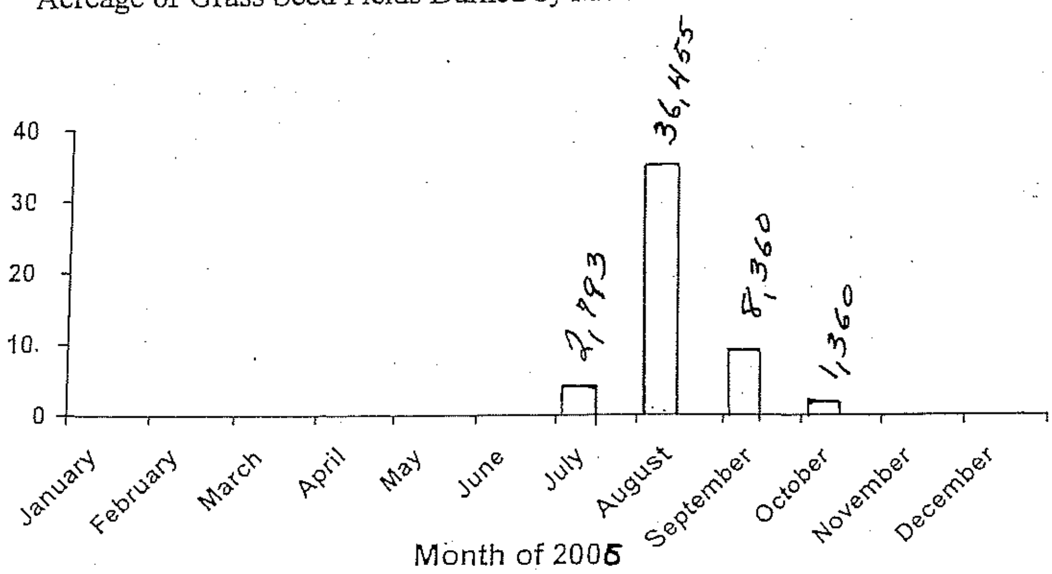
This project is supported by the Centers for Disease Control and Prevention, Cooperative Agreement #U59/CCU017777.

Figure 22 Number of hospitalizations due to asthma by month in 2005



Source: Oregon Hospital Discharge Index, 2005

Acreage of Grass Seed Fields Burned by Month



Source Oregon Department of Agriculture

Lower Figure Inserted by OSC and not a part of original report.

Exposure and Health Assessments of the Effects of Agricultural Field Burning in Young Adults with Asthma Living in Pullman Washington

Principal Investigator: Lee-Jane Sally Liu
Department of Environmental & Occupational Health Sciences
University of Washington

A final report to Grant Pfeifer of the Air Quality Program
Washington State Department of Ecology

Final Report
April 6, 2005

3.1 Abstract

To determine whether wheat field burning has adverse pulmonary effects in adults with mild to moderate asthma, we performed repeated measures of on-line exhaled nitric oxide (eNO)(594 measures) and coached spirometry (591 measures) on 32 individuals with asthma during field burning season (September-October 2002) in Pullman, WA. These pulmonary measures were assessed against measurements of fine particulate air pollution ($PM_{2.5}$) at a central location and to agricultural (Ag) burning related exposure estimates for each individual. We hypothesized that participants who were not using anti-inflammatory medication would show a positive association of exhaled nitric oxide (eNO) and negative association of forced expiratory volume in one second (FEV_1) and maximal mid-expiratory flow (MMEF) with the peak 1-h average of $PM_{2.5}$ during the previous 24 hours. Pulmonary effects of $PM_{2.5}$ were assessed with a generalized estimating equation model that included fixed covariates for gender, age, BMI, time of day, an interaction term between medication use and exposure and adjusted for temperature and relative humidity. The 32 participants ranged in age from 18 –52 years (median 24y), and 66% were female. 11 individuals were prescribed asthma controller medications and 3 individuals had baseline FEV_1< 80% of predicted. The observed 1-h average $PM_{2.5}$ concentrations ranged between 0.3 and 59.6 $\mu g/m^3$, averaging 13.0±9.2 $\mu g/m^3$ during the study period. There was no significant effect of peak 1-h $PM_{2.5}$ on measures of eNO among those not prescribed anti-inflammatory medications: -0.35 ppb (95% CI: -1.70, 1.01) or those prescribed controller medications: 1.68 ppb (95% CI: -1.51, 4.87) per 10 $\mu g/m^3$ increase of $PM_{2.5}$. Similar null effects of peak $PM_{2.5}$ exposure were noted for spirometric measures of MMEF and FEV_1. Sensitivity analyses with refined Ag burning specific exposure measures did not change these null results. In conclusion, at the observed range of $PM_{2.5}$ concentrations, we did not find an association between peak $PM_{2.5}$ episodes from field burning and decrements in pulmonary function or increases in on-line eNO measures in adults with mild to moderate asthma.

Health Measures

- Exhaled nitric oxide (eNO), a sensitive marker for inflammation in the lungs
- Lung function tests
  - FEV_1: forced expiratory volume in 1 second, an estimate of airflow obstruction
  - MEF: mid-expiratory flow, a measure of airflow from the small airways

Health Effects Assessment

Active subjects – 3 lab visits/week

- Breath samples for eNO
- Coached pulmonary function tests (Micro DL)
- Symptom/medication and time-activity diaries

On-call subjects – 3 lab visits/episode

- 3 consecutive-day lab visits (eNO, PFT, urine samples) during an "episode"
- Symptoms

Subject Symptom Reporting

	Anti-Inflammatory Medications		Overall
	No	Yes	
Missing data	25 (6%)	16 (8%)	41(7%)
Asthma severity code			
No worsening	342 (84%)	141 (68%)	483(79%)
1-3 mild periods of worsening	31 (8%)	38 (18%)	69 (11%)
4 or more mild periods of worsening	7 (2%)	8 (4%)	15 (3%)
1 or more severe worsening	0	3 (1%)	3 (1%)
Contacted provider for asthma	0	0	0
Missed class/work because of asthma	0	0	0
Rescue inhaler use (puffs/day)			
0	366 (90%)	168 (82%)	534 (87%)
1	12 (3%)	11 (5%)	23 (4%)
2	2 (1%)	11 (5%)	13 (2%)

25

Permanent Field-Burning Ban Considered

EUGENE, Ore. - Almost 1,200 Oregon residents have called the state tl field burning -- and some politicians are listening.

State Rep. Paul Holvey, a Democrat from Eugene, says he plans to intr in January. It would ban the practice that grass seed farmers use to ge

Other candidates from the southern Willamette Valley also want the le(Eddie, a Republican seeking a state senate seat. Eddie says while on tl you could eliminate field burning, I'd vote for you."

Each year about 200 Willamette Valley grass seed growers use fire to sanitize their fields and get r

10/12/2006

Online Poll

Do you think all field burning should be banned?

Thank you for participating in our poll. Here are the results so far.

Yes	30%
No	70%

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HOME

SHOULD GRASS SEED GROWERS BE BANNED FROM BURNING THEIR FIELDS..

YES, THE SMOKE BOTHERS ME

8.11 %

NO, SMOKE DOES NOT AFFECT ME

91.89 %

News On Demand: local, national, weather, and sports

Yes No

Yes No

Yes No

Get Quotes!

The letter below is shared with you by:
Oregon Seed Council
Dave Nelson, Executive Secretary
503-585-1157

This is an example of the rural urban collision that will be exacerbated in the future by the continued growth and increased density of population throughout the Willamette Valley and other agricultural valleys around Oregon. With or without commercial grass seed production, the land would be covered with some kind of vegetation and plants produce pollen.

June 10, 2007
Oregon Grass Seed Council
1193 Royvonne Ave. S., Suite 11
Salem, OR 97302

Dear Sir or Madam:

I am a life-long grass allergy sufferer living in Eugene, Oregon. The grass seed pollen from grass seed growers' practices makes me miserable from May through June every year.

I am enclosing a copy of my allergy medication receipt in hopes that you will financially reimburse me for my grass seed allergy-related costs. I hope to hear back from you soon.

Sincerely,

Michelle D'Amico
910 Tiara St
Eugene, OR 97405

KELLY Toneasha

From: HALLOCK Stephanie [Stephanie.Hallock@state.or.us]
Sent: Wednesday, June 20, 2007 10:12 AM
To: KELLY Toneasha
Subject: FW: Field burning petition

Please print the email and attachment and three hole punch. Please put in the public forum section of my EQC binder with the other field burning info. Thanks.

-----Original Message-----
From: GINSBURG Andy [mailto:Andy.Ginsburg@state.or.us]
Sent: Tuesday, June 19, 2007 6:52 PM
To: HALLOCK Stephanie; COBA Katy
Cc: HANSON Lisa R; Logan Paul S; LOTTRIDGE Helen; NELSON Kerri
Subject: RE: Field burning petition

Here's an pdf version of the petition, courtesy of Dave Nelson.

Andy

Andy Ginsburg
Air Quality Administrator
Oregon Department of Environmental Quality
ginsburg.andy@deq.state.or.us
503/229-5397

-----Original Message-----
From: GINSBURG Andy
Sent: Tuesday, June 19, 2007 6:48 PM
To: HALLOCK Stephanie; COBA Katy
Cc: HANSON Lisa R; 'Logan Paul S'; LOTTRIDGE Helen; NELSON Kerri
Subject: Field burning petition

I got a draft copy of the Lane County petition from the Register Guard. In short, it asks EQC to: 1) order a temporary emergency cessation of the program upon a finding of extreme danger to public health or safety under ORS 468.610(9); 2) exercise their authority and responsibility to ceases the issuance of burn permits upon a finding that reasonable and economically feasible, environmentally acceptable alternatives have been developed under ORS 468A.610(8)(b); 3) prohibit, restrict or limit field burning by rule to carry out the policy of ORS 468A.010 under ORS 468A.595(1); and 4) provide for a more rapid phased reduction by rule of field burning in the Willamette Valley under ORS 468A.595(2).

Emma will fax this to Paul Logan and Lisa Hanson in the morning.

Andy

Andy Ginsburg
Air Quality Administrator
Oregon Department of Environmental Quality
ginsburg.andy@deq.state.or.us
503/229-5397

T. 2. a.

Lane County Board of Commissioners

Bill Dwyer
Bill Fleenor
Bobby Green, Sr.
Peter Sorenson
Faye Hills Stewart

DRAFT- FOR INTERNAL REVIEW

June XX, 2007

Environmental Quality Commission
811 Sixth Ave., Portland, OR 97204-1390

Dear Members of the Commission:

On behalf of the Lane County Board of Health and the Lane County Board of Commissioners, we write to urge the Commission to exercise its authority under ORS 468A.610(9) to order a temporary cessation of open field burning in the Willamette Valley.[1] This action is needed to protect the lives and health of Lane County residents and others throughout the state who otherwise will be subjected to the public health danger of smoke inhalation and related toxic substances generated by field burning this summer.

The annual practice of field burning of grass seed residue,[2] conducted under the auspices of the Oregon Department of Environmental Quality and the Oregon Department of Agriculture, injects tons of fine particulates[3] and chemicals associated with incomplete combustion into the public airshed. It therefore presents a danger to public health and safety, particularly for downwind residents who already suffer from respiratory illnesses including asthma and chronic

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[1] In Oregon, grass seed is grown by 1,400 growers on over 500,000 acres, 460,000 of which are in the Willamette Valley. Oregon Seed Council, *Oregon Seed Industry – Fact Sheet* (updated 12/6/2004). The Oregon Departments of Environmental Quality (DEQ), the Agriculture (DOA), and Human Services (DHS) report that about 150 growers in the Willamette Valley burn their fields. *Open Field Burning In the Willamette Valley* (updated 2/13/2007). Accordingly, the vast majority of Oregon grass seed growers do not engage in field burning.

[2] Acreage of grass seed fields burned in Oregon, although reduced from levels of the 1980s, remains substantial. In 2006, nearly 52,000 acres were subjected to thermal residue treatment, of which approximately 49,000 acres were open-burned. Oregon Department of Agriculture, *Summary of the 2006 Field Burning Season* (Dec. 2006) 5-7.

[3] A recent study of emissions produced by Kentucky Bluegrass seed field burning noted that the 56 to 58 lbs of PM 2.5 produced per ton of residue consumed greatly exceeded that reported for most other agricultural burns, as well as that produced in wildfires and forest fires. Johnston and Colob, Washington State University, *Quantifying Post-Harvest Emissions from Bluegrass Seed Production Field Burning* (March 2004) 26. Where residues had not been reduced by baling, burning consumed a total of 3.2 tons of total material per acre. *Id.* at III. Research provided by the Department of Environmental Quality to Representative Paul Holvey in April, 2007, shows that during the field burning season, 40 percent of fine particulate pollution in the Willamette Valley is attributable to field burning, while during the four days of greatest burning, when about 50 percent of field burning occurs, smoke from the burning fields contributes 64 percent of fine particulate emissions. (DEQ research retained in the files of the Western Environmental Law Center). While the Department of Agriculture, which manages the field burning smoke program, intends for much of this smoke to disperse and not impact local communities, DEQ and DOA both acknowledge that impacts at times occur despite best intentions. According to other research released by Rep. Holvey's office, on the four days of major field burning, the ensuing smoke contributes 770 tons of fine particulates, 4,885 tons of carbon monoxide, and more than 676 tons of toxic air pollutants. Holvey letter to the Oregon Agriculture and Natural Resources Committee (April 30, 2007).

obstructive pulmonary diseases, those who suffer cardiovascular disease or diabetes, children under 18 – whose lungs are still developing,[4] and elderly residents.

Oregon's present field burning program was developed in the early 1990's without full knowledge of the dangers presented by smoke that entrains fine particles. The medical evidence, now, is overwhelming. Particulates less than 2.5 micrometers in diameter (PM 2.5) are too small to be filtered effectively by the upper respiratory system.[5] They can travel to the alveoli at the base of the lungs and impact the cardiopulmonary and cardiovascular systems. Exposure to PM 2.5 has been found to aggravate asthma, chronic bronchitis, cystic fibrosis and emphysema, and has been implicated in reduced lung function, irregular heartbeat, heart attack[6] and premature death in people with cardiovascular disease.[7] A 2006 study in the Journal of the American Medical Association found that even short-term exposure to PM 2.5 increases the risk for hospital admission for cardiovascular and respiratory diseases.[8] Oregon state agencies similarly acknowledge that field burning can result in serious public health impacts.[9] While additional studies of the health impacts of field burning smoke could quantify the numbers of additional illnesses and deaths attributable to Oregon's program,[10] there is ample evidence presently in existence. Decision-makers must not be side-tracked from their responsibility to terminate this harmful practice.

Under state law, the Oregon Department of Agriculture (ODA) regulates the practice of field burning in the Willamette Valley to reduce smoke impacts on populated areas, but its

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[4] Particulate pollution has been linked to infant death, premature birth, and low birth weight. American Academy of Pediatrics Committee on Environmental Health, Ambient Air Pollution: Health Hazards to Children. *Pediatrics* 2004; 114: 1699-1707. According to the American Lung Association of Oregon, "[c]hildren's lungs develop mostly after they're born and air pollution from burning can affect the ability of [their] lungs to develop normally, leading to a lifetime of breathing problems. Children are also outside more than adults, so they risk breathing more of this pollution." Letter to Oregon House of Representatives Health Care Committee (April 6, 2007).

[5] In addition to both coarse and fine particulates, the smoke from grass seed burning "contains a complex mixture of chemicals, known carcinogens such as benzene and acrolein." Lane County Medical Society letter to state legislators (April 5, 2007). The smoke also contains chemicals that are usually associated with the process of incomplete combustion, including polycyclic aromatic hydrocarbons (PAHs), phenols, and volatile organic compounds (VOC). Grass Seed Field Smoke and Its Impact on Respiratory Health, *Environmental Health* (June 1998) 10-11.

[6] Increased Particulate Air Pollution and the Triggering of Myocardial Infarction, *Circulation* (June 12, 2001) 2810-2815.

[7] EPA, *Fact Sheet: Final Revisions to the National Ambient Air Quality Standards for Particle Pollution (Particulate Matter)*, 1, (September 21, 2006), http://epa.gov/pm/pdfs/20060921_factsheet.pdf (last visited January 26, 2007). Oregonians may be particularly vulnerable to field burning smoke in light of the state's relatively high incidence of asthma. Oregon Asthma Program, *Oregon Asthma Surveillance Summary Report*, 12 (March 2007), http://oregon.gov/DHS/ph/asthma/docs/report.pdf (last visited January 26, 2007). Oregonians have the 4th worst prevalence of asthma in the nation. Behavioral Risk Factor Surveillance System, *Prevalence Data: Asthma 2005*, http://apps.nccd.cdc.gov/brfss/list.asp?cat=AS&yr=2005&qkey=4416&state=All (last visited January 26, 2007).

[8] Journal of the American Medical Association, *Fine Particulate Air Pollution and Hospital Admission for Cardiovascular and Respiratory Diseases* (March 8, 2006).

[9] The Oregon Departments of Environmental Quality (DEQ), Agriculture (DOA), and Human Services (DHS) note that although field burning events are too brief in duration to violate federal air quality standards, exposure "can still pose health risks" including, for the general public, "eye irritation, scratchy throat, runny nose, headaches, and allergic reactions" and serious problems "for people with pre-existing respiratory problems" or for "sensitive populations such as young children and the elderly." *Open Field Burning In the Willamette Valley* (updated 2/13/2007).

[10] *Open Field Burning In the Willamette Valley*, op. cit. note. 1, states that the "Oregon Department of Agriculture, in conjunction with researchers at Oregon State University, is currently planning to conduct a human health risk assessment of field burning in the Willamette Valley."

success is limited by "unexpected wind shifts, rapidly changing mixing heights, rapidly decreasing transport wind speeds and directions, other meteorological factors and inefficient lighting techniques."[11] Incursions into heavily populated areas of the Willamette Valley are common during the burn season. The Lane Regional Air Protection Agency (LRAPA) reports that one-third of the 1,030 air pollution complaints it receives annually on average are related to field burning.[12] Eugene, Springfield and other highly populated areas of Lane County are frequently impacted by smoke intrusions, a function of prevailing southerly winds and upper valley air stagnation. Surrounding communities of relatively lower population density, including Sweet Home, Mill City, and Harrisburg, among others, also suffer heavy intrusions because they are frequently in the pathway of the smoke plumes. Oregon's smoke management plan suffers the "critical defect" that it is virtually impossible to predict wind behavior over a period of a few hours and that "the outcome of any smoke management plan…comes down to a choice as to which group of people is going to be the target."[13]

Since 1990, in conjunction with the grass seed industry, the state has funded over $300,000 annually for research into alternatives to field burning.[14] The state has also provided tax credits for growers to purchase equipment to promote alternatives to burning.[15] Markets for grass seed straw and practical, reasonable alternatives to burning have been developed.[16] And yet, although state public policy is "to reduce the practice of open field burning while developing and providing alternative methods,"[17] the numbers of acres burned has remained virtually unchanged since 1998,[18] while the population in downwind towns and cities has increased.

State law prohibits Lane County and other local governments from directly protecting the health of their residents by barring regional agencies, including the Lane Regional Air Protection Agency (LRAPA), from issuing their own restrictions on field burning.[19] State law also requires that permits for burning "shall be issued and burning shall be allowed for the maximum acreage specified" in the statute.[20] However, as noted, the law also authorizes the EQC to order a temporary emergency cessation of the program upon a finding of extreme danger to public health or safety. ORS 468.610(9). We urge you to make the finding of a public health threat and

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[11] Oregon Department of Agriculture, Natural Resources Division, Smoke Management Program, *Summary of the 2006 Field Burning Season*, 7-8 (December 2006), www.oregon.gov/ODA/NRD/docs/pdf/smoke_fb_sum2006.pdf, (last visited January 26, 2007).

[12] LRAPA also reports that two-thirds of the complaints received by the Oregon Department of Agriculture are from the Eugene-Springfield areas and other parts of the southern Willamette Valley. LRAPA letter to Representative Paul Holvey, (November 15, 2006).

[13] Declaration of Eric Skelton, Director of the Spokane (WA) County Air Pollution Control Authority and National President of the Association of Local Air Pollution Control Officials, discussing Washington and Idaho Smoke Management Plan's impact on Spokane County. *Safe Air for Everyone v. Wayne Meyer, et al.*, Case # 02-0241N-EJL (June 1, 2002).

[14] ORS 468A.585; DEQ, DOA and DHS report, *supra.* note1.

[15] DEQ, DOA and DHS report, *supra* note 1..

[16] OSU Extension, *The Search for Solutions* (Jan. 1989); CH2M Hill, *Opportunities in Grass Straw Utilization* (Feb. 1991); USDA and OSU Agricultural Experiment Station, *Low-Input On-Farm Composting of Grass Straw Residue* (Oct. 1998).

[17] ORS 468A.555.

[18] *See* ORS 468A.610; and Oregon Department of Agriculture, *Summary of the 2006 Field Burning Season, supra* note 2, at 17.

[19] ORS 468A.595(4); Still, in light of LRAPA's mission "*{t}o protect public health, community well-being and the environment,*" the agency urged the legislature in 2006 to "craft legislation to eliminate the practice [of field burning] in the Willamette Valley at the earliest possible date." LRAPA Letter to Representative Paul Holvey (November 15, 2006).

[20] *See* ORS 468A.610 (2) and (8).

exercise your power under ORS 468A.610(9) as the most direct means of protecting Lane County residents and other Oregonians this summer and next.[21] We note, in addition, that the relevant statutes invest in the Commission authority and responsibility:

(1) To cease the issuance of burn permits after a hearing and then a finding that "other reasonable and economically feasible, environmentally acceptable alternatives have been developed." ORS 468A610(8)(b).

(2) To "prohibit, restrict or limit" field burning, by rule, if necessary to carry out the policy of ORS 468A.010. ORS 468A.595(1).

(3) To "provide for a more rapid phased reduction," again by rule, of field burning in Willamette Valley counties. ORS 468A.595(2).[22]

Such determinations and rules, all long overdue, must be undertaken with state public policy in mind to "restore and maintain the quality of the air resources of the state in a condition as free from air pollution as is practicable, consistent with the overall public welfare of the state." ORS 468A.010.[23] The full statutory scheme illustrates that state law places the Commission at the center of the decision-making process over whether Lane County and other state residents will be protected, both in the short-term and in the long-run, or whether they will suffer again and again from the ill effects of smoke incursions and related toxins that predictably attend the summer field burning program. However, because the burning season and its consequential danger to public health is nearly upon us, specific emergency action pursuant to ORS 468A.610(9) is needed as a first step. A commencement of rulemaking to permanently end this archaic and harmful practice is warranted, but an immediate moratorium now is needed to protect public health.

We have been informed, through the testimony of neighbors, physicians, and local leaders, letters in local papers, sentiment conveyed to state legislators, and the sharp upward trend in complaints compiled by the Oregon Department of Agriculture – 1,182 received from Willamette Valley residents in 2006, exceeding the 1,106 complaints received in 2005, 475 in 2004, 206 in 2003, 705 in 2002, and 608 in 2001[24] – that public patience with field burning has been exhausted. Willamette Valley residents have written recently of being driven from their homes during field burning season,[25] of smoke-induced tearing too severe to enable them to locate the proper number so as to call-in a complaint,[26] of concern that a loved one driving in smoke-darkened conditions would be in an accident,[27] of suffering chronic sinus infections,[28] of exacerbated asthma with each smoke intrusion,[29] of headaches and nosebleeds,[30] of swollen

[21] With Eugene hosting the U.S. Olympic Trials in 2008, more attention will be focused on Lane County air quality.
[22] The Commission is also obliged to provide for "a more rapid phased reduction" of burns in Multnomah, Washington, Clackamas, Marion, Polk, Yamhill, Linn, and Benton Counties. *See* ORS 468A.610 (2) and (8)..
[23] Toward that end, state and local government agencies are required to coordinate their air quality programs, working together to promote public welfare by restoring the air. *Id.*
[24] *Id.* at (8).
[25] Statement of Dixie Maurer-Clemons of Eugene (Mar. 1, 2007).
[26] Statement of Maxine Kovarik, Springfield (Feb. 27, 2007).
[27] Statement of Penny Spencer, Creswell (Mar. 2, 2007).
[28] Statement of Dorothy Bucher, Eugene (Feb. 24, 2007).
[29] Statement of Pam Perryman, Eugene (Feb. 10, 2007).
[30] Statement of Ronald and Doris Gates, Springfield (Feb. 1, 2007).

glands, wheezing, fatigue, and migraines,[31] of burning lungs,[32] of children battling bronchial and nasal congestion,[33] of black ash as big as a fist drifting into ones yard,[34] of being trapped at home during 90 degree weather without air conditioning, unable to open windows for fear of the smoke,[35] of smoke so thick it set off a school fire alarm,[36]of an elite track star coughing up blood after a meet that coincided with a burn day.[37] These are just a few of the examples of affects on the lives of Oregonians.

This year, the Lane County Board of Commissioners and citizens throughout the Willamette Valley urged the State Legislature to protect public health by ceasing the grass seed burning program. Toward that end, Representative Paul Holvey introduced HB 3000, a measure to end open field burning in Oregon. The measure was favorably reported out by the House Health Committee, but later held by the Agriculture Committee, without a vote, past the deadline for reporting measures to the House floor. We therefore appeal to the Commission almost as a last resort.

Action by the Commission to halt field burning would follow precedent established by the state of Washington. In 1996, the Washington Department of Ecology issued an emergency ruling that reduced the number of acres of grass fields that could be burned. A subsequent Washington State University report to the Department of Ecology's Air Quality Program concluded that the financial benefits of ending field burning, including reduced health care costs for the at-risk population of persons with existing cardiopulmonary conditions, would outweigh potentially reduced returns for growers.[38] In 1998, after The Department of Ecology concluded that mechanical residue management constitutes a practical alternative agricultural method for all phases of seed production, the agency banned open grass field burning.[39]

Moreover, grass seed field burning is illegal in Idaho. In 1972, Idaho submitted a State Implementation Plan (SIP) under the Clean Air Act, which stated, "No person shall allow, suffer, cause or permit any open burning operation which does not fall into at least one of the categories of Section 3." Field burning was included in the types of burning allowed by Section 3, but was significantly limited. In 1993, the Environmental Protection Agency (EPA) approved amendments to the Idaho SIP that contained a general prohibition on open air burning. In 2003, an amended SIP was filed, but did not change the language regarding the general prohibition to open air burning. In 2005, Idaho amended its SIP once again. This amendment would have permitted open burning of crop residue in agricultural fields. The Environmental Protection Agency approved Idaho's amendment of it's SIP, and a lawsuit was filed to contest the approval. The 9th Circuit Federal Court of Appeals reversed the EPA's approval of Idaho's SIP. The Court found that the approval was based on an erroneous premise that the preexisting Idaho SIP

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[31] Statement of Victoria Whitman, Eugene (Feb. 8, 2007).
[32] Statement of Jeff Wyman, Eugene (Mar. 8, 2007).
[33] Statement of Hewitt and Patricia Berrien, Eugene (Mar. 7, 2007).
[34] Statement of R. Gunn, East Marion County (Apr. 1, 2007).
[35] Statement of Terry Sitton, Sweet Home (Apr. 4, 2007).
[36] Statement of Steve Nielsen, Mill City (Apr. 6, 2007)
[37] Statement of Glen and Thoda Love, Eugene (Mar. 18, 2007).
[38] Estimates of the Benefits and Costs from Reductions in Grass Seed Field Burning (Dec. 27, 1996). In fact, revenues for the Washington Grass Seed industry have increased since the ban was imposed, just as in Oregon the grass seed industry has grown even as acreage burned declined from pre-1991 burn levels.
[39] RCW 70.94.656(3); WAC 173-430-045. The Department of Ecology is authorized to grant limited exceptions to allow open field burning only if a grower, among other things, "establishes that mechanical residue management is not reasonably available on specific portions of a field under specific production conditions due to slope."

did not ban field burning. The Court remanded the case to the EPA for it's consideration of Idaho's proposed amendment as a change in a preexisting SIP, rather than a clarification of the prior SIP. Therefore, at this time, open burning of crop residue is still illegal in Idaho. Evidence presented in that case demonstrated that field burning smoke inundates large portions of rural Idaho and surrounding states, that doctors regard the smoke to have severe consequences for individuals with respiratory ailments, that such persons have fled their homes during burning season, and that a coroner's report linked at least one fatality to field burning.[40]

These developments now leave Oregonians as the only Pacific Northwest residents without effective protection from grass seed field burning, despite suffering from many, if not all, of the same problems identified in Idaho and Washington.

On behalf of the public health of residents within and around the Willamette Valley – particularly those whose present medical conditions or age render them highly vulnerable to injuries that result from the inhalation of fine particulates and chemicals entrained in field burning smoke – we urge you to take prompt, decisive action. Specifically, we urge you now to make the finding that field burning presents an extreme danger to public health, and to order a temporary emergency cessation of the practice in the Willamette Valley at least through the summer of 2008.

If you do not find that there is an extreme danger, warranting an order to temporarily cease the practice of grass seed burning immediately, we would ask you to begin a rule adoption process for Lane County and the Southern Willamette Valley to phase in a reduction or elimination of open field burning pursuant to ORS 468A.595(2).

Thank you,

Faye Stewart, Chair
Lane County Board of Commissioners
Lane County Board of Health

[40] *Safe Air for Everyone v. US EPA*, No. 05-75269, 475 F.3d 1096, 1101(9th Cir. 2007), reaff'd 2007 WL 1531819 (9th Cir. May 29, 2007).

Commissioners:

Here is some background information from David Collier, Air Quality Manager, on field burning. This may be useful for you to read prior to the public forum, in anticipation of testimony from the Lane County Commission and the Western Environmental Law Center.

Helen

Fact Sheet

Open Field Burning In the Willamette Valley

State of Oregon
Department of Environmental Quality

Air Quality Division
Airshed Planning Program
811 SW 6th Avenue
Portland, OR 97204
Phone: (503) 229-6278
(800) 452-4011
Fax: (503) 229-5675
Contact: Brian Finneran
www.deq.state.or.us

Background

The Oregon Department of Agriculture (ODA) Smoke Management Program regulates the burning of up to 65,000 acres of annual and perennial grass seed crop residue and cereal grain residue within the Willamette Valley each summer.

Field burning disposes of leftover straw and stubble on fields after grass seed harvesting. It controls weeds, insects and plant diseases which helps maintain grass seed purity, reduces use of pesticides and herbicides, and improves yields. The practice began more than 50 years ago, with as much as 250,000 acres being burned in the mid-1980s.

A 1988 accident on Interstate 5 involving multiple cars and causing one fatality was attributed to decreased visibility due to field burning smoke. This led to passage of House Bill 3343, which called for the phase-down of field burning from 250,000 acres to the current 65,000 acres. Currently, the state's Smoke Management Program affords greatest protection to the Willamette Valley's major population centers, but offers lesser protection to some smaller population areas.

Quick Facts:

- *The phase-down of field burning occurred from 1991 to 1998, with the acreage limit reduced from 180,000 down to 40,000 acres. The current limit of 65,000 is based on 40,000 acres plus a 25,000-acre limitation for certain fire- dependent grass species and grasses grown on highly erodable soils on steep slopes.*
- *Although state law allows the burning of 65,000 acres, over the past five years actual burning has averaged about 50,000 acres.*
- *Field burning typically starts mid-July and ends mid-October, with a majority of burning in August/early September. Most fields are not burned every year.*
- *To avoid smoke impacts in populated areas, burning is permitted only after careful evaluation of weather conditions using the latest meteorological forecasting techniques.*
- *About 75% of all the acreage is burned on just 10 to 15 days during the summer.*
- *Currently there are about 150 growers who burn in the Willamette Valley.*
- *The Smoke Management Program is funded exclusively through grower fees.*
- *In 1995, ODA was directed by House Bill 3044 to operate the entire field burning program, through a contractual agreement with DEQ.*

Health effects from smoke

Field burning smoke is comprised of several pollutants that have the potential to cause health problems, depending on the level and duration of exposure. Field burning smoke contains fine particulate matter, which can be inhaled deep into the lungs. In addition, field burning smoke contains carbon monoxide and carcinogenic compounds such as polycyclic aromatic hydrocarbons, benzene, aldehydes and metals.

While efforts are made to conduct burning under optimum smoke dispersal conditions, some field burning smoke impacts do occur. However, these impacts rarely cause air quality to exceed the federal fine particulate health standard. This is because most field burning smoke impacts are of relatively short duration, and occur during the summer months, when particulate air pollution levels are generally much lower than they are in winter months.

Although field burning is unlikely to cause violations of federal health standards, exposure to field burning smoke can still pose health risks. Short-term exposure can cause health problems for people with pre-existing respiratory problems (e.g., asthma, bronchitis and chronic obstructive pulmonary disease), or to sensitive populations such as young children and the elderly.

For the general public, short-term exposure to smoke may result in eye irritation, scratchy throat, runny nose, headaches, and allergic reactions. While little is known about the long-term health effects from exposure to field burning smoke, some research has shown health effects can range from reduced lung function to development of chronic bronchitis, and even premature death.

The Oregon Department of Agriculture, in conjunction with researchers at Oregon State University, is currently planning to conduct a

Oregon Department of Agriculture

For more information:
ODA Smoke Management Program, Salem:
http://oregon.gov/ODA/NRD/smokefrontpage.shtml
(503) 986-4701

DHS
Oregon Department of Human Services
Contact: Ken Kauffman, Portland, (971) 673-0435

Alternative formats:
Alternative formats (Braille, large type) of this document can be made available. Contact DEQ's Office of Communications & Outreach, Portland, (503) 229-5696 (toll-free in OR at 1-800-452-4011, x5696)

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By: Brian White

human health risk assessment of field burning in the Willamette Valley. This assessment will help characterize exposure and risk in affected communities.

Visibility effects from smoke

In addition to health effects, smoke can affect outdoor recreation activities and impair visibility or the ability to view nearby mountains and other scenic areas. Federal visibility protection rules require states to adopt smoke management plans that address outdoor burning practices like field burning and forestry burning.

The phase down in Willamette Valley field burning over the years has led to some improvements in summertime visibility in Oregon's wilderness areas and Crater Lake National Park. This improvement can also be attributed to weekend restrictions on field burning, which are in place from July 1 through Sept. 15, to protect visibility in the Oregon Cascades during the highest visitation and recreation use period.

Alternatives to field burning

In addition to smoke management, ODA manages research and development into alternatives. This includes finding ways to maintain high yields without burning, straw removal and marketing, and alternative crops. Alternatives to field burning are currently practiced throughout the Willamette Valley. These include crop rotation, chemical applications, straw removal and propane flaming. The baling and selling of grass seed straw has become an important agricultural commodity. The straw is sold all over the world as an animal feed supplement and for other uses.

Grant funding from ODA and the Oregon Seed Council (OSC) is used for research into alternatives to field burning. In 2006, ODA and OSC distributed approximately $370,000 for "Alternatives to Field Burning" research projects. ODA and OSC have funded an average of $319,000 annually in research projects since the 1999-2000 funding cycle. State tax credits are also used to provide equipment and infrastructure to promote alternatives to burning.

Minimizing smoke impacts from burning

For the 65,000 acres currently allowed for burning, ODA controls the time, amount and location of burning in order to avoid smoke intrusions into cities or impacts on the public. The best conditions for burning are when smoke rises to high elevations, disperses, and is transported away from major populated areas. This practice makes the smoke plume visible from long distances, often causing public reaction and complaints, but actually minimizes ground smoke impacts to the public.

Quick facts:

- *Growers are required to register their fields and obtain burn permits. Permits require being able to light a field within one hour. This helps ensure that the burning takes place when conditions are still favorable.*
- *Growers must follow specific burning instructions issued by ODA. ODA also maintains an enforcement program which can result in fines for violations of program rules.*
- *Growers must also meet fire safety requirements set by the State Fire Marshal.*
- *ODA uses state-of-the-art weather forecasting techniques and computer models to determine geographic locations where fields can be ignited to minimize the smoke impact on the public.*
- *Other elements of the program include a network of air monitors placed in major population centers throughout the Willamette Valley, to track air quality and smoke impacts.*
- *The program is staffed full-time by a program manager, program coordinator and meteorologist. Seasonally, the program employs two inspectors and two field coordinators.*

Complaints about field burning

ODA operates two field burning complaint lines, which are available to the public year-round. The Salem number is for callers in the north Willamette Valley; the Eugene number is for callers in the south portion of the Valley.

Salem Complaint Line: (503) 986-4709
Eugene Complaint Line: (541) 686-7600

Comments and complaints provide supplemental information on the extent and location of smoke problems. Callers may receive a tape recording asking the caller to leave a message describing the smoke problem. Complaints are compiled weekly and reported to the Governor's Office. In 2006, ODA received 1,182 complaints, up slightly from 2005's total of 1,106. In previous years the numbers of complaints were as follows: 2004 (275), 2003 (206), 2002 (705), 2001 (608).

468A.550 Definitions for ORS 468A.555 to 468A.620 and 468A.992. (1) As used in ORS 468A.555 to 468A.620 and 468A.992:

(a) "Research and development of alternatives to field burning" includes, but is not limited to, projects concerned with cultural practices for producing grass seed without field burning, environmental impacts of alternative seed production methods, straw marketing and utilization and alternative crops.

(b) "Smoke management" means the daily control of the conducting of open field burning to such times and places and in such amounts so as to provide for the escape of smoke and particulate matter therefrom into the atmosphere with minimal intrusion into cities and minimal impact on public health and in such a manner that under existing meteorological conditions a maximum number of acres registered can be burned in a minimum number of days without substantial impairment of air quality.

(c) "Smoke management program" means a plan or system for smoke management. A smoke management program shall include, but not be limited to, provisions for:

(A) Annual inventorying and registering, prior to the burning season, of agricultural fields for open field burning;

(B) Preparation and issuance of open field burning permits by affected governmental agencies;

(C) Gathering and disseminating regional and sectional meteorological conditions on a daily or hourly basis;

(D) Scheduling times, places and amounts of agricultural fields that may be open burned daily or hourly, based on meteorological conditions during the burning season;

(E) Conducting surveillance and gathering and disseminating information on a daily or more frequent basis;

(F) Effective communications between affected personnel during the burning season; and

(G) Employment of personnel to conduct the program.

(2) As used in this section, "open field burning" does not include propane flaming of mint stubble or stack or pile burning of residue from Christmas trees, as defined in ORS 571.505. [Formerly 468.453; 1997 c.473 §3; 1999 c.439 §2; 2001 c.70 §1]

468A.555 Policy to reduce open field burning. The Legislative Assembly declares it to be the public policy of this state to reduce the practice of open field burning while developing and providing alternative methods of field sanitization and alternative methods of utilizing and marketing crop residues. [1991 c.920 §3]

468A.560 Applicability of open field burning, propane flaming and stack and pile burning statutes. (1) Except for the fee imposed under ORS 468A.615 (1)(c), the provisions of ORS 468A.550 to 468A.620 and 468A.992 shall apply only to open field burning, propane flaming and stack or pile burning of grass seed or cereal grain crop residues on acreage located in the counties specified in ORS 468A.595 (2).

(2) Nothing in this section shall apply to the propane flaming of mint stubble. [1991 c.920 §2; 1997 c.473 §4]

468A.565 Use of certified alternative thermal field sanitizer. Notwithstanding any provision of ORS 468A.550 to 468A.620 and 468A.992, any acreage sanitized by the use of an alternative thermal field sanitizer certified by the Environmental Quality Commission and the Director of Agriculture shall be exempt from the provisions of ORS 468A.550 to 468A.620 and 468A.992. [1991 c.920 §5]

468A.570 Classification of atmospheric conditions; marginal day. (1) As used in this section:

(a) "Marginal conditions" means atmospheric conditions such that smoke and particulate matter escape into the upper atmosphere with some difficulty but not such that limited additional smoke and particulate matter would constitute a danger to the public health and safety.

(b) "Marginal day" means a day on which marginal conditions exist.

(2) For purposes of ORS 476.380 and 478.960, the Environmental Quality Commission shall classify different types or combinations of atmospheric conditions as marginal conditions and shall specify the extent and types of burning that may be allowed under different combinations of atmospheric conditions. A schedule describing the types and extent of burning to be permitted on each type of marginal day shall be prepared and circulated to all public agencies responsible for providing information and issuing permits under ORS 476.380 and 478.960. The schedule shall give first priority to the burning of perennial grass seed crops used for grass seed production, second priority to annual grass seed crops used for grass seed production, third priority to grain crop burning, and fourth priority to all other burning and shall prescribe duration of periods of time during the day when burning is authorized.

(3) In preparing the schedule under subsection (2) of this section, the commission shall provide for the assignment of fourth priority burning by the State Department of Agriculture in accordance with the memorandum of understanding established pursuant to ORS 468A.585.

(4) In preparing the schedule required under subsection (2) of this section, the commission shall weigh the economic consequences of scheduled burnings and the feasibility of alternative actions, and shall consider weather conditions and other factors necessary to protect the public health and welfare.

(5) None of the functions of the commission under this section or under ORS 476.380 or 478.960, as it relates to agricultural burning, shall be performed by any regional air quality control authority established under ORS 468A.105. [1991 c.920 §6]

468A.575 Permits for open burning, propane flaming or stack or pile burning. (1) Permits for open burning, propane flaming or stack or pile burning of the residue from perennial grass seed crops, annual grass seed crops and cereal grain crops are required in the counties listed in ORS 468A.595 (2) and shall be issued in accordance with rules adopted by the Environmental Quality Commission and subject to the fee prescribed in ORS 468A.615. The permit described in this section shall be issued in conjunction with permits required under ORS 476.380 or 478.960.

(2) By rule the Environmental Quality Commission may delegate to any county court, board of county commissioners, fire chief of a rural fire protection district or other responsible person the duty to deliver permits to burn acreage if the acreage has been

registered under ORS 468A.615 and fees have been paid as required in ORS 468A.615. [1991 c.920 §7]

468A.580 Permits; inspections; planting restrictions. (1) Permits under ORS 468A.575 for open field burning of cereal grain crops shall be issued in the counties listed in ORS 468A.595 (2) only if the person seeking the permit submits to the issuing authority a signed statement under oath or affirmation that the acreage to be burned will be planted to seed crops other than cereal grains which require flame sanitation for proper cultivation.

(2) The Department of Environmental Quality shall inspect cereal grain crop acreage burned under subsection (1) of this section after planting in the following spring to determine compliance with subsection (1) of this section.

(3) Any person planting contrary to the restrictions of subsection (1) of this section shall be assessed by the department a civil penalty of $25 for each acre planted contrary to the restrictions. Any fines collected by the department under this subsection shall be deposited by the State Treasurer in the Department of Agriculture Service Fund to be used in carrying out the smoke management program in cooperation with the Oregon Seed Council and for administration of this section.

(4) Any person planting seed crops after burning cereal grain crops under subsection (1) of this section may apply to the department for permission to plant contrary to the restrictions of subsection (1) of this section if the seed crop fails to grow. The department may allow planting contrary to the restrictions of subsection (1) of this section if the crop failure occurred by reasons other than the negligence or intentional act of the person planting the crop or one under the control of the person planting the crop. [1991 c.920 §8]

468A.585 Memorandum of understanding with Department of Agriculture. (1) The Environmental Quality Commission shall enter into a memorandum of understanding with the State Department of Agriculture that provides for the State Department of Agriculture to operate all of the field burning program.

(2) Subject to the terms of the memorandum of understanding required by subsection (1) of this section, the State Department of Agriculture:

(a) May perform any function of the Environmental Quality Commission or the Department of Environmental Quality relating to the operation and enforcement of the field burning smoke management program.

(b) May enter onto and inspect, at any reasonable time, the premises of any person conducting an open field burn to ascertain compliance with a statute, rule, standard or permit condition relating to the field burning smoke management program.

(c) May conduct a program for the research and development of alternatives to field burning. [1991 c.920 §4; 1995 c.358 §3; 2001 c.70 §2]

468A.590 Duties of Department of Agriculture. Pursuant to the memorandum of understanding established under ORS 468A.585, the State Department of Agriculture:

(1) Shall:

(a) Conduct the smoke management program established by rule by the Environmental Quality Commission as it pertains to open field burning, propane flaming and stack or pile burning.

(b) Aid fire districts and permit agents in carrying out their responsibilities for administering field sanitization programs.

(c) Subject to available funding, conduct a program for the research and development of alternatives to field burning.

(2) May:

(a) Enter into contracts with public and private agencies to carry out the purposes set forth in subsection (1) of this section;

(b) Obtain patents in the name of the State of Oregon and assign such rights therein as the State Department of Agriculture considers appropriate;

(c) Employ personnel to carry out the duties assigned to it; and

(d) Sell and dispose of all surplus property of the State Department of Agriculture related to smoke management, including but not limited to straw-based products produced or manufactured by the State Department of Agriculture. [1991 c.920 §9; 2001 c.70 §3]

468A.595 Commission rules to regulate burning pursuant to ORS 468A.610. In order to regulate open field burning pursuant to ORS 468A.610:

(1) In such areas of the state and for such periods of time as it considers necessary to carry out the policy of ORS 468A.010, the Environmental Quality Commission by rule may prohibit, restrict or limit classes, types and extent and amount of burning for perennial grass seed crops, annual grass seed crops and grain crops.

(2) In addition to but not in lieu of the provisions of ORS 468A.610 and of any other rule adopted under subsection (1) of this section, the commission shall adopt rules for Multnomah, Washington, Clackamas, Marion, Polk, Yamhill, Linn, Benton and Lane Counties, which provide for a more rapid phased reduction by certain permit areas, depending on particular local air quality conditions and soil characteristics, the extent, type or amount of open field burning of perennial grass seed crops, annual grass seed crops and grain crops and the availability of alternative methods of field sanitation and straw utilization and disposal.

(3) Before promulgating rules pursuant to subsections (1) and (2) of this section, the commission shall consult with Oregon State University and may consult with the United States Natural Resources Conservation Service, or its successor agency, the Agricultural Stabilization Commission, the state Soil and Water Conservation Commission and other interested agencies. The Department of Environmental Quality shall advise the commission in the promulgation of such rules. The commission must review and show on the record the recommendations of the department in promulgating such rules.

(4) No regional air quality control authority shall have authority to regulate burning of perennial grass seed crops, annual grass seed crops and grain crops.

(5) Any amendments to the State Implementation Plan prepared by the state pursuant to the federal Clean Air Act, as enacted by Congress, December 31, 1970, and as amended by Congress August 7, 1977, and November 15, 1990, and Acts amendatory thereto shall be only of such sufficiency as to gain approval of the amendment by the United States Environmental Protection Agency and shall not include rules promulgated by the commission pursuant to subsection (1) of this section not necessary for attainment of national ambient air quality standards. [Formerly 468.460; 1997 c.249 §163]

468A.597 Duty to dispose of straw. Unless otherwise specifically agreed by the parties, after straw is removed from the fields of the grower, the responsibility for the further disposition of the straw, including burning or disposal, shall be upon the person who bales or removes the straw. [1993 c.414 §2]

468A.600 Standards of practice and performance. The Environmental Quality Commission shall establish standards of practice and performance for open field burning, propane flaming, stack or pile burning and certified alternative methods to open field burning. [1991 c.920 §10]

468A.605 Duties of Department of Environmental Quality. The Department of Environmental Quality, in coordinating efforts under ORS 468.140, 468.150, 468A.020, 468A.555 to 468A.620 and 468A.992, shall:

(1) Enforce all field burning rules adopted by the Environmental Quality Commission and all related statutes; and

(2) Monitor and prevent unlawful field burning. [1991 c.920 §11; 1995 c.358 §4]

468A.610 Reduction in acreage to be open burned, propane flamed or stack or pile burned. (1) Except as provided under ORS 468A.620, no person shall open burn or cause to be open burned, propane flamed or stack or pile burned in the counties specified in ORS 468A.595 (2), perennial or annual grass seed crop or cereal grain crop residue, unless the acreage has been registered under ORS 468A.615 and the permits required by ORS 468A.575, 476.380 and 478.960 have been obtained.

(2) The maximum total registered acreage allowed to be open burned per year pursuant to subsection (1) of this section shall be:

(a) For 1991, 180,000 acres.

(b) For 1992 and 1993, 140,000 acres.

(c) For 1994 and 1995, 120,000 acres.

(d) For 1996 and 1997, 100,000 acres.

(e) For 1998 and thereafter, 40,000 acres.

(3) The maximum total acreage allowed to be propane flamed under subsection (1) of this section shall be:

(a) In 1991 through 1997, 75,000 acres per year; and

(b) In 1998 and thereafter, 37,500 acres per year may be propane flamed.

(4)(a) After January 1, 1998, fields shall be prepared for propane flaming by removing all loose straw or vacuuming or prepared using other techniques approved by rule by the Environmental Quality Commission.

(b) After January 1, 1998, propane equipment shall satisfy best available technology.

(5) Notwithstanding the limitations set forth in subsection (2) of this section, in 1991 and thereafter, a maximum of 25,000 acres of steep terrain and species identified by the Director of Agriculture by rule may be open burned and shall not be included in the maximum total permitted acreage.

(6) Acreage registered to be open burned under this section may be propane flamed at the registrant's discretion without reregistering the acreage.

(7) In the event of the registration of more than the maximum allowable acres for open burning in the counties specified in ORS 468A.595 (2), after 1996, the commission,

after consultation with the State Department of Agriculture, by rule or order may assign priority of permits based on soil characteristics, the crop type, terrain or drainage.

(8) Permits shall be issued and burning shall be allowed for the maximum acreage specified in subsection (2) of this section unless:

(a) The daily determination of suitability of meteorological conditions, regional or local air quality conditions or other burning conditions requires that a maximum number of acres not be burned on a given day; or

(b) The commission finds after hearing that other reasonable and economically feasible, environmentally acceptable alternatives to the practice of annual open field burning have been developed.

(9) Upon a finding of extreme danger to public health or safety, the commission may order temporary emergency cessation of all open field burning, propane flaming or stack or pile burning in any area of the counties listed in ORS 468A.595 (2).

(10) The commission shall act on any application for a permit under ORS 468A.575 within 60 days of registration and receipt of the fee required under ORS 468A.615. The commission may order emergency cessation of open field burning at any time. Any other decision required under this section must be made by the commission on or before June 1 of each year. [1991 c.920 §12; 1995 c.358 §5]

468A.615 Registration of acreage to be burned; fees. (1)(a) On or before April 1 of each year, the grower of a grass seed crop shall register with the county court or board of county commissioners, the fire chief of a rural fire protection district, the designated representative of the fire chief or other responsible persons the number of acres to be open burned or propane flamed in the remainder of the year. At the time of registration, the Department of Environmental Quality shall collect a nonrefundable fee of $2 per acre registered to be sanitized by open burning or $1 per acre to be sanitized by propane flaming. The department may contract with counties and rural fire protection districts or other responsible persons for the collection of the fees which shall be forwarded to the department. Any person registering after April 1 of each year shall pay an additional fee of $1 per acre registered if the late registration is due to the fault of the late registrant or one under the control of the late registrant. Late registrations must be approved by the department. Copies of the registration form shall be forwarded to the department. The required registration must be made and the fee paid before a permit shall be issued under ORS 468A.575.

(b) Except as provided in paragraph (d) of this subsection, the department shall collect a fee in accordance with paragraph (c) of this subsection for issuing a permit for open burning, propane flaming or stack or pile burning of perennial or annual grass seed crop or cereal grain crop residue under ORS 468A.555 to 468A.620 and 468A.992. The department may contract with counties and rural fire protection districts or other responsible persons for the collection of the fees which shall be forwarded to the department.

(c) The fee required under paragraph (b) of this subsection shall be paid within 10 days after a permit is issued and shall be:

(A) $8 per acre of crop sanitized by open burning in the counties specified in ORS 468A.595 (2);

(B) $4 per acre of perennial or annual grass seed crop sanitized by open burning in any county not specified in ORS 468A.595 (2);

~~(C) $2 per acre of crop sanitized by propane flaming;~~

(D) For acreage from which 100 percent of the straw is removed and burned in stacks or piles:

(i) $2 per acre from January 1, 1992, to December 31, 1997;

(ii) $4 per acre in 1998;

(iii) $6 per acre in 1999;

(iv) $8 per acre in 2000; and

(v) $10 per acre in 2001 and thereafter; and

(E) For acreage from which less than 100 percent of the straw is removed and burned in stacks or piles, the same per acre as the fee imposed under subparagraph (D) of this paragraph, but with a reduction in the amount of acreage for which the fee is charged by the same percentage as the reduction in the amount of straw to be burned.

(d) The fee required by paragraph (b) of this subsection shall not be charged for any acreage where efficient burning of stubble is accomplished with equipment certified by the department for field sanitizing purposes or with any other certified alternative method to open field burning, propane flaming or stack or pile burning. The fee required by paragraph (b) of this subsection shall not be charged for any acreage not harvested prior to burning or for any acreage not burned.

(2) All fees collected under this section shall be deposited in the State Treasury to the credit of the Department of Agriculture Service Fund. Such moneys are continuously appropriated to the State Department of Agriculture for the purpose of carrying out the duties and responsibilities carried out by the State Department of Agriculture pursuant to the memorandum of understanding established under ORS 468A.585.

(3) It is the intention of the Legislative Assembly that the programs for smoke management, air quality monitoring and the enforcement of rules under ORS 468A.550 to 468A.620 and 468A.992 be operated in a manner that maximizes the resources available for the research and development program. Therefore, with regard to the disbursement of funds collected under subsection (1) of this section, the State Department of Agriculture shall act in accordance with the intent of the Legislative Assembly and shall:

(a) Pay an amount to the county or board of county commissioners or the fire chief of the rural fire protection district or other responsible person, for each fire protection district, $1 per acre registered for each of the first 5,000 acres registered for open field burning and propane flaming in the district, 75 cents per acre registered for each of the second 5,000 acres registered in the district and 35 cents per acre registered for all acreage registered in the district in excess of 10,000 acres, to cover the cost of and to be used solely for the purpose of administering the program of registration of acreage to be burned, issuance of permits, keeping of records and other matters directly related to agricultural field burning. For each acre from which straw is removed and burned in stacks or piles, the State Department of Agriculture shall pay to the county or board of county commissioners, or the fire chief of the rural fire protection district or other responsible person, 25 cents per acre.

(b) Designate an amount to be used for the smoke management program. The State Department of Agriculture by contract with the Oregon Seed Council or otherwise shall organize rural fire protection districts and growers, coordinate and provide communications, hire ground support personnel, provide aircraft surveillance and provide such added support services as are necessary.

(c) Retain funds for the operation and maintenance of the Willamette Valley field burning air quality impact monitoring network and to insure adequate enforcement of rules established by the Environmental Quality Commission governing standards of practice for open field burning, propane flaming and stack or pile burning.

(d) Of the remaining funds, designate an amount to be used for additional funding for research and development proposals described in the plan developed pursuant to section 15, chapter 920, Oregon Laws 1991. [1991 c.920 §13; 1993 c.414 §3; 1995 c.79 §285; 1995 c.358 §6]

468A.620 Experimental field sanitization; rules. (1) Notwithstanding the provisions of ORS 468A.610, for the purpose of improving by demonstration or investigation the environmental or agronomic effects of alternative methods of field sanitization, the Environmental Quality Commission shall by rule allow experimental field sanitization under the direction of the Department of Environmental Quality for up to 1,000 acres of perennial grass seed crops, annual grass seed crops and grain crops in such areas and for such periods of time as it considers necessary. Experimental field sanitization includes but is not limited to:

(a) Development, demonstration or training personnel in the use of special or unusual field ignition techniques or methodologies.

(b) Setting aside times, days or areas for special studies.

(c) Operation of experimental mobile field sanitizers and improved propane flaming devices.

(d) Improved methods of stack or pile burning.

(2) The commission may allow open burning under this section of acreage for which permits have not been issued under ORS 468A.610 if the commission finds that the experimental burning:

(a) Can, in theory, reduce the adverse effects on air quality or public health from open field burning; and

(b) Is necessary in order to obtain information on air quality, public health or the agronomic effects of an experimental form of field sanitization.

(3) The commission may, by rule, establish fees, registration requirements and other requirements or limitations necessary to carry out the provisions of this section. [1991 c.920 §14]