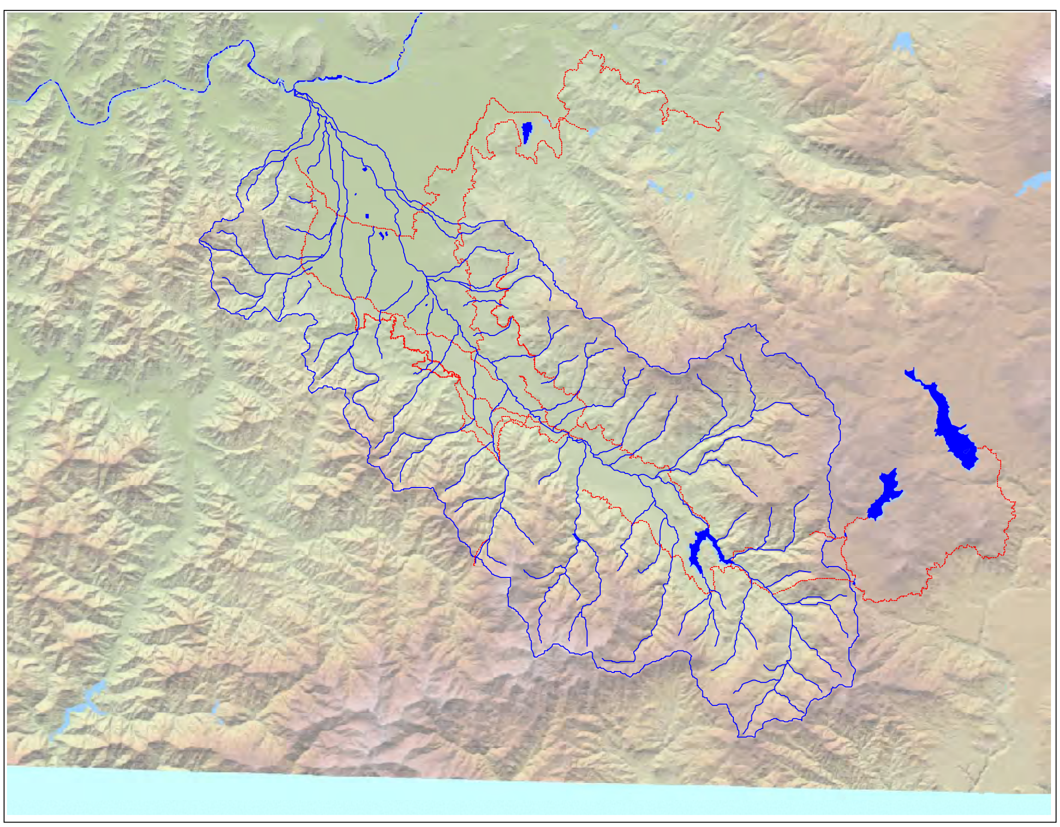
Appendix A

Bear Creek Watershed Temperature Assessment

Prepared by
Oregon Department of Environmental Quality

Bear Creek Watershed Temperature Modeling Appendix

October 2006



Introduction

Purpose

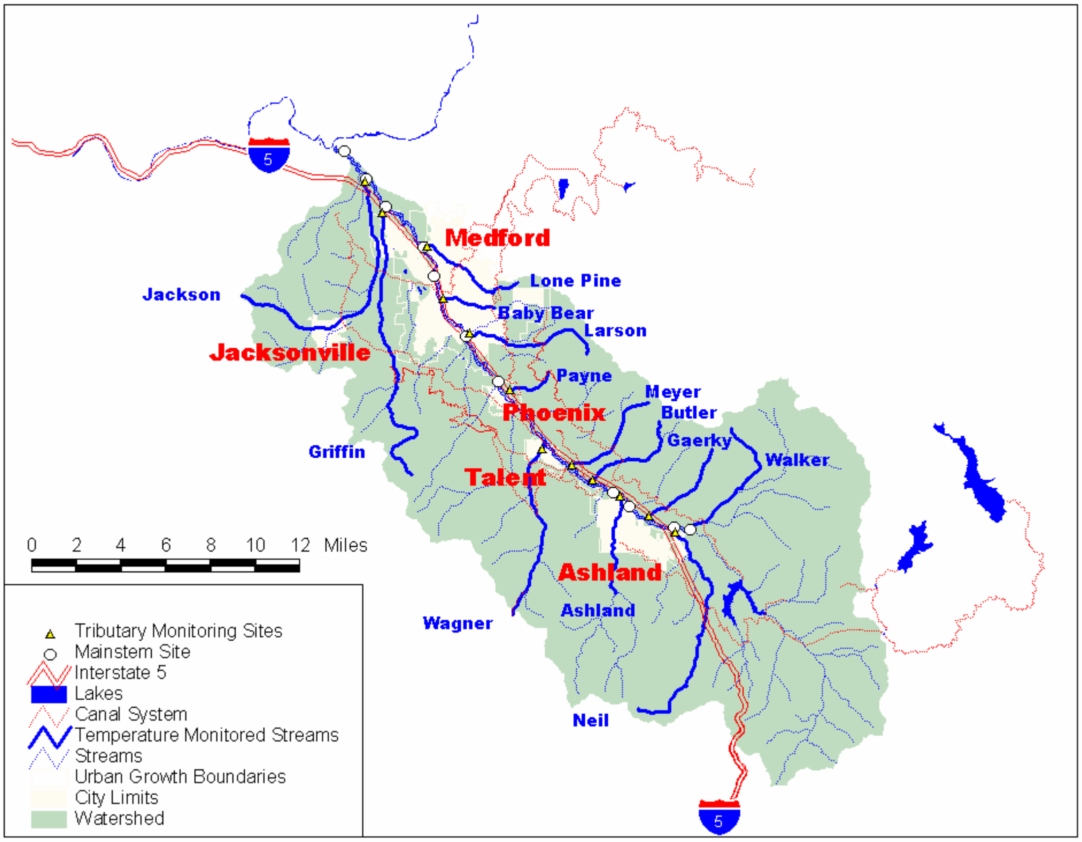
Field measured data was used to calibrate the *Heat Source 6.0* stream temperature model (Boyd, M. and B. Kasper. 2003). The Heat Source model has the ability to predict changes in water temperature resulting from changes in stream morphology and landscape conditions. As a result it is being utilized as a tool to estimate the potential of a stream to attain the temperature criteria. An in-depth analysis of the ability of a stream to attain water quality criteria is a required component of a TMDL.

The Bear Creek model was calibrated using data collected on August 2nd and 3rd, 1999. The model uses field measurements and model-derived parameters as inputs to simulate how stream temperatures respond to changed conditions within the watershed. Once the model parameters have been balanced so that the simulation accurately describes the current temperature conditions measured in the field (the calibration step), the conditions within the watershed are changed and input into the model. The model re-summates the amount of energy reaching the stream and re-calculates stream temperatures based on those changed conditions.

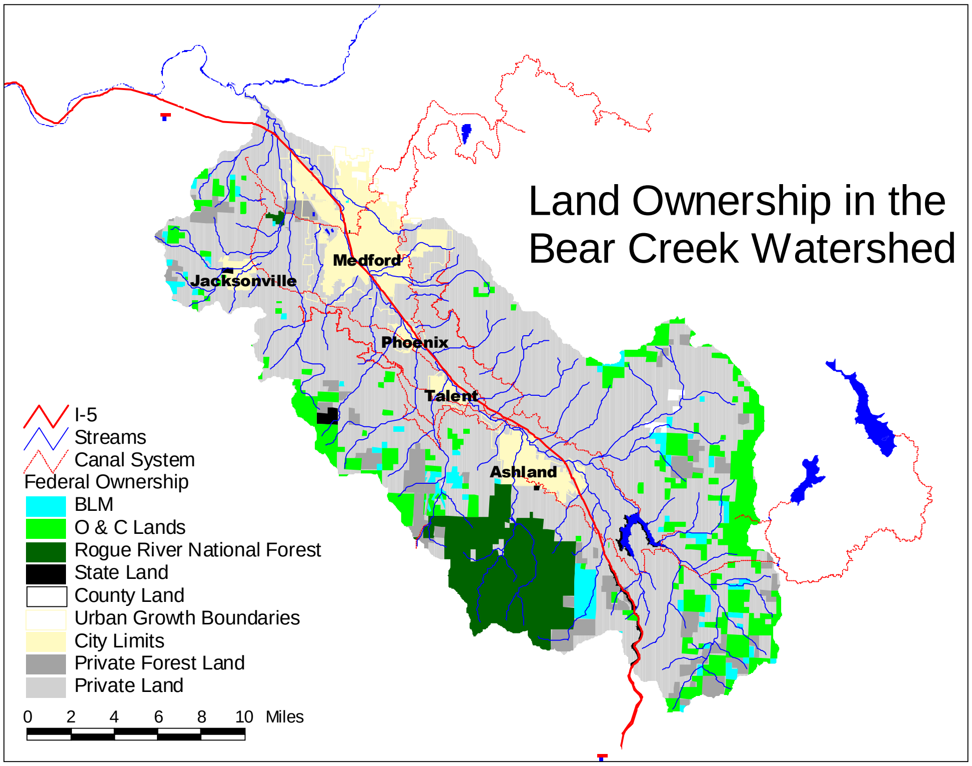
Area Modeled

The Bear Creek modeled reach begins at the confluence of Walker and Emigrant Creeks and extends to the confluence of Bear Creek and the Rogue River, a distance of 27.5 miles. It is broken up into four hundred and forty five 100 meter segments. Twelve tributaries had temperature data and flow volume measured at their confluence with Bear Creek. The Bear Creek mainstem had 11 sites where both temperature and flow were measured (Map 1). Map 2 shows detailed ownership for the Bear Creek Watershed.

Map 1 Bear Creek Data Sites



Map 2. Bear Creek Ownership



Note: Both O&C Lands and BLM Lands are managed by BLM.

Methods for Field Data Collection

<u>Temperature Sets</u>

Instantaneous stream temperatures were taken throughout the summer of 1999 at 23 sites (11 mainstem and 12 tributary). Each data logger recorded two temperature values per hour (1/2 hour interval). Data sets for August 3, 1999 were thinned to 24 observations; the value closest to the top of the hour was used.

<u>Stream Discharge Measurements</u>

Flow measurements were taken at 24 sites in the Bear Creek Watershed. Measurement transacts were chosen in areas with wadeable cross-sections and good stream velocities. Each transect consisted of a minimum of 10 individual measurements. The model was calibrated for conditions on August 3rd, 1999, the day when most flow measurements were taken. All flow measurements used in the model were taken on either August 2nd or August 3rd of 1999.

<u>Stream/Shade Conditions</u>

Riparian characteristics relating to shade quality and quantity were measured from aerial photography, digital imagery, and on site field measurements. The shading values so calculated were: shade height, shade width, shade density, and shade overhang. Values assumed for the site potential vegetation conditions were based on forest characteristics appropriate to the Bear Creek ecoregion, given the soil class, species composition and expected tree density. Channel wetted widths and the near stream disturbance zone were measured via field observations and from digital aerial photos. Riparian and shade characteristics are summarized in the TMDL Assessment Report: Riparian Shade Bear Creek OR. (DEQ, 2000)

Weather Data

All weather data came from the station at the OSU Extension facility, Hanley Road, Central Point. Weather data can be extremely limiting during the calibration process. Weather conditions can be highly variable and site specific throughout the landscapes included in this modeling exercise. Weather conditions at some sites and times were changed to improve the fit of the model calibration.

Model Inputs

Elevation/Gradient

Elevations were obtained from digital elevation information (Digital Elevation Model - DEM - type data). The elevation of each reach break was derived from the DEM. These elevations were related to the elapsed reach lengths so that gradient profiles could also be calculated (Figures 1 & 2).

Figure 1 Average Gradient Bear Creek

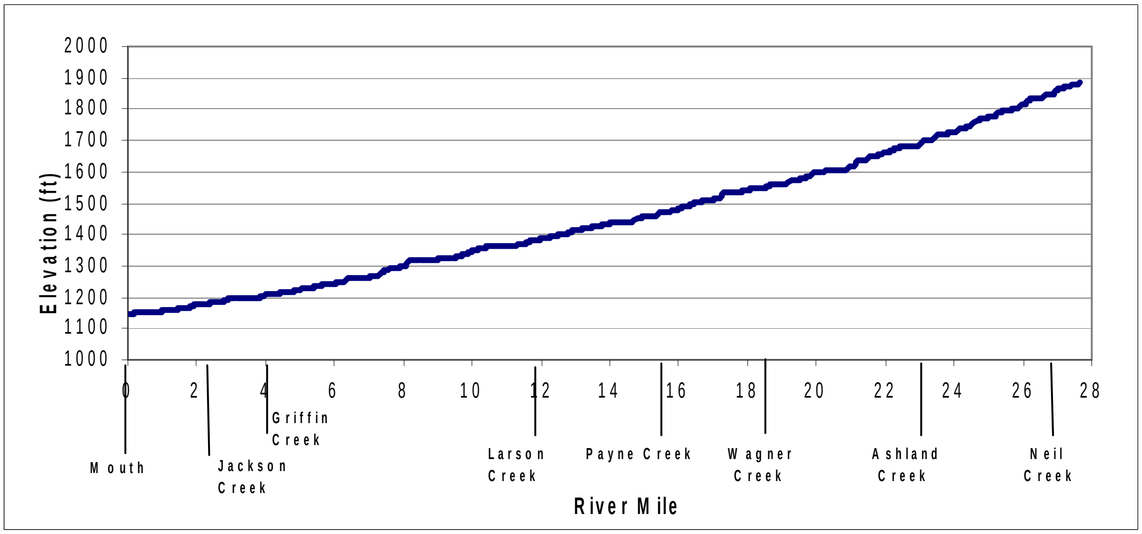
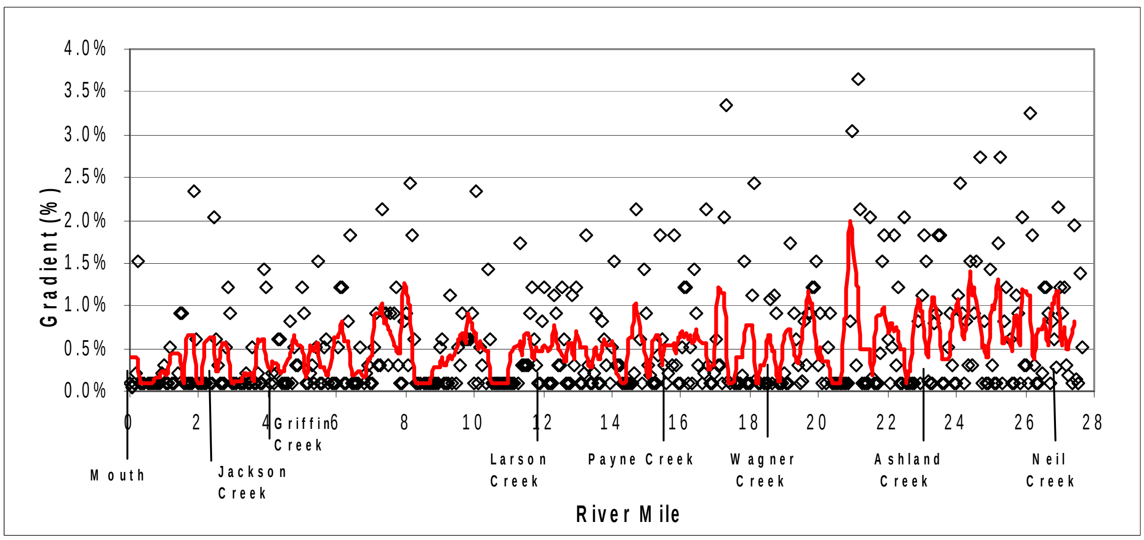


Figure 2 Bear Creek running 5-data-point-average gradient

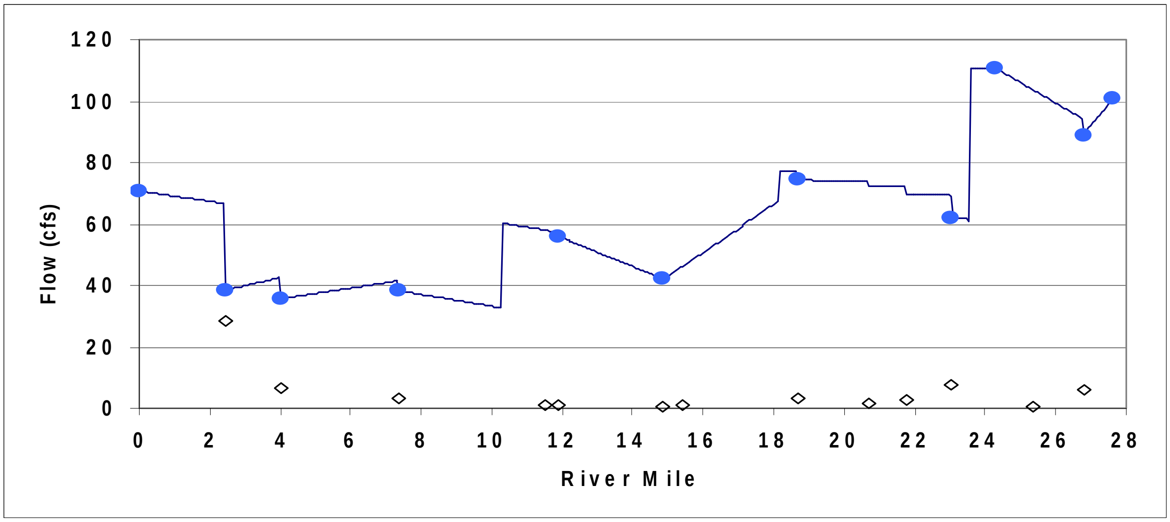


Note: *Points show individual reach gradients, the line shows the running 5-data-point-average gradient.*

<u>Flow Volume</u>

Flow was measured at the sites shown in Map 1. Between points of field-measurement, flow values are interpolated. The complete flow profile as determined for August 3, 1999 is presented in Figure 3 (Blue Circles). The open diamonds show tributary flows into Bear Creek.

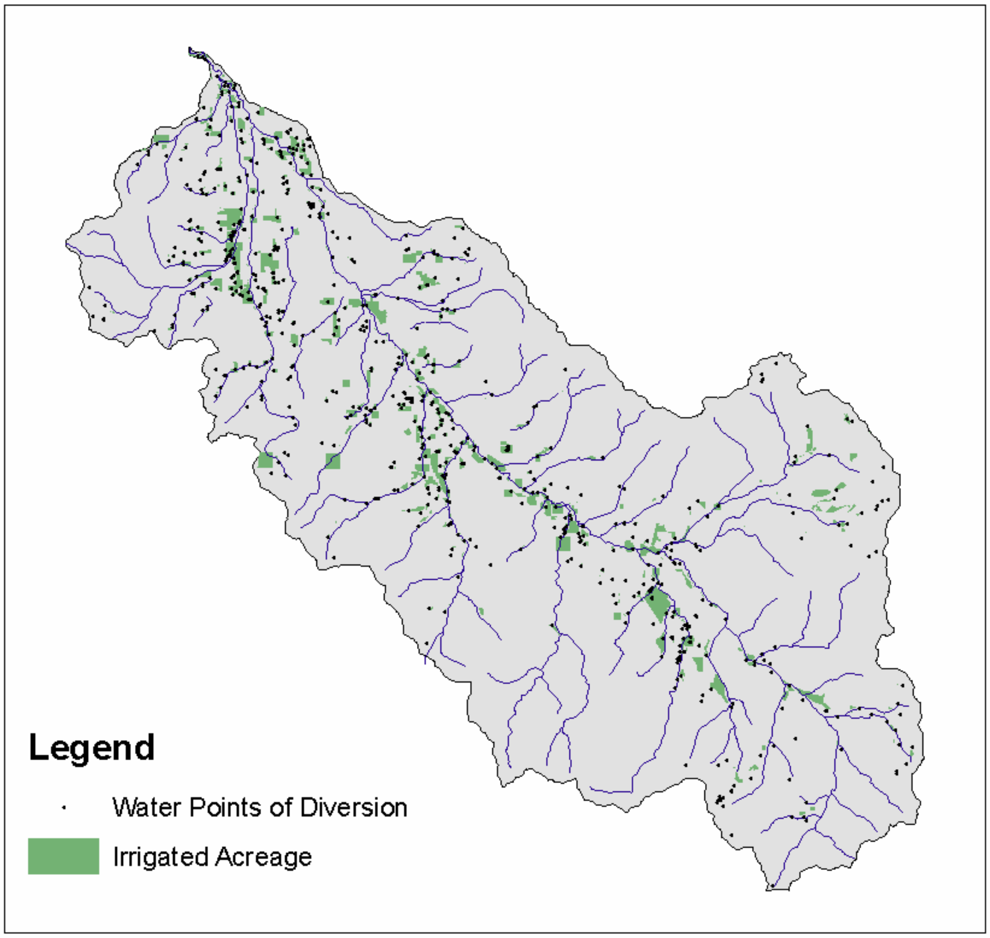
Figure 3 Bear Creek Current Flow August 3, 1999



The movement of irrigation water down the Bear Creek system has a tremendous effect on flow volume in the mainstem. Irrigation needs, in particular that three large irrigation districts in the valley (TID, MID, RRVID) remove large percentages of Bear Creek flow at the heads of their systems. Bear Creek has approved surface water withdrawal rights at 421 locations (Map 3), many of them are very senior rights (Over 50 water rights pre-date Oregon statehood in 1859).

On the day modeled August 3, 1999, it was unknown which diversions were actively diverting water. Diversions could have been diverting their full allocation or a fraction of that allocation. Likewise the impact of return flows back into Bear Creek on the day modeled is also unknown. Return flows may be steady or variable throughout the day. It is simply not possible to characterize the flow volume of each and every diversion and return in the Bear Creek system by field measurement. Because of this, it is important to realize that any HeatSouce simulation of current conditions relies on a greatly simplified flow scenario.

Map 3 Bear Creek Points of Diversion



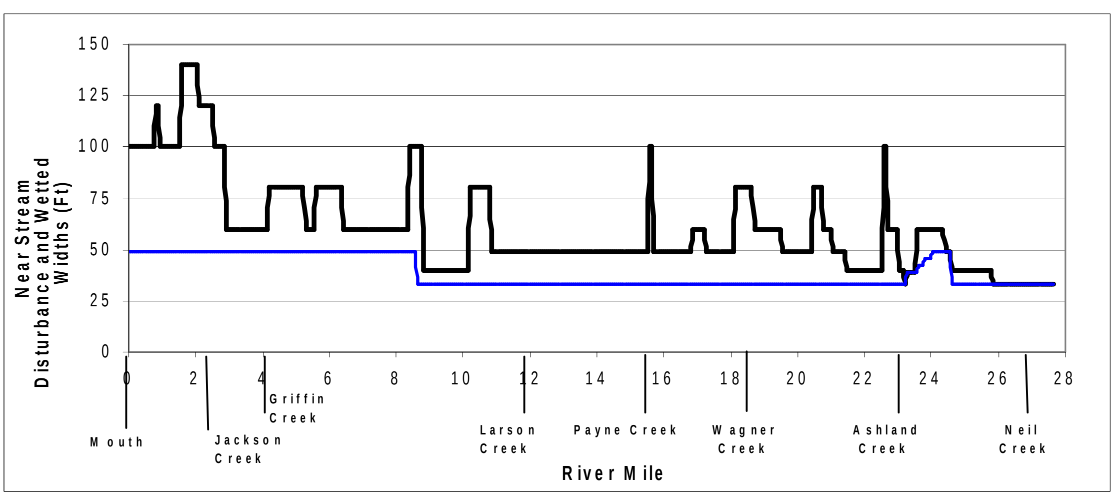
Source: Oregon Water Resources 2005

<u>Channel Wetted Width/Near Stream Disturbance Zone Width</u>

Wetted channel widths (dark blue line) and near stream disturbance zone widths (NSDZ – dark black line) were scaled from aerial photos and field measurements. The near stream disturbance zone is defined as the distance across the stream from one the shade-producing area to the shade-producing area on the opposite bank. Figure 4 shows the width profiles used in the model.

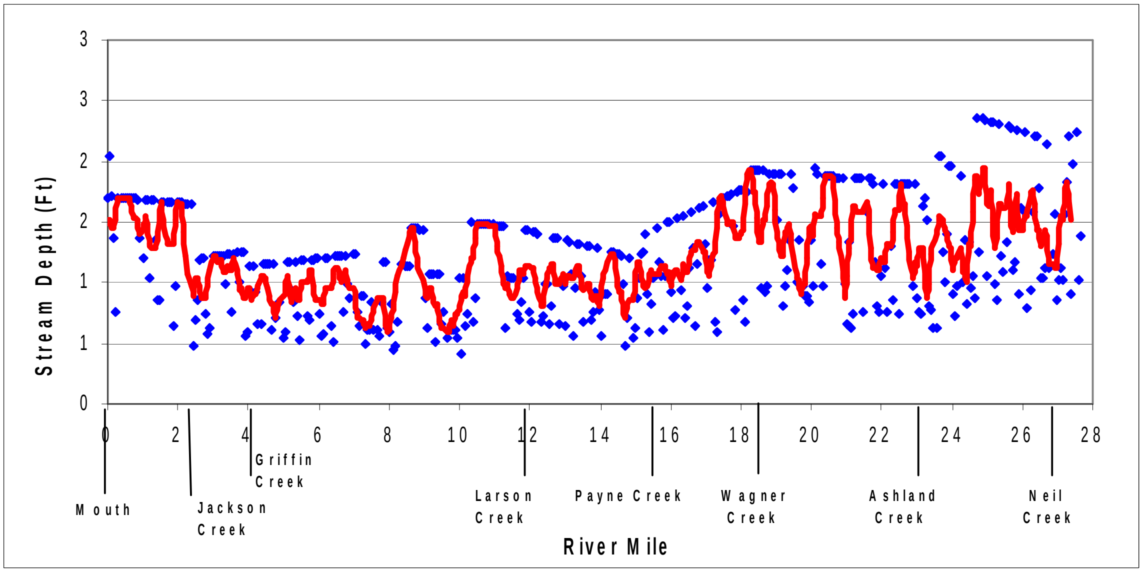
Figure 4. Channel Wetted Width/Near Stream Disturbance Zone Width

Note: Wetted channel widths (dark blue line) and near stream disturbance zone widths (NSDZ – dark black line)



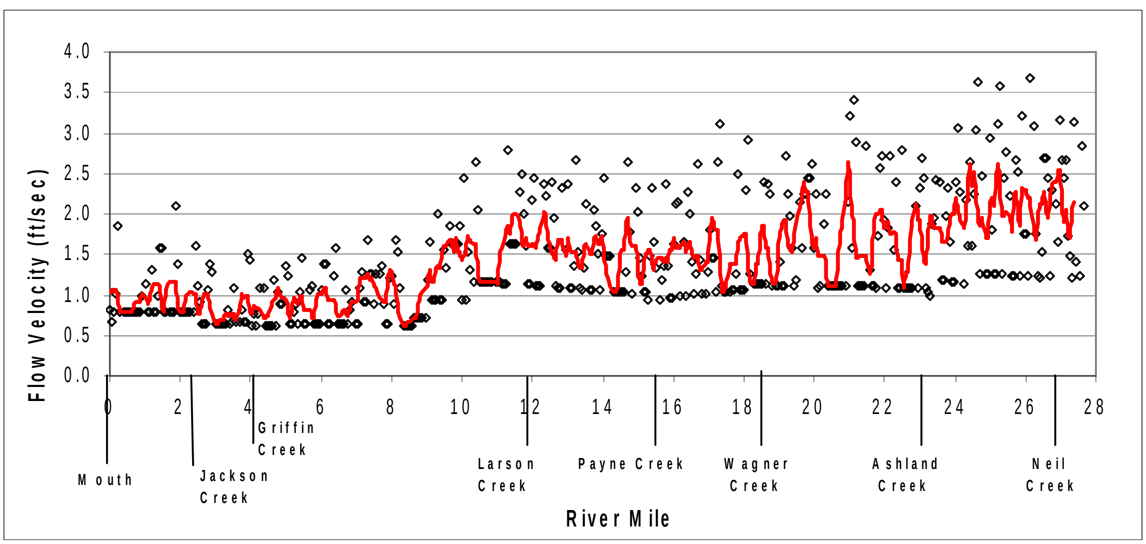
Average Depth
Average depth for each segment was calculated from the flow volume and wetted width values used for that segment. Points show depths for each segment, the line shows a running-5-data-point-average of depth. Figure 5 shows the average depth profile used in the model.
.

Figure 5. Average depth



Flow Velocity
Average velocity for each segment was calculated from the channel geometry, segment slope and Manning's "n" used for that segment (Figure 6). The black points are the calculated velocities in each segment; the red line is a 5-data-point moving average.

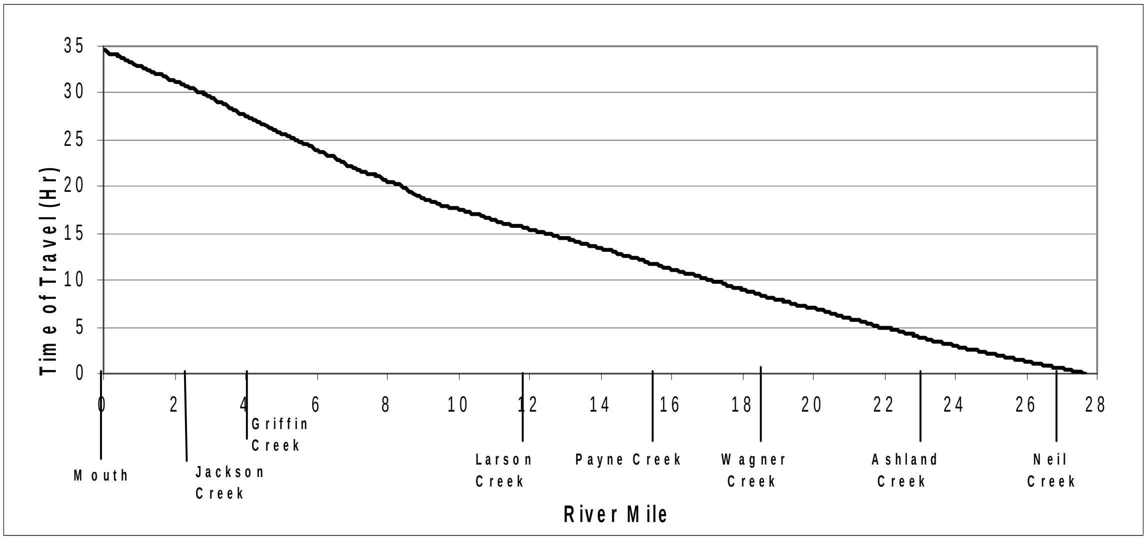
Figure 6. Average velocity



Note: The black points are the calculated velocities in each segment, the red line is a 5-data-point moving average

Using the velocities shown in Figure 6, an average time of travel can be calculated for the Bear Creek mainstem (Figure 7).

Figure 7. Time of Travel



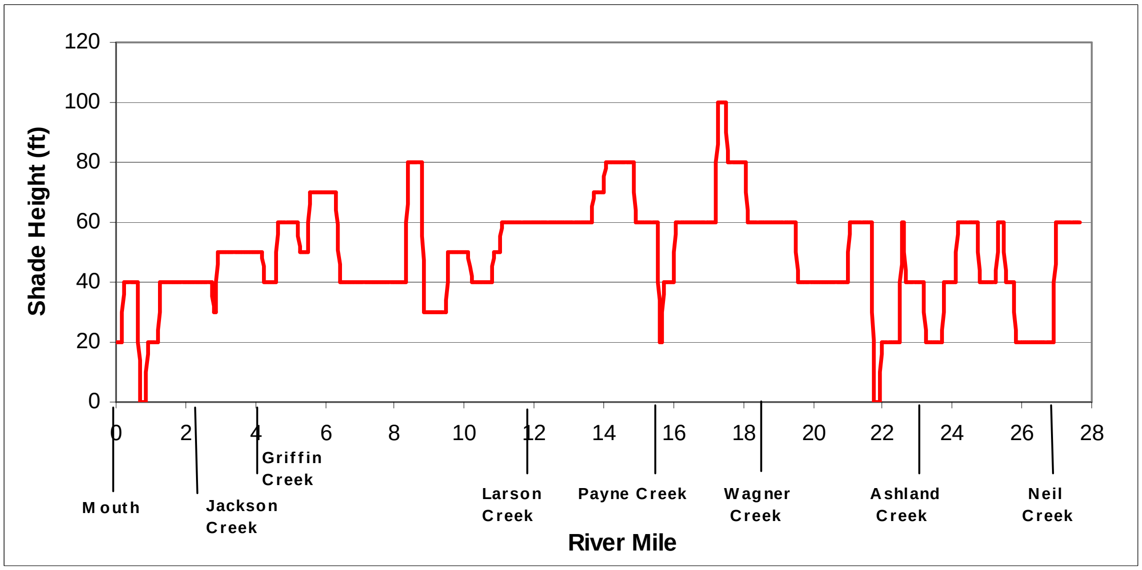
Stream Aspect

Stream aspect is the compass heading of the each stream reach. This determines the amount of surface area of the reach potentially exposed to solar energy.

Shade Height

Shade height is defined as the height of trees standing in the riparian corridor. It is a shade characteristic that was changed as part of Heat Source model simulations. Figure 8 shows the current measured shade heights.

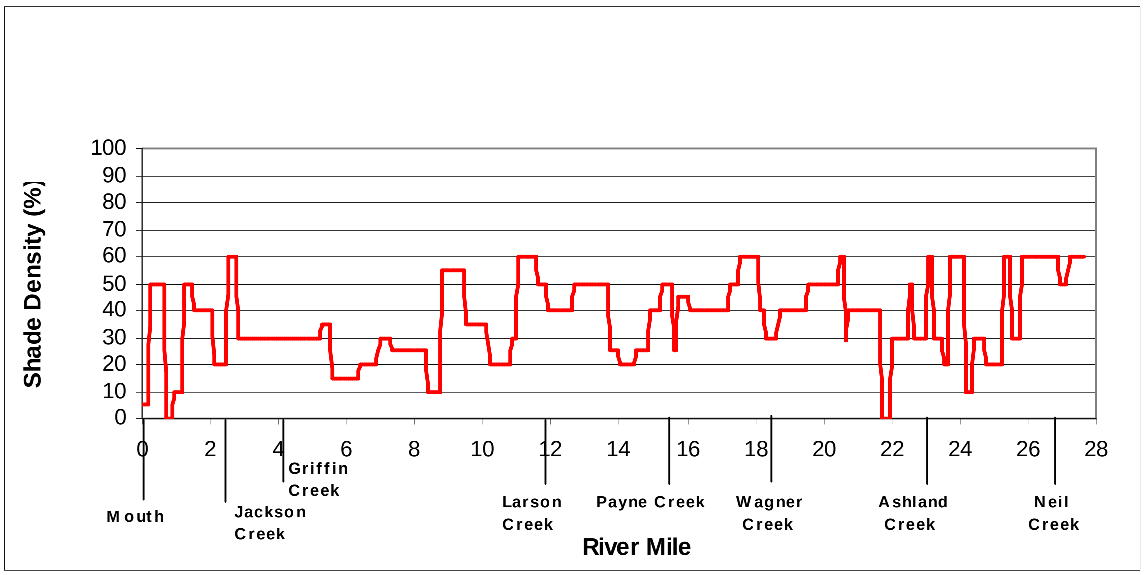
Figure 8. Current Conditions Shade height



Shade Density

Shade density describes how much sunlight penetrates the riparian shade vegetation. It is also changed as part of the model simulations. Figure 9 values are the shade density average for both the left-bank and right-bank values for each segment.

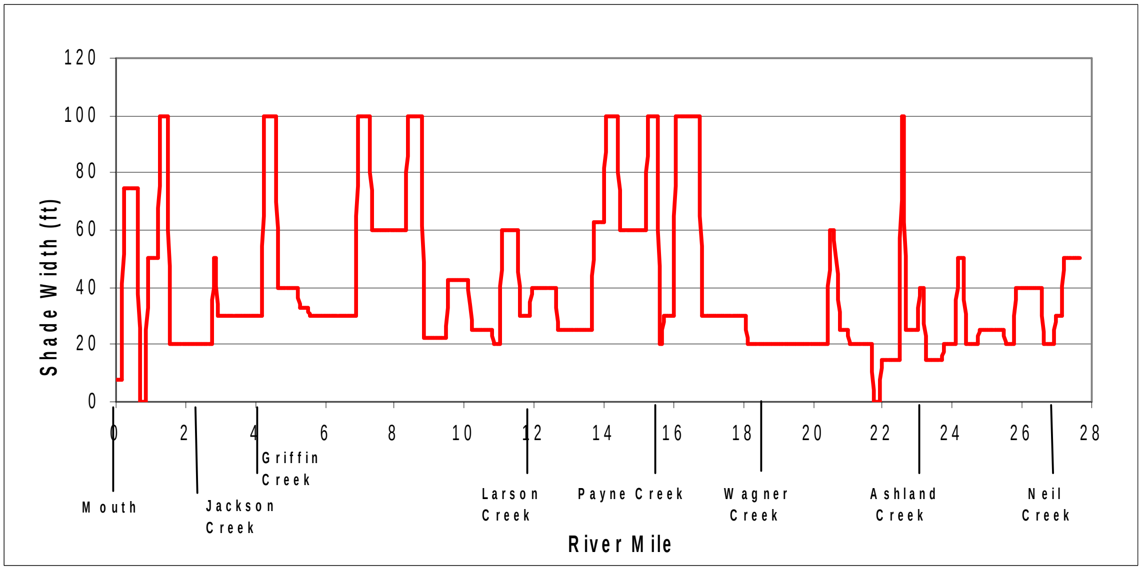
Figure 9. Current Conditions Shade Density



Shade Width

The widths of the current shade–producing riparian belts are shown in Figure 10. The charted values are the average of the left-bank and right-bank values for each stream reach.

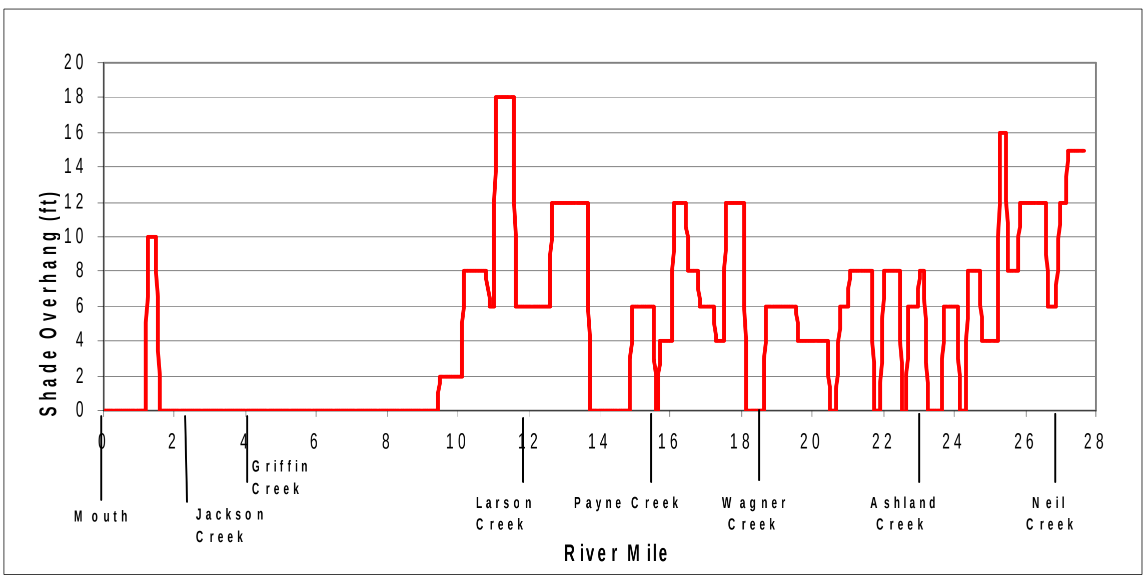
Figure 10. Current Condition Shade Width



Shade Overhang

The current condition shade overhang profiles are shown in Figure 11. Values shown are overhang averaged for both the left and right bank at each location.

Figure 11. Current Conditions Shade Overhang

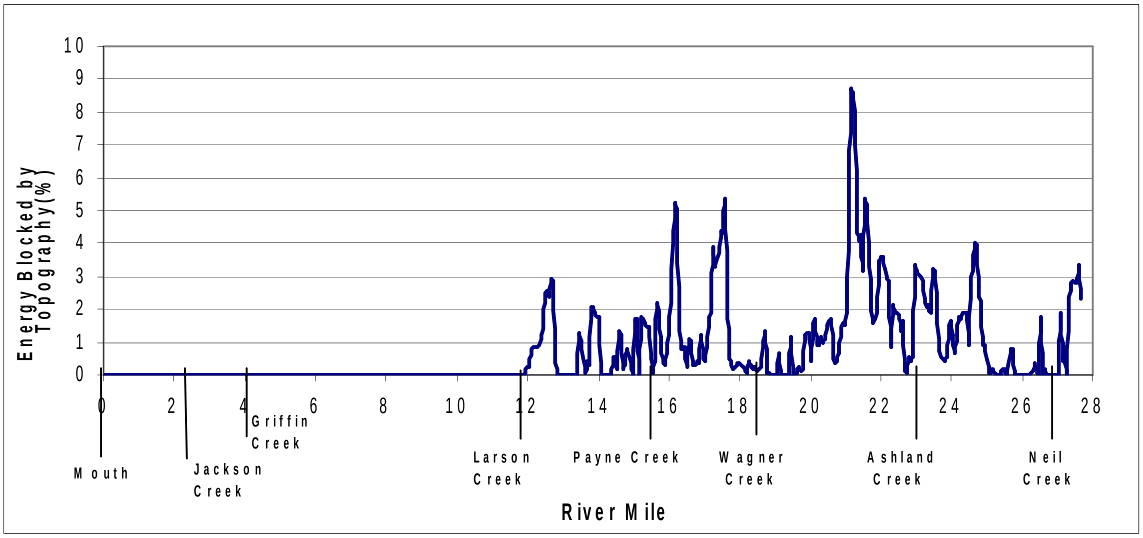


Topographic Shading

Topographic shading is defined as the shading provided to the stream by ridgelines or hills. It is extremely localized and unique for each system. Southern side stream shading can result in an appreciable lowering of solar energy received during the day. East/West shading effectively shortens the amount of daylight hours by delaying local sunrise or hastening local sunset. The map shown on the front cover of this appendix shows some of the topographic character of the Bear Creek watershed.

The lower part of the system receives no shading from topographic features. Throughout the system, the amount of topographic shading averages to less than 1 percent of the ambient solar energy available (Figure 12).

Figure 12. Topographic Shading



Model Input Data Summary

Below is a summary of the parameters input into the Heat Source 6.0 model as part of model calibration. The source of data, whether measured or calculated is also stated (Table 1).

Table 1. Current Conditions Model Parameters.

Data Class	Parameter	Method (measured/calculated)	Source
Stream	Elevation	Measured	DEM Data
	Gradient	Calculated	Model Calculated
	Topographic Shade	Calculated	GIS Utility
	Stream Reach Aspect	Calculated	GIS Utility
Flow	Volume	Measured	Field Measurement
	Velocity	Calculated	Model Calculated
	Depth	Calculated	Model Calculated
Channel	Bankful Width	Measured	DOQ Measurement
	Wetted Width	Calculated	Field Measurement
	Channel Substrate	Measured	Field Measurement
Shade	Height	Measured	DOQ Measurement
	Width	Measured	DOQ Measurement
	Density	Measured	DOQ Measurement
	Near Stream Disturbance Zone (NSDZ)	Measured	DOQ Measurement
	Overhang	Measured	DOQ Measurement
Stream Temperature	Main Stem	Measured	Field Measurement
	Tributaries	Measured	Field Measurement
Weather	Humidity	Measured	Field Measurement
	Wind Speed	Measured	Field Measurement
	Air Temperature	Measured	Field Measurement

Model Calibration

All models require some calibration to make the computer simulation match the observed data. For this *Heat Source* simulation, the Manning's "n" was changed to make the model's calculated stream velocities and depths match field-measured data. The humidity, windspeed and air temperatures were changed at some locations to make the model output match the instream temperature data recorded in the field.

At each of the 11 mainstem sites, 24 hourly model predictions are compared to the field-measured values. A statistical measure of how well those values match is called the "r-squared" value. These values range from 1 (a perfect fit) to 0 (a completely random association). The r-squared values of the model fit at each of the 11 mainstem sites are shown in the following table. All values are over 0.900 with an average of 0.96 (Figure 13, Table 2). This means that the model tracks very closely to field-measured data. There is very high confidence that the model developed for Bear Creek can predict the relationship between solar energy and stream temperature.

Figure 13. Calibration: Modeled vs. Measured Temperatures

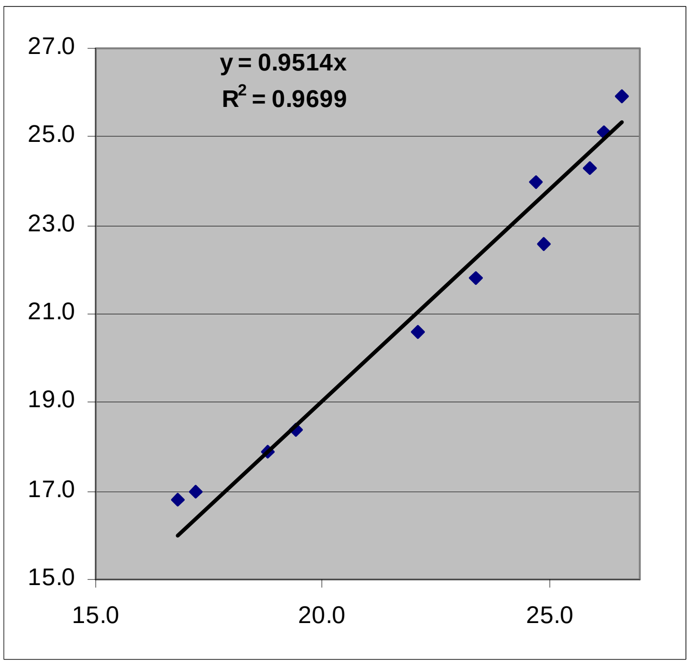


Table 2. Heatsource Calibration Summary Statistics

Logger Location	Approximate River Mile	"r Squared" Value	Standard Deviation (Deg)	Standard Error (Deg)	
Confluence of Emigrant/Walker	27.6	1.000	0.00	0.00	
U/S Neil	26.8	0.991	0.21	0.11	
D/S Kitchen	24.3	0.959	0.38	0.34	
U/S Ashland	23.2	0.973	0.40	0.30	
U/S Coleman	14.9	0.976	0.82	0.34	
U/S Larson	11.9	0.972	1.25	0.36	
Approx RM 8.4	8.4	0.939	1.12	0.53	
U/S Lone Pine	7.4	0.965	0.78	0.39	
U/S Griffin	4.1	0.976	0.67	0.42	
U/S Jackson	2.5	0.928	0.86	0.68	
Mouth	0.0	0.970	0.73	0.42	
	Sum		7.220		Deg C
	Avg	0.968	0.656	0.354	Deg C
	Sum		12.996		Deg F
	Avg		1.181	0.637	Deg F

Natural Thermal Potential Analysis

A natural thermal potential analysis was performed as a part of determining the applicable temperature criteria for Bear Creek. As defined in OAR 341-041-0002 (35) “Natural Thermal Potential” means the determination of the thermal profile of a water body using best available methods of analysis and the best available information on the site potential riparian vegetation, stream geomorphology, stream flows and other measures to reflect natural conditions.

Where the department determines that the natural thermal potential of all or a portion of a water body exceeds the biologically-based criteria in section (4) of this rule, the natural thermal potential temperatures supersede the biologically-based criteria, and are deemed to be the applicable temperature criteria for that water body (OAR 340-041-0028 Natural Conditions Criteria).

Determining the natural thermal potential of a system requires making an estimate of what the temperatures might have been historically. A basin-wide set of un-ambiguous temperature data collected before human-induced changes in the Bear Creek system simply does not exist. In order to estimate what historic conditions might have been, we have to work backwards from conditions that exist today. To run a simulation of natural thermal potential, the Heat Source model needs several specific inputs representative of natural thermal potential conditions; site potential vegetation, natural flow volumes for Bear Creek (pre-dam/pre-irrigation conveyance), upstream temperatures at the top of the modeled reach, and an estimate of the temperature of tributaries as they entered the Bear Creek mainstem.

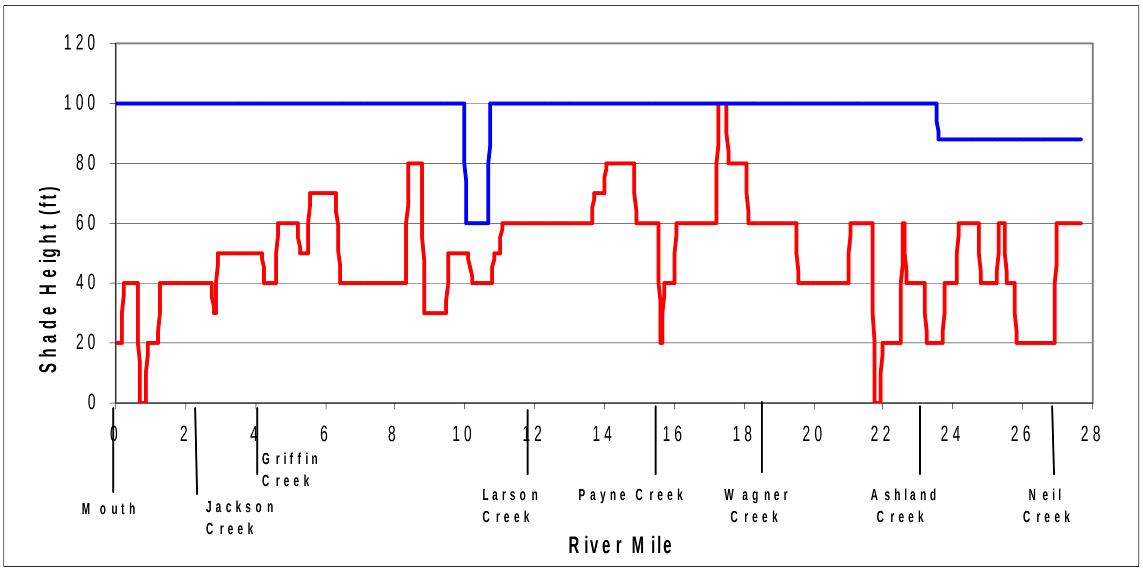
Site Potential Vegetation

Site potential is defined as an estimate of a condition without anthropogenic activities that disturb or remove near stream vegetation. This condition is defined by riparian vegetation that is mature and undisturbed; vegetation height and density at or near the potential expected for the given plant community, vegetation buffer is sufficiently wide to maximize solar attenuation, vegetation width accommodates channel migrations.

Shade Height

Shade height is defined as the height of trees standing in the riparian corridor. Figure 14 shows the current measured shade heights (red line) and the shade heights at site potential as used for the natural thermal potential scenario (blue line). Site potential shade heights and natural vegetative conditions are explained in more detail in DEQ 2000. Numbers displayed for each condition are the average values of both the left and right banks.

Figure 14. Natural Thermal Potential Shade height

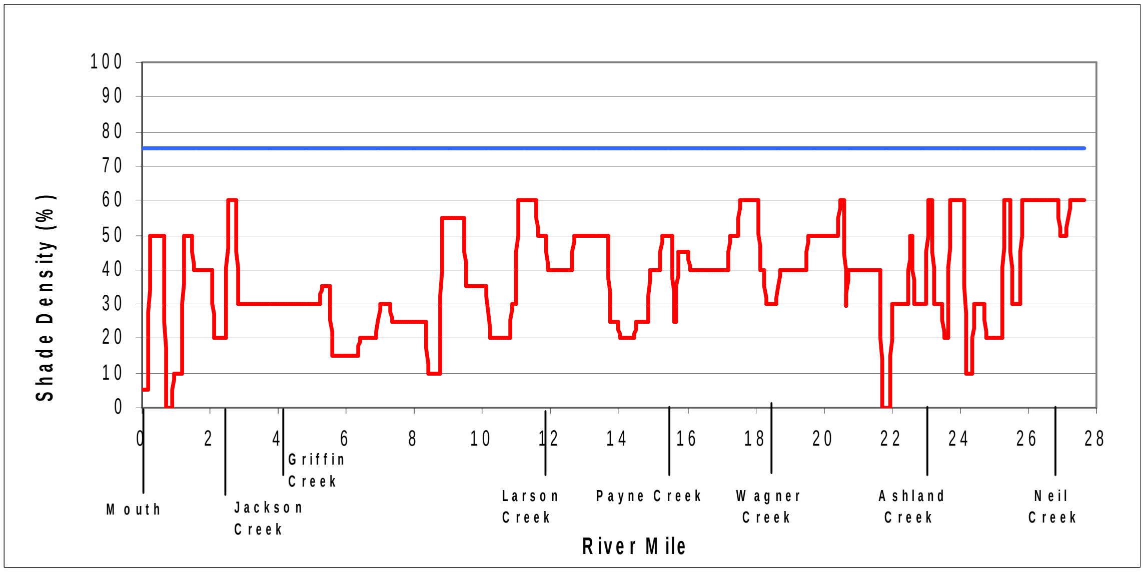


Note: current measured shade heights are shown in the red line and the shade heights used for the site potential are the blue line.

Shade Density

Shade density describes how much sunlight penetrates the riparian shade vegetation. Figure 15 values are the shade density average for both the left-bank and right-bank values for each segment. The red line is current conditions, the blue line is the assumed site potential value and is used in the natural thermal potential conditions simulation.

Figure 15. Natural Thermal Potential Shade Density



Note: The red line is current conditions, the blue line is site potential conditions.

<u>Shade Width</u>

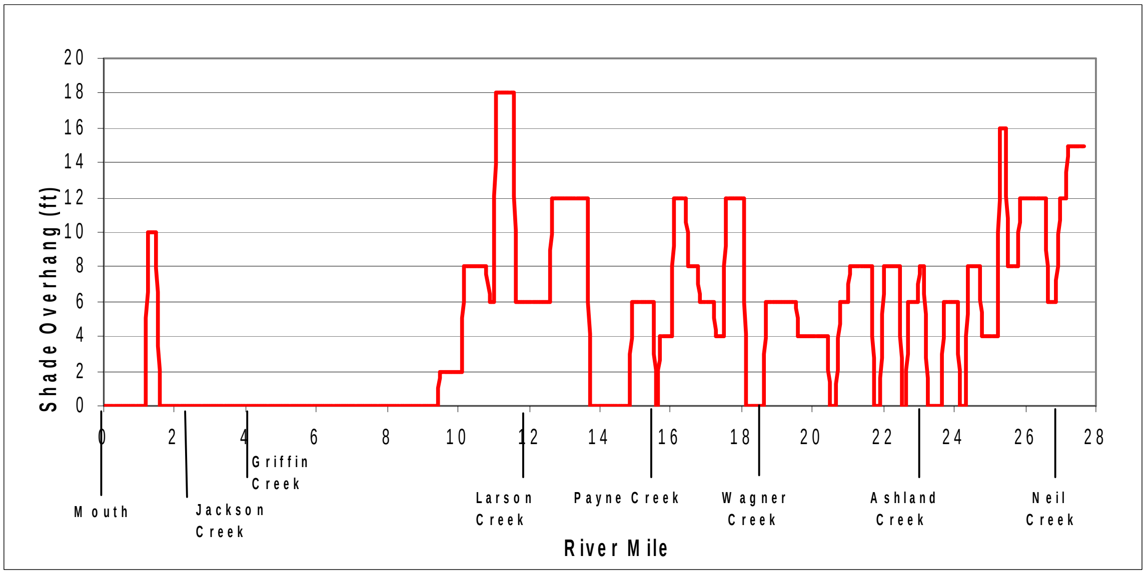
The widths of shade producing riparian belts currently vary from zero to greater than 100 ft as shown previously in Figure 10. The charted values are the average of the left-bank and right-bank values for each segment. The site potential values used in the natural thermal potential condition scenario assumed a shade width wide enough to not limit shade production upon the Bear Creek mainstem.

Note: Buffer widths required to meet the site potential shade targets will vary given potential vegetation, topography, stream width, and aspect.

<u>Shade Overhang</u>

The shade overhang profiles are shown in Figure 16. Values shown are estimated overhang values averaged for both the left and right bank at each location. Site potential shade estimates in the natural thermal potential simulation do not change from current values.

Figure 16. Natural Thermal Potential Shade Overhang



Solar Flux

Figure 17 shows the total daily solar flux loading available by river mile. The upper (black) line shows the total amount of solar energy available to reach the stream. The variations in available energy are due to local topographic shading conditions. The next line down (thick red) is the daily solar flux available for stream heating under current vegetation conditions. The lowest line (thick dark blue) shows the energy available under the natural thermal potential condition with site potential vegetation: maximum height, width, density of riparian vegetation.

Figure 17. Natural Thermal Potential Solar Flux

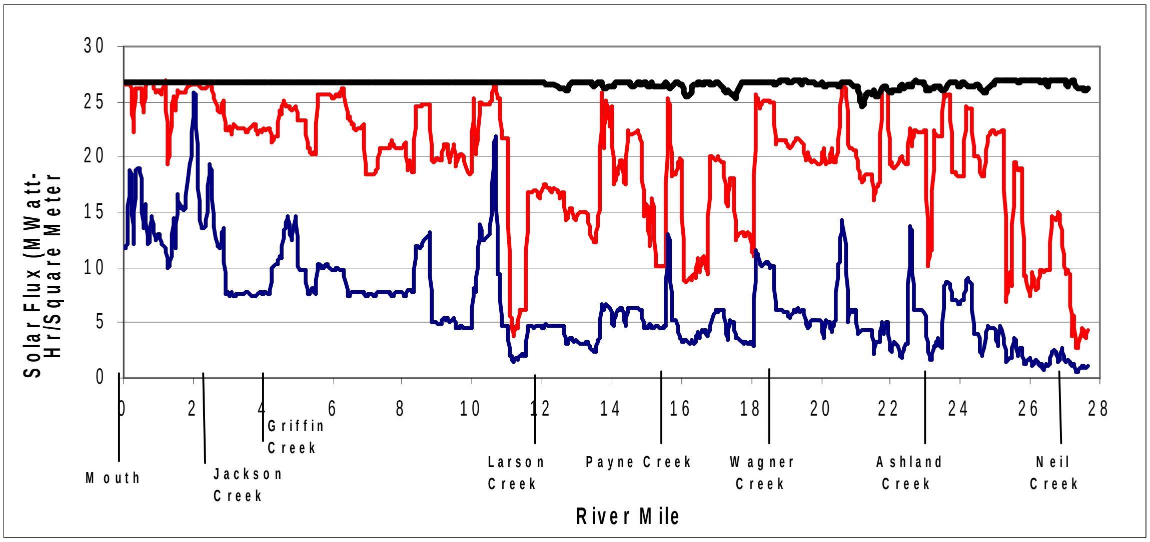
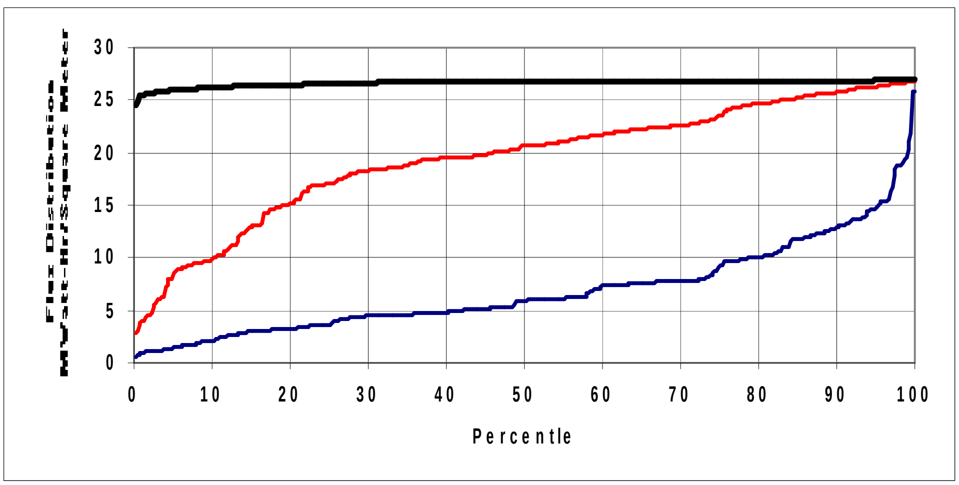


Figure 18 shows the solar flux information displayed as a percentile plots. The upper (black) line shows the total amount of solar energy available. The next line down (thick red) is the daily solar flux available for stream heating under current vegetation conditions. The lowest line (thick dark blue) uses the assumptions of the natural thermal potential condition.

Figure 18. Percentile plots of solar flux



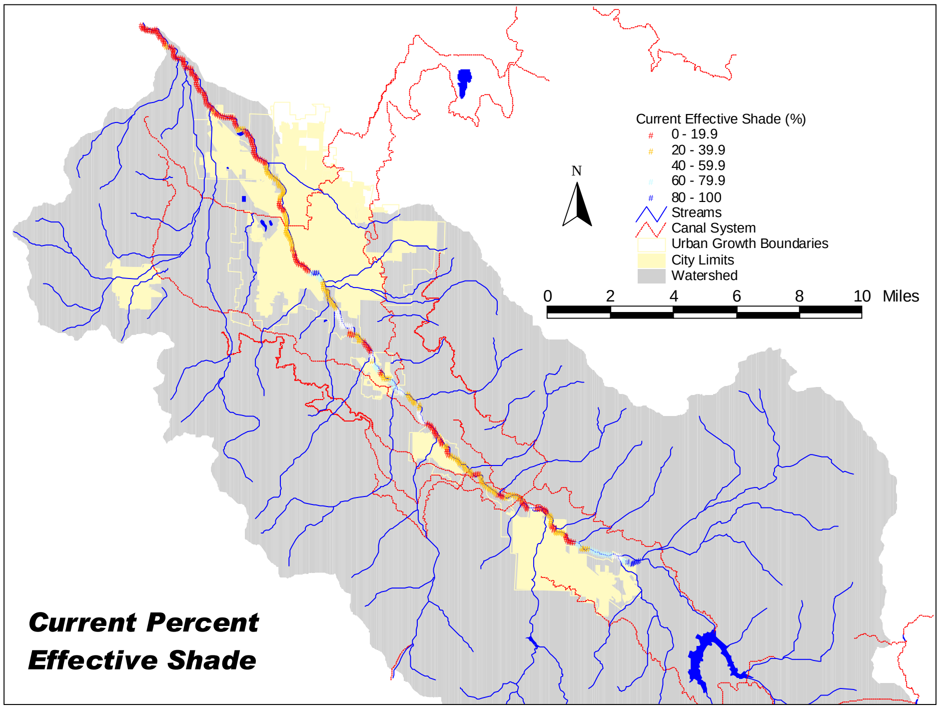
Percent Effective Shading in the Riparian Zone

Effective shading is defined as the percent of available solar flux intercepted before reaching the stream. A situation which allows 10 MWatt-hr/Square Meter to enter the stream when the available solar flux is 25 MWatt-hr/Square Meter would be calculated as (all units are MWatt-hr/Square Meter) as follows:

Total Energy after Topographic Shading	25
Energy Allowed Through	10
Energy Blocked	25-10 = 15
Percent Effective Shade	(15 / 25) * 100 = 60% Effective Shading

Map 4 shows current percent effective shade on the Bear Creek mainstem. Map 5 shows the expected percent effective shade at site potential shade.

Map 4. Current Percent Effective Shade



Map 5. Natural Thermal Potential Percent Effective Shade

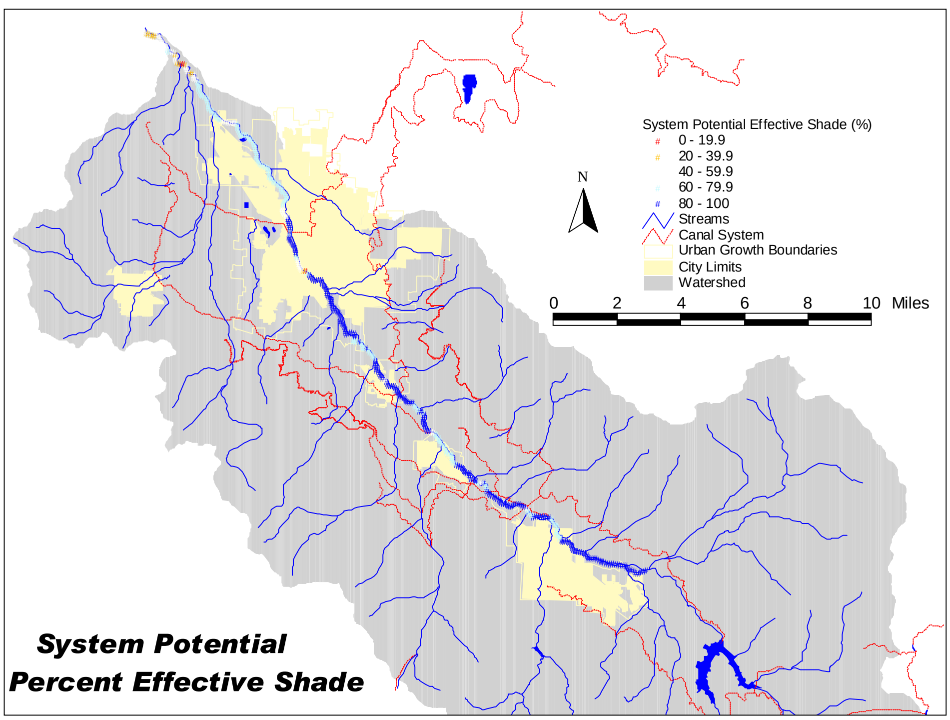


Figure 19 shows the effective shade longitudinal profiles under current conditions and at natural thermal potential conditions. The bottom (red) lines are current conditions and the top (blue) line are natural thermal potential conditions.

Figure 19. Natural Thermal Potential percent effective shade

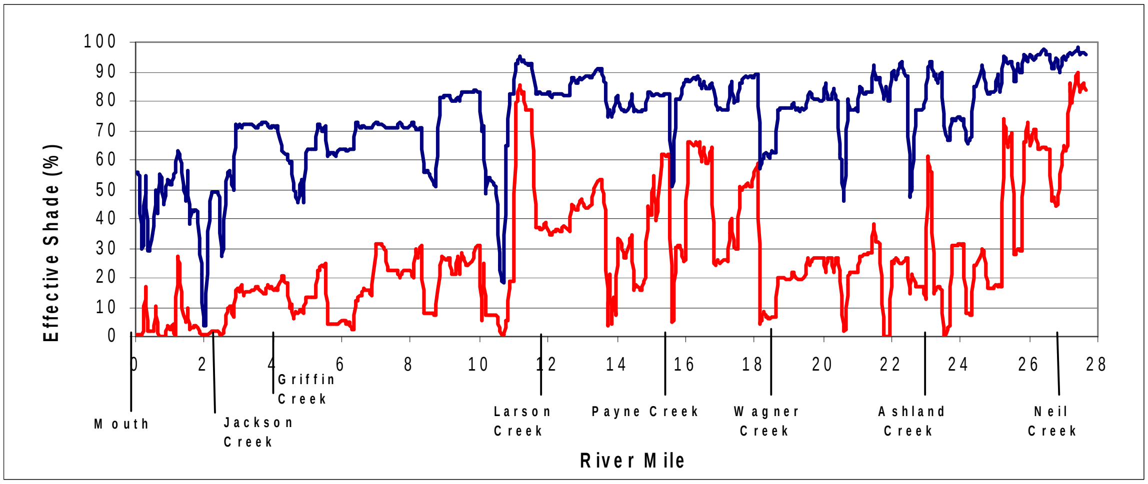
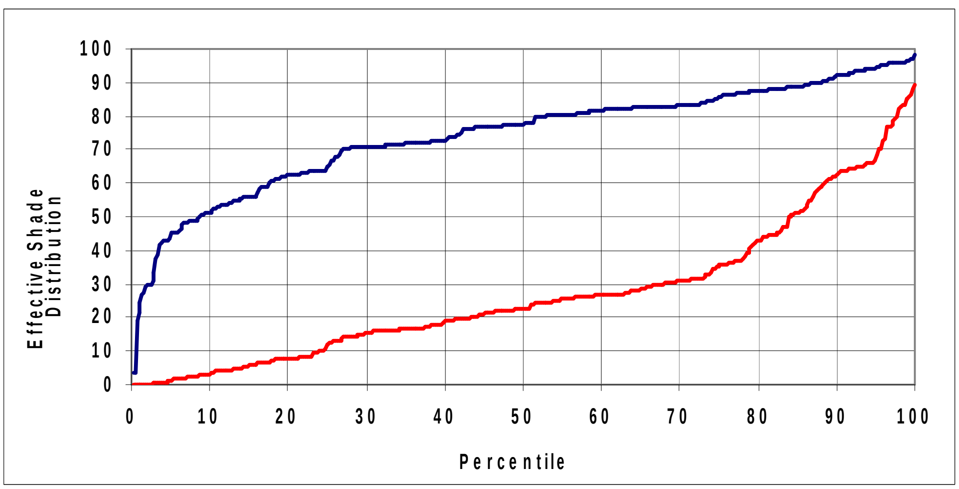


Figure 20 shows the percentile plot for effective shading. The bottom (red) lines are current conditions and the top (blue) line are natural potential conditions.

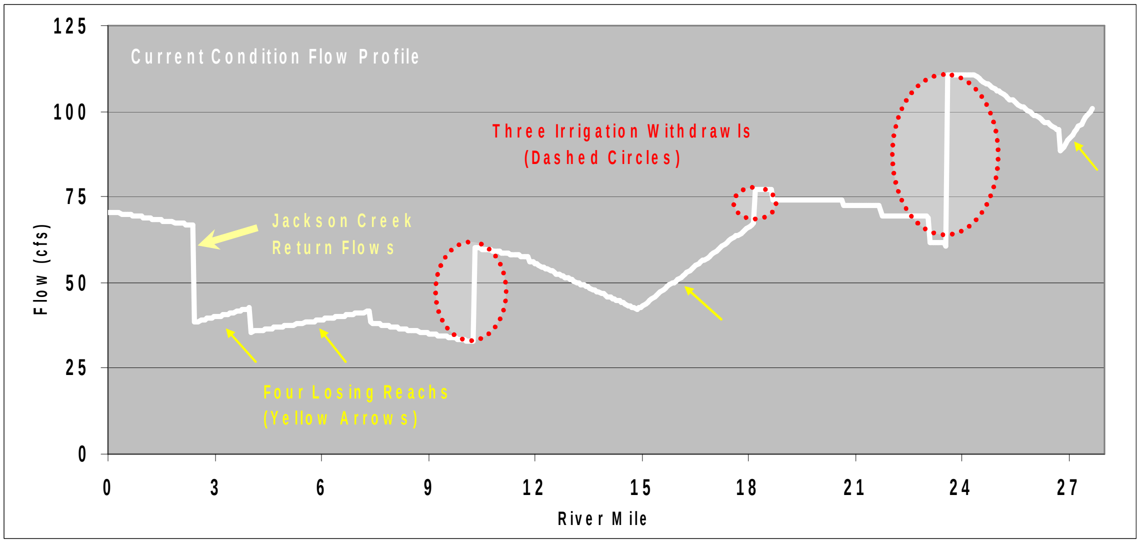
Figure 20. Percentile plots Percent Effective shade



Natural Thermal Potential Flows

The present irrigation-season flow profile is profoundly influenced by the conveyance of irrigation water throughout the system. The flow profile that was used for Heat Source model calibration was constructed using gauging station data and field measured flows (Figure 21).

Figure 21. Current Flow Profile



Most apparent are the three points of water withdrawal to the canal system. These are shown at the points circled by red dashed lines in Figure 22. Secondly, the amount of water coming into Bear Creek from the Jackson Creek drainage is well out of proportion to other tribs of the same size. Much of the water withdrawn from Bear Creek travels the irrigation canal system which moves water down the valley. That transfer continues until it reaches the lowest tributary in the watershed – Jackson Creek. Because of this, Jackson Creek has a higher discharge during the summer than would happen under natural conditions. Lastly, four reaches exhibit significant instream water withdrawal (yellow arrows Figure 22).

To establish a closer-to-natural flow profile for the model, the following changes were made to the existing Bear Creek flow profile:

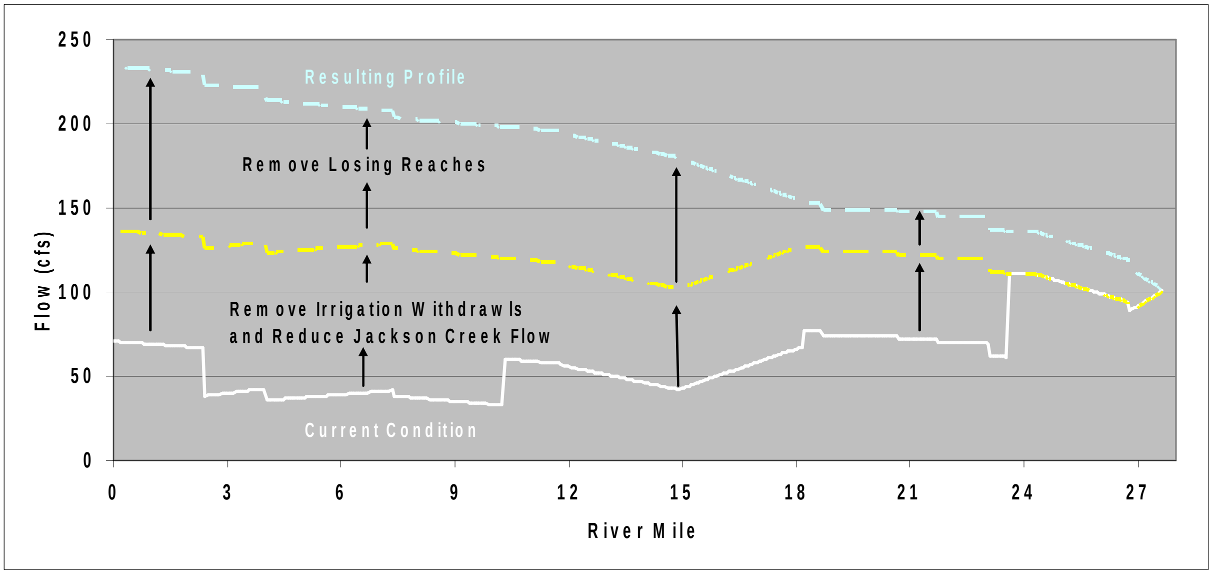
1). The three points of large irrigation withdrawal were removed.

2). The Jackson Creek flow volume was reduced from 28.3 cfs to 6.75 cfs, the same flow volume as the adjacent and similar-in-size Griffin Creek sub-watershed. Griffin Creek is undoubtedly also enhanced in flow compared to historic conditions, but this analysis did not assume any change to Griffin Creek flow from what is seen today.

3). Reaches that lose flow (through irrigation withdrawal) were made to gain flow in the same proportion as other typical gaining reaches in the system. Some streams have perfectly natural losing reaches, but historic accounts of Bear Creek speak of a system with a very high water table. Therefore, all reaches were adjusted to gain in flow rather than to lose flow.

How these assumptions change the Bear Creek flow profile is shown in the Figure 22.

Figure 22. Adjusted Bear Creek flow profile



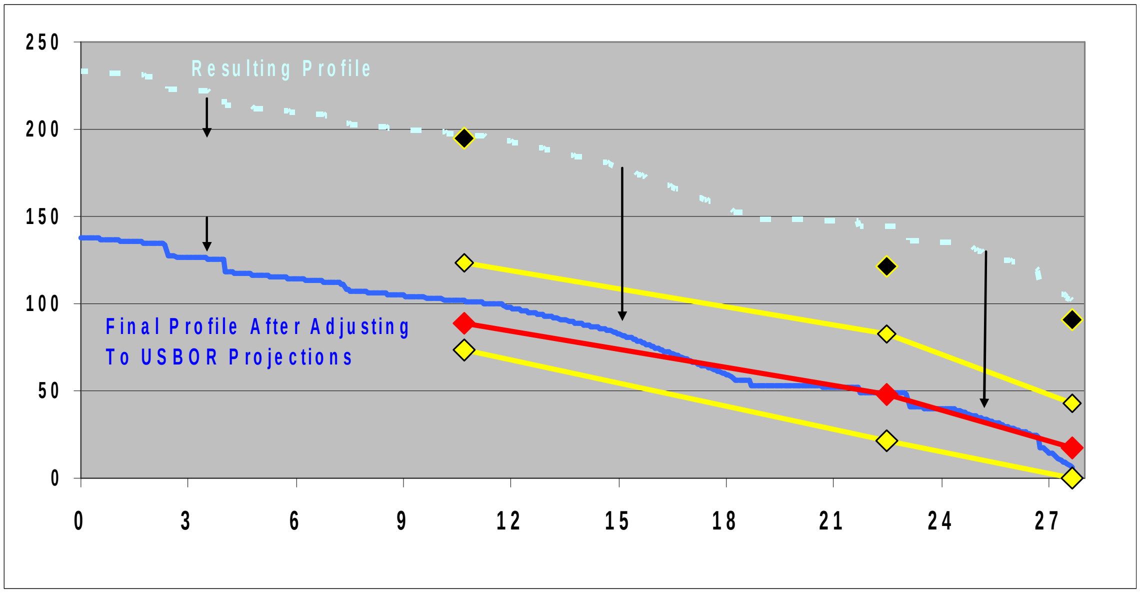
The resulting profile (shown as the dashed light blue line), is much more like that of a natural system. Flow increases as one moves downstream and there are no large fluctuations of gain (except at tributary confluences) or loss to that volume.

An estimation of flow volumes in an un-regulated Bear Creek watershed was done by the Bureau of Reclamation (USBR) (Leslie Stillwater, USBR, personal communication). A model was constructed that estimated the flow discharges at three points along Bear Creek at current rainfall levels if all cross-basin water transfers from the Klamath Basin and Applegate Sub-Basin were eliminated and if there was no stored water at the Emigrant Lake Reservoir. This gave an estimate of flow at three locations that was an approximation of historic conditions in the Bear Creek system. These three points were used to normalize the flow profile constructed in the preceding section.

The USBR model predicts discharges at the base of Emigrant Dam (approximately 3.5 miles above the Emigrant/Walker confluence-the "headwaters" of Bear Creek which is also upper end of the Heat Source modeled reach), at the Ashland gage (approximate River Mile 22.5) and at the Medford gage (approximate River Mile 10.7). Model output is in average monthly flows. Data for July and August, from the years 1990-1999, was aggregated into a set of values most representative of the time of year that is of interest.

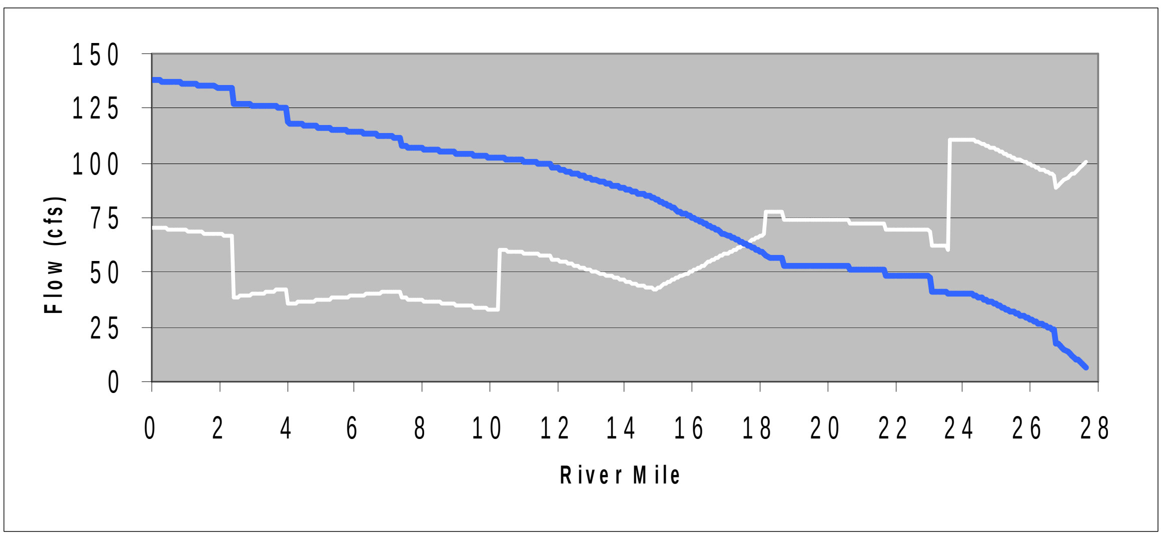
This USBR data is shown in Figure 23. The yellow diamonds with the black outline, connected by the yellow lines are the 25th and 75th percentiles of flow at each of the three "normalization" points. The black diamonds with yellow outlines are the maximum flow estimated at the "normalization" points. The red line with red diamonds is the 50th percentile of flow at the "normalization" points. The flow profile previously constructed was lowered until it matched the 50th percentile value at the Ashland gage point. At this level, the fit at the other two normalization points was also good, and all the flows fit within the 25th-75th percentile values.

Figure 23. USBR Normalized Flow Profile



The Bear Creek flow profile used in the natural thermal potential scenario is shown as the blue line (Figure 24). The current conditions flow profile as measured in august 1999 is shown as the white line.

Figure 24. Flow under Current Conditions and Estimated Natural Thermal Potential Flow



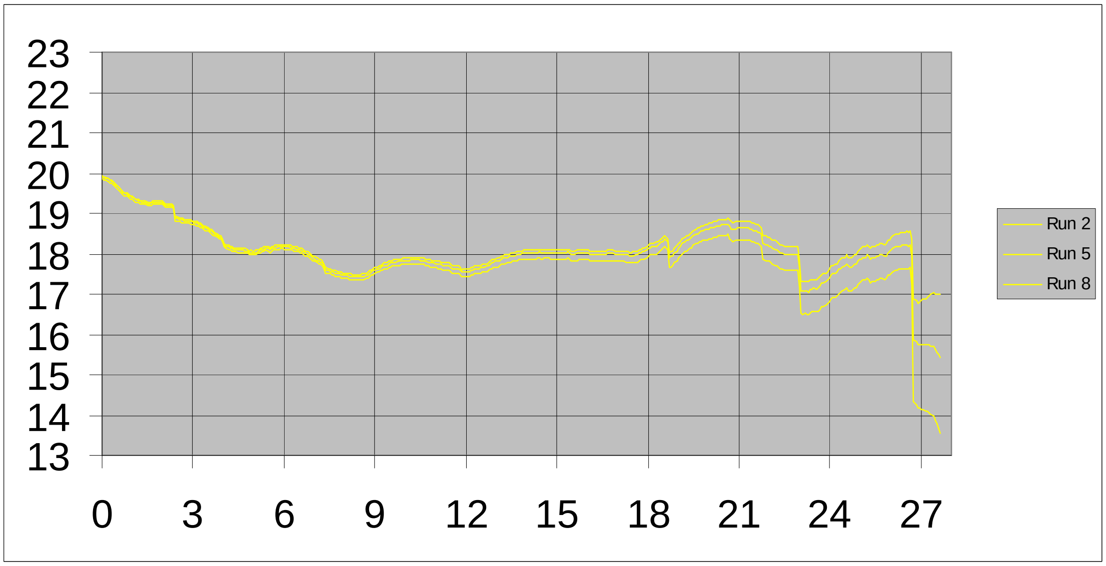
Boundary Condition Temperatures

The heat source model of natural thermal potential begins at river mile 27.5. In order to determine the temperature input to begin the model (the boundary condition temperature), temperature data from the top of the watershed (above Emigrant Lake) was examined. A data set from the summer of 1999 on Baldy Creek was of interest. The Baldy Creek site is high in the watershed, currently has 72 % effective shade (DEQ 2000) and is considered relatively undisturbed. The creek is a tributary with a similar flow volume as Emigrant Creek above the reservoir.

The data from July 15 1999 through August 15 1999 was aggregated into one data population. From this, the median value for each hour-of-the-day was determined. These 24 hourly median values were used as the boundary condition data for the model.

Because of the uncertainly involved in trying to estimate temperatures under natural thermal potential conditions, a sensitivity analysis was done using a range of temperatures at the upstream starting point for the model (river mile 27.5 the confluence of Walker and Emigrant Creeks). The range of temperatures used in the sensitivity analysis varied by 6.2F (+/- 3.1°F, (1.7°C)) at the boundary condition and had a large effect on Bear Creek mainstem temperatures (Figure 25). This analysis indicates that the system is very sensitive to boundary condition temperatures and that future monitoring should focus on gaining better data on the natural conditions temperatures of the tributaries that feed Emigrant Reservoir.

Figure 25. Boundary Temperatures - Sensitivity Analysis °C



Tributary Temperatures

A sensitivity analysis was done to measure what effect the temperature of the tributaries might have on temperatures in the mainstem of Bear Creek. One scenario assumed that tributaries in the past were just as warm as they are today. A second scenario assumed that all tributary temperatures have been cooled to no more that 64.4 °F at the mouth. The tributary temperature scenario chosen had a large influence on the predicted temperature in the Bear Creek mainstem.

In order to better estimate tributary temperatures under natural conditions, a third scenario was developed. The relationship between the daily high temperature in Bear Creek tributaries and the associated level of shading was examined (Figure 26). The relationship between shading and daily median temperature was similarly examined. The temperature data came from instream measurements, at the mouth of each tributary. The existing percent shade is a distance-weighted average value for each tributary. While there is significant “spread” in the relationship, the graph does describe a fairly good association between daily maximum temperature and percent effective shade. The Bear Creek Shade Analysis (DEQ, 2000) from which the percent shade values are derived, estimated that at site potential vegetation, percent effective shading for tributaries in the Bear Creek watershed would hover around 80%. The dashed red line in the graph shows that at 80% shade, the maximum tributary temperatures should not exceed 70 °F.

Therefore for the modeling scenario using site potential vegetation condition to determine natural thermal potential, the maximum temperature in each tributary was held to 70°F. For those streams with a maximum temperature less than 70°F, input temperatures were reduced to 64.4 (the biological based numeric criteria for salmonid streams) (Table 3).

Figure 26. Tributary Streams. Maximum Temperatures vs. Shade.

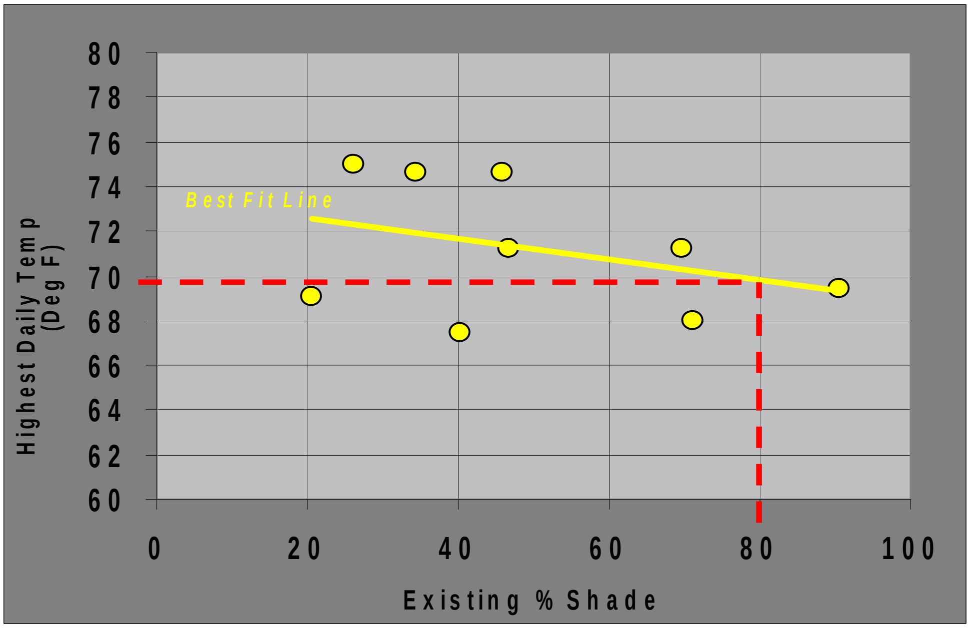


Table 3. Natural Thermal Potential inputs: Tributary Temperatures

Tributary	Current Max T (°F)	Current % Shade* (°F)	Site Potential Shade* (°F)	% improve-ment* (°F)	Amount Lowered (°F)	Temperature at Site Potential (°F). (Entered into NTP model)
Neil Creek	**68**	**71**	**88**	**17**	**4**	**64.4**
Gaerkey Creek	**77.4**	No Data	No Data	No Data	**7.4**	**70**
Ashland Creek**	**69.4**	**66**	**82**	**16**	**5.0**	**64.4**
Butler Creek	**69.1**	**21**	**84**	**63**	**4.7**	**64.4**
Meyer Creek	**67.5**	**40**	**83**	**43**	**3.1**	**64.4**
Wagner Creek	**71.4**	**70**	**91**	**21**	**1.4**	**70**
Payne Creek	**69.8**	No Data	No Data	No Data	**5.4**	**64.4**
Larson Creek	**74.9**	**34**	**82**	**47**	**4.9**	**70**
Lazy Creek	**75.2**	**26**	**82**	**56**	**5.2**	**70**
Lone Pine Creek	**83.5**	No Data	No Data	No Data	**13.5**	**70**
Griffin Creek	**71.4**	**47**	**85**	**38**	**1.4**	**70**
Jackson Creek	**74.9**	**46**	**88**	**42**	**4.9**	**70**

*** Source: DEQ, 2000.**
****Ashland Creek average percent effective shade determined from Hosler Dam down to the mouth.**

Summary of Natural Thermal Potential Assumptions

The Heat Source model inputs that comprise the natural thermal potential scenario are summarized in Table 4.

Table 4. Natural Thermal Potential Model Parameters.

Data Class	Parameter	Changed as part of Natural Thermal Potential Scenario
Stream	Elevation	No
	Gradient	No
	Topographic Shade	No
	Stream Reach Aspect	No
Flow	Volume	Yes
	Velocity	Yes
	Depth	Yes
Channel	Bankful Width	No

	Wetted Width	No
	Channel Substrate	No
Shade	Height	Yes
	Width	Yes
	Density	Yes
	NSDZ	No
	Overhang	No
Stream Temperature	Main Stem	Yes
	Tributaries	Yes
Weather	Humidity	No
	Wind Speed	No
	Air Temperature	No

Results: Natural Thermal Potential Temperatures

Figure 26 shows the natural thermal potential temperature profile (in yellow) along with current conditions (in red). All data simulates temperatures at 4:00 pm in early August. The simulations indicate that temperatures in Bear Creek under the natural thermal potential scenario are mostly cooler than current conditions. The difference in degrees F between current conditions and natural thermal potential is show in Figure 27. Natural thermal potential conditions are warmer by 1F in a small section of Bear Creek below Neil Creek (river mile 25-27) due to much lower flows in the natural thermal potential scenario than are in the creek currently. The natural thermal potential temperatures in the rest of Bear Creek is cooler by up to 14°F (Figure 27, Figure 28).

Note: Additional improvements in Bear Creek channel function (reduction of width-to-depth ratio or better connection of groundwater) or more profound cooling of tributary temperatures could result in further cooling of the natural thermal potential condition. That cooling could occur at any point along Bear Creek.

Figure 27: Bear Creek Natural Thermal Potential Temperatures

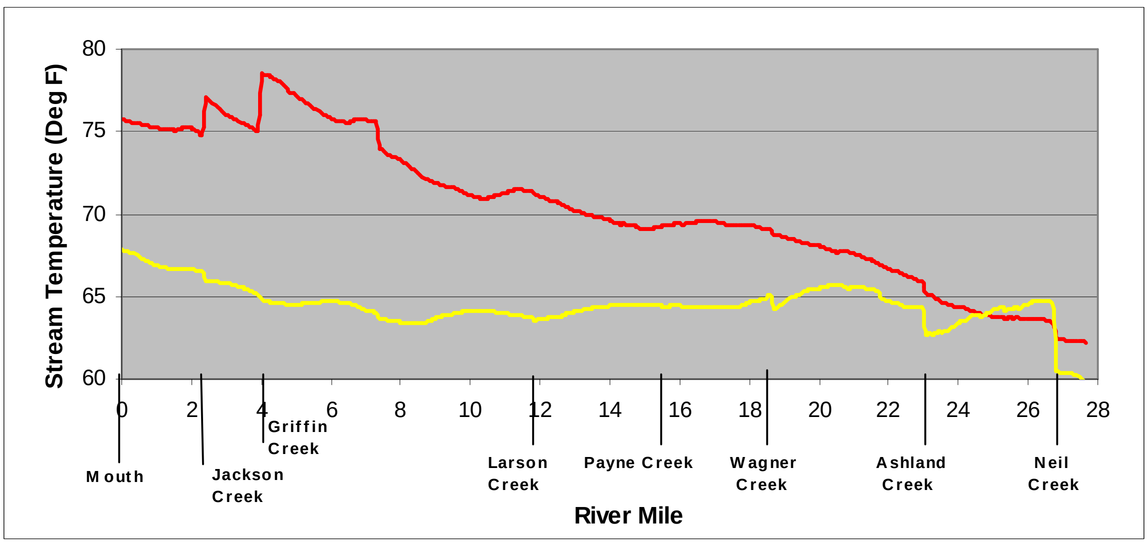
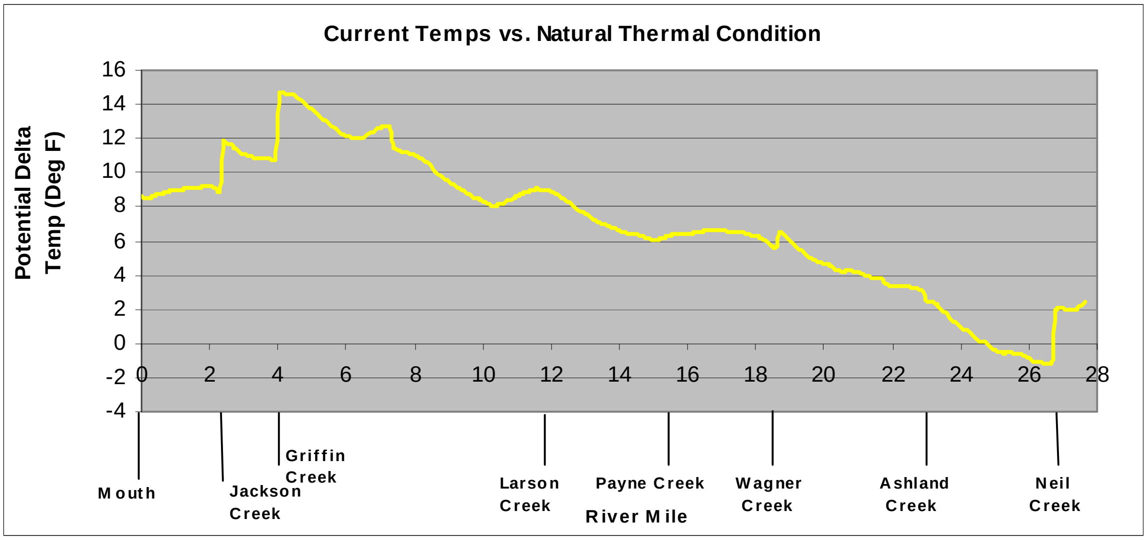
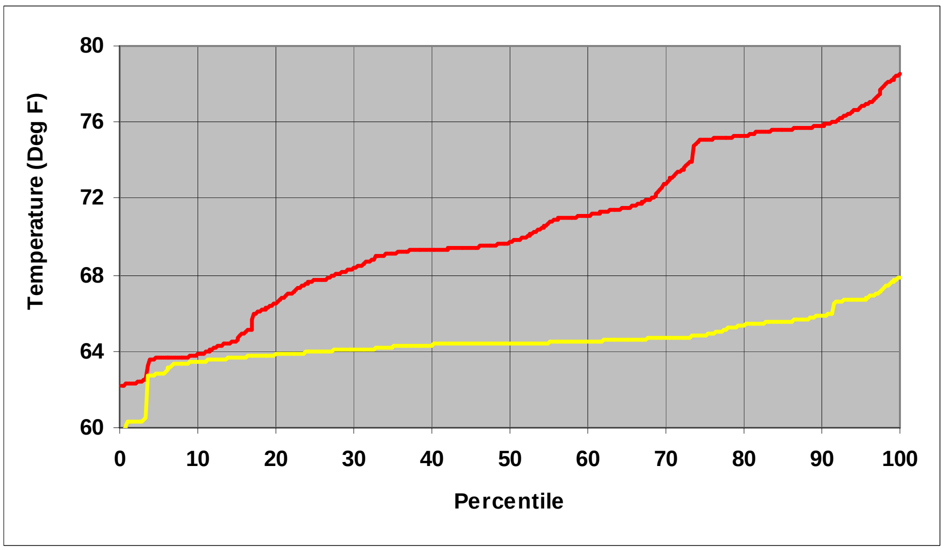


Figure 28. Change in Temperature (delta T): current conditions vs. natural thermal potential



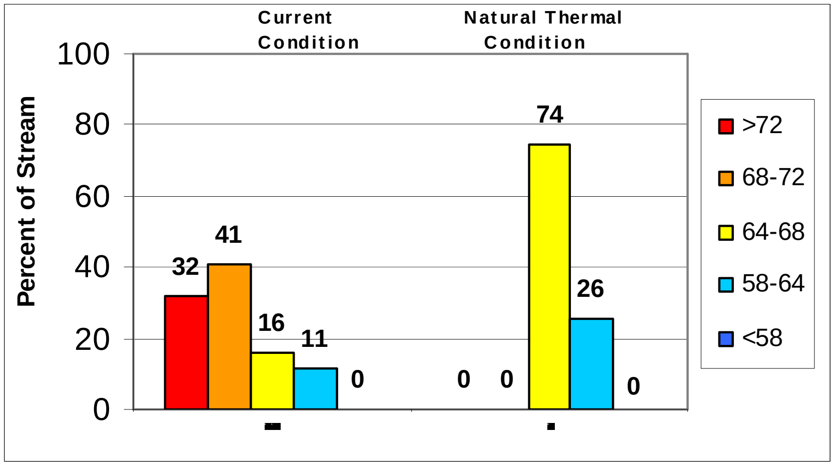
The data shown in Figure 27 are shown as a cumulative frequency plot (Figure 29). Red is current conditions and yellow is the predicted temperatures at natural thermal potential.

Figure 29. Cumulative Frequency Temperatures



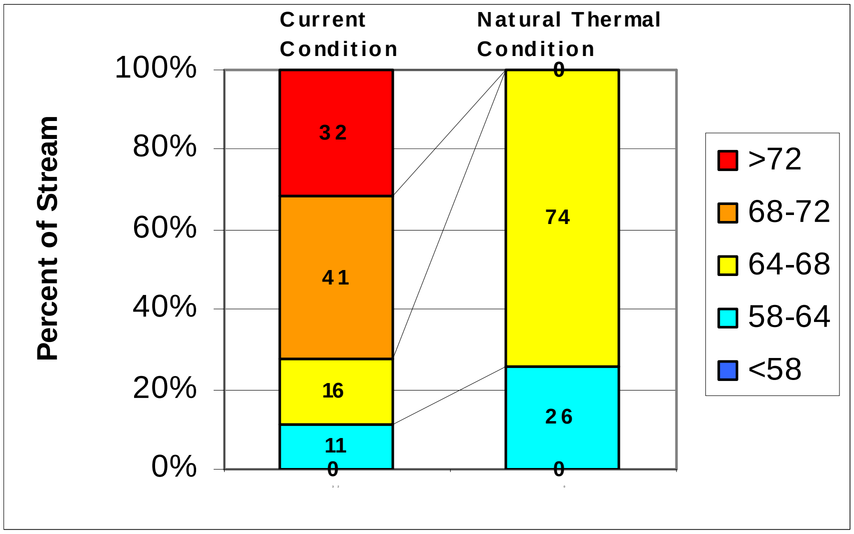
Figures 30 and 31 show temperature data broken into 5 different temperature range intervals for both current conditions and the natural thermal potential condition. These intervals are roughly comparable to the probable success of salmonid survival/reproduction. At the extremes, temperatures below 58°F are optimal for reproduction; temperatures above 72°F are lethal to immature fish. The two graphs show the same information for Bear Creek, only displayed in different formats as expected at 4 PM on the day modeled.

Figure 30. NTP temperature distributions



Current Condition
Natural Thermal Condition
Percent of Stream
100
80
60
40
20
0
32
41
16
11
0
0
0
74
26
0
>72
68-72
64-68
58-64
<58

Figure 31. NTP temperature distributions



Human Use Allowance Calculations: Ashland WWTF (NPDES-DOM-C1a permit #101609)

Thermal waste load allocations are calculated to ensure that a point source will not increase stream temperatures beyond the applicable criterion by more than the allowable Human Use Allowance (HUA) cumulatively at the stream's point of maximum impact. Points of maximum impact are locations where the greatest thermal change due to the point source is observed in a stream and include impacts at the point of discharge as well as downstream where the cumulative impacts of multiple sources are the greatest. These locations vary spatially and temporally.

In accordance with the human use allowance provision OAR 340-0041-0028(b), the Ashland WWTF is allocated a 0.1^{0}C increase (HUA) above the applicable criterion in Ashland Creek as well as at the point of maximum impact. The allocations apply at the point of discharge where an individual source has its maximum impact on river temperature as well as downstream where the cumulative impacts of multiple sources may be the greatest. Impacts on Ashland Creek were determined using a mass balance calculations (Eq 2.1), downstream impacts on Bear Creek were determined using the Heat Source model. Stream flows for all scenarios were set to 7Q10[1] low flow conditions with shade and riparian vegetation at site potential for Bear Creek and all tributaries. The 7Q10 low flow conditions were used because these conservative flows are the lowest conditions to which the temperature criteria apply. Exceedance of the criteria under less than 7Q10 flow conditions is not considered a permit violation 340-041-0028 (12)(b)(D)(d). Ashland Creek 7Q10 flows during the low flow season are 1 CFS and the critical flows during the high flow season are 3 CFS as determined in DEQ 2004. The Bear Creek 7Q10 values used in the analysis were calculated in Carollo, 1997 using a Log Pearson Type III analysis of data from 1928-1996. Far-field temperature modeling of Bear Creek was only performed for the summertime critical period in August. In order to simulate a conservative worst case scenario, facility dry weather design flows (2.3 MGD (3.65 CFS)) were used both scenarios. Simulations assume 100% of the river is used for mixing.

The amount of heat energy a point source can add to a receiving stream is dependant upon the flow of the receiving water, the discharge flow from the plant, and the human use allowance. The allowable heat energy is determined by the following mass balance equation:

EQ. 2.1 $H_{WLA}=(HUA)(Q_{PS}+Q_{R})(c)/1{,}000{,}000$

[1] 7Q10 refers to the streamflow that occurs over 7 consecutive days and has a 10-year recurrence interval period, or a 1 in 10 chance of occurring in any one year. Daily streamflows in the 7Q10 range are general indicators of drought or lowflow conditions. 7Q10 values are also frequently used to regulate water withdrawals and discharges into streams.

Where:
H_{WLA} = Waste Load Allocation Heat Load (MW)
Q_{PS} = Point Source Effluent Flow (cms)
Q_R = Upstream River Flow (cms)
HUA = Human Use Allowance (^oC)
c = Specific Heat of Water = 1.0 cal/g*C = 4.1868 x 10^6 J/m3*C
1,000,000 = conversion factor from J/sec to MW

In order to translate the thermal waste load allocation into an effluent temperature useful for managing the plant, the applicable temperature criterion must also be accounted for. For the case of the Ashland WWTF the applicable criterion is 13^0C (55.4F) October 15 through May 15; 18^0C (64.4F) May 16 through October 14 (Biologically Based Numeric Criteria OAR 340-0041-0028(4). The following equation is used to calculate the effluent temperature limit for any given effluent flow and river flow:

EQ. 2.2 $$T_{WLA}=((\ T_R + HUA)(Q_{PS}+Q_R\,) - (Q_R\,)(\ T_R))/\ Q_{PS}$$

Where:
T_{WLA} = Waste Load Allocation Temperature
Q_{PS} = Point Source Effluent Flow (cms)
Q_R = Upstream River Flow (cms)
T_R = Applicable Temperature Criterion
HUA = Human Use Allowance (^oC)

Providing the Ashland WWTF a human use allowance of 0.1C above the applicable criteria did not result in near-field impacts on Ashland Creek or far field impacts on Bear Creek in exceedance of 0.1C HUA. The resulting waste load allocations are summarized in Table 12. The city of Ashland has expressed an interest in potentially moving the WWTF outfall to Bear Creek. This scenario was also examined through modeling with the facility outfall placed directly into Bear Creek above the confluence with Ashland Creek given a HUA of 0.1C. The waste load allocations associated with this scenario are shown in Table 13. Note: Table 13 is included for informational purposes only.

Near-field and far field impacts far-field thermal impacts from the Ashland WWTF greater than the 0.1C HUA were not observed in the Heat Source model. For this reason, the point of maximum impact is considered to be the mixing zone during both the summertime and fall critical periods as shown in Table 12 and 13.

The intent of Tables 12 and 13 is to provide waste load allocations and permit limits that account for seasonal variability and future attainment of the applicable standard under the worst case conditions as represented by 7Q10 flows and the WWTF discharging at design flows. As part of the NPDES permit renewal process, the city of Ashland may wish to compute daily or monthly thermal waste load allocations based on the applicable standard, actual receiving water flows, and actual WWTF discharges.

Table 5. Ashland WWTF Waste Load Allocation – Current Outfall into Ashland Creek

Month	Applicable Criterion ^oC	Dry Weather Design Flows CFS Q_{PS}	Receiving Water 7Q10 CFS[1] Q_R	Human Use Allowance ^oC HUA	WLA (MW) H_{WLA}	Effluent Temp Limit ^oC T_{WLA}
May 16 – Oct 14	18C	3.65	1	0.1C	.055	18.13
Oct 15 – May 15	13C	3.65	3	0.1C	.079	13.18

[1] Seasonal 7Q10 flows are taken from DEQ, 2004.

Table 6. Ashland WWTF Waste Load Allocation – Outfall into Bear Creek

Month	Applicable Criterion °C	Dry Weather Design Flows CFS Q_{PS}	Receiving Water 7Q10 CFS[1] Q_R	Human Use Allowance °C HUA	WLA (MW) H_{WLA}	Effluent Temp Limit °C T_{WLA}
May 16-31	18C	3.65	9.3	0.1C	.153	18.36
June	18C	3.65	6.1	0.1C	.115	18.27
July	18C	3.65	4.4	0.1C	.095	18.22
August	18C	3.65	3.5	0.1C	.085	18.20
Sept	18C	3.65	3.4	0.1C	.083	18.19
October 1-14	18C	3.65	4.1	0.1C	.092	18.21
October 15-31	13C	3.65	4.1	0.1C	.092	13.21
November	13C	3.65	7.7	0.1C	.134	13.31
December	13C	3.65	9.7	0.1C	.158	13.37
January	13C	3.65	14.9	0.1C	.220	13.51
February	13C	3.65	17.6	0.1C	.252	13.58
March	13C	3.65	19.4	0.1C	.273	13.63
April	13C	3.65	3.6	0.1C	.086	13.20
May 1-15	13C	3.65	9.3	0.1C	.153	13.36

[1] 7Q10s for Bear Creek are based on a correlation of the Bear Creek gage in Medford (RM 10.1) with the Bear Creek gage in Ashland (RM 20) using a Log Pearson Type III analysis of data from 1928-1996. Source Carollo, 1997.

References Cited

.

Boyd, M. and B. Kasper. 2003. Analytical Methods for Dynamic Open Channel Heat and Mass Transfer: Methodology for Heat Source Model Version 7.0. (Downloadable at Oregon DEQ website.)

BCWC, 2005. Bear Creek Watershed Riparian Canopy Assessment. Bear Creek Watershed Council, June 2005. BCWC, PO Box 1548, Medford OR 97501.

DEQ, 2000. TMDL Assessment Report: Riparian Shade. Bear Creek Oregon, Rogue River Basin, Middle Rogue Sub-basin. Oregon Department of Environmental Quality May 9, 2000.

Leslie Stillwater, 2005, Personal Communication. Hydraulic Engineer, US Bureau of Reclamation, Pacific Northwest Region 1150 North Curtis Road, Boise, Idaho 83706-1234, Phone (208) 378.5202, Fax (208) 378.5305

Other References of interest:

.

Beschta, R. L., R. E. Bilby, G. W. Brown, L. B. Holtby, and T. D. Hofstra. 1987. Stream temperature and aquatic habitat: Fisheries and forestry interactions. Pages 191-232 in E. O. Salo and T. W. Cundy, eds. *Streamside management: Forestry and fishery interactions*. University of Washington, Institute of Forest Resources, Seattle, USA

Leopold, L. B., M. G. Wolman and J. P. Miller. 1964. Fluvial Processes in Geomorphology. Freeman, San Francisco, California. 522 pp.

Oregon Department of Fish & Wildlife. 1997. ODFW Aquatic Inventories Project Stream Habitat Distribution Coverages. Natural Production Section. Corvallis. Oregon Department of Fish & Wildlife.

Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology. Pagosa Springs, Colorado.

Rotz, W. and E. Falk, D. Wood, and J. Mulrow. 2001. *A Comparison of Random Number Generators Used in Business*. Presented at Joint Statistical Meetings, Atlanta, GA.

Thorson, T.D., S.A. Bryce, D.A. Lammers, A.J. Woods, J.M. Omernik, J. Kagan, D.E. Pater, and J.A. Comstock. 2003. Ecoregions of Oregon (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:1,500,000). http://www.epa.gov/wed/pages/ecoregions/or_eco.htm.