DEQ Water Quality Division

Trend Analysis of Food Processor Land Application Sites in the Lower Umatilla Basin Groundwater Management Area

State of Oregon Department of Environmental Quality

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Questions or comments about this document should be directed to:

Phil Richerson
Department of Environmental Quality
700 SE Emigrant Street, #330
Pendleton, OR 97801
(541) 278-4604
Richerson.Phil@deq.state.or.us

This document can be found on the Department's web site at:

http://www.deq.state.or.us/wq/groundwa/LUBGWMgmtArea.htm

For printed copies please contact the DEQ Eastern Region Office in Pendleton at (541) 276-4063.

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EXECUTIVE SUMMARY

This document describes a trend analysis of nitrate concentrations in groundwater monitoring wells at ten sites operated by six facilities located in the Lower Umatilla Basin Groundwater Management Area (LUB GWMA) where food processor wastewater is treated through land application.

Purpose of this Report
The purpose of this report is to evaluate one specific measure of progress detailed in the LUB GWMA Action Plan (the Action Plan). That measure of progress (Section VII, Item G.3.b) relates to the land application of food processing wastewater and states that, in part, that by December 2001 "monitoring data shows improving groundwater quality trends for nitrate". Average nitrate concentrations and each site's hydrogeology were also evaluated in order to better evaluate the factors affecting nitrate concentrations.

Methods
Nitrate concentrations at groundwater monitoring wells were evaluated for monotonic trends using the Seasonal Kendall technique. A data smoothing algorithm was used to produce a LOWESS line which is useful for identifying non-linear water quality changes. Maps depicting the nitrate trends at each well were produced, as well as maps depicting the average nitrate concentrations at each well. When possible, groundwater elevation maps were prepared, and used to select upgradient and downgradient wells. Conclusions regarding nitrate trends, as well as potential effects from each facility, were drawn using groundwater quality data and water level information, often including the selected upgradient and downgradient wells.

Conclusions
Nitrate concentrations are increasing at most wells, and at most sites. Therefore, the measure of Action Plan progress that states "monitoring data shows improving groundwater quality trends for nitrate" was not met. In addition, the average nitrate concentration at most sites exceeds the GWMA trigger level. However, the trend analysis does not by itself provide an indication of whether or not the nitrate contamination is the result of current facility operations. Other factors that can affect nitrate trends include historical facility activities, offsite activities (both current and historical), and the site's hydrogeology. Potential methods exist to assess current facility operations, and include "age dating" groundwater samples and/or performing a detailed evaluation of the site's hydrogeology, land use, and contaminant transport regime.

Recommendations
Both site-specific and general recommendations are made in this report. The site-specific recommendations involve additional assessment activities at five facilities in order to better define the site's groundwater flow regime and/or to determine the source of nitrate in groundwater. The general recommendations include pursuing funding to gauge the effects of BMP implementation, continued and expanded BMP implementation, and completion of the Action Plan-required trend analysis after 2005.

Although nitrate concentrations are increasing at most wells and at most sites, there are some wells and sites where nitrate concentrations are decreasing. It is also recommended that DEQ and the food processors work together to identify what combination of factors produces the improving water quality trends, then apply those factors elsewhere, with the hope of improving water quality trends across the GWMA.

REGISTERED PROFESSIONAL GEOLOGIST SEAL

In accordance with Oregon Revised Statutes Chapter 672.505 to 672.705, specifically ORS 672.605 which states:

"All drawings, reports, or other geologic papers or documents, involving geologic work as defined in ORS 672.505 to 672.705 which shall have been prepared or approved by a registered geologist or a subordinate employee under the direction of a registered geologist for the use of or for delivery to any person or for public record within this state shall be signed by the registered geologist and impressed with the seal or the seal of a nonresident practicing under the provisions of ORS 672.505 to 672.705, either of which shall indicate responsibility for them.",

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Document Title: Trend Analysis of Food Processor Land Application Sites in the Lower Umatilla Basin Groundwater Management Area

Document Author(s): Phil M. Richerson

Document Date: December 29, 2004

Name of Oregon RPG: Phil M. Richerson (G1906)

Signature of Oregon RPG: Phil Richerson

Date of Seal: 12/29/04

1.0 INTRODUCTION

1.1 Establishment of the Lower Umatilla Basin Groundwater Management Area

Oregon's Groundwater Protection Act of 1989 requires the DEQ to declare a Groundwater Management Area (GWMA) if area-wide groundwater contamination, caused primarily by nonpoint source pollution, exceeds certain trigger levels. In the case of nitrate, the trigger level is 7 mg/l nitrate-nitrogen. Nonpoint source pollution of groundwater results from contaminants coming from diffuse land use practices, rather than from discrete sources such as a pipe or ditch. The contaminants of nonpoint source pollution can be the same as from point source pollution, and can include sediment, nutrients, pesticides, metals, and petroleum products. The sources of nonpoint source pollution can include construction sites, agricultural areas, forests, stream banks, roads, and residential areas.

The Groundwater Protection Act also requires the establishment of a local Groundwater Management Area Committee comprised of affected and interested parties. The committee works with and advises the state agencies that are required to develop an action plan that will reduce groundwater contamination in the area.

The LUB GWMA was declared in 1990 after nitrate contamination was identified in a 352,000-acre area in the northern portions of Umatilla and Morrow counties. The location of the LUB GWMA is shown in Figure 1-1. Groundwater samples from private wells had nitrate contaminations above the federal safe drinking water standard in many samples collected from the area. A four-year comprehensive study of the area was conducted in the early 1990s by the DEQ, the Oregon Water Resources Department, and the Oregon Health Division. The 1995 report titled "Hydrogeology, Groundwater Chemistry, & Land Use in the Lower Umatilla Basin Groundwater Management Area" identified five potential sources of nitrate loading to groundwater:

1. Irrigated Agriculture
2. Land Application of Food Processing Wastewater
3. Septic Systems (rural residential areas)
4. Confined Animal Feeding Operations, and
5. The Umatilla Chemical Depot Washout Lagoons

The LUB GWMA Action Plan was finalized in December 1997. The Action Plan details the activities to be conducted by the various agencies and organizations involved. The Umatilla and Morrow County Soil and Water Conservation Districts are the local agencies leading implementation of the Action Plan. The ODEQ and ODA have oversight responsibility. Local governments, private industry, and the US Army are also involved in implementation of the Action Plan.

DEQ and the Committee decided to implement the Action Plan on a voluntary basis recognizing that individuals, businesses, organizations, and governments will, if given adequate information and encouragement, take positive actions to adopt or modify practices and activities to reduce contaminant loading to groundwater.

The Action Plan recommends general activities and specific tasks to be conducted by involved agencies and groups representing the five sources of nitrate loading. The Action Plan also identifies methods and a schedule for evaluating progress in implementing the Action Plan.

1.2 Purpose of This Report

The purpose of this report is to evaluate one specific measure of progress detailed in the Action Plan. That measure of progress (Section VII, Item G.3.b) relates to the land application of food processing wastewater and states, in part, that by December 2001, "monitoring data shows improving groundwater quality trends for nitrate". There are six facilities within the LUB GWMA that land apply food processing wastewater at ten sites. Figure 1-2 indicates the location of these ten sites.

The nitrate trend analysis at these wells does not by itself provide an indication of whether or not the nitrate contamination is the result of current facility operations. Other factors that can affect nitrate trends include historical facility activities, offsite activities (both current and historical), and the site's hydrogeology. In an attempt to account for some of these other factors, average nitrate concentrations and the site's hydrogeology were evaluated in order to better evaluate the factors affecting nitrate concentrations.

1.3 Methodology

The evaluation described in this report involved three aspects:

1) an evaluation of nitrate trends at wells located near where food processing wastewater is land applied,
2) an evaluation of average nitrate concentrations at these wells, and
3) an evaluation of the hydrogeology of each of these sites.

Trend Analysis Technique Used

One of the conclusions from a 2003 trend analysis of groundwater nitrate concentrations in Eastern Oregon's Northern Malheur County Groundwater Management Area was that using different trend analysis techniques and data sets generated by multiple analytical techniques can cause differences in the calculated trends. These include differences in both trend line direction and magnitude. The fact that using different <u>data sets</u> produces different trends indicates the importance of maintaining a consistent analytical technique throughout the data set. The fact that using different trend analysis <u>techniques</u> produces different trends has two major implications:

1) it underscores the importance of using a technique that accommodates the complicating aspects of water quality data sets (e.g., missing data, non-normal distributions, and censored data), and
2) it suggests that the exclusive use of one technique (that is appropriate for all data set characteristics) would eliminate variations in trend estimates produced by using multiple methods, and produce results better suited for making comparisons between wells and over time. The results would be more comparable both between wells for any given time (e.g., compare simultaneous trends in different areas), and at the same well at two different times (e.g., comparing a current trend to a past trend at a particular well). In other words, differences in calculated trends would be attributable to changes in water quality rather than changes in the analytical technique.

Based on the conclusions discussed above, the Seasonal Kendall technique was selected as the trend analysis technique used in this study. In order to be consistent with previous trend analyses conducted by DEQ in Eastern Oregon's Northern Malheur County Groundwater Management Area, a confidence level of 80% was used to distinguish between statistically significant trends (i.e., those with an 80% or higher confidence level) versus statistically insignificant trends (i.e., those with less than 80% confidence level). Appendix 1 includes a discussion of the principles of trend analysis, including the Seasonal Kendall technique.

In addition to calculation the Seasonal Kendall trend, a LOWESS line was also calculated for each well. The LOWESS line is similar to a moving average and provides a good depiction of the underlying structure of the data. The LOWESS technique is discussed in more detail in Appendix 1.

Average Nitrate Concentrations

The monitoring wells at the ten land application sites were installed at various times. The average values indicated in summary tables of this report include the entire data set used for the trend analysis. However, in order to better facilitate comparisons across a particular site, the average values indicated in the figures of this report use the timeframe in which all wells were installed and sampled.

Hydrogeology

The aspects of a site's hydrogeology that were evaluated as part of this investigation include the groundwater flow direction, depth to water, effects of nearby surface water features, and recharge and discharge features. Particular emphasis was placed on how these hydrogeological aspects can affect nitrate concentrations. Not all of these aspects were relevant at each site evaluated.

Groundwater Flow Direction
Groundwater flow direction can affect groundwater nitrate concentrations. Knowing the groundwater flow direction across a site allows an evaluation of the potential contaminant contribution from a site through a comparison of upgradient and downgradient concentrations. Groundwater elevations at wells form the basis of developing a groundwater table map. However, many large sites often have relatively few wells. The incorporation of other information is often necessary to "fill in the blanks" between wells. Land surface topography is often an important factor affecting groundwater flow direction. Because gravity is the dominant driving force in groundwater movement, groundwater in higher areas flows "downhill" to lower areas. This frequently causes the water table to be a subdued replica of the land surface, especially in humid areas. However, this generalization does not always hold true; especially in arid regions. Other factors (such as aquifer boundaries or the amount and location of recharge and discharge features) may be more influential on groundwater flow direction than land surface topography.

Depth to Water
The depth to water can affect groundwater nitrate concentrations because the deeper the groundwater, the longer it will take water to percolate from land surface to the water table. Similarly, if past practices at a site caused a build up of nitrate in the unsaturated zone above the water table, a thicker unsaturated zone (i.e., deeper to groundwater) would store more nitrate and take longer to flush than a thinner unsaturated zone.

Effects of Nearby Surface Water Features
Surface water features can affect groundwater nitrate concentrations. Surface water features that are hydraulically connected to groundwater can have a significant effect. For example, major streams and rivers often have flood plains associated with them that contain water flowing in and out of the stream channel. Surface water can affect the quality of the groundwater, and vice versa, as water flows in and out of the stream channel and flood plain. Similarly, water infiltrating from a leaky irrigation canal can mix with groundwater and alter the water quality. Surface water bodies that are not hydraulically connected to groundwater can also have an effect. For example, wastewater from a leaky lagoon, or irrigation water from a canal whose base is above the water table can infiltrate to the water table and alter groundwater quality.

Recharge and discharge features
Recharge features (i.e., something that adds water to the aquifer such as precipitation, deep infiltration of irrigation water, or leaky irrigation canal) and discharge features (i.e., something that takes water out of an aquifer such as a spring, base flow to a gaining stream, or well) can affect the groundwater flow direction and nitrate concentration.

Trend Analysis Steps
The specific steps used to conduct the trend analyses and prepare the tables and figures in this report include the following 13 steps:

1 *Compile the data submitted to DEQ by the permittee for each site*. Most of the data were in electronic format. Some recent data were provided verbally or from documents recently submitted to DEQ. It was assumed that the data sets were correct and complete. No attempts were made by DEQ to verify the data submitted. Furthermore, it was assumed that sampling and analytical procedures were consistent at each well.

2 *Thin the data to one sample per quarter*. Some wells at some facilities were sampled monthly for a while and then were sampled quarterly. In order to avoid biasing summary statistics, these data sets were thinned. The data point closest to the middle of the quarter was retained while the remainder of the data points was deleted.

3 *Condition the data*. Data conditioning was performed on censored data and sample dates. Data conditioning of censored data consisted of replacing values reported as "below detection limits" with ½ the value of the highest detection limit. If ½ the value of the highest detection limit exceeded any reported values, the reported values were raised to ½ the value of the highest detection limit. Data conditioning of sample dates consisted of (1) replacing "month/year" sample dates with the 15th day of

the month (e.g., February 1995 was replaced with 2/15/95), (2) replacing "quarter/year" sample dates with the date of the middle of the quarter (e.g., 1st Quarter 1995 was replaced with 2/15/95), and (3) converting sample dates to a decimal date format (e.g., 2/15/95 = 1995.123) for plotting purposes.

4 *Create input files for the statistical and graphing software programs used.* Input files for the software programs used to calculate summary statistics, evaluate data set characteristics, perform the trend analyses, and prepare graphs were prepared. Software programs used in this study include DataQUEST version QA96 (from USEPA), WQHydro version 2032 (from Eric Aroner), Minitab version 12.2 (from Minitab, Inc.), and Grapher version 3 (from Golden Software, Inc). The use of product names is for information purposes only. DEQ does not advocate the use of any particular software.

5 *Evaluate data set characteristics* including minimum, maximum, mean, median, coefficient of skewness, sample size, and percentage of censored data.

6 *Calculate a monotonic trend line using the Seasonal Kendall technique.*

7 *Calculate a LOWESS line through nitrate data for each well.*

8 *Create time series plots* for each well including the trend line and LOWESS line at a scale appropriate for the nitrate range at each well.

9 *Create a one-page summary of LOWESS and trend lines at a scale appropriate for the nitrate range at each site.*

10 *Create a plot of all nitrate data from the site with a LOWESS line fit through the data.*

11 *Create a map illustrating the magnitude and direction of nitrate trends at each well.*

12 *Create a map illustrating the average nitrate concentration at each well.*

13 Create a water table contour map and *identify upgradient and downgradient wells.*

14 *Create a time series plot and box plot of upgradient and downgradient nitrate concentrations.*

2.0 PORT OF MORROW

2.1 Introduction

The Port of Morrow currently land applies approximately 1.3 billion gallons of wastewater annually consisting of potato, cheese, mint, and onion processing wastewater generated by local industry. In addition to the food processing wastewater, the Port of Morrow also land applies cooling tower wastewater, boiler lowdown, the City of Boardman's treated sewage (applied to Circle 52 at Farm 1), and floor/equipment wash water from the Portland General Electric Coyote Springs Co-Generation Plant. Future plans include the land application of wastewater from another co-generation plant, a wine bottle manufacturing plant.

The wastewater typically contains:

- approximately 104 mg/l Total Kjeldahl Nitrogen (TKN),
- approximately 34 mg/l ammonia (NH_4-N),
- approximately 1,720 mg/l Total Dissolved Solids (TDS),
- approximately 886 mg/l Total Suspended Solids (TSS), and
- approximately 2,936 mg/l Chemical Oxygen Demand (COD).

The Port of Morrow land application areas are located approximately 3 miles east of the City of Boardman, in the vicinity of US Interstate 84 and US Highway 730 (Figure 1-2). The process wastewater, along with supplemental fresh water, is land applied on three parcels of land known as Farm 1, Farm 2, and Farm 3.

Principal components of the Port of Morrow's wastewater treatment and disposal system include a clarifier and vacuum filter for potato processing wastewater, a pump station with lined overflow pond, land application areas, and a 196 million gallon lined storage lagoon. Farm 1 is located north of Interstate 84 on 1,698.7 acres. Farm 2 is located south of Interstate 84 on 1,600 acres. The Port of Morrow contracts for management of the farming activity on the farms where process wastewater is land applied. The land application system at a portion of Farm 3 was approved by DEQ in August 2002. Since the trend analysis evaluations only include data through 2001, Farm 3 was not included in the evaluation. The trend analyses discussed below include only Farm 1 and Farm 2.

2.2 Farm 1

As indicated in Section 2.1, the Port of Morrow Farm 1 consists of 1,698.7 acres located north of Interstate 84. Crops grown using the process wastewater include a rotation of alfalfa, winter wheat, spring wheat, hard red winter wheat, field corn, sweet corn, silage corn, mint, peas, potatoes, and sugar beets.

The land application system at Farm 1 began in 1971 in the area where circles 53, 54, and 55 are located today. Prior to the land application system, the land occupied by Farm 1 was operated as a commercial farm.

Farm 1 is located within the Columbia Basin physiographic province. The area is underlain by Columbia River Flood basalts overlain by sand, gravel, and silt. The overlying sediments were deposited during past flooding and damming of the Columbia River, and further reworked by wind. The soils at land surface are well drained to excessively drained loamy fine sands and sands (SCS, 1983). Topographic slopes are typically small (0 to 5%; some up to 12%) but pockets of dune lands slope 5 to 60% (SCS, 1983). Land surface topography at Farm 1 ranges from approximately 370 to 265 feet above mean sea level.

Nearby surface water features include the John Day Pool of the Columbia River and the West Extension Irrigation Canal. The John Day Pool forms a portion of the eastern boundary of Farm 1 and extends approximately 76 miles from the upstream side (i.e., the fore bay) of the John Day Dam to the downstream side (i.e., the tail water) of the McNary Dam. The West Extension Irrigation Canal crosses the southeastern portion of Farm 1 and delivers water from the Umatilla River to irrigated lands in the area.

The depth to water beneath Farm 1 ranges from less than 6 (typically about 2½) feet below land surface (at well MW-6 located just south of Farm 1) to more than 80 feet below land surface (at wells MW-2, MW-4, MW-SP1, and MW-SP2 (located in the northeastern portion of the site). With all other variables being equal, wells with a greater depth to water would be slower to respond to changes in practices at land surface.

2.2.1 Hydrogeology

Figure 2-1 is a groundwater elevation contour map of the area including Port of Morrow Farms 1, 2 and 3. The data used to construct this map are from March 4, 2002, and were selected because it is the first date water levels were measured at all three Port of Morrow Farms. Data from all three farms were used to create a groundwater contour map, allowing a more regional assessment of groundwater flow directions than using data only from one farm.

Groundwater flow in the vicinity of the Port of Morrow is generally to the north with discharge to the John Day Pool of the Columbia River. A significant subsurface geologic feature in the area is the line where the basalt surface underlying the unconsolidated sediments rises to an elevation above the John Day Pool elevation. This hinge point separates the low-gradient area to the north (with a 1-foot contour interval) from the high-gradient area (with a 25-foot contour interval) to the south (Figure 2-1). The saturated thickness of the alluvial sediments near this hinge line is generally less than 10 feet, while closer to the river there is more than 80 feet of saturated alluvial sediments.

The water level contours in Figure 2-1 are based on the water levels measured at the 25 alluvial aquifer wells, the John Day Pool elevations recorded by the US Army Corps of Engineers, land surface topography, locations of wetlands, and the elevation of the underlying basalt surface. Water levels shown in parentheses are in basalt wells and are not directly contoured, even though hydrographs from most shallow and deep well pairs indicate very similar groundwater elevations and a significant hydraulic connection.

Based on the well log for well MW-3, the water level at well MW-3 is not believed to represent the regional water table, but instead is perched above the regional water table by a clay layer. The well log indicates 4 feet of saturated sand on top of 2 feet of clay on top of 13 feet of unsaturated sand. The presence of perching clay is also consistent with the fact that irrigation water purged from the West Extension Irrigation Canal (near MW-3a) forms a wetland west and southwest of MW-3 rather than rapidly infiltrating.

Based on the regional water table map presented in Figure 2-1 (showing a general north-northwesterly groundwater flow direction), upgradient wells at Farm 1 would be located south and southeast of the land application activities, and downgradient wells at Farm 1 would be located north and northwest of land application activities. Figure 2-2 shows the water table map for Farm 1 in relation to the land application sites.

In order to evaluate the influence of fluctuations of the John Day pool on Farm 1 wells close to the river, groundwater levels in wells MW-9 and MW-10 were compared to surface water elevations at either end of the John Day pool (i.e., the McNary Dam tail water and the John Day Dam fore bay). Figure 2-3 graphically depicts available water level data from these locations collected from 1991 through 2001. Figure 2-3 illustrates two concepts: (1) well MW-9 (located approximately 2500' from the River) is consistently upgradient from well MW-10 (located approximately 500' from the River), and (2) the water level in well MW-10 is generally between the McNary tail water elevation and the John Day fore bay elevation. This indicates the hydraulic gradient (and therefore the groundwater flow direction) is normally from well MW-10 toward the Columbia River. However, Figure 2-3 suggests it is possible to have short-term reversals of the hydraulic gradient causing water to flow from the Columbia River a short distance inland. The reversals are not sufficient to cause groundwater to flow from well MW-10 to MW-9.

Based on the water levels in Figures 2-2 and 2-3, upgradient wells for Farm 1 include MW-6 and MW-3a. Because well MW-3a was installed in early 2002, there is not enough water quality data from this well to evaluate the nitrate trend. However, the initial samples from this well indicate relatively low (less than 5 ppm) nitrate. Therefore, well MW-6 is the only upgradient well with enough data to evaluate upgradient water quality. Well MW-3 is not considered an upgradient well because it is located primarily downgradient of Circle 52, and it is likely that water in this well is perched above the regional water table. Water recharging well MW-3 is expected to come from a relatively nearby source (e.g., the irrigation water discharged to the wetland located directly west of the well or Circle 52 located directly east of the well). Well MW-7 is not considered an upgradient well due to its close proximity to Circle 46 and being located approximately downgradient from Circles 56 and 57.

Based on the water levels in Figure 2-2, downgradient wells for Farm 1 include MW-10, MW-11, MW-5, and MW-8. The remaining wells are either internal to the farm (i.e., MW-1, MW-2, MW-4 and MW-9) or were installed specifically to evaluate leakage from the wastewater storage lagoon (i.e., MW-SP1 and MW-SP2).

2.2.2 Nitrate Trends

A trend analysis of nitrate concentrations at each of the 13 Port of Morrow Farm 1 wells was conducted as described in Section 1.3 and Appendix 1. Table 2-1 summarizes the data used in this analysis and includes some data set statistics (e.g., mean and maximum values), a summary of the trend analysis (e.g., the slope and confidence level of the line) and a description of the LOWESS[1] pattern (e.g., increasing then decreasing). Time series graphs of nitrate concentrations at each Port of Morrow well are included in Appendix 2.

Table 2-1 lists the individual results of the trend analyses for each well. The results can be summarized as follows:

- 9 wells have increasing trends
- 1 well has a decreasing trend
- 3 wells have statistically insignificant trends

In summary, most wells (69%) have statistically significant increasing trends. The trends range from increasing at 2.65 ppm/yr at MW-3 to decreasing at 0.02 ppm/yr at MW-6. The site-wide average nitrate trend (i.e., the average of all 13 slopes) is increasing at approximately 1.1 ppm/yr. The average trend of the 10 statistically significant results is increasing at approximately 1.3 ppm/yr.

It is important to note that the three statistically insignificant trends have average concentrations of greater than 20 ppm. The fact that a statistically significant linear trend cannot be drawn through the data does not mean that the concentrations are insignificant or unworthy of attention. Instead, it means that the statistical test could not identify a linear trend with a high degree of assurance.

Table 2-1 also lists a description of the LOWESS pattern for individual wells. The LOWESS patterns observed can be summarized as follows:

- 2 wells show a steadily increasing pattern
- 1 well shows an increasing pattern with some fluctuations
- 1 well shows an increasing then leveling off pattern
- 1 well shows a flat then increasing pattern
- 5 wells show an increasing then decreasing pattern
- 2 wells show a decreasing then increasing pattern
- 1 well shows a fluctuating pattern

[1] The distinction between a trend line and a LOWESS line is that a trend line is the best straight line fit through the data that describes the overall change in water quality across the entire timeframe, while a LOWESS line is a type of data smoothing that describes the general pattern of the data throughout the timeframe. Changes in nitrate concentration are usually not a straight line. So, although it is useful to characterize changes as a "straight" trend line, additional useful information can be gained by evaluating "smoothed" LOWESS lines.

In summary, approximately half of the wells exhibit either consistently increasing or recently increasing LOWESS patterns.

Figure 2-4 is a graph of all nitrate data from the 13 Farm 1 wells, with a LOWESS line drawn through the data. Figure 2-4 consists of many stacks of data points at approximately 3 month intervals. Each of these stacks of data represents one quarterly sampling event and contains one data point for each well sampled that event. It is evident from Figure 2-4 that the highest concentrations detected have occurred in the latter portion of the dataset. The increasing LOWESS line reflects the generally increasing nitrate concentrations at Farm 1.

Figure 2-5 includes the nitrate trends and LOWESS lines at each of the 13 Port of Morrow Farm 1 wells. The 13 graphs are plotted at the same scale to allow a comparison of trends between wells. The wells are arranged in rows from steepest increasing trend to steepest decreasing trend, with statistically insignificant trends placed toward the bottom right (i.e., the steepest increasing trend is in the upper left corner of Figure 2-5).

Useful information can be gained by comparing trend lines with LOWESS lines. Examination of LOWESS lines through the nitrate data illustrates non-linear changes in nitrate concentrations. For example, Figure 2-5 illustrates the following:

- The 2.65 ppm/yr trend line at MW-3 is less steep than the LOWESS line (due to the low concentrations in the early part of the data set) indicating nitrate is increasing more rapidly than 2.65 ppm/yr recently,
- Nitrate concentrations at MW-8 increased steeply through 1997 but then started to decrease, and
- Nitrate concentrations at MW-4 increased through 1994 but then decreased.

Figure 2-6 is a map view of the site illustrating nitrate trends at each of the wells. With the exception of wells MW-1, MW-6, MW-SP1 and MW-SP2, all wells have increasing trends. The steepest increasing trends are at well MW-3 (screened in perched water), and wells MW-8 and MW-11 (located on the northern downgradient boundary of Farm 1). The one decreasing trend is at well MW-6 located south (upgradient) of Farm 1. Wells MW-1, MW-SP1, and MW-SP2 have statistically insignificant trends. The high percentage of increasing trends illustrates that nitrate concentrations are generally increasing. The steep trends at the downgradient boundary of Farm 1 suggest facility operations have affected groundwater quality.

2.2.3 Average Nitrate Concentrations

Figure 2-7 illustrates the average nitrate concentrations at each of the Farm 1 wells from March 1995 through September 2001, the timeframe in which all 13 wells were installed and being sampled. The averages in Table 2-1 use all data since each well was installed. With the exception of well MW-6 (which averages 1.0 ppm), the average nitrate concentration at each well is greater than 10 ppm. The highest average concentrations are in the vicinity of the process wastewater storage lagoon area (41.5 ppm at MW-SP2; 40.5 ppm at MW-8; 37.9 ppm at MW-SP2) suggesting that water leaking from the lagoon has affected groundwater quality. The next highest averages are in the southern portion of Farm 1 at well MW-3 (38.8 ppm), in the eastern portion of Farm 1 at well MW-2 (36.0 ppm), and in the northwestern portion of Farm 1 at well MW-11 (31.1 ppm).

2.2.4 Upgradient to Downgradient Comparisons

Based on the selection of well MW-6 as the upgradient well and wells MW-5, MW-8, MW-10, and MW-11 as downgradient wells, a comparison of upgradient to downgradient nitrate concentrations was made.

Figure 2-8(a) is a time series graph showing the nitrate concentrations at the upgradient well and the downgradient wells. In addition to the individual data points connected by a thin line, a thick LOWESS line is drawn through the data. Figure 2-8(a) shows the upgradient nitrate concentration has remained fairly constant at approximately 1 ppm while the downgradient nitrate concentration (represented by the LOWESS line) has increased from about 15 ppm to over 35 ppm.

Figure 2-8(b) is a box and whisker plot summarizing the nitrate concentrations from the upgradient well (MW-6) and the downgradient wells (MW-5, MW-8, MW-10, and MW-11)[2]. Figure 2-8(b) shows the average upgradient nitrate concentration is approximately 0.8 ppm, and the IQR (i.e., the middle half of the data) is from approximately 0.2 to 0.7 ppm. Figure 2-8(b) also shows the average downgradient nitrate concentration is approximately 26 ppm, and the IQR is from approximately 21 to 31 ppm.

2.2.5 Conclusions

Based on the discussion of the data for the Port of Morrow Farm 1 site discussed above, the following conclusions have been made, and are grouped by topic:

Hydrogeology

- Groundwater flow beneath the Port of Morrow Farm 1 generally flows north-northwest toward the Columbia River.
- The average depth to water beneath Farm 1 ranges from about 2½ to more than 80 feet below land surface.
- Upgradient wells for Farm 1 would be located south and east of facility operations.
  - Upgradient wells for Farm 1 include MW-3a and MW-6. MW-3a did not have sufficient data to include in the analysis but, so far, has nitrate concentrations similar to MW-6.
- Downgradient wells for Farm 1 would be located north and west of facility operations.
  - Downgradient wells for Farm 1 include MW-10, MW-11, MW-5, and MW-8.

Nitrate Trends

- Nitrate concentrations at Farm 1 are generally increasing, as evidenced by:
  - 69% of wells exhibit statistically significant increasing trends.
  - Trends range from decreasing at 0.02 ppm/yr to increasing at 2.65 ppm/yr with the site-wide average nitrate trend increasing at least 1.07 ppm/yr.
  - Approximately half of the wells exhibit either consistently increasing or recently increasing LOWESS patterns.
  - The highest concentrations occur in the latter portion of the dataset.

Factors Affecting Nitrate Concentrations

- Facility operations have affected groundwater quality, as evidenced by:
  - Downgradient concentrations are greater than upgradient concentrations.
  - The steepest increasing trends are located in perched groundwater and at downgradient wells, and
  - The highest average concentrations are near the process wastewater storage lagoon.
- The fact that 69% of the wells exhibit increasing trends, half of the wells exhibit either consistently increasing or recently increasing LOWESS patterns, and the highest average nitrate concentrations are near the process wastewater storage lagoon suggests facility operations continue to affect groundwater quality. Potential methods to assess the effectiveness of current facility operations are discussed in Section 8.2.
- The large range of depth to water across the site could cause substantial variability in the timing of groundwater quality responses to activities at land surface.

[2] The "box" portion of the plot identifies the interquartile range (IQR). The IQR is the middle half of the data (i.e., those data between the 25th and 75th percentiles). The "whisker" portion of the plot extends outwards from the box to any point within 1.5 times the IQR. Any point beyond the whiskers is plotted individually. The horizontal line through the box represents the median value. The star represents the average value.

2.3 Farm 2

As indicated in Section 2.1, the Port of Morrow Farm 2 consists of 1,600 acres located south of Interstate 84. Crops grown using the process wastewater include a rotation of alfalfa, winter wheat, spring wheat, hard red winter wheat, field corn, sweet corn, silage corn, mint, peas, potatoes, and sugar beets.

The land application system at Farm 2 began in 1992. Prior to the land application system, the land occupied by Farm 2 was farmed by a local farmer.

As is the case with Farm 1, Farm 2 is located within the Columbia Basin physiographic province. The area is underlain by Columbia River Flood basalts overlain by sand, gravel, and silt. The overlying sediments were deposited during past flooding and damming of the Columbia River, and further reworked by wind. The soils at land surface are somewhat excessively drained to excessively drained loamy fine sands and sands. Topographic slopes are typically small to moderate (0 to 12%) but pockets of dune lands slope 5 to 60%. Land surface topography at Farm 2 ranges from approximately 470 to 370 feet above mean sea level.

Nearby surface water features include the West Extension Irrigation Canal and two wetlands. The West Extension Irrigation Canal is primarily located north of Farm 2 but also forms a portion the farm's northwestern boundary. Two wetlands straddle the eastern boundary of Farm 2.

The depth to water beneath Farm 2 ranges from approximately 22 feet below land surface (at well MW-18 located in the northeastern corner of the site) to approximately 58 feet below land surface (at well MW-15 (located in the southeastern corner of the site). With all other variables being equal, wells with a greater depth to water would be slower to respond to changes in practices at land surface.

2.3.1 Hydrogeology

Based on the regional water table map presented in Figure 2-1 and discussed in Section 2.2.1 (showing a general north-northwesterly groundwater flow direction), upgradient wells at Farm 2 would be located south and southeast of the land application activities, and downgradient wells at Farm 2 would be located north and northwest of land application activities. Figure 2-9 shows the water table map for Farm 2 in relation to the land application sites. Several land surface contours and wetlands are also included in Figure 2-9 to show localized effects of surface water and topography on groundwater flow in the area south of MW-18.

The wetlands that straddle the eastern boundary of Farm 2 and the wetlands located southeast of Boardman Junction (approximately 1 mile north) have emerged and expanded over the past 2 decades. The emergence and expansion of these wetlands is presumed to be the result of deep percolation of irrigation water filling the alluvial aquifer to the point that groundwater rises to land surface. It is possible that the wetlands located south and southeast of MW-18 act as flow through wetlands in which groundwater discharges into the upgradient side of the wetland, flows through it, and recharges the groundwater on the downgradient side of the wetland. An investigation could be performed to evaluate this theory.

Based on the water levels in Figure 2-9, upgradient wells for Farm 2 include MW-15, MW-15s, MW-16, MW-16s and MW-17 while downgradient wells include MW-12, MW-12s, MW-13, MW-13s, MW-14 and MW-14s. Wells MW-12, MW-13, MW-14, MW-15, MW-16 and MW-17 are completed in the underlying basalt. Wells MW-13s, MW-14s and MW-16s are completed in the alluvial sediments overlying the basalt. Wells MW-12s and MW-15s are completed in the alluvial sediments and perhaps in the Alkali Canyon Formation (located between the alluvial sediments and the basalt). The Alkali Canyon Formation consists of tuffaceous silts and sands and moderately indurated gravels which were shed from the rising Blue Mountains in late Miocene and Pliocene times (DEQ, 1995).

The remaining well (MW-18) is harder to classify. Due to the land surface topography and presence of wetlands in the vicinity of Circle 15 and well MW-18, it is believed that groundwater flow directions range from west to southwest to northwest in that area (Figure 2-9). The Port of Morrow's use of a subsurface drain located between Circle 15 and Bombing Range Road likely lowers groundwater elevations directly east of Circle 15 and causes local variations in groundwater flow directions not identifiable at the scale of Figure 2-9. The Port of Morrow reports that the tile drain became overwhelmed by the volume of water, so in Spring 2004, Morrow County used a large track hoe to make an open ditch along the road side.

2.3.2 Nitrate Trends

A trend analysis of nitrate concentrations at each of the 9 Port of Morrow Farm 2 wells that consistently have water in them[3] was completed using the methodology described in Section 1.3 and Appendix 1. Table 2-2 summarizes the data used in this analysis and includes some data set statistics (e.g., mean and maximum values), a summary of the trend analysis (i.e., the slope and confidence level of the line) and a description of the LOWESS pattern (e.g., increasing then decreasing). Time series graphs of nitrate concentrations at each Port of Morrow well are included in Appendix 2.

The results of the trend analysis shown in Table 2-2 indicate all 9 wells have increasing trends. The trends range from 3.85 ppm/yr at MW-15s to 0.89 ppm/yr at MW-18. The site-wide average nitrate trend (i.e., the average of all 9 slopes) is increasing at approximately 2.5 ppm/yr.

Table 2-2 also lists a description of the LOWESS pattern for individual wells. The LOWESS patterns observed can be summarized as follows:

- 4 wells show a steadily increasing pattern
- 1 well shows an increasing pattern with some fluctuations
- 4 wells shows an increasing then leveling off pattern

In summary, approximately half of the wells exhibit either consistently increasing or recently increasing LOWESS patterns.

Figure 2-10 is a graph of all nitrate data from the 9 Farm 2 wells, with a LOWESS line drawn through the data. Figure 2-10 consists of many stacks of data points at approximately 3 month intervals. Each of these stacks of data represents one quarterly sampling event and contains one data point for each well sampled that event. It is evident from Figure 2-10 that the highest concentrations detected have occurred in the latter portion of the dataset. Furthermore, the LOWESS line increases steeply from 1992 through 1997, then less steeply from 1998 through 2001. The increasing LOWESS line reflects the increasing nitrate concentrations at Farm 2.

Figure 2-11 includes the nitrate trends and LOWESS lines at each of the 9 Port of Morrow Farm 2 wells. The 9 graphs are plotted at the same scale to allow a comparison of trends between wells. The wells are arranged in Figure 2-11 from steepest increasing trend to least steep increasing trend (i.e., the steepest increasing trend is in the upper left corner of Figure 2-11).

As mentioned previously, useful information can be gained by comparing trend lines with LOWESS lines. For example, Figure 2-11 illustrates the following:

- Nitrate concentrations at the overall steepest trend (3.85 ppm/yr at MW-15s) increased, then leveled off, then increased again at a rate steeper than the overall trend,
- Nitrate trends at 4 wells (MW-14, MW-14s, MW-16 and MW-17) increased until about 1998 or 1999, and then started to level off.

Figure 2-12 is a map view of the site illustrating the nitrate trends at each of the wells. All 9 wells have increasing trends. The steepest increasing trend is at well MW-15s located near the southeastern (upgradient) corner of Farm 2. The least steep increasing trend is at well MW-18 located near the northeastern corner of Farm 2.

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[3] Wells MW-12s, MW-13s and MW-16s rarely have enough water to collect a sample.

2.3.3 Average Nitrate Concentrations

Figure 2-13 illustrates the average nitrate concentrations at each of the wells from January 1995 through September 2001, the timeframe in which all 9 wells were installed and being sampled. The averages in Table 2-2 use all data since each well was installed. With the exception of well MW-18 (which averages 7.0 ppm), the average nitrate concentration at each well is greater than 30 ppm. The highest average concentrations are at the southern (upgradient) and northern (downgradient) boundary near the central portion of the farm (50.0 ppm at MW-16 and 48.3 ppm at MW-13). The next highest averages are near the southwestern (upgradient) and southeastern (upgradient) corners of Farm 2 at well MW-17 (44.3 ppm) and well MW-15 (40.9 ppm).

2.3.4 Upgradient to Downgradient Comparisons

As discussed in Section 2.3.1, upgradient wells for Farm 2 include MW-15, MW-15s, MW-16, MW-16s and MW-17 while downgradient wells include MW-12, MW-12s, MW-13, MW-13s, MW-14 and MW-14s. Wells MW-12, MW-13, MW-14, MW-15, MW-16 and MW-17 are completed in the underlying basalt. Wells MW-13s, MW-14s and MW-16s are completed in the uppermost alluvial sediments. Wells MW-12s and MW-15s are completed in the alluvial sediments and perhaps the Alkali Canyon Formation (located between the alluvial sediments and the basalt). However, wells MW-12s, MW-13s, and MW-16s rarely have enough water to collect a sample, making the use of these wells in upgradient to downgradient comparisons difficult.

Figure 2-14 is a comparison of water levels and nitrate concentrations at the two pairs of deep and shallow wells that consistently have water in them (i.e., the MW-14 / MW-14s pair and the MW-15 / MW-15s pair). The distance between the well screens is 34 feet at the MW-14 pair and 9 feet at the MW-15 pair. The similar pattern of water level and nitrate concentration over time at each well pair is evident in Figure 2-14. This similarity suggests the wells are in hydraulic communication and are potentially monitoring portions of the same aquifer. Due to the similarity of data from the two well pairs and the lack of data from the other shallow wells, the upgradient to downgradient comparison conducted for this report used only the wells completed in the basalt.

It is noteworthy that both water levels and nitrate concentrations at these wells generally increase with time. More specifically, water levels at MW-14 and MW-14s increased from 1992 through 1997 then decreased through 2001 while nitrate concentrations increased from 1992 through 1997 then leveled off (Figure 2-14). Both water levels and nitrate concentrations at MW-15 and MW-15s increased from 1992 through 2001 (Figure 2-14). Water levels at other Farm 2 wells (not presented in this report) show similar patterns of increase or increase followed by leveling off.

Based on the selection of wells MW-15, MW-16 and MW-17 as the upgradient wells and wells MW-12, MW-13, and MW-14 as downgradient wells, the following comparison of upgradient to downgradient nitrate concentrations was made.

Figure 2-15(a) is a time series graph showing the nitrate concentrations at the upgradient wells and the downgradient wells. In addition to the individual data points connected by a thin line, a thick LOWESS line is drawn through the data. Figure 2-15(a) shows both the upgradient and downgradient nitrate concentrations rose fairly steeply from late 1991 until about 1997, then increased at a slower rate through 2001. Throughout this time frame, upgradient concentrations were generally greater than downgradient concentrations.

Figure 2-15(b) is a box and whisker plot summarizing the nitrate concentrations from the upgradient wells (MW-15, MW-16, and MW-17) and the downgradient wells (MW-12, MW-13, and MW-14)[4]. Individual box

[4] The "box" portion of the plot identifies the interquartile range (IQR). The IQR is the middle half of the data (i.e., those data between the 25th and 75th percentiles). The "whisker" portion of the plot extends outwards from the box to any point within 1.5 times the IQR. Any point beyond the whiskers is plotted individually. The horizontal line through the box represents the median value. The star represents the average value.

and whisker plots are also included for wells MW-14s and MW-15s. Figure 2-15(b) shows the average upgradient nitrate concentration is approximately 40 ppm, and the middle half of the data is from approximately 32 to 49 ppm. Figure 2-15(b) also shows the average downgradient nitrate concentration is approximately 34 ppm, and the middle half of the data is from approximately 26 to 41 ppm.

2.3.5 Conclusions

Based on the discussion of the data for the Port of Morrow Farm 2 site discussed above, the following conclusions have been made, and are grouped by topic:

Hydrogeology

- Groundwater beneath the Port of Morrow Farm 2 generally flows north-northwest.
- The depth to water beneath Farm 2 ranges from approximately 22 to 58 feet below land surface.
- Upgradient wells for Farm 2 would be located south and east of facility operations.
    - Upgradient wells include MW-15, MW-15s, MW-16, MW-16s, and MW-17.
    - Data from MW-15 and MW-15s are quite similar suggesting the wells are in hydraulic communication and are potentially monitoring portions of the same aquifer.
    - MW-16s rarely has enough water to collect a sample so there was not enough data to use in the analysis.
- Downgradient wells for Farm 2 would be located north and west of facility operations.
    - Downgradient wells include MW-12, MW-12s, MW-13, MW-13s, MW-14, and MW-14s.
    - Data from MW-14 and MW-14s are quite similar suggesting the wells are in hydraulic communication and are potentially monitoring portions of the same aquifer.
    - MW-12s and MW-13s rarely have enough water to collect a sample so there was not enough data from these wells to use in the analysis.

Nitrate Concentrations and Trends

- Nitrate concentrations at the Port of Morrow Farm 2 are increasing, as evidenced by:
    - 100% of wells exhibit statistically significant increasing trends.
    - Trends range from increasing at 0.89 ppm/yr to 3.85 ppm/yr with the site-wide average nitrate trend increasing at approximately 2.5 ppm/yr.
    - Approximately half of the wells exhibit either consistently increasing or recently increasing LOWESS patterns.
    - The highest concentrations occur in the latter portion of the dataset.

Factors Affecting Nitrate Concentrations

- There is evidence suggesting that facility operations have affected, and continue to affect, groundwater quality. There is, however, also evidence suggesting the possibility of a significant upgradient source of nitrate. Therefore, additional information is needed to determine the cause of increasing nitrate concentrations at the site, and whether the land application activities at Farm 2 are adding significant nitrate to the groundwater.
    - Nitrate concentrations are elevated in all wells except MW-18, and nitrate trends are increasing in all wells suggesting facility operations are affecting groundwater.
    - Water levels and nitrate concentrations have increased since the site was used for land application of process wastewater.
    - The higher nitrate concentrations in the upgradient wells suggest the possibility of a significant upgradient source of nitrate. However, no upgradient source of nitrate has been documented.
    - The fact that all of the wells exhibit increasing trends, and approximately half exhibit consistently or recently increasing trends suggests that facility operations are affecting groundwater quality. Potential methods to assess the effectiveness of current facility operations are discussed in Section 8.2.
- The substantially different nitrate concentrations at well MW-18 versus all other Farm 2 wells suggest different hydrogeologic and/or geochemical controls exist near well MW-18.

  - It is possible that the wetlands located south and southeast of MW-18 act as flow through wetlands in which groundwater discharges into the upgradient side of the wetland, flows through it, and recharges the groundwater on the downgradient side of the wetland. The physical and chemical processes associated with such a flow through wetland could account for the lower nitrate and sulfate concentrations observed at well MW-18. An investigation could be performed to evaluate this theory.
- The large range of depth to water across the site could cause substantial variability in the timing of groundwater quality responses to activities at land surface.

2.4 Link Between BMP Implementation and Groundwater Quality Improvement

The following sections describe the Port of Morrow's efforts to improve groundwater quality through the adoption of Best Management Practices (BMPs) as well as some of the limitations to rapid improvement in groundwater quality. The information in Section 2.4.1 was provided by the Port of Morrow.

2.4.1 Efforts to Improve Groundwater Quality

The Port of Morrow has modified practices and procedures over the years to reduce the amount of nitrate and hydraulic loading to the groundwater system. The Port of Morrow has modified practices and procedures over the years to reduce the amount of nitrate and hydraulic loading to the groundwater system. Changes include improving the primary treatment of the wastewater, wastewater storage, irrigation scheduling, soil sampling, plant tissue sampling, and crop rotation strategies. Details of some of these changes were provided by the Port of Morrow and are summarized below.

Primary Treatment – Efforts have been made to ensure that solid particles do not plug the sprinklers that apply the wastewater, so that the water is applied evenly and at the desired rate. For example, Lamb Weston uses a clarifier and vacuum filter to settle and filter out the large organic particles from their wastewater. Similarly, Oregon Potato did a pilot study and determined that a Diffused Air Floatation unit would best suit their waste discharge. They also added a hycor rotating drum to the system. Logan International uses a large double screened rotating drum assembly to filter out their large particles. All of the plants that have come on line in recent years have adhered to the Port of Morrow Ordinance that protects against introducing particles into the system larger than 0.0625 inches. Finally, to provide additional assurance, the Port of Morrow installed Amiad self-cleaning filters at each discharge pump at the lift station.

Wastewater Storage – In the mid-1990's, the Port of Morrow constructed a lined pond to store wastewater during the winter. Since that time, additional acreage has been added to their land application system. Currently, the pond is not used for winter storage of wastewater.

Irrigation Scheduling – In 1994, the Port of Morrow implemented the use of an irrigation scheduling system designed by the Umatilla Electric Cooperative and Bonneville Power Administration. The irrigation scheduling program uses a Neutron probe to measure the amount of water in the soil to a depth of five feet. Soil moisture data are used to determine whether additional irrigation is required, as well as to assist in limiting deep percolation of irrigation water.

Soil Sampling – Soil samples are collected at each field between crop rotations to gauge the amount of nitrogen remaining in the soil. Samples are collected at multiple depths to gauge nutrient concentrations throughout the root zone. The nitrogen remaining in the soil is subtracted from the amount of nitrogen budgeted for the next crop.

Plant Tissue Sampling – Random samples collected from forage and grain crops from each field are composited before being analyzed for total nitrogen. The information is used in two ways: to estimate additional crop needs during that crop rotation, and along with crop yield, to estimate the total amount of nitrogen removed at harvest. Crop yield is quantified by weighing each truck as it leaves the field. This estimate of total amount of nitrogen removed at harvest is compared to the amount of nitrogen applied to gauge the efficiency of the land application system.

Crop Rotation and Double Cropping – Specific crop rotations are practiced to facilitate nitrogen removal at different depths and to minimize disease. Typical crop rotations include following peas with deeper-rooted corn, and following potatoes with deeper-rooted wheat. Double cropping is used to lengthen the growing season for a particular field so that more wastewater can be treated in a particular growing season.

2.4.2 Timing of Groundwater Quality Improvement

As discussed above, the land application activities at Farm 1 have contributed to the regional nitrate contamination but due to the high upgradient nitrate concentration, it is not clear that land application activities at Farm 2 have affected groundwater. However, as discussed in Section 2.4.1, the Port of Morrow has implemented BMPs over the past nine years to reduce the nitrate and hydraulic loading to the groundwater system. The timeframe of expected water quality improvements is difficult to quantify. Several factors inhibit the rapid improvement of groundwater quality in the study area. These involve both hydrogeologic and cultural factors and include, but are not necessarily limited to, the source of aquifer recharge, nitrogen in the unsaturated zone, nitrate in upgradient groundwater, groundwater flow velocity, and the continued application of process wastewater. A discussion of these factors is provided in Section 8.2. Potential methods to assess the effectiveness of current facility operations are discussed in Section 8.3.

2.5 Recommendations

Based on the conclusions and discussion above, the following recommendations are made:

- The source of the elevated and increasing nitrate concentrations at Farm 2 should be determined.
- In order to gauge when the effects of BMP implementation will be observed as improving groundwater quality, it is recommended that funding be pursued to allow additional research into factors including: (1) quantifying the amount of nitrate that exists between the root zone and the water table, (2) the rate of nitrate transport through the unsaturated zone, and (3) more precisely quantifying groundwater flow velocity at the site.
- Due to the high percentage of increasing trends and affects to groundwater from land application activities, it is recommended that BMP implementation to reduce the area-wide extent of elevated nitrate concentrations be continued and, when possible, improved.
- In accordance with the Action Plan, it is recommended that a trend analysis of data from the same wells be conducted in 2005 to evaluate progress towards improving groundwater quality at the food processing wastewater land application sites.

3.0 LAMB-WESTON SITES

3.1 Introduction

Lamb-Weston currently land applies approximately 700 to 800 million gallons of wastewater annually consisting of potato processing wastewater, defrost wastewater and wash water from Americold, and the Hermiston Co-Generation facility wastewater. From 1992 through 1999, average values for Lamb-Weston's wastewater include:

- 1,940 mg/l Chemical Oxygen Demand (COD)
- 106.5 mg/l Total Kjeldahl Nitrogen (TKN)
- 36 mg/l ammonia
- 1,475 mg/l total dissolved solids (TDS)
- 303 mg/l total suspended solids (TSS)
- 5.36 pH

Principal components of Lamb-Weston's process wastewater treatment system include screens, a primary clarifier, an oil/grease separator, a lined surge pond, and an unlined five million gallon storage lagoon. The process wastewater is applied on two parcels of land: the North Farm and Madison Ranch. The locations of the North Farm and Madison Ranch are indicated in Figure 1-2. The North Farm is owned by Lamb-Weston and consists of 693 acres, while the Madison Ranch site is owned by Madison Farms and consists of approximately 4,200 acres. Both sites are managed by Madison Farms and are irrigated with center pivot and wheel line systems. Crops grown using the process wastewater include a rotation of alfalfa, wheat, corn, peas, pasture grass, and canola.

It should be noted that nitrate data from both Lamb-Weston sites collected prior to October 1995 are not included in this analysis because sampling procedures (and hence analytical results) changed at that time.

3.2 North Farm

The Lamb-Weston North Farm is located approximately 4 miles west of the City of Hermiston, northwest of Interstate 82 and east of the Umatilla Ordnance Depot (Figure 1-2). The land application system at the North Farm began in 1972 or 1973. Prior to the land application system, the land occupied by the North Farm was dry land. Approximately 75 to 100 million gallons of wastewater are applied on the North Farm per year.

The North Farm is located on the southeast flank of a relatively broad topographic ridge trending northeast/southwest. The ridge slopes down to the Umatilla River to the east and down to the Columbia River to the north and west. Coyote Coulee (a dry ravine) bisects the ridge and is located approximately ½ mile northwest of the North Farm.

Soils at the North Farm are excessively drained loamy fine sands and sands. Topographic slopes of up to 25% are present. Land surface elevation at the North Farm drops fairly evenly approximately 90 feet from the northwest corner (approximately 650 feet above mean sea level) to the southeastern boundary (approximately 560 feet above mean sea level). Based solely on land surface topography, groundwater flow across the North Farm would be expected to be towards the southeast. However, as will be discussed in Section 3.2.1, that is not the case.

Nearby surface water features include the unlined pond located in the south-central portion of the site, and the Westland A canal which parallels the southeastern boundary of the property. The gravel pits located immediately south of the Farm occasionally receive overflow from the Westland A Canal.

The average depth to water beneath the North Farm ranges from approximately 13 feet (at the "shallow" well MW-7 located southeast of the storage lagoon) to approximately 76 feet (at the "deep" well MW-3 located on the western property boundary). With all other variables being equal, wells with a greater depth to water would be slower to respond to changes in practices at land surface.

3.2.1 Hydrogeology

The topographic ridge on which the North Farm is located consists of a mix of gravel, sand, silt, and clay overlying the Columbia River Flood Basalts. In general, coarse-grained materials (e.g., sand and gravel) dominate the shallow sediments while finer-grained materials (e.g., silt and clay) dominate the deeper materials. The 10 Lamb-Weston wells include 7 "deep" and 3 "shallow" wells. The shallow wells are screened either in silt (MW-7 and MW-10) or gravel and silt (MW-8). The deeper wells are screened in clay and gravel (MW-1), sandstone (MW-2, MW-3, and MW-4), sand, gravel, and basalt (MW-5), or basalt (MW-6 and MW-9). Wells installed on the adjacent Umatilla Chemical Depot landfill wells are screened either in silt or sandy silt at elevations comparable to Lamb-Weston's deep wells.

Figure 3-1 is a water table elevation contour map of the area including the Lamb-Weston North Farm. The data used to construct this map were collected on October 24 (at the Umatilla Chemical Depot landfill) and November 7, 2001 (at Lamb-Weston's North Farm). Maps drawn using data collected at other times of the year are similar.

Figure 3-1 indicates a groundwater mound exists beneath the North Farm. This mound is consistent with other observations and conclusions (including those of DEQ (1995)). It is assumed that this groundwater mound is shaped somewhat like the northeast/southwest trending topographic ridge on which the North Farm sits.

Water flows radially away from the center of a groundwater mound. However, because no water level data are available from north of the North Farm, it is not possible to determine either the exact shape of the mound or the location of the center of the mound. Based on available information, the center of the mound is believed to be located near, or somewhere northeast of, well MW-4. Additional water level data (i.e., more wells) could fine tune or perhaps alter this interpretation.

It is evident from Figure 3-1 that more than topographic relief affects groundwater flow direction. If land surface topography was the only control, groundwater would flow southeast across the Umatilla Chemical Depot landfill. However, the water level data indicate groundwater flows southwest across the Depot landfill. Hydrographs of the Depot landfill wells indicate water levels have risen 4 to 10 feet in about 7 years (October 1995 through August 2002). Rising water levels over this amount of time indicate a transient groundwater flow system rather than a steady state system. In other words, the water table is not in equilibrium. Instead, it is responding to recharge and/or discharge stresses over and above seasonal fluctuations.

It is theorized that the rising water levels and groundwater flow direction at the landfill are related to the amount and location of aquifer recharge. With the exception of the Umatilla Chemical Depot (where no water is applied at land surface), irrigation water is applied to the North Farm and nearly all lands north and northwest of the North Farm. Some of this irrigation water passes through the soil zone and recharges the local water table. DEQ (1995) concluded that deep percolation of irrigation water is a primary source of aquifer recharge in the region. Because no irrigation water is applied on the Depot, a hydraulic low spot, rather than a mound, exists. The hydraulic gradient from the center of the mound towards this hydraulic low is enhanced, causing water to flow southwest towards the hydraulic low rather than southeast towards the topographic low.

Water levels at the three well pairs corroborate the idea of local recharge. As indicated in Figure 3-1, water levels at the shallow wells (MW-7, MW-8, and MW-10) are higher than water levels at the corresponding deeper wells (MW-9, MW-6, and MW-3) indicating a downward flow potential which suggests local recharge. The downward flow potential between shallow and deep wells is persistent throughout the data set.

Based on the water levels in Figure 3-1, upgradient wells for the North Farm would be located near the center of the groundwater mound along the northern property boundary. Downgradient wells would be located near the southern, eastern, and western property boundaries. Because the source of nitrate loading is at land surface, shallow wells that bracket the water table provide the most useful water quality and water level information to gauge the effects of facility operations. Because the lithology at the site is variable, the most meaningful evaluation of potential effects from the North Farm would be made using comparisons between wells completed in similar materials at similar elevations.

No shallow well is currently located in an upgradient location. Therefore, no upgradient to downgradient comparison can be made in the shallow zone. However, the deep well MW-4 is located in an upgradient location. This well is screened in silt and clay at an elevation of approximately 500 to 510 feet above sea level. Wells MW-2 and MW-3 are constructed in moderately similar material (sand at MW-2; clay at MW-3) and at similar elevations. Therefore, the best upgradient to downgradient comparison using the existing well network is using MW-4 as an upgradient well and MW-3 and MW-2 as downgradient wells.

3.2.2 Nitrate Trends

A trend analysis of nitrate concentrations at the 10 Lamb-Weston North Farm wells was conducted as described in Section 1.3 and Appendix 1. Table 3-1 summarizes the data used in this analysis and includes some data set statistics (e.g., mean and maximum values), a summary of the trend analysis (e.g., the slope and confidence level of the line) and a description of the LOWESS pattern (e.g., increasing then decreasing). Time series graphs of nitrate concentrations at each Lamb-Weston well are included in Appendix 3.

Table 3-1 lists the individual results of the trend analyses for each well. The results can be summarized as follows:

- 5 wells exhibit increasing trends,
- 2 wells exhibit decreasing trends, and
- 3 wells exhibit statistically insignificant trends.

The trends range from increasing at 6.93 ppm/yr at MW-7 to decreasing at 0.33 ppm/yr at MW-3. The site-wide average nitrate trend (i.e., the average of all 10 slopes) is increasing at approximately 1.1 ppm/yr. The average of the 7 statistically significant trends is approximately 1.5 ppm/yr.

Table 3-1 also lists the description of the LOWESS pattern for individual wells. The LOWESS patterns observed can be summarized as follows:

- 5 wells show a steadily increasing pattern
- 3 wells shows an increasing then decreasing pattern
- 1 well shows an increasing then leveling off pattern
- 1 well shows a decreasing pattern

In summary, half of the wells exhibit consistently increasing LOWESS patterns. All but one of the remaining wells exhibit an early increasing pattern followed either by leveling off or decreasing concentrations.

Figure 3-2 is a graph of all nitrate data from the 10 North Farm wells, with a LOWESS line drawn through the data. Figure 3-2 consists of many stacks of data points at approximately 3 month intervals. Each of these stacks of data represents one quarterly sampling event and contains one data point for each well sampled that event. It is evident from Figure 3-2 that the highest concentrations detected have occurred in the latter portion of the dataset and that the minimum concentration detected is increasing. The LOWESS line increases more steeply in 1996 and 1997 then from 1998 through 2001. The increasing LOWESS line reflects the increasing nitrate concentrations at the North Farm.

Figure 3-3 includes the nitrate trends and LOWESS lines at each of the 10 North Farm wells. The 10 graphs are plotted at the same scale to allow a comparison of trends between wells. The wells are arranged in Figure 3-3 from steepest increasing trend through steepest decreasing trend to statistically insignificant trends (i.e., the steepest increasing trend is in the upper left corner of Figure 3-3).

Useful information can be gained by comparing trend lines with LOWESS lines. Examination of LOWESS lines through the nitrate data illustrates non-linear changes in nitrate concentrations. For example, Figure 3-3 illustrates the following:

- Nitrate concentrations at the overall steepest trend (6.93 ppm/yr at MW-7) increased, then began to level off,
- Nitrate trends at MW-8 increased until about 1999, and then decreased.

Figure 3-4 is a map view of the site illustrating the nitrate trends at each of the wells. The three shallow wells have increasing trends. The 7 deep wells are a mix of increasing, decreasing, and statistically insignificant trends. The steepest increasing trend (6.93 ppm/yr) is at the shallow well MW-7 located near the storage lagoon. The next steepest increasing trend (0.76 ppm/yr) is at the deep upgradient well MW-4 located near the northern property boundary. The steepest decreasing trend is at deep well MW-3 located near the eastern boundary of the North Farm. The fact that the steepest increasing trend is located downgradient of the storage lagoon suggests process waste water may be leaking from the storage lagoon. The fact that the upgradient well has an increasing trend suggests some of the increasing nitrate may be the result of off site activities.

3.2.3 Average Nitrate Concentrations

Figure 3-5 is a map view of the site illustrating the average nitrate concentrations at each of the North Farm wells from January 1996 through November 2001. The highest average nitrate concentrations are at the 3 shallow wells (50.2 ppm at MW-8, 46.6 ppm at MW-10, and 36.8 ppm at MW-7). The lowest average nitrate concentrations are at the 2 wells completed in basalt (4.8 ppm at MW-6 and 7.2 ppm at MW-9). The remaining wells have average nitrate concentrations ranging from 10.7 to 25.6 ppm. The decreasing nitrate concentration with depth suggests facility operations have affected groundwater.

3.2.4 Upgradient to Downgradient Comparisons

Based on the selection of well MW-4 as the upgradient well and well MW-2 and MW-3 as downgradient wells, the following comparison of upgradient to downgradient nitrate concentrations was made. It should be noted that these wells are deep wells; no upgradient shallow well exists to allow comparisons. Furthermore, due to the radial nature of groundwater flow, this one upgradient/downgradient comparison may not be representative of the entire site.

Figure 3-6(a) is a time series graph showing the nitrate concentrations at the upgradient well and the downgradient wells. In addition to the individual data points connected by a thin line, a thick LOWESS line is drawn through the data. Figure 3-6(a) shows while the upgradient nitrate concentrations rose from 1996 through 2001, the downgradient concentrations remained fairly constant. Throughout this time frame, upgradient concentrations were greater than downgradient concentrations.

Figure 3-6(b) is a box and whisker plot summarizing the nitrate concentrations from the upgradient deep well (MW-4) and the downgradient deep wells (MW-2, and MW-3)[5]. Figure 3-6(b) shows the average upgradient deep nitrate concentration is approximately 25 ppm, and half of the values are from approximately 24 to 26 ppm. Figure 3-6(b) also shows the average downgradient deep nitrate concentration is approximately 15 ppm, and half of the values are from approximately 9 to 19 ppm.

Based on a comparison of the deep upgradient well MW-4 to deep downgradient wells MW-2 and MW-3, land application activities have not caused an increase above background nitrate concentrations in the deeper sediments at the western portion of the North Farm.

[5] The "box" portion of the plot identifies the interquartile range (IQR). The IQR is the middle half of the data (i.e., those data between the 25th and 75th percentiles). The "whisker" portion of the plot extends outwards from the box to any point within 1.5 times the IQR. Any point beyond the whiskers is plotted individually. The horizontal line through the box represents the median value. The star represents the average value.

3.2.5 Conclusions

Based on the discussion of the data for the Lamb-Weston North Farm site presented above, the following conclusions have been made, and are grouped by topic:

Hydrogeology

- A groundwater mound exists beneath the North Farm (and land to the north) that is created by local recharge. Groundwater flows radially away from the center of the mound.
- The average depth to water beneath the North Farm ranges from approximately 13 to 76 feet below land surface.
- Upgradient wells at the North Farm would be located near the center of the groundwater mound situated near the northern property boundary.
    - The single upgradient well at the North Farm is the deep well MW-4. No shallow upgradient well exists.
- Downgradient wells would be located at the southern, eastern, and western property boundaries.
- Upgradient to downgradient comparisons should be made between wells completed in similar materials at similar elevations.
    - The best upgradient/downgradient well pair in the existing network includes deep wells MW-2 and MW-3 which are located downgradient of MW-4 and screened in similar materials at similar elevations.

Nitrate Concentrations and Trends

- Nitrate concentrations at the North Farm are generally increasing, as evidenced by:
    - 50% of the wells have statistically significant increasing trends.
    - Another 30% of the wells have statistically insignificant increasing trends.
    - Trends range from decreasing at 0.33 ppm/yr to increasing at 6.93 ppm/yr with the site-wide average nitrate trend increasing at least 1.1 ppm/yr.
    - Half of the wells exhibit consistently increasing LOWESS patterns.
    - The highest concentrations occur in the latter portion of the data set.
    - Minimum concentrations detected are increasing.

Factors Affecting Nitrate Concentrations

- There is evidence suggesting facility operations have affected, and continue to affect, groundwater quality. However, there is also evidence suggesting an upgradient source of nitrate. The existing groundwater monitoring network is insufficient to adequately evaluate upgradient to downgradient nitrate concentrations.
    - Shallow groundwater has higher nitrate concentrations and steeper nitrate trends than deeper groundwater.
    - The 3 shallow wells have increasing nitrate trends while the 7 deeper wells are a mix of increasing, decreasing, and statistically insignificant trends.
    - The highest average concentrations are in the 3 shallow wells while the lowest average concentrations are in the 2 deep wells completed in basalt.
    - The steepest increasing trend is located in a shallow well downgradient of the storage lagoon suggesting process wastewater may be leaking from the storage lagoon.
- The fact that the deep upgradient well has elevated nitrate and an increasing trend suggests some of the increasing nitrate may be the result of off site activities.
- Based on a comparison of the deep upgradient well MW-4 to deep downgradient wells MW-2 and MW-3, land application activities have not caused an increase above background nitrate concentrations in the deeper sediments of the western portion of the North Farm.
- The large range of depth to water across the site could cause substantial variability in the timing of groundwater quality responses to activities at land surface.

3.3 Madison Ranch

The Lamb-Weston Madison Ranch site is located approximately 5 miles south of the City of Hermiston, south of Interstate 84 and west of State Road 207 (Figure 1-2). The land application system at Madison Ranch began in 1991. The Butter Creek flood plain portion of Madison Ranch has been farmland since the 1800's. Prior to the land application system, the land occupied by the upland portion of Madison Ranch was unfarmed dry land. Approximately 700 million gallons of process wastewater are applied on Madison Ranch per year.

The Madison Ranch site includes portions of both the Butter Creek flood plain and the uplands to the west of the flood plain. Soils within the flood plain include silt loams, loamy sands, and sandy loams that are predominantly well drained. Soils that are somewhat poorly drained, moderately well drained, and excessively drained also occur in the flood plain. Topographic slopes are generally 0 to 5%, but slopes of 5% to 25% also occur. The dominant soils within the uplands also include silt loams, loamy sands, and sandy loams, but are well drained to excessively drained. Topographic slopes within the uplands are generally less than 7%, but slopes of up to 25% are common. Small portions of the site have steeper slopes.

Land surface elevation within the Butter Creek flood plain slopes fairly evenly from approximately 800 feet above mean sea level at the southern property boundary to 640 feet above mean sea level at the northern property boundary. The uplands are cut by several ephemeral drainages with land surface elevation ranging from approximately 1040 feet above mean sea level at the southern property boundary to approximately 640 feet above mean sea level at the northern property boundary.

Nearby surface water features include Butter Creek which flows northward through the eastern portion of the site, several unnamed irrigation canals and ditches within the Butter Creek flood plain, and the High Line canal which forms a portion of the northern property boundary before emptying into Lost Lake located approximately ½ mile north/northwest of the property.

The average depth to water beneath the Butter Creek flood plain portion of the Madison Ranch site ranges from approximately 12 feet below land surface (at well MW-10) to 15 feet below land surface (at wells MW-11 and MW-12). The average depth to water beneath the upland portion of the Madison Ranch site ranges from approximately 33 feet below land surface (at well MW-3) to more than 150 feet below land surface (at well MW-2). With all other variables being equal, wells with a greater depth to water would be slower to respond to changes in practices at land surface.

3.3.1 Hydrogeology

The importance of land surface topography in groundwater flow direction was discussed in Section 1.3. The topography of the base of the aquifer can also affect groundwater flow direction. The base of the surficial aquifer beneath Lamb-Weston Madison Ranch is the Columbia River Flood Basalts. Figure 3-7 is a map of the basalt surface topography in the Butter Creek area that includes the Lamb-Weston Madison Ranch site.

As indicated in Figure 3-7, the basalt topography beneath Madison Ranch is characterized by a trough that follows the axis of Butter Creek, and a ridge trending north-northeast located just west of Butter Creek. The ridge has previously been interpreted as both an anticline (folded rock) and as an erosional feature. Regardless of the origin of the feature, it very likely affects groundwater flow direction. Groundwater flowing down the Butter Creek drainage is expected to be constrained by the basalt surface trough resulting in a groundwater flow direction roughly perpendicular to basalt surface contours (i.e., N-NE). Based on the available information, it is expected that groundwater flows essentially straight down the drainage. There is no reason to suspect that groundwater within the Butter Creek drainage would flow very far out of either side of the drainage. Similarly, groundwater beneath the uplands is also expected to be affected by the basalt surface.

Figure 3-8 is a Spring 2002 water table map of the Butter Creek area. Figure 3-9 is a Fall 2002 water table map of the Butter Creek area. These maps include water level information from Lamb-Weston Madison Ranch and adjacent facilities. The groundwater elevation contours on Figures 3-8 and 3-9 are based on professional judgment, water levels measured at the alluvial aquifer wells, land surface topography, location of surface water features, the elevation of the underlying basalt surface, and the migration of diesel contamination at Union Pacific Rail Road Hinkle Rail yard.

During the preparation of these maps, it was assumed that shallow groundwater in the Butter Creek drainage is directly connected to shallow groundwater on either side of the drainage. It was also assumed that topographic relief and basalt surface topography are major controls of shallow groundwater flow.

Due to the large area, large topographic relief, and few wells located on the Lamb-Weston Madison Ranch property, observations from hydrographs were used to gain insight into the shallow groundwater flow system. Table 3-2 is a summary of observations made from examining the Madison Ranch well hydrographs. The wells are grouped on Table 3-2 according to geographic location (i.e., Butter Creek flood plain, upland, near Lost Lake, or near Highline Canal). Observations regarding the timing of water level highs and lows, as well as median annual fluctuation were used to infer the predominant influence on water levels. The inferred influence on water levels affected the way the data were contoured.

The water level contours north and west of Ward Butte are based largely on land surface topography but are affected by the location of irrigated circles (potential recharge sources) and observations from hydrographs of nearby wells. For instance, because the water level in well MW-7 is consistently rising at about 1.2 ft/yr (indicating a significant amount of water is reaching the well), several contours were included near that well. In contrast, the hydrograph at well MW-2 is generally flat but has big fluctuations (over 10’ between quarterly measurements). Fewer contours near well MW-2 were included to reflect these observations.

For the Spring 2002 data set (Figure 3-8), groundwater levels in the upper portion of Butter Creek are contoured as being directly affected by Butter Creek losing water (a mound of groundwater is shown along Butter Creek) and Madison Ranch’s horizontal collector well in Section 36 (the 740’ groundwater contour is strongly affected by the horizontal well). Because Butter Creek is dry at and downstream of staff gauge SG-4, the mound of losing water from Butter Creek dissipates.

For the Fall 2002 data set (Figure 3-9), the contours outside of the areas close to the Umatilla River or Butter Creek change little, if at all. This is due to the relatively small annual fluctuations (typically 1’ to 4’) and relatively large contour interval (10’). Because Butter Creek is dry, contours in the Butter Creek drainage are drawn so that groundwater flows essentially straight down the valley.

Based on the discussion above, upgradient wells in the Butter Creek drainage would be located south of facility operations while downgradient wells in the Butter Creek drainage would be located north of facility operations. Well MW-12 is an upgradient well for the Butter Creek drainage. Wells MW-5 and MW-11 are downgradient of most or all facility operations. However, it is expected that shallow groundwater enters the Butter Creek drainage from upstream as well as from either side of the drainage (see groundwater flow direction arrows on Figure 3-8 or 3-9). Because the water quality at wells MW-5 and MW-11 is likely affected by activities off Lamb-Weston property, these wells are not good downgradient wells to compare to upgradient water quality. Currently there are no Butter Creek flood plain wells that are solely downgradient of Lamb-Weston activities.

Based on the discussion above, upgradient wells for the uplands would be located either at the upper ends of drainages (e.g., where Fourmile Canyon enters the property) or near the center of topographic and hydraulic “islands” (e.g., Ward Butte). Currently there are no upgradient wells for the uplands.

Based on the discussion above, downgradient wells for the uplands would be located either at the lower ends of drainages (e.g., MW-3 is located where Fourmile Canyon exits the property) or downgradient of topographic and hydraulic islands (e.g., depending on where upgradient wells are eventually installed, perhaps MW-4A or MW-9).

It is worth repeating that the groundwater elevation contours west of Butter Creek depicted in Figures 3-8 and 3-9 are a combination of professional judgment, groundwater elevations, land surface topography, surface water features, and basalt topography. This interpretation is subject to changes as additional information is obtained.

3.3.2 Nitrate Trends

A trend analysis of nitrate concentrations at the 12 Lamb-Weston Madison Ranch wells was conducted as described in Section 1.3 and Appendix 1. Table 3-3 summarizes the data used in this analysis and includes some data set statistics (e.g., mean and maximum values), a summary of the trend analysis (e.g., the slope and confidence level of the line) and a description of the LOWESS pattern (e.g., increasing then decreasing). Time series graphs of nitrate concentrations at each Lamb-Weston well are included in Appendix 3.

Table 3-3 lists the individual results of the trend analysis for each well. The results can be summarized as follows:

- 7 wells exhibit increasing trends, and
- 5 wells exhibit statistically insignificant trends

Statistically significant trends range from 3.16 ppm/yr at MW-6 to 0.01 ppm/yr at MW-2. The site-wide average nitrate trend (i.e., the average of all 12 slopes) is increasing at approximately 0.3 ppm/yr. The average of the 7 statistically significant trends is approximately 0.5 ppm/yr.

Table 3-3 also lists the description of the LOWESS pattern for each individual well. The LOWESS patterns observed can be summarized as follows:

- 6 wells show a steadily increasing pattern
- 5 wells shows an increasing then decreasing pattern
- 1 well shows slightly decreasing then slightly increasing pattern

In summary, half of the wells exhibit consistently increasing LOWESS patterns. All but one of the remaining wells exhibit an early increasing pattern followed by decreasing concentrations.

Figure 3-10 is a graph of all nitrate data from the 12 Madison Ranch wells, with a LOWESS line drawn through the data. Figure 3-10 consists of many stacks of data points at approximately 3 month intervals. Each of these stacks of data represents one quarterly sampling event and contains one data point for each well sampled that event. It is evident from Figure 3-10 that the highest concentrations detected have occurred in the latter portion of the dataset. The LOWESS line has a gentle upward curve through 1998 then gently decreases through 2001. The relatively flat LOWESS line reflects the generally consistent nitrate concentrations between wells and relatively flat trends at individual wells.

Figure 3-11 includes the nitrate trends and LOWESS lines at each of the 12 Madison Ranch wells. The 12 graphs are plotted at the same scale to allow a comparison of trends between wells. The wells are arranged in rows from steepest increasing trend to statistically insignificant trends (i.e., the steepest increasing trend is in the upper left corner of Figure 3-3).

As mentioned previously, useful information can be gained by comparing trend lines with LOWESS lines. For example, Figure 3-11 illustrates that nitrate concentrations at 4 wells (MW-1, MW-5, MW-7, MW-10, & MW-11) increased then decreased.

Figure 3-12 is a map view of the site illustrating the nitrate trends at each of the wells. The wells in both the Butter Creek flood plain and the uplands west of Butter Creek exhibit increasing and statistically insignificant trends. MW-6 (located on the eastern edge of the flood plain) exhibits the steepest increasing trend (3.16 ppm/yr). The next steepest trend (1.03 ppm/yr) is at well MW-12 located at the upgradient edge of Butter Creek floodplain. The remaining Butter Creek floodplain wells exhibit statistically insignificant trends. The steepest increasing trend at an upland well (0.24 ppm/yr) is at well MW-8. Other upland wells and wells near the northern property boundary exhibit slight increasing or statistically insignificant trends.

The fact that the steepest increasing trends are located near the upgradient and eastern edge of Butter Creek floodplain suggests some impact is occurring to the site from off site activities. The fact that upland wells and wells near the northern property boundary exhibit slight increasing trends suggests facility operations are affecting groundwater.

3.3.3 Average Nitrate Concentrations

Figure 3-13 illustrates the average nitrate concentrations at each of the Madison Ranch wells from late 1995 through late November 2001. The highest average nitrate concentration is at well MW-6 (located on the eastern edge of the floodplain). The lowest average nitrate concentrations are at the 2 deepest upland wells (0.2 ppm at MW-2 and 0.4 ppm at MW-7). The remaining wells have average nitrate concentrations ranging from 0.8 to 9.7 ppm. The lower average nitrate concentration in upland wells may reflect better process wastewater management, the greater depth to groundwater, and/or shorter duration of process wastewater application.

3.3.4 Upgradient to Downgradient Comparisons

Based on the groundwater flow regime discussed in Section 3.3.1, there are currently no Butter Creek flood plain wells that are solely downgradient of Lamb-Weston activities. Similarly, there are currently no upgradient wells located within the uplands. Therefore, no meaningful comparisons of upgradient to downgradient concentrations within the Butter Creek flood plain or within the uplands can be made.

3.3.5 Conclusions

Based on the discussion of the data for the Lamb-Weston Madison Ranch site discussed above, the following have been made, and are grouped by topic:

Hydrogeology

- Groundwater flows north-northeast down the Butter Creek flood plain, with some variation near pumping wells and, when they contain water, near Butter Creek and irrigation canals.
- The groundwater flow regime of the uplands is complex, and is likely affected by land surface topography, basalt surface topography, and locations of recharge.
- Upgradient wells in the Butter Creek drainage would be located south of facility operations.
    - Well MW-12 is located upgradient of the Madison Ranch portion of the Butter Creek flood plain.
- Downgradient wells in the Butter Creek flood plain would be located north of facility operations.
    - Because it is expected that shallow groundwater enters the Butter Creek flood plain from upstream as well as from either side of the drainage, there are no Butter Creek flood plain wells that are solely downgradient of Lamb-Weston activities.
- Because there are no Butter Creek flood plain wells that are solely downgradient of Lamb-Weston activities, no comparison to downgradient nitrate concentrations is possible in that area.
- Upgradient wells for the uplands would be located either at the upper ends of drainages or near the center of topographic and hydraulic "islands".
    - Currently there are no upgradient wells for the uplands.
- Because there are no upgradient wells located within the uplands, no comparison to downgradient nitrate concentrations is possible in that area.

Nitrate Concentrations and Trends

- Nitrate concentrations at the North Farm are generally increasing.
    - 58% of the wells have statistically significant increasing trends.
    - The site-wide average nitrate trend is increasing at least 0.3 ppm/yr.
    - Half of the wells exhibit consistently increasing LOWESS patterns.
    - The highest concentrations occur in the latter portion of the dataset.

- Wells in both the Butter Creek drainage and the uplands exhibit both increasing and statistically insignificant trends.

Factors Affecting Nitrate Concentrations

- The existing groundwater monitoring network is insufficient to adequately evaluate upgradient to downgradient nitrate concentrations in both the uplands and the Butter Creek flood plain, as evidenced by:
  - The fact that upland wells near the downgradient property boundary exhibit slight increasing trends (suggesting facility operations may be affecting groundwater), but there are no upgradient upland wells with which to make comparisons, and
  - The fact that the steepest increasing trends are located near the upgradient and eastern edge of Butter Creek floodplain (suggesting some of the increasing nitrate is coming from off site activities).
- Lower average nitrate concentrations in the upland wells may reflect better process wastewater management, the greater depth to groundwater, and/or the shorter duration of process wastewater application.
- The large range of depth to water across the site could cause substantial variability in the timing of groundwater quality responses to activities at land surface.

3.4 Link Between BMP Implementation and Groundwater Quality Improvement

The following sections describe Lamb-Weston's efforts to improve groundwater quality through the adoption of Best Management Practices (BMPs) as well as some of the limitations to rapid improvement in groundwater quality. The information in Section 3.4.1 was provided by Lamb-Weston.

3.4.1 Efforts to Improve Groundwater Quality

The Lamb-Weston, Inc. land application systems at Madison Ranch and the North Farm utilize both nutrient and hydraulic management techniques to be protective of groundwater.

High nutrient utilization is the goal. Nutrient management includes soil testing, water testing and, in some cases, plant tissue testing, to minimize nitrogen application while ensuring healthy plant growth. Nitrogen application is usually limited to the agronomic rate of a specific crop. It is, however, sometimes applied at a rate exceeding the agronomic rate of the first crop in a rotation, with the goal of removing the excess nitrogen with the second crop in a rotation. Tissue testing can be used to assist in fine-tuning actual applications to plant needs and reduce over-application of fertilizer.

Hydraulic management is controlled using local weather data, rain gauge data and neutron probe data from each field; as well as observation of the crops while growing. Water is intentionally stored in the soil profile, but is monitored so that movement beyond the root zone is minimized. The farm is typically deficit irrigated and managed to minimize leaching under normal conditions. The current design has evolved to accommodate a 10-year return of excess rainfall (i.e., the current design strives to accommodate all but the wettest year in 10 without leaching).

Management plans are developed and executed annually, with some carryover from year to year of both nutrients and water. Management plans are made with the best available information at the time the plans are made, but due to the inherent uncertainties of weather, the plans must be flexible to accommodate greater or lesser precipitation. The farm has several sources of water and they are managed to maximum utility and for maximum conservation.

3.4.2 Timing of Groundwater Quality Improvement

As discussed above, the monitoring well networks at Lamb-Weston's North Farm and Madison Ranch are not sufficient to allow a direct comparison of upgradient to downgradient nitrate concentrations. However, available information suggests that impacts are occurring at the North Farm and Madison Ranch from both offsite activities and facility operations.

However, as discussed in Section 3.4.1, Lamb-Weston has implemented BMPs over the years to reduce the nitrate and hydraulic loading to the groundwater system. The timeframe of expected water quality improvements is difficult to quantify. Several factors inhibit the rapid improvement of groundwater quality in the study area. These involve both hydrogeologic and cultural factors and include, but are not necessarily limited to, the source of aquifer recharge, nitrogen in the unsaturated zone, nitrate in upgradient groundwater, groundwater flow velocity, and the continued application of process wastewater. A discussion of these factors is provided in Section 8.2. Potential methods to assess the effectiveness of current facility operations are discussed in Section 8.3.

3.5 Recommendations

Based on the conclusions and discussion above, the following recommendations are made:

- Expand the well network at the North Farm to allow upgradient to downgradient comparisons in the shallow sediments.
- Expand the well network at Madison Ranch to allow upgradient to downgradient comparisons in the Butter Creek flood plain and in the uplands.
- In order to gauge when the effects of BMP implementation will be observed as improving groundwater quality, it is recommended that funding be pursued to allow additional research into factors including: (1) quantifying the amount of nitrate that exists between the root zone and the water table, (2) the rate of nitrate transport through the unsaturated zone, and (3) more precisely quantifying groundwater flow velocity at the site.
- Due to the high percentage of increasing trends and impacts to groundwater from land application activities, it is recommended that BMP implementation to reduce the area-wide extent of elevated nitrate concentrations be continued and, when possible, improved.
- In accordance with the Action Plan, it is recommended that a trend analysis of data from the same wells be conducted in 2005 to evaluate progress towards improving groundwater quality at the food processing wastewater land application sites.

4.0 SIMPLOT SITES

4.1 Introduction

Simplot's wastewater system handles approximately 2.35 million gallons per day (MGD). The bulk of the water (2.0 MGD) is food processing wastewater from the preparation and packaging of potato products. Other sources of wastewater that are land applied include co-generation wastewater from the adjacent Calpine steam electric generation facility (0.35 MGD), and filter back wash wastewater from the Umatilla Regional Water Facility.

In 2000, Simplot land applied approximately 616 million gallons. From 1991 through 2000, average values for Simplot's wastewater include:

- 1,350 mg/l Chemical Oxygen Demand (COD)
- 145 mg/l Total Kjeldahl Nitrogen (TKN)
- 104 mg/l ammonia
- 1,672 mg/l total dissolved solids (TDS)
- 1 mg/l nitrate-nitrogen (NO_3)
- 107 mg/l chloride (Cl)
- 28 mg/l calcium (Ca)
- 103 mg/l sodium (Na)
- 46 mg/l magnesium (Mg)
- 363 mg/l potassium (K)
- 795 mg/l bicarbonate (HCO_3)
- 58 mg/l total phosphorus (P)

As of the end of 2001, the water was applied on four parcels of land: the Plant Site, the Terrace Site, the Expansion Site, and the Levy Site. The locations of the Plant Site, Terrace Site, and Expansion Site are indicated in Figure 1-2. There was insufficient water quality data from the Levy Site wells by the end of 2001 to establish a database from which to perform a trend analysis. Therefore, the trend analysis discussed below includes only the Plant Site, the Terrace Site, and the Expansion Site.

As of 2001, the process wastewater was applied at the Simplot sites at approximately the following rates:

- 4% on the Plant Site,
- 25% on the Terrace Site,
- 71% on the Expansion Site, and
- 0% on the Levy Site.

4.2 Plant Site

The Simplot Plant Site is located approximately 3 miles south of the City of Hermiston, northeast of the junction of US Interstate 84 and Oregon 207 (Figure 1-2). Process wastewater is screened, treated (using a primary clarifier, diffused air flotation system, and an anaerobic digester) at the Plant Site, and then stored in a surge pond or a storage pond before being applied to agricultural land at one of Simplot's four parcels of land. At the Plant Site, process wastewater has historically been applied to as many as 12 fields comprising as much as 220 acres. Crops grown using the process wastewater include a rotation of grain (corn, wheat, and barley), forage grasses (tall fescue, reed canary grass, and other suitable forage grass species), and alfalfa. When alfalfa is used in a rotation, it is maintained for four or more years.

The land application system at the Plant Site began in 1977. Prior to the land application system, the land occupied by the Plant Site included houses and small farming operations using Umatilla River water for irrigation.

The geomorphology of the Plant Site includes an upland terrace and the Umatilla River flood plain. The terrace and flood plain generally exhibit gentle slopes (0 to 5%) except where they meet, when slopes reach 25%. Topography at the Plant Site ranges from approximately 530 to 610 feet above mean sea level.

Nearby surface water features include the Umatilla River (which flows east to west across the property), Manns Pond and several un-named irrigation canals located south of the River, and the Feed Canal (delivering water from the Umatilla River to Cold Springs Reservoir) approximately ½ mile northeast of the Plant Site. Because deep percolation of irrigation water is a major source of recharge to the alluvial aquifer, wells closer to leaky fresh water canals (and for that matter fresh water streams) are more likely to exhibit lower nitrate concentrations due to dilution from the surface water.

The depth to water beneath the Plant Site ranges from approximately 6 feet below land surface (at wells MW-17 and MW-19; located within the flood plain) to approximately 122 feet below land surface (at well MW-59 located on the terrace). Wells monitoring the deeper portion of the aquifer beneath the terrace (i.e., MW-13d) have water levels as deep as 149 feet below land surface. With all other variables being equal, wells with a greater depth to water would be slower to respond to changes in practices at land surface.

In the 1990's, Simplot suspected that their land application practices at the Plant Site were impacting groundwater. Simplot began acquiring additional land for process wastewater disposal, and began reducing the hydraulic and nutrient loading to the Plant Site. In 1999, Simplot and DEQ entered into a Mutual Agreement and Order requiring Simplot to conduct a Remedial Investigation and Feasibility Study to evaluate impacts of past practices on groundwater quality.

4.2.1 Hydrogeology

As discussed in Section 1.3, groundwater flow direction can be affected by land surface topography, the topography of the base of the aquifer, recharge and discharge features, and surface water features. The base of the surficial aquifer beneath the Simplot Plant Site (as well as the other Simplot Sites) is the Columbia River Flood Basalts. Figure 3-7 is a map of the basalt surface topography in the Butter Creek Area that includes the Simplot Sites. As indicated in Figure 3-7, the basalt topography beneath the Simplot Plant Site slopes away from the Service Anticline (expressed at land surface as Emigrant Buttes). The basalt surface slopes predominantly northwest, approximately paralleling the Umatilla River.

Figures 3-8 and 3-9 are Spring and Fall 2002 water table maps of the Butter Creek area, respectively. These maps include water level information from several food processing wastewater land application facilities in the vicinity of the Simplot Plant site. The groundwater elevation contours on Figures 3-8 and 3-9 are based on professional judgment, water levels measured at the alluvial aquifer wells, land surface topography, location of surface water features, the elevation of the underlying basalt surface, and the migration of diesel contamination at the UPRR Hinkle Rail yard. For the purpose of preparing these maps, it was assumed that shallow groundwater in the Butter Creek drainage was directly connected to shallow groundwater on either side of the drainage. It was also assumed that topographic relief and basalt surface topography were major controls of shallow groundwater flow.

Based on land surface topography and the idea that the Umatilla River is in large part fed by groundwater, it was expected that shallow groundwater would flow towards the river from both directions (north and south). However, based on the observed water levels and migration of diesel contamination at Hinkle Rail yard, this does not appear to be the case. Figures 4-1 and 4-2 are May 2002 and October 2002 water table maps at the Simplot Plant Site, respectively. These figures show that groundwater flows toward the river from the south but not from the north. Groundwater continues to flow generally northwest across the site regardless of season.

The unexpected groundwater flow regime prompted a more detailed evaluation of water levels, water quality, and subsurface lithology. Results of the evaluation are summarized in Table 4-1 and discussed below.

As indicated in Table 4-1, the wells at the Simplot Plant site can be classified as either a flood plain well or an alluvial well. This distinction is based on location, typical water level, timing of water level fluctuations, typical lithology, and general water quality. Well logs and cross sections prepared by Simplot's consultants show the flood plain wells are generally screened in coarser-grained sediments than the alluvial wells on the terrace.

Flood plain wells are located within the Umatilla River flood plain, are generally screened in coarser-grained sediments (sand and gravel), exhibit water levels near 540', fluctuate annually with highest water levels typically in the winter or spring, and lowest water levels in the summer and fall. In addition, the total dissolved solids (TDS) concentrations of flood plain wells are less than alluvial wells but higher than river concentrations.

Alluvial wells are located on the terrace on either side of the flood plain, are generally screened in finer-grained sediments (silty sands), exhibit water levels near 500', and fluctuate annually with highest water levels in summer and fall, and lowest water levels in winter and spring. TDS concentrations are higher in alluvial wells than in flood plain wells or the river.

It is assumed that underlying basalt structure controls the regional direction of the river (i.e., turning it from west to north). The implication of Figures 4-1 and 4-2 is that some shallow groundwater is "cutting the corner", so to speak, from where the river changes from flowing west to flowing north. These maps suggest a shallow groundwater flow path extends under the terrace that underlies the Simplot Plant site towards Minnehaha Spring. It is interesting to note that the area of dramatic head drop occurs at or just past the area where the Service Anticline crosses the trend of the Umatilla River flood plain. It is possible that a basalt high associated with the anticline acts as a hydraulic dam to limit groundwater flow through this area. Another possibility is that the transition from finer to coarser grained sediments could cause the clustering of water level contours at the base of the alluvial terrace. Even though the cause of the dramatic head drop near the Simplot site area has not been determined, the data show that it does occur.

Results from alluvial wells, flood plain wells, and surface water samples were plotted on a piper diagram to assess water quality differences between the flood plain wells and the alluvial wells. Figure 4-3 illustrates these sample results. Figure 4-3 illustrates the Umatilla River has substantial influence on the flood plain wells, but there is no water quality evidence for a separate and distinct "flood plain aquifer". Observations made from Figure 4-3 include:

- There is substantial overlap between the alluvial field and flood plain field, with flood plain wells plotting somewhat lower on the diagram (reflecting the higher sodium and bicarbonate values in the flood plain wells).
- The surface water sample fields plot almost entirely within the flood plain field indicating some common characteristics.
- Of the seven flood plain wells evaluated, two plot completely out of the alluvial water field with the other five overlapping into the alluvial water field.
- Samples from flood plain well MW-19 (located approximately 50 yards north of the river at SG-2) and surface water sample SG-2 significantly overlap indicating very similar water quality.
- Water quality variation at MW-19 and SG-2 appears more correlated to year rather than season. Water quality "evolves" down the diagram with increasing time (generally increasing Na and decreasing Ca, Mg, TDS, and HCO_3). In other words, water quality at these locations is progressively moving away from the alluvial-type water and towards flood plain-type water.

Based on the discussion above, upgradient wells for the Simplot Plant site would be located south and east of facility operations, while downgradient wells would be located north and west of facility operations. Wells MW-50, MW-19, and MW-49 are located upgradient of current facility operations. Wells MW-50 and MW-19 are located north of the River while MW-49 is located south of the River. It should be noted that process wastewater was historically applied at the 4 fields located upgradient of MW-49 and MW-19 (between Umatilla Meadows Road and I-84) from 1981 to not later than 1990. Therefore, the potential exists for these wells to be affected by those facility operations. However, time versus concentration graphs in Appendix 4 indicate low nitrate concentrations (always less than 2 mg/l) at all three of these wells, suggesting these wells have not been affected by facility operations. However, because MW-49 is on the south side of the River and all current facility operations are north of the river, it is not an ideal upgradient well. Therefore, for the purposes of this report, wells MW-50 and MW-19 are considered upgradient wells.

Wells MW-16, MW-17, MW-20, MW-21, and MW-45 are located within the flood plain and downgradient of facility operations, thus making them potentially usable in upgradient to downgradient comparisons of flood plain water quality. Because there are some differences in general water quality between alluvial wells and flood plain wells, it would be ideal to have both upgradient and downgradient comparison wells in both areas. Wells MW-10s, MW-11s, and MW-46 are located onsite and downgradient of facility operations. However, based on the elevated nitrate concentrations at wells MW-12, MW-48, MW-13s, and others, there are no upgradient alluvial wells unaffected by facility operations. Therefore, all upgradient to downgradient comparisons in this report are made with wells MW-50 and MW-19 as the only upgradient wells.

4.2.2 Nitrate Trends

A trend analysis of nitrate concentrations at the 19 wells located on Simplot property and 4 wells located offsite was conducted as described in Section 1.3 and Appendix 1. Table 4-2 summarizes the data used in this analysis and includes some data set statistics (e.g., mean and maximum values), a summary of the trend analysis (e.g., the slope and confidence level of the line) and a description of the LOWESS pattern (e.g., increasing then decreasing). Time series graphs of nitrate concentrations at each Simplot well are included in Appendix 4.

Table 4-2 lists the individual results of the trend analysis for each well. The results can be summarized as follows:

- the onsite wells exhibit:
  - 2 increasing trends,
  - 4 decreasing trends,
  - 3 flat trends, and
  - 10 statistically insignificant trends.
- the offsite wells exhibit:
  - 1 increasing trend, and
  - 3 statistically insignificant trends.

Statistically significant trends range from increasing at 1.52 ppm/yr (at MW-47) to decreasing at 2.92 ppm/yr (at MW-45). The site-wide average nitrate trend (i.e., the average of all 19 slopes) is decreasing at approximately 0.6 ppm/yr. The average of the 9 statistically significant trends is decreasing less steeply; at approximately 0.3 ppm/yr.

Table 4-2 also lists the description of the LOWESS patterns for individual wells. The LOWESS patterns observed can be summarized as follows:

- 2 wells show a steadily decreasing pattern
- 2 wells shows a decreasing, then increasing, then decreasing again pattern
- 1 well show a decreasing then increasing pattern
- 5 wells show an increasing then decreasing pattern
- 9 wells show a flat or nearly flat pattern

In summary, 9 of the wells exhibit consistently decreasing or recently decreasing LOWESS patterns, 9 wells exhibit a nearly flat pattern, and 1 well exhibits a recently increasing pattern.

Figure 4-4 is a graph of all nitrate data from the 19 onsite Simplot Plant Site wells, with a LOWESS line drawn through the data. Figure 4-4 consists of many stacks of data points at approximately 3 month intervals. Each of these stacks of data represents one quarterly sampling event and contains one data point for each well sampled that event. It is evident from Figure 4-4 that the highest concentrations detected have occurred in the early to middle portion of the dataset. The LOWESS line has a gentle downward slope reflecting the overall decrease in nitrate concentrations at the site.

Figure 4-5 includes the nitrate trends and LOWESS lines at each of the 23 Simplot Plant Site wells. The 23 graphs are plotted at the same scale to allow a comparison of trends between wells. The wells are arranged in Figure 4-5 from steepest increasing trend through steepest decreasing trend to statistically insignificant trends (i.e., the steepest increasing trend is in the upper left corner of Figure 4-5).

Useful information can be gained by comparing trend lines with LOWESS lines. For example, Figure 4-5 illustrates that nitrate concentrations at several wells (most notably MW-16, MW-18, & MW-48) increased then decreased.

Figure 4-6 is a map view of the site illustrating the nitrate trends at each of the wells. Most wells exhibit increasing but statistically insignificant trends. Statistically significant trends range from increasing at 1.52 ppm/yr to decreasing at 2.92 ppm/yr. MW-47 (located on the western portion of the alluvial terrace) exhibits the steepest increasing trend (1.52 ppm/yr). The other two increasing trends are at the alluvial well MW-56 (0.40 ppm/yr) located offsite to the north, and the flood plain well MW-18 (0.22 ppm/yr). The steepest decreasing trends are at 3 flood plain wells (i.e., 1.5 ppm/yr at MW-20, 2.92 ppm/yr at MW-45, and 2.39 ppm/yr at MW-16). The alluvial well MW-11s also exhibits a decreasing trend (0.14 ppm/yr).

The fact that the majority of wells exhibit decreasing, flat, or statistically insignificant trends with generally decreasing LOWESS lines suggests groundwater quality may be responding to the reductions in nitrate loading at the site. However, diesel biodegradation may also be reducing nitrate concentrations beneath a portion of the site. This idea is discussed in more detail in Section 4.2.4. The fact that wells exhibiting increasing trends also have recently decreasing LOWESS lines suggests groundwater impacts are also beginning to decrease at these locations.

4.2.3 Average Nitrate Concentrations

Figure 4-7 is a map view of the site illustrating the average nitrate concentrations at each of the Simplot Plant Site wells from 1996 through 2001, the timeframe in which all wells except MW-18 were installed and sampled. The averages in Table 4-2 use all data since each well was installed. MW-18 was sampled from November 1988 through June 1996, and abandoned shortly thereafter. In summary, average nitrate concentrations were highest in the 10 onsite alluvial wells, lower in the 4 offsite alluvial wells, and lowest in the 8 flood plain wells.

The highest average nitrate concentration (39.1 ppm) is at the alluvial well MW-48. The lowest average nitrate concentrations are generally at flood plain wells (MW-50, MW-17, MW-19, and MW-49 all average less than 1 ppm) although the offsite alluvial well MW-59 also averaged 0.6 ppm nitrate. The remaining wells have average nitrate concentrations ranging from less than 1 to 23.3 ppm. The lower average nitrate concentrations in flood plain wells may reflect improvements in process wastewater management, dilution of groundwater by surface water (i.e., the Umatilla River), and/or the effects of diesel biodegradation.

4.2.4 Effects of Diesel Biodegradation on Nitrate Concentrations

It has been shown that aromatic hydrocarbons and polycyclic aromatic hydrocarbons (primary constituents of diesel fuel) can be degraded in the presence of nitrate by microbes (Fetter, 1993). During the degradation process, the nitrate molecule is broken down into oxygen (which is used to oxidize one hydrocarbon into the next hydrocarbon in the degradation chain) and nitrogen gas (which is released to the environment). Biodegradation indicators (i.e., physical and chemical changes resulting from the microbial action on hydrocarbons) include a lowering of nutrient concentrations, dissolved oxygen (DO), and the oxidation-reduction potential (ORP), along with an increase in dissolved iron (Fe) and manganese (Mn).

In 1994, diesel fuel was discovered in Simplot monitoring wells MW-10s, MW-10d, MW-20, and MW-21. In November 1996, Union Pacific Railroad (UPRR) performed a preliminary assessment to determine if the diesel fuel originated from the Hinkle Rail Yard located immediately north and east of the Simplot Plant Site. In 1999, UPRR entered into an agreement with DEQ that required UPRR to perform a Remedial Investigation and Feasibility Study. The February 2002 Remedial Investigation Report presented results from 5 areas of investigation (AOI). AOI 1 includes the former Engine House and active mainline fueling area at Hinkle Rail Yard as well as the Simplot Plant Site. Information from the Remedial Investigation (RI) Report and subsequent Groundwater Monitoring Reports was reviewed to evaluate the effects of diesel bioremediation on nitrate concentrations at the Simplot Plant Site. A summary of that review is described below.

Figure 4-8 illustrates the locations of diesel-related impacts near the Simplot Plant Site. It should be noted that some wells have never been measured for free product and/or sampled for diesel impacts, while others have been measured and/or sampled multiple times. The presence or absence of diesel impacts at individual wells has varied over time. Figure 4-8 includes the "worst case" result from each well. The stars indicate the approximate locations of the presumed sources of diesel contamination in AOI 1 (i.e., the former diesel platform, former underground storage tanks, and potentially a current above ground storage tank). Different symbols are used to indicate which type, if any, of diesel-related impacts each well has exhibited. At least six Simplot wells (MW-20, MW-21, MW-10s, MW-10d, MW-58, and MW-59) have been impacted by diesel.

The July 2002 Revised Groundwater Monitoring Plan for the UPRR Hinkle Rail Yard concludes biodegradation of the Total Petroleum Hydrocarbons (TPH)[6] plume is occurring in AOI 1 citing the following reasons:

- Dissolved oxygen concentrations are low in wells with TPH detections indicating aerobic degradation has occurred,
- Nitrate reduction has occurred as evidenced by low and non-detect nitrate concentrations in wells located with TPH detections,
- Manganese reduction has occurred as evidenced by elevated manganese concentrations in wells with detections of TPH,
- Iron reduction has occurred as evidenced by elevated alkalinity concentrations (alkalinity also indicates nitrate and sulfate reduction),
- Sulfate reduction has occurred as evidenced by decreased sulfate concentrations with TPH detections,
- Methanogenesis is underway as evidenced by high methane concentrations in wells with TPH detections and no methane detected in wells without TPH detections.

It is concluded from the discussion above that groundwater flow has transported the diesel (in both floating product and dissolved form) westward from the source area to impact wells MW-10s, MW-10d, MW-58, and MW-59. Furthermore, nitrate concentrations are being decreased at these locations by the microbial activity associated with the diesel degradation.

Two small ponds are located north of wells MW-20 and MW-21 but south of the former Engine House. These ponds collect surface water runoff, do not contain water year round, and are not connected to any other surface water body. The Hinkle Rail Yard RI Report states "runoff from surface spills of petroleum products and the wastewater treatment plant could have impacted these ponds in the past" and "discharges from surface spills of petroleum products were suspected to have impacted these ponds". Analytical results for sediment and water samples collected from these ponds indicate TPH in the diesel and heavy oil range were detected in all four samples. The steep hydraulic gradient from wells MW-20 and MW-21 towards the north and northwest suggest it would be very difficult to get petroleum products to these wells via groundwater flow (Figure 4-8). It is concluded that the diesel-related impacts at wells MW-20 and MW-21 resulted from overland flow of spilled diesel into these two small ponds followed by dispersion in groundwater.

[6] Total Petroleum Hydrocarbons (TPH) is a measure of the total amount of dissolved hydrocarbons in a sample. The analysis can be conducted so that it includes the range of hydrocarbons typically found in gasoline, diesel, and/or heavy oil.

Based on the discussion above, it is concluded that the biodegradation of diesel has consumed some of the nitrate in groundwater beneath the Simplot Plant Site and thus affects nitrate trends and average nitrate concentrations.

4.2.5 Upgradient to Downgradient Comparisons

Figure 4-9(a) is a time series graph showing the nitrate concentrations at the upgradient flood plain wells MW-50 and MW-19 and the downgradient flood plain wells MW-16, MW-20, MW-21, and MW-45. In addition to the individual data points connected by a thin line, a thick LOWESS line is drawn through the data. Figure 4-9(a) shows upgradient nitrate concentrations are consistently low (less than 2 ppm) while the downgradient nitrate concentration are significantly higher (the LOWESS line begins at approximately 15 ppm). It is noteworthy that downgradient concentrations are decreasing.

Figure 4-9(b) is a box and whisker plot summarizing the nitrate concentrations from the upgradient wells (MW-19 & MW-50) and the downgradient wells (MW-16, MW-20, MW-21, and MW-45)[7]. Figure 4-9(b) shows the average upgradient nitrate concentration is approximately 0.6 ppm with all concentrations less than 2 ppm. Figure 4-9(b) also shows the average downgradient nitrate concentration is approximately 13 ppm with half of the concentrations between approximately 0.5 and 19.5 ppm.

Based on comparisons of nitrate concentrations at upgradient flood plain wells and downgradient flood plain wells, facility operations have impacted groundwater quality.

As indicated in Section 4.2.1, there are currently no upgradient wells that are unaffected by facility operations. Therefore, wells MW-50 and MW-19 are considered the best upgradient wells available for comparisons to both downgradient flood plain wells and alluvial wells. As discussed in Section 4.2.1, alluvial wells generally have higher nitrate concentrations than floodplain wells. Therefore, a hypothetical upgradient alluvial well would likely exhibit slightly higher nitrate concentrations than those at MW-19 and MW-50.

Figure 4-10(a) is a time series graph showing the nitrate concentrations at the upgradient *flood plain* wells MW-50 and MW-19 and the downgradient *alluvial* wells MW-10s, MW-11s, and MW-46. Figure 4-10(a) shows upgradient nitrate concentrations are consistently low (less than 2 ppm) while the downgradient nitrate concentration are significantly higher (the LOWESS line begins at approximately 13 ppm). It is noteworthy that downgradient concentrations are decreasing.

Figure 4-10(b) is a box and whisker plot summarizing the nitrate concentrations from the upgradient wells (MW-19 & MW-50) and the downgradient wells (MW-10s, MW-11s, and MW-46). Figure 4-10(b) shows the average upgradient nitrate concentration is approximately 0.6 ppm with all concentrations less than 2 ppm. Figure 4-9(b) also shows the average downgradient nitrate concentration is approximately 8 ppm with half of the concentrations between approximately 4 and 12 ppm.

Based on comparisons of nitrate concentrations at upgradient flood plain wells and downgradient alluvial wells, facility operations have impacted groundwater quality in the past but nitrate concentrations are currently decreasing.

4.2.6 Conclusions

Based on the discussion of the data for the Simplot Plant site presented above, the following conclusions have been made, and are grouped by topic:

[7] The "box" portion of the plot identifies the interquartile range (IQR). The IQR is the middle half of the data (i.e., those data between the 25th and 75th percentiles). The "whisker" portion of the plot extends outwards from the box to any point within 1.5 times the IQR. Any point beyond the whiskers is plotted individually. The horizontal line through the box represents the median value. The star represents the average value.

Hydrogeology

- Groundwater at the Simplot Plant Site flows toward the Umatilla River from the south but not from the north. Groundwater flows generally northwest across the site regardless of season.
- Wells at the Simplot Plant site can be classified as either a flood plain well or an alluvial well based on location, typical water level, timing of water level fluctuations, typical lithology, and general water quality.
    - Flood plain wells are located within the Umatilla River flood plain, are generally screened in coarser-grained sediments, exhibit water levels near 540', exhibit TDS concentrations less than alluvial wells but higher than river concentrations, and fluctuate annually with highest water levels typically in the winter or spring and lowest water levels in the summer and fall.
    - Alluvial wells are located on either side of the Umatilla River flood plain, are generally screened in finer-grained sediments, exhibit water levels near 500', exhibit TDS concentrations higher than flood plain wells and the River, and fluctuate annually with highest water levels typically in the summer and fall, and lowest water levels in winter and spring.
    - The depth to water beneath the Plant Site ranges from approximately 6 to 149 feet below land surface.
- Upgradient wells for the Simplot Plant Site would be located south and east of facility operations.
    - Upgradient wells in the flood plain include MW-19 and MW-50.
    - Because there are some differences in general water quality between alluvial wells and flood plain wells, it would be ideal to have both upgradient and downgradient comparison wells in both areas. However, no upgradient alluvial wells are unaffected by facility operations.
- Downgradient wells for the Simplot Plant Site would be located north and west of facility operations.
    - Downgradient wells in the flood plain include MW-16, MW-20, MW-21, and MW-45.
    - Downgradient wells in the alluvium include MW-10s, MW-11s, and MW-46.

Nitrate Concentrations and Trends

- Nitrate concentrations at the Simplot Plant Site are generally decreasing.
    - 90% of wells exhibit decreasing (21%), flat (16%), or statistically insignificant (53%) trends.
    - Trends range from increasing at 1.52 ppm/yr to decreasing at 2.92 ppm/yr with the site-wide average nitrate trend decreasing at least 0.3 ppm/yr.
    - Half of the wells exhibit consistently or recently decreasing LOWESS patterns.
    - Wells exhibiting increasing trends also have recently decreasing LOWESS lines.
    - The highest concentrations occur in the early to middle portion of the dataset.

Factors Affecting Nitrate Concentrations

- Facility operations have affected groundwater quality in the past, but water quality is improving.
    - Downgradient wells have higher nitrate concentrations than upgradient wells indicating facility operations have impacted groundwater quality.
    - Average nitrate concentrations are highest in the onsite alluvial wells, lower in the offsite alluvial wells, and lowest in the flood plain wells. The lower average nitrate concentrations in flood plain wells may reflect improvements in process wastewater management, dilution of groundwater by surface water (i.e., the Umatilla River), and/or the effects of diesel biodegradation.
- Wells closer to leaky fresh water canals and fresh water streams are more likely to exhibit lower nitrate concentrations due to dilution from the surface water.
- Biodegradation of diesel is occurring at a portion of the site which is reducing nitrate concentrations.
- The general site-wide decrease in nitrate concentrations is likely due to a combination of better process wastewater management, dilution of groundwater by surface water, and biodegradation of diesel.
- The large range of depth to water across the site could cause substantial variability in the timing of groundwater quality responses to activities at land surface.

4.3 Terrace Site

The Simplot Terrace Site is located approximately 4 miles south of the City of Hermiston, southeast of the junction of US Interstate 84 and Oregon 207 (Figure 1-2). As indicated in Section 4.2, process wastewater is screened, treated at the Plant Site, and then stored in a surge pond or a storage pond before being applied to agricultural land at one of Simplot's parcels of land. At the Terrace Site, process wastewater is applied to as many as 6 fields comprising as much as 582 acres.

The land application system at the Terrace Site began in 1981. Prior to the land application system, the land occupied by the Terrace Site was a mixture of farmland and unfarmed dry land.

The Terrace Site is located on an upland terrace, situated between Emigrant Buttes (the surface expression of the Service Anticline) and the Butter Creek flood plain. The terrace exhibits a gentle northward slope (0 to 5%). Topography at the Terrace Site ranges from approximately 610 to 700 feet above mean sea level.

Nearby surface water features include Butter Creek (which is located just west of the site and flows south to north), and the Hunt Ditch (a component of the Westland Irrigation District delivering water from the Umatilla River to irrigated land in the vicinity) which wraps around the east, north, and west property boundaries. The Hunt Ditch is closest to the Terrace site at the northeast property boundary. The depth to water beneath the Terrace Site ranges from approximately 50 feet below land surface (at MW-51; a well located close to the Butter Creek flood plain) to approximately 90 feet below land surface (at MW-53; a well in the northern portion of the site).

4.3.1 Hydrogeology

As discussed in Section 1.3, groundwater flow direction can be affected by land surface topography, the topography of the base of the aquifer, recharge and discharge features, and surface water features. The base of the surficial aquifer beneath the Simplot Terrace Site (as well as the other Simplot sites) is the Columbia River Flood Basalts. Figure 3-7 is a map of the basalt surface topography in the Butter Creek Area that includes the Simplot Sites. As indicated in Figure 3-7, the basalt topography beneath the Simplot Terrace Site slopes away from the Service Anticline. The basalt surface slopes predominantly west-northwest.

Figures 3-8 and 3-9 are Spring and Fall 2002 water table maps of the Butter Creek area, respectively. These maps include water level information from several food processing wastewater land application facilities in the vicinity of the Simplot Terrace site. The groundwater elevation contours on these figures are based on professional judgment, water levels measured at the alluvial aquifer wells, land surface topography, location of surface water features, the elevation of the underlying basalt surface, and the migration of diesel contamination at Hinkle Rail yard. During the preparation of these maps, it was assumed that shallow groundwater in the Butter Creek drainage is directly connected to shallow groundwater on either side of the drainage. It was also assumed that topographic relief and basalt surface topography are major controls of shallow groundwater flow. Figure 4-11 is a map of fourth quarter 2001 groundwater elevations at the Simplot Terrace Site.

As indicated in Figure 4-11 (and Figures 3-8 and 3-9), groundwater flows north to northwest across the site. Based on the groundwater flow direction indicated in these figures, upgradient wells for the Simplot Terrace site would be located south and east of facility operations, while downgradient wells would be located north and west of facility operations. Wells MW-40 and MW-54 are located upgradient of current facility operations. Wells MW-22, MW-52, and MW-53 are located downgradient of current facility operations.

4.3.2 Nitrate Trends

A trend analysis of nitrate concentrations at the 10 wells located at the Simplot Terrace Site was conducted as described in Section 1.3 and Appendix 1. Table 4-3 summarizes the data used in this analysis and includes some data set statistics (e.g., mean and maximum values), a summary of the trend analysis (e.g., the slope and confidence level of the line) and a description of the LOWESS pattern (e.g., increasing then decreasing). Time series graphs of nitrate concentrations at each Simplot well are included in Appendix 4.

Table 4-3 lists the individual results of the trend analysis for each well. The results can be summarized as follows:

- 9 wells exhibit increasing trends, and
- 1 well exhibits a statistically insignificant trend.

Statistically significant trends range from increasing at 0.95 ppm/yr (at MW-38) to 2.25 ppm/yr (at MW-52). The site-wide average nitrate trend is increasing at approximately 1.4 ppm/yr.

Table 4-3 also lists the description of the LOWESS pattern for individual wells. The LOWESS patterns observed can be summarized as follows:

- 4 wells show increasing patterns with some fluctuations
- 1 well shows an increasing pattern then starts to level off
- 3 wells show increasing then decreasing patterns
- 1 well shows a decreasing then increasing pattern
- 1 well shows a decreasing, then increasing, then decreasing again pattern

In summary, 7 of the wells exhibit consistently increasing or recently increasing LOWESS patterns, and 3 wells exhibit an increasing then decreasing pattern.

Figure 4-12 is a graph of all nitrate data from the 10 Simplot Terrace Site wells, with a LOWESS line drawn through the data. The solid data points represent those from well MW-53. It is evident from Figure 4-12 that (1) nitrate concentrations at well MW-53 are substantially higher than at all other wells, and (2) the highest concentrations detected have occurred in the latter portion of the dataset, even if well MW-53 is not considered. The LOWESS line has an upward slope reflecting the overall increase in nitrate concentrations at the site.

Figure 4-13 includes the nitrate trends and LOWESS lines at each of the 10 Simplot Terrace Site wells. The 10 graphs are plotted at the same scale to allow a comparison of trends between wells. Useful information can be gained by comparing trend lines with LOWESS lines. For example, Figure 4-13 illustrates that nitrate concentrations at a few wells (most notably MW-52 & MW-53) increased then decreased.

Figure 4-14 is a map view of the site illustrating the nitrate trends at each of the wells. Nine out of ten wells exhibit increasing trends. The remaining well exhibits a statistically insignificant increasing trend. MW-52 (located along the northwestern property boundary) exhibits the steepest increasing trend (2.25 ppm/yr). The remaining increasing trends range from 1.8 ppm/yr to 0.95 ppm/yr. The statistically insignificant trend also increases at 0.95 ppm/yr.

The fact that 90% of the wells exhibit increasing trends, and 70% of the wells exhibit consistently increasing or recently increasing LOWESS patterns, suggests the facility operations are impacting groundwater quality.

4.3.3 Average Nitrate Concentrations

Figure 4-15 illustrates the average nitrate concentrations at each of the Simplot Terrace Site wells from 1996 through 2001, the timeframe in which all wells except MW-15 were installed and sampled. The average at MW-15 is from 1996 through February 1998. It was abandoned shortly thereafter. Due to the increasing trend there, an average over the same timeframe as other wells would likely be higher than 14 ppm. In summary, average nitrate concentrations range from approximately 12 to 60 ppm, and were higher in the downgradient wells than in the upgradient wells.

The highest average nitrate concentration (60.3 ppm) is at well MW-53, located along the northern downgradient property boundary. The lowest average nitrate concentration (12.4 ppm) is at well MW-38, located at the northeast corner of the property. Well MW-38 is located in a cross gradient position (i.e., neither upgradient nor downgradient of facility operation). Although not presented in this report, it has been observed that water levels at MW-38 fluctuate annually with the highest water levels occurring in the summer or fall quarters, and the lowest water levels occurring in the winter or spring quarters. Because of this water level fluctuation, it is possible that water leaking from the nearby irrigation canal affects the water level and water quality at well MW-38 (i.e., diluting groundwater nitrate concentrations with surface water).

4.3.4 Upgradient to Downgradient Comparisons

Figure 4-16(a) is a time series graph showing the nitrate concentrations at the upgradient wells MW-40 and MW-54 and the downgradient wells MW-22, MW-52, and MW-53. In addition to the individual data points connected by a thin line, thick LOWESS lines are drawn through the data to illustrate general patterns. Figure 4-16(a) shows both upgradient and downgradient nitrate concentrations are increasing at similar rates, but downgradient concentrations are approximately 10 to 15 ppm higher than upgradient concentrations. If downgradient well MW-53 is not considered, this relationship still holds true except downgradient concentrations are approximately 8 to 10 ppm higher than upgradient concentrations (Figure 4-16).

Figure 4-16(b) is a box and whisker plot summarizing the nitrate concentrations from the upgradient wells (MW-40 & MW-54) and the downgradient wells (MW-22, MW-52, and MW-53)[8]. Because the downgradient well MW-53 is substantially different than the other downgradient wells, box plots for both the individual wells and the combined data are presented. Figure 4-16(b) shows the average upgradient nitrate concentration is approximately 16 ppm with all concentrations less than 24 ppm. Figure 4-16(b) also shows the average downgradient nitrate concentration is approximately 24 ppm (if only wells MW-22 and MW-52 are used) or 32 ppm (if MW-22, MW-52, & MW-53 are used).

Based on comparisons of nitrate concentrations at upgradient wells and downgradient wells, facility operations have impacted groundwater quality.

4.3.5 Conclusions

Based on the discussion of the data for the Simplot Terrace site presented above, the following conclusions have been made, and are grouped by topic:

Hydrogeology

- Groundwater at the Simplot Terrace Site flows north-northwest toward the Butter Creek flood plain.
- The depth to water beneath the Terrace Site ranges from approximately 50 to 90 feet below land surface.
- Upgradient wells for the Simplot Terrace Site would be located south and east of facility operations.
    - Upgradient wells include MW-40 and MW-54.
- Downgradient wells for the Simplot Terrace Site would be located north and west of facility operations.
    - Downgradient wells include MW-22, MW-52, and MW-53.

Nitrate Concentrations and Trends

- Nitrate concentrations at the Simplot Terrace Site are increasing.
    - 90% of wells exhibit statistically significant increasing trends.
    - Trends range from increasing at 0.95 ppm/yr to 2.25 ppm/yr with the site-wide average nitrate trend increasing at approximately 1.4 ppm/yr.
    - 70% of the wells exhibit consistently or recently increasing LOWESS patterns.
    - The highest concentrations occur in the latter portion of the dataset.

[8] The "box" portion of the plot identifies the interquartile range (IQR). The IQR is the middle half of the data (i.e., those data between the 25th and 75th percentiles). The "whisker" portion of the plot extends outwards from the box to any point within 1.5 times the IQR. Any point beyond the whiskers is plotted individually. The horizontal line through the box represents the median value. The star represents the average value.

Factors Affecting Nitrate Concentrations

- Facility operations have affected groundwater quality.
  - Downgradient wells have higher nitrate concentrations than upgradient and cross-gradient wells indicating facility operations have affected groundwater quality.
- The fact that 90% of the wells exhibit increasing trends, and 70% of the wells exhibit consistently increasing or recently increasing LOWESS patterns, suggests that facility operations continue to affect groundwater quality. Potential methods to assess the effectiveness of current facility operations are discussed in Section 8.2.
- Wells closer to leaky fresh water canals and fresh water streams are more likely to exhibit lower nitrate concentrations due to dilution from the surface water.
- The range of depth to water across the site could cause substantial variability in the timing of groundwater quality responses to activities at land surface.

4.4 Expansion Site

The Simplot Expansion Site is located approximately 4 miles south of the City of Hermiston, southwest of the junction of US Interstate 84 and Oregon 207 (Figure 1-2).

The land application system at the Expansion Site began in 1991. Prior to the land application system, the land occupied by the Expansion Site was used for farmland and cattle grazing.

The Expansion Site is located primarily within the Butter Creek flood plain but the western portion of the site also includes a portion of an upland terrace. The flood plain exhibits a gentle northward slope (0 to 5%). The terrace portion exhibits a steeper eastward slope (5 to 25%). Topography at the Expansion Site ranges from approximately 550 to 680 feet above mean sea level.

Nearby surface water features include Butter Creek (which flows south to north through the Site), as well as the Hunt Ditch, the High Line Canal, and various un-named irrigation canals (components of the Westland Irrigation District delivering water from the Umatilla River to irrigated land in the vicinity) which flow across the property at several locations. The depth to water beneath the Expansion Site ranges from as shallow as 2½ feet below land surface (at MW-25; a well close to an irrigation ditch) to 87 feet below land surface (at MW-42; an upland well located along the western property boundary).

4.4.1 Hydrogeology

As discussed in Section 1.3, groundwater flow direction can be affected by land surface topography, the topography of the base of the aquifer, recharge and discharge features, and surface water features. The base of the surficial aquifer beneath the Simplot Expansion Site (as well as the other Simplot Sites) is the Columbia River Flood Basalts. Figure 3-7 is a map of the basalt surface topography in the Butter Creek Area that includes the Simplot Sites. As indicated in Figure 3-7, the basalt topography beneath the Simplot Expansion Site slopes from the east and west toward Butter Creek, but also northward toward the Umatilla River.

Figures 3-8 and 3-9 are Spring and Fall 2002 water table maps of the Butter Creek area, respectively. These maps include water level information from several food processing wastewater land application facilities in the vicinity of the Simplot Expansion site. Figure 4-17 is a map of fourth quarter 2001 groundwater elevations at the Simplot Expansion Site. As indicated in Figure 4-17 (and Figures 3-8 and 3-9), groundwater generally flows north-northeast across the site. Based on the groundwater flow direction indicated in Figure 4-17, upgradient wells for the Simplot Expansion site would be located south and west of facility operations, while downgradient wells would be located north and east of facility operations. Wells MW-36, MW-41, MW-42, MW-43, and MW-44 are located upgradient of current facility operations. Wells MW-31, MW-32, MW-33, and MW-55 are located downgradient of current facility operations.

4.4.2 Nitrate Trends

A trend analysis of nitrate concentrations at the 20 wells located at the Simplot Expansion Site was conducted as described in Section 1.3 and Appendix 1. Table 4-4 summarizes the data used in this analysis and includes some data set statistics (e.g., mean and maximum values), a summary of the trend analysis (e.g., the slope and confidence level of the line) and a description of the LOWESS pattern (e.g., increasing then decreasing). Time series graphs of nitrate concentrations at each Simplot well are included in Appendix 4.

Table 4-4 lists the individual results of the trend analysis for each well. The results can be summarized as follows:

- 19 wells exhibit increasing trends, and
- 1 well exhibits a statistically insignificant trend.

Statistically significant trends range from increasing at 0.25 ppm/yr (at MW-23 & MW-34) to 2.02 ppm/yr (at MW-41). The site-wide average nitrate trend is increasing at approximately 0.6 ppm/yr.

Table 4-4 also lists the description of the LOWESS patterns for individual wells. The LOWESS patterns observed can be summarized as follows:

- 6 wells show increasing, then decreasing, then increasing again patterns
- 5 wells show increasing then decreasing patterns,
- 4 wells show increasing patterns,
- 3 wells show increasing patterns then begin to level off,
- 1 well shows an increasing pattern with fluctuations, and
- 1 well shows a flat then increasing pattern.

In summary, 15 of the wells (75%) exhibit generally increasing or recently increasing LOWESS patterns, and 5 wells (25%) exhibits an increasing then decreasing pattern.

Figure 4-18 is a graph of all nitrate data from the 20 Simplot Expansion wells, with a LOWESS line drawn through the data. It is evident from Figure 4-18 that the highest concentrations detected have occurred in the latter portion of the dataset. The LOWESS line has an upward slope of approximately 1 ppm/yr from 1990 through 1996, when it becomes nearly flat through 2001. The LOWESS line and pattern of data indicate the general increase of nitrate concentrations at the site.

Figure 4-19 includes the nitrate trends and LOWESS lines at each of the 20 Simplot Expansion Site wells. The 20 graphs are plotted at the same scale to allow a comparison of trends between wells. Useful information can be gained by comparing trend lines with LOWESS lines. For example, Figure 4-19 illustrates that nitrate concentrations well MW-55 increased then decreased. Figure 4-19 also illustrates that nitrate concentrations at MW-41 were flat for a while and then began increasing at a rate steeper than the long-term trend.

Figure 4-20 is a map view of the site illustrating the nitrate trends at each of the wells. Nineteen out of twenty wells exhibit increasing trends. The remaining well exhibits a statistically insignificant increasing trend. MW-41 (located near the northeastern property boundary) exhibits the steepest increasing trend (2.0 ppm/yr). The remaining increasing trends range from 0.25 ppm/yr to 1.2 ppm/yr. The statistically insignificant trend also increases at 0.07 ppm/yr.

The fact that all of the wells exhibit increasing trends, and 75% of the wells exhibit consistently increasing or recently increasing LOWESS patterns, suggests the facility operations are impacting groundwater quality.

4.4.3 Average Nitrate Concentrations

Figure 4-21 illustrates the average nitrate concentrations at each of the Simplot Expansion Site wells from 1996 through 2001, the time frame in which all wells were installed and sampled. In summary, average nitrate concentrations range from approximately 7 to 17 ppm, and were generally higher in the downgradient wells than in the upgradient wells.

The highest average nitrate concentration (17 ppm) is at downgradient well MW-55, located near the northwestern property boundary. The lowest average nitrate concentration (6.5 ppm) is at the upgradient well MW-44, located near the southwest corner of the property. The fact that average concentrations are lowest at an upgradient well and highest at a downgradient well indicates facility operations have impacted groundwater.

4.4.4 Upgradient to Downgradient Comparisons

Figure 4-22(a) is a time series graph showing the nitrate concentrations at the upgradient wells MW-36, MW-41, MW-42, MW-43, and MW-44 and the downgradient wells MW-31, MW-32, MW-33, and MW-55. In addition to the individual data points connected by a thin line, thick LOWESS lines are drawn through the data to illustrate general patterns. Figure 4-22(a) shows both upgradient and downgradient nitrate concentrations follow similar patterns (i.e., increase at approximately 1 ppm/yr from 1991 through 1996, then begin to flatten out), but downgradient concentrations are approximately 3 to 4 ppm higher than upgradient concentrations. (Figure 4-22).

Figure 4-16(b) is a box and whisker plot summarizing the nitrate concentrations from the upgradient wells and the downgradient wells. Figure 4-22(b) shows the average upgradient nitrate concentration is approximately 6.8 ppm with half of the concentrations between 3.4 and 8.3 ppm. Figure 4-16(b) also shows the average downgradient nitrate concentration is approximately 9.7 ppm with half of the concentrations between 7.2 and 11.7 ppm.

Based on comparisons of nitrate concentrations at upgradient wells and downgradient wells, facility operations have impacted groundwater quality.

4.4.5 Conclusions

Based on the discussion of the data for the Simplot Expansion site presented above, the following conclusions have been made, and are grouped by topic:

Hydrogeology

- Groundwater at the Simplot Expansion Site flows north-northeast, down the Butter Creek flood plain.
- The depth to water beneath the Expansion Site ranges from 2½ to 87 feet below land surface.
- Upgradient wells for the Simplot Expansion Site would be located south and west of facility operations.
  - Upgradient wells include MW-36, MW-41, MW-42, MW-43, and MW-44.
- Downgradient wells for the Simplot Expansion Site would be located north and east of facility operations.
  - Downgradient wells include MW-31, MW-32, MW-33, and MW-55.

Nitrate Concentrations and Trends

- Nitrate concentrations at the Simplot Expansion Site are generally increasing.
  - 95% of wells exhibit statistically significant increasing trends.
  - Trends range from increasing at 0.25 ppm/yr to 2.02 ppm/yr with the site-wide average nitrate trend increasing at approximately 0.6 ppm/yr.
  - 75% of the wells exhibit consistently or recently increasing LOWESS patterns.
  - The highest concentrations occur in the latter portion of the dataset.

Factors Affecting Nitrate Concentrations

- Facility operations have affected groundwater quality.
  - Downgradient wells have higher nitrate concentrations than upgradient wells indicating facility operations have affected groundwater quality.

- Wells closer to leaky fresh water canals and fresh water streams are more likely to exhibit lower nitrate concentrations due to dilution from the surface water.
- The fact that 95% of the wells exhibit increasing trends and 75% of the wells exhibit consistently increasing or recently increasing LOWESS patterns suggests that facility operations continue to impact groundwater quality. Potential methods to assess the effectiveness of current facility operations are discussed in Section 8.2.
- The large range of depth to water across the site could cause substantial variability in the timing of groundwater quality responses to activities at land surface.

4.5 Link Between BMP Implementation and Groundwater Quality Improvement

The following sections describe Simplot's efforts to improve groundwater quality through the adoption of Best Management Practices (BMPs) as well as some of the limitations to rapid improvement in groundwater quality. The information provided in Section 4.5.1 was provided by Simplot.

4.5.1 Efforts to Improve Groundwater Quality

Simplot has modified practices and procedures over the years to reduce the amount of nitrate and hydraulic loading to the groundwater system. Some of the changes include:

- *Expansion of land application areas* – Simplot increased the land area used to apply process wastewater to include the Terrace Site in 1981, the Expansion Site in 1991, and the Levy Site in 2002.
- *Improved waste treatment process* – In 1987, Simplot built a digester and improved solids removal by installing a centrifuge. In 1995, Simplot built a larger clarifier and installed a second centrifuge for additional solids removal.
- *Limiting winter irrigation* – In 1991, Simplot built the Terrace Site Lagoon so that water could be stored during a portion of the winter months rather than land applied.
- *Eliminating winter irrigation* – In 2002, Simplot built a second lagoon so that water could be stored during the entire winter, which eliminated winter irrigation.
- *Reducing nitrogen loading* – In 2001, Simplot stopped taking credit for ammonia volatilization which equates to a 40% reduction in planned nitrogen loading. In 2002, Simplot reduced the loading on alfalfa at the Levy property to 250 lb/acre.

4.5.2 Timing of Groundwater Quality Improvement

As discussed above, the nitrate data at the Simplot Plant Site indicate the facility has impacted groundwater, and that groundwater quality is improving. As discussed in Section 4.5.1, Simplot has implemented BMPs over the past 23 years to reduce the nitrate and hydraulic loading to the groundwater system. The timeframe of expected water quality improvements is difficult to quantify. Several factors inhibit the rapid improvement of groundwater quality in the study area. These involve both hydrogeologic and cultural factors and include, but are not necessarily limited to, the source of aquifer recharge, nitrogen in the unsaturated zone, nitrate in upgradient groundwater, groundwater flow velocity, and the continued application of process wastewater. A discussion of these factors is provided in Section 8.2. Potential methods to assess the effectiveness of current facility operations are discussed in Section 8.3.

4.6 Recommendations

Based on the conclusions and discussion above, the following recommendations are made:

- In order to gauge when the effects of BMP implementation will be observed as improving groundwater quality, it is recommended that funding be pursued to allow additional research into factors including: (1) quantifying the amount of nitrate that exists between the root zone and the water table, (2) the rate of nitrate transport through the unsaturated zone, and (3) more precisely quantifying groundwater flow velocity at the site.
- Due to the high percentage of increasing trends and impacts to groundwater from land application activities, it is recommended that BMP implementation to reduce the area-wide extent of elevated nitrate concentrations be continued and, when possible, improved.

Trend Analysis of Food Processor Land Application Sites in the LUB GWMA

- In accordance with the Action Plan, it is recommended that a trend analysis of data from the same wells be conducted in 2005 to evaluate progress towards improving groundwater quality at the food processing wastewater land application sites.

5.0 HERMISTON FOODS SITE

5.1 Introduction

Hermiston Foods, LLC (Hermiston Foods) operates a vegetable processing plant and wastewater treatment facility near Hermiston, Oregon. The vegetable processing plant was constructed in 1990 and operates seasonally to process asparagus, peas, lima beans, potatoes, and carrots. The company's wastewater treatment facility includes a land application system located approximately one mile south of the plant. Hermiston Foods land applied approximately 100.7 million gallons of wastewater in 2001 consisting of process wastewater, boiler blow-down, condenser water, and storm water. Average values for Hermiston Food's process wastewater in 2001 include:

- 3,561 mg/l Chemical Oxygen Demand (COD)
- 39 mg/l Total Kjeldahl Nitrogen (TKN)
- 2,675 mg/l total dissolved solids (TDS)
- 177 mg/l potassium (K)
- 11 mg/l total phosphorus (P)

5.2 Hermiston Foods Site

The Hermiston Foods land application site is located approximately 3 miles south of the City of Hermiston, east of the junction of US Highway 395 and Feedville Road at property owned by the Windblown Ranch (Figure 1-2). The land application system at the Hermiston Foods site began in 1990. The process wastewater is land applied at two 125-acre center pivot irrigation circles (one installed in 1990, the other installed in 1991) for the purpose of growing alfalfa and small grains. In addition, during the months of April through September, a portion of the process wastewater is discharged to a 14.6 acre hybrid poplar tree plantation (installed in 1999). Prior to the land application system, the land occupied by the Hermiston Foods site was undeveloped.

When process wastewater does not meet crop needs (typically from approximately April through October), supplemental irrigation water from an irrigation ditch is applied on the site.

The Hermiston Foods Site is located within the Deschutes-Umatilla Plateau physiographic province. The site generally exhibits gentle slopes of 0 to 5%. Soils at the site include well drained fine sandy loam and excessively drained fine sand. Topography at the Hermiston Foods Site ranges from approximately 700 to 650 feet above mean sea level.

Nearby surface water features include the Furnish Ditch (which delivers irrigation water to nearby fields) located northwest of the site, and an unnamed canal extending southwest from the Furnish Ditch that passes within approximately 300 feet of the northwest corner of the site and terminates approximately 800 feet west of the site.

The average depth to water beneath the Hermiston Foods Site ranges from approximately 30 feet below land surface (at well MW-1; located in the southeastern corner of the site) to approximately 70 feet below land surface (at well MW-4 located in the northeastern corner of the site). The depth to water at well MW-2 averages approximately 55 feet below land surface but exceeds 85 feet below land surface when a nearby irrigation well is pumping. The site-wide average depth to water is approximately 50 feet below land surface.

5.2.1 Hydrogeology

As discussed in Section 1.3, groundwater flow direction can be affected by land surface topography, the topography of the base of the aquifer, recharge and discharge features, and surface water features.

The base of the surficial aquifer beneath the Hermiston Foods Site is the Columbia River Flood Basalts. The depth to basalt at the site ranges from approximately 200 to 223 feet below land surface at 3 Windblown Ranch wells located on the western portion of the property. Based on the regional geologic mapping by DEQ (1995), the basalt surface beneath the Hermiston Foods Site slopes generally northwest.

Because land surface topography does not vary much across the site (approximately 50 feet), and the basalt surface is relatively flat, the primary factors affecting groundwater flow at the site (other than the regional groundwater flow direction) are likely to be recharge/discharge stresses and surface water features.

Figure 5-1 includes hydrographs for the 6 Hermiston Foods wells constructed with 5 years of monthly water level data. The large drop in water levels at MW-2 during the spring and/or summer months (typically summer) illustrate the effects of pumping an irrigation well (known as UMAT 2879[9]) located approximately 100 feet west of well MW-2 on an adjacent property. Water levels at MW-2 are typically highest in the winter months.

The effects of pumping UMAT 2879 also seem to be apparent in the hydrograph for MW-4; but not to a significant degree at any other well (Figure 5-1). In contrast, the hydrograph for MW-3 appears to be responding to the nearby irrigation canal: water levels are lowest in March or April (the beginning of irrigation season), and highest in September or October (the end of irrigation season) (Figure 5-1).

Figure 5-2 includes two potentiometric surface maps: Figure 5-2 (A) shows the minimum influence of the offsite irrigation well (i.e., the minimum difference between water levels at MW-2 and other wells), and Figure 5-2 (B) shows the maximum influence of the offsite irrigation well (i.e., the maximum difference between water levels at MW-2 and other wells). Both maps were prepared based on the inferences drawn from examination of the hydrographs (i.e., the pumping well appears to significantly affect water levels at MW-2 and MW-4, but not the other wells). The hydrographs and potentiometric surface maps suggest the groundwater flow direction in the northern portion of the site (but not at well MW-3) is affected by the pumping of the offsite irrigation well.

As indicated in Figure 5-2(A), when the offsite irrigation well is not pumping, groundwater enters the site along the western and southern boundaries flowing east/northeast, but turns progressively more northward and exits the site along the northern boundary of the site flowing nearly due north. Pumping the offsite irrigation well appears to alter the flow direction in the northern portion of the site causing water to flow towards the pumped well and exit the site flowing northwestward (Figure 5-2(B)).

Based on the groundwater flow direction indicated in Figure 5-2, upgradient wells for the Hermiston Foods site would be located south and west of facility operations, while downgradient wells would be located north and east of facility operations. Wells MW-3 and MW-5 are located upgradient of current facility operations. Wells MW-4 and MW-6 are located downgradient of current facility operations.

Well MW-2 is located downgradient of well MW-3, but the land between the wells is not part of the Hermiston Foods site. When the offsite irrigation well is not pumping, groundwater apparently flows from well MW-3 towards MW-2 beneath the land that is not part of the Hermiston Foods site. However, when the offsite irrigation well is pumping, groundwater apparently flows towards the pumping well from all directions, including from a portion of the Hermiston Foods site. This change in groundwater flow direction indicates well MW-2 is sometimes downgradient from a portion of the Hermiston Foods site but is never entirely downgradient of the facility operations. Therefore, well MW-2 is not an adequate downgradient well for evaluating potential effects of facility operations. It is, however, very useful in evaluating the groundwater flow regime of the site.

5.2.2 Nitrate Trends

A trend analysis of nitrate concentrations at the 6 wells located at the Hermiston Foods site was conducted as described in Section 1.3 and Appendix 1. Table 5-1 summarizes the data used in this analysis and includes some data set statistics (e.g., mean and maximum values), a summary of the trend analysis (e.g., the slope and

[9] OWRD (1989) reports that well UMAT 2879 (known in that report as the Chowning #4 well) was drilled to a depth of 130 feet, has perforated casing from 84 to 104 feet, and penetrated only the alluvial aquifer. The owner reported that this well has been deepened to 241 feet, although no water well report is on file with OWRD for the deepening.

confidence level of the line) and a description of the LOWESS pattern (e.g., increasing then decreasing). Time series graphs of nitrate concentrations at each Hermiston Foods well are included in Appendix 5.

Table 5-1 lists the individual results of the trend analysis for each well. The results indicate 2 wells show statistically significant increasing trends and 4 wells show statistically insignificant trends. Both statistically significant trends are increasing at 0.29 ppm/yr (at MW-2 and MW-4). The site-wide average nitrate trend is increasing at approximately 0.1 to 0.3 ppm/yr (depending on whether or not the statistically insignificant trends are included) (Table 5-1).

Table 5-1 also lists the description of the LOWESS patterns for individual wells. The LOWESS patterns observed can be summarized as follows:

- 2 wells show a steadily increasing pattern
- 2 well show a nearly flat pattern
- 1 well shows an increasing, then decreasing, then increasing pattern
- 1 well shows a decreasing, then increasing, then decreasing pattern

In summary, 3 of the wells exhibit consistently increasing or recently increasing LOWESS patterns, 2 wells exhibit a nearly flat pattern, and 1 well exhibits a recently decreasing pattern.

Figure 5-3 is a graph of all nitrate data from the 6 Hermiston Foods wells, with a LOWESS line drawn through the data. Figure 5-3 consists of many stacks of data points at approximately 3 month intervals. Each of these stacks of data represents one quarterly sampling event and contains one data point for each well sampled that event. It is evident from Figure 5-3 that the nitrate concentrations detected have not varied considerably since sampling began, but the highest concentrations have occurred in the latter portion of the dataset. The LOWESS line has a slight upward slope reflecting the overall increase in nitrate concentrations at the site.

Figure 5-4 includes the nitrate trends and LOWESS lines at each of the 6 Hermiston Foods wells. The 6 graphs are plotted at the same scale to allow a comparison of trends between wells. The wells are arranged in Figure 5-4 from steepest increasing trend through least steep increasing trend (i.e., the steepest increasing trend is in the upper left corner of Figure 5-4).

Useful information can be gained by comparing trend lines with LOWESS lines. For example, Figure 5-4 illustrates that nitrate concentrations at well MW-1 increased for several years, then decreased for several years, then began increasing again.

Figure 5-5 is a map view of the site illustrating the nitrate trends at each of the wells. The 2 wells along the northern property boundary (i.e., MW-2 and MW-4) exhibit increasing trends (0.29 ppm/yr), while the other 4 wells exhibit statistically insignificant trends. As described above, MW-4 is located downgradient of current facility operations, as is therefore, an appropriate downgradient well. MW-2, however, is not an adequate downgradient well for evaluating potential effects of facility operations. The other appropriate downgradient well, MW-6, exhibits a statistically insignificant increasing trend. The upgradient wells exhibit statistically insignificant decreasing trends.

The fact that a downgradient well exhibits an increasing trend, and half of the wells exhibit consistently increasing or recently increasing LOWESS lines suggests the facility operations have impacted groundwater quality.

5.2.3 Average Nitrate Concentrations

Figure 5-6 is a map view of the site illustrating the average nitrate concentrations at each of the Hermiston Foods wells. The averages in Table 5-1 use all data since each well was installed. In summary, average nitrate concentrations are highest in the southeastern portion of the property, and lowest in the northwestern portion of the property. Specifically, the highest average nitrate concentration (11.5 ppm) is at downgradient well MW-6, followed by the cross gradient well MW-1 (10.1 ppm). The lowest average nitrate concentration is at the upgradient well MW-3 (4.5 ppm). The lower nitrate concentrations at this well are likely in part the result of dilution by surface water from the nearby irrigation canal. Average nitrate concentrations at other wells range from 6.8 to 8.8 ppm.

5.2.4 Upgradient to Downgradient Comparisons

Figure 5-7(a) is a time series graph showing the nitrate concentrations at the upgradient wells MW-3 and MW-5; and the downgradient wells MW-4 and MW-6. In addition to the individual data points connected by a thin line, thick LOWESS lines are drawn through the data to illustrate general patterns. MW-5 is approximately upgradient of MW-4, so comparing the nitrate concentrations between these wells is an appropriate way to gauge potential impacts from facility operations. However, site conditions and the existing well network prohibit the use of MW-3 and MW-6 for evaluating potential impacts from facility operations. For example, MW-3 (the well with the lowest average nitrate concentration) is an upgradient well with no associated downgradient well. Similarly, MW-6 (the well with the highest average nitrate concentration) is a downgradient well with no associated upgradient well.

Figure 5-7(a) shows well MW-6 generally has higher nitrate concentrations than MW-5, which has higher concentrations than MW-4, which has higher concentrations than MW-3. Because MW-5 is generally upgradient of MW-4, an upgradient/downgradient comparison can be made with data from these wells. During the timeframe in which both wells were installed and sampled, MW-5 exhibited higher nitrate concentrations than MW-4 84% of the time, and has a slightly higher average nitrate concentration (7.7 mg/l vs. 6.8 mg/l).

Figure 5-7(b) is a box and whisker plot summarizing the nitrate concentrations from the upgradient wells and the downgradient wells. Figure 5-7(b) shows the nitrate concentrations are highest at the downgradient well MW-6, lower at the upgradient well MW-5, lower still at the downgradient well MW-4, and lowest at the upgradient well MW-3.

Based on comparison of nitrate concentrations at wells MW-5 and MW-4, facility operations have not significantly affected groundwater quality. As indicated above, site conditions and the existing well network prohibit the use of MW-3 and MW-6 for evaluating potential impacts from facility operations.

5.2.5 Conclusions

Based on the discussion of the data for the Hermiston Foods site presented above, the following conclusions have been made, and are grouped by topic:

Hydrogeology

- When the offsite irrigation well is not pumping, groundwater enters the site along the western and southern boundaries flowing east/northeast, turns progressively more northward, and exits the site along the northern boundary of the site flowing nearly due north.
- Pumping the offsite irrigation well appears to alter the flow direction in the northern portion of the site causing water to flow towards the pumped well and exit the site flowing northwestward.
- Pumping the offsite irrigation well does not appear to affect water levels in well MW-3 or wells in the southern portion of the site.
- Well MW-3 appears to be responding to the nearby irrigation canal: water levels are lowest in March or April (the beginning of the irrigation season), and highest in September or October (the end of irrigation season).
- With all other variables being equal, wells with a greater depth to water would be slower to respond to changes in practices at land surface. The depth to water beneath the Hermiston Foods Site ranges from approximately 30 feet below land surface (at well MW-1 located in the southeastern corner of the site) to approximately 70 feet below land surface (at well MW-4 located in the northeastern portion of the site). The site-wide average depth to water is approximately 50 feet below land surface.

Nitrate Concentrations and Trends

- Nitrate concentrations at the Hermiston Foods Site are generally increasing, as evidenced by:
  - 33% of wells exhibit statistically significant increasing trends.
  - Trends (regardless of statistical significance) range from increasing at 0.29 ppm/yr to decreasing at 0.12 ppm/yr with the site-wide average nitrate trend increasing at approximately 0.1 to 0.3 ppm/yr.
  - 50% of the wells exhibit consistently increasing or recently increasing LOWESS patterns.
  - The highest concentrations occur in the latter portion of the dataset.

Factors Affecting Nitrate Concentrations

- Some observations suggest facility operations have impacted, and continue to impact, groundwater quality. These include the fact that the downgradient wells exhibit increasing trends (although the trend at MW-6 is statistically insignificant), and half of the wells exhibit consistently increasing or recently increasing LOWESS patterns.
- Some observations suggest offsite operations have impacted, and continue to impact, groundwater quality. These include the fact that even though downgradient well MW-4 has increasing nitrate concentrations, its upgradient well MW-5 has higher nitrate concentrations. Similarly, nitrate concentrations at well MW-1(probably unaffected by facility operations) are the second highest of any well at the site.
- Limitations of the existing well network do not allow definitive conclusions regarding the source of the observed nitrate trends. Potential methods to assess the effectiveness of current facility operations are discussed in Section 8.2.
- Wells closer to leaky fresh water canals and fresh water streams are more likely to exhibit lower nitrate concentrations due to dilution from the surface water.

5.3 Link Between BMP Implementation and Groundwater Quality Improvement

The following sections describe Hermiston Food's efforts to improve groundwater quality through the adoption of Best Management Practices (BMPs) as well as some of the limitations to rapid improvement in groundwater quality. The information in Section 5.3.1 was provided by Hermiston Foods.

5.3.1 Efforts to Improve Groundwater Quality

Hermiston Foods has modified practices and procedures over the years to reduce the amount of nitrate and hydraulic loading to the groundwater system. Over the past few years Hermiston Foods has been able to gain a much higher level of understanding about managing process water application between Hermiston Foods and the irrigator at the application site. This understanding together with cooperation has lead to a much better application rate of water and has reduced the use of commercial fertilizer to the point of only applying as a crop starter. In conjunction with this, Hermiston Foods has managed to reduce the process water delivery to the application site. Water use per pound packed in 2001 was 28% less than it was five years ago, and Hermiston Foods continues to work on plant water use reduction. This reduction of plant water use, coupled with improved cropping strategies and increased acres, has reduced the process water to less than 50% of the total water applied. Hermiston Foods has gone to a deep-rooted crop, alfalfa, and using wheat as a rotational crop, every three to four years. Hermiston Foods is also experimenting with a small acreage of poplar trees. These changes have dramatically improved their nutrient utilization in the last five years.

5.3.2 Timing of Groundwater Quality Improvement

As discussed above, some nitrate data at the Hermiston Foods Site suggest the facility has impacted groundwater, while other nitrate data suggest offsite activities are impacting groundwater. As discussed in Section 5.3.1, Hermiston Foods has implemented BMPs over the past five years to reduce the nitrate and hydraulic loading to the groundwater system. The timeframe of expected water quality improvements is difficult to quantify. Several factors inhibit the rapid improvement of groundwater quality in the study area. These involve both hydrogeologic and cultural factors and include, but are not necessarily limited to, the source of aquifer recharge, nitrogen in the unsaturated zone, nitrate in upgradient groundwater, groundwater flow velocity, and the continued application of process wastewater. A discussion of these factors is provided in Section 8.2. Potential methods to assess the effectiveness of current facility operations are discussed in Section 8.3.

5.4 Recommendations

Based on the conclusions and discussion above, the following recommendations are made:

- In order to utilize the downgradient well MW-6 to evaluate potential impacts from facility operations, an additional upgradient monitoring well needs to be installed near the southwest corner of the property.
- In order to gauge when the effects of BMP implementation will be observed as improving groundwater quality, it is recommended that funding be pursued to allow additional research into factors including: (1) quantifying the amount of nitrate that exists between the root zone and the water table, (2) the rate of nitrate transport through the unsaturated zone, and (3) more precisely quantifying groundwater flow velocity at the site.
- Due to the high percentage of increasing trends and impacts to groundwater from land application activities, it is recommended that BMP implementation to reduce the area-wide extent of elevated nitrate concentrations be continued and, when possible, improved.
- In accordance with the Action Plan, it is recommended that a trend analysis of data from the same wells be conducted in 2005 to evaluate progress towards improving groundwater quality at the food processing wastewater land application sites.

6.0 A.E. STALEY SITE

6.1 Introduction

The A.E. Staley Manufacturing Company (Staley) processes reclaimed potato starch into starch flakes for use in the production of paper products. Staley land applied 9.8 million gallons of process wastewater in 2001, with an average monthly flow of 0.8 million gallons. Average values for Staley's process wastewater in 2001 include:

- 3,869 mg/l Chemical Oxygen Demand (COD)
- 194 mg/l Total Kjeldahl Nitrogen (TKN)
- 11.4 mg/l ammonia
- 7,219 mg/l total dissolved solids (TDS)
- 2.5 mg/l nitrate-nitrogen (NO_3)
- 1,932 mg/l chloride (Cl)
- 969 mg/l calcium (Ca)
- 209 mg/l sodium (Na)
- 42 mg/l magnesium (Mg)
- 287 mg/l potassium (K)
- 232 mg/l bicarbonate (HCO_3)
- 20 mg/l total phosphorus (P)
- 57.7 mg/l sulfate (SO_4)

6.2 Staley Site

The Staley Site is located on the western edge of the City of Stanfield, northwest of the junction of US Interstate 84 and US Highway 395 (Figure 1-2). The site is bounded by the City of Stanfield Wastewater Treatment Plant land application site to the north, municipal and commercial development (including the City of Stanfield Wastewater Treatment Plant) to the east, and the Umatilla River to the south and west. The land application system at the Staley Site began in 1977. The original land application area consisted of 8.9 acre tract (Field A), which received approximately 7 million gallons of process wastewater annually. In early 1990, Staley expanded the land application acreage to approximately 40 acres by adding fields B (10.5 acres) and C (20 acres). Subsequently, fields E (12 acres) and F (16 acres) were added to the land application system. Currently, Staley applies the process wastewater to 67.4 acres. Prior to the land application system, the land occupied by the Staley Site was used for agricultural purposes.

Process wastewater from this facility is land applied daily on 67.4 acres of agricultural land where fescue and alfalfa hay are grown. When process wastewater does not meet crop needs (typically from approximately April through October), supplemental irrigation water obtained from the Stanfield Drain and an infiltration well is applied on the site as described below.

During the irrigation season (typically April through October), Staley employees commonly use boards to dam the Stanfield Drain at the crossing located near the center of the site. Within approximately 3 hours of the dam being constructed, water levels rise approximately 4 feet behind the dam. Water is usually pumped from behind the dam at a rate of 300 or 600 gallons per minute (depending on if one or two pumps are being used) for 5 to 6 days a week, and used as supplemental irrigation water. The pumping rate can be as low as 150 gpm during hay cutting season. The water level behind the dam reportedly remains fairly constant during pumping. Historically, the Stanfield Drain supplied all of Staley's supplemental irrigation water. In recent times, however, (i.e., since 2000), the majority of the supplemental irrigation water has been obtained from the infiltration well described below.

In 1998, the City of Stanfield and Staley installed an infiltration well near the western property boundary. The infiltration well consists of a vertical culvert located approximately 120 feet southwest of well MW-4S that is connected to two pieces of horizontal pipe buried approximately 22 feet deep in a gravel deposit. One horizontal pipe extends approximately 120 feet west from the culvert while the other pipe extends approximately 60 feet south. During the irrigation season, water is pumped from this well at a rate of approximately 200 to 900 gpm (depending on the need) and used as supplemental irrigation water at the Staley site and/or at the City of Stanfield land application area located immediately north of the Staley site. A report prepared subsequent to the well installation concluded that the infiltration well was hydraulically connected to the River.

The Staley Site is located within the Umatilla River flood plain. The flood plain generally exhibits gentle slopes of 0 to 5%. Topography at the Staley Site ranges from approximately 570 to 590 feet above mean sea level.

Nearby surface water features include the Umatilla River (which forms the southern and western boundaries of the property), and the Stanfield Drain (which bisects the site). The Umatilla River flows west then north around the site. The Stanfield Drain flows west across the site where it empties into the Umatilla River. The Stanfield Drain is an unlined ditch excavated in the late 1920's to drain shallow groundwater beneath the irrigated land in the vicinity of, and northeast of Stanfield in the area known as Fourmile Gap (Kopacz, 2004). Groundwater seeps into the Drain at a rate sufficient to maintain flow year round within the lower 3 to 4 miles of the Drain (including the Staley Site).

The depth to water beneath the Staley Site ranges from approximately 9 feet below land surface (at well MW-3S; located in the western portion of the site near the Umatilla River) to approximately 18 feet below land surface (at well MW-1D located in the northeastern portion of the site). The site-wide average depth to water is approximately 13 feet below land surface.

6.2.1 Hydrogeology

As discussed in Section 1.3, groundwater flow direction can be affected by land surface topography, the topography of the base of the aquifer, recharge and discharge features, and surface water features.

The base of the surficial aquifer beneath the Staley Site is the Columbia River Flood Basalts. The depth to basalt at the site ranges from 56 feet below land surface (at the production well located just west of the plant building) to 63 feet below land surface (at MW-1D located near the eastern property boundary and MW-3D located near the western property boundary). Based on the regional geologic mapping by DEQ (1995), the basalt surface in the vicinity of the Staley Site slopes generally northwest.

Because land surface topography does not vary much across the site (approximately 20 feet), and the basalt surface is relatively flat, the primary factors affecting groundwater flow at the site (other than the regional groundwater flow direction) are likely to be recharge/discharge stresses and surface water features.

The conceptual model of the groundwater flow regime at the Staley site used to date involves the hydraulic connection of groundwater with the Umatilla River, but not the Stanfield Drain. The following discussion provides evidence supporting the idea of a hydraulic connection between groundwater with the Stanfield Drain.

Water temperatures were measured in both groundwater and surface water (i.e., the Umatilla River and the Stanfield Drain) on three occasions during the summer of 1994: June 30th, July 27th, and August 24th. The temperature of the Umatilla River ranged from 21.9ºC to 26.5ºC and averaged 24.1ºC while the temperature of the Stanfield Drain ranged from 19.9ºC to 24.0ºC and averaged 21.3ºC. The temperature of the groundwater ranged from 13.4ºC to 20.5ºC and averaged 15.5ºC. These data indicate the Umatilla River was approximately 2.8ºC (5ºF) warmer than the Stanfield Drain, which in turn was approximately 5.8ºC (10ºF) warmer than the groundwater.

Figure 6-1 presents the average water temperature measured at each groundwater and surface water monitoring station during these three events. As indicated in Figure 6-1, the average groundwater temperature at well MW-2S is considerably warmer than the average groundwater temperature at all other wells, yet cooler than the surface water in the Drain and the River. This temperature relationship, in combination with water levels, suggests that groundwater and surface water are in communication at this location. Specifically, it suggests that groundwater at well MW-2S is warmed by Umatilla River water "cutting the corner" across the meander where MW-2S is located.

As discussed above, the conceptual model of the groundwater flow regime at the Staley site used to date involves the hydraulic connection of groundwater with the Umatilla River, but not the Stanfield Drain. Water table maps drawn using this conceptual model suggest wells MW-1S, MW-E1S, and MW-E2S are upgradient wells while wells MW-5S and MW-6S are downgradient wells. There is evidence, however, suggesting the Stanfield Drain is also hydraulically connected to groundwater at the Staley Site. Specifically, temperature data suggest the Drain gains groundwater, at least during the summer months. The degree of hydraulic connection is important because if the Drain is hydraulically connected to groundwater, wells MW-1S, MW-E1S, and MW-E2S may not always be upgradient wells while wells MW-5S and MW-6S may not be downgradient wells. The rationale for a hydraulic connection between the Stanfield Drain and groundwater is summarized below.

The Stanfield Drain was excavated in the late 1920s to drain shallow groundwater from beneath irrigated lands in the Fourmile Gap area (i.e., the area between Stanfield and Cold Spring Reservoir). The Stanfield Drain is located in the downhill extent of Stage Gulch. It is expected that groundwater flows subsurface through Stage Gulch, then through the Fourmile Gap area, and finally into the Umatilla River floodplain. The Stanfield Drain is unlined throughout its length, thus permitting groundwater to enter and/or exit the Drain (depending on the head difference between groundwater and the drain). The supposition that the Drain is hydraulically connected to groundwater is consistent with the observation by DEQ (1995) that unlined irrigation canals in the LUB GWMA typically exhibit significant leakage. In other words, the permeability of canal walls is not significantly reduced by deposition of fine particles. Although no tile drains (i.e., subsurface water collection systems piping groundwater directly into the Drain) are known to exist (Kopacz, 2004), the lowermost 3 to 4 miles of the Drain flow throughout the year.

OWRD (1991) reports that the Stanfield Drain has a steady discharge of about 10 to 20 cubic feet per second (cfs). Ziari (2002) reports more recent measurements of flow that are consistent with the OWRD measurements. Both Ziari (2002) and measurements made by Staley indicate that, during the summer, water in the Stanfield Drain is cooler than water in the Umatilla River. Ziari (2002) attributes the 7 degree Fahrenheit decrease in temperature (as compared to the temperature downstream of Echo and the Dillon Diversion which is approximately 3½ river miles upstream) to the influence of the Stanfield Drain and seeps/groundwater recharge from the Echo Meadows area. This information indicates that the Drain consistently gains groundwater, at least in its upper reaches. The relationship between groundwater and the Drain in its lower reaches is not completely understood, but there is evidence suggesting the Drain also gains groundwater at the Staley site, at least during the summer months.

As previously mentioned, water levels and water temperatures were measured in both groundwater and surface water on three occasions during the summer of 1994. Figure 6-1 presents the average water temperature measured at each groundwater and surface water monitoring station during these three events. As indicated in Figure 6-1, the average temperature *increases* 0.9ºC downgradient in the Umatilla River, but *decreases* 0.8ºC downgradient in the Stanfield Drain. The decrease in average temperature of the Stanfield Drain as it crosses the Staley site suggests that the Drain is gaining groundwater. However, this temperature change could also be influenced by other factors.

Similar comparisons made using temperature data from each of the measuring events (rather than average data) show the same difference during 2 of 3 events. The June 30th and July 27th data sets show similar results, but the August 24th data set does not:

- June 30th – Stanfield Drain cools downstream by 1.3ºC; Umatilla River warms downstream by 2.0ºC,
- July 27th – Stanfield Drain cools downstream by 1.0ºC; Umatilla River warms downstream by 1.1ºC,
- August 24th – Stanfield Drain warms downstream by 0.1ºC; Umatilla River cools downstream by 0.4ºC.

Due to the uncertainty in the sampling procedures and analytical precision associated with these temperature measurements, inferences made from these data should be substantiated.

A water level map drawn using July 1994 measurements and assuming that both the Umatilla River and the Stanfield Drain are hydraulically connected to the water table (not included in this report) suggests wells MW-1S, MW-E1S, and MW-E2S are not upgradient wells when the Stanfield Drain is dammed at the crossing. Additional water level data, additional water temperature data, and a more in-depth review of existing water quality data would be needed to determine the degree of the suspected interconnection of the groundwater and the Stanfield Drain at the Staley site, and whether or not these wells are consistently upgradient.

6.2.2 Nitrate Trends

A trend analysis of nitrate concentrations at the 10 wells located at the Staley site was conducted as described in Section 1.3 and Appendix 1. Table 6-1 summarizes the data used in this analysis and includes some data set statistics (e.g., mean and maximum values), a summary of the trend analysis (e.g., the slope and confidence level of the line) and a description of the LOWESS pattern (e.g., increasing then decreasing). Time series graphs of nitrate concentrations at each Staley well are included in Appendix 6.

Table 6-1 lists the individual results of the trend analysis for each well. The results indicate all 10 wells show statistically significant increasing trends. Trends range from increasing at 0.03 ppm/yr (at MW-3D) to 1.41 ppm/yr (at MW-1S). The site-wide average nitrate trend (i.e., the average of all 10 slopes) is increasing at approximately 0.4 ppm/yr.

Table 6-1 also lists the description of the LOWESS patterns for individual wells. The LOWESS patterns observed can be summarized as follows:

- 6 wells show a steadily increasing pattern
- 1 well shows a decreasing then increasing pattern
- 1 well shows an increasing then leveling off pattern
- 1 well shows a decreasing then increasing pattern
- 1 well shows an increasing, then decreasing, then leveling off pattern

In summary, 7 of the wells exhibit consistently increasing or recently increasing LOWESS patterns, 2 wells exhibit a recently leveling off pattern, and 1 well exhibits a recently decreasing pattern.

Figure 6-2 is a graph of all nitrate data from the 10 Staley wells, with a LOWESS line drawn through the data. Figure 6-2 consists of many stacks of data points at approximately 3 month intervals. Each of these stacks of data represents one quarterly sampling event and contains one data point for each well sampled that event. It is evident from Figure 6-2 that the highest concentrations detected have occurred in the latter portion of the dataset. The LOWESS line has an upward slope reflecting the overall increase in nitrate concentrations at the site.

Figure 6-3 includes the nitrate trends and LOWESS lines at each of the 10 Staley wells. The 10 graphs are plotted at the same scale to allow a comparison of trends between wells. The wells are arranged in Figure 6-3 from steepest increasing trend through least steep increasing trend (i.e., the steepest increasing trend is in the upper left corner of Figure 6-3).

Useful information can be gained by comparing trend lines with LOWESS lines. For example, Figure 6-3 illustrates that nitrate concentrations at well MW-5S increased for several years then leveled off. Similarly, well nitrate concentrations at well MW-E1S increased for several years then decreased.

Figure 6-4 is a map view of the site illustrating the nitrate trends at each of the wells. All wells exhibit increasing trends. Trends range from increasing at 0.03 ppm/yr to 1.41 ppm/yr. MW-1S (located along the eastern property boundary) exhibits the steepest increasing trend.

The fact that all wells exhibit increasing trends and 70% of the wells exhibit consistently increasing or recently increasing LOWESS lines suggests the facility operations are impacting groundwater quality. However, the degree to which these impacts are being caused by the facility is unknown because there is the potential for upgradient sources to contribute to the nitrate contamination.

6.2.3 Average Nitrate Concentrations

Figure 6-5 illustrates the average nitrate concentrations at 8 of the Staley wells from 1994 through 2001, the timeframe in which all wells except MW-1D and MW-3D were installed and sampled. The averages at wells MW-1D and MW-3D are from 1994 through May 1998. Sampling is no longer required at wells MW-1D and MW-3D. The averages in Table 6-1 use all data since each well was installed. In summary, average nitrate concentrations are highest along the eastern property boundary, followed by the northern property boundary, and lowest near the southwestern property boundary.

The lowest average nitrate concentration is at well MW-2S (1.2 ppm). The lower nitrate concentrations at the southwestern portion of the site are likely in part the result of dilution by surface water "cutting the corner" of the Umatilla River meander. The highest average nitrate concentration (11.3 ppm) is at well MW-1S. The source of nitrate at this well is unknown but may be from offsite.

6.2.4 Upgradient to Downgradient Comparisons

The previous interpretation of the groundwater flow regime at the Staley site is that the Stanfield Drain is not connected to groundwater. This interpretation leads to the conclusion that wells along the eastern property boundary are upgradient, and that wells near the northwestern property boundary are downgradient. As mentioned in Section 6.2.1, however, if the Drain is hydraulically connected, this interpretation may not be correct. Additional water level and temperature data are needed to determine the true nature of the groundwater / surface water connection. Due to the uncertain nature of groundwater flow at this site, which affects the wells that can be called upgradient and downgradient, a comparison of upgradient to downgradient nitrate concentrations is not made in this report.

6.2.5 Conclusions

Based on the discussion of the data for the Staley site presented above, the following conclusions have been made, and are grouped by topic:

Hydrogeology

- Groundwater at the site is hydraulically connected to the Umatilla River.
- The relationship between groundwater and the Stanfield Drain is not completely understood, but there is evidence suggesting the Drain gains groundwater at, and upgradient of, the Staley site.
- Additional water level, additional water temperature data, and a more in-depth review of existing water quality data are needed to determine the degree of the suspected interconnection of the groundwater and the Stanfield Drain at the Staley site, and where upgradient and downgradient wells would be located.
- The depth to water beneath the Staley Site ranges from approximately 9 feet below land surface (at well MW-3S; located in the western portion of the site near the Umatilla River) to approximately 18 feet below land surface (at well MW-1D located in the northeastern portion of the site). The site-wide average depth to water is approximately 13 feet below land surface. With all other variables being equal, wells with a greater depth to water would be slower to respond to changes in practices at land surface. The relatively small variation in depth to water at the Staley Site is not expected to significantly affect the timing of groundwater response to land surface changes.

Nitrate Concentrations and Trends

- Nitrate concentrations at the Staley Site are increasing, as evidenced by:
  - 100% of wells exhibit increasing trends.

- Trends range from increasing at 0.03 ppm/yr to 1.41 ppm/yr with the site-wide average nitrate trend increasing at approximately 0.4 ppm/yr.
- 70% of the wells exhibit consistently increasing or recently increasing LOWESS patterns.
- The highest concentrations occur in the latter portion of the dataset.

Factors Affecting Nitrate Concentrations

- The fact that 100% of the wells exhibit increasing trends and 70% of the wells exhibit consistently increasing or recently increasing LOWESS patterns indicates that groundwater quality has been and continues to be impacted. However, the degree to which these impacts are being caused by the facility is unknown because groundwater flow at the site is not well enough understood. It is also possible that offsite sources are contributing to the nitrate contamination. Potential methods to assess the effectiveness of current facility operations are discussed in Section 8.2.
- Wells closer to leaky fresh water canals and fresh water streams are more likely to exhibit lower nitrate concentrations due to dilution from the surface water.

6.3 Link Between BMP Implementation and Groundwater Quality Improvement

The following sections describe Staley's efforts to improve groundwater quality through the adoption of Best Management Practices (BMPs) as well as some of the limitations to rapid improvement in groundwater quality. The information provided in Section 6.3.1 was provided by Staley.

6.3.1 Efforts to Improve Groundwater Quality

Staley has modified practices and procedures over the years to reduce the amount of nitrate and hydraulic loading to the groundwater system. Some of the changes include several expansions to the land application site, formulation changes in its starch production processes, and intense system monitoring.

6.3.2 Timing of Groundwater Quality Improvement

As discussed above, the nitrate data at the Staley Site suggest the facility has impacted groundwater quality. However, the degree to which these impacts are being caused by the facility is unknown because the groundwater flow regime at the site is not adequately understood. In addition, there is the potential for offsite sources to contribute to the nitrate contamination. As discussed in Section 6.3.1, Staley has implemented BMPs over the past 15 years to reduce the nitrate and hydraulic loading to the groundwater system. The timeframe of expected water quality improvements is difficult to quantify. Several factors inhibit the rapid improvement of groundwater quality in the study area. These involve both hydrogeologic and cultural factors and include, but are not necessarily limited to, the source of aquifer recharge, nitrogen in the unsaturated zone, nitrate in upgradient groundwater, groundwater flow velocity, and the continued application of process wastewater. A discussion of these factors is provided in Section 8.2. Potential methods to assess the effectiveness of current facility operations are discussed in Section 8.3.

6.4 Recommendations

Based on the conclusions and discussion above, the following recommendations are made:

- Collection and evaluation of additional water level and water temperature data, as well as a more in-depth review of existing water quality data, should be conducted to determine the degree of the suspected interconnection of the groundwater and the Stanfield Drain at the site, and where upgradient and downgradient wells would be located. If there are no acceptable existing upgradient and downgradient wells, then the facility should install them.
- In order to gauge when the effects of BMP implementation will be observed as improving groundwater quality, it is recommended that funding be pursued to allow additional research into factors including: (1) quantifying the amount of nitrate that exists between the root zone and the water table, (2) the rate of nitrate transport through the unsaturated zone, and (3) more precisely quantifying groundwater flow velocity at the site.

- Due to the high percentage of increasing trends and impacts to groundwater at the site, it is recommended that the potential source(s) of this contamination (e.g., upgradient sources and land application activities) be better defined and delineated.
- Due to the high percentage of increasing trends and impacts to groundwater from land application activities within the GWMA, it is recommended that BMP implementation to reduce the area-wide extent of elevated nitrate concentrations be continued and, when possible, improved.
- In accordance with the Action Plan, it is recommended that a trend analysis of data from the same wells be conducted in 2005 to evaluate progress towards improving groundwater quality at the food processing wastewater land application sites.

7.0 SNAKCORP SITE

7.1 Introduction

Snakcorp, Inc. (Snakcorp) operates a potato chip and cheese puff processing plant and wastewater treatment facility near Hermiston, Oregon. The company operates the plant seasonally and currently land applies 32 million gallons of process wastewater per year on 292 acres of cropland owned and operated by Betz Farms. Wastewater is generated from potato washing, peeling, slicing, waste elimination, and starch recovery. In addition, the company accepts approximately 5,000 gallons per day, or approximately 1.82 million gallons per year, of potato rinsate from the adjacent Bud Rich fresh pack facility.

Average values for Snakcorp's process wastewater include:

- 2,131 mg/l Chemical Oxygen Demand (COD)
- 130 mg/l Total Kjeldahl Nitrogen (TKN)
- 25 mg/l Fats Oils and Grease (FOG)

7.2 Snakcorp Site

The Snakcorp land application site is located approximately 3 miles south of the City of Hermiston, west of the junction of US Interstate 84 and Oregon 207 (Figure 1-2). The land application system at the Snakcorp site began in 1992 and was operated by Columbia Sun, Inc. (until 10/92), then by Universal Frozen Foods (until 10/94), then by Lamb-Weston (until 5/96), and finally by Snakcorp. The process wastewater is land applied at up to six center pivot irrigation circles for the purpose of growing primarily alfalfa, but also cereal grains, grass, onions, potatoes, corn and turf grass. Prior to the land application system, the land occupied by the Snakcorp site was irrigated agricultural land.

When process wastewater does not meet crop needs (typically from approximately April through October), supplemental irrigation water obtained from the Westland Irrigation District system is applied on the site.

The Snakcorp Site is located within the Deschutes-Umatilla Plateau physiographic province. The site generally exhibits gentle slopes of 0 to 5%. Soils at the site are predominantly excessively drained loamy fine sand, but also include well drained silt loam. Topography at the Snakcorp Site ranges from approximately 565 to 520 feet above mean sea level.

Nearby surface water features include the Umatilla River (which forms much of the northern property boundary), Butter Creek (which forms the southeastern property boundary), and a Westland Irrigation District canal (which forms a portion of the southern property boundary). The Umatilla River is perennial (i.e., it has flow all year) while Butter Creek and the canal are intermittent (i.e., they have flow only part of the year).

The average depth to water beneath the Snakcorp Site ranges from approximately 29 feet below land surface (at well MW-4; located near the Umatilla River in the northern portion of the site) to approximately 47 feet below land surface (at well MW-1; located near the southern edge of the site).

7.2.1 Hydrogeology

The base of the surficial aquifer beneath the Snakcorp Site is the Columbia River Flood Basalts. Figure 3-7 is a map of the basalt surface topography in the Butter Creek Area that includes the Snakcorp site. The depth to basalt at the site is approximately 179 feet below land surface at the irrigation well located in the southwestern portion of the property. Based on Figure 3-7, and the regional geologic mapping by DEQ (1995), the basalt surface beneath the Snakcorp Site slopes generally northward.

Figure 7-1 is a map of the site showing groundwater elevations measured April 8, 2002. The figure indicates that groundwater flows northeast across the site toward the Umatilla River. Based on the groundwater flow direction indicated in Figure 7-1, upgradient wells for the Snakcorp site would be located south and perhaps west of facility operations, while downgradient wells would be located north and perhaps east of facility operations. Well MW-1 is located upgradient of current facility operations. Well MW-4 is located downgradient of current facility operations. Wells MW-2 and MW-3 are located within the land application area between fields.

As indicated in Section 7.2, much of the site boundary consists of intermittent or perennial surface water bodies. However, the nature of the interaction between groundwater and surface water at the site is unknown. Although the relationship between groundwater and surface water could be assessed through the evaluation of groundwater and surface water levels, it is unlikely to affect the current interpretation of upgradient and downgradient wells.

7.2.2 Nitrate Trends

A trend analysis of nitrate concentrations at the 4 wells located at the Snakcorp site was conducted as described in Section 1.3 and Appendix 1. Table 7-1 summarizes the data used in this analysis and includes some data set statistics (e.g., mean and maximum values), a summary of the trend analysis (e.g., the slope and confidence level of the line) and a description of the LOWESS pattern (e.g., increasing then decreasing). Time series graphs of nitrate concentrations at each Snakcorp well are included in Appendix 7.

Table 7-1 lists the individual results of the trend analysis for each well. The results indicate 1well (MW-3) shows a decreasing trend and the other 3 wells show statistically insignificant trends. Nitrate concentrations at MW-3 are decreasing at approximately 0.6 ppm/yr. The statistically insignificant trends range from increasing at 0.01 ppm/r to decreasing at 0.25 ppm/yr. The site-wide average nitrate trend is decreasing at approximately 0.3 to 0.6 ppm/yr (depending on whether or not the statistically insignificant trends are included) (Table 7-1).

Table 7-1 also lists the description of the LOWESS patterns for individual wells. The LOWESS patterns observed can be summarized as follows:

- 1 well shows a decreasing then increasing pattern
- 1 well shows an increasing then leveling off pattern, and
- 2 wells show an increasing then decreasing pattern

Figure 7-2 is a graph of all nitrate data from the 4 Snakcorp wells, with a LOWESS line drawn through the data. Figure 7-2 consists of many stacks of data points at approximately 3 month intervals. Each of these stacks of data represents one quarterly sampling event and contains one data point for each well sampled that event. It is evident from Figure 7-2 that the nitrate concentrations detected have not varied considerably since sampling began, but the highest concentrations have occurred in the latter portion of the dataset. The LOWESS line has a fluctuating, nearly flat slope reflecting the overall consistency in nitrate concentrations at the site.

Figure 7-3 includes the nitrate trends and LOWESS lines at each of the 4 Snakcorp wells. The 4 graphs are plotted at the same scale to allow a comparison of trends between wells. The wells are arranged in Figure 7-3 from steepest increasing trend through steepest decreasing trend (i.e., the steepest increasing trend is in the upper left corner of Figure 7-3).

Useful information can be gained by comparing trend lines with LOWESS lines. For example, Figure 7-3 illustrates that although the trend line shows nitrate concentrations at well MW-1 to be decreasing over time, the LOWESS line shows the concentrations actually decreased for several years, and then began increasing quite significantly again.

Figure 7-4 is a map view of the site illustrating the nitrate trends at each of the wells. The upgradient well (MW-1), the downgradient well (MW-4), and one of the intermediate wells (MW-2) exhibit statistically insignificant trends. The intermediate well MW-3 is the only well that exhibited a statistically significant trend (decreasing at 0.64 ppm/yr).
The fact that the one statistically significant trend is decreasing, two of the three statistically insignificant trends have decreasing slopes, and the site wide trend is decreasing suggests groundwater quality is improving and may

be responding to the reductions in nitrate loading at the site. The fact that the upgradient well MW-1 shows an increasing LOWESS line in recent years suggests offsite activities may be impacting groundwater quality at the site.

7.2.3 Average Nitrate Concentrations

Figure 7-5 is a map view of the site illustrating the average nitrate concentrations at each of the Snakcorp wells. The averages in Table 7-1 use all data since each well was installed. In summary, average nitrate concentrations are lowest in the southern portion of the property at the upgradient well, and increase northward to the downgradient well. Specifically, the lowest average nitrate concentration (4.0 ppm) is at upgradient well MW-1, followed by the intermediate wells MW-3 (8.7 ppm) and MW-2 (10.2 ppm). The highest average nitrate concentration is at the downgradient well MW-4 (16.6 ppm).

7.2.4 Upgradient to Downgradient Comparisons

Figure 7-6(a) is a time series graph showing the nitrate concentrations at the upgradient well MW-1 and the downgradient well MW-4. In addition to the individual data points connected by a thin line, thick LOWESS lines are drawn through the data to illustrate general patterns. Figure 7-6(a) shows nitrate concentrations at well MW-1 decreased from 1995 through 1998, then increased through 2001. During the time when both wells were installed and sampled, MW-1 exhibited lower nitrate concentrations than MW-4.

Figure 7-6(b) is a box and whisker plot summarizing the nitrate concentrations from the upgradient well and the downgradient well. Figure 7-6(b) shows the nitrate concentrations are higher at the downgradient well MW-4 than at the upgradient well MW-1.

Based on comparison of nitrate concentrations at wells MW-1 and MW-4, facility operations have affected groundwater quality.

7.2.5 Conclusions

Based on the discussion of the data for the Snakcorp site presented above, the following conclusions have been made, and are grouped by topic:

Hydrogeology

- Groundwater flows northeast across the site toward the Umatilla River.
- The nature of the interaction between groundwater and surface water at the site is not known.
- With all other variables being equal, wells with a greater depth to water would be slower to respond to changes in practices at land surface. The depth to water beneath the Snakcorp site ranges from approximately 29 to 47 feet below land surface. The relatively small variation in depth to water at the Snakcorp Site is not expected to significantly affect the timing of groundwater response to land surface changes.

Nitrate Concentrations and Trends

- Nitrate concentrations at the Snakcorp Site are generally decreasing, as evidenced by:
  - The one statistically significant trend is decreasing.
  - Trends (regardless of statistical significance) range from increasing at 0.01 ppm/yr to decreasing at 0.64 ppm/yr with the site-wide average nitrate trend decreasing at approximately 0.3 to 0.6 ppm/yr.
  - 50% of the wells exhibit recently decreasing LOWESS patterns.

Factors Affecting Nitrate Concentrations

- The fact that average nitrate concentrations increase across site from upgradient to downgradient suggests that facility operations have impacted groundwater quality.
- The fact that the one statistically significant trend is decreasing, and that the site-wide average trend is decreasing, suggests that groundwater quality may be responding to reduced nitrate loading at the

facility. Potential methods to assess the effectiveness of current facility operations are discussed in Section 8.2.
- The fact that the upgradient well MW-1 shows an increasing LOWESS line in recent years suggests offsite activities may be impacting groundwater quality at the site.

7.3 Link Between BMP Implementation and Groundwater Quality Improvement

The following sections describe Snakcorp's efforts to improve groundwater quality through the adoption of Best Management Practices (BMPs) as well as some of the limitations to rapid improvement in groundwater quality. The information provided in Section 7.3.1 was provided by Snakcorp.

7.3.1 Efforts to Improve Groundwater Quality

Snakcorp has modified practices and procedures over the years to reduce the amount of nitrate and hydraulic loading to the groundwater system. Some of these changes are described below.

Pre-Washed Potatoes - One of the changes involves contractual requirements with their potato growers to pre-wash the potatoes prior to delivery to the plant. Snakcorp currently utilizes approximately 80,000,000 lbs of raw potatoes, and estimates that prior to pre-washing, approximately 1% of the total load (400 tons) was comprised of dirt and other non-usable organic material. This material is removed by the farmer and returned to the farmer's fields. Although the majority of the dirt was removed prior to land application in a settling bunker, the soluble components (i.e., residual fertilizers) were land applied with the process wastewater.

Water Conservation - Other changes involve several projects related to water conservation. The largest impact has been Snakcorp's ability to get multiple uses out of water. Fresh water is used for the most critical process functions. The solids are then removed from this water through the use of vibratory screens, followed by the removal of the high density solids with cyclones and vacuum filters. The resulting water is then used for less critical functions related to the process.

Starch Removal System - Snakcorp invested in an ultra efficient starch removal system that removes in excess of 95% of free starches from raw slice wash tanks. This allows for the reuse of 100% of the water that passes through starch removal system as well as a significant load reduction on the clarifier. Snakcorp generates approx 500,000 pounds of dry starch for resale annually.

Employee Training Programs - Employees are trained to minimize the amount of dry waste products that are conveyed through the trench drains via water. Dry products are removed with a broom and shovel, then transferred to a by-product feed truck to minimize the load on the primary clarifier.

7.3.2 Timing of Groundwater Quality Improvement

As discussed above, the nitrate data at the Snakcorp suggest the facility has impacted groundwater, yet groundwater quality appears to be improving at downgradient wells. As discussed in Section 7.3.1, Snakcorp has implemented BMPs over the years to reduce the nitrate and hydraulic loading to the groundwater system. The timeframe of expected water quality improvements is difficult to quantify. Several factors inhibit the rapid improvement of groundwater quality in the study area. These involve both hydrogeologic and cultural factors and include, but are not necessarily limited to, the source of aquifer recharge, nitrogen in the unsaturated zone, nitrate in upgradient groundwater, groundwater flow velocity, and the continued application of process wastewater. A discussion of these factors is provided in Section 8.2. Potential methods to assess the effectiveness of current facility operations are discussed in Section 8.3.

7.4 Recommendations

Based on the conclusions and discussion above, the following recommendations are made:

- In order to gauge when the effects of BMP implementation will be observed as improving groundwater quality, it is recommended that funding be pursued to allow additional research into factors including: (1) quantifying the amount of nitrate that exists between the root zone and the water table, (2) the rate of nitrate transport through the unsaturated zone, and (3) more precisely quantifying groundwater flow velocity at the site.

- Due to the impacts to groundwater from land application activities, it is recommended that BMP implementation to reduce the area-wide extent of elevated nitrate concentrations be continued and, when possible, improved.
- In accordance with the Action Plan, it is recommended that a trend analysis of data from the same wells be conducted in 2005 to evaluate progress towards improving groundwater quality at the food processing wastewater land application sites.

8.0 DISCUSSION

8.1 Comparison of All Trends

Nitrate trends at 113 wells located at the ten sites within the LUB GWMA that land applied food processing wastewater as of 2001 were calculated. Table 8-1 summarizes the direction and magnitude of nitrate trends by site. The table indicates that most wells (72 of 113) exhibited increasing trends. A few wells (8 of 113) exhibited decreasing trends. Even fewer wells (3 of 113) exhibited flat trends. Statistically insignificant trends accounted for 30 of 113 trends calculated.

Additional observations made from Table 8-1 include:

- the average slope of trends at each site ranged from decreasing at 0.6 ppm/yr to increasing at 2.5 ppm/yr
- 8 of 10 sites exhibited overall increasing trends
- the site-wide average for individual sites (which is the average nitrate concentrations at each well averaged over each site) ranged from 3.7 to 33.6 ppm
- 8 of 10 sites exhibited site-wide average concentrations above the 7 ppm GWMA trigger level

Figure 8-1 provides a different way to compare all 113 trends. All 113 trends are illustrated both as a bar graph and as box plots. Figure 8-1(a) is a bar graph in which the length of the bar indicates the timeframe of the data evaluated, and the vertical position of the bar on the graph indicates the nitrate trend. Figure 8-1(b) is a box plot of the 83 statistically significant trends, the 30 statistically insignificant trends, and all 113 trends. As noted in Figure 8-1, 50% of the trends are between 0.0 and 1.0 ppm/yr, while 94% of the trends are between 2.73 to -0.68 ppm/yr.

The timeframe of the data used to calculate the 113 trends ranged from 2.3 to 14.3 years. The average timeframe was 9.1 years. Half of the wells had between 6.1 and 11.5 years of data. An examination of Figure 8-1(a) does not suggest a relationship between the length of the data set and the trend slope (i.e., the longer time frames are not grouped together). In order to statistically evaluate the potential correlation between data set length and trend slope, three correlation coefficients were calculated: Pearson's R, Spearman's Rho, and Kendall's Tau. Each of these correlation coefficients indicated a very low coefficient (<0.05) indicating there is no correlation between data set length and trend slope.

In summary, the trend analysis indicates that nitrate concentrations are increasing at most wells, and at most sites. Furthermore, the average nitrate concentration at most sites exceeds the GWMA trigger level. However, the trend analysis does not by itself provide an indication of whether or not the nitrate contamination is the result of current facility operations. Other factors that can affect nitrate concentrations include historical facility activities, offsite activities (both current and historical), and the site's hydrogeology.

8.2 Factors Affecting the Timing of Groundwater Quality Improvement

Several factors affect the timing of groundwater quality improvement in the study area. These involve both hydrogeologic and cultural factors and include, but are not necessarily limited to, the following:

- *The source of aquifer recharge* – DEQ (1995) identifies potential sources of aquifer recharge to be precipitation, canal leakage, stream leakage, reservoir leakage, and deep percolation of applied irrigation water. The available data indicate that canal losses are a major source of recharge to the alluvial aquifer. Basin-wide recharge from deep percolation may be substantial but recharge rates probably vary widely depending upon irrigation practices. Recharge from reservoirs and streams may be significant but is of limited extent. Recharge from precipitation is probably negligible. In other words, because a significant percentage of aquifer recharge comes from irrigation water, much of the recharge is not pristine water but contains the agricultural chemicals that are, in part, the focus of this investigation.

- *Nitrogen in the unsaturated zone* – Past practices at some food processor land application sites included applying wastewater at rates significantly greater than agronomic rates. At those sites, considerable amounts of nitrate and ammonia may exist below the root zone and above the water table. The quantity of nitrogen present in this zone that is unavailable for plant uptake, but has not yet reached the groundwater system is unknown. Therefore, it is expected that, where present, this may continue to be a source of nitrate to groundwater even though BMPs have improved.

- *Nitrate in upgradient groundwater –* Contaminant concentrations at any well are influenced in part by the contaminant concentrations in upgradient groundwater. As this upgradient groundwater reaches a well, it provides a baseline of contamination that is then affected by activities nearer the well. Therefore, it is expected that some wells will exhibit upward nitrate trends prior to exhibiting downward nitrate trends because they are located downgradient of areas with greater contamination. When high enough, upgradient contamination can also mask lesser onsite contamination.

- *Groundwater flow velocity –* DEQ (1995) estimates the rate of groundwater movement ranges from 0.0002 to 8 feet per day in the study area. In addition, the groundwater flow velocity at specific locations could be affected by the interaction of canals, ditches, and other waterways. Therefore, groundwater can take many years (perhaps many decades) to travel through the aquifer and discharge into the Umatilla River or Columbia River. This slow movement of water beneath a site may be one reason that improved water quality is not being observed yet.

- *Continued application of process wastewater –* Use of the food process wastewater as a source of water and nutrients for plants is a good use of the product and can be a sound environmental choice when managed properly. However, food processor wastewater is a source of significant nitrate and must be continuously managed.

8.3 Potential Methods to Assess Current Facility Operations

At several food processing land application sites, downgradient wells have higher nitrate concentrations than upgradient wells, indicating facility operations have negatively affected groundwater quality in the past. At many of these facilities, the majority of wells exhibit increasing trends and consistently increasing and/or recently increasing LOWESS patterns, suggesting facility operations continue to impact groundwater quality. However, a definitive answer to the question "Are *current* facility operations negatively affecting groundwater quality?" is elusive. Although answering this question is beyond the scope of this report, the following discussion addresses some of the issues that would need to be considered when attempting to answer this question.

To evaluate whether or not current practices are sufficient to be protective of groundwater quality, groundwater samples could be "age dated" using tracers such as tritium or chlorofluorocarbons. Groundwater "age" refers to the time elapsed since recharge and isolation of the newly recharged water from the soil atmosphere. The age applies to the date of introduction of the tracer rather than the date of the water itself. Chemical and physical processes can also affect the tracer concentration. For this reason, the term "age" is normally qualified with the word "model" or "apparent", that is, "model age" or "apparent age" (USGS, 1999).

As an example of how age dating groundwater could be used to assess the effectiveness of current practices, consider the following example. Assuming practices presumed protective of groundwater were adopted 10 years ago, and if nitrate-rich groundwater beneath a facility was determined to be decades old, it would be reasonable to conclude that changes made within the last decade are not yet reflected in groundwater quality. On the other hand, if nitrate-rich groundwater beneath a facility was determined to be 5 years old, it would be reasonable to conclude that changes made within the last 10 years are not sufficiently protective of groundwater quality.

However, the inherent complexity, complications, and expense of determining the apparent age of groundwater can make using the technique undesirable.

In lieu of performing groundwater age dating, the effectiveness of BMPs could be assessed by a detailed evaluation of the site's hydrogeology, land use, and contaminant transport regime. This assessment would involve the evaluation of many factors, including:

- Depth to groundwater
    - the deeper the groundwater, the longer it will take water to percolate from land surface to the water table,
    - the deeper the groundwater, the larger the reservoir is for storing nitrate-rich water waiting to reach the water table,
- Effects of nearby surface water features
- Unusual precipitation events
- Crops grown at fields upgradient of sampled wells
    - Different crops have different hydraulic and nutrient requirements
    - As crops are rotated, so do crop requirements
    - Crop yield versus nutrients applied and residual soil nitrate
- Hydraulic loading
    - Amount and timing of fresh water application
    - Amount and timing of process wastewater application
- Contaminant transport regime
    - Unsaturated zone flow velocity (i.e., how long does it take for nitrate applied at land surface to reach groundwater?)
    - Groundwater flow velocity (i.e., how long does it take for groundwater to travel from an upgradient well to a downgradient well?)
    - Physical and chemical processes affecting nitrate movement and concentrations

9.0 CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

Site-specific conclusions regarding each site's hydrogeology, nitrate concentrations and trends, and factors affecting nitrate concentrations are presented at the end of each facility's chapter. Based on the site-specific information, several overall conclusions were drawn. The major overall conclusions drawn from this study are:

- Nitrate concentrations are increasing at most wells, and at most sites.
- The measure of Action Plan progress related to the land application of food processing wastewater (Section VII, Item G.3.b), that states in part, that by December 2001, "monitoring data shows improving groundwater quality trends for nitrate" was not met.
- The trend analysis does not by itself provide an indication of whether or not the nitrate contamination is the result of current facility operations. Other factors that can affect nitrate trends include historical facility activities, offsite activities (both current and historical), and the site's hydrogeology.
- The timing of groundwater quality improvements is a result of several factors. Hydrogeologic and cultural factors include the source of aquifer recharge, nitrogen in the unsaturated zone, nitrate in upgradient groundwater, groundwater flow velocity, and the continued application of process wastewater.
- Potential methods exist to assess current facility operations. These potential methods include "age dating" groundwater samples and/or performing a detailed evaluation of the site's hydrogeology, land use, and contaminant transport regime.

9.2 Recommendations

Both site-specific and general recommendations are made in this report. The site-specific recommendations involve additional assessment activities at five facilities in order to better define the site's groundwater flow regime and/or to determine the source of nitrate in groundwater. The general recommendations include:

- pursuing funding to gauge the effects of BMP implementation,
- continued and, when possible, expanded BMP implementation, and
- completion of the Action Plan-required trend analysis after 2005.

Although nitrate concentrations are increasing at most wells and most sites, there are some wells and sites where nitrate concentrations are decreasing. It is also recommended that DEQ and the food processors work together to identify what combination of factors produces the improving water quality trends, then apply those factors elsewhere, with the hope of improving water quality trends across the GWMA.

10.0 REFERENCES

Cleveland, W.S., 1979. Robust Locally Weighted Regression and Smoothing Scatterplots: *J. Am. Stat. Assoc. 74*, 829-836.

DEQ, 2003. Northern Malheur County Groundwater Management Area Trend Analysis Report.

DEQ, 1995. Hydrogeology, Groundwater Chemistry and Land Uses in the Lower Umatilla Basin Groundwater Management Area.

EPA, 1997. Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls. EPA 841-B-96-004. 236 pgs.

EPA, 2000. Guidance for Data Quality Assessment, Practical Methods for Data Analysis, EPA QA/G-9, QA00 Update, EPA/600/R-96/084. 162 pgs.

Fetter, 1993. Contaminant Hydrogeology by C.W. Fetter. Macmillan Publishing Co. New York, NY. 1993

Gibbons, R. O., 1994. Statistical Methods For Groundwater Monitoring. John Wiley & Sons, Inc. 286 pgs.

Gilbert, R. O., 1987. Statistical Methods For Environmental Pollution Monitoring. John Wiley & Sons, Inc. 320 pgs.

Helsel, D.R. and R.M. Hirsch, 1992. Statistical Methods in Water Resources. Studies in Environmental Science 49, Elsevier Science B.V. Amsterdam. 529 pgs.

Hirsch, R. M., J. R. Slack, and R. A. Smith, 1982. Techniques of Trend Analysis for Monthly Water Quality Data, *Water Resources Research, Vol. 18, No. 1*, pg 107-121

Kopacz, 2004. Personal communication on 3/17/04 with Ray Kopacz, Stanfield Irrigation District Manager.

Loftis, J.C., G.B., McBride, and J.C. Ellis, 1991. Considerations of Scale in Water Quality Monitoring and Analysis. Water Resources Bulletin. 27(2):255-264.

OWRD, 1989. Aquifer Test of the Glenn Chowning Well No. 2, Umatilla County, Oregon. Oregon Water Resources Department Groundwater Open File Report No. 89-11. by Michael J. Zwart.

OWRD, 1991. Umatilla River Return Flow Analysis During 1985 and 1986. Oregon Water Resources Dpt.

Piper, A. M. 1944, A Graphic Procedure in the Geochemical Interpretation of Water Analyses: *American Geophysical Union Transactions, v. 25*, pg.914-923.

Practical Stats Internet Site, 2000. http://www.practicalstats.com/Pages/tip.html October 2000 Tip of the Month**.** *Note that this web page changes monthly and may no longer be available.*

USGS, 1999. Tracing and Dating Young Ground Water. USGS Fact Sheet 134-99. September 1999.

van Belle, G., and J.P. Hughes, 1984. Nonparametric tests for trend in water quality. Water Resources Research. 20(1):127-136.

Ziari, 2002. "Echo Meadows Project Winter Artificial Recharge", Project No. 2001-01500, 215 electronic pages, (BPA Report DOE/BP-00006925-1. December 2002.

Table 2-1
Summary of Nitrate Trend Analyses - Port of Morrow Farm 1
Trend Analysis of Food Processing Land Application Sites in the LUBGWMA

Sample Location	Data Set Statistics									Trend Analysis Results		Trend Direction	LOWESS Pattern
	Starting Date	Ending Date	Min	Max	Mean	Median	Skewness	n	% BDL	Slope (ppm/yr)	C.L.		
MW-1	Jun-87	Sep-01	11.2	42.6	22.7	20.1	1.21	57	0%	0.21	< 80%	No Significant Trend	Increasing with some fluctuations
MW-2	Jun-87	Sep-01	4.81	47.0	25.3	24.7	0.14	52	0%	1.65	99%	Increasing	Increasing then decreasing
MW-3	Jun-87	Sep-01	0.07	95.4	19.5	3.9	1.18	59	0%	2.65	99%	Increasing	Flat then increasing
MW-4	Jun-87	Sep-01	0.15	43.2	9.4	3.6	1.17	57	1.8%	0.31	90%	Increasing	Increasing then decreasing
MW-5	Jun-87	Sep-01	6.98	36.0	22.4	22.6	-0.05	55	0%	0.67	99%	Increasing	Increasing then decreasing
MW-6	Jun-87	Jun-00	0.15	9.7	0.8	0.5	5.16	51	20%	-0.02	80%	Decreasing	Decreasing then increasing
MW-7	Oct-91	Sep-01	9.75	29.2	14.6	13.9	1.43	41	0%	0.41	90%	Increasing	Decreasing then increasing
MW-8	Oct-91	Sep-01	6.48	54.5	34.0	36.2	-0.41	41	0%	2.48	99%	Increasing	Increasing then decreasing
MW-9	Oct-91	Sep-01	5.2	33.1	18.1	18.2	0.45	41	0%	1.41	99%	Increasing	Increasing
MW-10	Oct-91	Sep-01	11.5	40.1	24.7	23.9	0.26	41	0%	1.51	99%	Increasing	Increasing then leveling off
MW-11	Oct-91	Sep-01	5.35	47.0	27.9	27.9	0.09	42	0%	2.24	99%	Increasing	Increasing
MW-SP1	Apr-95	Sep-01	31.4	53.6	37.9	36.8	1.42	23	0%	0.67	< 80%	No Significant Trend	Increasing then decreasing
MW-SP2	Apr-95	Sep-01	32.6	49.9	41.5	39.7	0.16	23	0%	-0.25	< 80%	No Significant Trend	Fluctuating

# of Increasing Trends ==>	9
# of Decreasing Trends ==>	1
# of Flat Trends ==>	0
# of Statistically Insignificant Trends ==>	3
Average slope of significant trends (ppm/yr) ==>	1.33
Average slope of all trends (ppm/yr) ==>	1.07

Notes:
Min = minimum, Max = maximum, n = number of samples
BDL = below detection limit, C.L. = confidence level

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Table 2-2
Summary of Nitrate Trend Analyses - Port of Morrow Farm 2
Trend Analysis of Food Processing Land Application Sites in the LUBGWMA

Sample Location	Data Set Statistics									Trend Analysis Results		Trend Direction	LOWESS Pattern
	Starting Date	Ending Date	Min	Max	Mean	Median	Skewness	n	% BDL	Slope (ppm/yr)	C.L.		
MW-12	Dec-91	Sep-01	13	45.4	30.0	31.0	-0.20	40	0%	1.63	99%	Increasing	Increasing
MW-13	Dec-91	Sep-01	16.8	61.6	43.6	45.9	-0.62	39	0%	2.73	99%	Increasing	Increasing
MW-14	Dec-91	Sep-01	0.02	45.2	27.8	32.5	-0.53	40	0%	3.59	99%	Increasing	Increasing then starts leveling off
MW-14s	Jan-95	Sep-01	8.12	49.2	36.6	39.5	-1.57	22	0%	2.27	80%	Increasing	Increasing then levels off
MW-15	Dec-91	Sep-01	9.7	55.9	36.3	38.6	-0.46	40	0%	2.69	99%	Increasing	Increasing
MW-15s	Jan-95	Sep-01	15.5	55.2	38.6	39.5	-0.93	21	0%	3.85	99%	Increasing	Increasing with some fluctuations
MW-16	Dec-91	Sep-01	6.06	58.3	44.9	50.4	-1.34	39	0%	2.63	99%	Increasing	Increasing then levels off
MW-17	Dec-91	Sep-01	5.89	53.4	39.2	43.2	-1.21	40	0%	2.32	99%	Increasing	Increasing then levels off
MW-18	Dec-91	Sep-01	0.03	14.4	5.6	5.2	0.80	40	0%	0.89	99%	Increasing	Increasing

# of Increasing Trends ==>	9
# of Decreasing Trends ==>	0
# of Flat Trends ==>	0
# of Statistically Insignificant Trends ==>	0
Average slope of significant trends (ppm/yr) ==>	2.51
Average slope of all trends (ppm/yr) ==>	2.51

Notes:
Min = minimum, Max = maximum, n = number of samples
BDL = below detection limit, C.L. = confidence level

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Table 3-1
Summary of Nitrate Trend Analyses - Lamb-Weston North Farm
Trend Analysis of Food Processing Land Application Sites in the LUBGWMA

Sample Location	Data Set Statistics									Trend Analysis Results		Trend Direction	LOWESS Pattern
	Starting Date	Ending Date	Min	Max	Mean	Median	Skewness	n	% BDL	Slope (ppm/yr)	C.L.		
MW-1	Oct-95	Nov-01	8.4	56.6	19.5	17.3	2.25	24	0%	0.43	< 80%	No Significant Trend	Increasing then decreasing then leveling off
MW-2	Oct-95	Nov-01	15.1	21	18.0	18.2	-0.15	24	0%	0.31	99%	Increasing	Increasing
MW-3	Oct-95	Nov-01	7.9	50.4	10.7	8.8	4.59	25	0%	-0.33	99%	Decreasing	Decreasing
MW-4	Oct-95	Nov-01	20.6	27.1	24.7	25.1	-1.03	25	0%	0.76	99%	Increasing	Increasing steeply then less steeply
MW-5	Oct-95	Nov-01	19.4	28.4	25.3	26.0	-0.89	25	0%	0.30	< 80%	No Significant Trend	Increasing steeply then less steeply
MW-6	Oct-95	Nov-01	3.09	8.14	4.8	4.5	0.68	25	0%	0.60	99%	Increasing	Increasing
MW-7	Oct-95	Nov-01	11.4	55.8	35.8	39.1	-0.31	25	0%	6.93	99%	Increasing	Increasing steeply then less steeply
MW-8	Oct-95	Nov-01	7.9	70.4	49.8	50.1	-1.35	25	0%	1.66	< 80%	No Significant Trend	Increasing then decreasing
MW-9	Oct-95	Nov-01	6.22	8.14	7.2	7.1	0.27	25	0%	-0.03	80%	Decreasing	Increasing then decreasing
MW-10	Jan-96	Nov-01	9.1	64.7	46.6	49.1	-2.16	23	0%	0.78	80%	Increasing	Increasing then decreasing

# of Increasing Trends ==>	5
# of Decreasing Trends ==>	2
# of Flat Trends ==>	0
# of Statistically Insignificant Trends ==>	3
Average slope of significant trends (ppm/yr) ==>	1.45
Average slope of all trends (ppm/yr) ==>	1.14

Notes:
Min = minimum, Max = maximum, n = number of samples
BDL = below detection limit, C.L. = confidence level

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Table 3-2
Summary of Madison Ranch Well Hydrographs
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA

Criteria	Flood Plain Wells	Upland Wells	Well Near Lost Lake	Wells Near Canal
Wells	MW-5, 6, 10, 11, & 12	MW-2, 7, & 8	MW-3	MW-4A & 9
Water Level Highs	Apr/May (except MW-6 where it's Aug) (water levels typically measured in Feb, May, Aug, & Nov)	Variable: MW-2 = no pattern MW-7 = steady increase MW-8 = May	Oct/Nov	Aug
Water Level Lows	Oct/Nov	Variable: MW-2 = no pattern MW-7 = steady increase MW-8 = Oct/Nov	April	Jan/Feb to April
Median Annual Fluctuation (ft)	MW-5 = 2.9' MW-6 = 2.5' MW-10 = 4.3' MW-11 = 1.5' MW-12 = 8.6' (nearby irrigation ditch is a strong influence)	MW-2 = 4.1' MW-7 = steady 1.2' increase MW-8 = 1.0	1.2'	MW-4A = 2.8' MW-9 = 2.6'
Inferred Influence on Water Levels	Spring runoff down Butter Creek flood plain, and leaky canals and ditches (MW-6 may also be affected by a flood irrigated field to the SW and/or irrigation east of flood plain)	Local deep percolation of precipitation and irrigation of circles	Delayed influence from leakage from Lost Lake and/or subsurface drainage down Fourmile Canyon	Leakage from Highline Canal

Table 3-3
Summary of Nitrate Trend Analyses - Lamb-Weston Madison Ranch
Trend Analysis of Food Processing Land Application Sites in the LUBGWMA

Sample Location	Data Set Statistics									Trend Analysis Results		Trend Direction	LOWESS Pattern
	Starting Date	Ending Date	Min	Max	Mean	Median	Skewness	n	% BDL	Slope (ppm/yr)	C.L.		
MW-1	Jan-96	Apr-00	2.93	7.44	5.9	6.4	-1.29	7	0%	-0.14	< 80%	No Significant Trend	Increasing then decreasing
MW-2	Oct-95	Nov-01	0.05	0.45	0.2	0.2	1.12	20	0%	0.01	95%	Increasing	Increasing
MW-3	Jan-96	Nov-01	2.68	13.2	3.6	3.1	4.43	23	0%	0.05	95%	Increasing	Increasing
MW-4	Nov-95	Nov-01	0.06	1.11	0.9	0.9	-2.34	24	0%	0.05	90%	Increasing	Increasing
MW-5	Oct-95	Nov-01	6.24	26.1	9.7	8.5	3.03	24	0%	-0.32	< 80%	No Significant Trend	Increasing then decreasing
MW-6	Oct-95	Nov-01	0.97	40.9	19.3	18.0	0.41	24	0%	3.16	99%	Increasing	Increasing
MW-7	Oct-95	Nov-01	0.01	0.48	0.4	0.4	-3.82	24	0%	0.00	< 80%	No Significant Trend	Increasing then decreasing
MW-8	Oct-95	Nov-01	0.26	5.06	4.4	4.7	-3.17	24	0%	0.24	99%	Increasing	Increasing steeply then less steeply
MW-9	Oct-95	Nov-01	0.01	3.2	0.8	0.7	3.54	24	0%	0.04	95%	Increasing	Decreasing slightly then increasing slightly
MW-10	Oct-95	Nov-01	1.11	14.3	7.8	7.9	0.03	24	0%	-0.68	< 80%	No Significant Trend	Increasing then decreasing
MW-11	Oct-95	Nov-01	0.63	25.5	8.3	8.1	2.99	25	0%	0.05	< 80%	No Significant Trend	Increasing then decreasing
MW-12	Oct-95	Aug-01	0.27	9.26	5.4	5.0	-0.07	23	0%	1.03	99%	Increasing	Increasing

# of Increasing Trends ==>	7
# of Decreasing Trends ==>	0
# of Flat Trends ==>	0
# of Statistically Insignificant Trends ==>	5
Average slope of significant trends (ppm/yr) ==>	0.47
Average slope of all trends (ppm/yr) ==>	0.29

Notes:
Min = minimum, Max = maximum, n = number of samples
BDL = below detection limit, C.L. = confidence level

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Table 4-1
Distinguishing Alluvial vs Flood Plain Wells Near Simplot Plant Site
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA

Criteria	**Alluvial Wells**	**Flood Plain Wells**	**Comment**
Example wells	MW-10s, 11s, 12, 13s, 38, 46, 47, 48, 53, 56, 57, 58, and 59	MW-16, 17, 18, 19, 20, 21, 45, 49, & 50	
Typical Water Level	Approximately 500'	Approximately 540'	Consistent 40' difference between flood plain wells and alluvial wells on bench
Water Level Highs	August and/or November (Water levels are measured in Feb, May, Aug, & Nov)	February and/or May (except MW-49 where it's Feb & Nov)	Timing of Highs and Lows reflect: • influence of irrigation on Alluvial wells, and • influence of the River on flood plain wells
Water Level Lows	February and/or May	August and/or November (except MW-49 where it's May & Aug)	
Typical lithology	Finer grained sediments (e.g., silty sands)	Coarser grained sediments (sand and gravel)	Transition from finer to coarser grained sediments could cause clustering of water level contours at base of alluvial bench
May 2002 TDS	372 to 1140 mg/l; median = 602	146 to 630 mg/l; median = 409 river = 88 to 108	TDS values in the flood plain wells are lower (closer to River TDS values) than alluvial wells, and generally increase away from the River reflecting influence of river on groundwater quality
Oct 2002 TDS	294 to 1080 mg/l; median = 644	162 to 638 mg/l; median = 384 river = 90 to 112	

Table 4-2
Summary of Nitrate Trend Analyses - Simplot Plant Site
Trend Analysis of Food Processing Land Application Sites in the LUBGWMA

Sample Location	Data Set Statistics									Trend Analysis Results		Trend Direction	LOWESS Pattern
	Starting Date	Ending Date	Min	Max	Mean	Median	Skewness	n	% BDL	Slope (ppm/yr)	C.L.		
MW-10S	Feb-92	Nov-01	0.5	13.9	2.7	0.5	1.618	39	59%	0.00	< 80%	No Significant Trend	Increasing then decreasing
MW-10D	Feb-92	Nov-01	0.5	4.9	0.7	0.5	5.268	39	82%	0.00	< 80%	No Significant Trend	Flat
MW-11S	Feb-88	Nov-01	7.2	18.0	11.8	11.5	0.284	52	0%	-0.14	80%	Decreasing	Decreasing, then increasing, then decreasing again
MW-11D	Feb-88	Nov-01	0.5	2.4	0.8	0.8	2.241	52	23%	0.00	< 80%	No Significant Trend	Flat with minor fluctuations
MW-12	Feb-88	Nov-01	12.7	39.2	20.6	19.8	1.235	52	0%	0.10	< 80%	No Significant Trend	Decreasing, then increasing, then decreasing again
MW-13S	Nov-88	Nov-01	8.9	53.0	15.7	13.4	3.035	53	0%	-0.13	< 80%	No Significant Trend	Nearly flat
MW-13D	Nov-88	Nov-01	0.4	3.3	1.7	1.6	0.865	52	0%	0.01	< 80%	No Significant Trend	Nearly flat
MW-16	Nov-88	Nov-01	0.5	100	19.8	8.5	1.383	53	26%	-2.39	99%	Decreasing	Increasing then decreasing
MW-17	Nov-88	Nov-01	0.5	31.4	1.3	0.5	6.449	52	81%	0.00	< 80%	No Significant Trend	Flat
MW-18	Nov-88	May-96	0.5	99.3	8.2	2.6	4.559	31	29%	0.22	80%	Increasing	Increasing then decreasing
MW-19	Nov-88	Nov-01	0.5	1.9	0.6	0.5	3.228	52	87%	0.00	< 80%	No Significant Trend	Flat
MW-20	Nov-88	Nov-01	2.1	43.3	16.4	14.6	0.647	53	0%	-1.50	99%	Decreasing	Decreasing
MW-21	Nov-88	Nov-01	0.5	8.9	1.3	0.5	2.648	53	75%	0.00	99%	Flat	Nearly flat
MW-45	Feb-92	Nov-01	0.5	48.3	13.2	6.1	1.211	39	10%	-2.92	99%	Decreasing	Decreasing
MW-46	Feb-96	Nov-01	5.1	11.1	8.2	8.6	-0.312	20	0%	-0.13	< 80%	No Significant Trend	Decreasing then increasing
MW-47	Feb-96	Nov-01	12.0	28.3	18.1	16.6	0.655	24	0%	1.52	95%	Increasing	Increasing then decreasing
MW-48	Feb-96	Nov-01	30.5	45.8	39.1	40.4	-0.324	24	0%	-0.38	< 80%	No Significant Trend	Increasing then decreasing
MW-49	Feb-96	Nov-01	0.5	1.2	0.6	0.5	1.457	24	75%	0.00	80%	Flat	Nearly flat
MW-50	Feb-96	Nov-01	0.5	1.3	0.6	0.5	1.372	24	75%	0.00	95%	Flat	Nearly flat
MW-56	Feb-96	Nov-01	0.5	31.8	9.0	8.2	1.858	21	5%	0.40	80%	Increasing	Decreasing, then increasing, then leveling off
MW-57	Feb-96	Nov-01	1.0	17.7	7.8	7.0	0.843	24	0%	-0.26	< 80%	No Significant Trend	Increasing then decreasing
MW-58	May-96	Nov-01	0.5	16.9	9.1	9.5	-0.114	23	22%	-0.50	< 80%	No Significant Trend	Decreasing then increasing
MW-59	Aug-96	Nov-01	0.5	1.0	0.6	0.5	2.119	22	86%	0.00	< 80%	No Significant Trend	Flat

# of Increasing Trends (onsite wells only) ==>	2
# of Decreasing Trends (onsite wells only) ==>	4
# of Flat Trends (onsite wells only) ==>	3
# of Statistically Insignificant Trends (onsite wells only) ==>	10
Average slope of significant trends at onsite wells (ppm/yr) ==>	-0.58
Average slope of all trends at onsite wells (ppm/yr) ==>	-0.30

Notes:
Min = minimum, Max = maximum, n = number of samples
BDL = below detection limit, C.L. = confidence level
For these calculations, values reported as BDL and those reported as equal to or less than one-half the highest detection limit were counted as BDL.
Wells MW-56 through MW-59 are offsite wells. All other wells are onsite wells.

E:\LUB\LandApp\[All Trends.xls]Simplot Plant

Table 4-3
Summary of Nitrate Trend Analyses - Simplot Terrace Site
Trend Analysis of Food Processing Land Application Sites in the LUBGWMA

Sample Location	Data Set Statistics									Trend Analysis Results		Trend Direction	LOWESS Pattern
	Starting Date	Ending Date	Min	Max	Mean	Median	Skewness	n	% BDL	Slope (ppm/yr)	C.L.		
MW-14	Nov-88	Nov-01	9.0	38.9	24.3	23.5	0.029	52	0%	1.80	99%	Increasing	Increasing with some fluctuations
MW-15	Nov-88	Feb-98	6.2	17.3	10.4	10.0	0.775	35	0%	0.73	99%	Increasing	Increasing with some fluctuations
MW-22	Nov-88	Nov-01	10.3	32.4	23.1	22.1	-0.252	51	0%	1.38	99%	Increasing	Increasing with some fluctuations
MW-38	May-92	Nov-01	2.3	18.7	10.3	11.5	-0.426	38	0%	0.95	99%	Increasing	Increasing with some fluctuations
MW-39	May-92	Nov-01	12.5	37.2	20.8	18.2	0.646	39	0%	1.80	99%	Increasing	Increasing then decreasing
MW-40	May-92	Nov-01	7.9	23.8	15.0	14.9	0.279	39	0%	1.37	99%	Increasing	Decreasing then increasing
MW-51	Feb-96	Nov-01	9.0	20.1	16.7	18.7	-0.683	24	0%	1.68	99%	Increasing	Increasing then starting to level off
MW-52	Feb-96	Nov-01	10.7	32.2	24.3	26.2	-0.765	24	0%	2.25	95%	Increasing	Increasing then decreasing
MW-53	Feb-96	Nov-01	20.8	72.3	60.3	63.3	-2.361	24	0%	0.95	< 80%	No Significant Trend	Increasing then decreasing
MW-54	Feb-96	Nov-01	14.7	21.6	18.5	19.3	-0.181	24	0%	1.04	99%	Increasing	Decreasing, then increasing, then decreasing again

# of Increasing Trends ==>	9
# of Decreasing Trends ==>	0
# of Flat Trends ==>	0
# of Statistically Insignificant Trends ==>	1
Average slope of significant trends (ppm/yr) ==>	1.44
Average slope of all trends (ppm/yr) ==>	1.39

Notes:
Min = minimum, Max = maximum, n = number of samples
BDL = below detection limit, C.L. = confidence level
For these calculations, values reported as BDL and those reported as equal to or less than one-half the highest detection limit were counted as BDL.
E:\LUB\LandApp\[All Trends.xls]Simplot Terrace

Table 4-4
Summary of Nitrate Trend Analyses - Simplot Expansion Site
Trend Analysis of Food Processing Land Application Sites in the LUBGWMA

Sample Location	Data Set Statistics									Trend Analysis Results		Trend Direction	LOWESS Pattern
	Starting Date	Ending Date	Min	Max	Mean	Median	Skewness	n	% BDL	Slope (ppm/yr)	C.L.		
MW-23	May-90	Nov-01	4.8	13.2	9.1	8.9	0.137	45	0%	0.25	99%	Increasing	Increasing, then decreasing, then increasing again
MW-24	May-90	Nov-01	3.8	12.3	7.7	7.4	0.064	43	0%	0.40	99%	Increasing	Increasing then decreasing
MW-25	May-90	Nov-01	3.5	13.8	7.6	7.4	0.476	44	0%	0.43	99%	Increasing	Increasing, then decreasing, then increasing again
MW-26	May-90	Nov-01	2.4	17.8	9.4	9.4	0.027	39	0%	0.94	99%	Increasing	Increasing, then decreasing, then increasing again
MW-27	May-90	Nov-01	2.6	13.4	6.9	7.0	0.473	38	0%	0.48	99%	Increasing	Increasing
MW-28	May-90	Nov-01	2.1	22.1	11.3	11.5	0.152	45	0%	1.16	99%	Increasing	Increasing
MW-29	May-90	Nov-01	1.7	11.0	6.6	6.5	0.002	46	0%	0.47	99%	Increasing	Increasing
MW-30	May-90	Nov-01	1.0	26.5	7.6	7.3	1.283	43	0%	0.67	99%	Increasing	Increasing then decreasing
MW-31	May-91	Nov-01	4.2	20.0	10.2	10.3	0.495	43	0%	0.58	99%	Increasing	Increasing then decreasing
MW-32	May-91	Nov-01	4.2	11.8	7.6	7.6	-0.079	43	0%	0.35	99%	Increasing	Increasing, then decreasing, then increasing again
MW-33	May-91	Nov-01	3.6	12.8	7.6	8.1	-0.218	42	0%	0.53	99%	Increasing	Increasing then beginning to level off
MW-34	May-91	Nov-01	4.0	24.5	8.1	7.2	2.646	43	0%	0.25	99%	Increasing	Increasing
MW-35	May-91	Nov-01	2.0	20.7	8.0	7.8	1.118	43	0%	0.46	99%	Increasing	Increasing then decreasing
MW-36	May-91	Nov-01	2.7	8.8	5.8	6.9	-0.194	43	0%	0.56	99%	Increasing	Increasing then beginning to level off
MW-37	May-91	Nov-01	1.0	37.2	8.4	5.7	2.152	41	0%	1.08	99%	Increasing	Increasing with fluctuations
MW-41	May-92	Nov-01	1.5	24.8	8.6	3.9	0.894	39	0%	2.02	99%	Increasing	Flat then increasing
MW-42	May-92	Nov-01	1.0	11.3	8.5	8.3	-2.089	36	0%	0.07	< 80%	No Significant Trend	Increasing, then decreasing, then increasing again
MW-43	May-92	Nov-01	2.1	9.4	5.5	5.7	-0.023	38	0%	0.75	99%	Increasing	Increasing then beginning to level off
MW-44	May-92	Nov-01	1.6	17.1	6.0	5.7	1.549	39	0%	0.40	99%	Increasing	Increasing, then decreasing, then increasing again
MW-55	Feb-96	Nov-01	12.1	19.8	17.0	17.4	-0.987	23	0%	0.80	95%	Increasing	Increasing then decreasing

# of Increasing Trends ==>	19
# of Decreasing Trends ==>	0
# of Flat Trends ==>	0
# of Statistically Insignificant Trends ==>	1
Average slope of significant trends (ppm/yr) ==>	0.66
Average slope of all trends (ppm/yr) ==>	0.63

Notes:
Min = minimum, Max = maximum, n = number of samples
BDL = below detection limit, C.L. = confidence level
For these calculations, values reported as BDL and those reported as equal to or less than one-half the highest detection limit were counted as BDL.

E:\LUB\LandApp\[All Trends.xls]Simplot Expansion

Table 5-1
Summary of Nitrate Trend Analyses - Hermiston Foods
Trend Analysis of Food Processing Land Application Sites in the LUBGWMA

Sample Location	Data Set Statistics									Trend Analysis Results		Trend Direction	LOWESS Pattern
	Starting Date	Ending Date	Min	Max	Mean	Median	Skewness	n	% BDL	Slope (ppm/yr)	C.L.		
MW-1	Apr-91	Dec-01	7.3	13.0	10.4	10.3	-0.145	36	0%	-0.12	< 80%	No Significant Trend	Increasing then decreasing then increasing
MW-2	Apr-91	Dec-01	0.8	16.6	7.9	7.6	0.864	34	0%	0.29	99%	Increasing	Increasing
MW-3	Apr-91	Dec-01	2.4	9.2	4.3	4.2	2.610	36	0%	-0.01	< 80%	No Significant Trend	Nearly flat
MW-4	Apr-91	Dec-01	0.6	8.1	5.8	6.0	-1.201	36	0%	0.29	99%	Increasing	Increasing
MW-5	May-97	Dec-01	4.5	13.0	7.6	7.3	1.497	18	0%	-0.01	< 80%	No Significant Trend	Nearly flat
MW-6	May-97	Dec-01	7.5	14.5	11.4	11.6	-0.677	18	0%	0.12	< 80%	No Significant Trend	Fluctuating but nearly flat, then increasing

# of Increasing Trends ==>	2
# of Decreasing Trends ==>	0
# of Flat Trends ==>	0
# of Statistically Insignificant Trends ==>	4
Average slope of significant trends (ppm/yr) ==>	0.29
Average slope of all trends (ppm/yr) ==>	0.09

Notes:
Min = minimum, Max = maximum, n = number of samples
BDL = below detection limit, C.L. = confidence level

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Table 6-1
Summary of Nitrate Trend Analyses - A.E. Staley Site
Trend Analysis of Food Processing Land Application Sites in the LUBGWMA

Sample Location	Data Set Statistics									Trend Analysis Results		Trend Direction	LOWESS Pattern
	Starting Date	Ending Date	Min	Max	Mean	Median	Skewness	n	% BDL	Slope (ppm/yr)	C.L.		
MW-1S	Aug-89	Nov-01	0.25	23.8	8.8	7.7	0.373	48	4%	1.41	99%	Increasing	Increasing
MW-1D	Aug-89	May-98	0.25	6.5	2.3	2.2	1.429	33	3%	0.28	99%	Increasing	Increasing
MW-2S	Aug-89	Nov-01	0.25	4.5	1.0	0.7	2.145	47	13%	0.06	99%	Increasing	Increasing
MW-3S	Aug-89	Nov-01	0.25	5.5	1.3	1.2	2.287	47	4%	0.10	99%	Increasing	Increasing
MW-3D	Aug-89	May-98	0.25	5.5	1.2	1.0	2.699	29	7%	0.03	80%	Increasing	Decreasing, then increasing
MW-4S	Aug-89	Nov-01	0.75	10.0	3.4	3.2	1.350	43	7%	0.28	99%	Increasing	Increasing
MW-5S	Aug-89	Nov-01	0.25	19.4	5.2	4.5	1.763	48	6%	0.56	99%	Increasing	Increasing, then leveling off
MW-6S	Apr-94	Nov-01	2.10	6.8	3.9	3.6	0.568	33	0%	0.39	99%	Increasing	Increasing
MW-E1S	Apr-94	Nov-01	2.20	8.0	4.9	4.8	0.151	33	0%	0.44	99%	Increasing	Increasing, then decreasing
MW-E2S	Apr-94	Nov-01	0.30	8.4	4.8	4.9	-0.069	33	0%	0.25	99%	Increasing	Increasing, decreasing, then leveling off

# of Increasing Trends ==>	10
# of Decreasing Trends ==>	0
# of Flat Trends ==>	0
# of Statistically Insignificant Trends ==>	0
Average slope of significant trends (ppm/yr) ==>	0.38
Average slope of all trends (ppm/yr) ==>	0.38

Notes:
Min = minimum, Max = maximum, n = number of samples
BDL = below detection limit, C.L. = confidence level
For these calculations, values reported as BDL and those reported as equal to or less than one-half the highest detection limit were counted as BDL.

E:\LUB\LandApp\[All Trends.xls]Staley

Table 7-1
Summary of Nitrate Trend Analyses - Snakcorp
Trend Analysis of Food Processing Land Application Sites in the LUBGWMA

Sample Location	Data Set Statistics									Trend Analysis Results		Trend Dierction	LOWESS Pattern
	Starting Date	Ending Date	Min	Max	Mean	Median	Skewness	n	% BDL	Slope (ppm/yr)	C.L.		
MW-1	Nov-94	Nov-01	0.7	11.1	3.7	2.9	1.084	29	0%	-0.28	<80%	No Significant Trend	Decrease then increase
MW-2	Nov-94	Nov-01	6.8	16.3	10.5	10.6	0.660	29	0%	0.01	<80%	No Significant Trend	Increase then level off
MW-3	Nov-94	Nov-01	4.2	20.0	10.3	10.1	1.021	29	0%	-0.64	95%	Decreasing	Increase then decrease
MW-4	Aug-99	Nov-01	6.8	33.2	16.6	17.4	0.756	10	0%	-0.25	<80%	No Significant Trend	Increase then decrease

# of Increasing Trends ==>	0
# of Decreasing Trends ==>	1
# of Flat Trends ==>	0
# of Statistically Insignificant Trends ==>	3
Average slope of significant trends (ppm/yr) ==>	-0.64
Average slope of all trends (ppm/yr) ==>	-0.29

Notes:
Min = minimum, Max = maximum, n = number of samples
BDL = below detection limit, C.L. = confidence level
For these calculations, values reported as BDL and those reported as equal to or less than one-half the highest detection limit were counted as BDL.

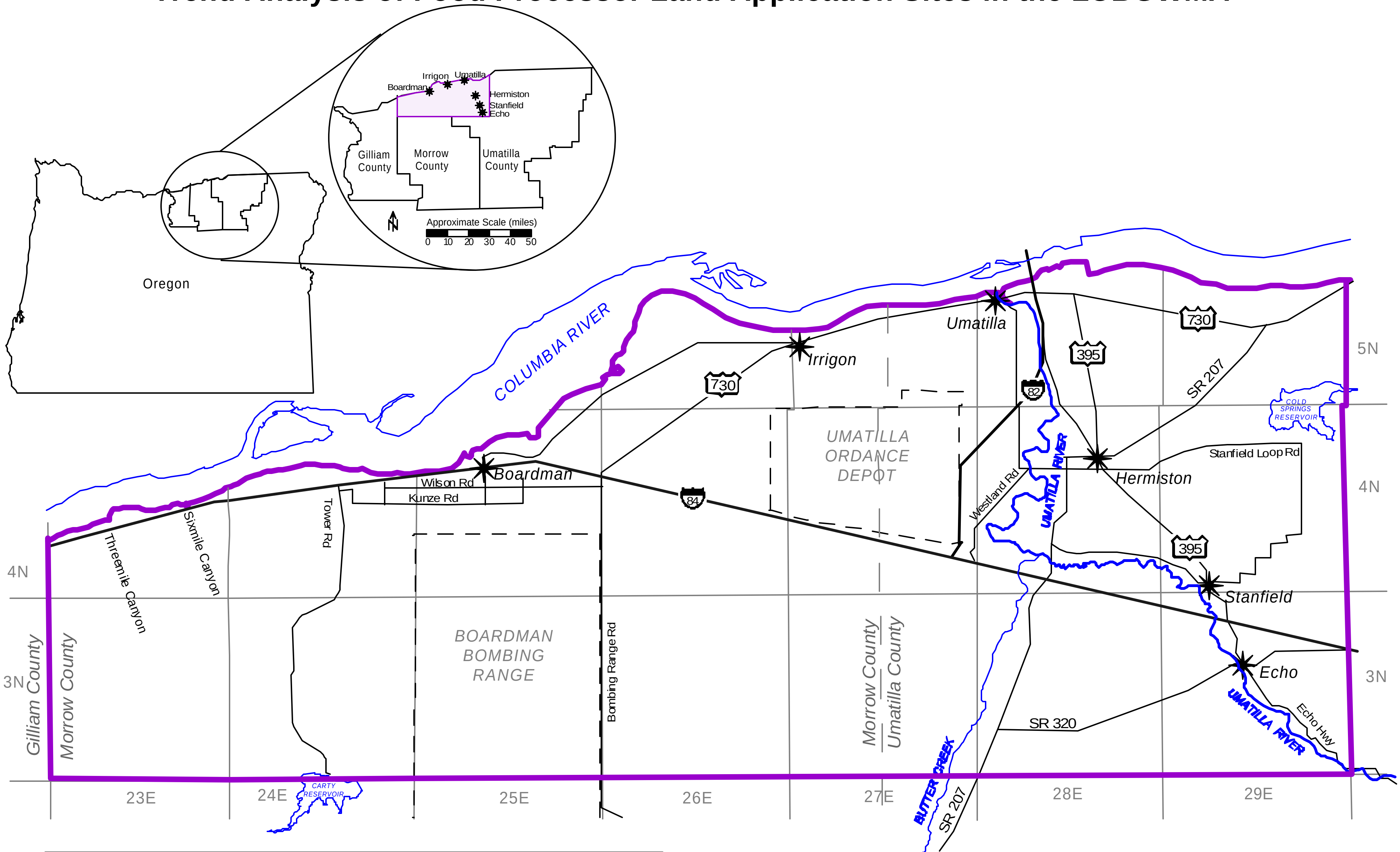
E:\LUB\LandApp\[All Trends.xls]Snakcorp

Table 8-1
Summary of Trend Direction and Magnitude by Site
Trend Analysis of Food Processing Land Application Sites in the LUBGWMA

Site	*# of Wells*	*Increasing Trends*		*Decreasing Trends*		*Flat Trends*		*Statistically Insignificant Trends*		*Average slope of trends (ppm/yr)*		*Average of Average Nitrate Concentrations at Each Well (ppm)*
		#	*%*	*#*	*%*	*#*	*%*	*#*	*%*	*Stat. Sig.*	*All*	
Port of Morrow (Farm 1)	13	9	69%	1	8%	0	0%	3	23%	**1.3**	**1.1**	**23.0**
Port of Morrow (Farm 2)	9	9	100%	0	0%	0	0%	0	0%	**2.5**	**2.5**	**33.6**
L-W (North Farm)	10	5	50%	2	20%	0	0%	3	30%	**1.5**	**1.1**	**24.2**
L-W (Madison Ranches)	12	7	58%	0	0%	0	0%	5	42%	**0.5**	**0.3**	**5.6**
Simplot (Plant Site)	19	2	11%	4	21%	3	16%	10	53%	**-0.6**	**-0.3**	**9.5**
Simplot (Expansion Site)	20	19	95%	0	0%	0	0%	1	5%	**0.7**	**0.3**	**8.4**
Simplot (Terrace Site)	10	9	90%	0	0%	0	0%	1	10%	**1.4**	**1.4**	**22.4**
Hermiston Foods	6	2	33%	0	0%	0	0%	4	67%	**0.3**	**0.1**	**7.9**
Staley	10	10	100%	0	0%	0	0%	0	0%	**0.4**	**0.4**	**3.7**
SnakCorp	4	0	0%	1	25%	0	0%	3	75%	**-0.6**	**-0.3**	**10.3**
Totals by Well	***113***	***72***	***64%***	***8***	***7%***	***3***	***3%***	***30***	***27%***			

Steepest Decreasing Trend At A Well = *-2.9 ppm/yr*
Steepest Increasing Trend At A Well = *6.9.ppm/yr*

Figure 1-1
Location and Boundaries of Lower Umatilla Basin Groundwater Management Area
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



Lower Umatilla Basin Groundwater Management Area Boundaries

North: Columbia River

South: 2N/3N Township Boundary

East: 29E/30E Range Boundary

West: 22E/23E Range Boundary (also the Morrow / Gilliam County line)

Figure 1-2
Location of Food Processor Land Application Sites in the LUBGWMA
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA

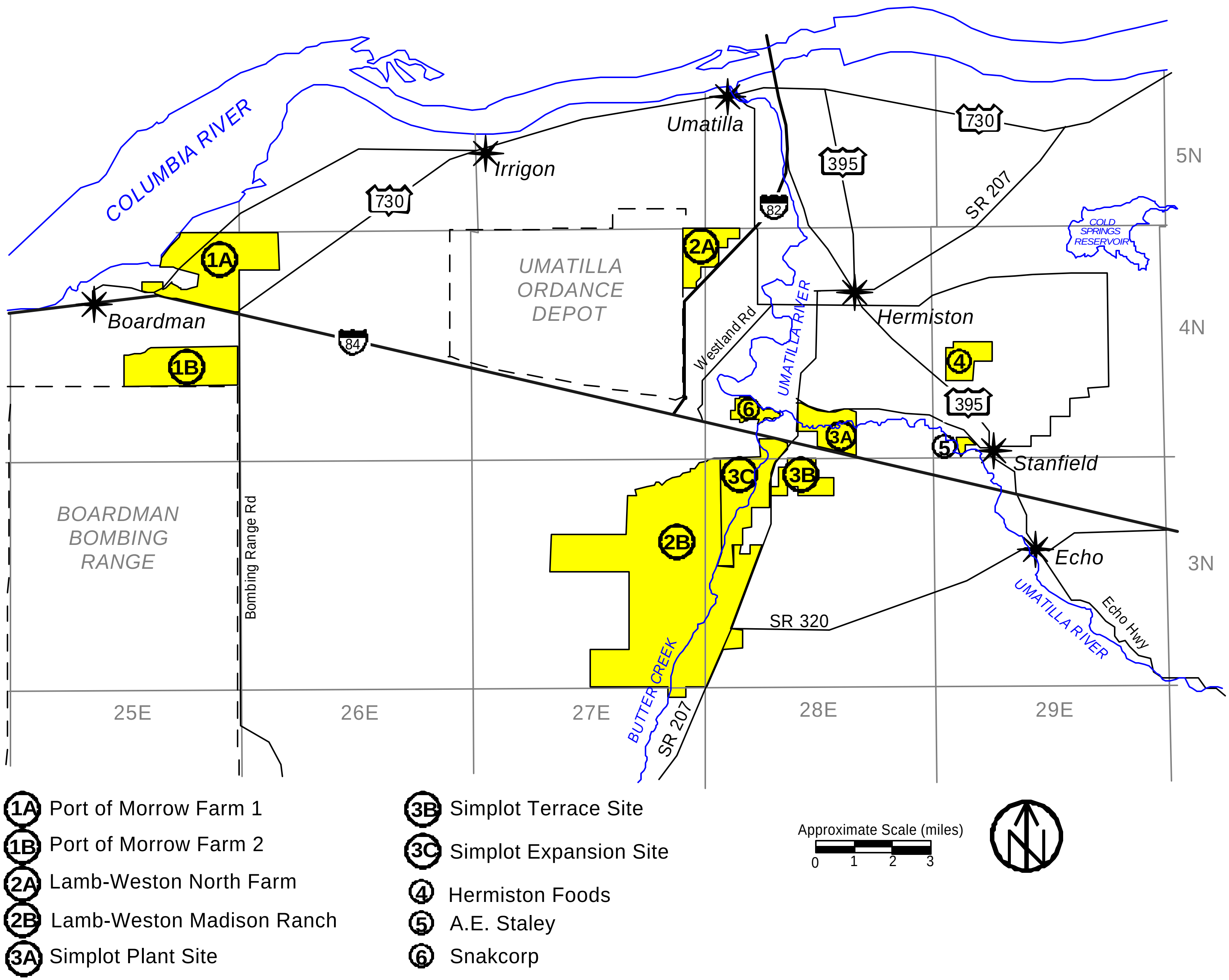
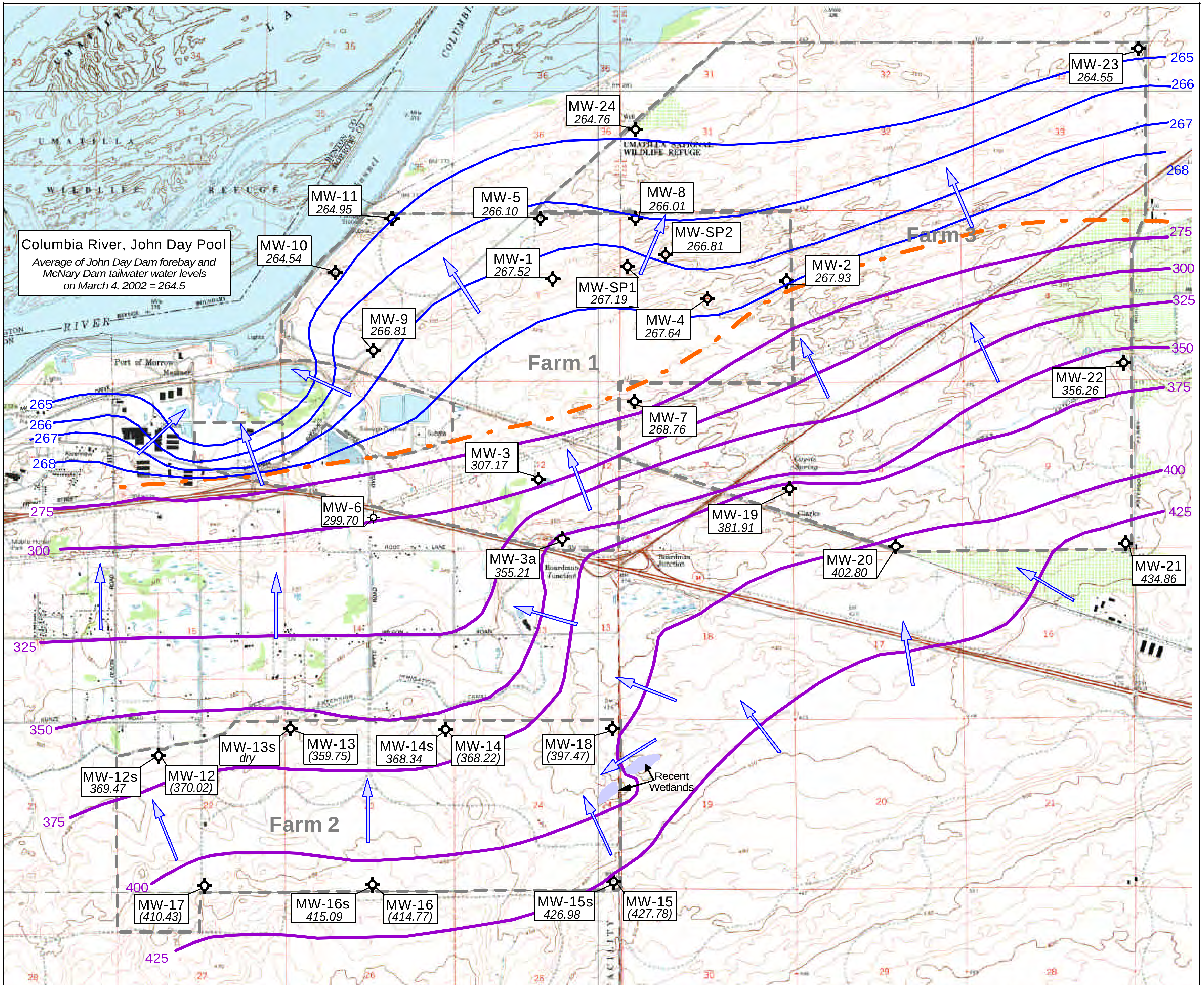


Figure 2-1
Water Table Elevations - Port of Morrow Area
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



e: lub landapp pom march 2002 wls.srf

EXPLANATION

- = Well Location
- MW-10 = Well ID; 264.54 = March 4, 2002 Water Level
- 268 = Water Table Contour (Contour Interval = 1 ft)
- 275 = Water Table Contour (Contour Interval = 25 ft)
- = Horizontal Groundwater Flow Direction (perpendicular to contours)
- = Line where the basalt surface rises above the John Day pool elevation. This hinge point separates the low-gradient area (with 1' contour interval) to the north from the high-gradient area (with 25' contour interval) to the south.

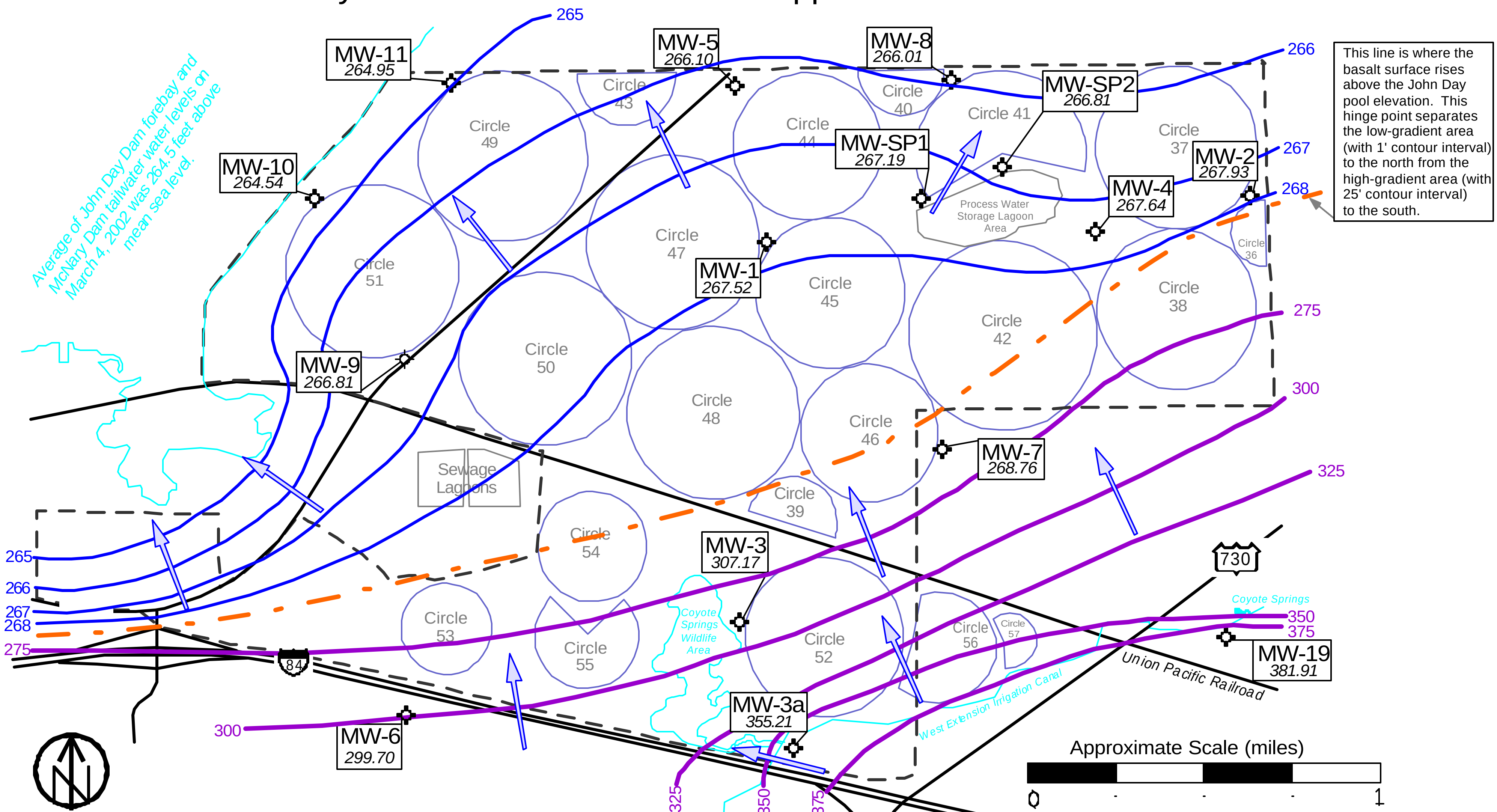
Notes:

(1) Water level contours are based on the water levels measured at the 25 alluvial aquifer wells, the John Day Pool elevations recorded by the Army Corps of Engineers, land surface topography, location of wetlands, and the elevation of the underlying basalt surface. Water levels shown in parentheses are in basalt wells and are not directly contoured.

(2) Based on the well log for well MW-3, the water level at well MW-3 is not believed to represent the regional water table, but instead is perched above the regional water table. The well log indicates 4' of saturated sand on top of 2' of clay on top of 13' of unsaturated sand. The presence of a perching clay is also consistent with the fact that irrigation water purged from the West Extension Irrigation Canal (near MW-3a) forms a wetland west and southwest of MW-3 rather than rapidly infiltrating.

Approximate Scale (miles)
0 1

Figure 2-2
March 4, 2002 Water Table Elevations - Port of Morrow Farm 1
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



EXPLANATION

MW-3 = Well ID
307.17 = Groundwater Elevation (feet above mean sea level)
= Well Location

265 = Groundwater Elevation Contour (contour interval = 1 ft)

275 = Groundwater Elevation Contour (contour interval = 25 ft)

= Groundwater Flow Direction (perpendicular to contours)

= Surface Water Feature

Notes:

(1) Water level contours are based on the water levels measured at the 25 alluvial aquifer wells, the John Day Pool elevations recorded by the Army Corps of Engineers, land surface topography, location of wetlands, and the elevation of the underlying basalt surface.

(2) Based on the well log for well MW-3, the water level at well MW-3 is not believed to represent the regional water table, but instead is perched above the regional water table. The well log indicates 4' of saturated sand on top of 2' of clay on top of 13' of unsaturated sand. The presence of a perching clay is also consistent with the fact that irrigation water purged from the West Extension Irrigation Canal (near MW-3a) forms a wetland west and southwest of MW-3 rather than rapidly infiltrating.

e: lub landapp pom wlmap1.srf

Figure 2-3

Comparison of Groundwater and Surface Water Elevations Near Port of Morrow Farm 1

Trend Analysis of Food Processing Land Application Sites in the LUBGWMA

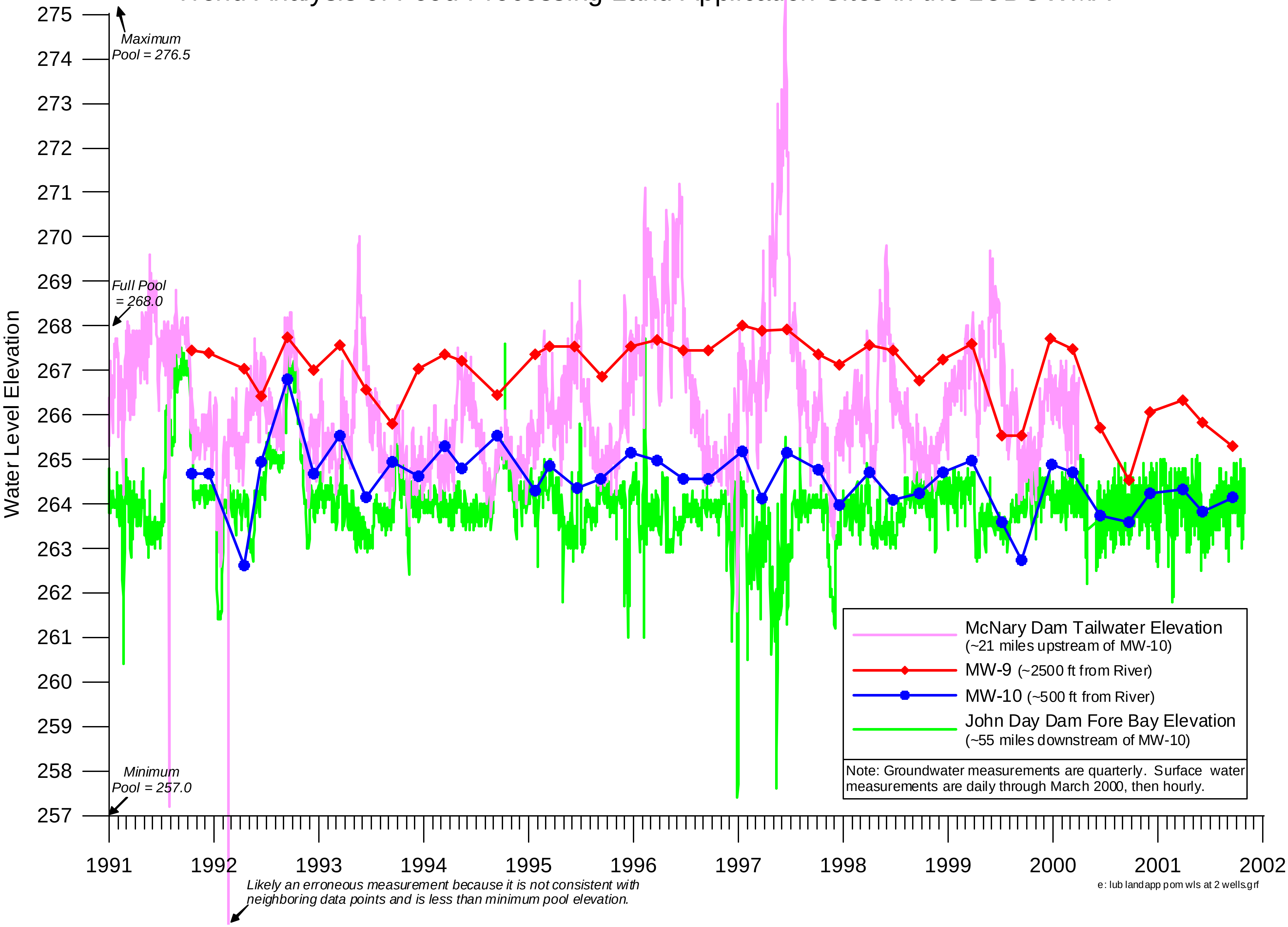


Figure 2-4
LOWESS Line Through All Nitrate Data - Port of Morrow Farm 1
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA

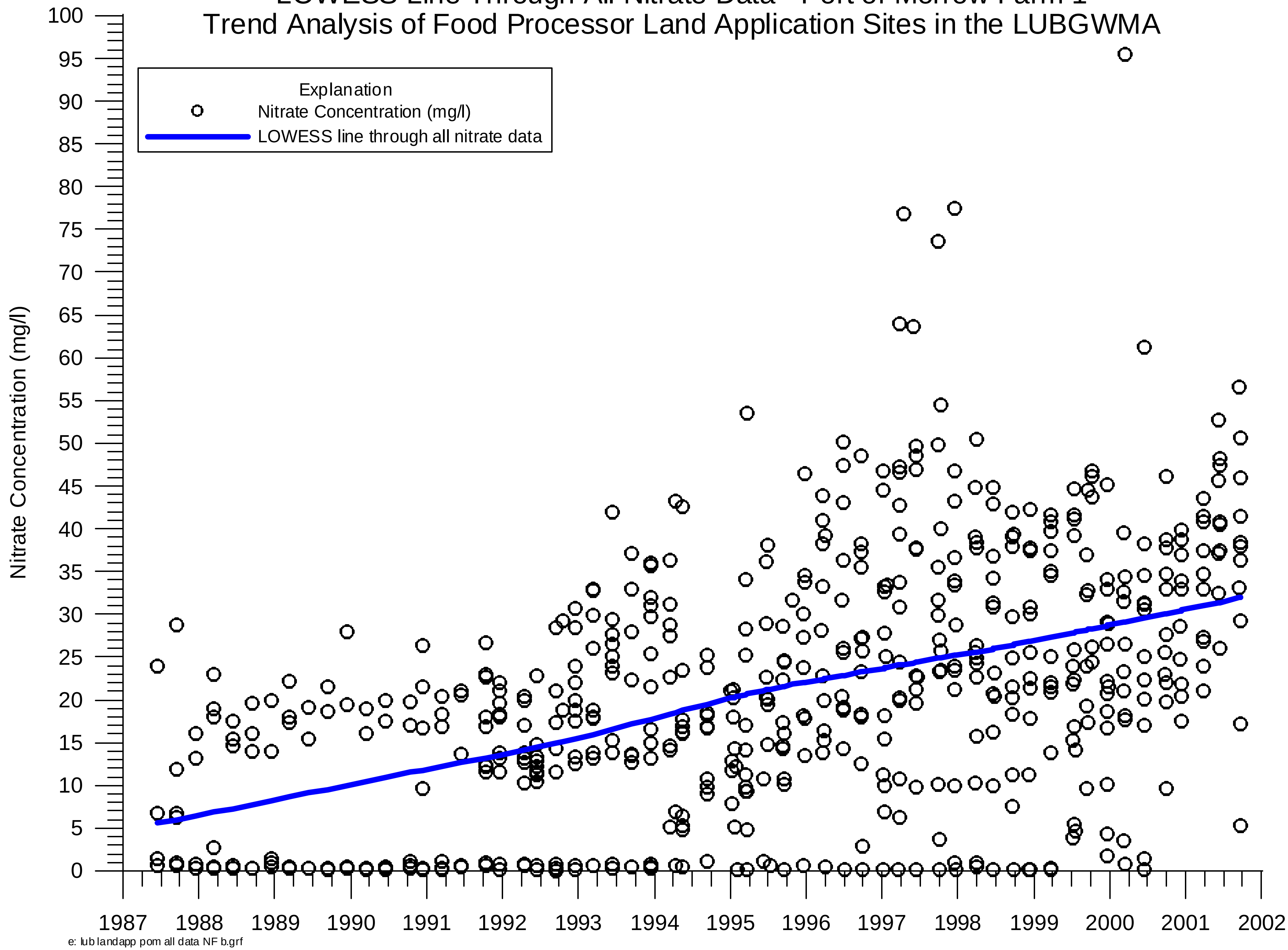
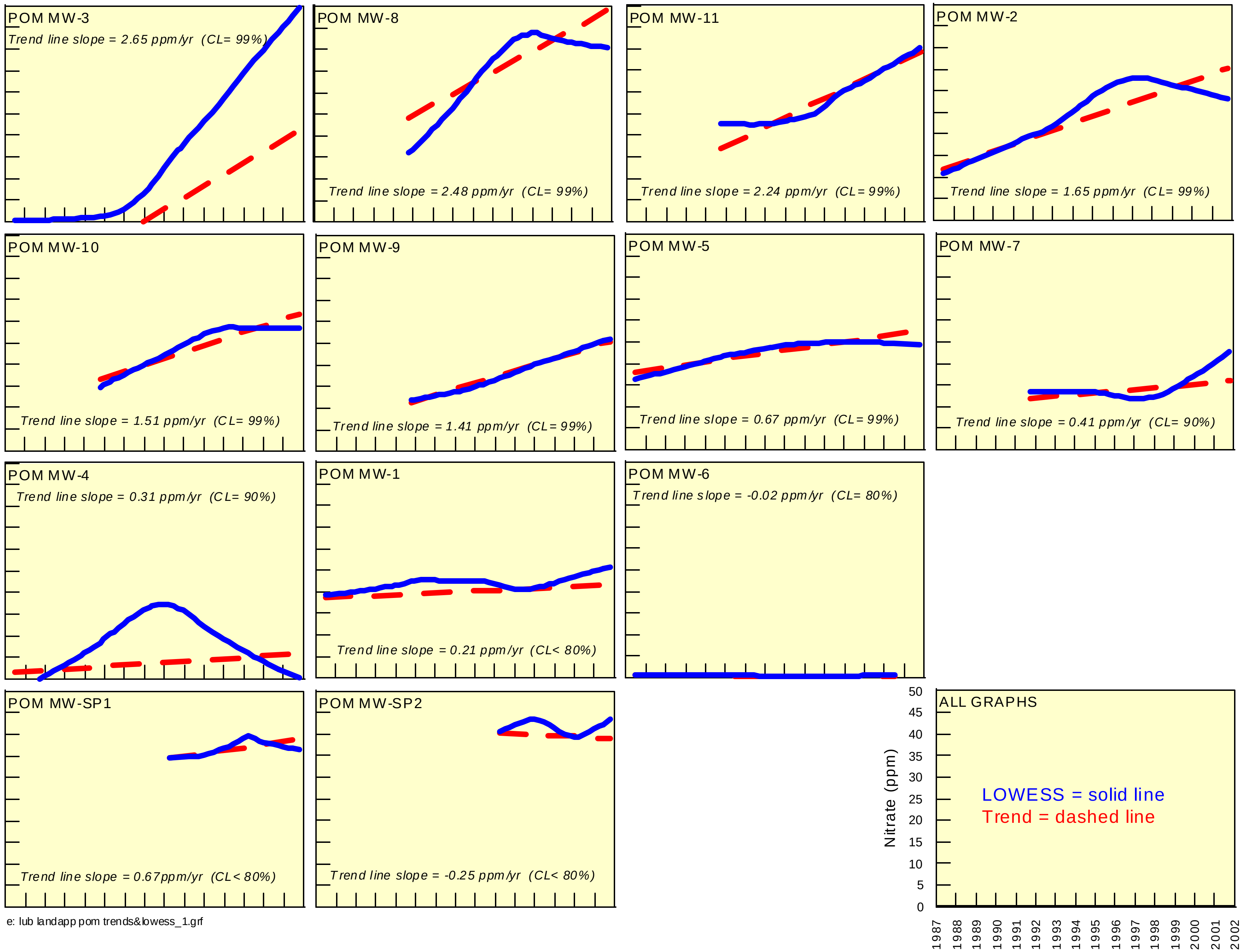
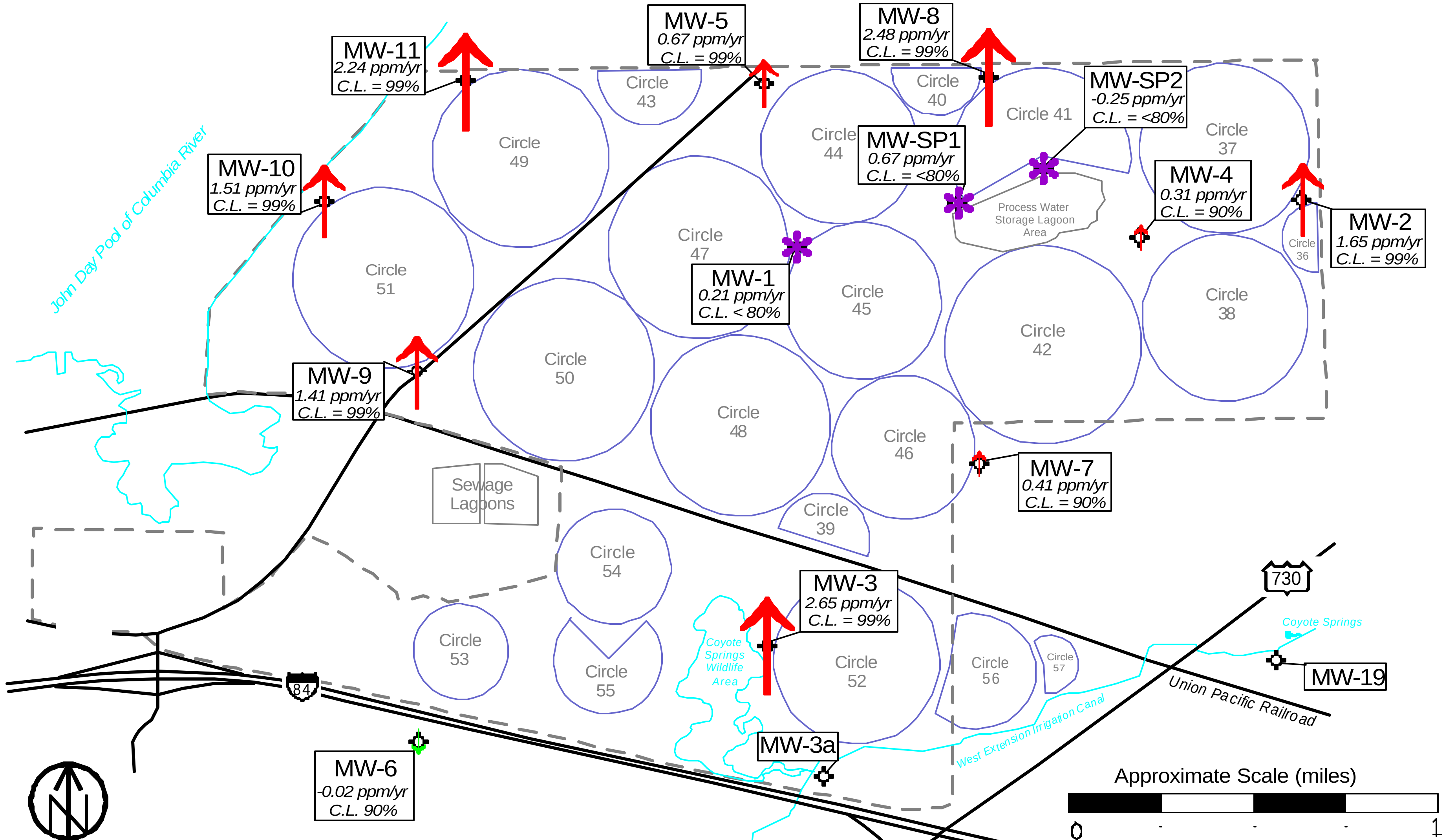


Figure 2-5
LOWESS Lines and Trend Lines Through Nitrate Data - Port of Morrow Farm 1
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



e: lub landapp pom trends&lowess_1.grf

Figure 2-6
Nitrate Trends - Port of Morrow Farm 1
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



EXPLANATION

MW-3 = Well ID
2.65 ppm/yr = Trend line slope in ppm/yr
C.L. = 99% = Confidence Level of trend line slope

= Surface Water Feature

Increasing Trend (9 wells)

Decreasing Trend (1 well)

Flat Trend (0 wells)

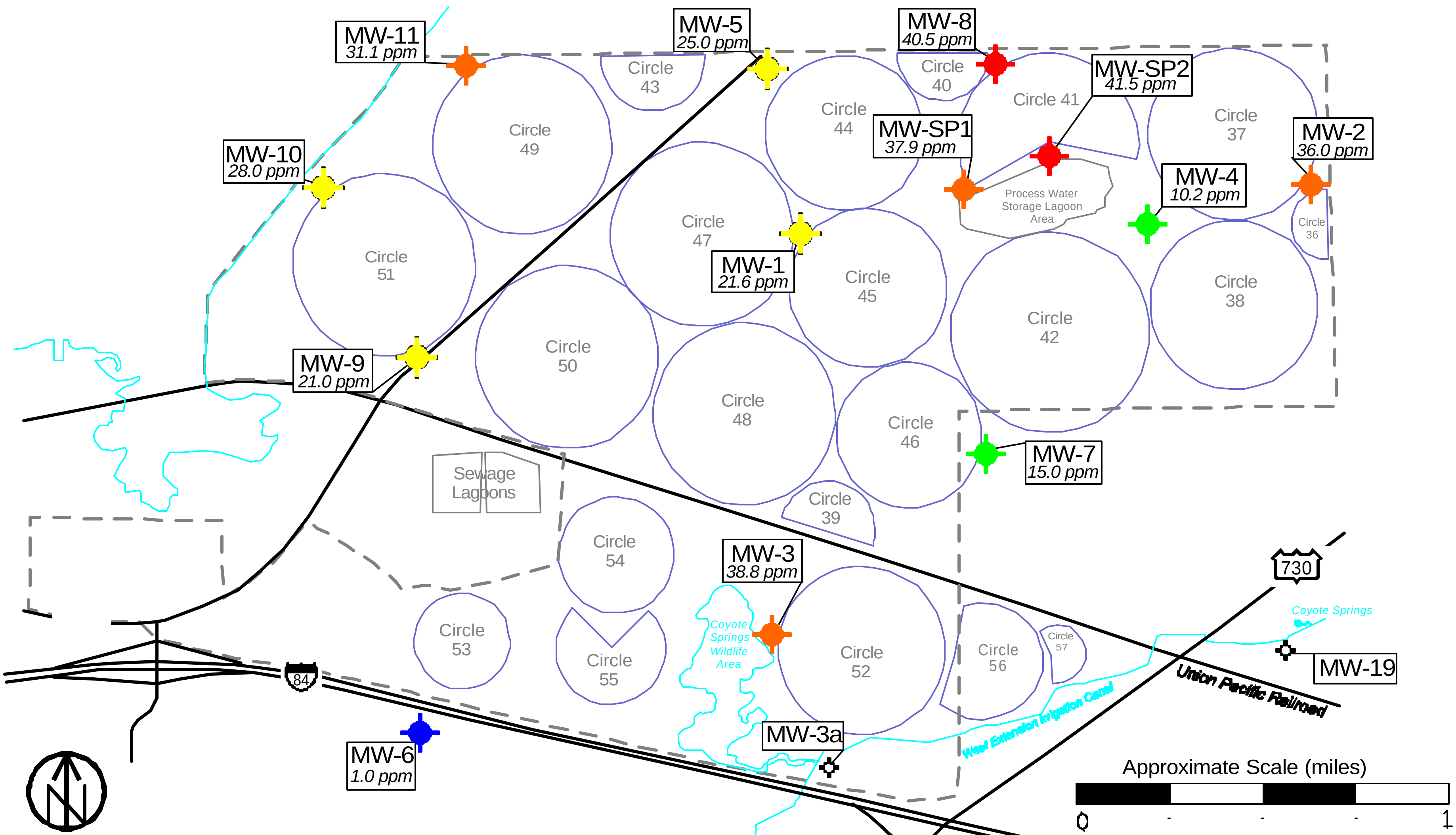
Statistically Insignificant Trend (3 wells)

The size of each symbol is proportional to the trend line slope:
Large symbols = wells with slopes > 2 ppm/yr
Medium symbols = wells with slopes between 1 & 2 ppm/yr
Small symbols = wells with slopes between 0.5 and 1 ppm/yr
Very Small symbols = wells with slopes less than 0.5 ppm/yr

Trends at MW-1 through MW-5 and MW-8 through MW-11 are for 6/87 through 9/01
Trend at well MW-6 is for 6/87 through 6/00
Trend at well MW-7 is for 10/91 through 9/01
Trends at wells MW-SP1 and MW-SP2 are for 4/95 through 9/01

e: lub landapp trends fm1.srf (01/08/04)

Figure 2-7
Average Nitrate Concentrations - Port of Morrow Farm 1
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



EXPLANATION

MW-6 = Well ID
1.3 ppm = Average Nitrate Concentrations (ppm)

= Well Location

Note:
Averages in this figure are from March 1995 through September 2000, the timeframe in which all 13 wells were installed and being sampled. The averages in Table 2-1 use all data since each well was installed.

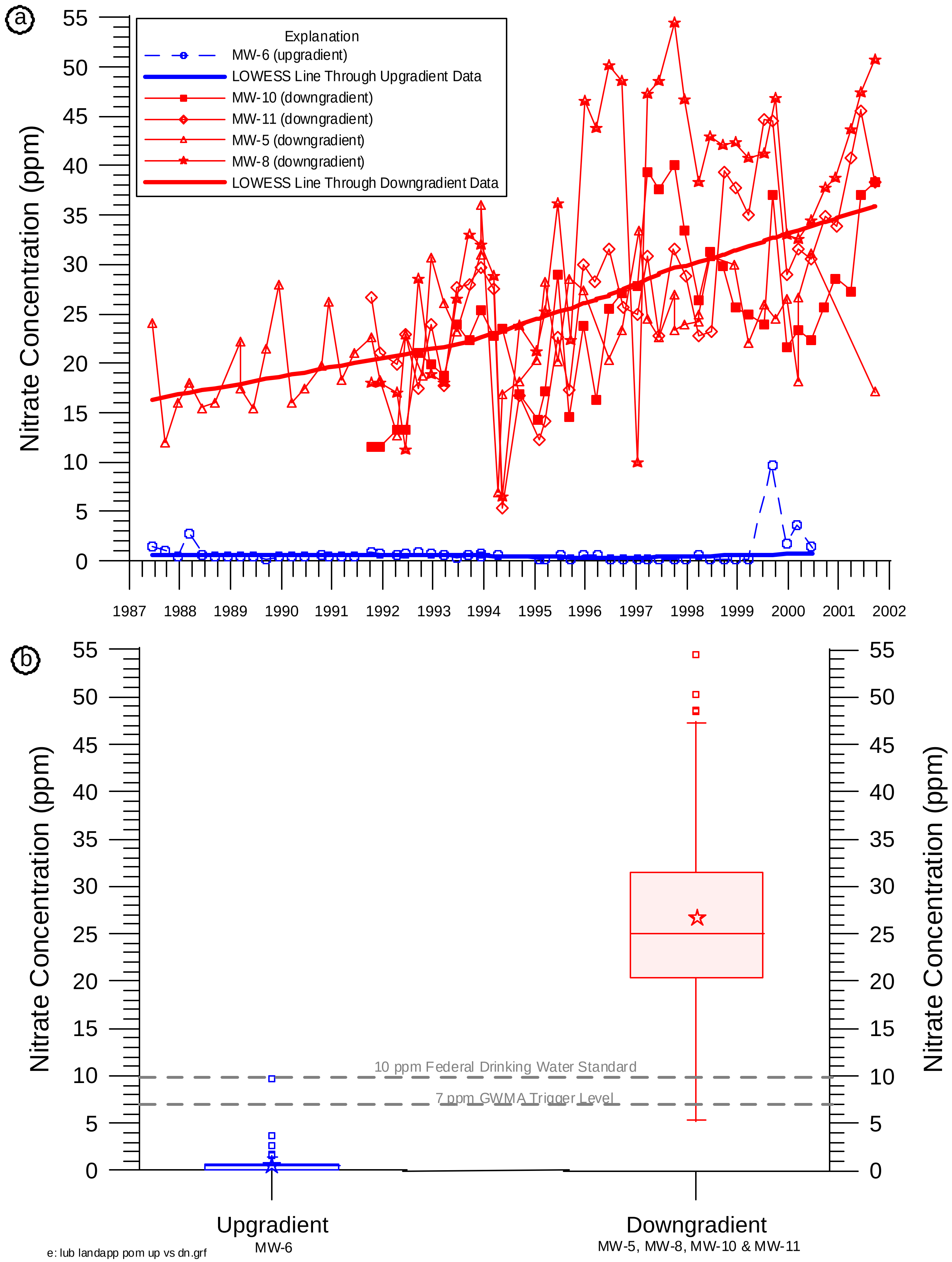
- Average Nitrate Concentration is between 40 and 50 ppm (1 well)
- Average Nitrate Concentration is between 30 and 40 ppm (2 wells)
- Average Nitrate Concentration is between 20 and 30 ppm (5 wells)
- Average Nitrate Concentration is between 10 and 20 ppm (3 wells)
- Average Nitrate Concentration is between 5 and 10 ppm (1 well)
- Average Nitrate Concentration is between 0 and 5 ppm (1 well)

e: lub landapp avgs fm1.srf

Figure 2-8

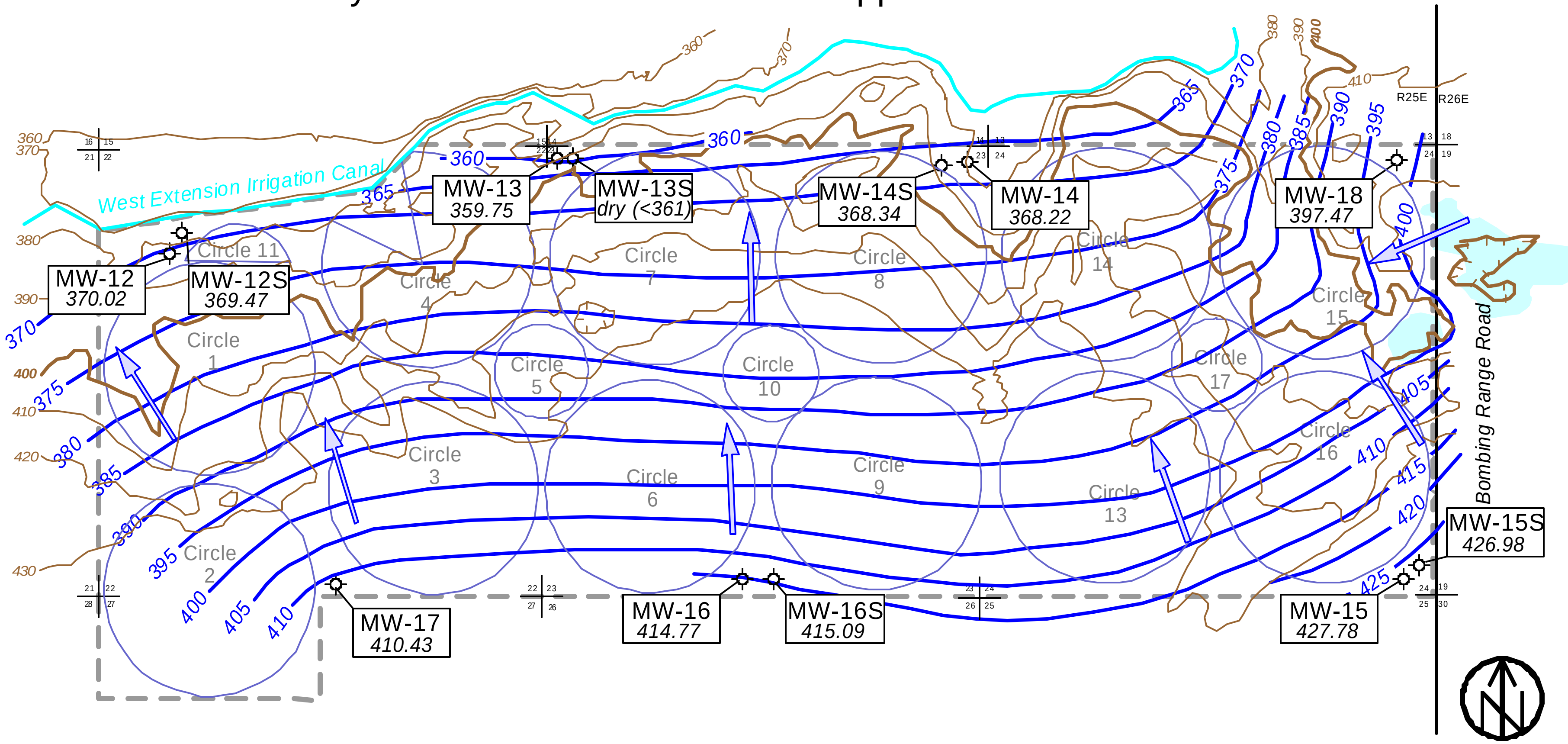
Upgradient vs. Downgradient Nitrate Comparisons - Port of Morrow Farm 1

Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



e: lub landapp pom up vs dn.grf

Figure 2-9
March 4, 2002 Groundwater Elevations - Port of Morrow Farm 2
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



EXPLANATION

MW-3 308.71
= Well ID
= Groundwater Elevation (feet above mean sea level)
= Well Location

265 = Groundwater Elevation Contour (contour interval = 5 ft)

= Groundwater Flow Direction (perpendicular to contours)

Approximate Scale (miles)

0 1

430 = Land Surface Contours (360 to 430 feet above mean sea level; contour interval = 10 ft)

= Wetland (from July 2001 aerial photograph)

Notes:

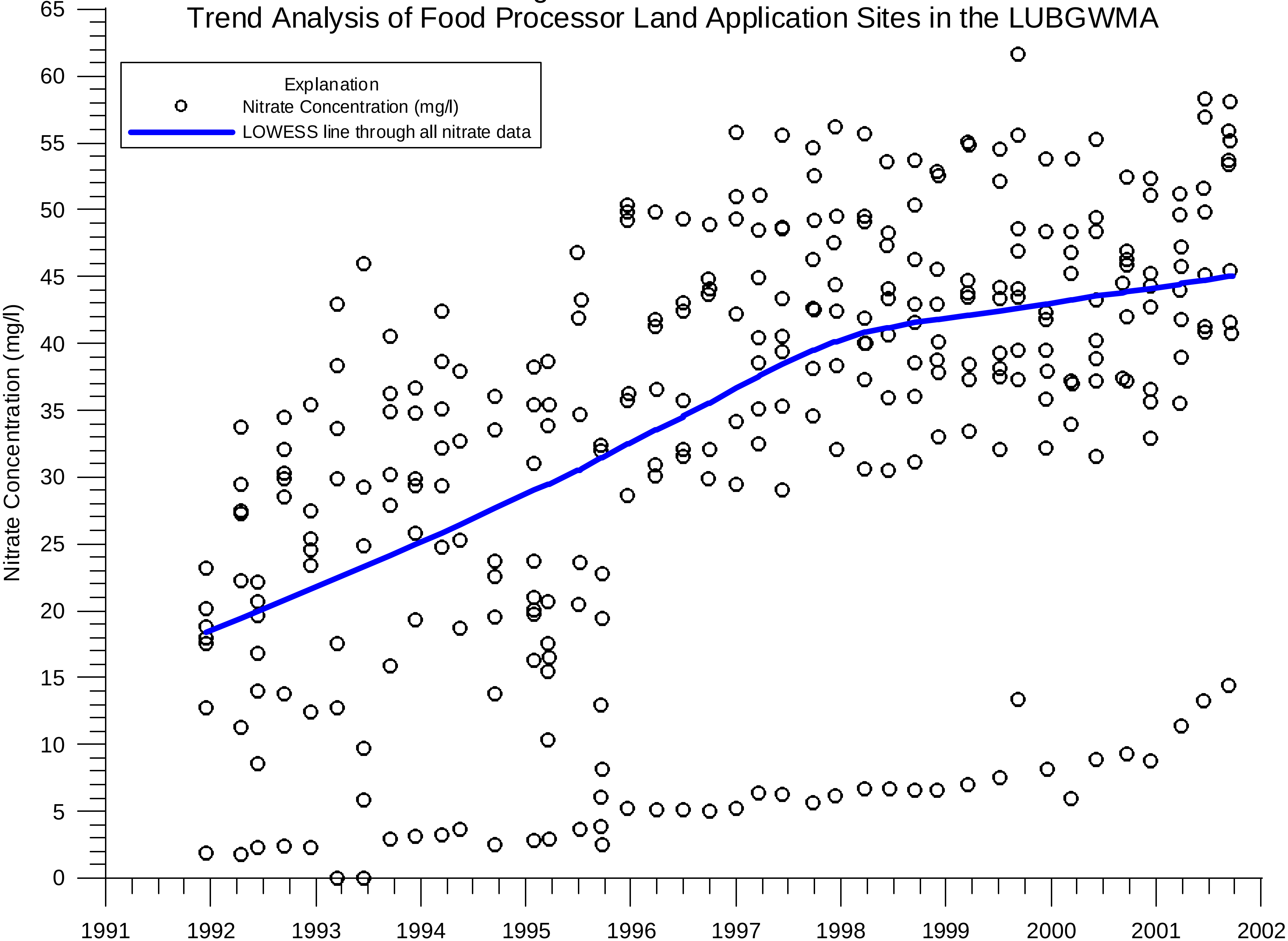
(1) Wells MW-12S, MW-14S, MW-15S, and MW-16S are alluvial aquifer wells. All other wells are basalt aquifer wells.

(2) In 1998, the Port of Morrow stopped applying water to the southern half of Circle 2. Since 1998, a neighboring farmer has applied fresh water to the southern half of Circle 2.

(3) Water level contours are based on water levels in wells, land surface topography, location of wetlands, and the elevation of the underlying basalt surface.

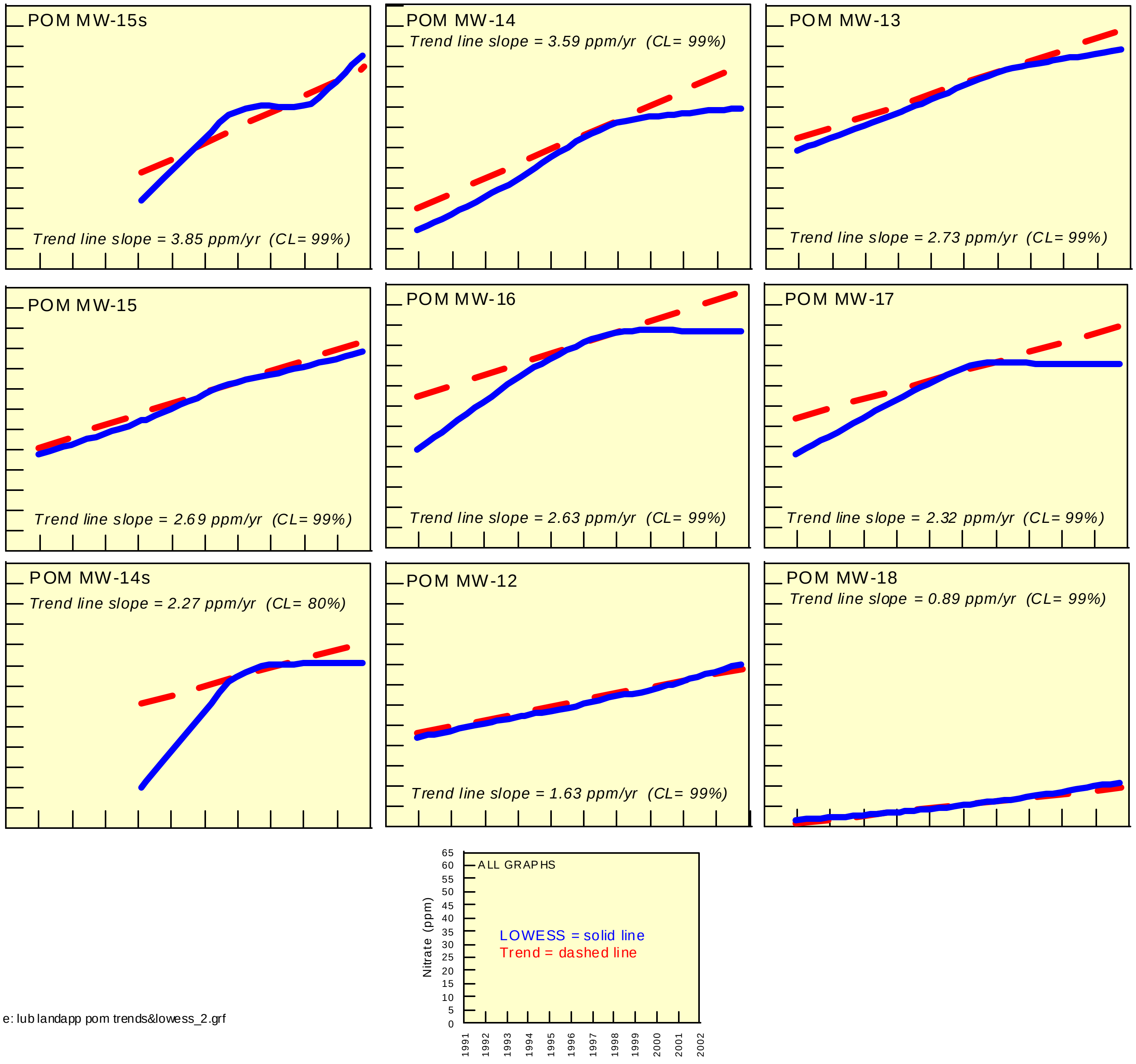
e: lub landapp pom wl_2c.srf

Figure 2-10
LOWESS Line Through All Nitrate Data - Port of Morrow Farm 2
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



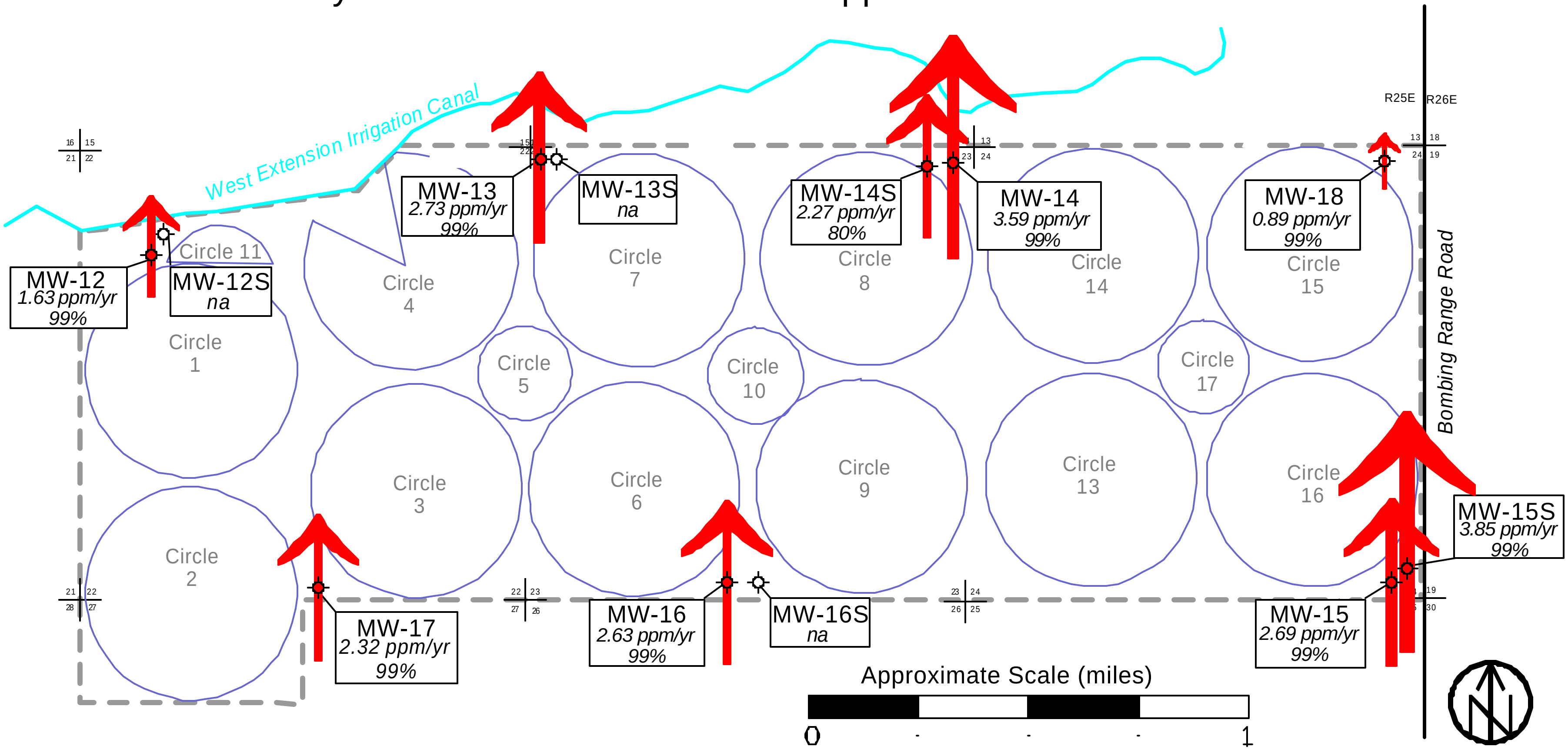
e: lub landapp pom all data fm2.grf

Figure 2-11
LOWESS Lines and Trend Lines Through Nitrate Data - Port of Morrow Farm 2
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



e: lub landapp pom trends&lowess_2.grf

Figure 2-12
Nitrate Trends - Port of Morrow Farm 2
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



EXPLANATION

MW-15 3.05 ppm/yr 99% = Well ID = Trend line slope in ppm/yr Confidence Level of trend line slope

= Well Location

na = Not Analyzed (there were no samples collected from this well from December 1991 through September 2001)

Increasing Trend (9 wells)

Decreasing Trend (0 wells)

Flat Trend (0 wells)

Statistically Insignificant Trend (0 wells)

The size of each symbol is proportional to the trend line slope

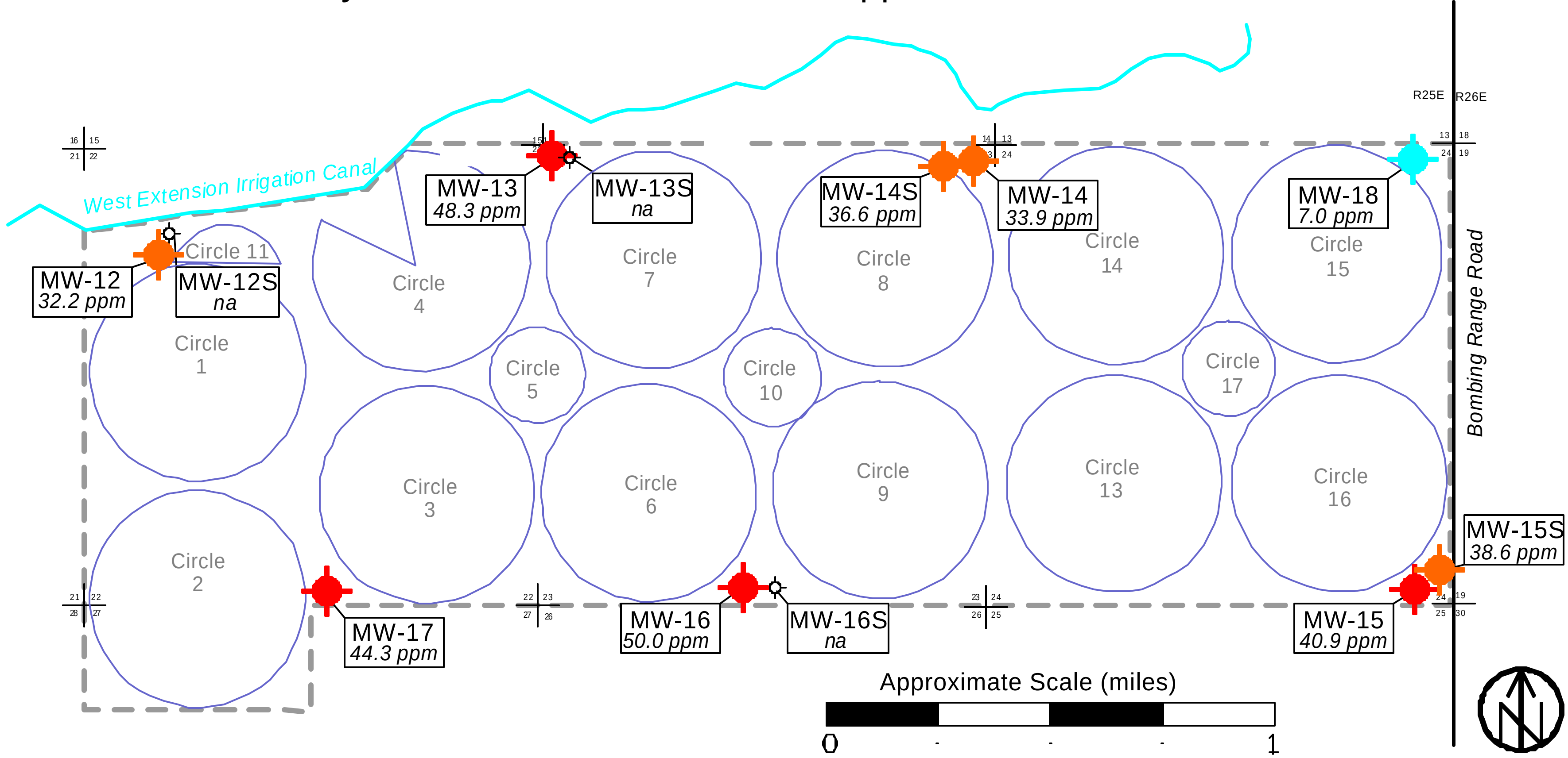
Notes:
Trends at MW-14s and MW-15s are from 1/95 through 9/01. Trends at MW-12, MW-13, MW-14, MW-15, MW-16, MW-17 & MW-18 are from 12/91 through 9/01.

In 1998, the Port of Morrow stopped applying water to the southern half of Circle 2. Since 1998, a neighboring farmer has applied fresh water to the southern half of Circle 2.

Wells MW-12s, MW-13s, MW-14s, MW-15s and MW-16s are alluvial aquifer wells. All other wells are basalt aquifer wells.

e: lub landapp pom trends fm2.srf (01/08/04)

Figure 2-13
Average Nitrate Concentrations - Port of Morrow Farm 2
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



EXPLANATION

MW-15 = Well ID
40.9 ppm = Average Nitrate Concentration (ppm)

= Well Location

na = Not Analyzed (there were no samples collected from this well from January 1995 through September 2001)

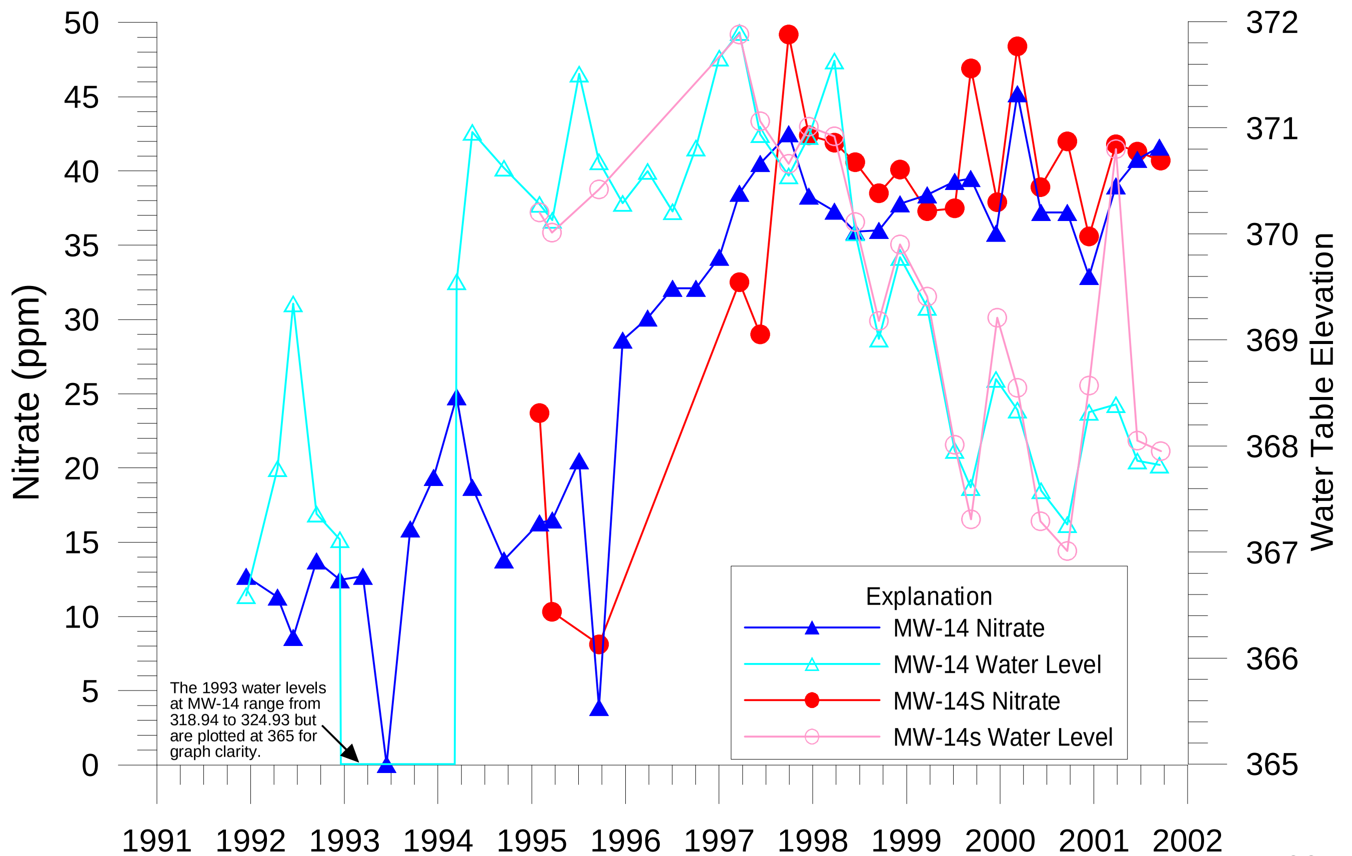
Notes:
Averages in this figure are from January 1995 through September 2001, the timeframe in which the 9 wells were installed and being sampled. The averages in Table 2-2 use all data since each well was installed

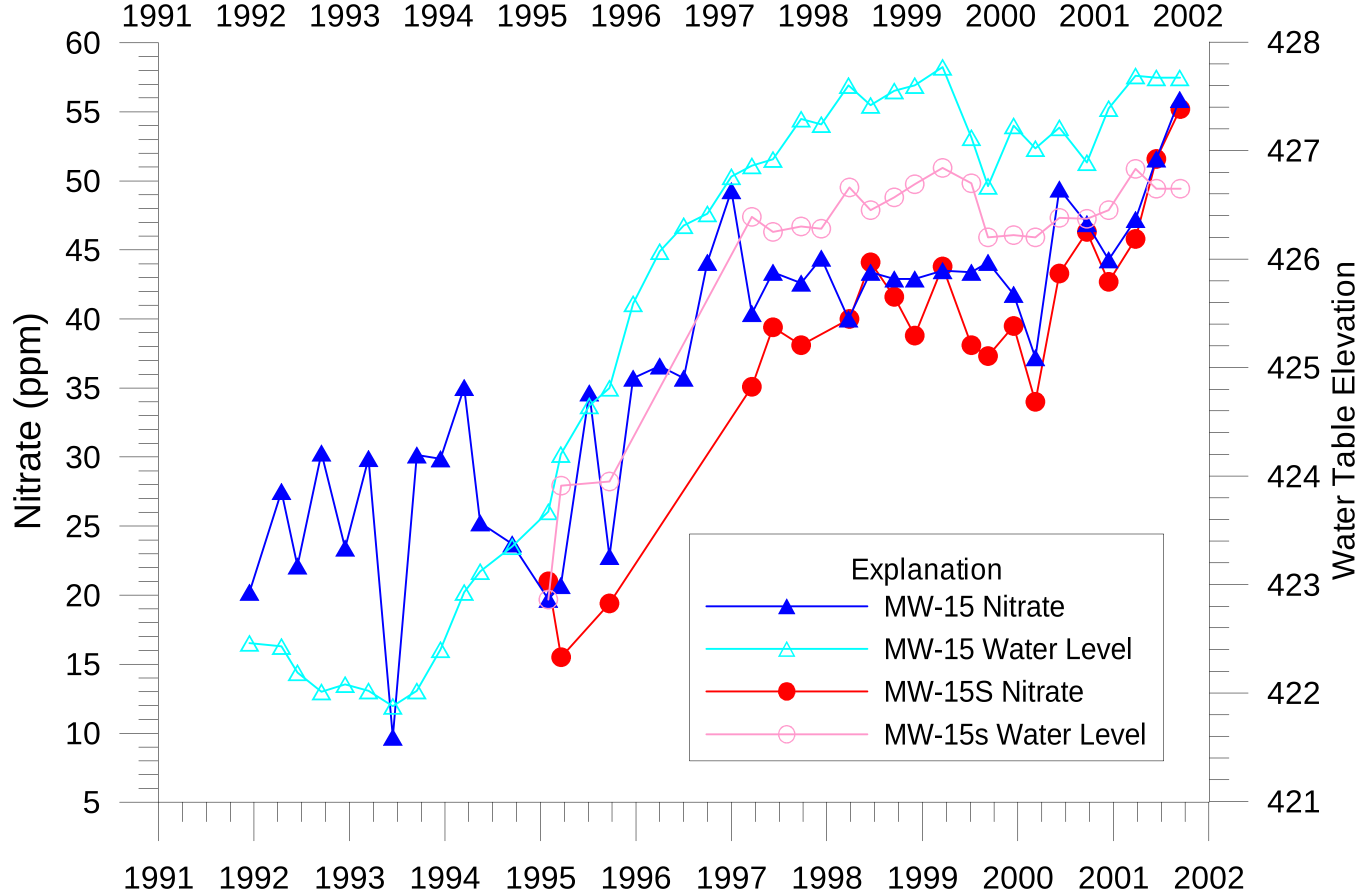
In 1998, the Port of Morrow stopped applying water to the southern half of Circle 2. Since 1998, a neighboring farmer has applied only fresh water to the southern half of Circle 2.

- Average Nitrate Concentration is between 40 and 50 ppm (4 wells)
- Average Nitrate Concentration is between 30 and 40 ppm (4 wells)
- Average Nitrate Concentration is between 20 and 30 ppm (0 wells)
- Average Nitrate Concentration is between 10 and 20 ppm (0 wells)
- Average Nitrate Concentration is between 5 and 10 ppm (1 well)
- Average Nitrate Concentration is between 0 and 5 ppm (0 wells)

e: lub landapp pom avgs fm2.srf

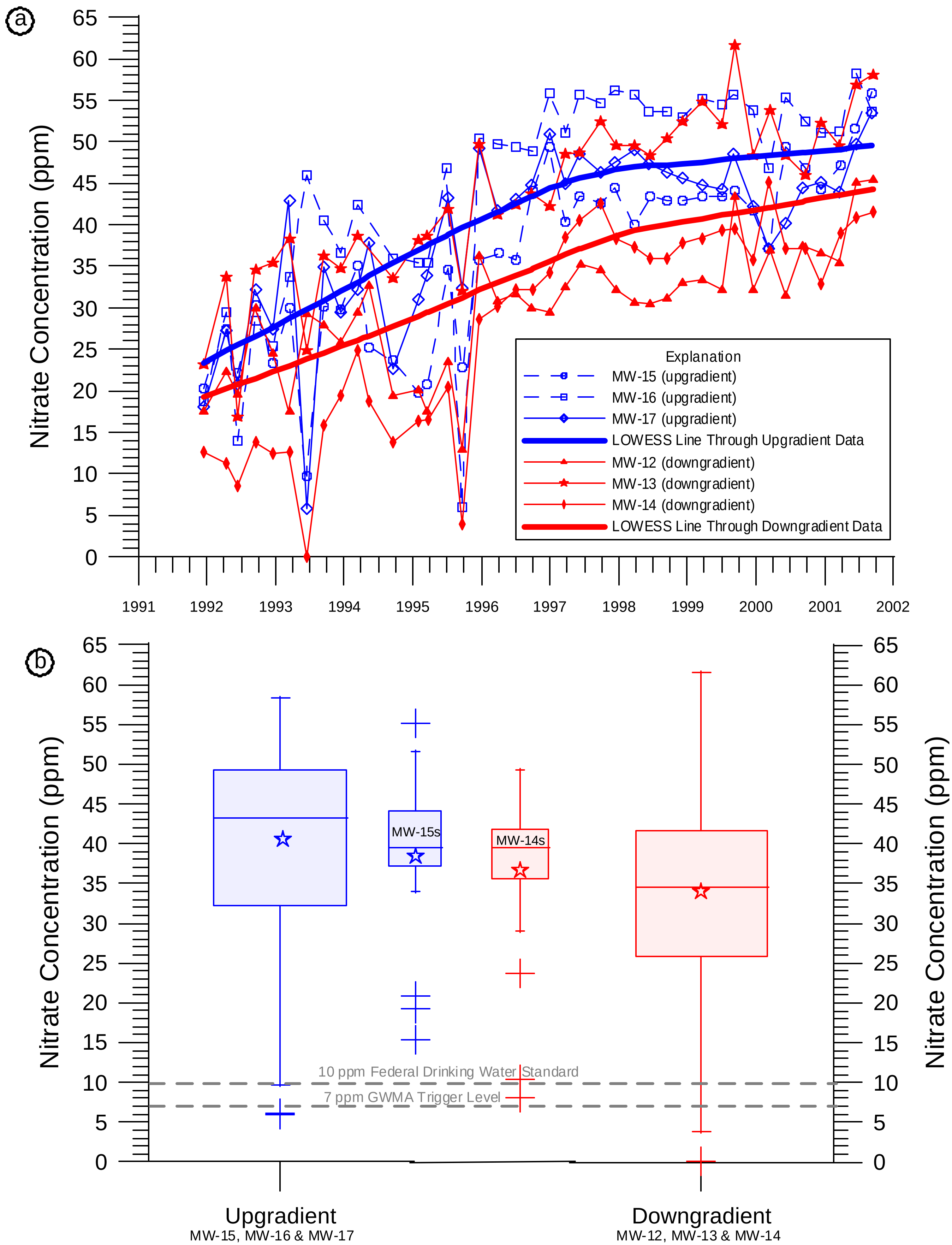
Figure 2-14
Comparision of Shallow and Deep Well Pairs - Port of Morrow Farm 2
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA





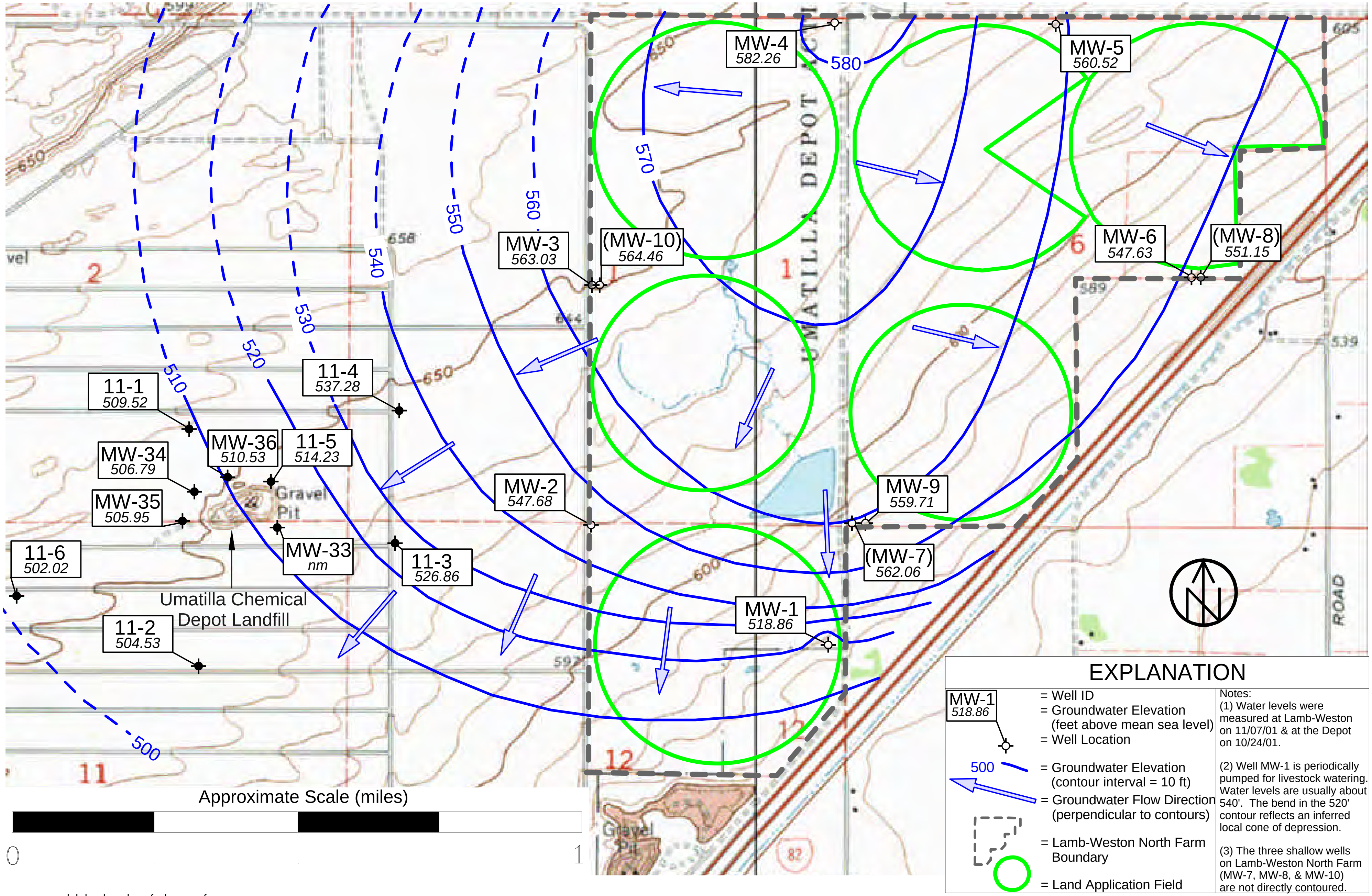
e: lub landapp pom shallow vs deep.grf

Figure 2-15
Upgradient vs. Downgradient Nitrate Comparisons - Port of Morrow Farm 2
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



e: \ub landapp ppm up vs dn 2.grf

Figure 3-1
Fall 2001 Water Level Elevations - Lamb-Weston North Farm
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



e: lub landapp l-w nf wl map.srf

Figure 3-2
LOWESS Line Through All Nitrate Data - Lamb-Weston North Farm
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA

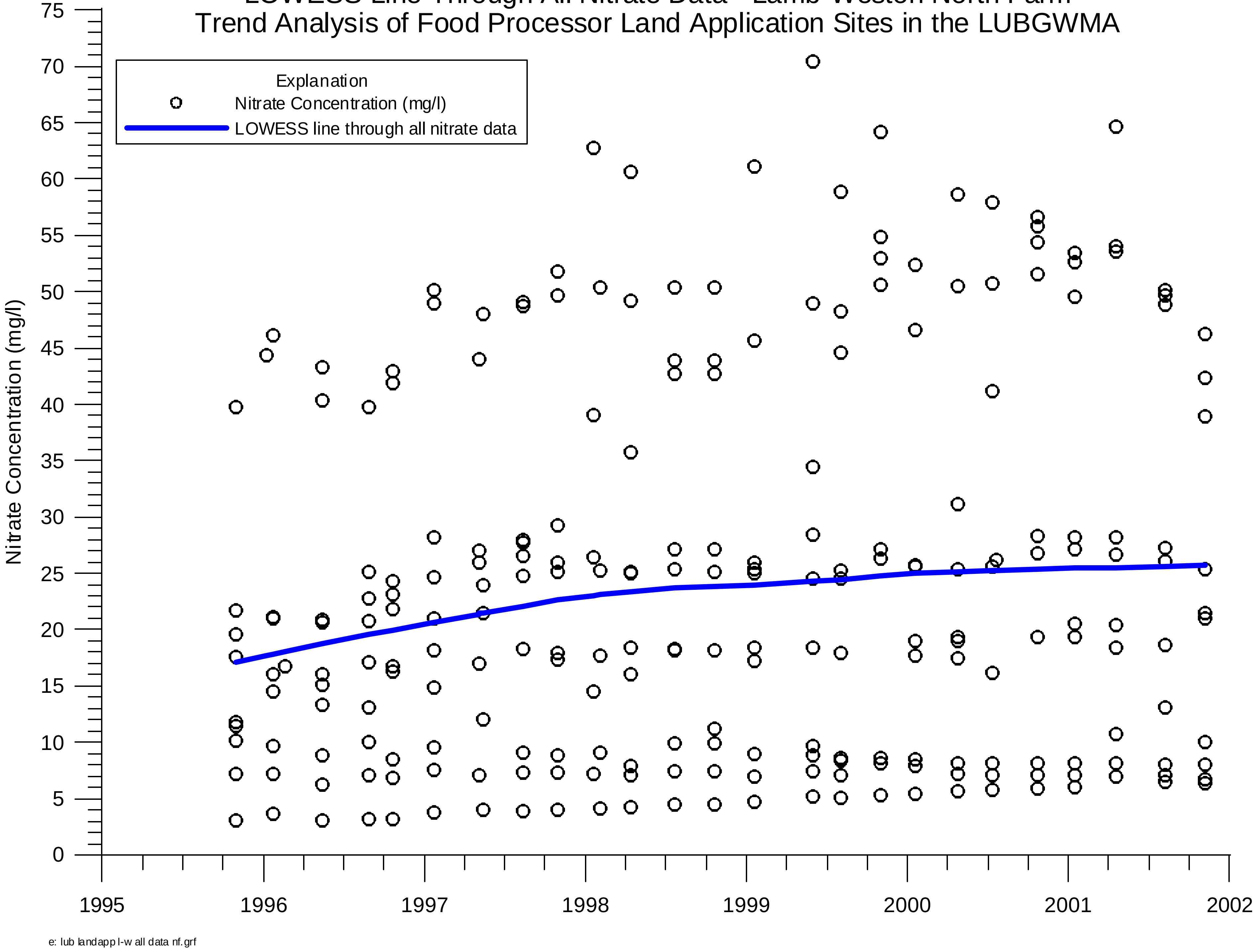
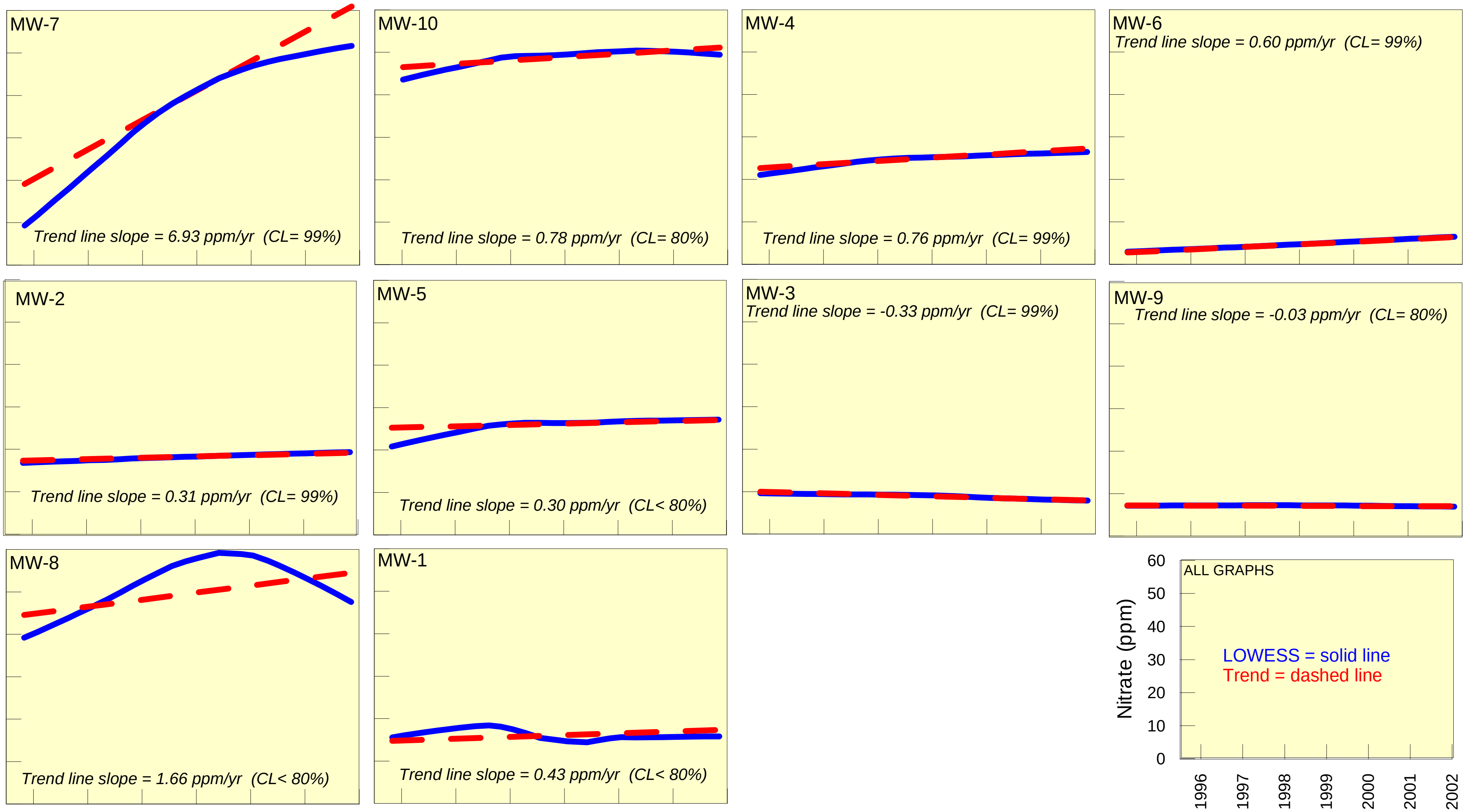
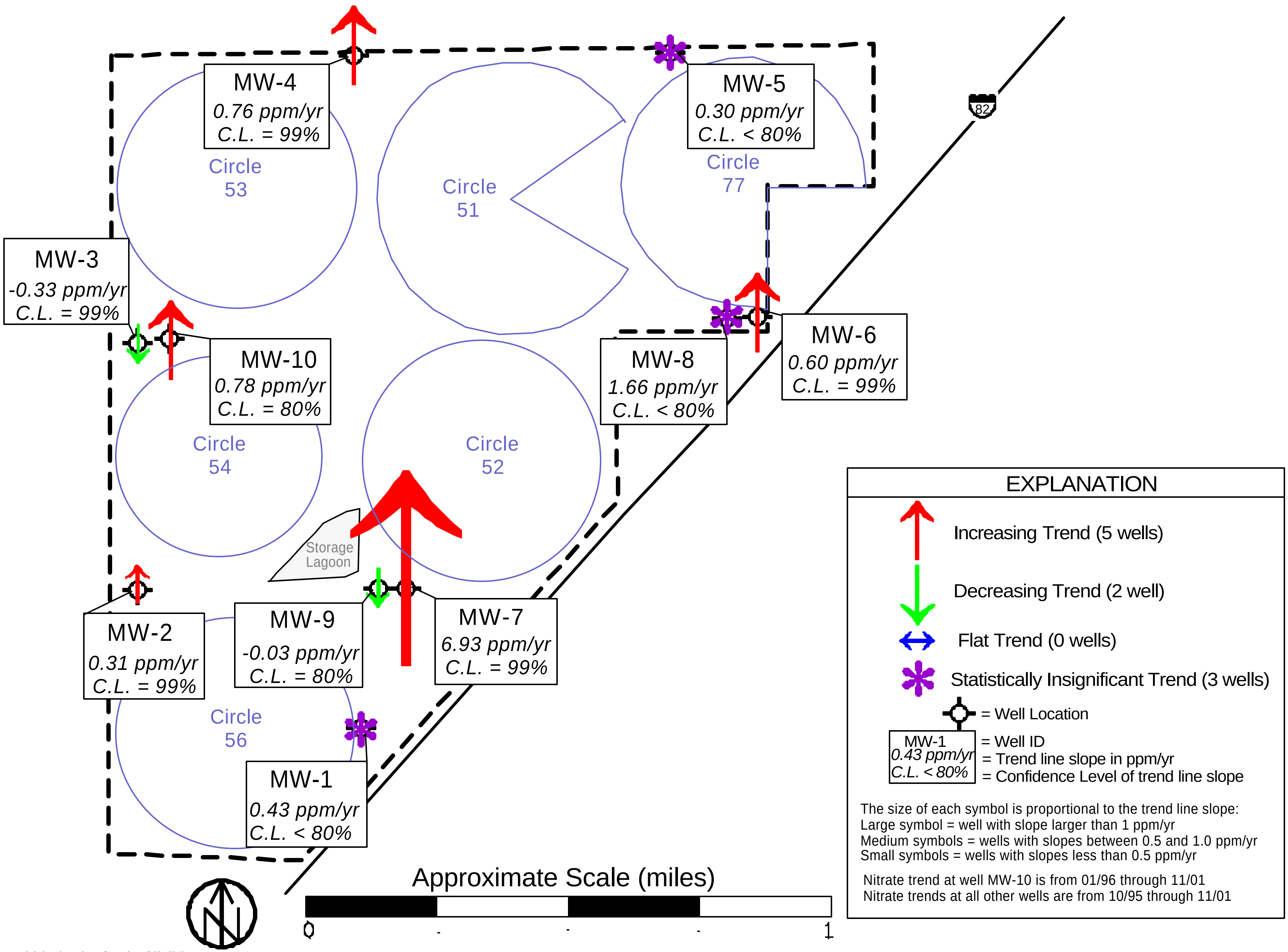


Figure 3-3
LOWESS Lines and Trend Lines Through Nitrate Data - Lamb-Weston North Farm
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



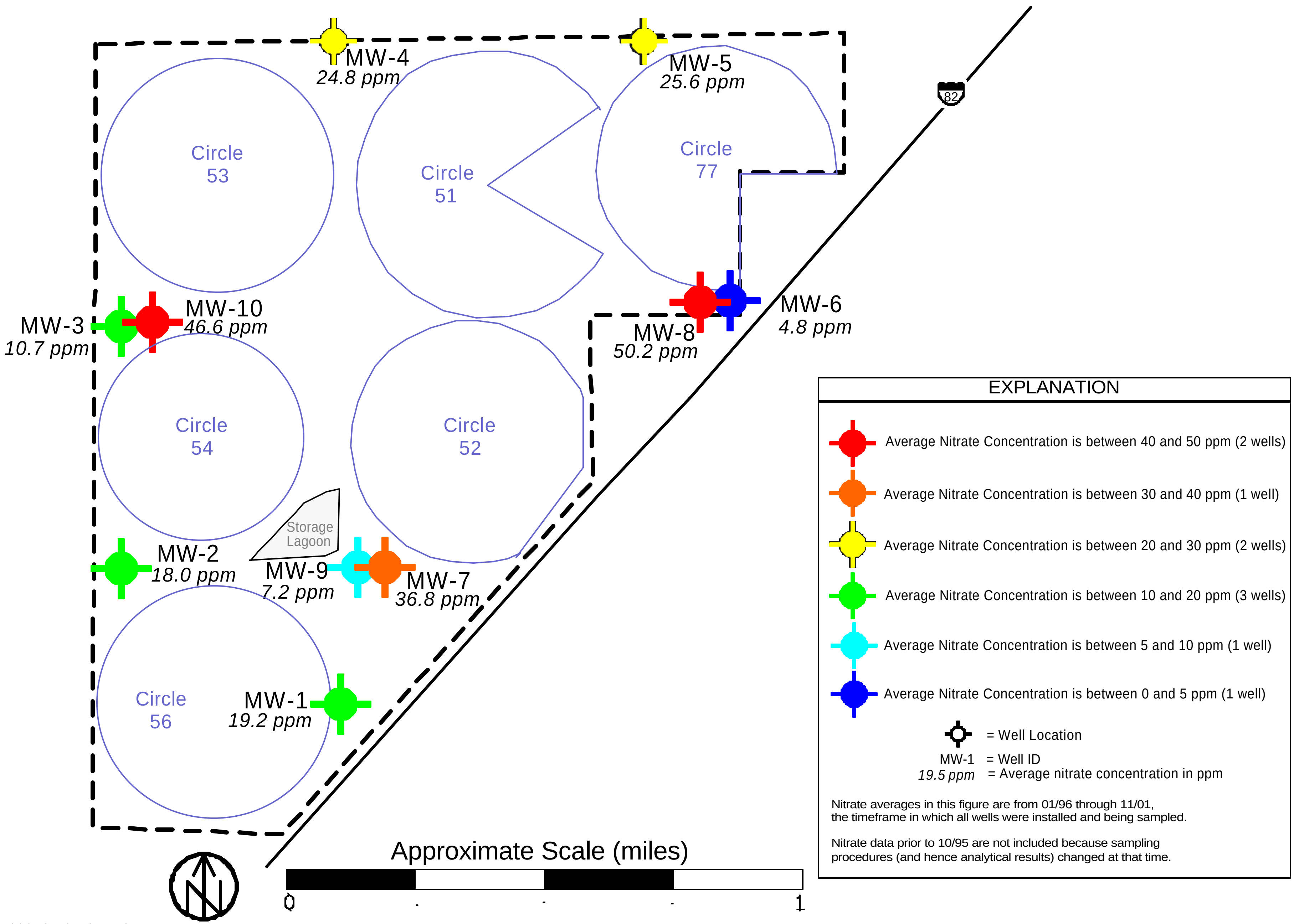
e: lub landapp l-w alltrend&lowess_nf.grf

Figure 3-4
Nitrate Trends - Lamb-Weston North Farm
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



e: lub landapp l-w nftrends.srf (01/04)

Figure 3-5
Average Nitrate Concentrations - Lamb-Weston North Farm
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA

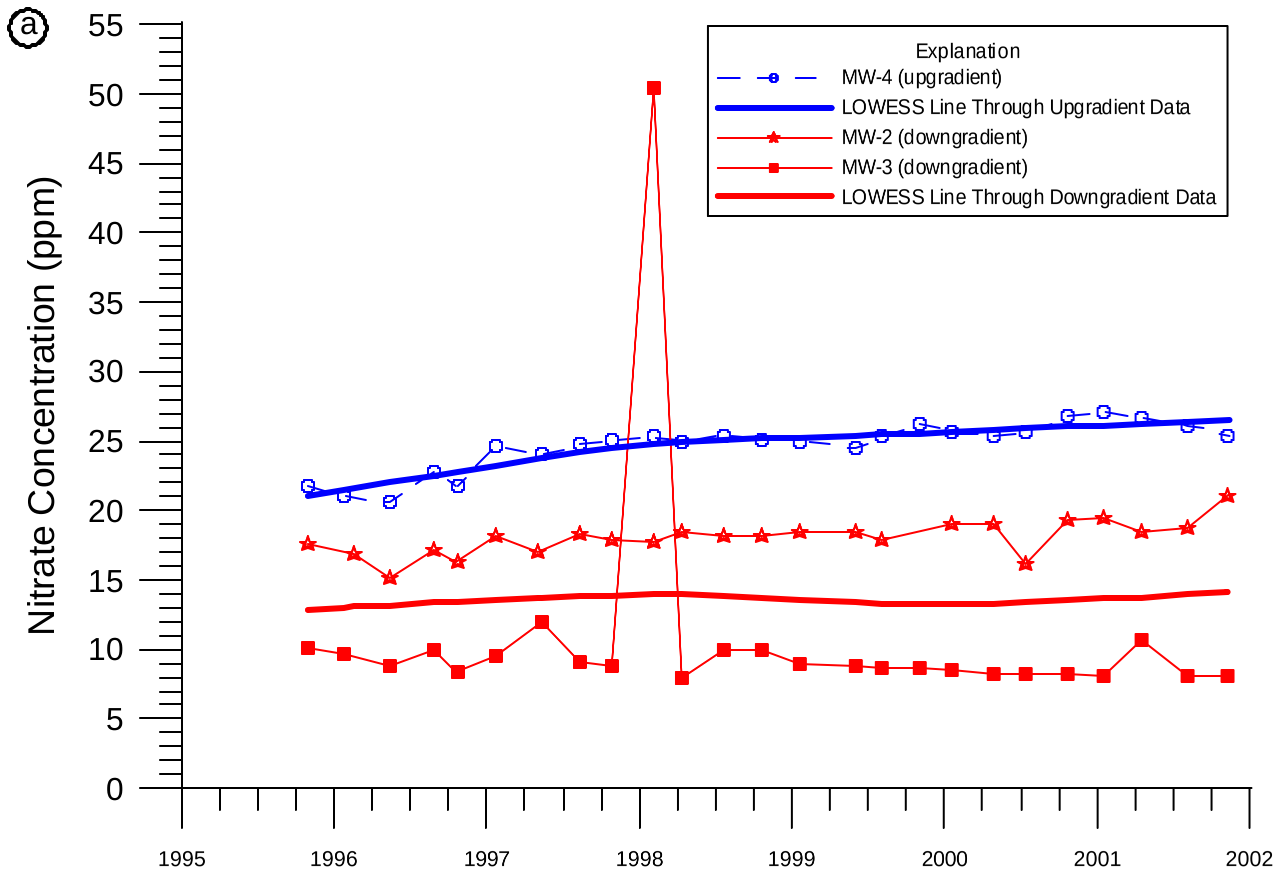


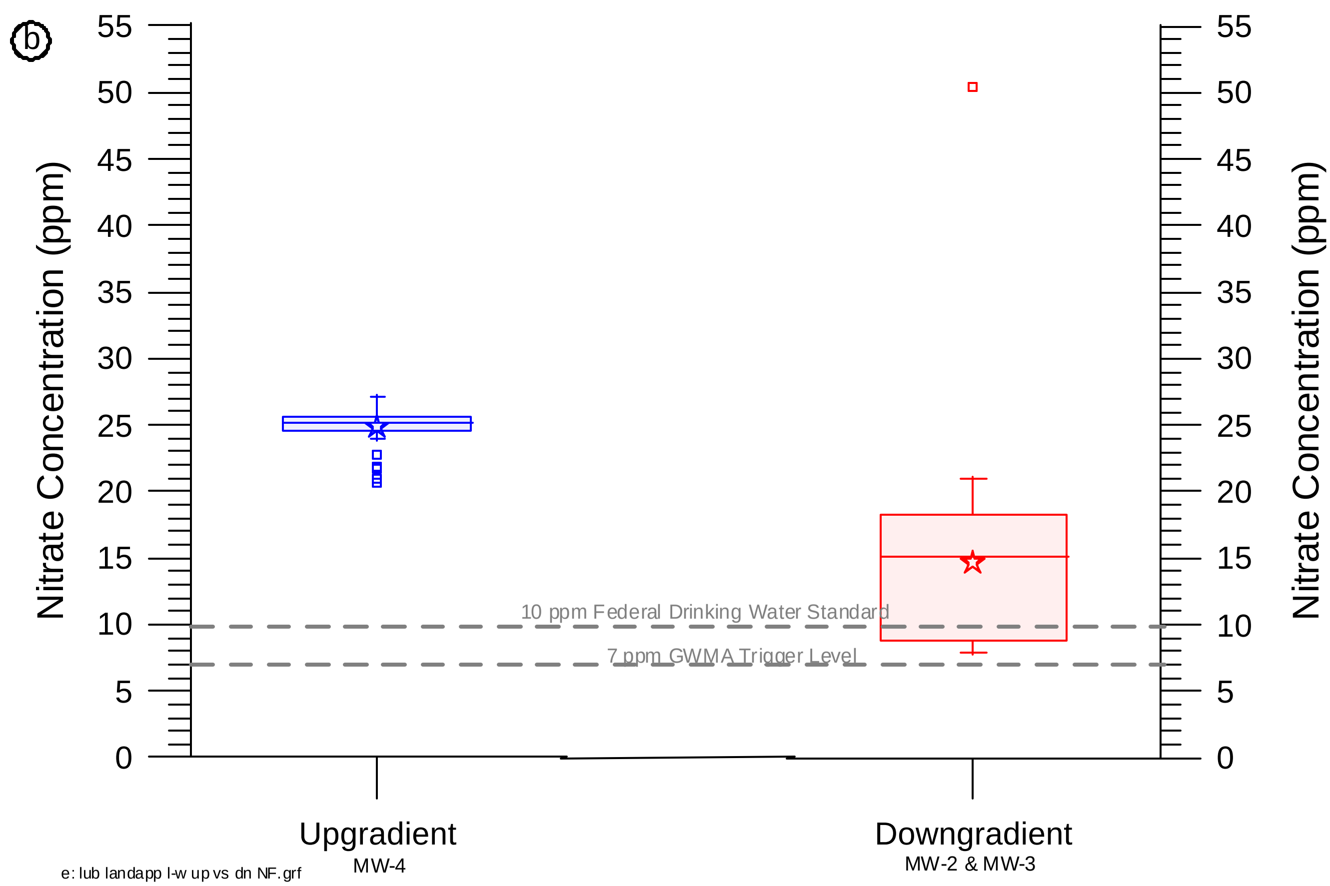
e: lub landapp l-w nfavgs.srf

Figure 3-6

Upgradient vs. Downgradient Nitrate Comparisons - Lamb-Weston North Farm

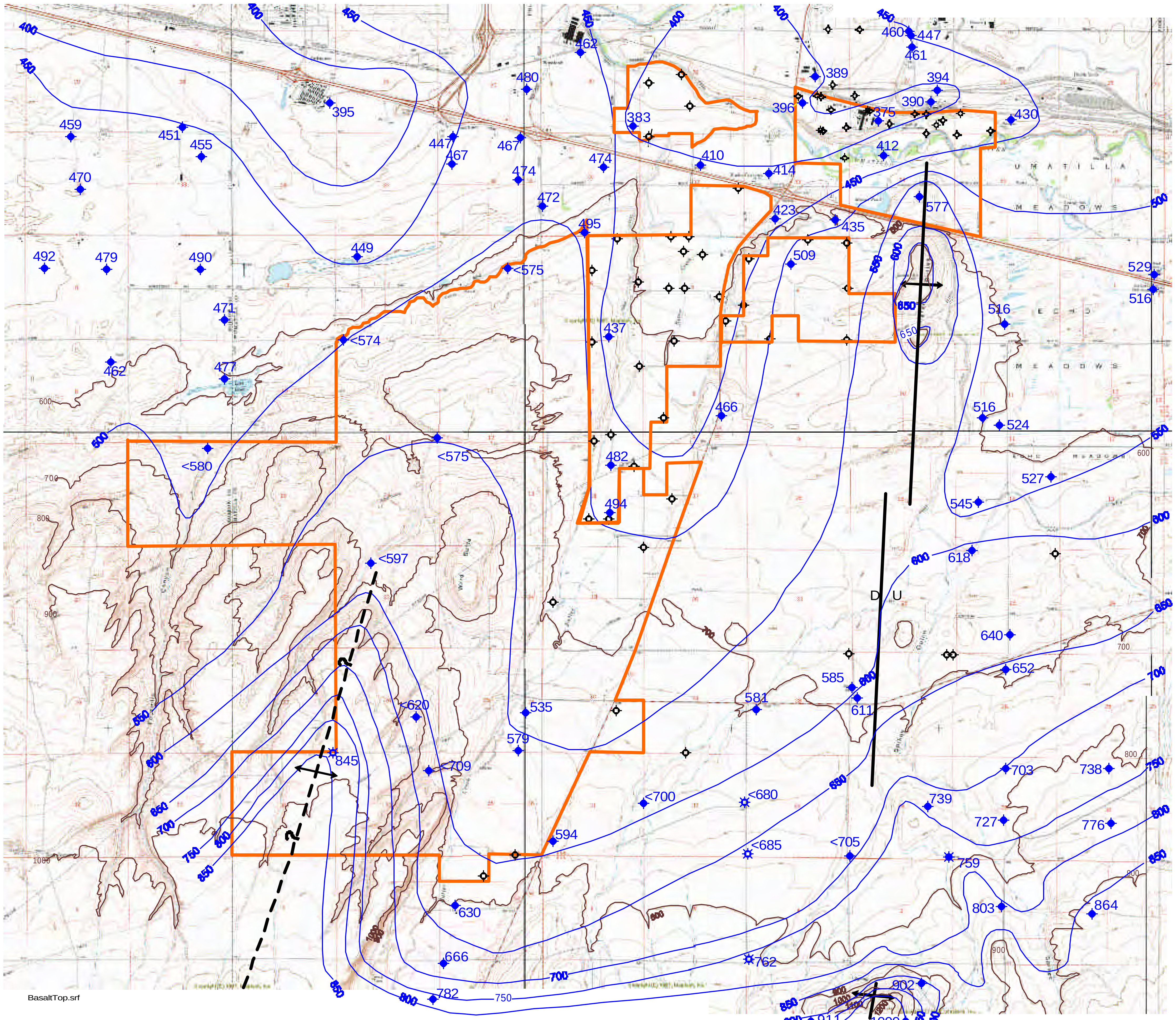
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA





e: lub landapp l-w up vs dn NF.grf

Figure 3-7
Basalt Surface Topography - Butter Creek Area
Trend Analysis of Food Processor
Land Application Sites
in the LUBGWMA



EXPLANATION

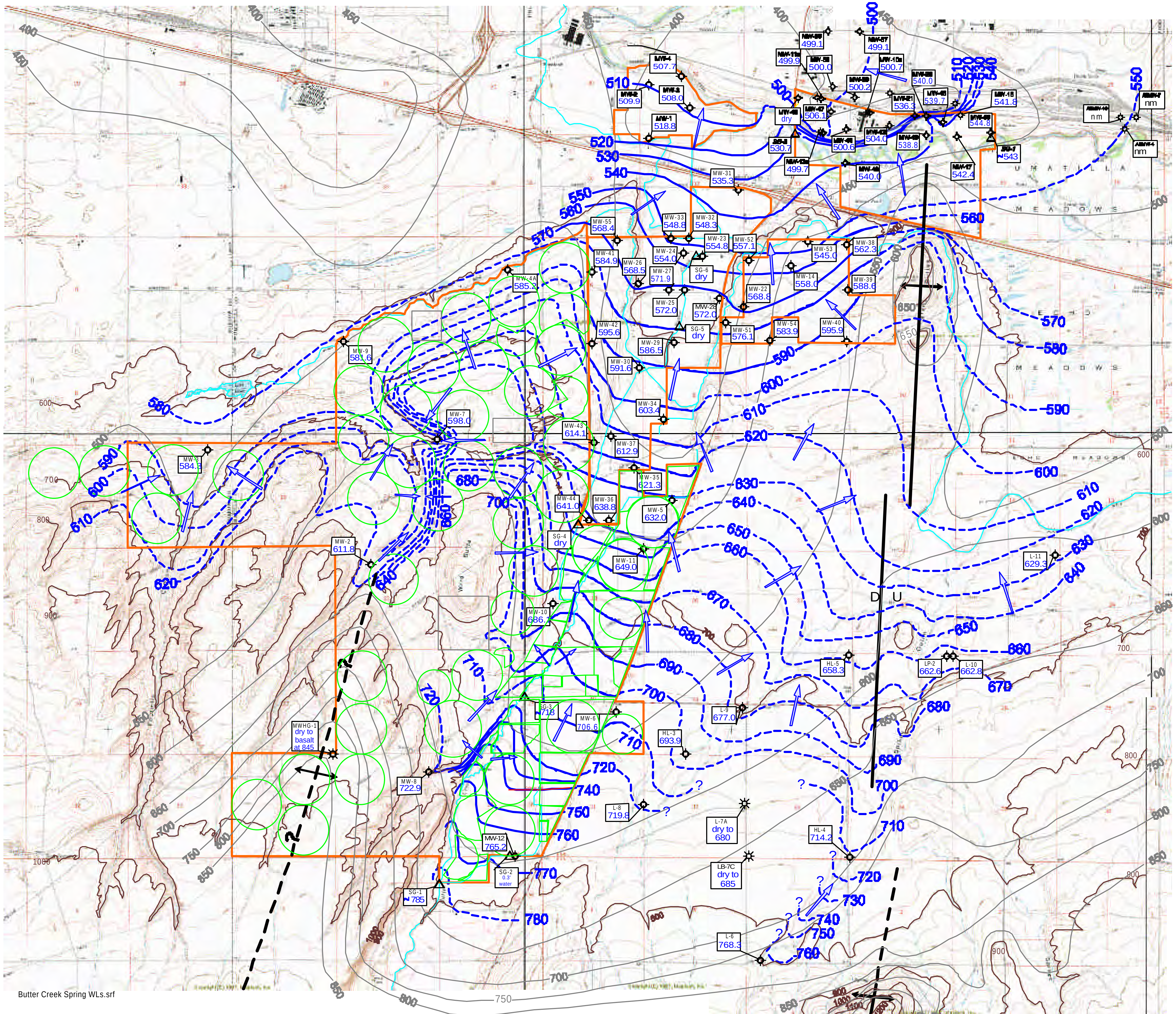
- = Location of Well Used To Contour Basalt Surface
- = Location of Well Not Used To Contour Basalt Surface
- = Location of Soil Boring Used To Contour Basalt Surface
- 650 = Basalt Surface Contour (Contour Interval = 50 ft)
- 600 = Land Surface Contour (600 to 1200 feet above mean sea level; contour interval = 100 ft)
- = Land Application Site Boundary
- = Service Anticline (from DEQ, et al., 1995)
- = Possible Anticline (from USGS, 1971)

  This feature has been mapped by others as an erosional feature.
- D U = Fault (from DEQ, et al., 1995)
  D indicates downthrown side
  U indicates upthrown side

Approximate Scale (miles)

0 1

Figure 3-8
Spring Water Table Elevations - Butter Creek Area
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



Butter Creek Spring WLs.srf

EXPLANATION

= Well Location

= Surface Water Gauge Location

= Well ID
= Water Level

= Dry Soil Boring Location

620 = Water Table Contour dashed where inferred (contour interval = 10 ft)

= Horizontal Groundwater Flow Direction (perpendicular to contours)

600 = Basalt Surface Contour (contour interval = 50 ft)

700 = Land Surface Contour (600 to 1200 feet above mean sea level; contour interval = 100 ft)

= Land Application Site Boundary

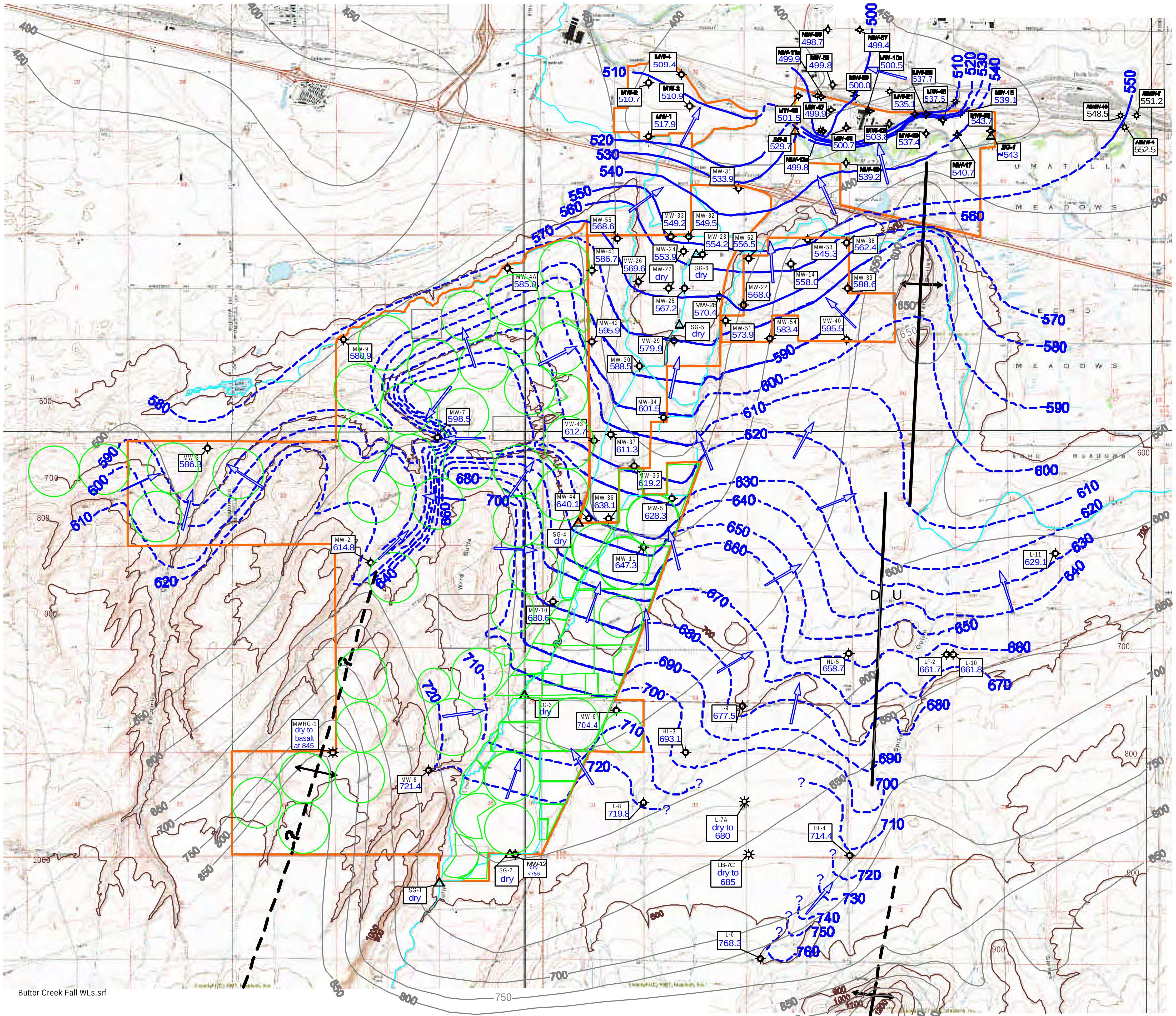
Groundwater elevation contours are based on the water levels measured at the alluvial aquifer wells, land surface topography, location of surface water features, the elevation of the underlying basalt surface, and the migration of diesel contamination at Hinkle Railyard.

Groundwater elevations were measured at:
SnackCorp on April 8, 2002
Simplot sites on May 15 & 16, 2002
Madison Ranch on April 30 & May 1, 2002.

Approximate Scale (miles)

0 1

Figure 3-9
Fall Water Table Elevations - Butter Creek Area
Trend Analysis of Food Processor
Land Application Sites
in the LUBGWMA



EXPLANATION

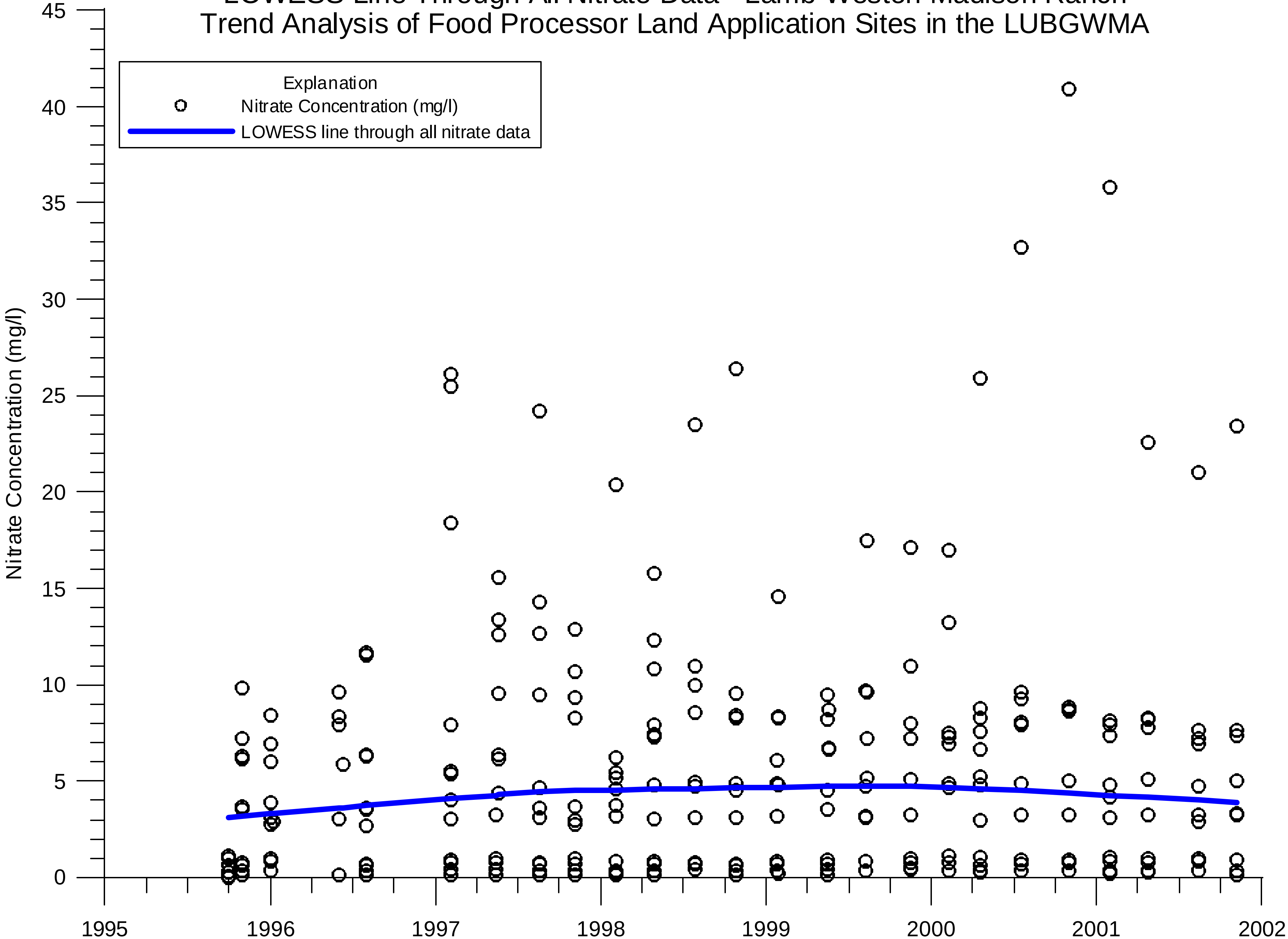
= Well Location
= Surface Water Gauge Location
= Well ID
= Water Level
= Dry Soil Boring Location
620 = Water Table Contour dashed where inferred (contour interval = 10 ft)
= Horizontal Groundwater Flow Direction (perpendicular to contours)
600 = Basalt Surface Contour (contour interval = 50 ft)
700 = Land Surface Contour (600 to 1200 feet above mean sea level; contour interval = 100 ft)
= Land Application Site Boundary

Groundwater elevation contours are based on the water levels measured at the alluvial aquifer wells, land surface topography, location of surface water features, the elevation of the underlying basalt surface, and the migration of diesel contamination at Hinkle Railyard.

Groundwater elevations were measured at:
SnackCorp on October 2, 2002
Simplot sites on October 21 & 22, 2002
Hinkle Railyard on November 4, 2002
Madison Ranch on November 19 & 20, 2002.

Approximate Scale (miles)
0 1

Figure 3-10
LOWESS Line Through All Nitrate Data - Lamb-Weston Madison Ranch
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



e: lub landapp l-w all data mr.grf

Figure 3-11

LOWESS Lines and Trend Lines Through Nitrate Data - Lamb-Weston Madison Ranch

Trend Analysis of Food Processor Land Application Sites in the LUBGWMA

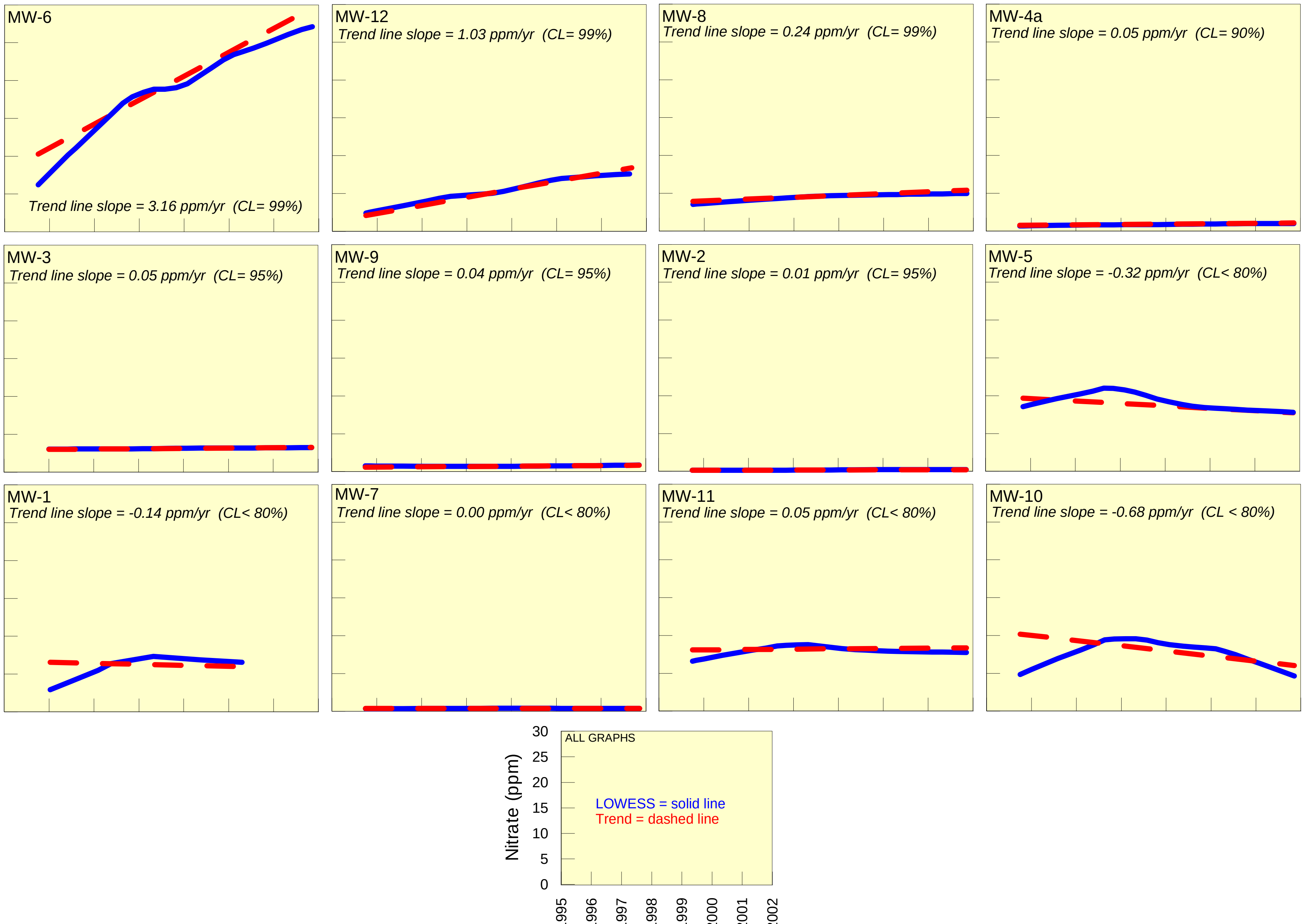
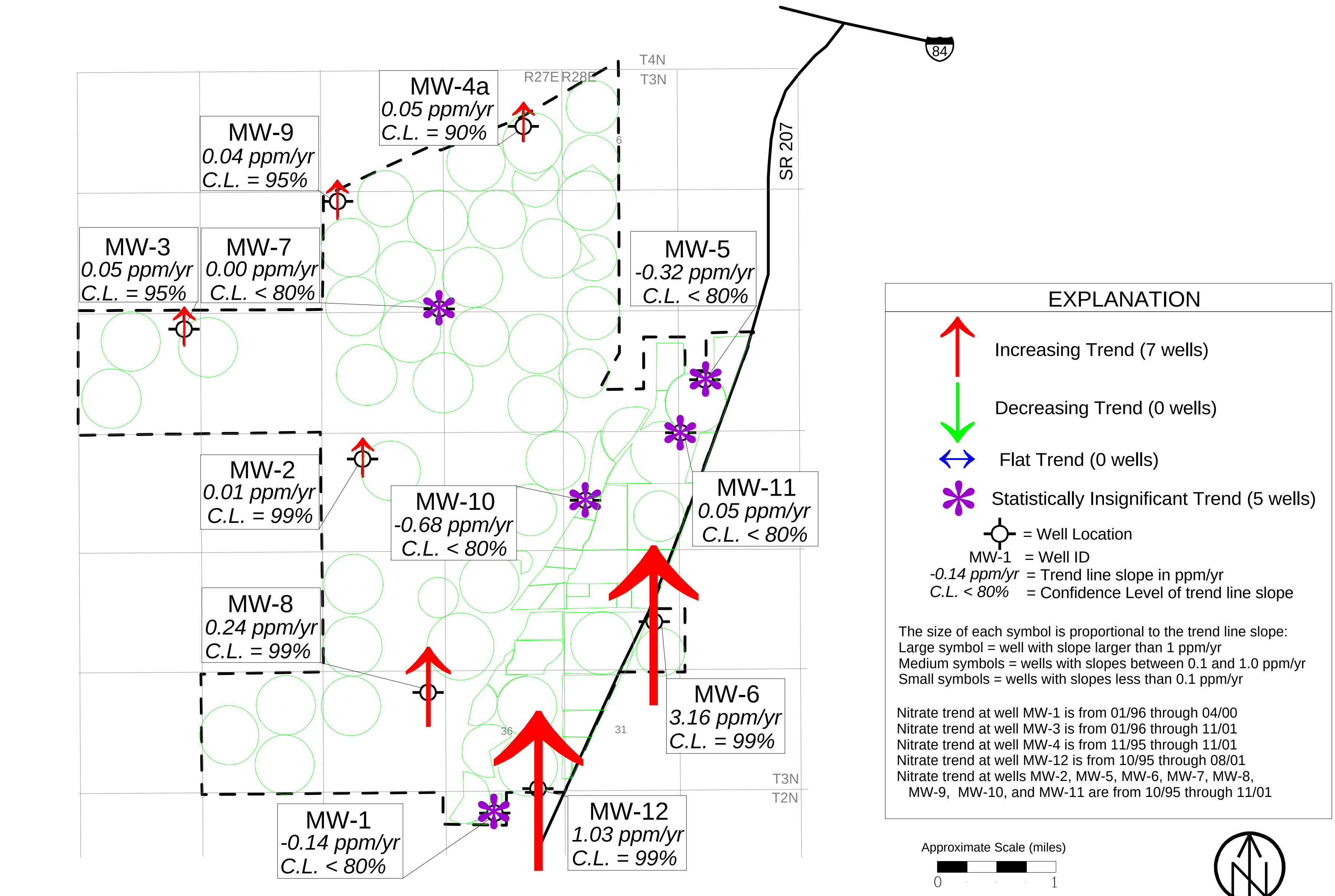
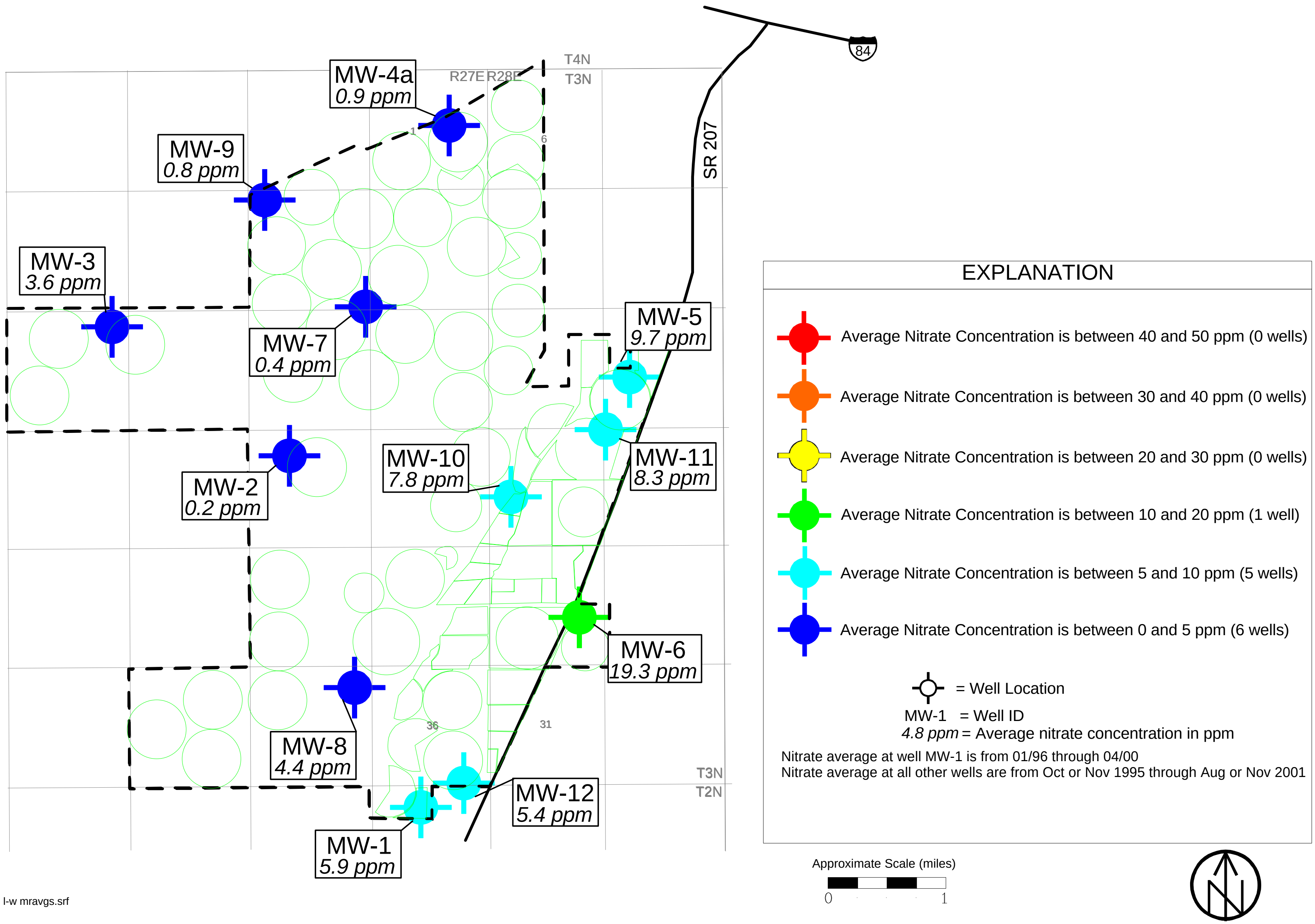


Figure 3-12
Nitrate Trends - Lamb-Weston Madison Ranch
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



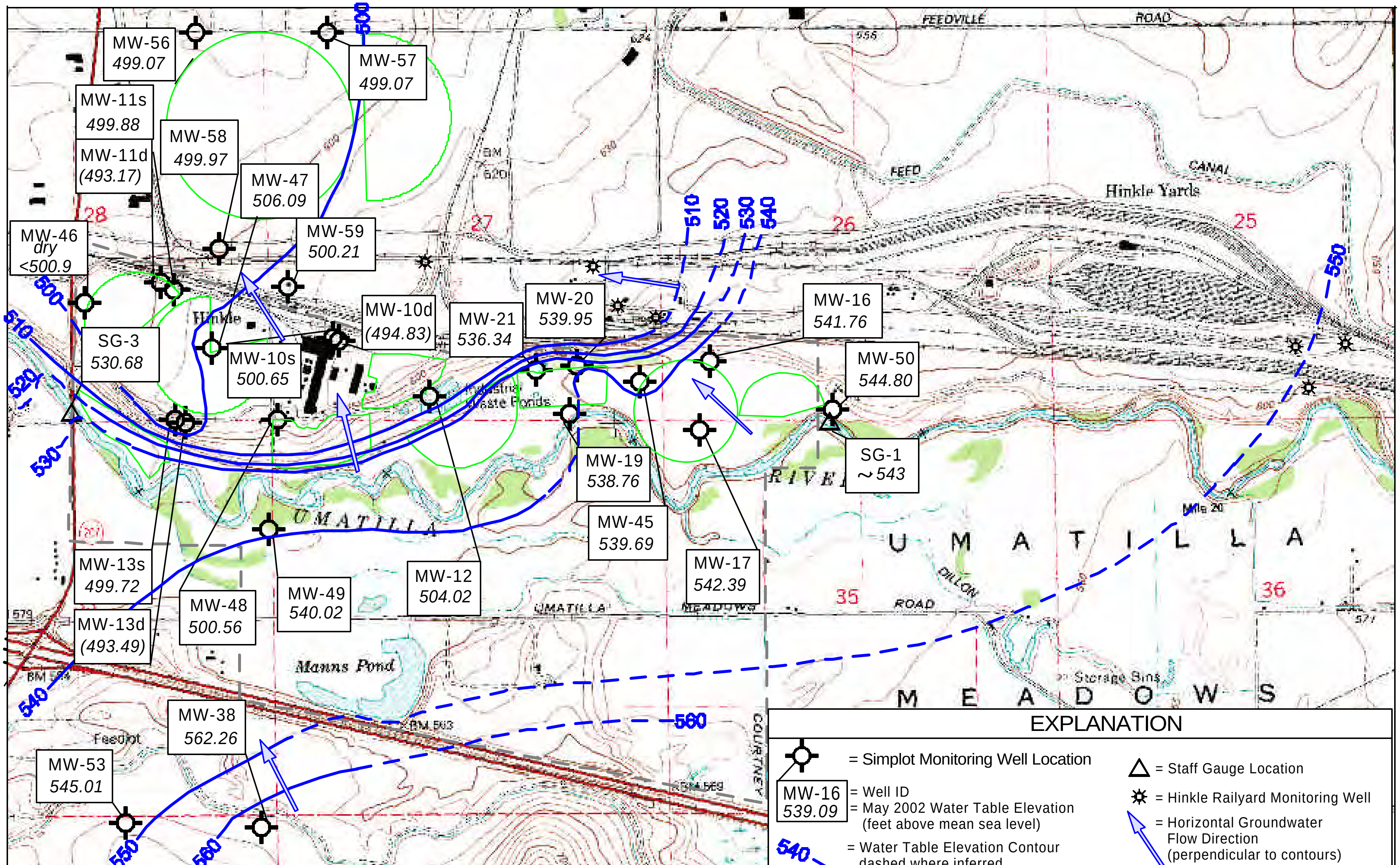
e: lub landapp l-w mrtrends.srf (01/04)

Figure 3-13
Average Nitrate Concentrations - Lamb-Weston Madison Ranch
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



e: lub landapp l-w mravgs.srf

Figure 4-1
May 2002 Water Table Elevations - Simplot Plant Site
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



EXPLANATION

= Simplot Monitoring Well Location

MW-16 = Well ID

539.09 = May 2002 Water Table Elevation (feet above mean sea level)

540 = Water Table Elevation Contour dashed where inferred (contour elevation = 10 feet)

= Staff Gauge Location

= Hinkle Railyard Monitoring Well

= Horizontal Groundwater Flow Direction (perpendicular to contours)

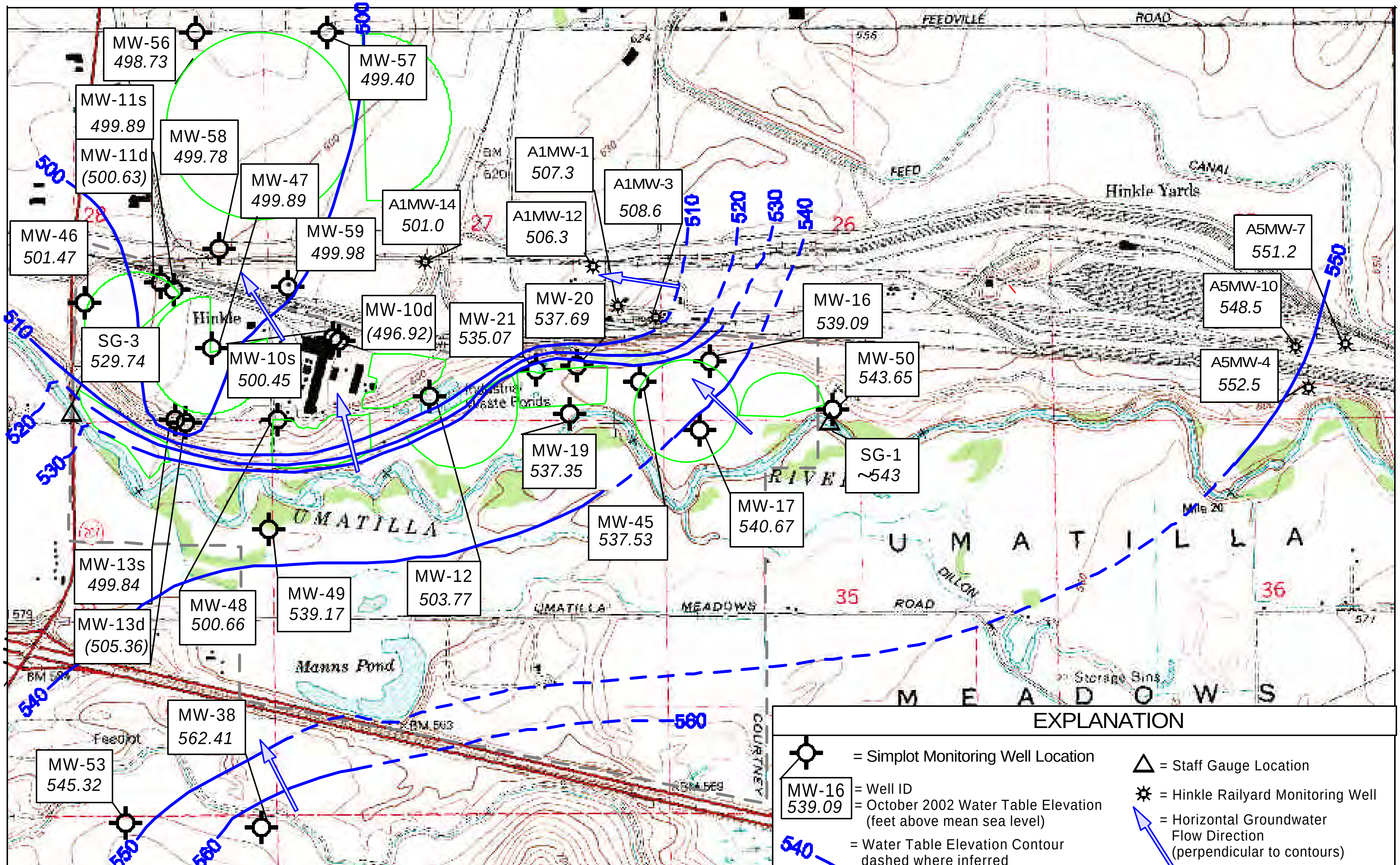
Notes:
(1) Groundwater elevation contours are based on the water levels measured at the unconfined alluvial aquifer wells, land surafce topography, location of surface water features, the elevation of the underlying basalt surface, and the migration of diesel contamination at Hinkle Railyard.
(2) Water levels in parentheses are in a deeper semi-confined alluvial aquifer and are not contoured.
(3) Due to differing survey datums used at Simplot and at Hinkle Railyard, water levels from Hinkle wells were adjusted by subtracting 3.3 feet to better fit with the elevations based on the Simplot survey datum.

Approximate Scale (miles)

0 1

e: lub landapp simplot Spring2002WLs.srf

Figure 4-2
October 2002 Water Table Elevations - Simplot Plant Site
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



Approximate Scale (miles)

0 - - - 1

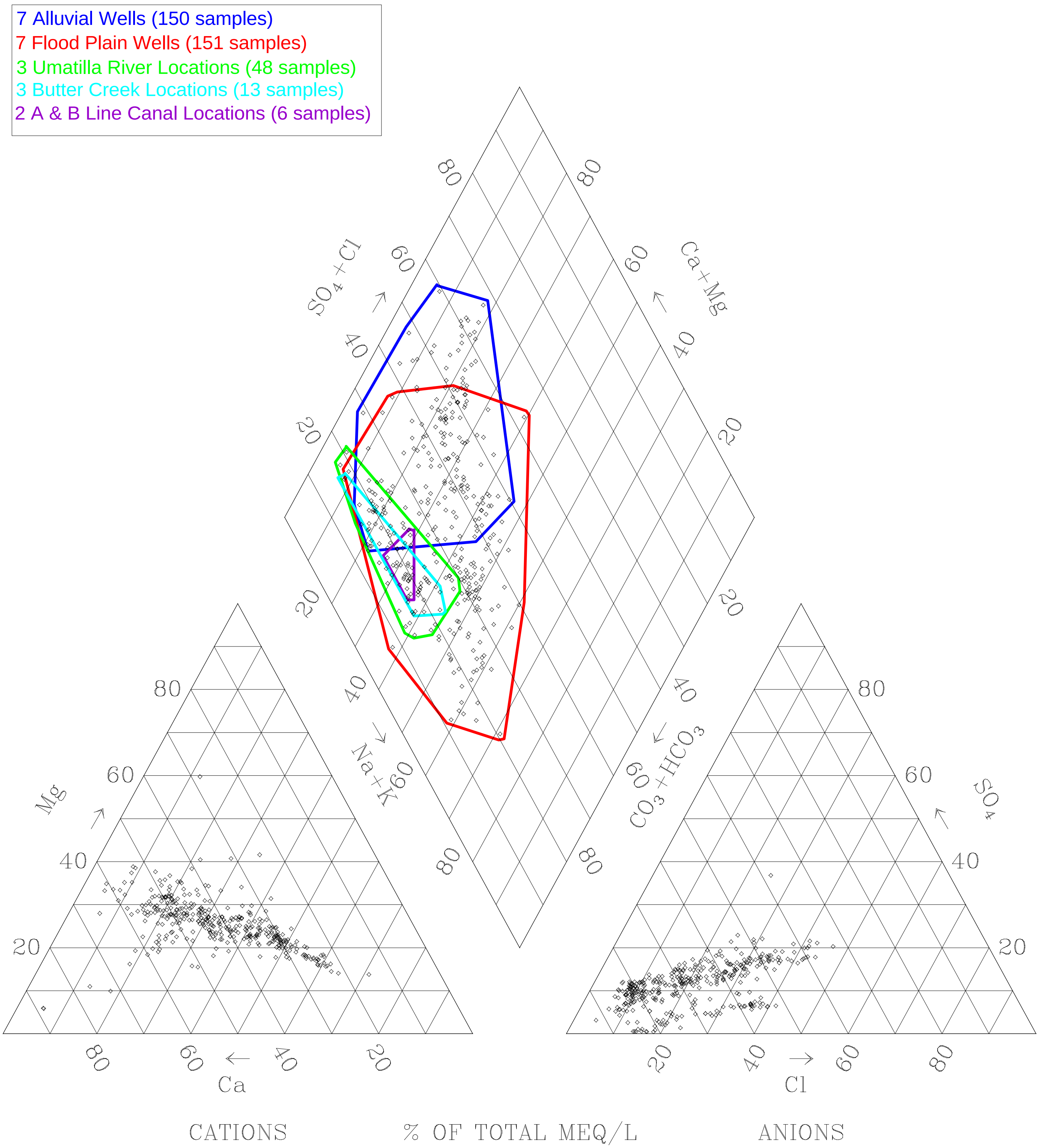
e: lub landapp simplot Fall2002WLs.srf

EXPLANATION

- = Simplot Monitoring Well Location
- MW-16 = Well ID
- 539.09 = October 2002 Water Table Elevation (feet above mean sea level)
- 540 = Water Table Elevation Contour dashed where inferred (contour elevation = 10 feet)
- = Staff Gauge Location
- = Hinkle Railyard Monitoring Well
- = Horizontal Groundwater Flow Direction (perpendicular to contours)

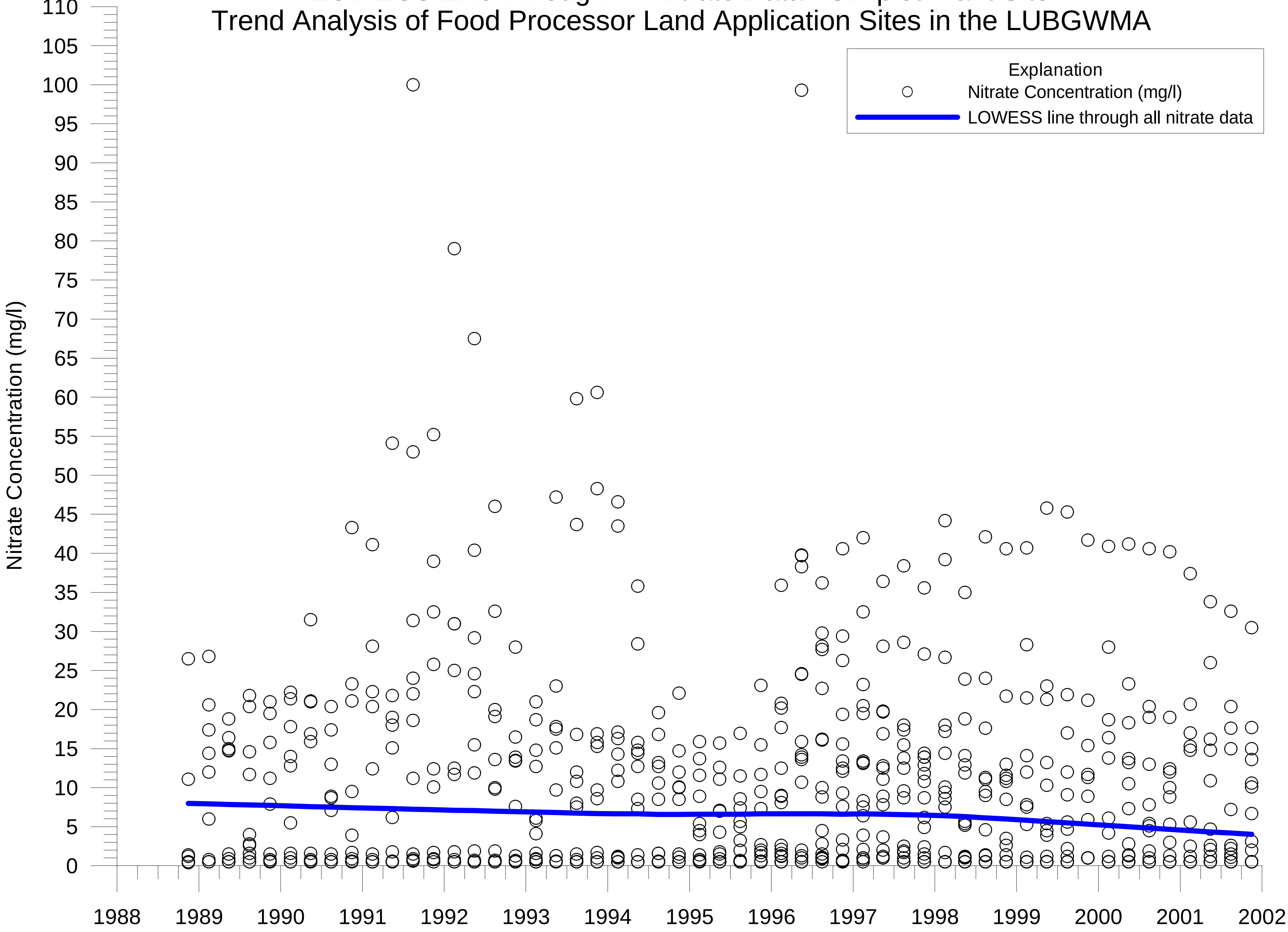
Notes:
(1) Groundwater elevation contours are based on the water levels measured at the unconfined alluvial aquifer wells, land surfce topography, location of surface water features, the elevation of the underlying basalt surface, and the migration of diesel contamination at Hinkle Railyard.
(2) Water levels in parentheses are in a deeper semi-confined alluvial aquifer and are not contoured.
(3) Due to differing survey datums used at Simplot and at Hinkle Railyard, water levels from Hinkle wells were adjusted by subtracting 3.3 feet to better fit with the elevations based on the Simplot survey datum.

Figure 4-3
Piper Diagram - Simplot Plant Site
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



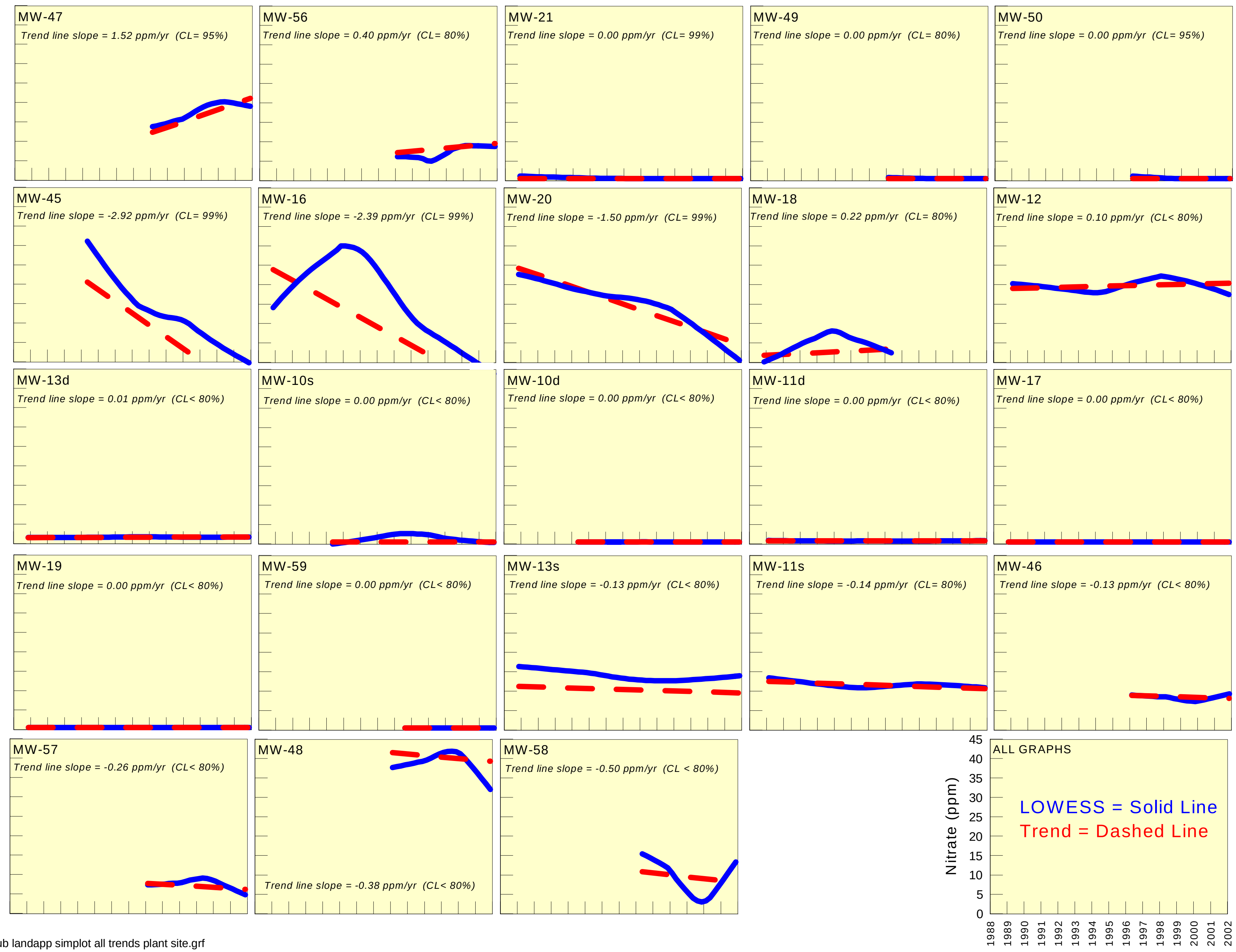
e: lub landapp simplot piper.srf

Figure 4-4
LOWESS Line Through All Nitrate Data - Simplot Plant Site
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



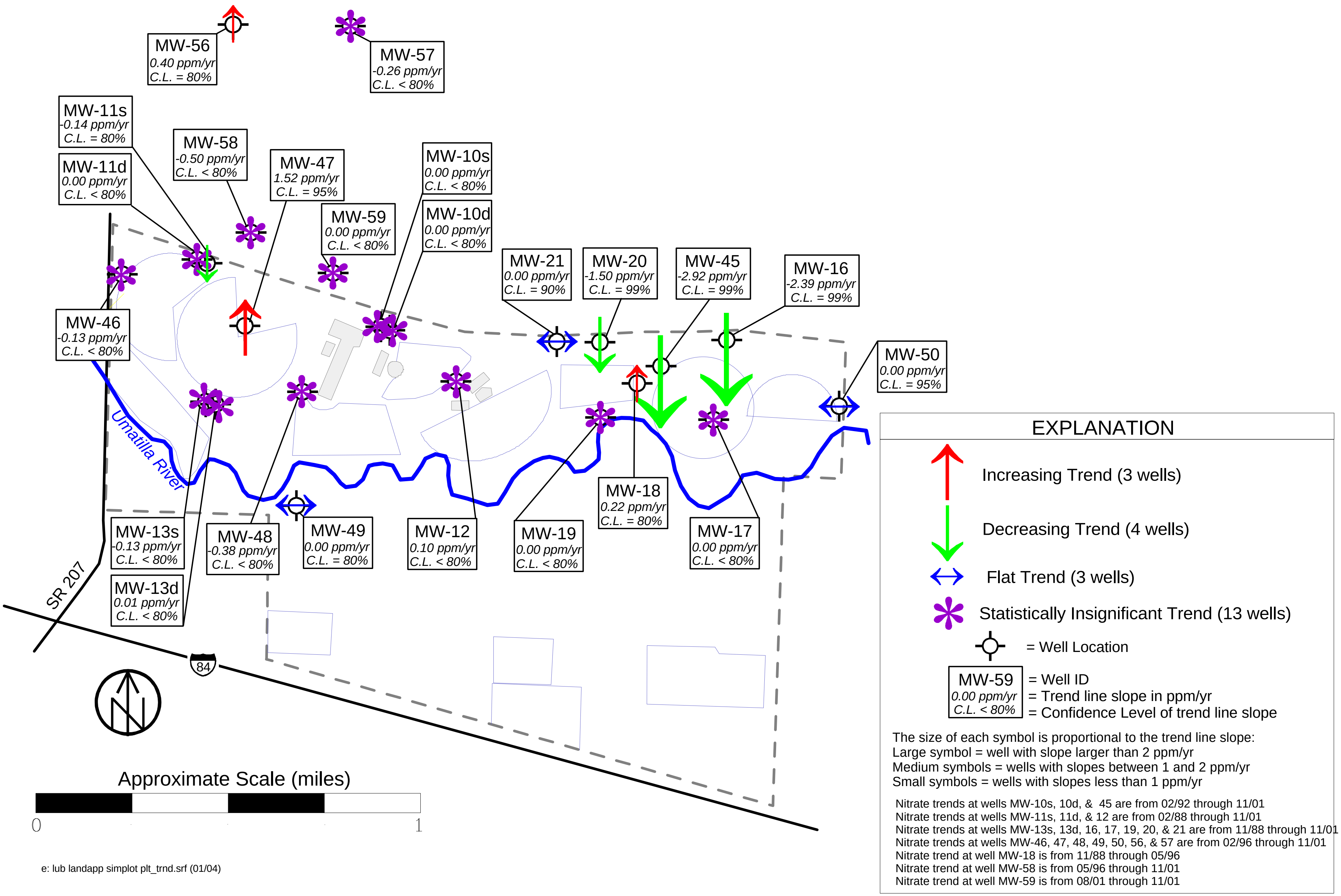
e: lub landapp simplot all data plant site.grf

Figure 4-5
LOWESS Lines and Trend Lines Through Nitrate Data - Simplot Plant Site
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



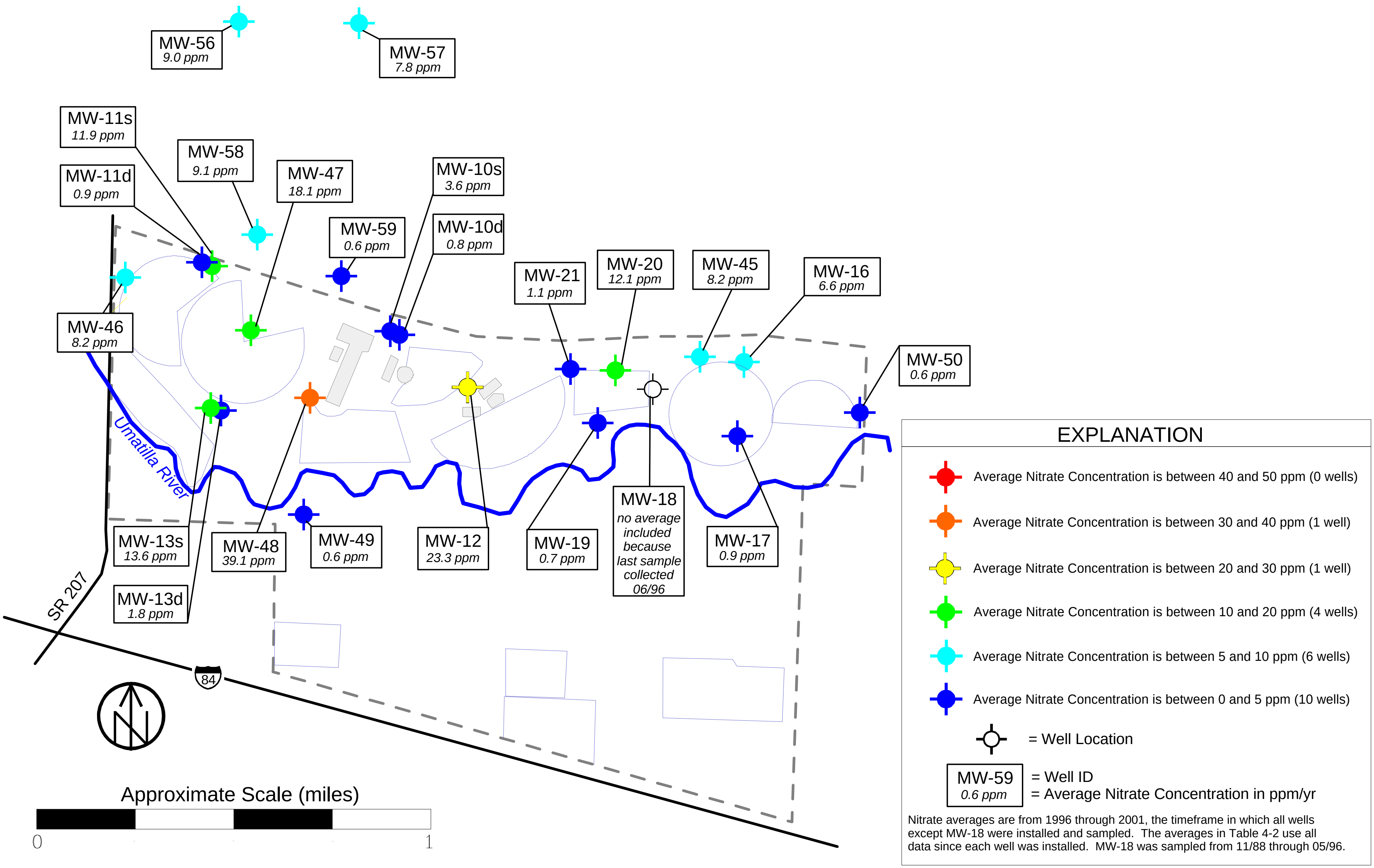
e: lub landapp simplot all trends plant site.grf

Figure 4-6
Nitrate Trends - Simplot Plant Site
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



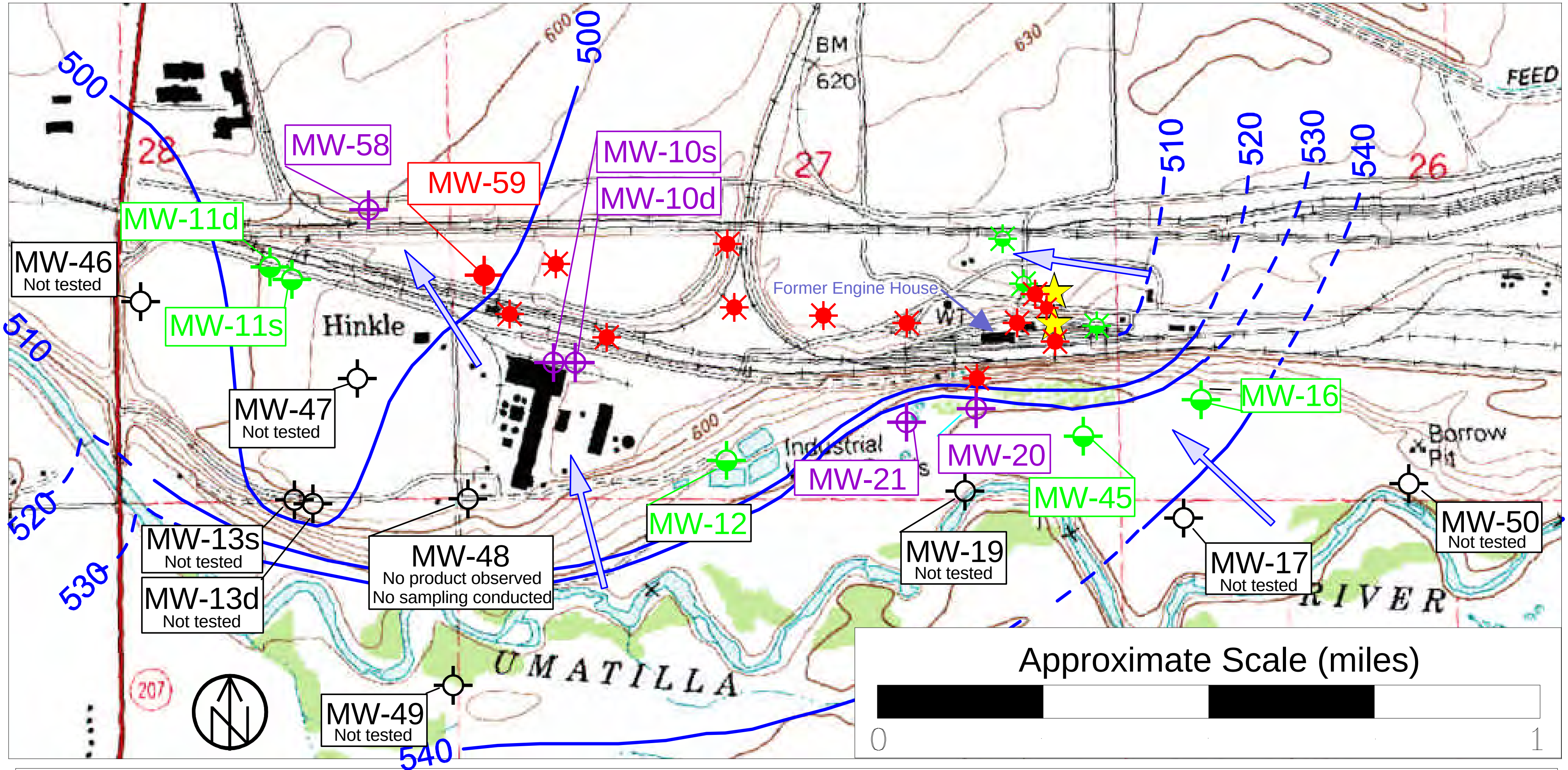
e: lub landapp simplot plt_trnd.srf (01/04)

Figure 4-7
Average Nitrate Concentrations - Simplot Plant Site
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



e: lub landapp simplot plt_averages.srf

Figure 4-8
Locations of Diesel-Related Impacts Near Simplot Plant Site Vicinity
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



EXPLANATION

= Simplot Monitoring Well Location

MW-10s = Well ID

= Hinkle Rail Yard Monitoring Well

= Horizontal Groundwater Flow Direction (perpendicular to contours)

540 = October 2002 Water Table Elevation Contour dashed where inferred (contour elevation = 10 feet)

= Presumed sources of diesel contamination (i.e, the former diesel platform, former underground storage tanks, and potentially a current above ground storage tank)

Well Symbols are:

BLACK for Simplot wells that have not been tested for diesel-related impacts.

RED for Simplot or Hinkle wells that have had dissolved petroleum product and/or floating petroleum product.

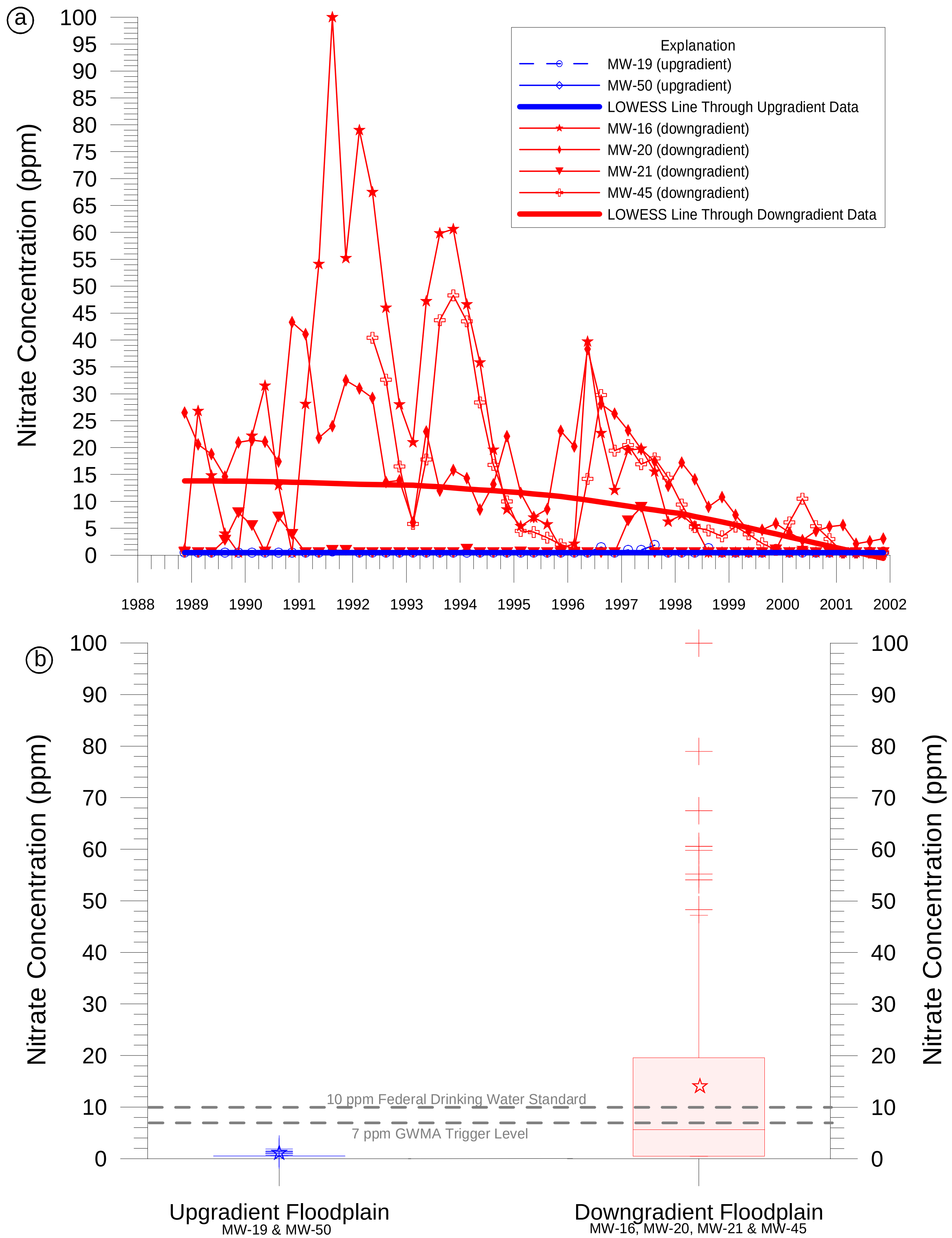
PURPLE for Simplot wells that have had petroleum odor and/or dissolved petroleum product.

GREEN for Simplot or Hinkle wells that have been tested and showed no evidence of diesel-related product.

Note: Some wells have never been measured for free product and/or sampled for diesel impacts, while others have been measured and/or sampled multiple times. The presence or absence of diesel impacts at individual wells has varied over time. This figure includes the "worst case" result from each well.

e: lub landapp simplot diesel hits3.srf

Figure 4-9
Upgradient vs. Downgradient Nitrate Comparisons - Simplot Plant Site Floodplain Wells
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA

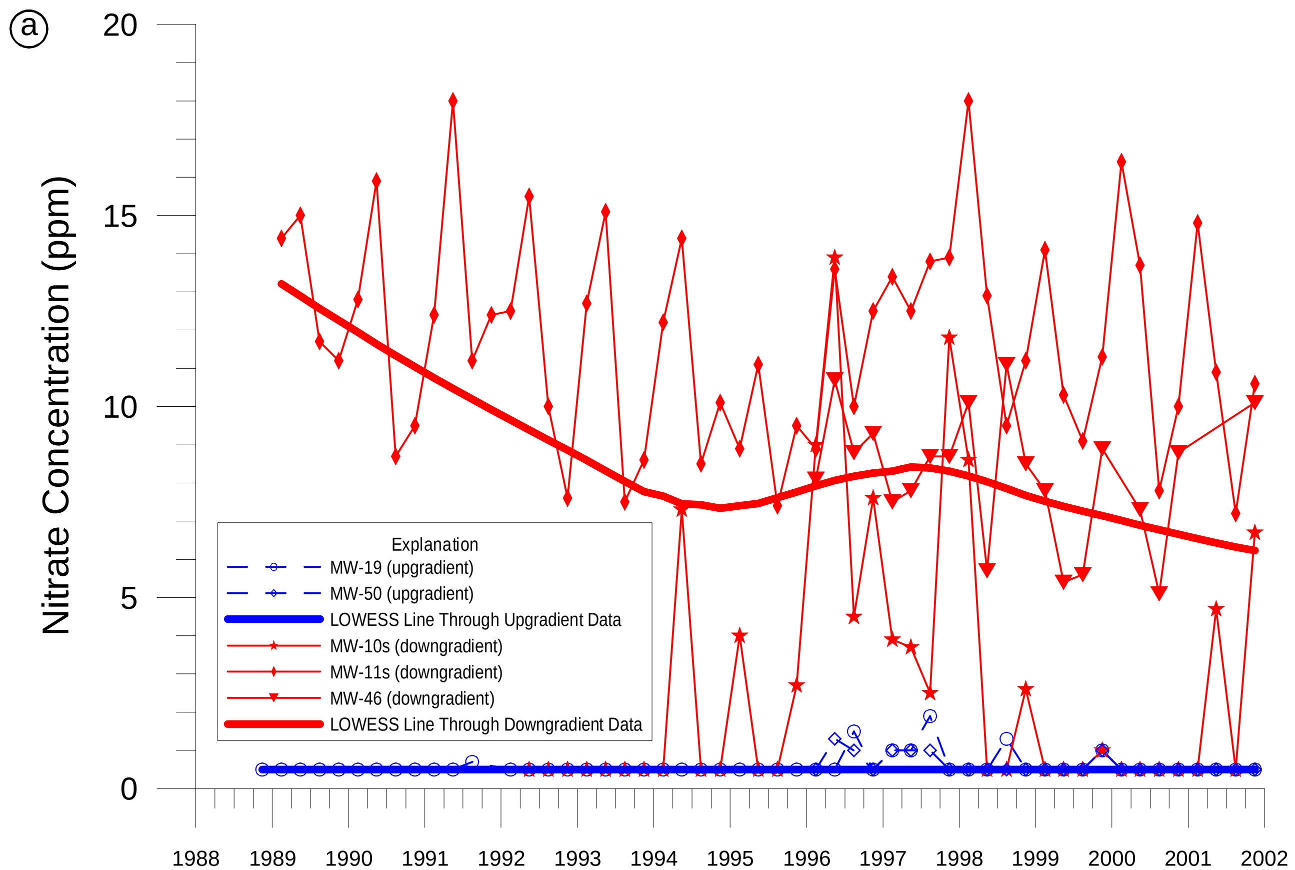


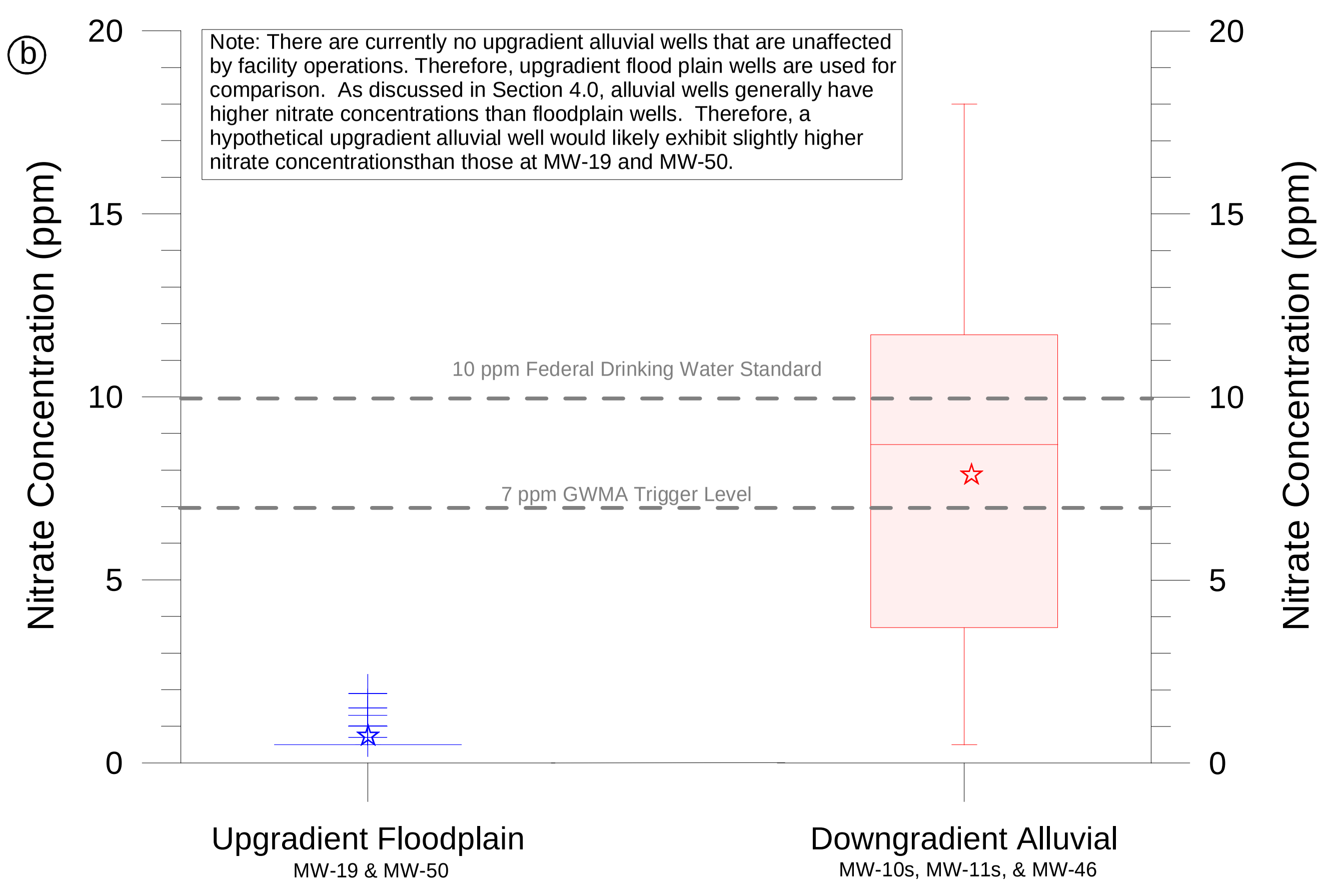
e: lub landapp simplot up vs dn plant fp.grf

Figure 4-10

Upgradient vs. Downgradient Nitrate Comparisons - Simplot Plant Site Alluvial Wells

Trend Analysis of Food Processor Land Application Sites in the LUBGWMA





e: lub landapp simplot up vs dn plant al.grf

Figure 4-11
Fourth Quarter 2001 Groundwater Elevations - Simplot Terrace Site
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA

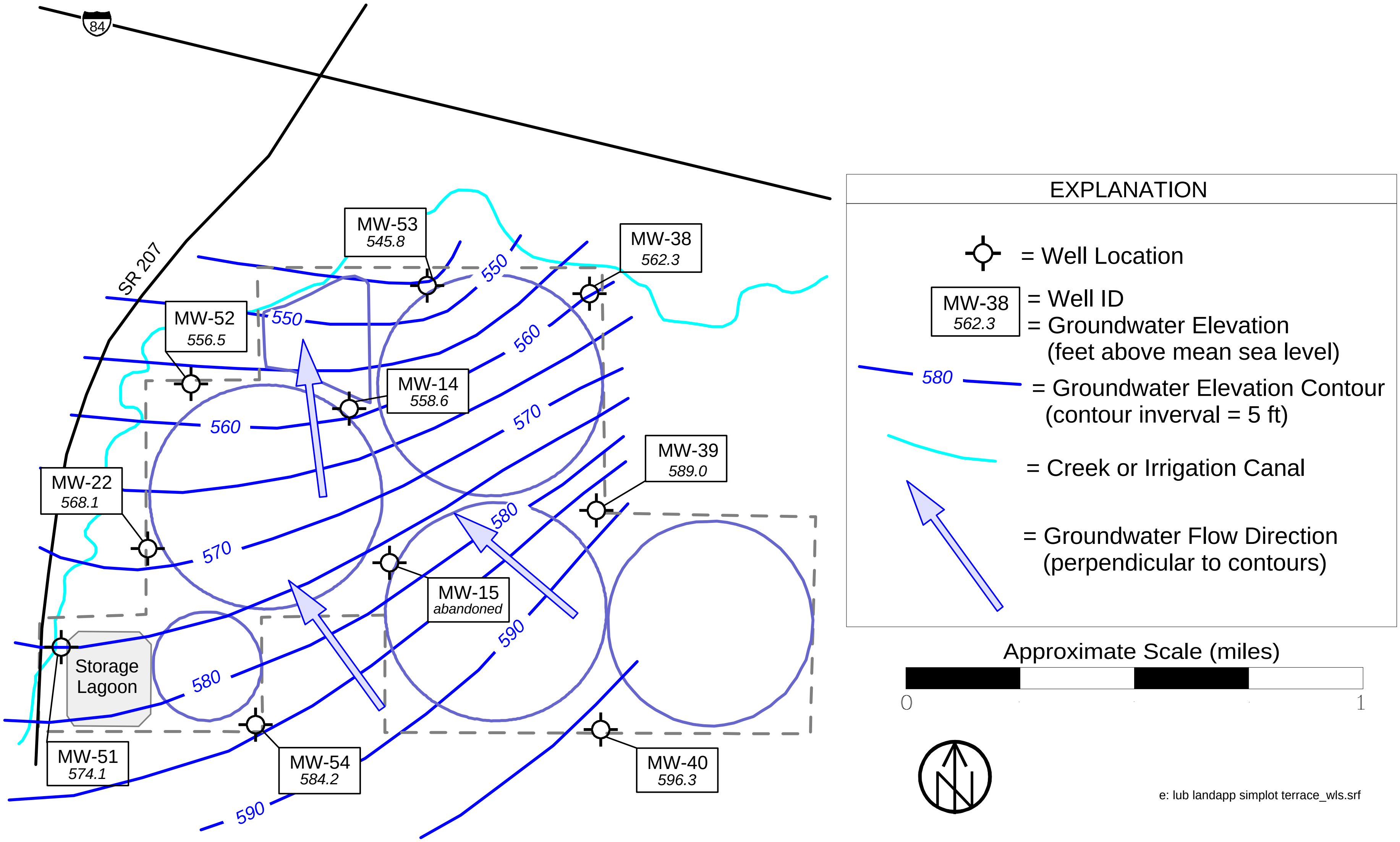
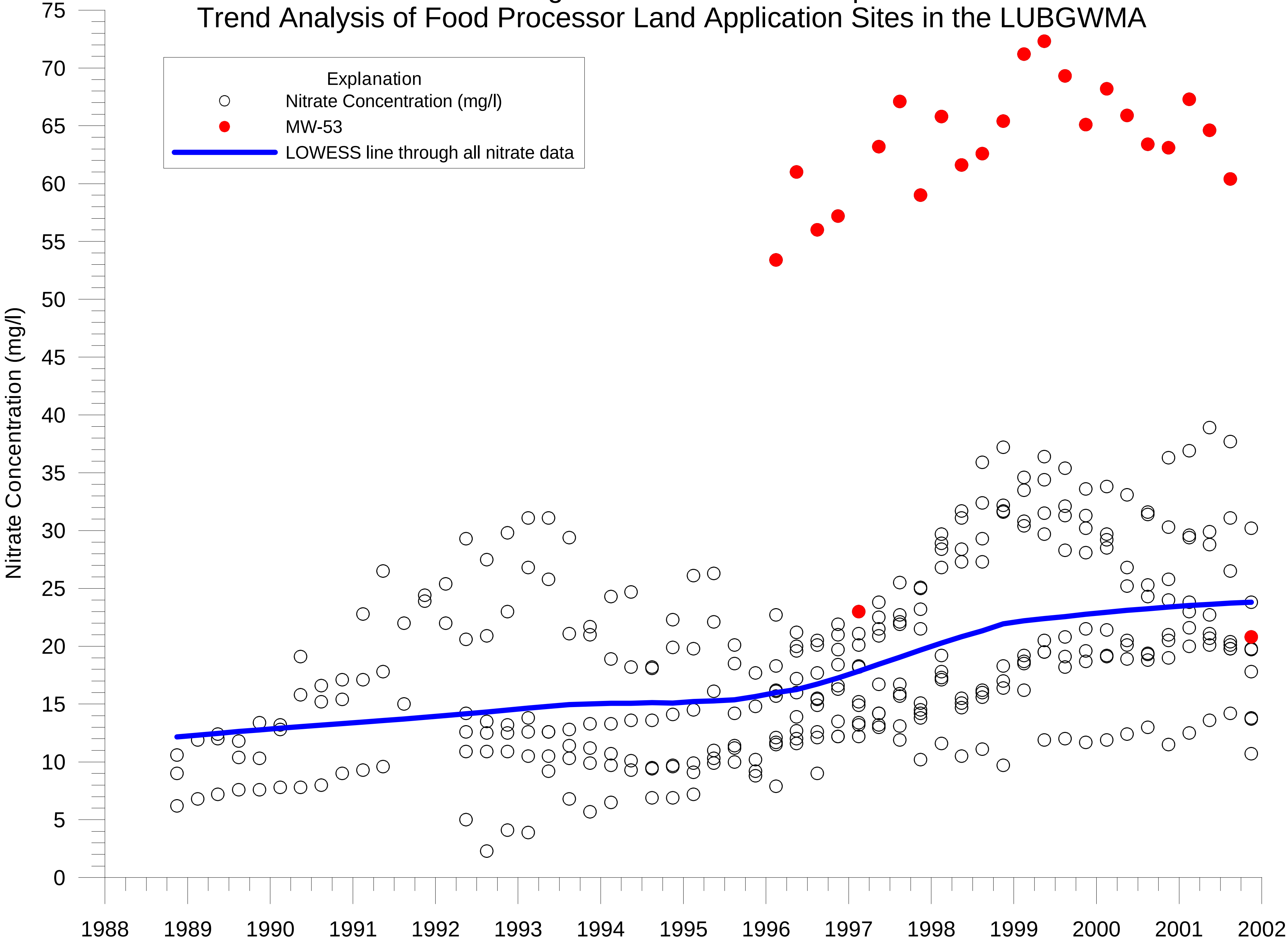
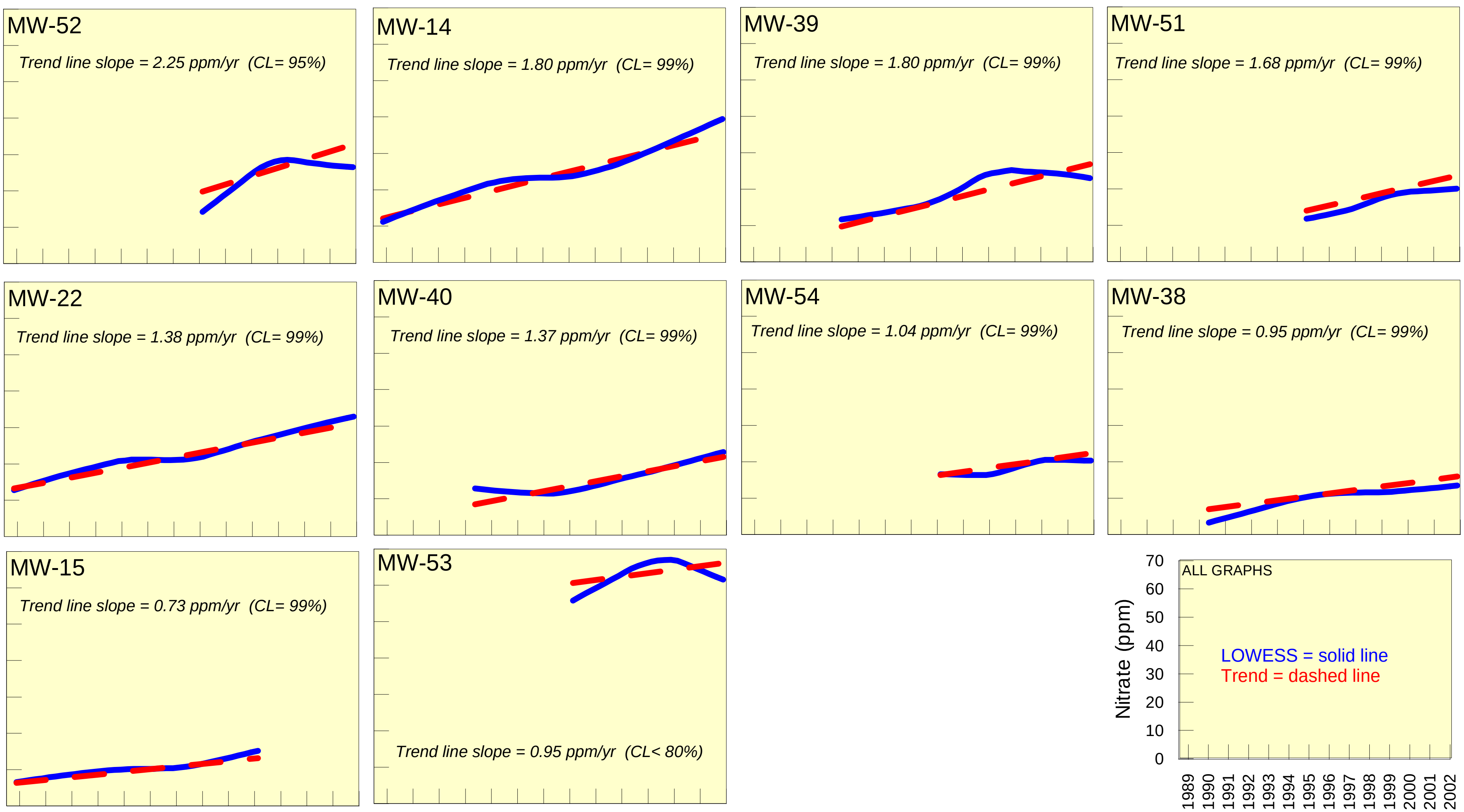


Figure 4-12
LOWESS Line Through All Nitrate Data - Simplot Terrace Site
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



e: lub landapp simplot all data terrace site2.grf

Figure 4-13
LOWESS Lines and Trend Lines Through Nitrate Data - Simplot Terrace Site
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



e: lub landapp simplot alltrends&lowess_ter.grf

Figure 4-14
Nitrate Trends - Simplot Terrace Site
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA

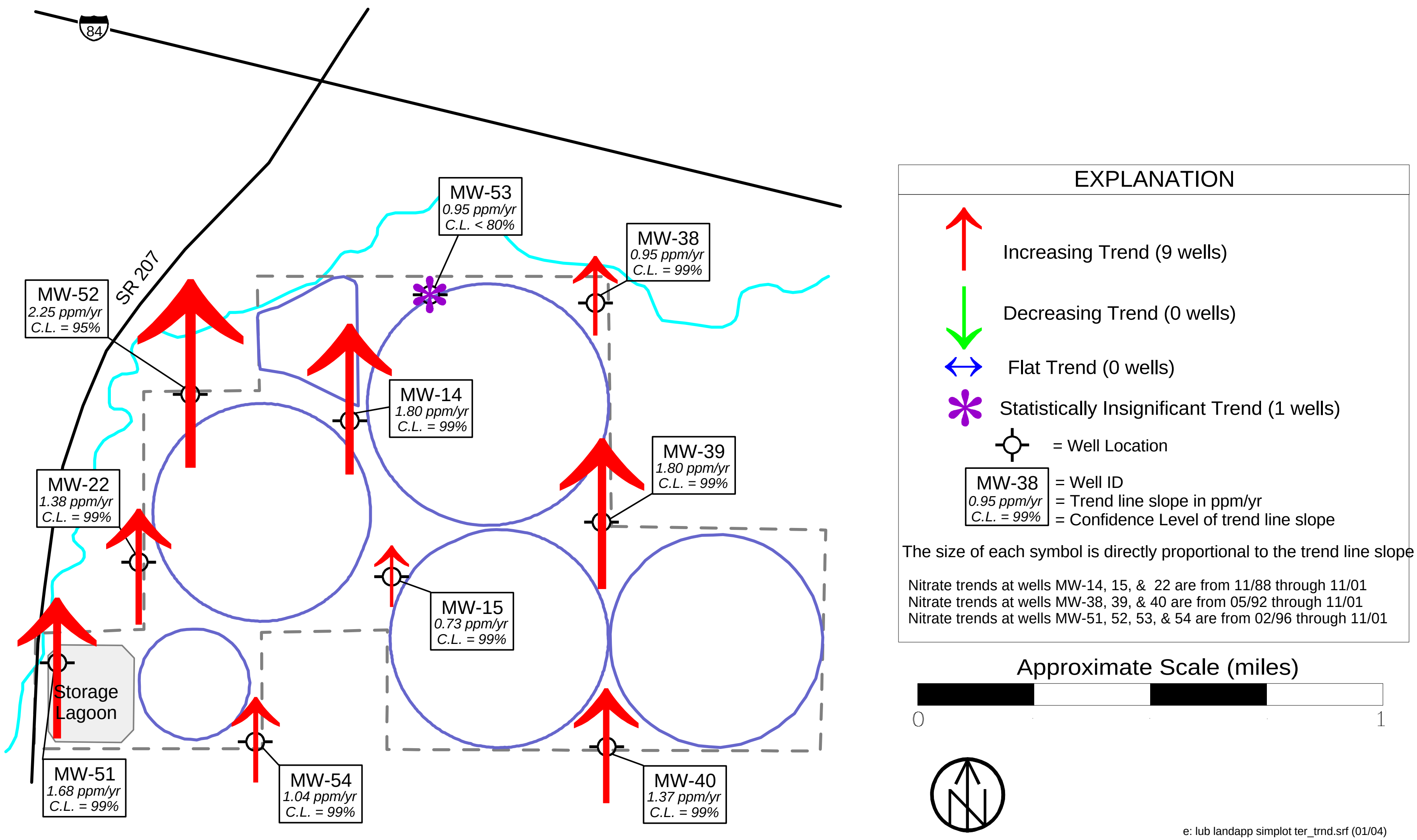


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Figure 4-15
Average Nitrate Concentrations - Simplot Terrace Site
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA

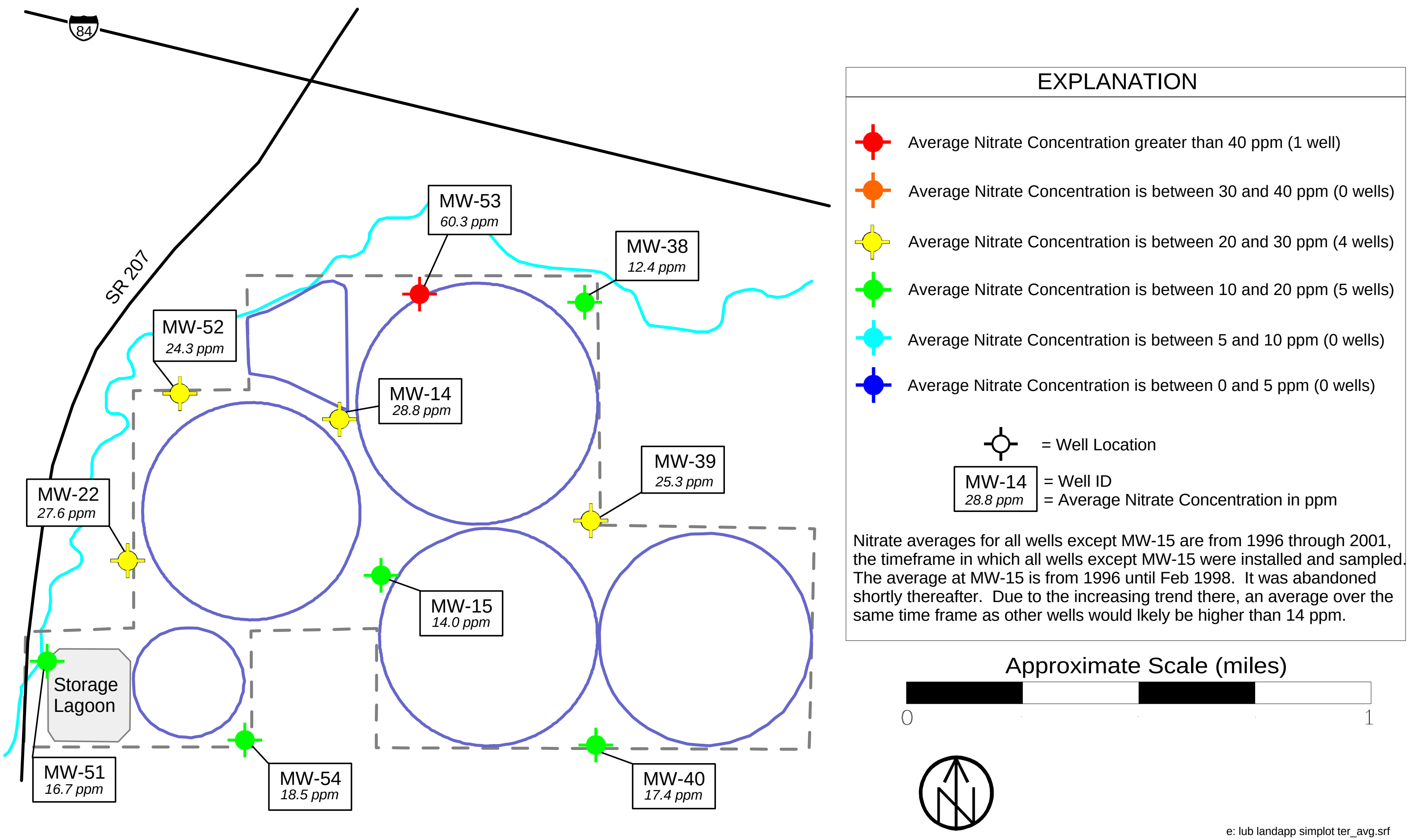
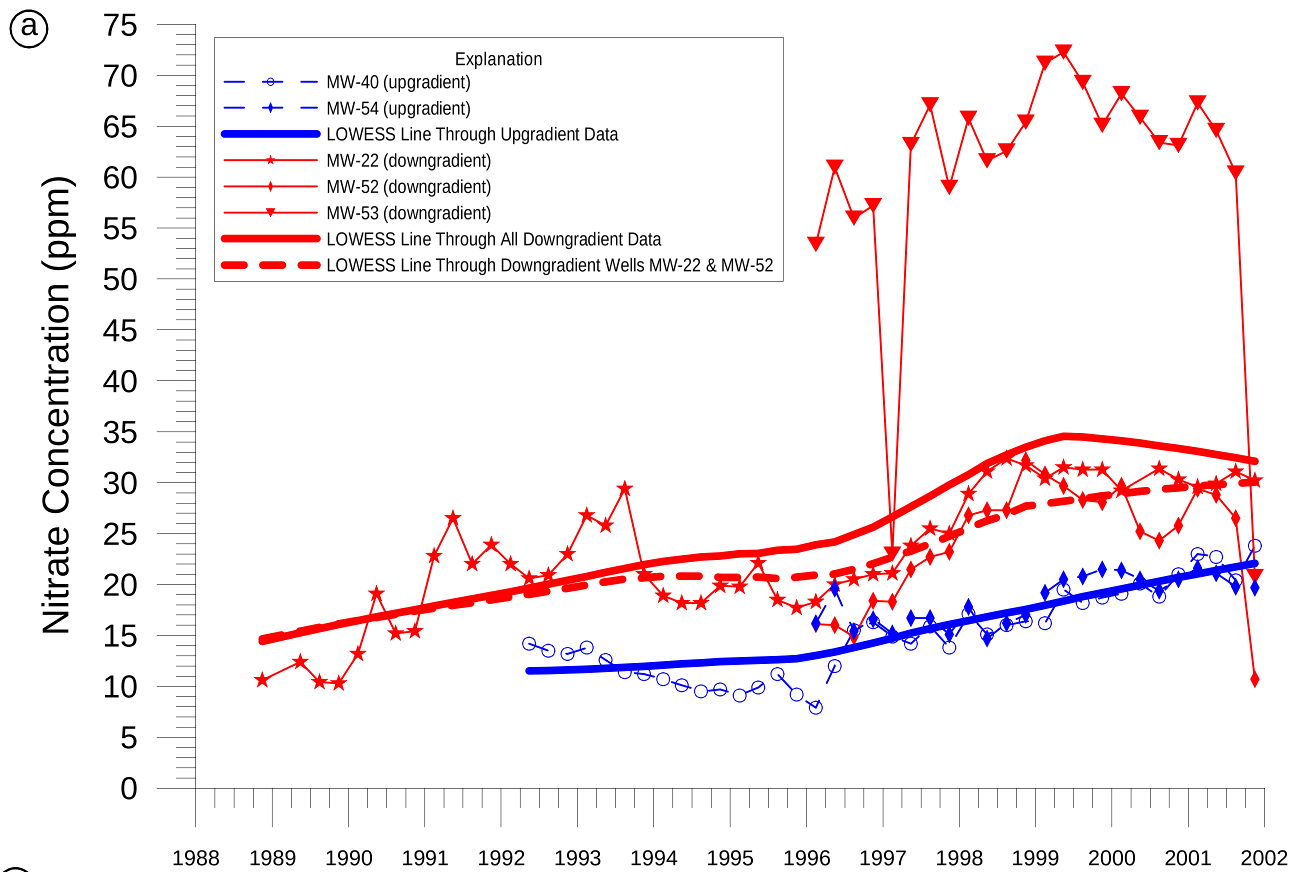
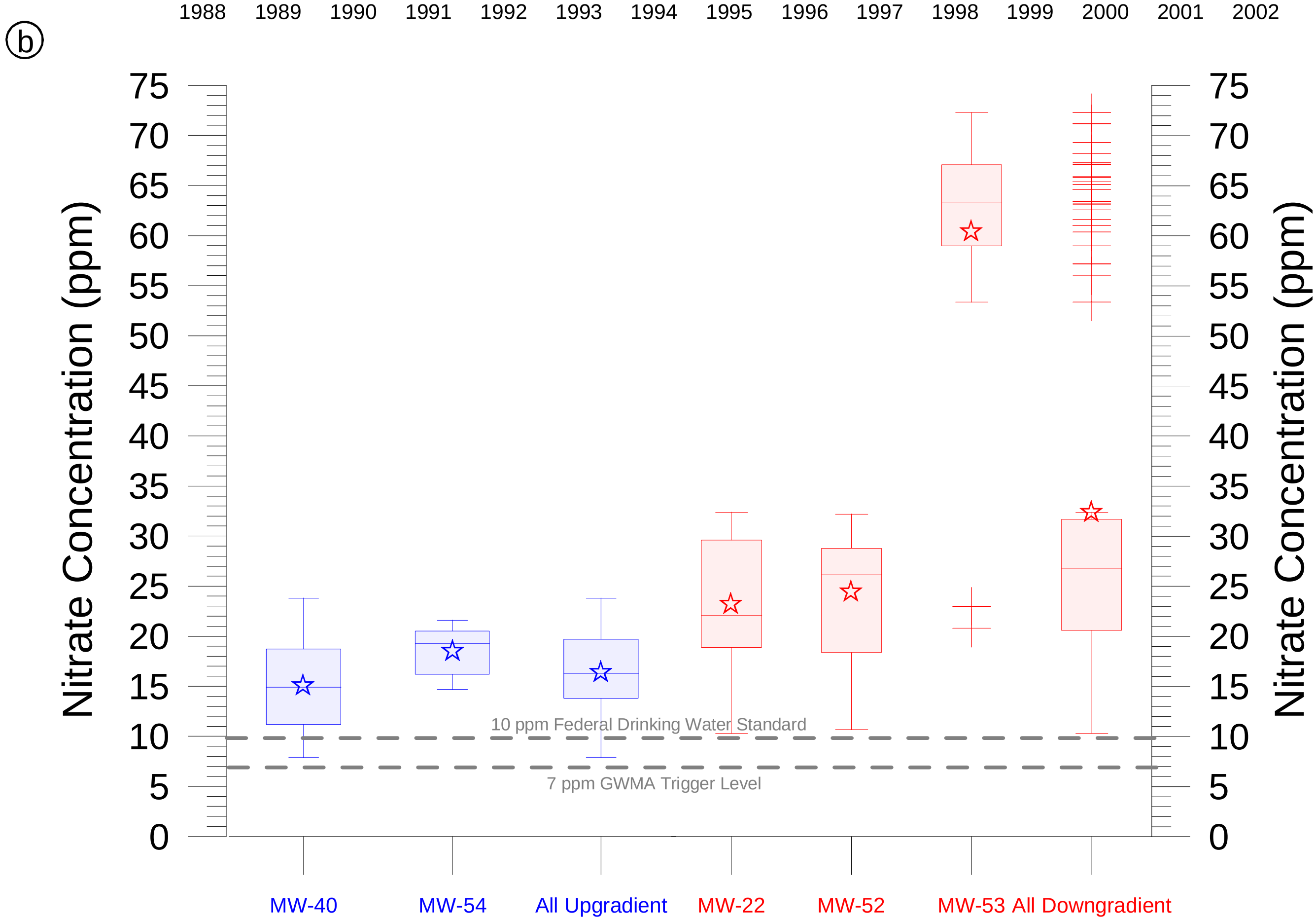


Figure 4-16

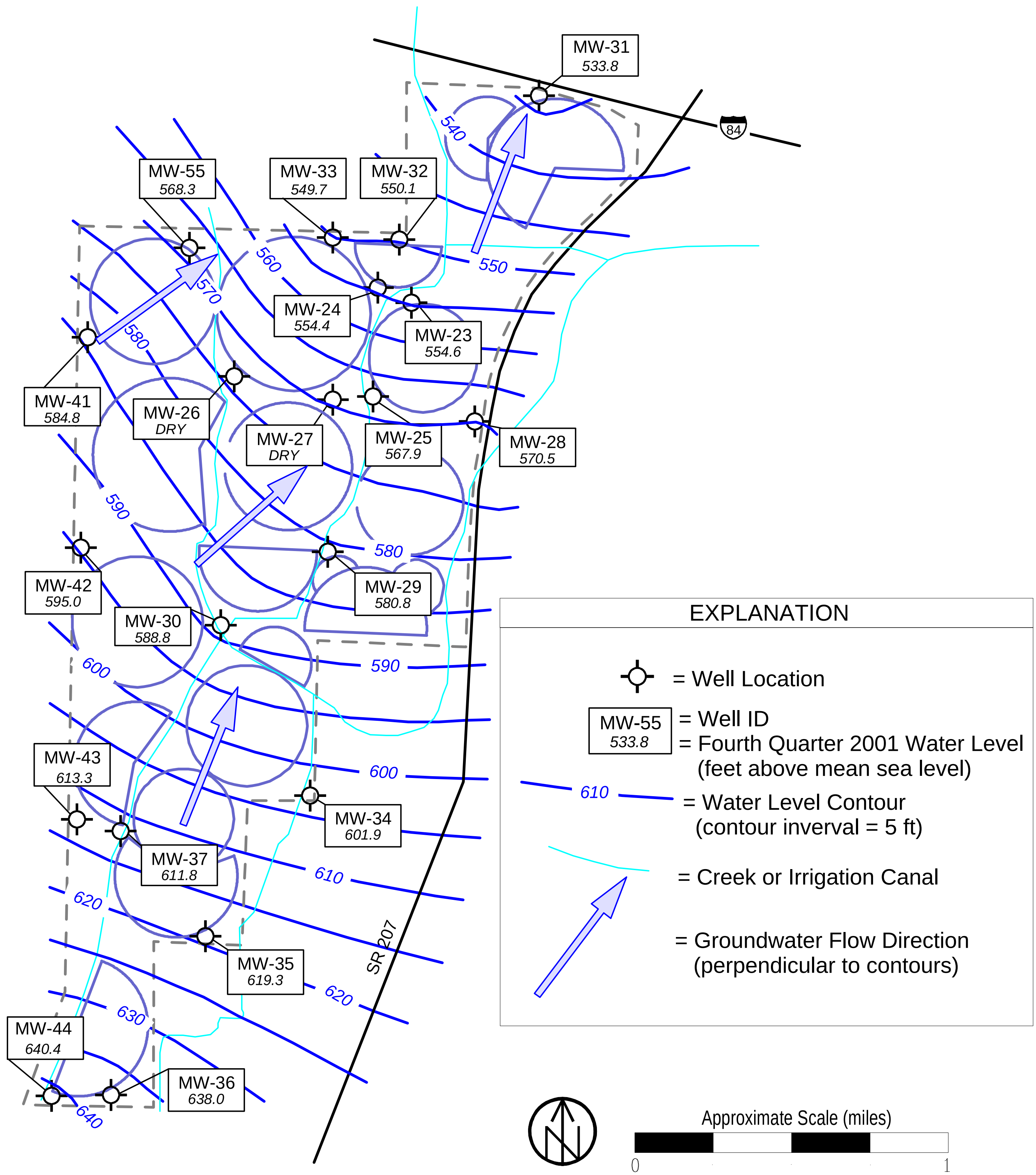
Upgradient vs. Downgradient Nitrate Comparisons - Simplot Terrace Site
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA





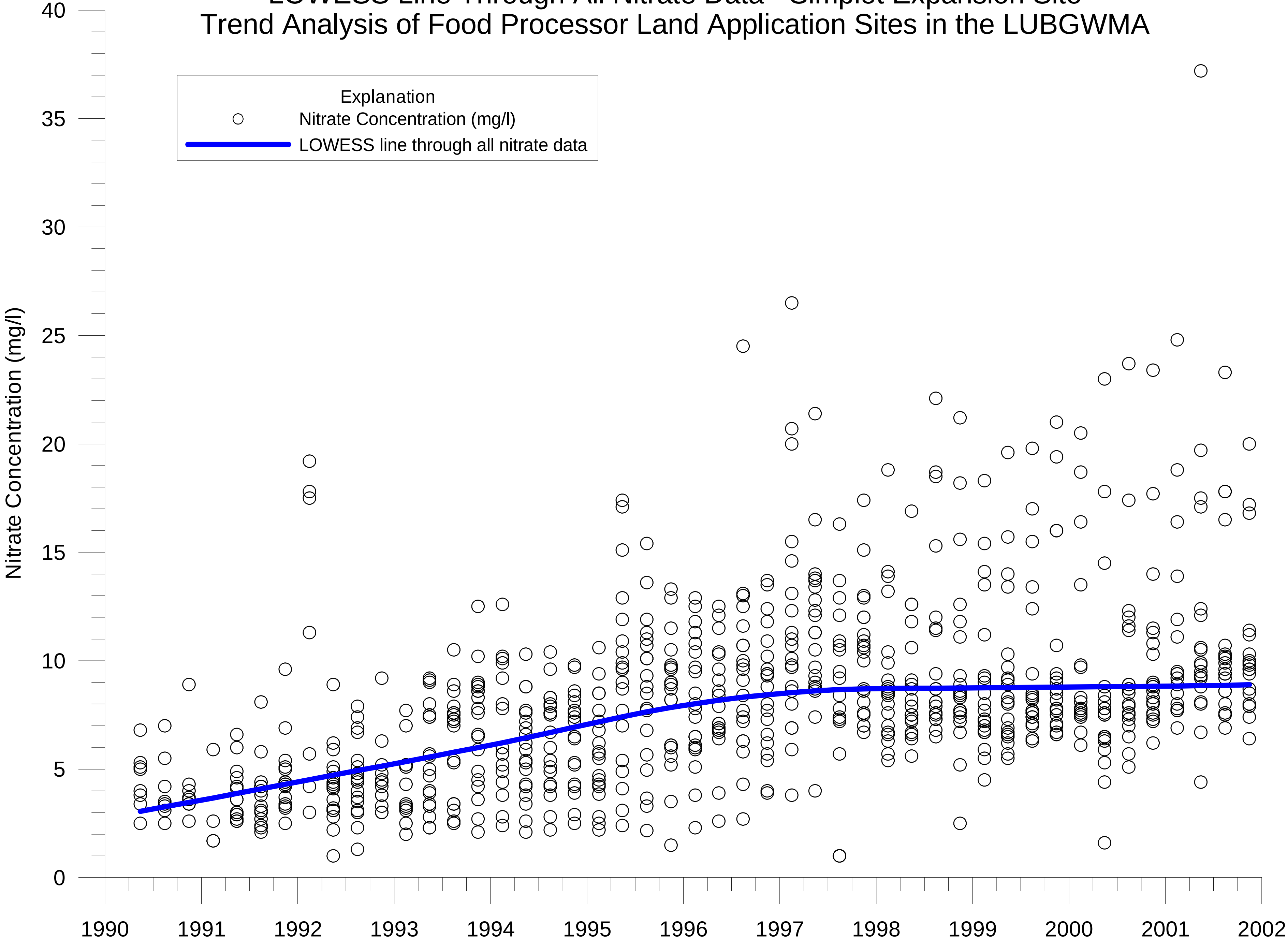
e: lub landapp simplot up vs dn terrace.grf

Figure 4-17
Fourth Quarter 2001 Water Levels - Simplot Expansion Site
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



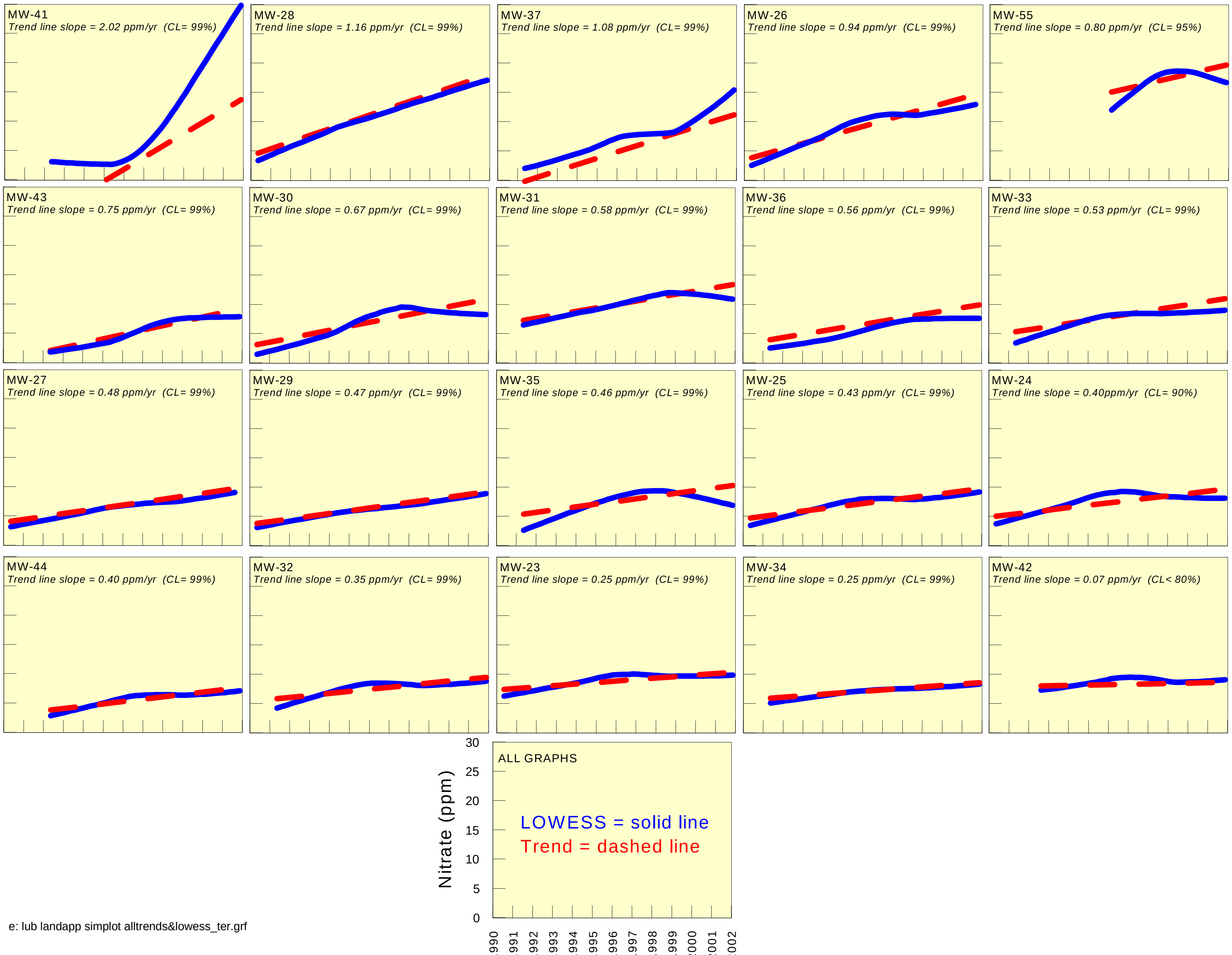
e: lub landapp simplot wls_exp.srf

Figure 4-18
LOWESS Line Through All Nitrate Data - Simplot Expansion Site
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



e: lub landapp simplot all data expansion site.grf

Figure 4-19
LOWESS Lines and Trend Lines Through Nitrate Data - Simplot Expansion Site
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



e: lub landapp simplot alltrends&lowess_ter.grf

Figure 4-20
Nitrate Trends - Simplot Expansion Site
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA

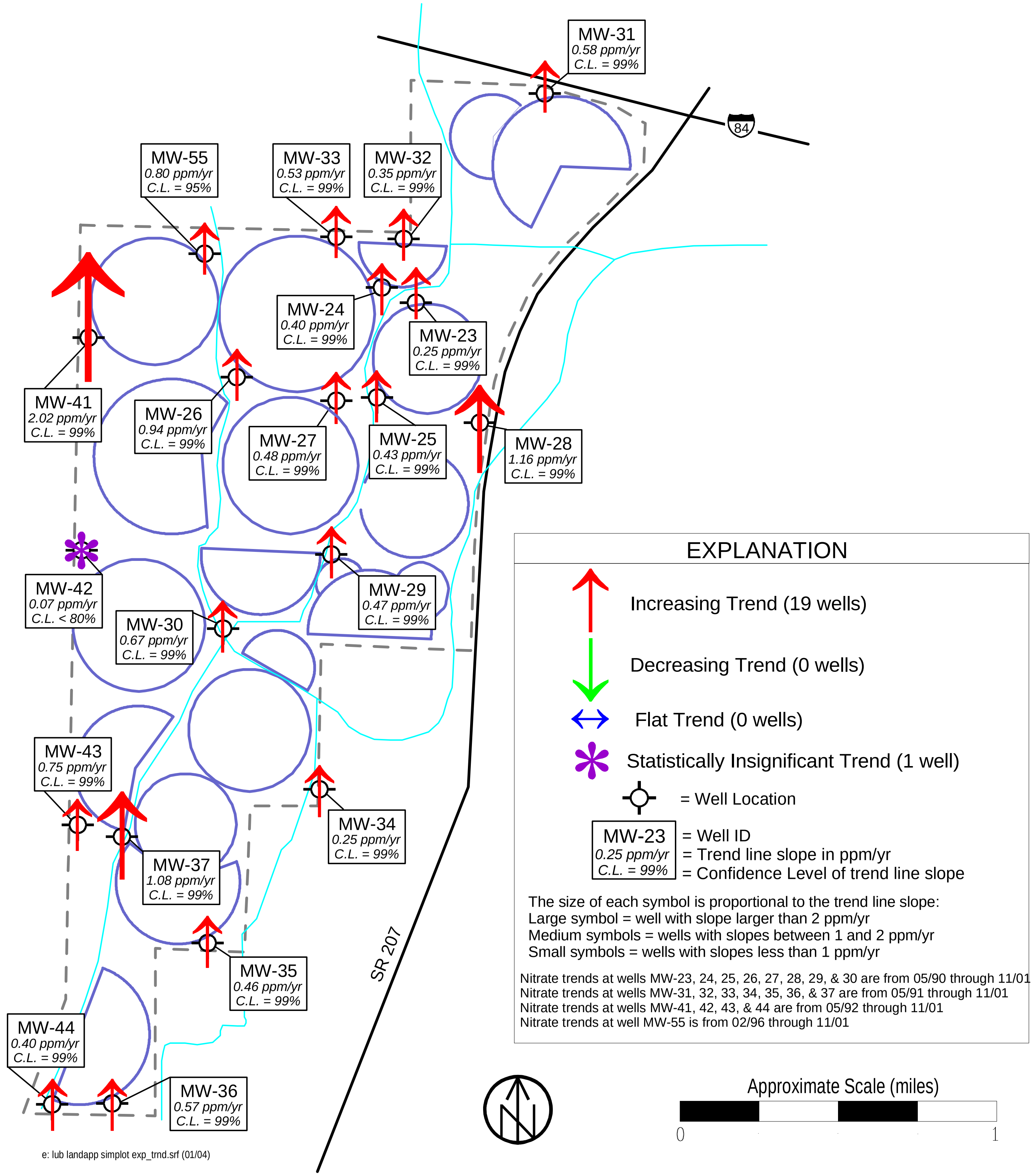


Figure 4-21
Average Nitrate Concentrations - Simplot Expansion Site
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA

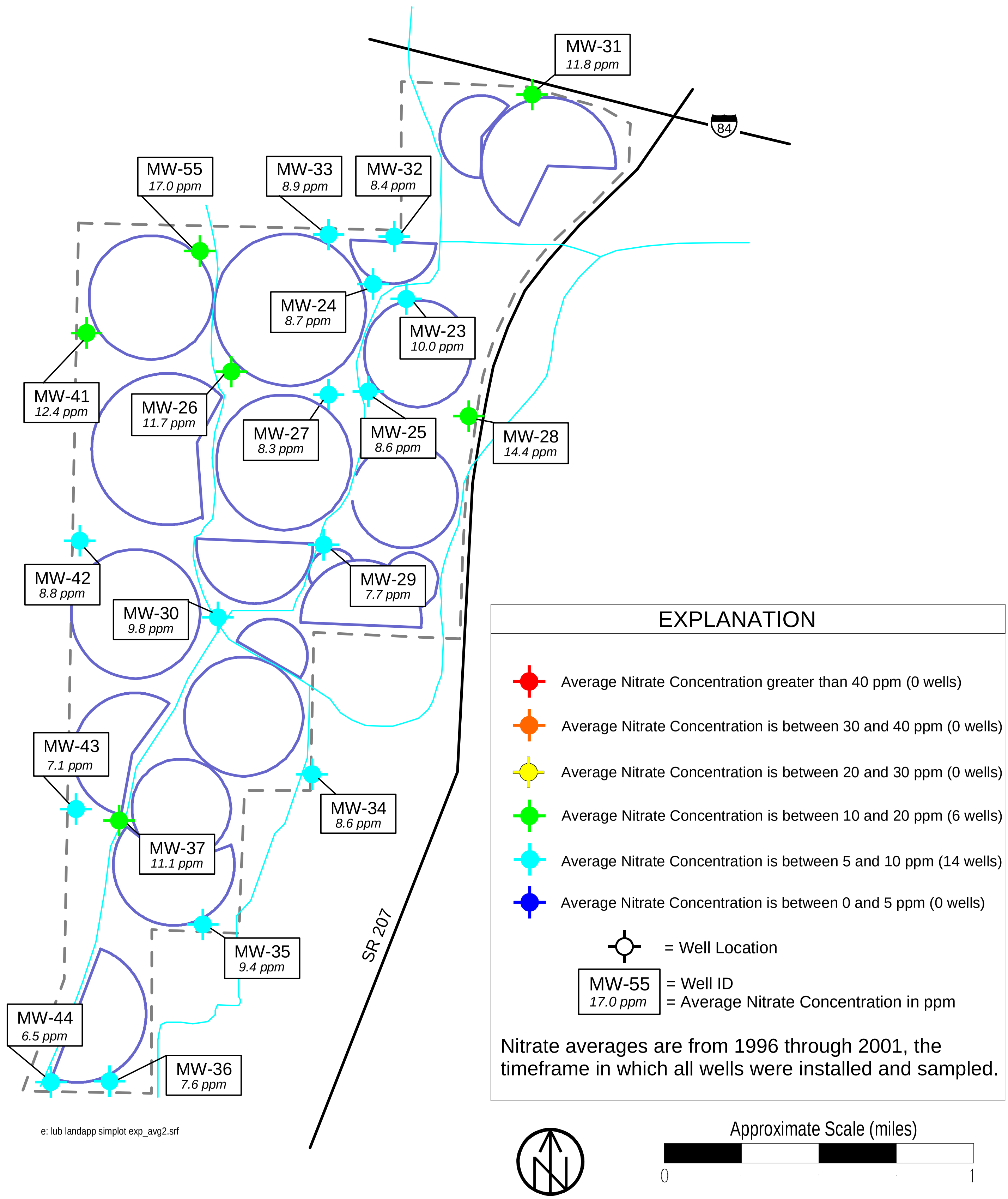
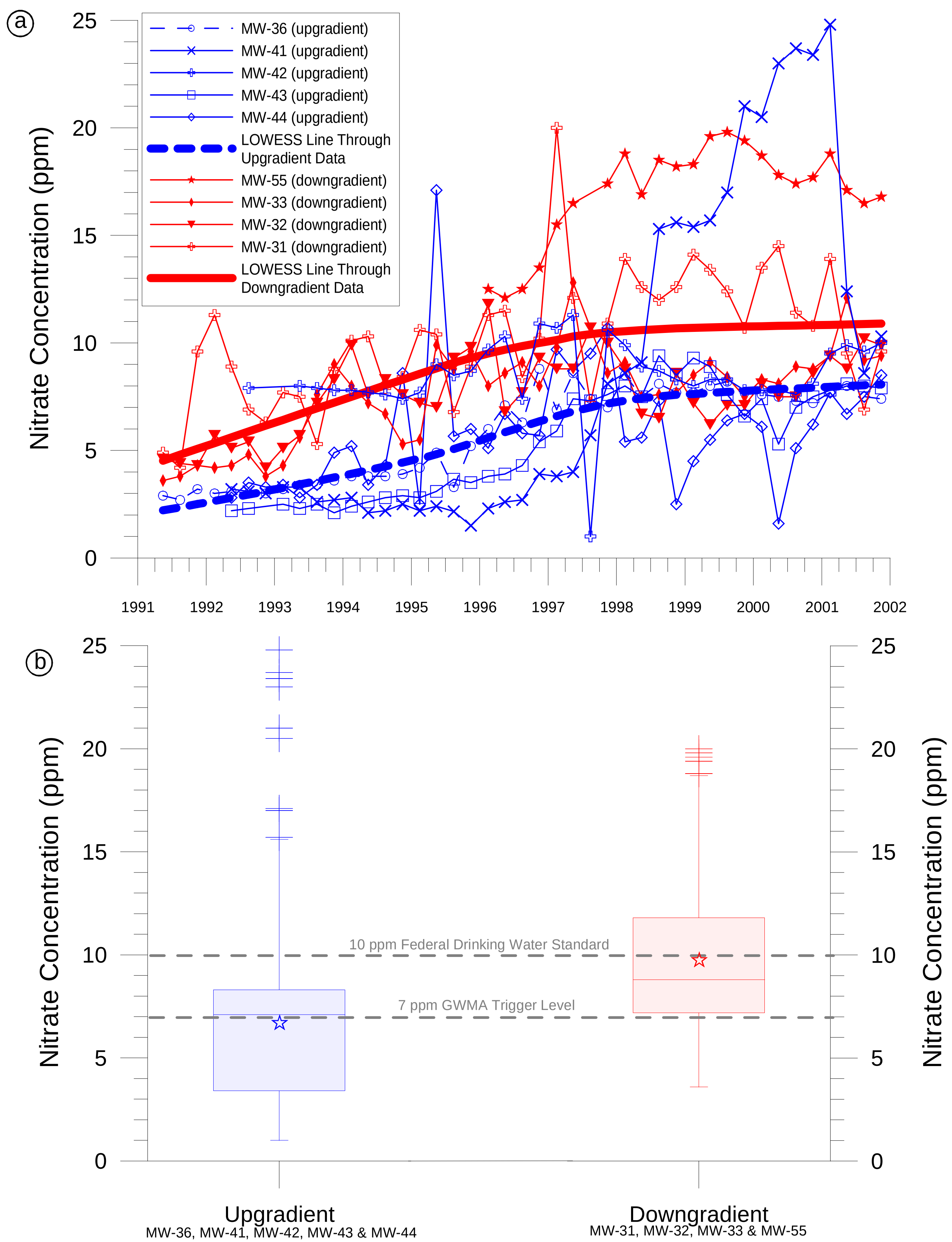


Figure 4-22

Upgradient vs. Downgradient Nitrate Comparisons - Simplot Expansion Site
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



e: lub landapp simplot up vs dn expansion.grf

Figure 5-1
Hydrographs - Hermiston Foods Site
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA

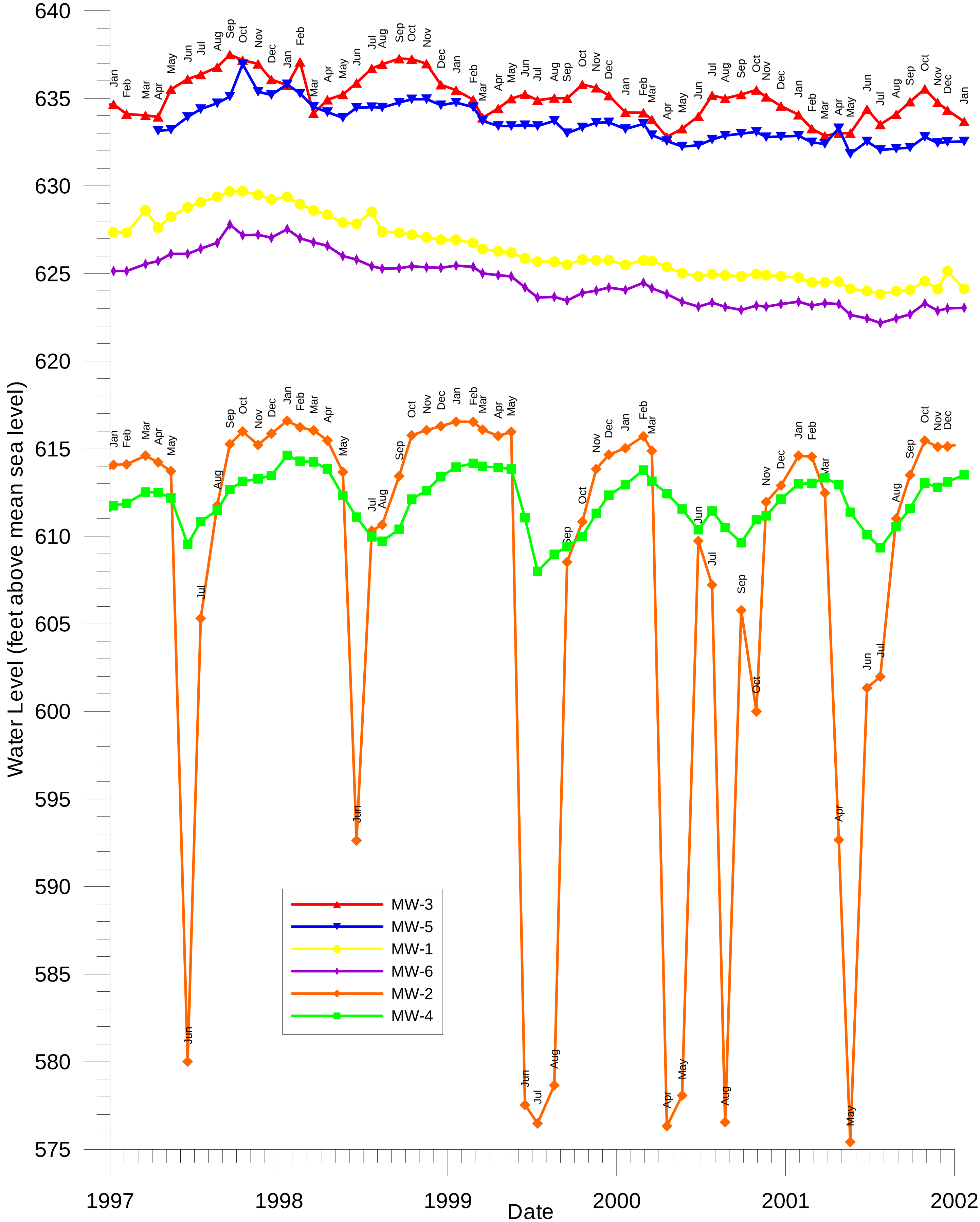
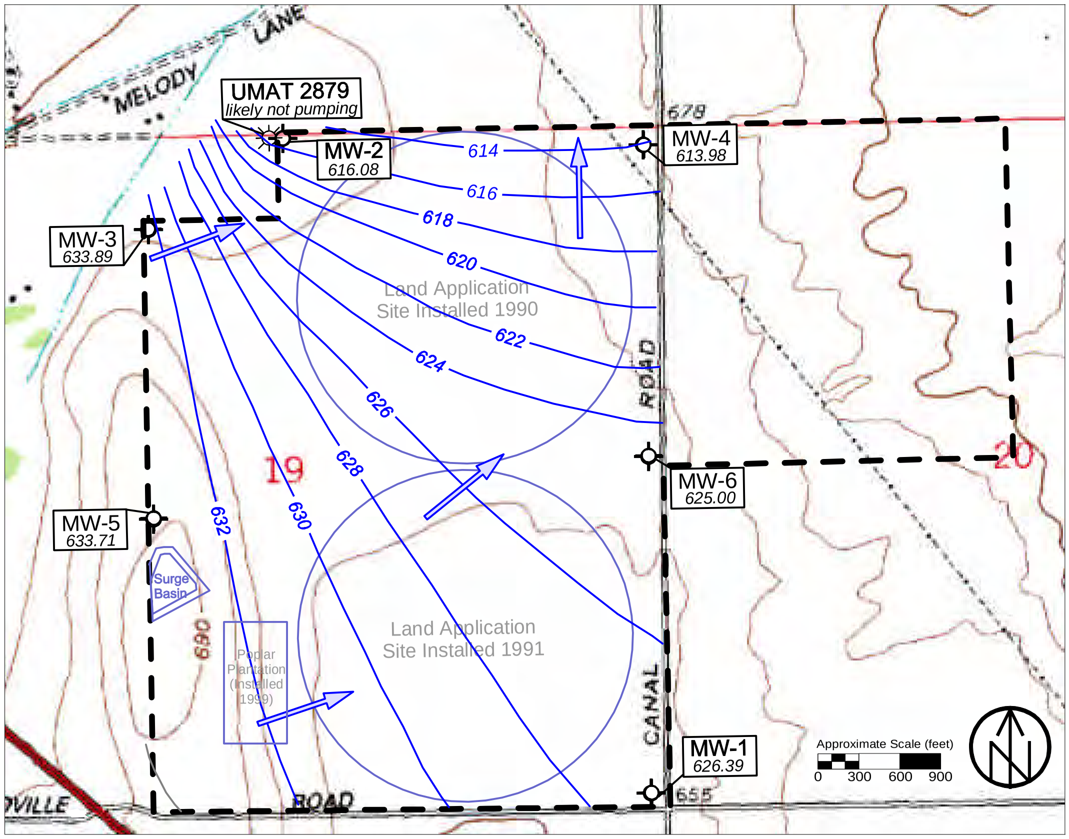
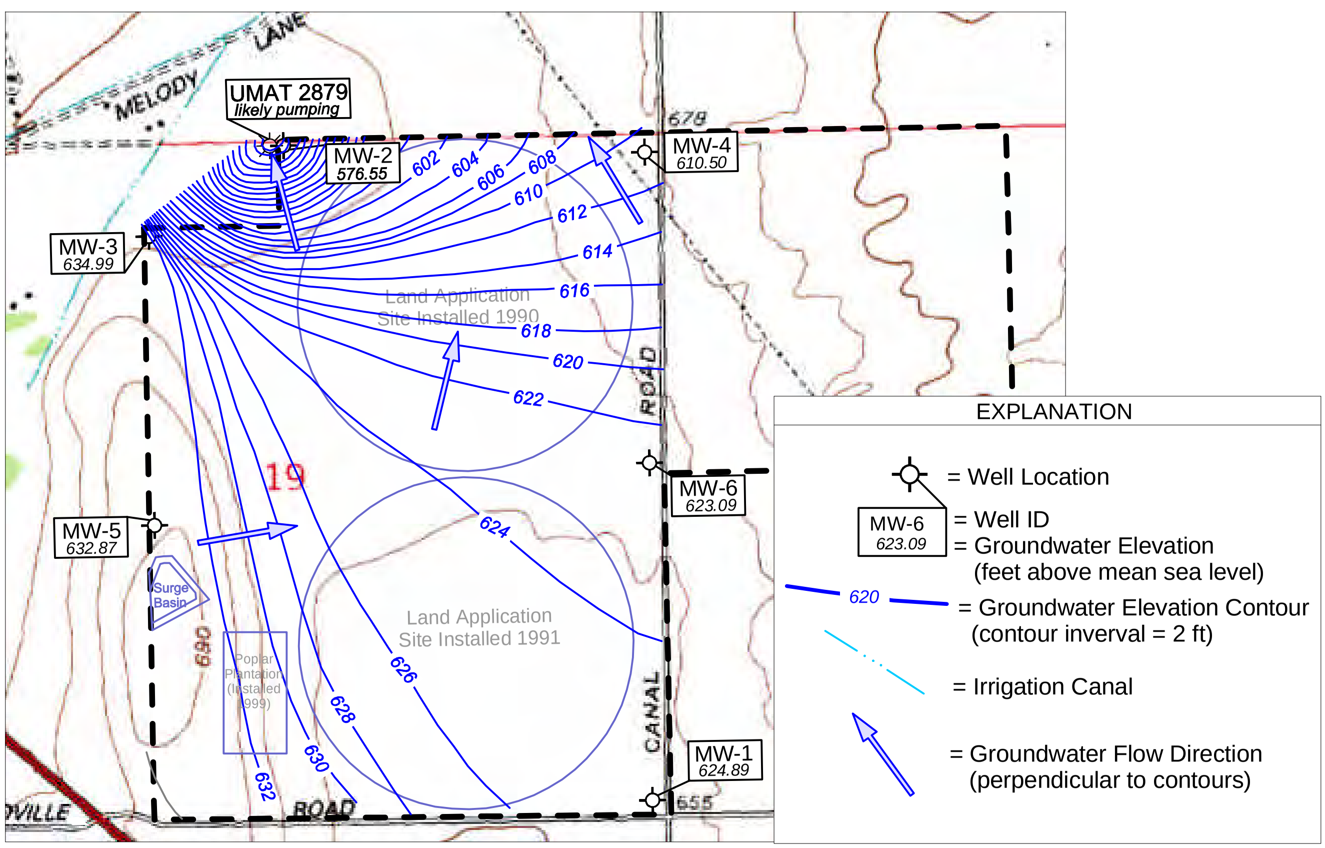


Figure 5-2
Potentiometric Surface Maps - Hermiston Foods
Trend Analysis of Food Processor Land Application Sites in the LUB GWMA

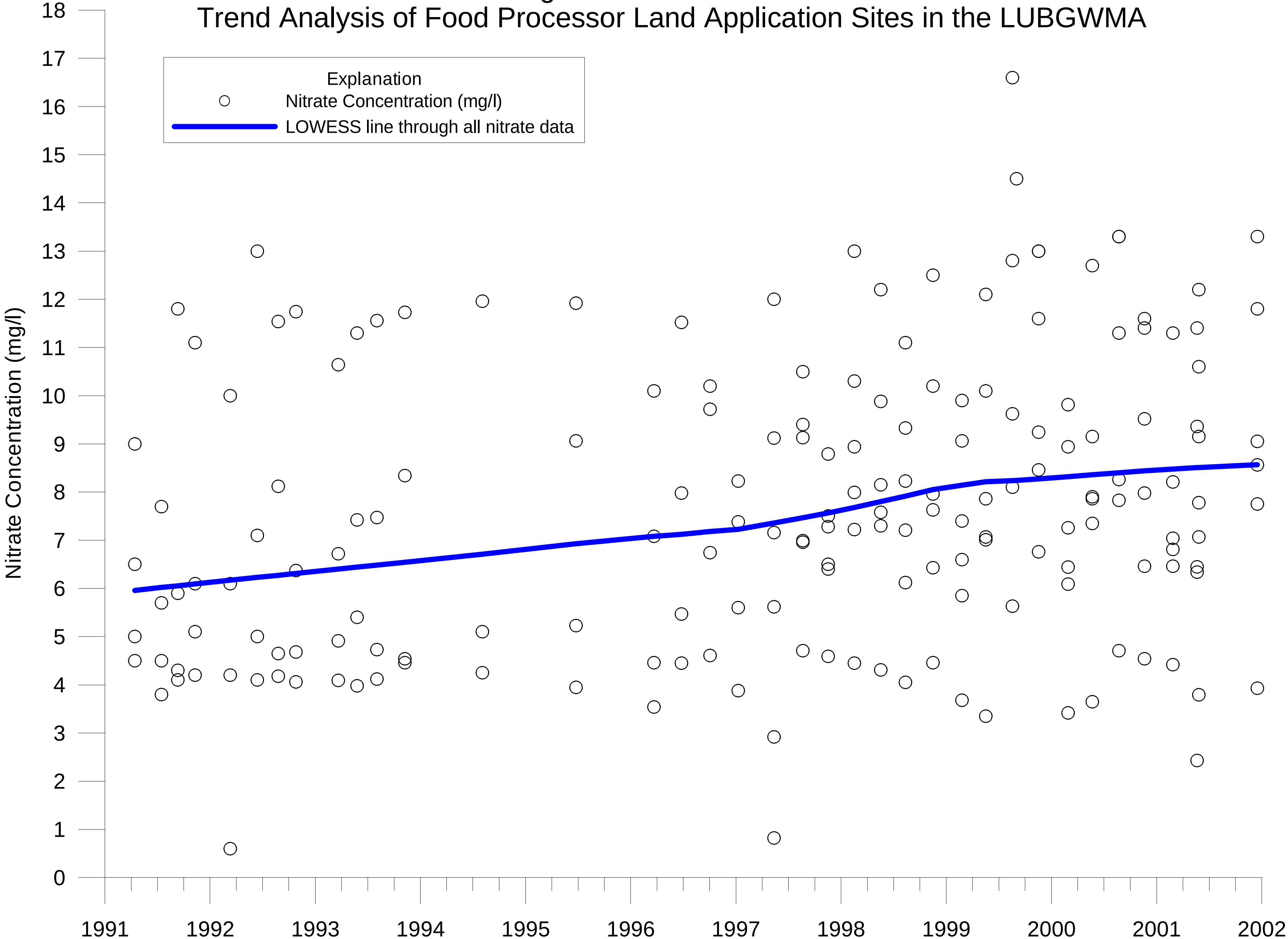


(A) 03/17/99 Potentiometric Surface Map Showing Minimum Influence of Offsite Irrigation Well



(B) 08/23/00 Potentiometric Surface Map Showing Maximum Influence of Offsite Irrigation Well

Figure 5-3
LOWESS Line Through All Nitrate Data - Hermiston Foods Site
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



e: lub landapp hermiston foods all data.grf

Figure 5-4
LOWESS Lines and Trend Lines Through Nitrate Data - Hermiston Foods
Trend Analysis of Food Processor Land Application Sites in the LUB GWMA

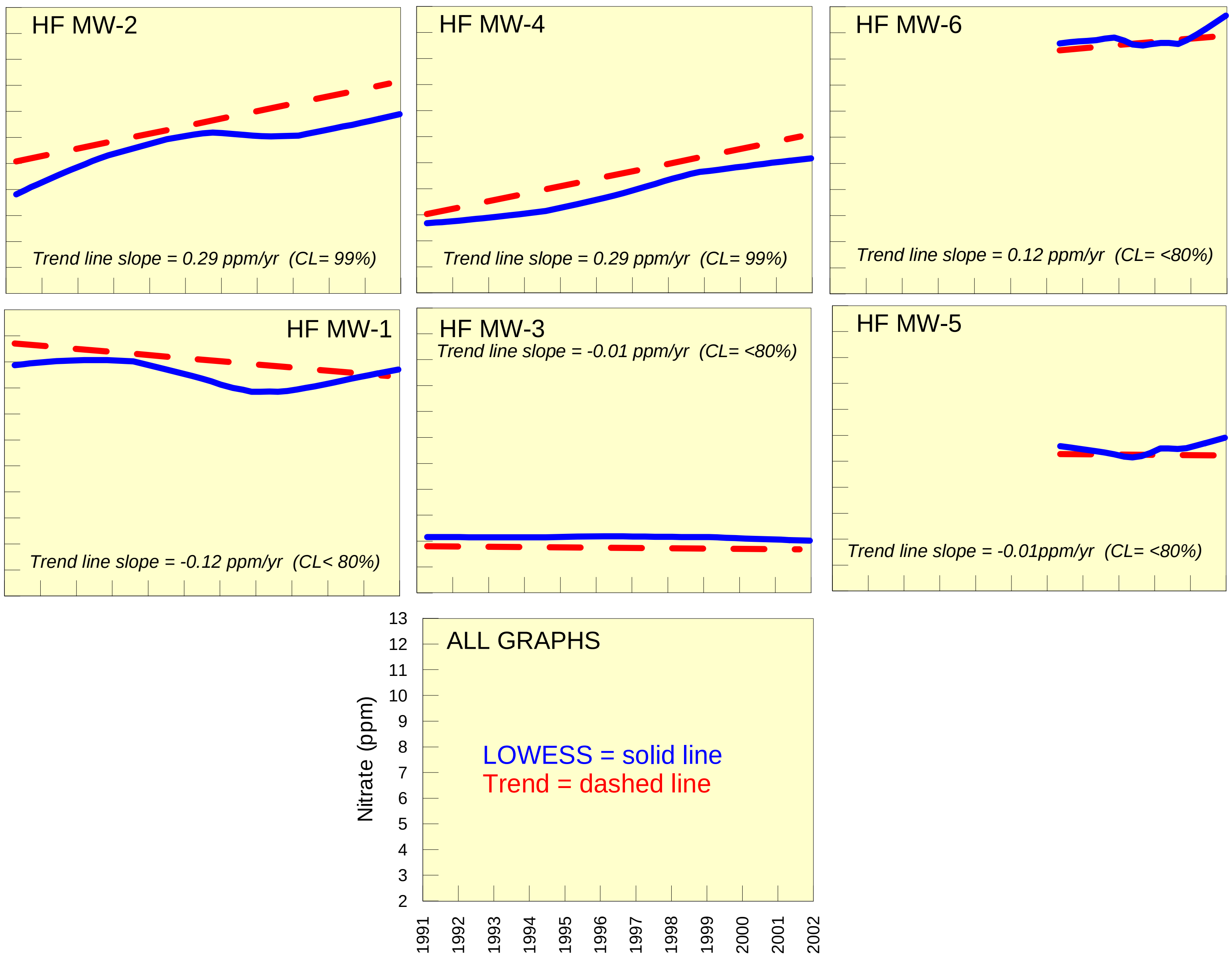
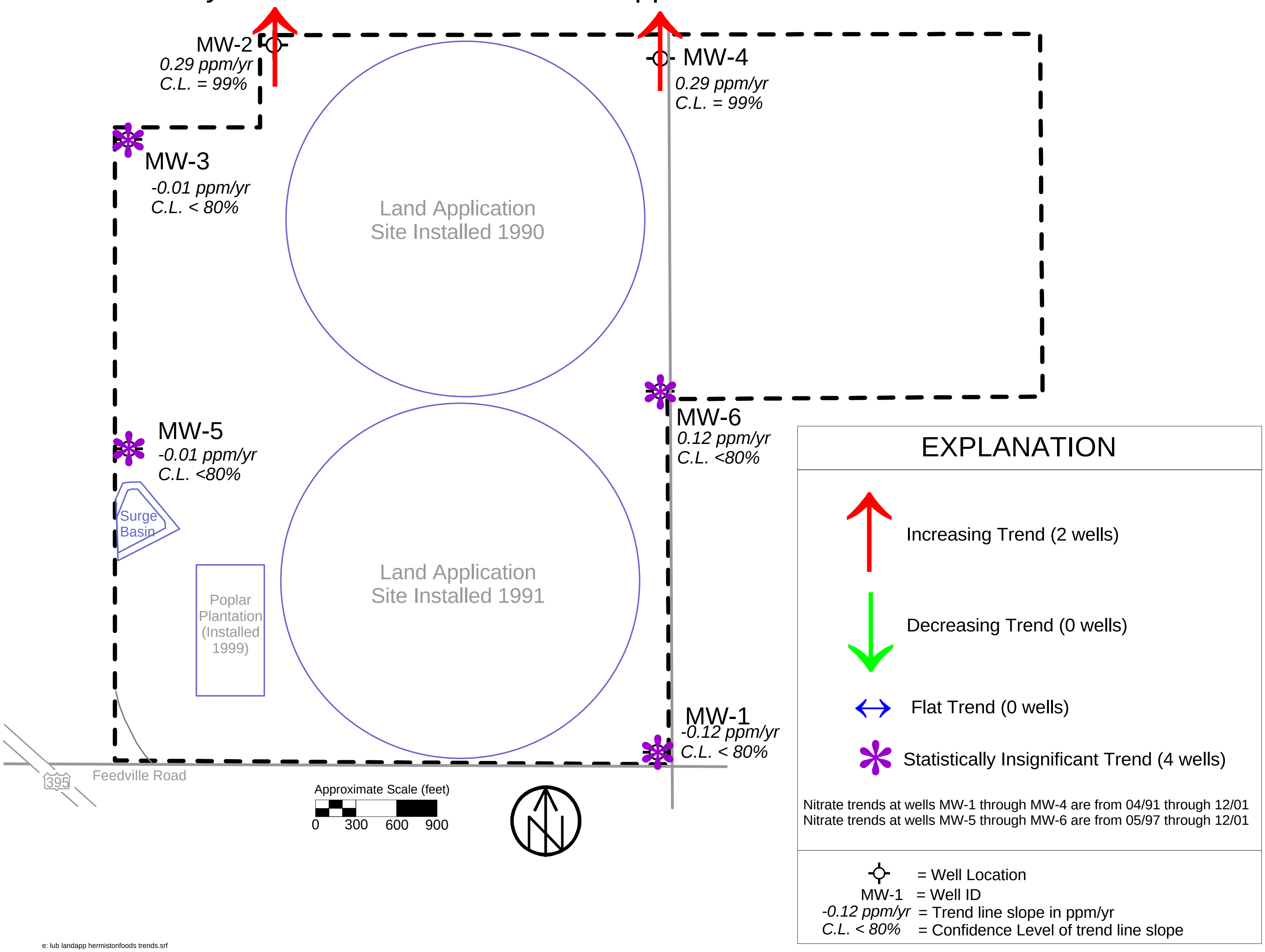
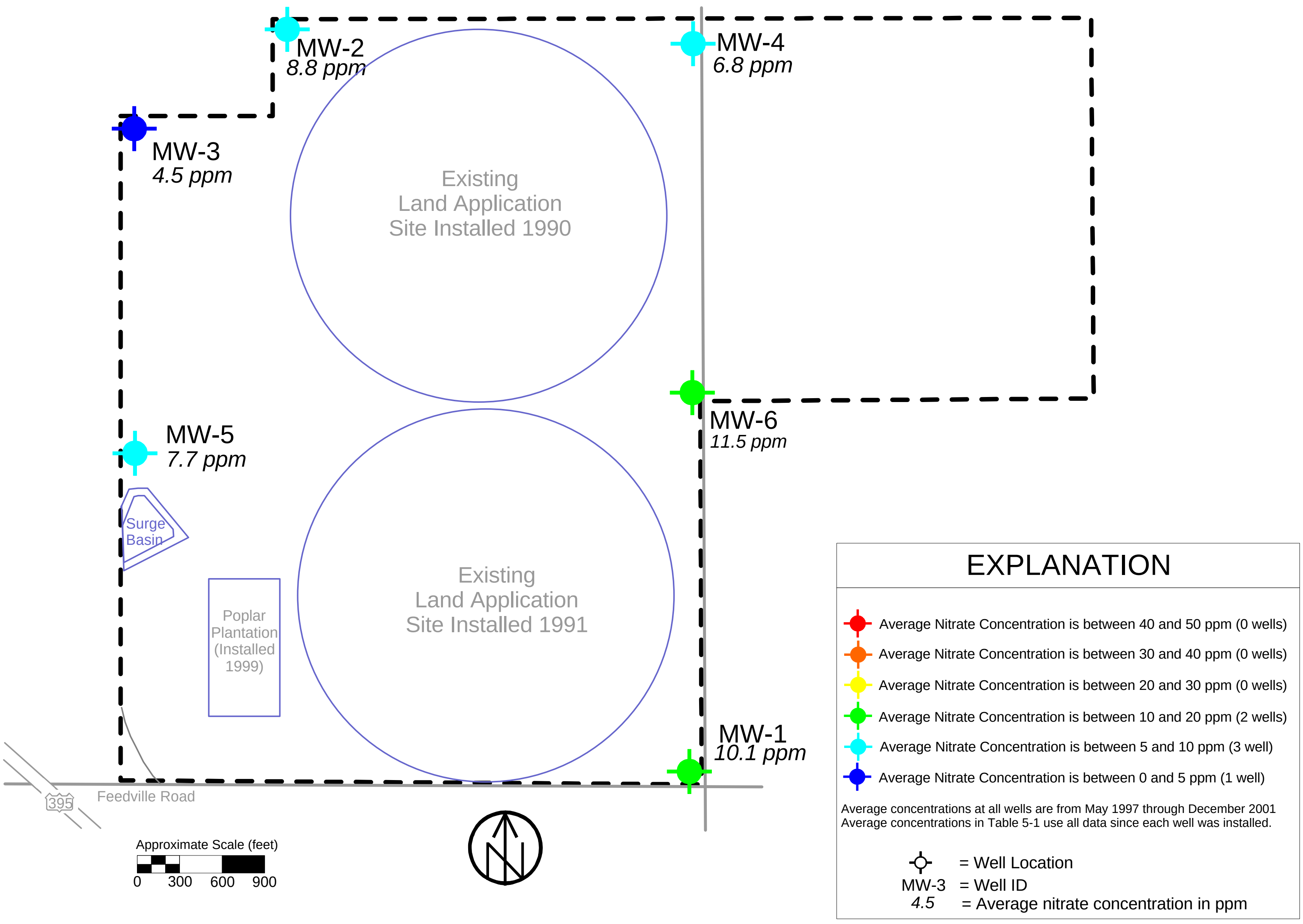


Figure 5-5
Nitrate Trends - Hermiston Foods
Trend Analysis of Food Processor Land Application Sites in the LUB GWMA



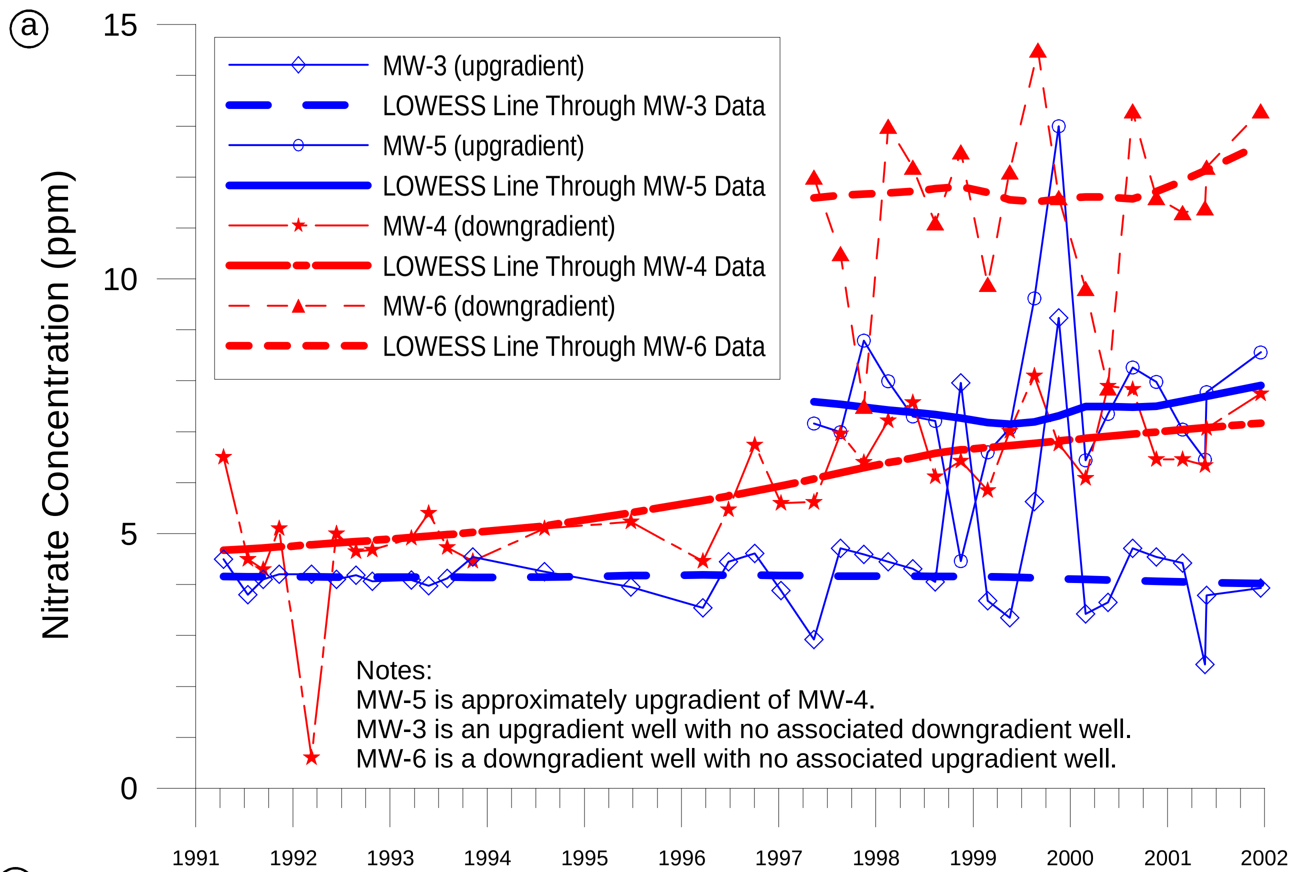
e: lub landapp hermistonfoods trends.srf

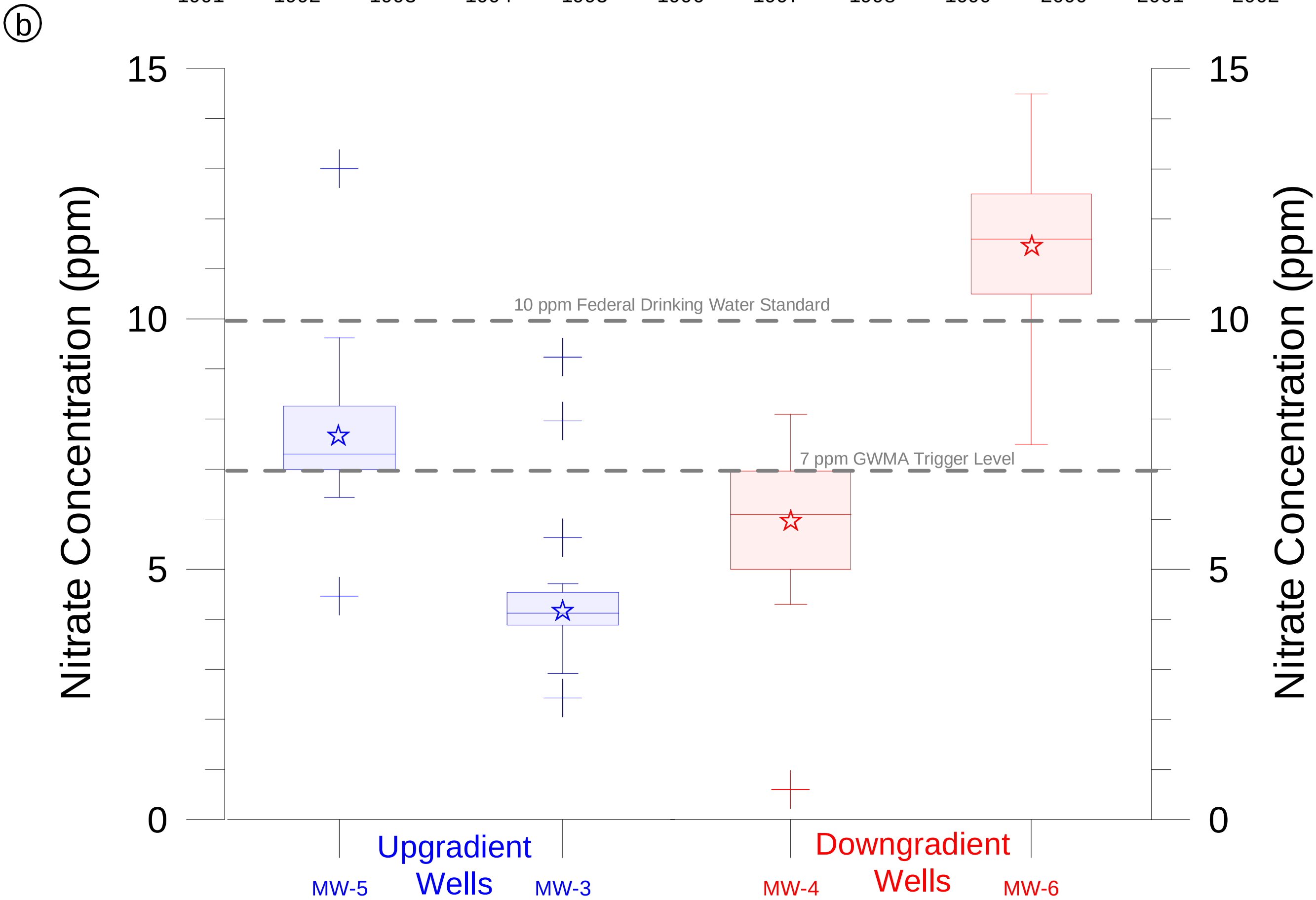
Figure 5-6
Average Nitrate Concentrations - Hermiston Foods
Trend Analysis of Food Processor Land Application Sites in the LUB GWMA



e: lub landapp hermistonfoods avg.srf

Figure 5-7
Upgradient vs. Downgradient Nitrate Comparisons - Hermiston Foods
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA





e: lub landapp hermistonfoods up v dn.grf

Figure 6-1
Summer 1994 Average Water Temperature - A.E. Staley
Trend Analysis of Food Processor Land Application Sites in the LUB GWMA

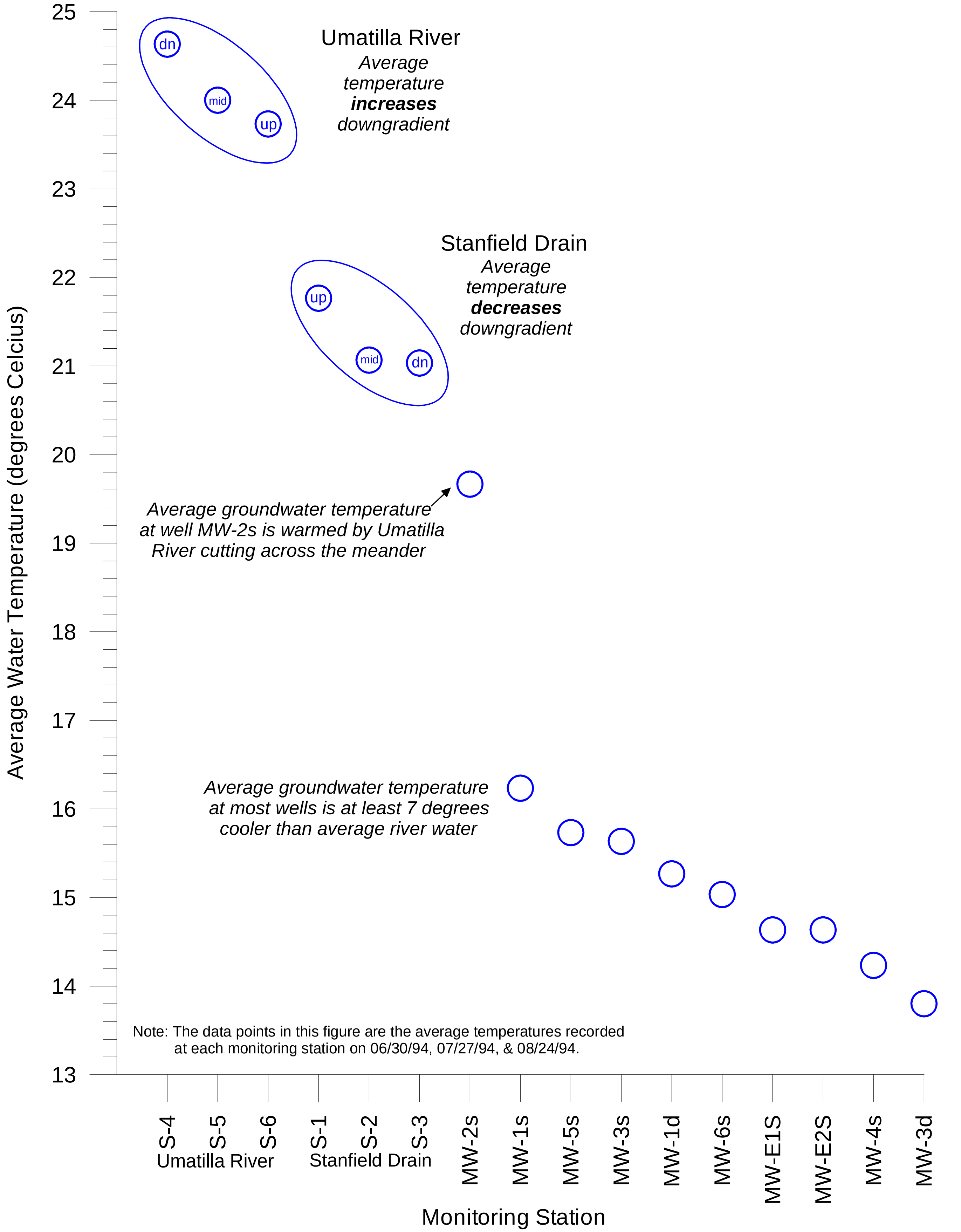
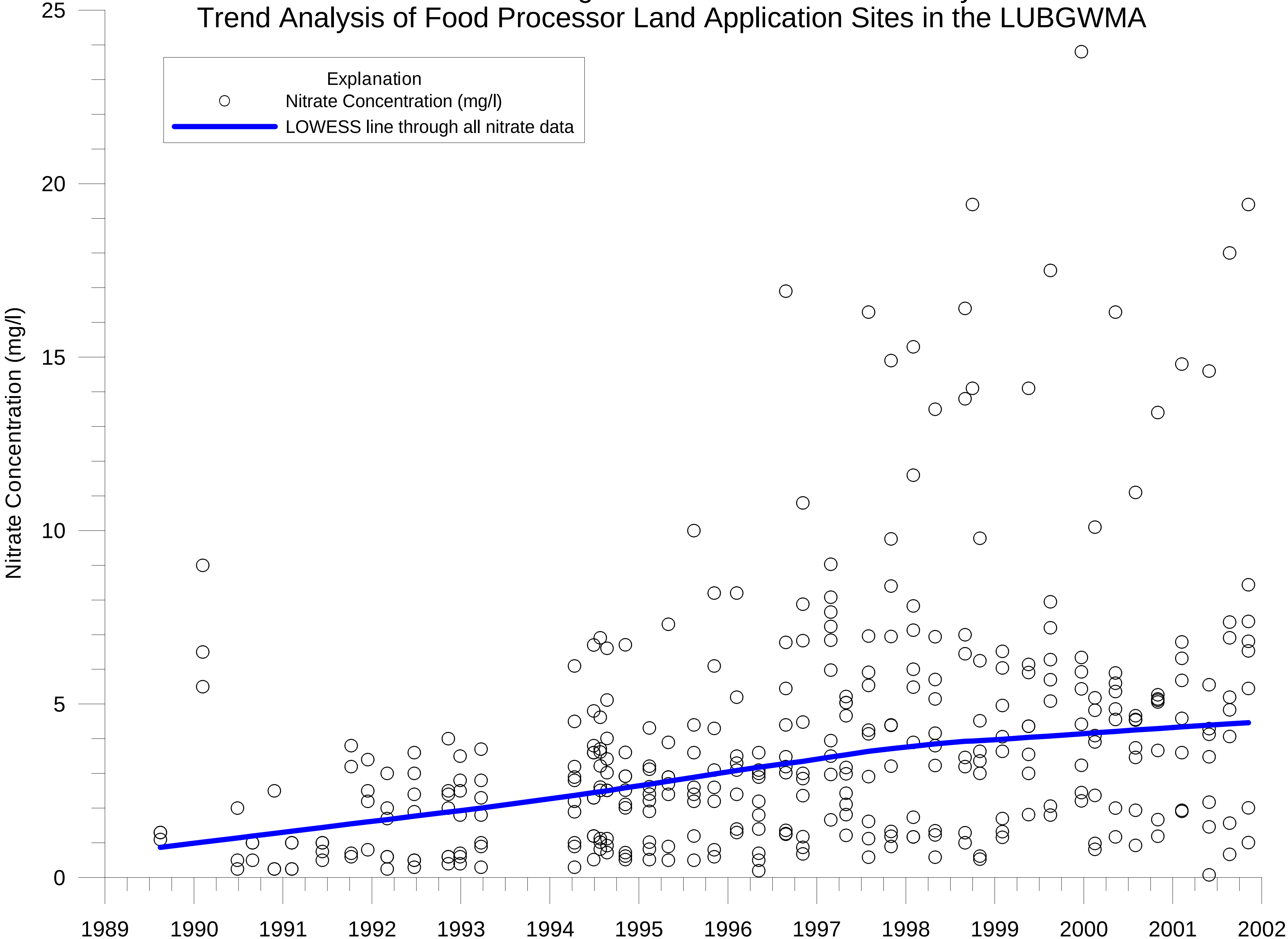


Figure 6-2
LOWESS Line Through All Nitrate Data - A.E. Staley Site
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



e: lub landapp staley all data.grf

Figure 6-3
LOWESS Lines and Trend Lines Through Nitrate Data - A.E. Staley Site
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA

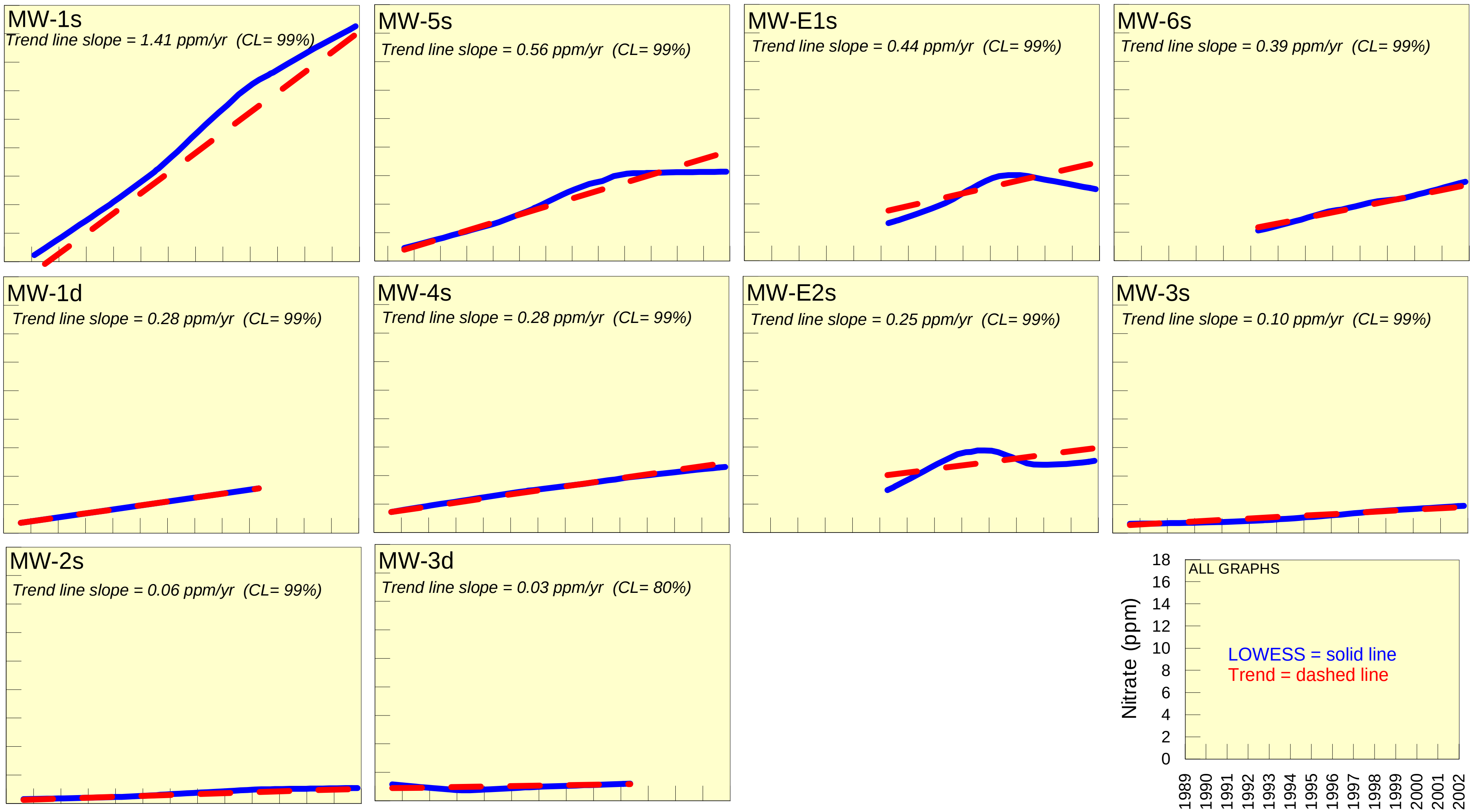
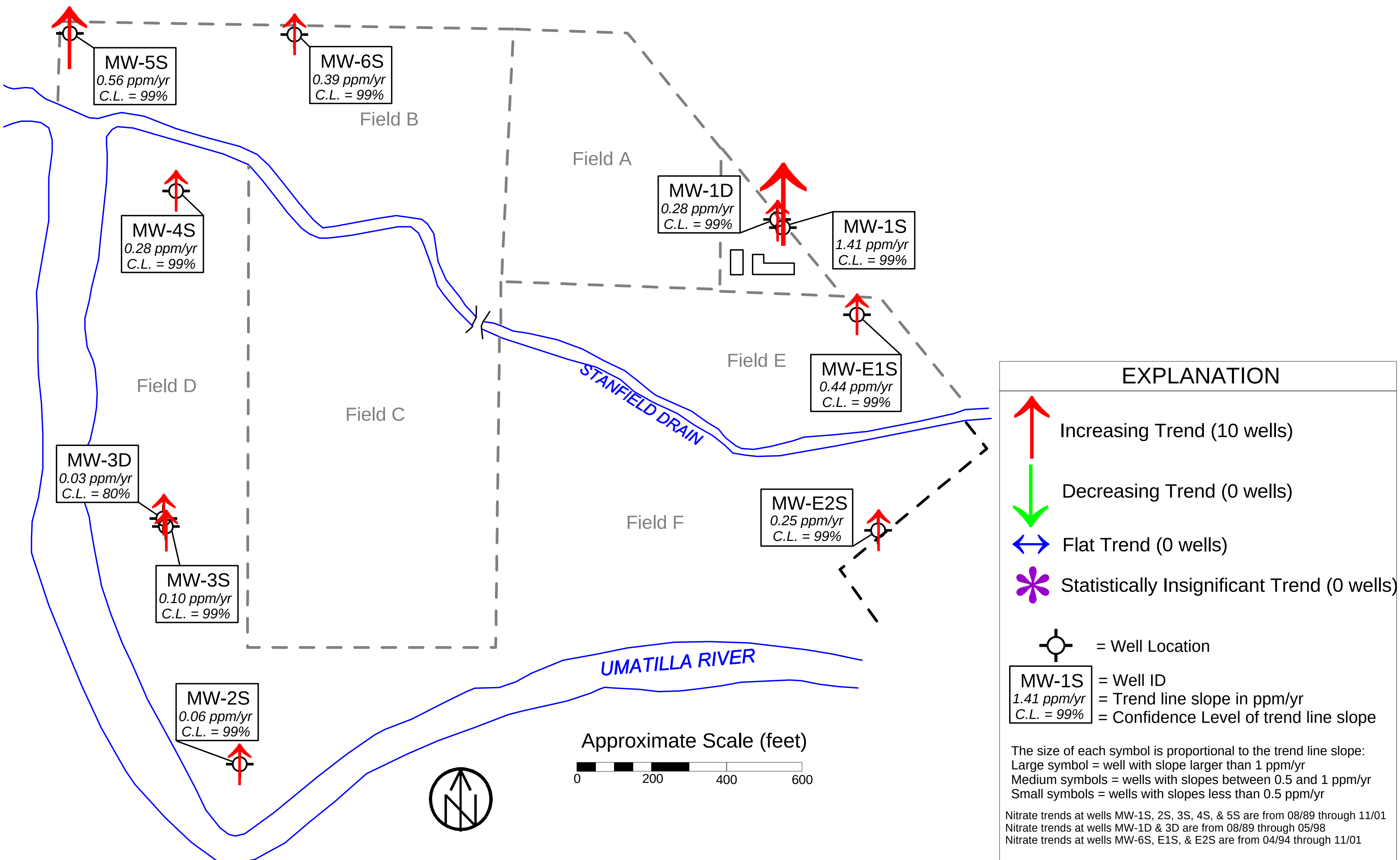
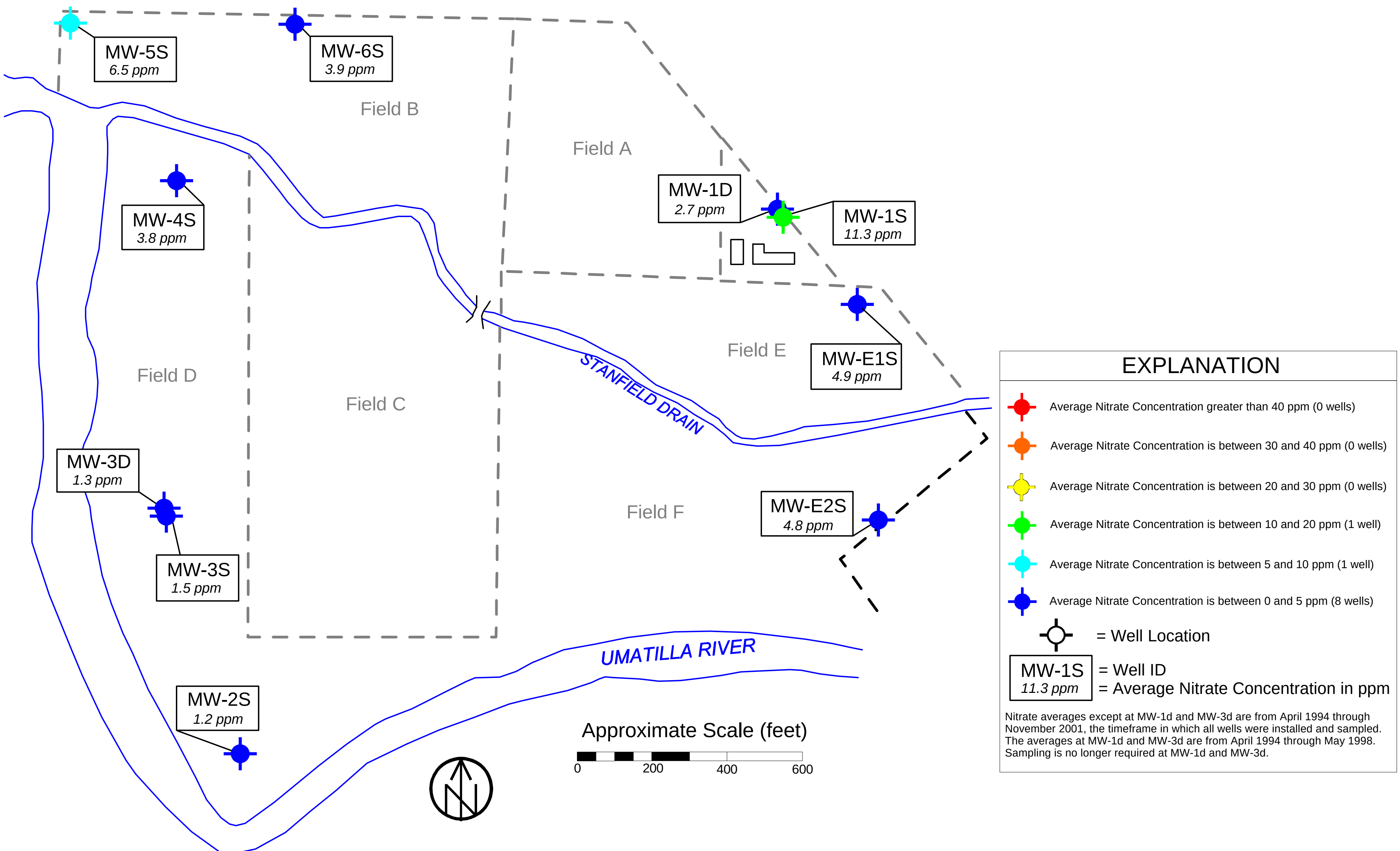


Figure 6-4
Nitrate Trends - A.E. Staley Site
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



e: lub landapp staley trends.srf

Figure 6-5
Average Nitrate Concentrations - A.E. Staley Site
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



e: lub landapp staley averages.srf

Figure 7-1
April 8, 2002 Groundwater Table Elevations - Snakcorp
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA

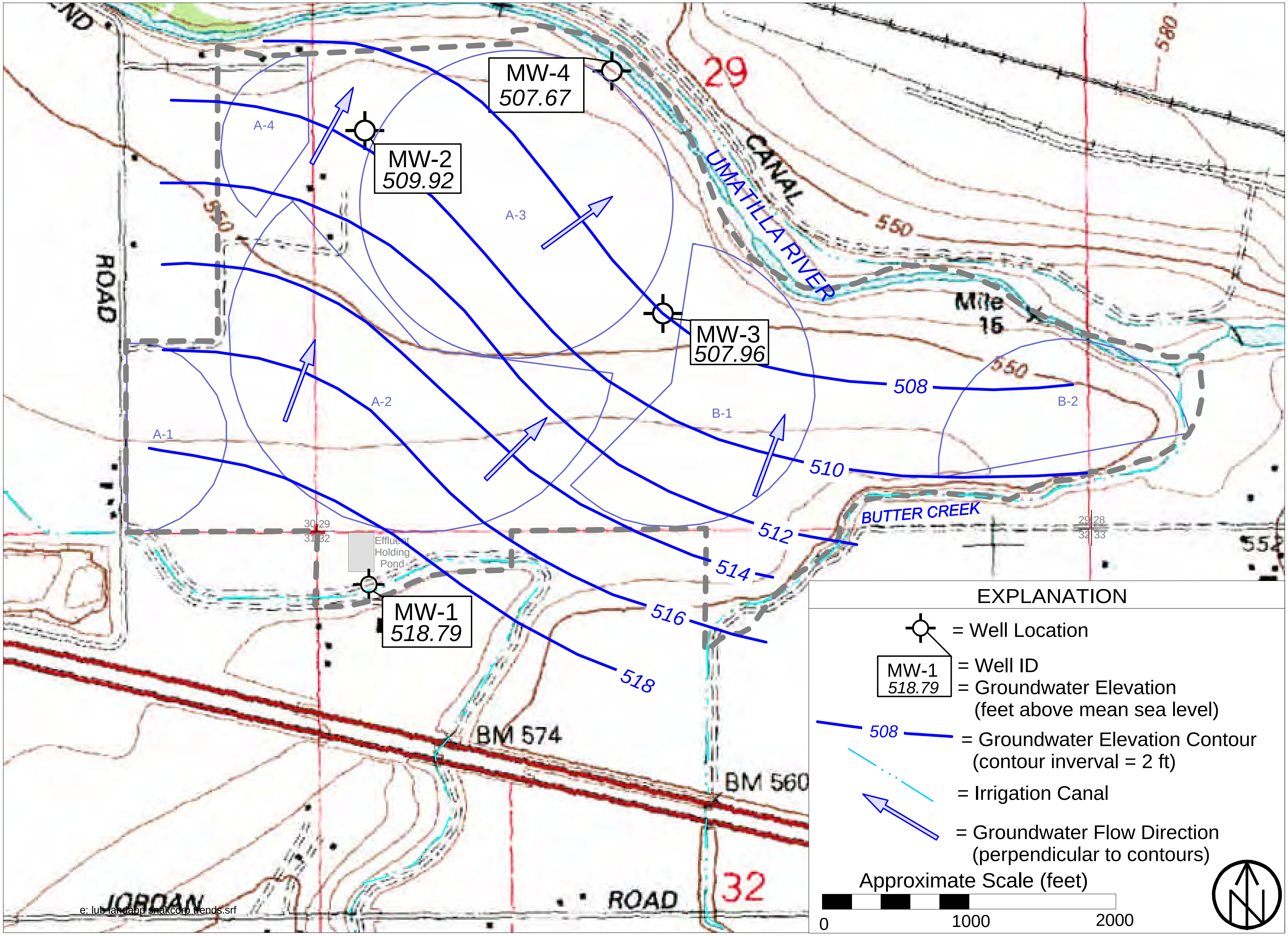
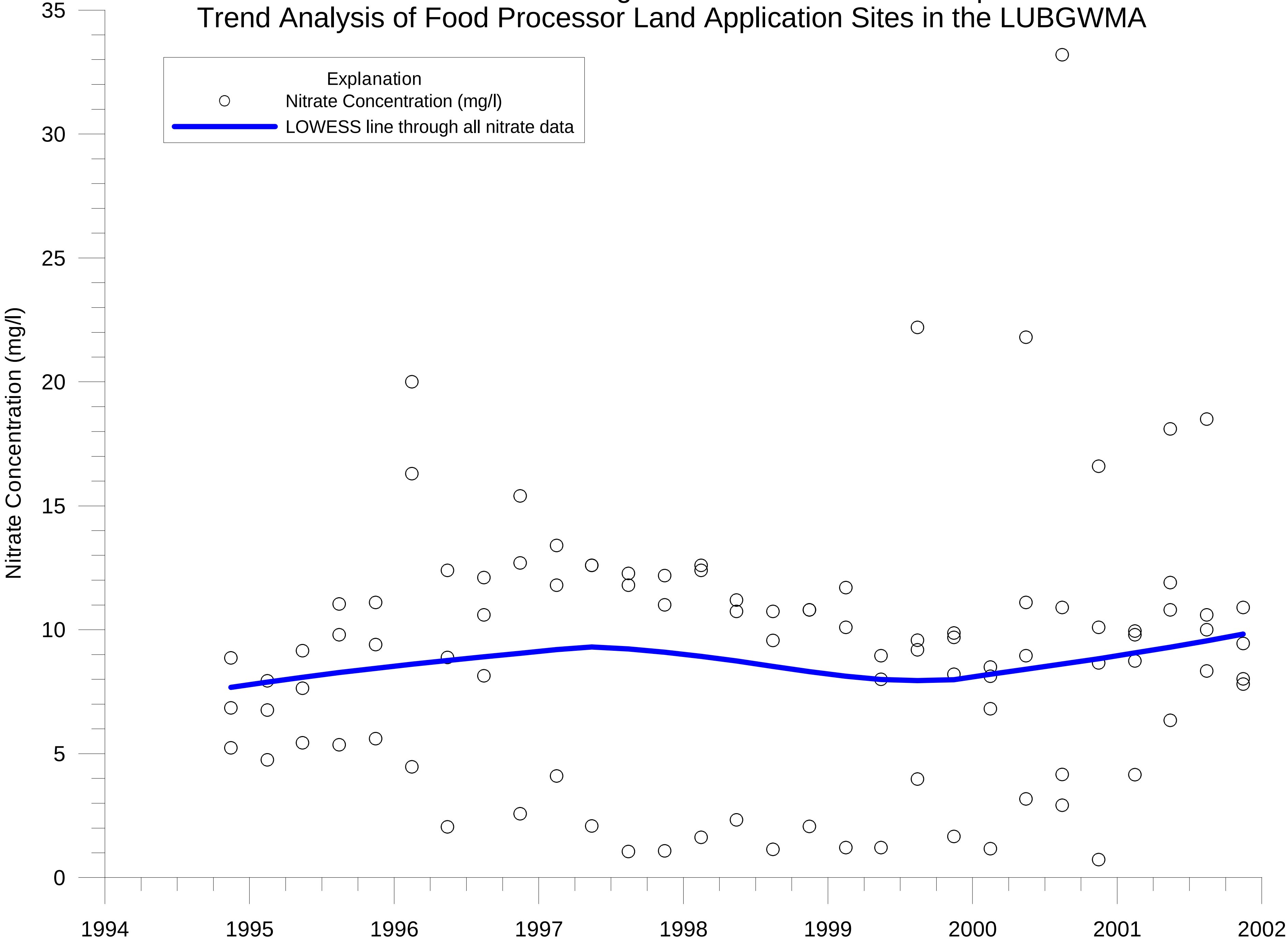


Figure 7-2
LOWESS Line Through All Nitrate Data - Snakcorp
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



e: lub landapp snackcorp all data.grf

Figure 7-3
LOWESS Lines and Trend Lines Through Nitrate Data - Snakcorp
Trend Analysis of Food Processor Land Application Sites in the LUB GWMA

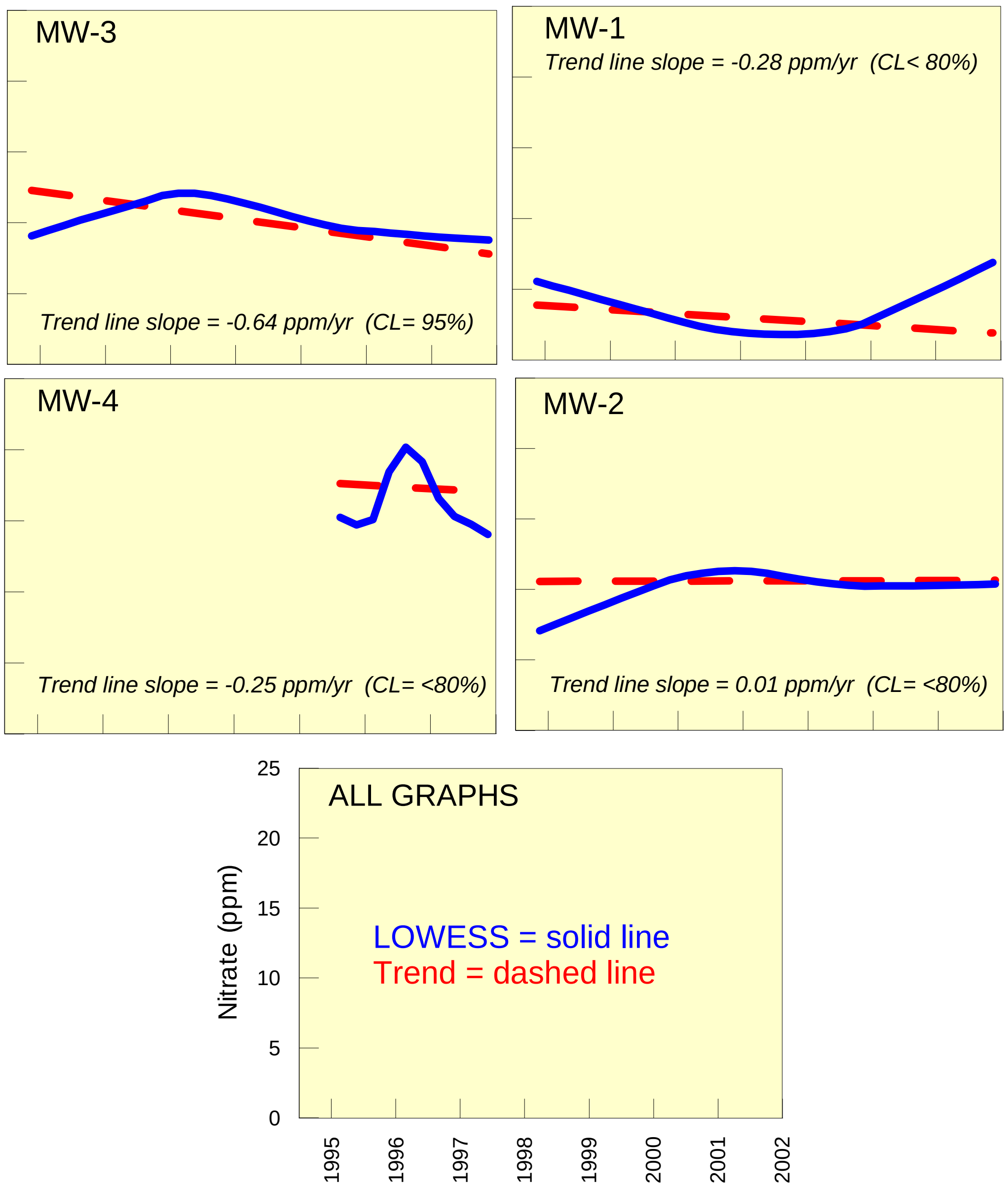
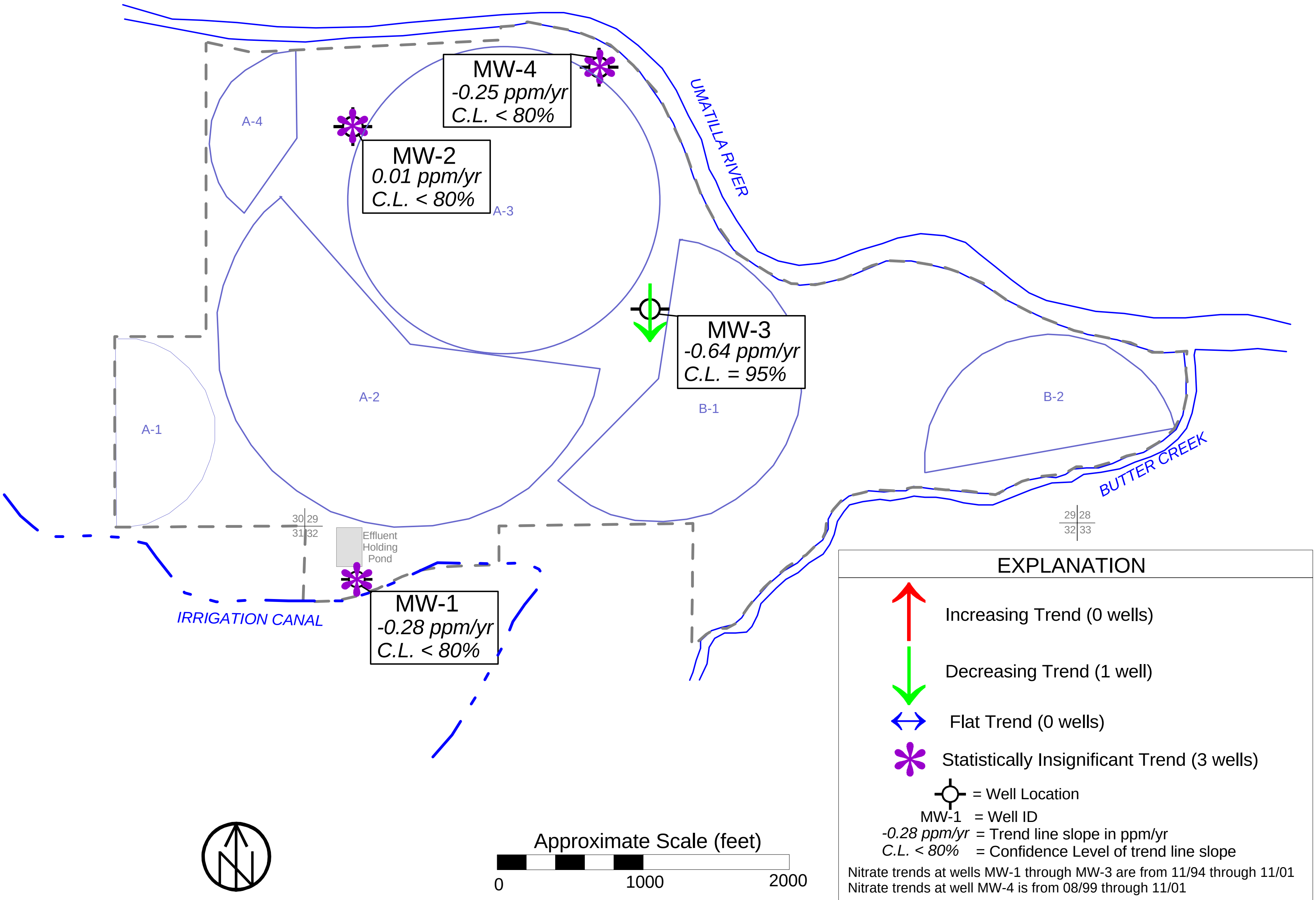
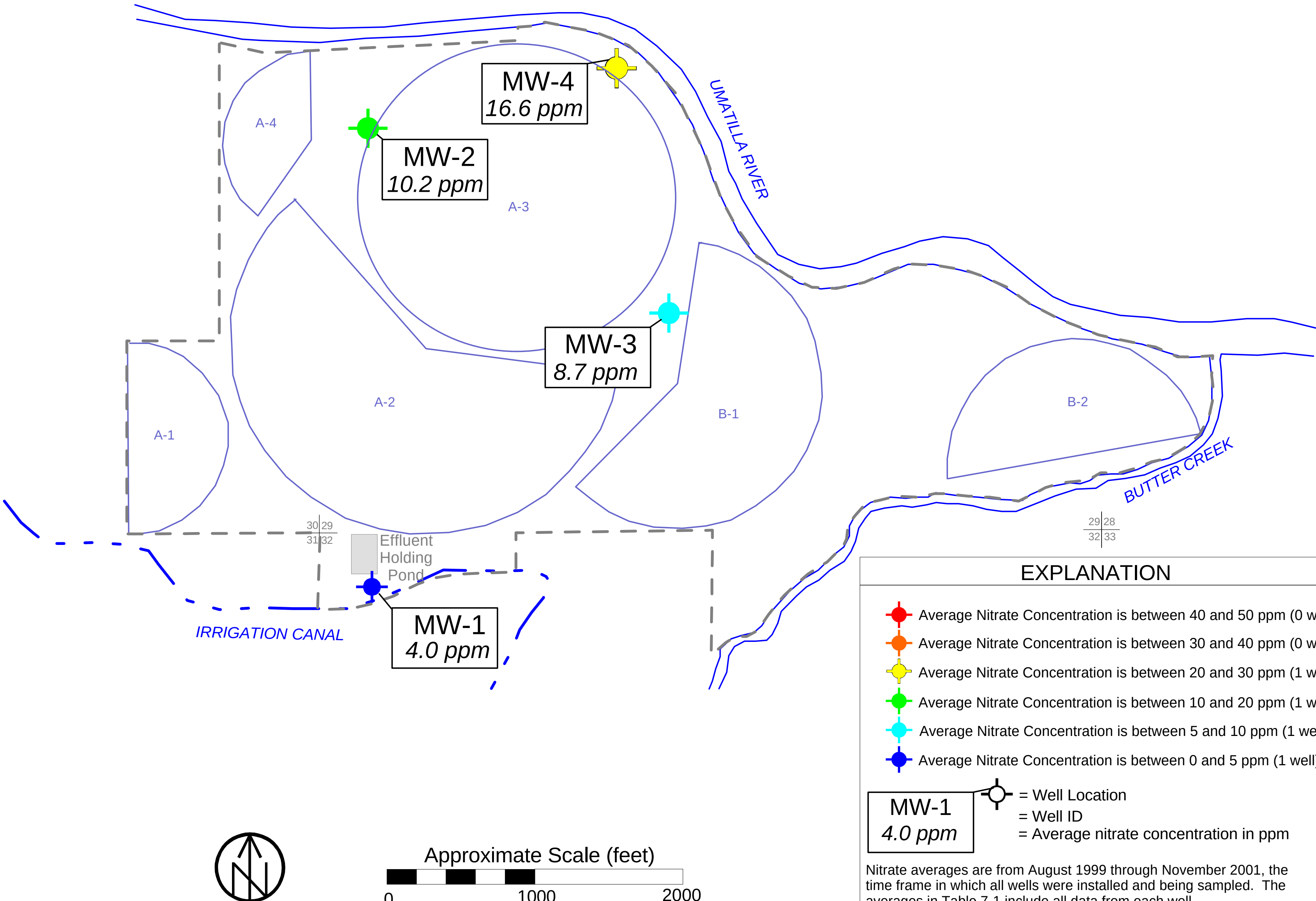


Figure 7-4
Nitrate Trends - Snakcorp
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



e: lub landapp snakcorp trends.srf

Figure 7-5
Average Nitrate Concentrations - Snakcorp
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



EXPLANATION

- Average Nitrate Concentration is between 40 and 50 ppm (0 wells)
- Average Nitrate Concentration is between 30 and 40 ppm (0 wells)
- Average Nitrate Concentration is between 20 and 30 ppm (1 well)
- Average Nitrate Concentration is between 10 and 20 ppm (1 well)
- Average Nitrate Concentration is between 5 and 10 ppm (1 well)
- Average Nitrate Concentration is between 0 and 5 ppm (1 well)

MW-1 / 4.0 ppm
= Well Location
= Well ID
= Average nitrate concentration in ppm

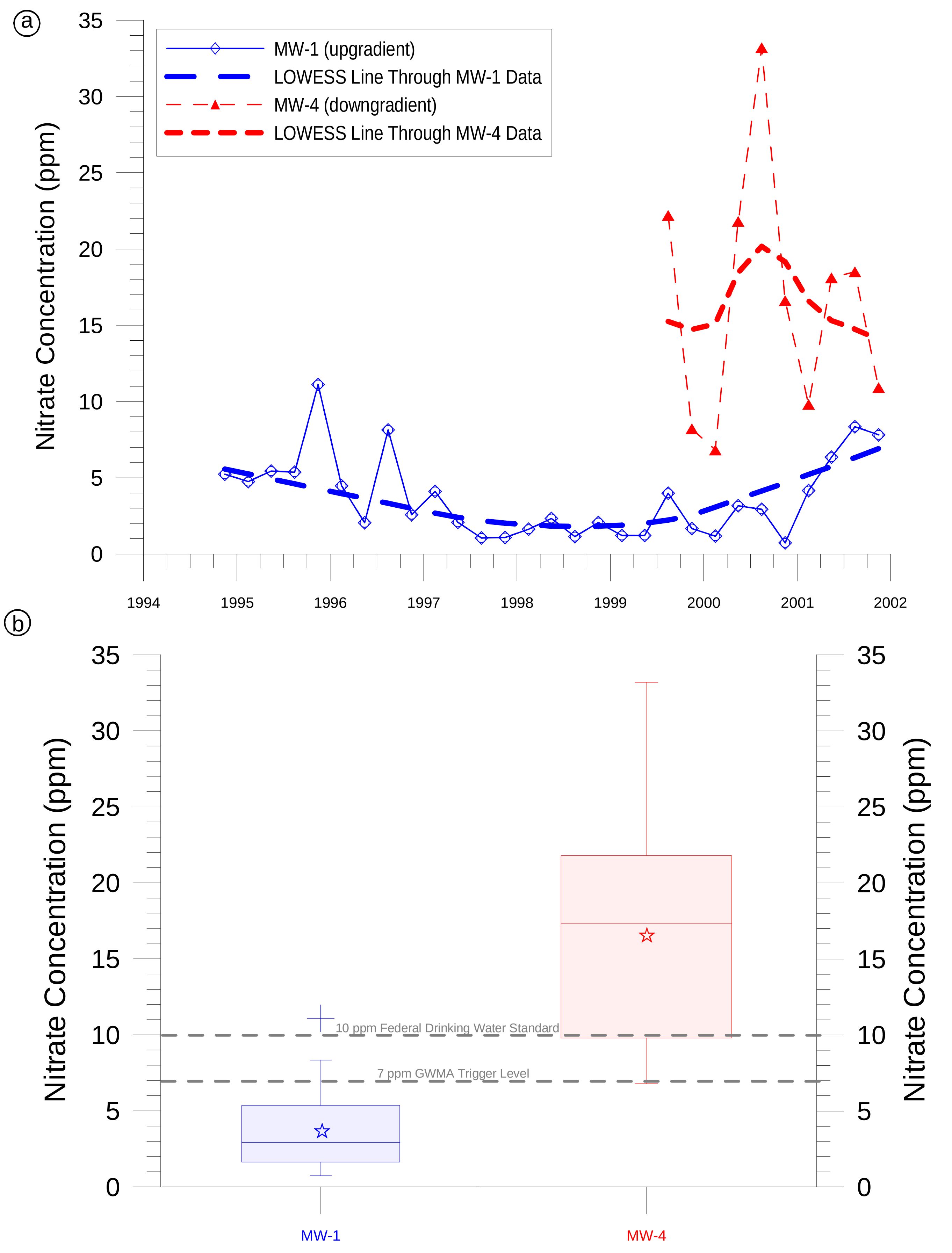
Nitrate averages are from August 1999 through November 2001, the time frame in which all wells were installed and being sampled. The averages in Table 7-1 include all data from each well.

e: lub landapp snakcorp avg.srf

Figure 7-6

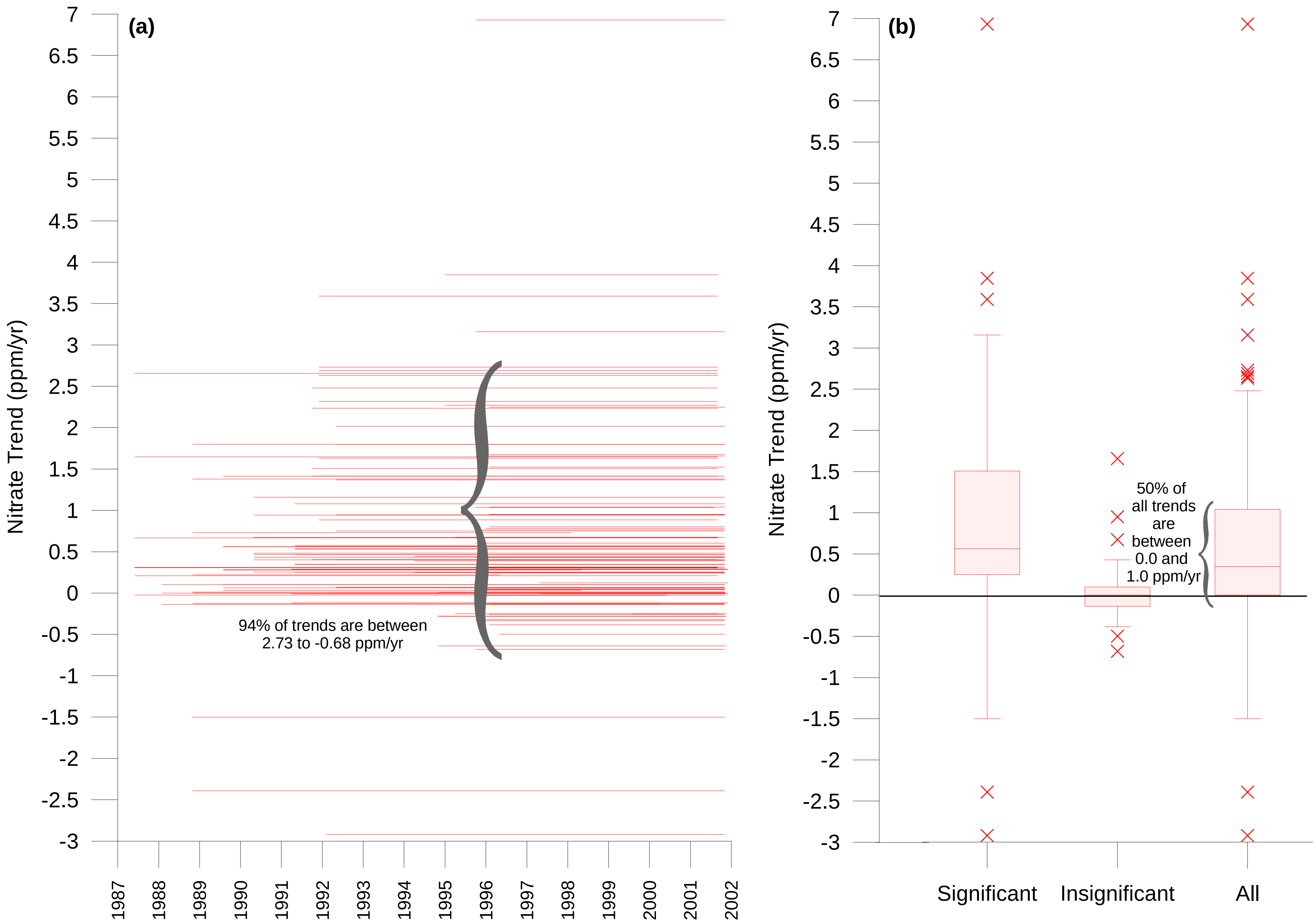
Upgradient vs. Downgradient Nitrate Comparisons - Snakcorp

Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



e: lub landapp snakcorp up v dn.grf

Figure 8-1
Comparison of All Trends
Trend Analysis of Food Processor Land Application Sites in the LUBGWMA



e: lub landapp trend analysis all trend bar & box graph.grf

APPENDIX 1
PRINCIPLES OF TREND ANALYSIS

This appendix provides information on the principles of conducting statistical trend analyses on groundwater quality data collected over an extended period of time, and on the types of statistical tests that are appropriate for this evaluation.

Appendices 2 through 7 contain graphs with nitrate concentrations plotted versus time for each of the wells evaluated. The Seasonal Kendall trend line on these graphs is hinged at median time and median concentration values. The trend line is rotated to coincide with the Sen slope.

Types of Trends

A primary goal of many water quality monitoring projects is to collect and analyze data so that changes in water quality over time (i.e., trends) can be detected. These trends can be related to both point sources and nonpoint sources; and are often related to changes in land use practices or patterns.

The two basic types of trends that can be statistically analyzed are step and monotonic. Step trends include either a sudden increase or decrease in concentration resulting from a sudden change in the primary activity controlling water quality. An example of a step trend would be a sudden increase in stream temperature downstream of a new surface water discharge. Monotonic trends are generally gradual changes that are either increasing or decreasing with no reversal of direction. An example of a monotonic trend would be the gradual decrease of groundwater nitrate concentrations as BMPs are implemented in an agricultural area.

Both step and monotonic trends can be increasing or decreasing. In addition, cycles (such as seasonal precipitation changes, tides, production schedules of industry, etc.) can be superimposed on trends. These cycles are not trends because they do not represent long-term changes.

For the purposes of this study, monotonic trend analysis techniques are believed to be most appropriate. This is largely due to the slow nature of contaminant transport in a groundwater system resulting in a relatively gradual change in groundwater quality in spite of the relatively rapid implementation of BMPs. In short, groundwater responds slowly; even to rapid changes at land surface.

Effects of Natural Fluctuations and Human Activity

It is possible for an apparent trend in water quality to be caused or masked by meteorological conditions such as precipitation cycles. It is also possible for an apparent trend in water quality to be caused or masked by human activities such as the production schedules of industry. Therefore, it is sometimes necessary to use special trending techniques to reduce the effect of outside influence (i.e., exogenous factors) on the data being examined. The purpose of adjusting the data for an exogenous variable is to reduce the background (i.e., "noise") so that the detection of trends (i.e., "signal") is more powerful.

For studies involving stream water quality trends, corrections are often needed to account for the flow/concentration relationship. In this study, the primary outside influence on the data is believed to be the seasonal changes in water quality caused by the irrigation season. Therefore, an evaluation of the seasonal component of water quality changes was conducted.

Measurements taken in close proximity over time are likely to be related to each other (known as autocorrelation or serial correlation), but most statistical tests require uncorrelated data (Gilbert, 1987). However, there are methods to detect serial correlation (e.g., the Durbin-Watson test). The Durbin-Watson statistic is a technique used to detect serial correlation in the residuals of a regression equation. The technique compares the residual from one time period with the residual from the previous time period, and computes a statistic that measures the significance of the correlation between these successive comparisons. The test statistic ranges from 0 to 4 and depends on the size of the data set, the number of explanatory variables in the regression equation, and the confidence level. A value near 2 indicates no serial correlation. A value near 0 indicates positive serial correlation. A value near 4 indicates negative serial correlation. There are also statistical techniques that have been developed which can account for serial correlation once it has been detected. One such technique is the Seasonal Kendall test with correction for correlation. For more information on this technique, the reader is referred to Hirsch, et al., 1984.

Loftis et.al., (1991) concludes that the distinction between serial correlation and trend is scale dependent. In other words, the distinction between serial correlation and trend is an artifact of the mathematical model used to evaluate the data as well as the time scale over which it is applied. For example, nitrate concentrations that are essentially constant over a long time (e.g., a flat trend) may contain short-term patterns which would be important from a management standpoint (e.g., decreasing trend within first half of observations). Loftis et. al., (1991) also notes that it is commonly, and probably appropriately, assumed that the scale of interest of a trend analysis is equal to the length of record (i.e., trend tests are applied to the entire record). Loftis et. al., (1991) further concludes that there is no “correct” way to approach water quality data analysis in terms of accounting for scale dependence but serial correlation can be ignored if the scale of interest is confined to the period of record.

It is clear that in order to detect or assess trends it is necessary that the data be collected at a given location using consistent collection and measurement techniques on a regular schedule and over a substantial number of years (Hirsch, et al., 1982). A change of analytical laboratories or of sampling and/or analytical procedures may occur during a long-term study. Unfortunately, this may cause a shift in the mean or in the variance of the measured values. Such shifts could be incorrectly attributed to changes in the underlying natural or man-induced processes generating the pollution (Gilbert, 1987).

Factors Complicating Trend Analysis

In order to conduct a statistically meaningful trend analysis of groundwater quality data, important assumptions regarding the data distribution (e.g., normal distribution) must be met for the chosen technique. In addition, several factors complicate the detection of groundwater quality trends. These complicating factors include seasonality, autocorrelation, missing values, outliers, and measurements near a detection limit. These complicating factors are discussed in more detail later in this report. Furthermore, results of the trend analysis must be examined for reasonableness (i.e., a “reality check”).

For example, a small but true water quality trend may not be detected in a data set with a high degree of seasonality by a technique that does not account for seasonality. As another example, if a series of measurements is reported at the detection limit, deviations from the trend line will not be normally distributed and the standard error of the least squares trend estimator will no longer apply. In many cases, outliers in the data will produce biased estimates of the least squares estimated slope itself (Gibbons, 1994).

For a steeply sloped trend, relatively few data points are necessary for the calculated values to be statistically significant. However, for a very small slope, a great deal more data may be required before the value can be confirmed as significant. Two possible consequences can occur as a result of this concept. First, two equally real trends in water quality may exist but only one will be found statistically significant because it will have a somewhat longer period of data collection. Second, an examination of an extensive data set may find a statistically significant trend that is so small as to be physically insignificant or meaningless (e.g., 0.001 mg/l/yr).

Parametric versus Nonparametric Techniques

A parametric technique is one whose validity depends upon the data being drawn from a specific known distribution (e.g., normal or log-normal). Parametric methods discussed in this report include simple least squares regression (linear regression), seasonal least squares regression, and sine/cosine seasonal least squares regression. A nonparametric (or distribution-free) technique is one whose validity does not depend upon the data being drawn from a specific distribution. The magnitude of data is ignored in favor of the relative values or ranks. Nonparametric techniques discussed in this report include the Mann-Kendall, Spearman's rho, Seasonal Kendall without correction for correlation, and the Seasonal Kendall with correction for correlation.

If the requirements of a regression equation were known to be true (i.e., a strictly linear relationship and normally distributed residuals), then fully parametric regression would be optimal (i.e., most powerful and lowest error variance for the slope). If the actual situation departs, even to a small extent, from these assumptions then a non-parametric (i.e., Mann-Kendall) procedure will perform either as well or better (Helsel & Hirsch, 1992). If one knows that the data to be examined for trends are normal and nonseasonal, then linear regression is clearly the best. If one knows that the data are normal but seasonal, then seasonal regression may be best (depending on the magnitude of the seasonality) (Hirsch, et al., 1982).

Nonparametric procedures are always nearly as powerful as regression, and the failure to edit out or correctly transform a small percentage of outlying data will not have a substantial effect on the results (Helsel & Hirsch, 1992). The advantage of non-parametric procedures is that there are very few underlying assumptions about the structure of the data making them robust against departures from normality. In addition, the use of ranks rather than actual values makes them insensitive to outliers, moderate levels of non-detected values, and missing values.

Given that departure from normality and the presence of seasonality are common features of water quality data, coupled with the rather small loss of power associated with using the Seasonal Kendall test where the linear regression test would be most powerful, the use of the Seasonal Kendall test is recommended as an exploratory test for trend by some researchers.

Monotonic Trend Analysis Techniques

There are several types of monotonic trend analysis techniques available for use. Not all techniques are appropriate for every data set. A trend can be visually examined by plotting the observed data versus time. However, a statistical test is required to analyze the trend. If plots of the data versus time suggest a simple linear increase or decrease over time, a linear regression of the variable against time may be fit to the data. A test can be used to evaluate if the slope is different than zero. This test can be misleading if seasonal cycles are present, the data are not normally distributed, and/or the data are serially correlated (Gilbert, 1987). In fact, the results may indicate a significant slope when the true slope actually is zero (Hirsch, et al., 1982).

The Mann-Kendall test is a nonparametric procedure particularly useful in water quality evaluations since missing values are allowed and the data need not conform to any particular distribution. Also, data reported as below a detection limit can be used by assigning them a common value that is smaller than the smallest measured value in the data set. This approach is valid because the Mann-Kendall test uses only the relative magnitudes of the data rather than their measured values (Gilbert, 1987). The Mann-Kendall test analyzes the sign difference between later-measured data and earlier-measured data. Each later-measured datum is compared to all data measured earlier. An increasing trend is identified if later-measured values tend to be larger than earlier-measured values. Conversely, a decreasing trend is identified if later-measured values tend to be smaller than earlier-measured values.

If a linear trend is present, the true slope may be estimated by linear regression methods. However, the regression-calculated slope can differ greatly from the true slope if there are gross data errors or outliers in the data. Sen's slope estimator is not greatly affected by gross data error or outliers, and it can be computed when data are missing. Sen's slope estimator is closely related to the Mann-Kendall statistic in that all possible slopes are calculated between all possible data pairs and the resulting median slope is the Sen slope. The Sen's slope estimator is used to estimate the slope for the Mann-Kendall test.

If seasonal cycles are present in the data, tests for trend that remove these cycles or are not affected by them should be used (Gilbert, 1987). The seasonal least squares regression technique and the sine/cosine seasonal least squares technique remove seasonality (deseasonalize the data) while the Seasonal Kendall test accounts for seasonality in the evaluation. The Seasonal Kendall test may be used even though there are missing, tied, or non-detected values. As mentioned previously, the validity of the test does not depend on the data being normally distributed.

Hirsch, et.al, (1982) evaluated the performance of linear regression applied to deseasonalized data. This procedure (called seasonal regression) gave test results that performed well when seasonality was present, the data were normally distributed, and serial correlation was absent. However, they suggest the Seasonal Kendall test is preferred to the simple or seasonal regression tests when data are skewed, cyclic, and serially correlated. When a time series contains any non-detected values, then parametric methods of trend detection become unusable. These non-detected values present no difficulty for nonparametric methods such as the Seasonal Kendall test because nonparametric tests require making comparisons of values to determine which is the larger. The non-detected data can all be considered to be smaller than any numerical value equal to or greater than the detection limit and tied with any other non-detected value. In cases where the detection limit has changed over time as more sensitive instruments are developed, it is necessary to take all data reported below the highest detection limit (including those reported as less than any lower detection limit) and consider them all to be tied at the highest detection limit (Hirsch, et al., 1982).

A variation of Sen's slope estimator called the Seasonal Kendall slope estimator (or the Seasonal Sen Slope estimator) is used to calculate the slope for the Seasonal Kendall test. The difference is that all possible slopes within each season are calculated with the median slope being the Seasonal Kendall slope.

A variation of the Seasonal Kendall technique is also available to account for serial correlation if it is present. However, the power to detect a trend is reduced when this technique is used.

EPA (1997) recommends the following. Use the Seasonal Kendall test for hypothesis testing when testing for monotonic trends. Linear regression might also be used but is generally discouraged. If the data do not have seasonal cycles, the Mann-Kendall test could be used. The

Seasonal Kendall slope estimator is recommended when estimating the magnitude of monotonic trends when seasonality is present and the Sen slope estimator when seasonality is not present.

Table A-1 presents a comparison of seven common monotonic trend analysis techniques. Some of the assumptions regarding data distribution and technique applicability, as well as the complicating issues, are identified. Table A-1 is not intended to be a comprehensive evaluation of these techniques. Rather, it is intended to provide the reader with some basis to distinguish the techniques. Readers interested in more details on how these techniques are used in water quality evaluations are encouraged to read Gilbert (1987) and Helsel and Hirsch (1992).

Multiple Observations at Multiple Locations

When evaluating multiple sample locations with multiple observations, it may be desirable to express the results as an overall regional summary statement across all sampling locations. However, there must be consistency in behavioral characteristics across sites over time in order for a single summary statement to be valid across all sampling locations. If the stations exhibit approximately steady trends in the same direction (upward or downward), with comparable slopes, then a single summary statement across stations is valid (EPA, 2000). Gilbert (1987) stated this idea slightly differently as "when data are collected at several stations within a region or basin, there may be interest in making a basin-wide statement about trends. A general statement about the presence or absence of monotonic trends will be meaningful if the trends at all stations are in the same direction – that is, all upward or all downward."

One method of evaluating whether there is a general trend evident throughout an entire region is by performing the "Regional Kendall test" (Practical Stats Internet Site, 2000). This is done by altering the Seasonal Kendall test so that instead of testing data from <u>all</u> sample locations collected from a specific time interval (e.g., a particular month), data from <u>individual</u> sample locations collected from specific time intervals are tested. In both the Seasonal Kendall test and the Regional Kendall test, data blocks are tested individually, and then combined into one overall test result. To conduct a Regional Kendall test, blocks of data are constructed of results from a specific location during the same time period. For example, consider an example of a data set consisting of 40 wells sampled every other month for 10 years. A block of data could consist of nitrate values for a particular well sampled in January of each year (i.e., 10 data points). The test statistic is computed for each location, and then summed for all locations. The overall test statistic is divided by its standard error, a continuity correction is applied and then compared to a table of the normal distribution. The result declares whether or not there is a significant up or down trend over time for the entire region. Note that if there is an increasing trend at one location and a decreasing trend at another, they will tend to cancel one another and no overall trend may be found, even if the individual tests are significant (Practical Stats Internet Site, 2000).

Another method of evaluating whether there is a general trend evident throughout an entire region is by performing a global trend test (van Belle and Hughes, 1984). The validity of the overall trend statistic is dependent on homogeneity between seasons, between stations, and a non-significant season-station interaction term. Procedures to evaluate these criteria and evaluate a global trend are computationally intensive and are not described in this report.

LOWESS

LOWESS stands for locally weighted scatterplot smoothing (Cleveland et al., 1979). It is not a monotonic trend analysis technique. It is a data smoothing algorithm that uses a moving window superimposed over a graph of data, with analyses being performed with each move, to produce a smoothed relationship of the two variables. Data near the center of the moving window influences the smoothed value more than those farther away. The smoothed relationship is then plotted as the LOWESS line. It provides a very good graphical depiction of the underlying structure of the data. LOWESS lines are included on each of the time series plots in Appendices 2 through 7.

An advantage of LOWESS is that no model, such as a linear or quadratic function, is assumed prior to computing a smoothed line. As such, LOWESS is an exploratory tool for discerning the form of relationship between y and x. Because no model form is assumed, the data describe the pattern of dependence of y on x. LOWESS is particularly useful to emphasize the shape of the relationship between two variables on a scatterplot of moderate to large sample size.

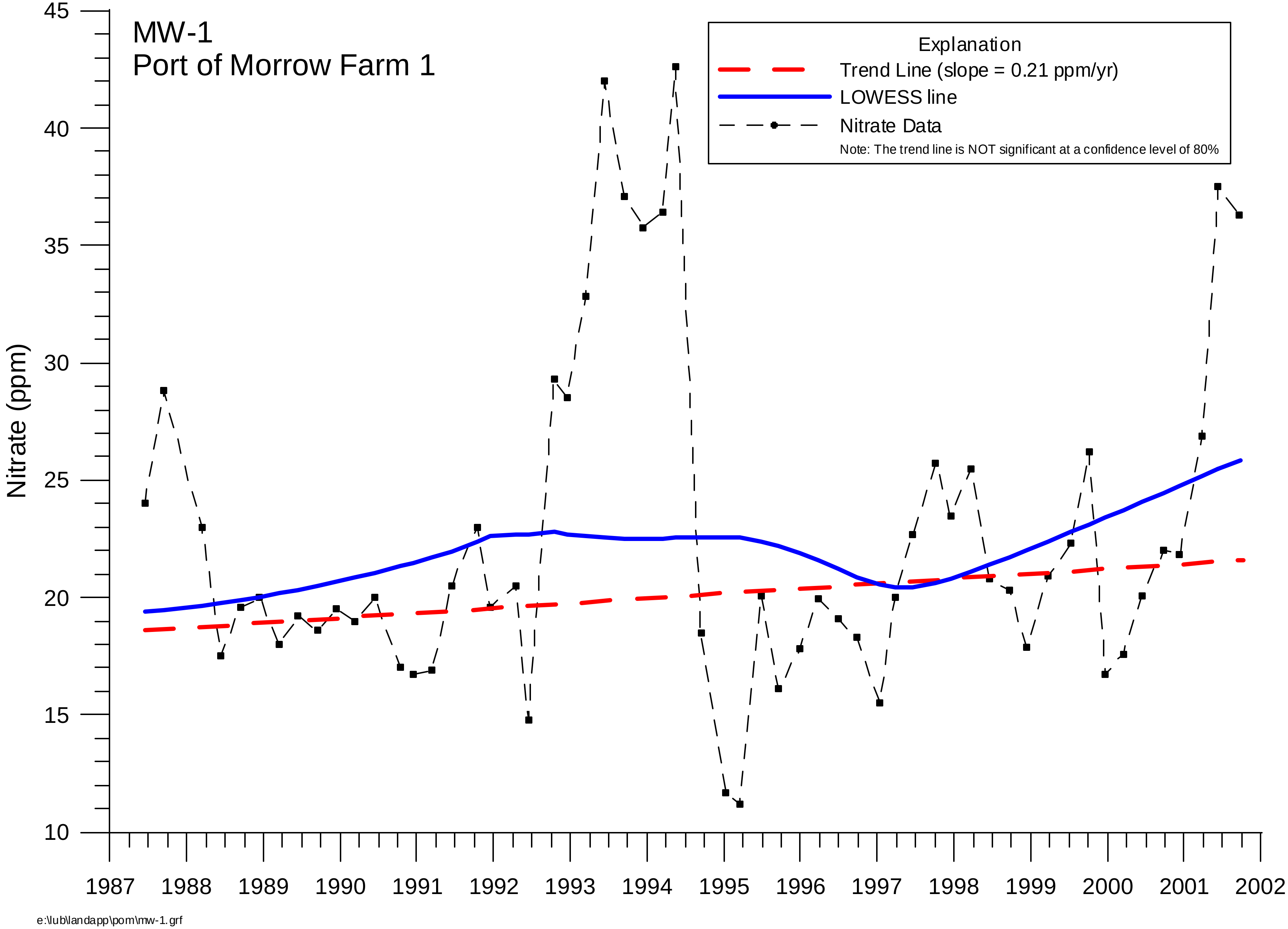
Because a LOWESS line reflects the underlying pattern of the data and is not fitting a straight line through the data as all monotonic trend techniques do, it allows an evaluation of changes within a time series data set. For example, a monotonic trend analysis result may indicate a statistically significant downward trend in a water quality variable over a 10-year time frame. However, the LOWESS line may suggest that the water quality variable decreased for 8 years and increased during the last 2 years. As another example, a monotonic trend analysis result may not identify a statistically significant trend in a water quality variable over a 10-year time frame. However, the LOWESS line may suggest that the water quality variable increased for 5 years then decreased for 5 years. These observations might be valuable and would not be apparent from the monotonic trend analyses.

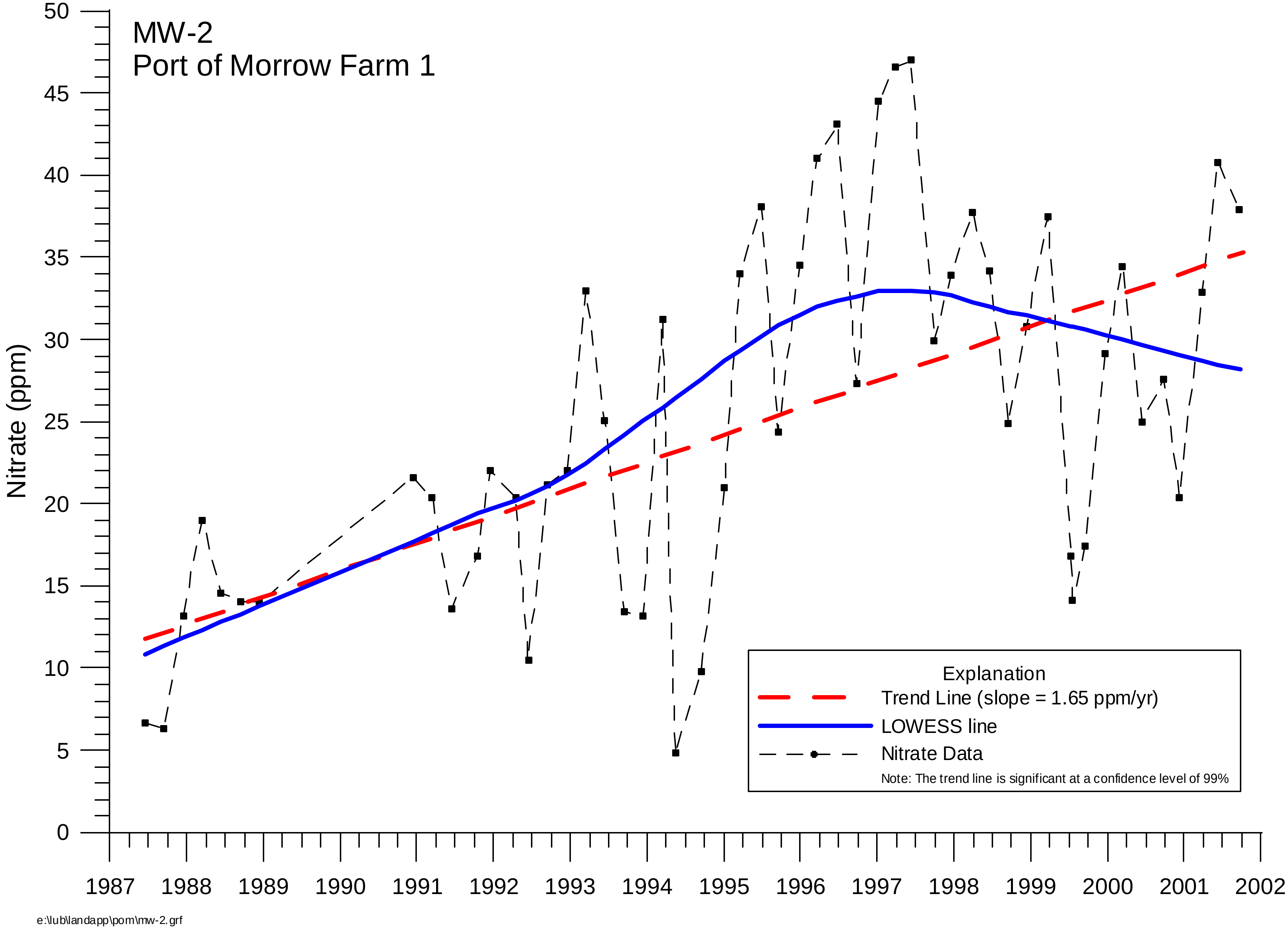
Predicting Future Concentrations

The ultimate question in analyzing time series data and computing trends is often "how long will it take?" until a particular event occurs. Answering this question requires predicting future concentrations. Predicting future concentrations with some degree of confidence requires advanced modeling techniques. This type of modeling commonly requires a considerable amount of data (e.g., hundreds of data points collected over regular intervals from a single sampling point). Environmental studies seldom include this much data. Most sample locations in this study include approximately 20 to 50 data points. Furthermore, specialized and relatively sophisticated statistical expertise is also required. Accurate prediction of future groundwater concentrations is beyond the scope of this report.

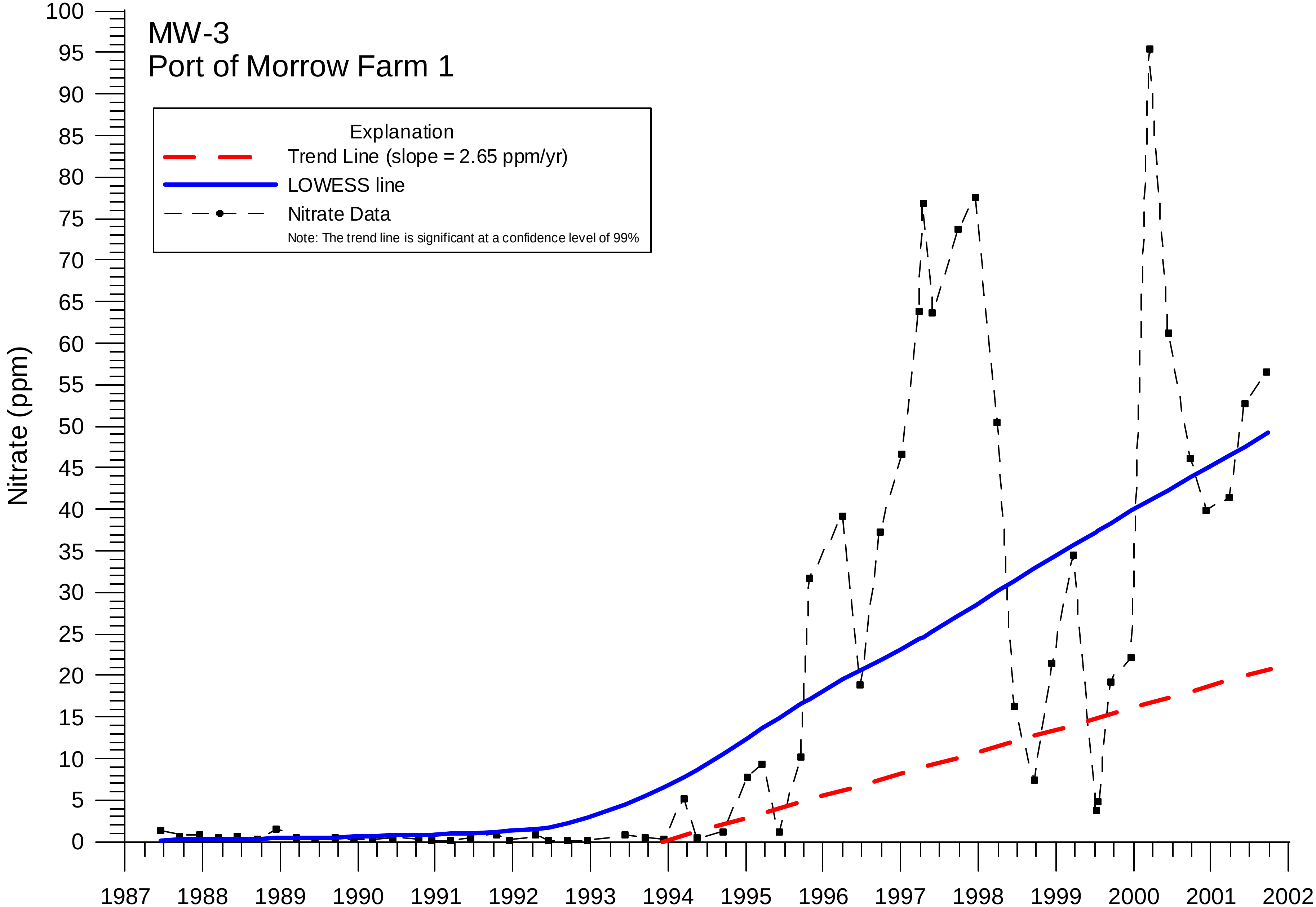
Table A-1
Comparison of Monotonic Trend Techniques
Trend Analysis of Food Processor Land Application Sites in the LUB GWMA

Trend Analysis Method	Parametric or Nonparametric	Account for Seasonality?	Advantages	Disadvantages
Simple Least Squares (Linear Regression)	Parametric	No	(1) The most powerful technique if data are normal, nonseasonal, & independent (2) Familiar technique to many people (3) Simple to compute a "best fit" line	(1) Environmental data rarely conforms to test assumptions (2) Sensitive to outliers (3) Difficult to handle non-detected values (4) Not robust against serial correlation (5) Does not account for seasonality
Mann-Kendall	Nonparametric	No	(1) Nondetects, outliers, and irregularly spaced data are permitted	(1) Does not account for seasonality (2) Not robust against serial correlation
Spearman Rho	Nonparametric	No	(1) Nondetects, outliers, and irregularly spaced data are permitted	(1) Not robust against missing observations (2) Does not account for seasonality (3) Not robust against serial correlation
Seasonal Least Squares Regression	Parametric	Yes, Deseasonalized values are obtained by subtracting monthly means averaged over years. The new values are then regressed against time.	(1) Accounts for seasonality (2) Produces a description of the seasonality pattern (i.e., seasonal means)	(1) Performs well only when data are normal (2) Not robust against serial correlation
Sine / Cosine Seasonal Least Square	Parametric	Yes, Deseasonalized values are obtained through fitting a sine curve through the data. The deviations from the curve are then regressed against time.	(1) Accounts for seasonality	(1) With few exceptions (e.g., temperature) there is little reason to believe the form of seasonality resembles a pure sine curve. (2) Performs well only when data are normal (3) Not robust against serial correlation
Seasonal Kendall without Correction for Correlation	Nonparametric	Yes, by comparing only data from the same "season".	(1) Accounts for seasonality (2) Robust against nondetects, outliers, and irregularly spaced data	(1) When applied to non-seasonal data, it has less power to detect trends than non-seasonal tests (2) Not robust against serial correlation
Seasonal Kendall with Correction for Correlation	Nonparametric	Yes, by comparing only data from the same "season".	(1) Accounts for seasonality (2) Robust against nondetects, outliers, and irregularly spaced data (3) Robust against serial correlation	(1) When applied to non-seasonal and/or non-correlated data, it has less power to detect trends than other tests.

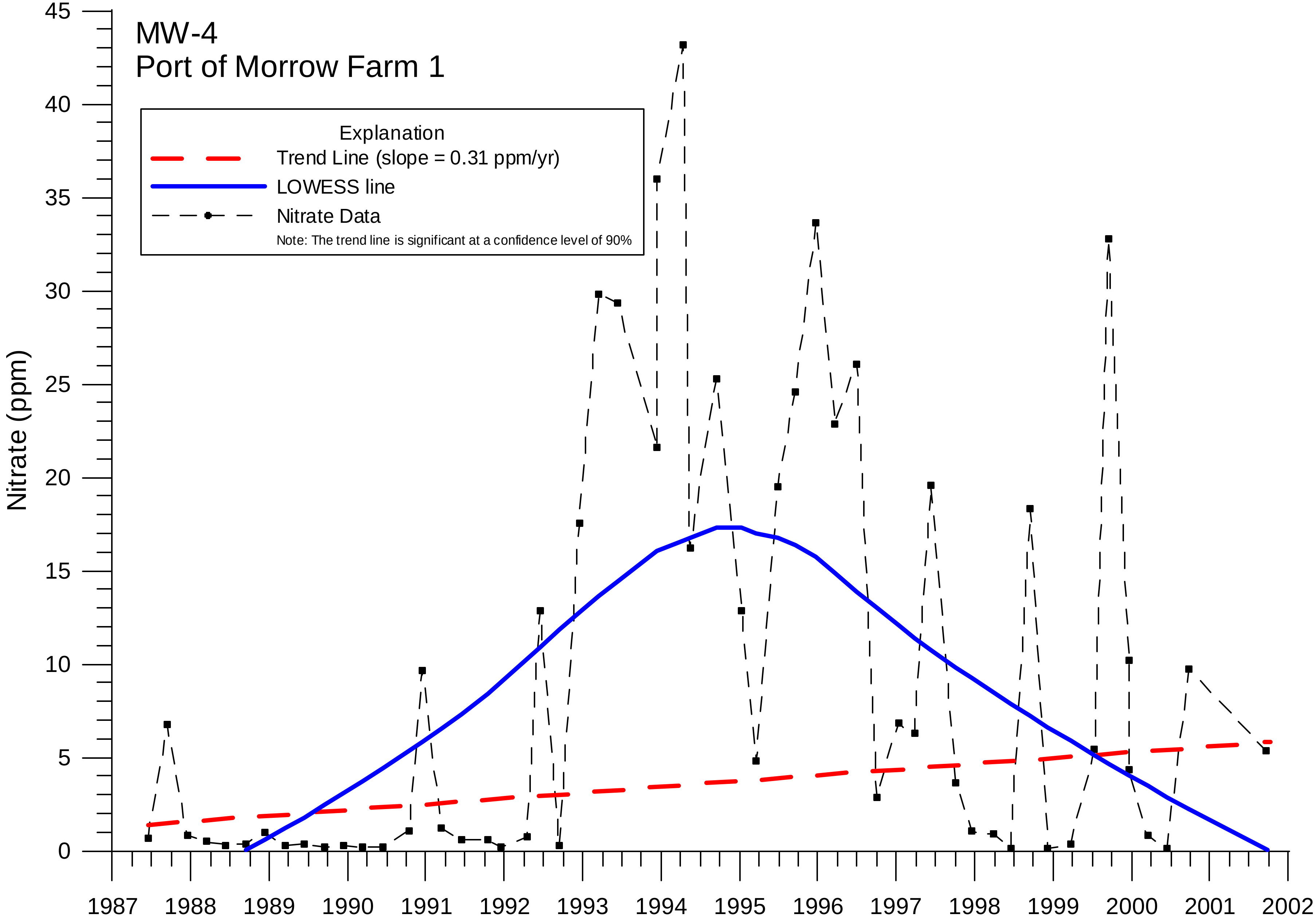

MW-1
Port of Morrow Farm 1
Explanation
Trend Line (slope = 0.21 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%
Nitrate (ppm)
10
15
20
25
30
35
40
45
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
e:\lub\landapp\pom\mw-1.grf

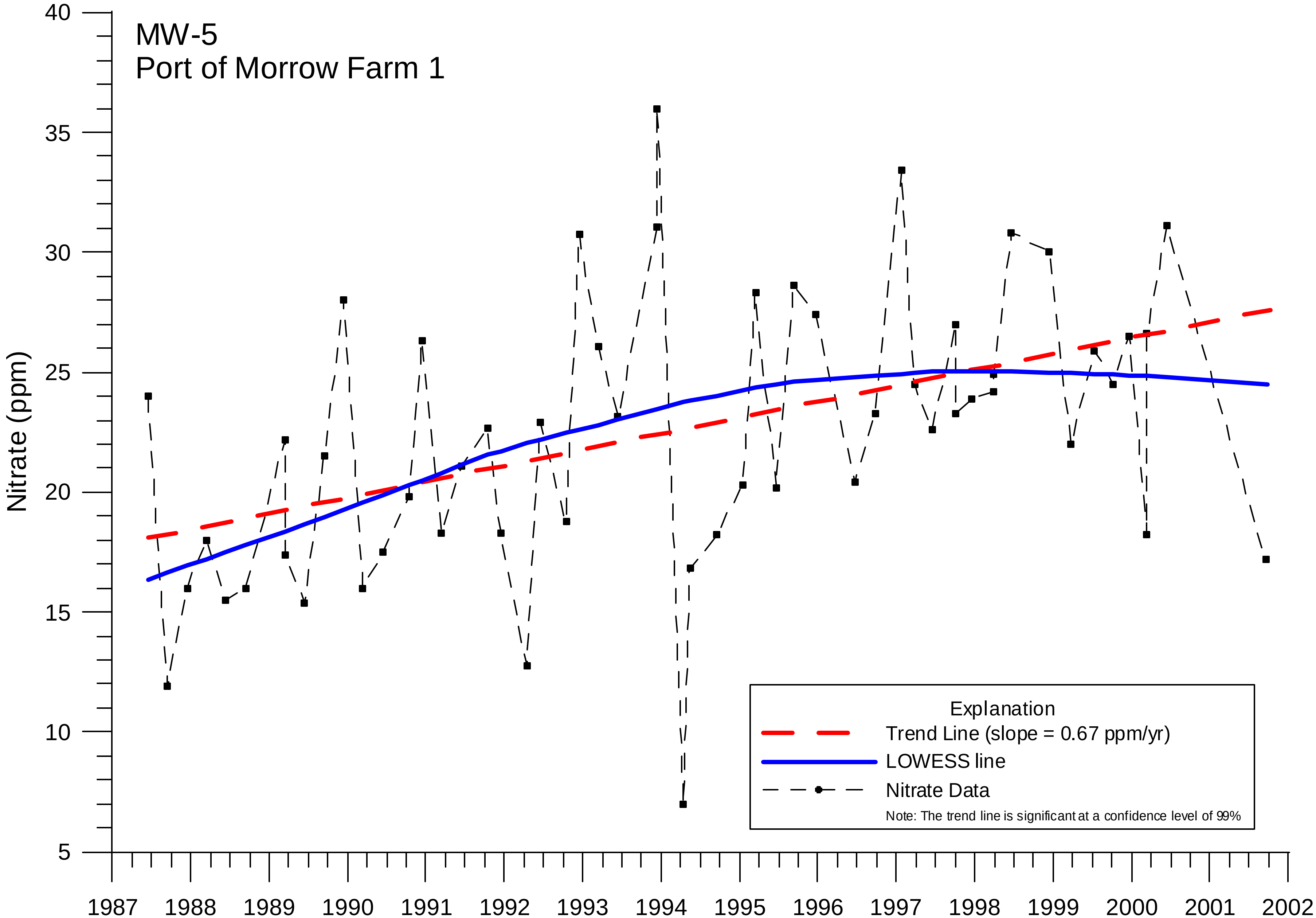


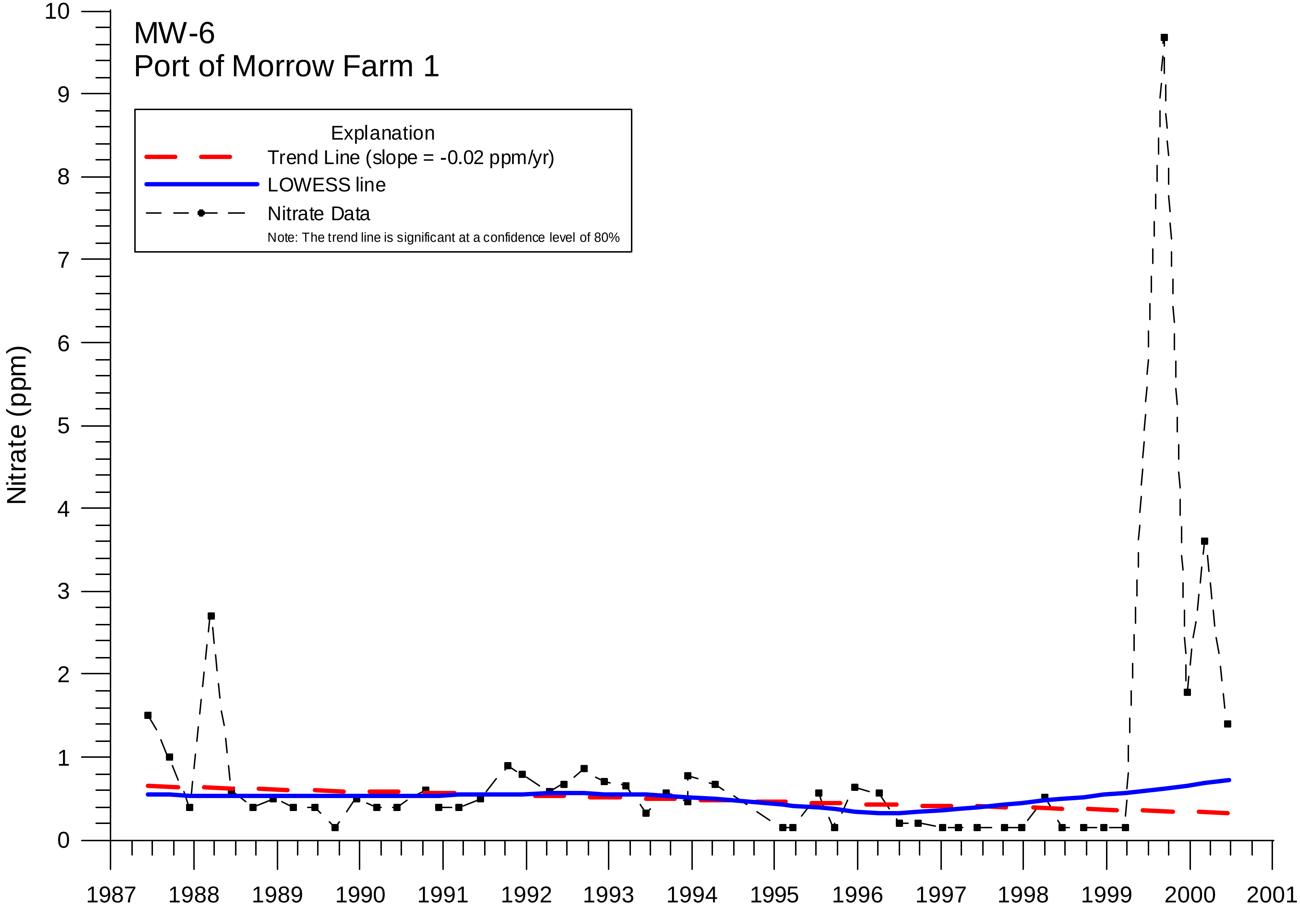
MW-2
Port of Morrow Farm 1
Nitrate (ppm)
0
5
10
15
20
25
30
35
40
45
50
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 1.65 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%
e:\lub\landapp\pom\mw-2.grf

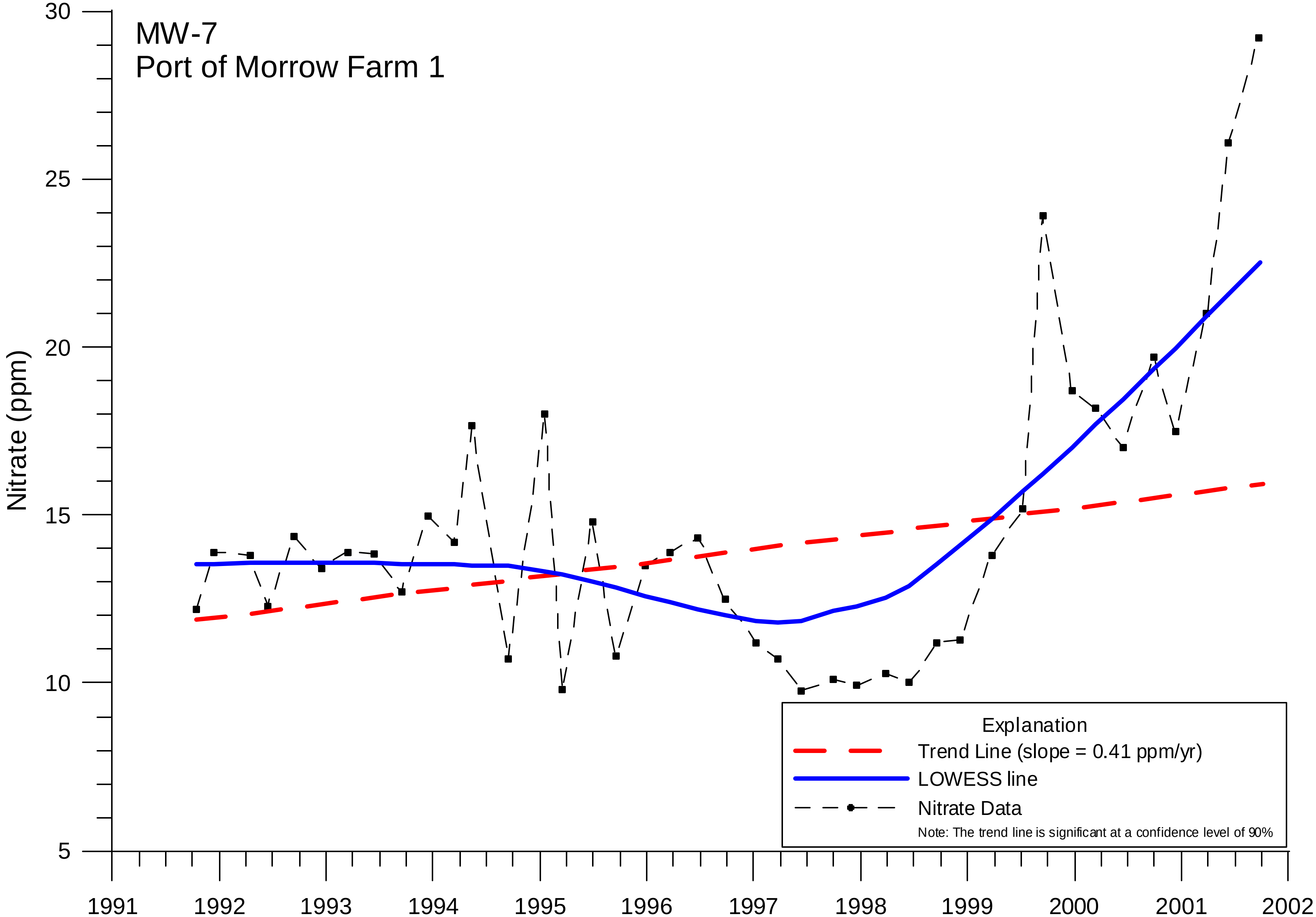


MW-3
Port of Morrow Farm 1
Explanation
Trend Line (slope = 2.65 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%
Nitrate (ppm)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002

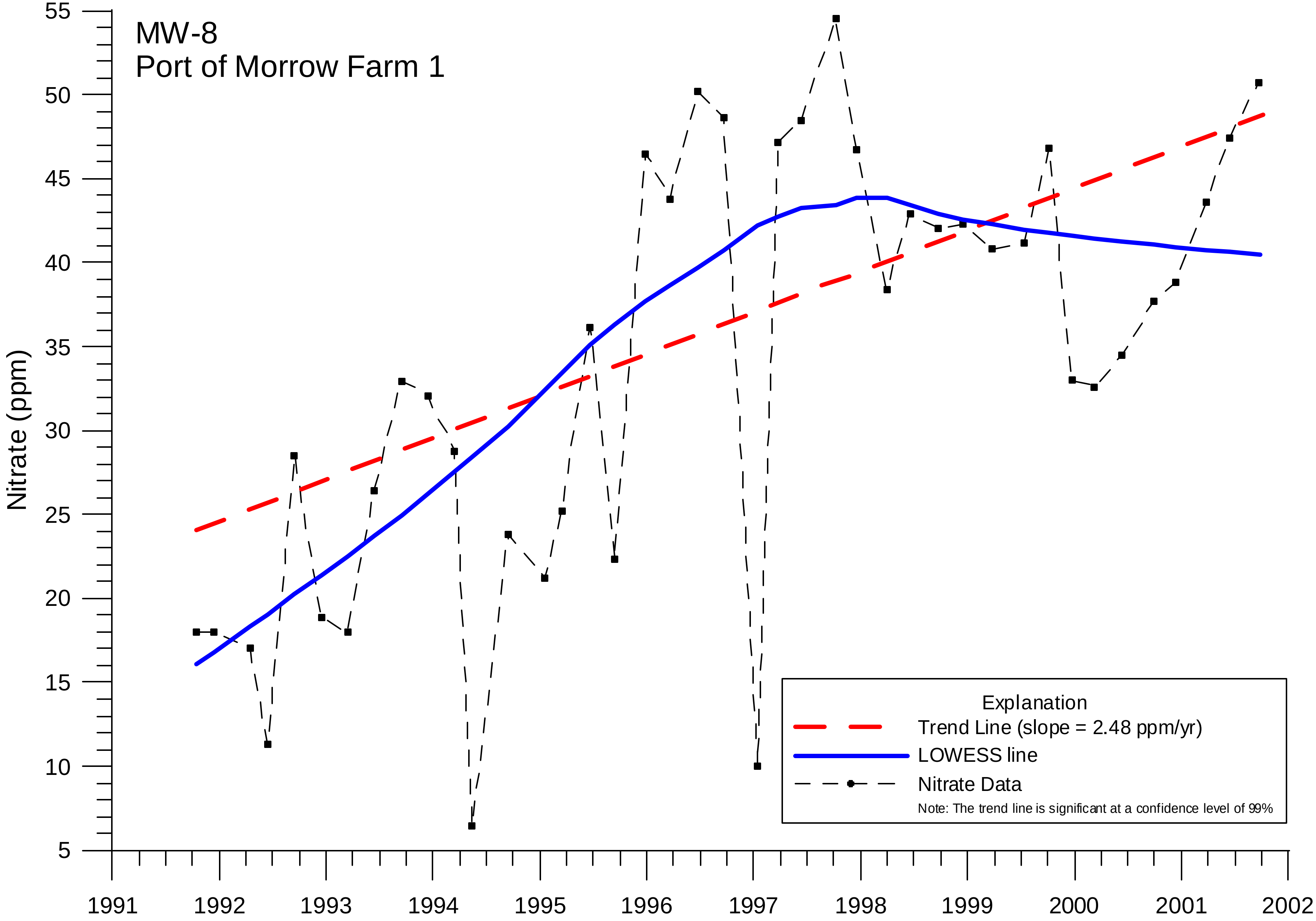

MW-4
Port of Morrow Farm 1
Explanation
Trend Line (slope = 0.31 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 90%
Nitrate (ppm)
0
5
10
15
20
25
30
35
40
45
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002

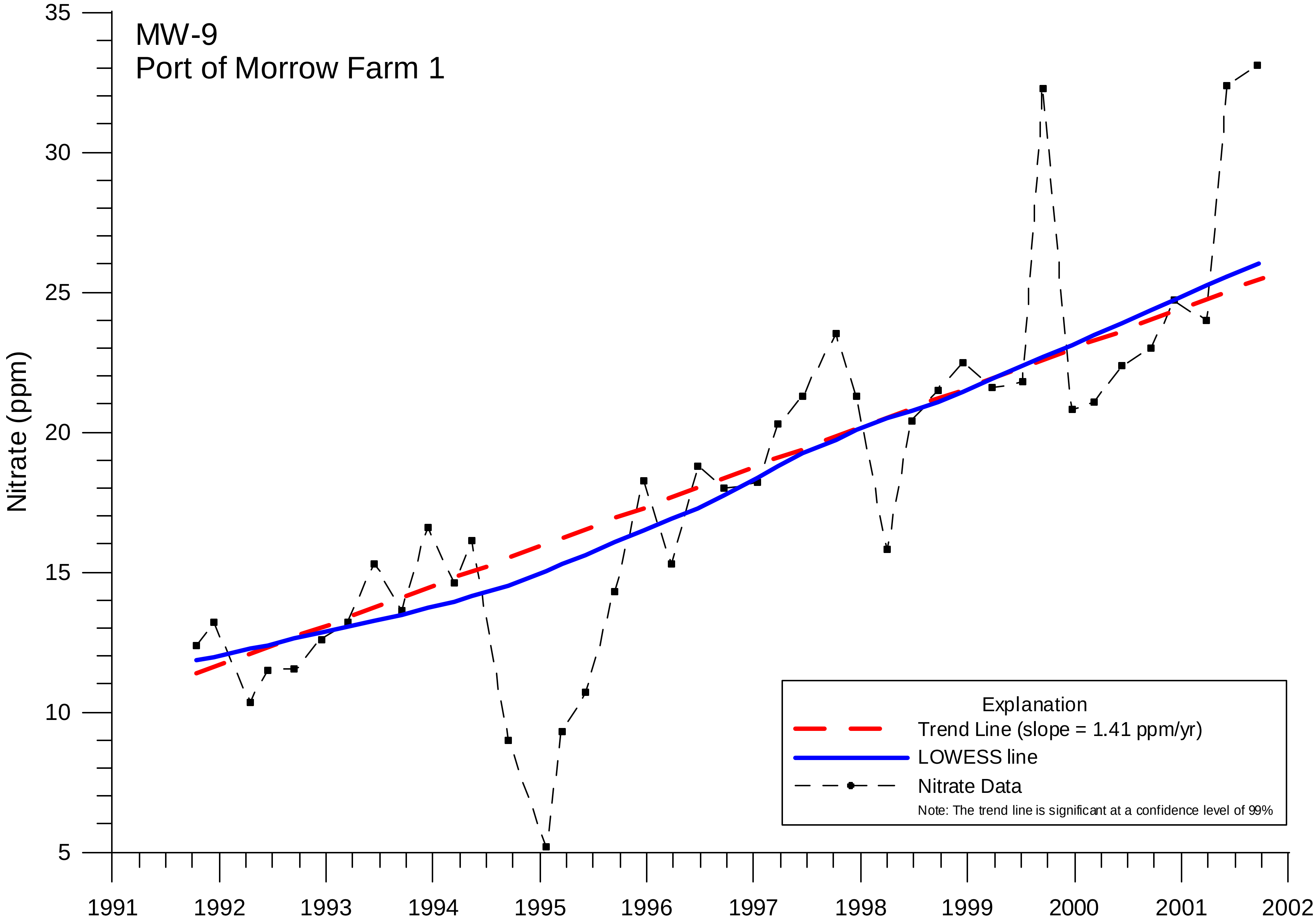

MW-5
Port of Morrow Farm 1
Nitrate (ppm)
40
35
30
25
20
15
10
5
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.67 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

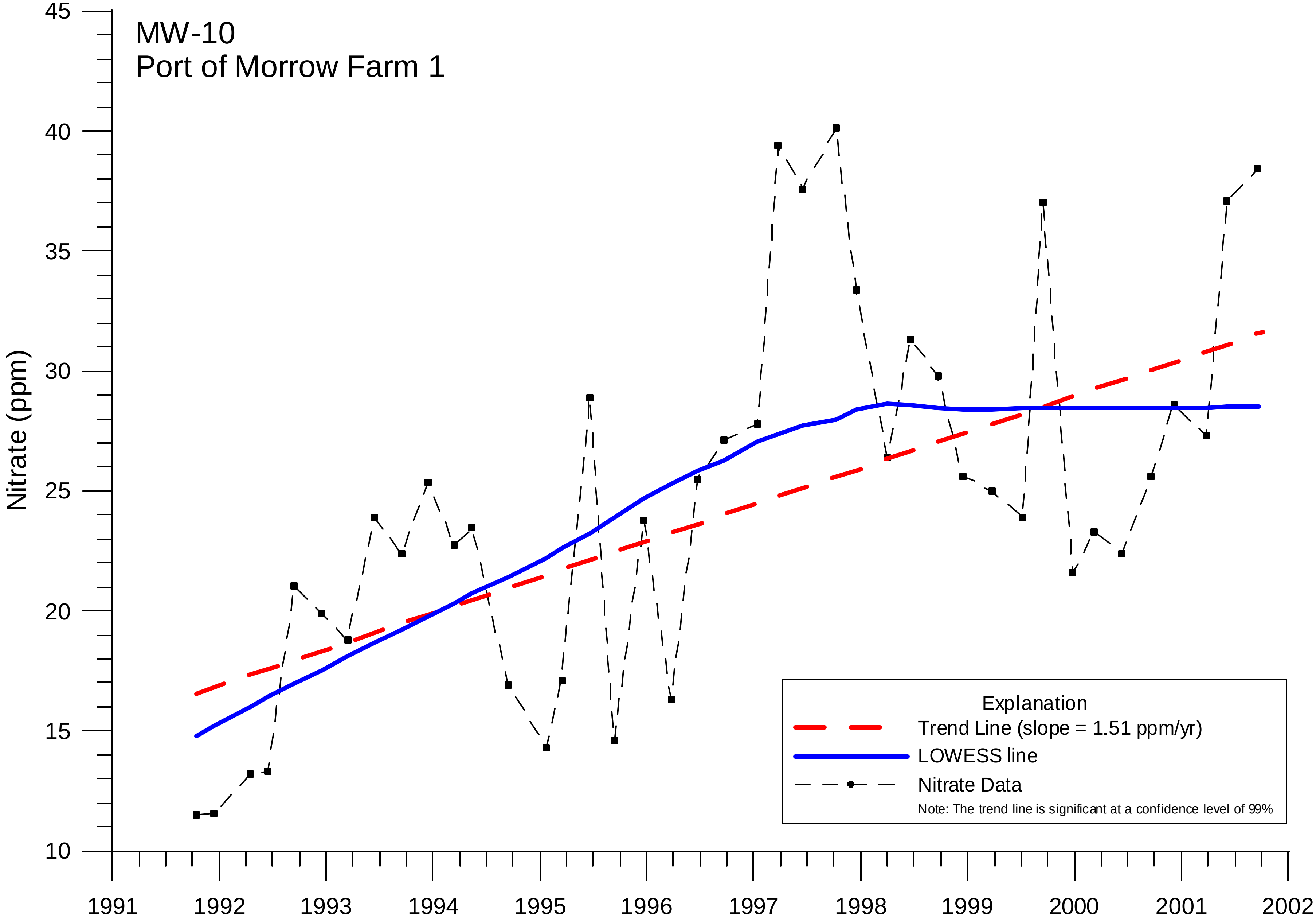

MW-6
Port of Morrow Farm 1
Explanation
Trend Line (slope = -0.02 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 80%
Nitrate (ppm)
0
1
2
3
4
5
6
7
8
9
10
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001



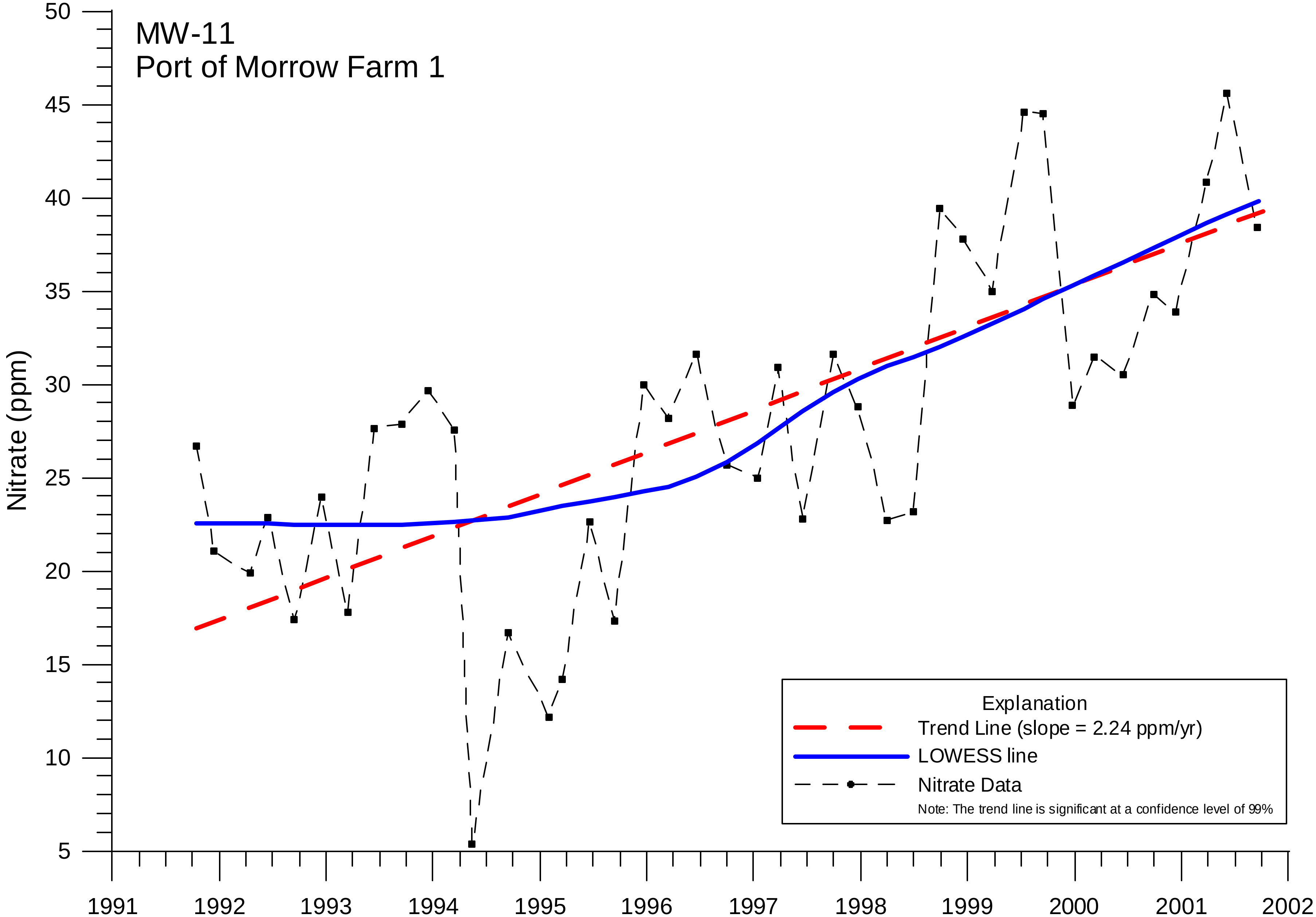
MW-7
Port of Morrow Farm 1
Nitrate (ppm)
30
25
20
15
10
5
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.41 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 90%


MW-8
Port of Morrow Farm 1
Nitrate (ppm)
55
50
45
40
35
30
25
20
15
10
5
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 2.48 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

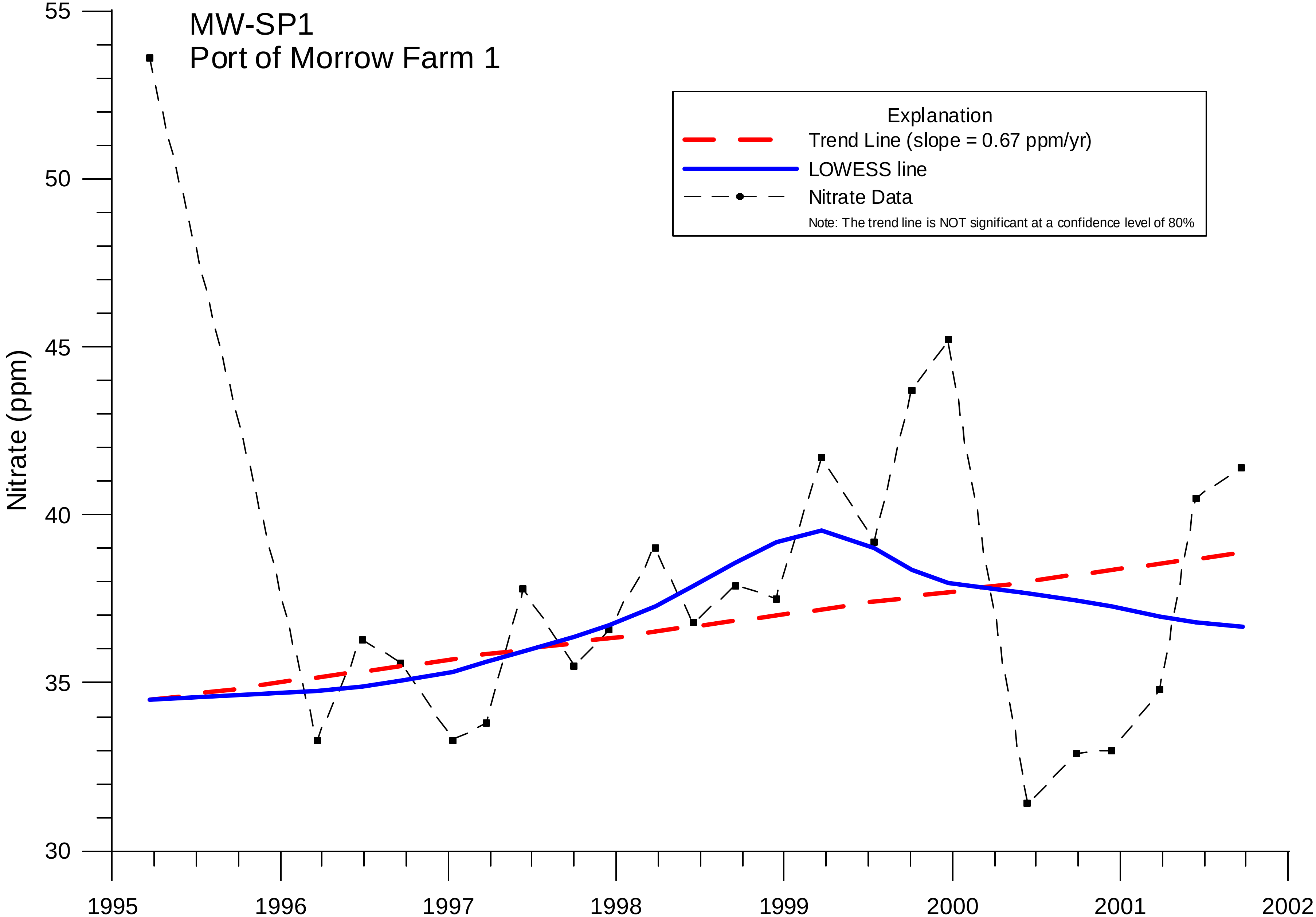

MW-9
Port of Morrow Farm 1
Nitrate (ppm)
35
30
25
20
15
10
5
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 1.41 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%



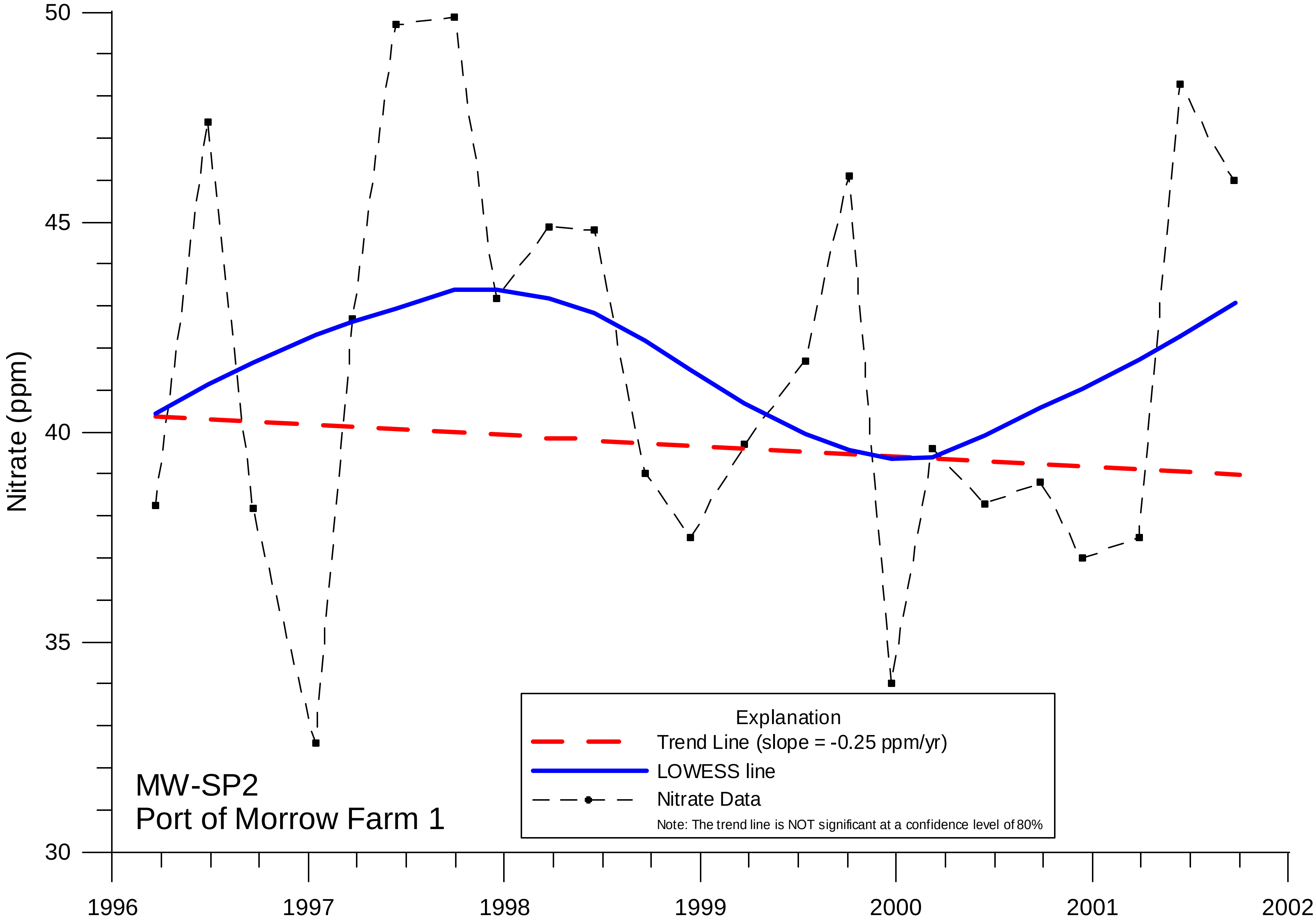
MW-10
Port of Morrow Farm 1
Nitrate (ppm)
45
40
35
30
25
20
15
10
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 1.51 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%



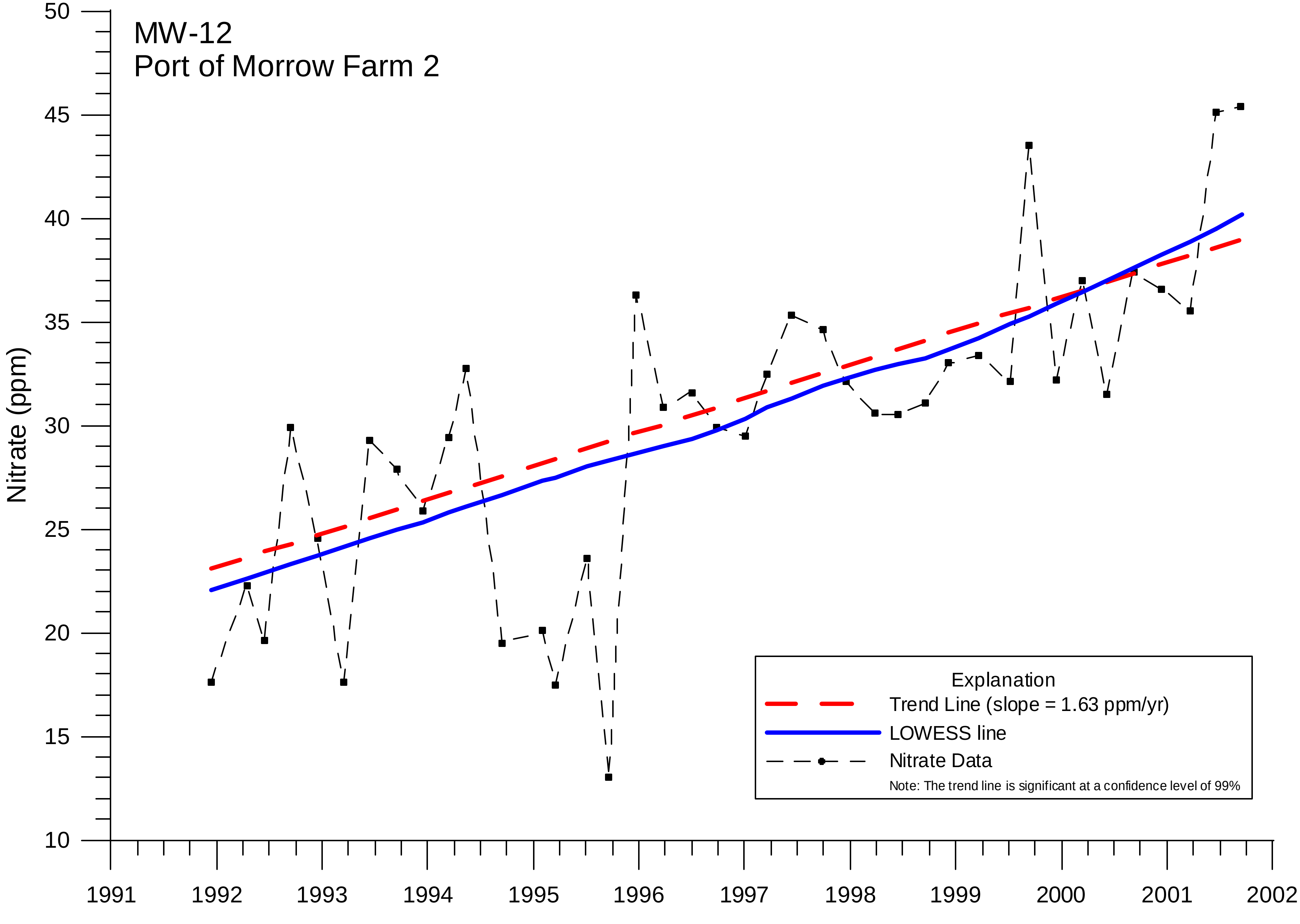
MW-11
Port of Morrow Farm 1
Nitrate (ppm)
50
45
40
35
30
25
20
15
10
5
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 2.24 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

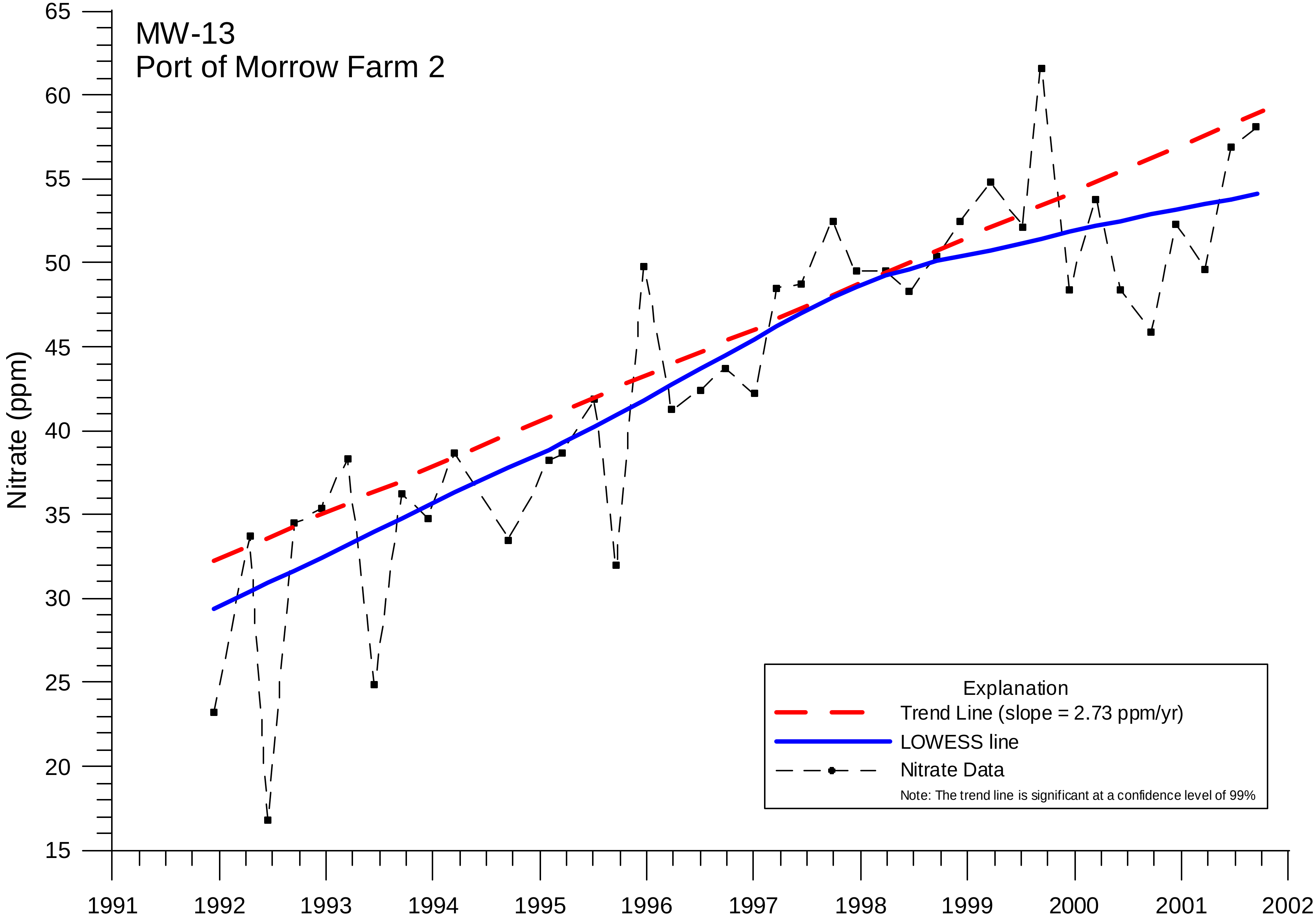


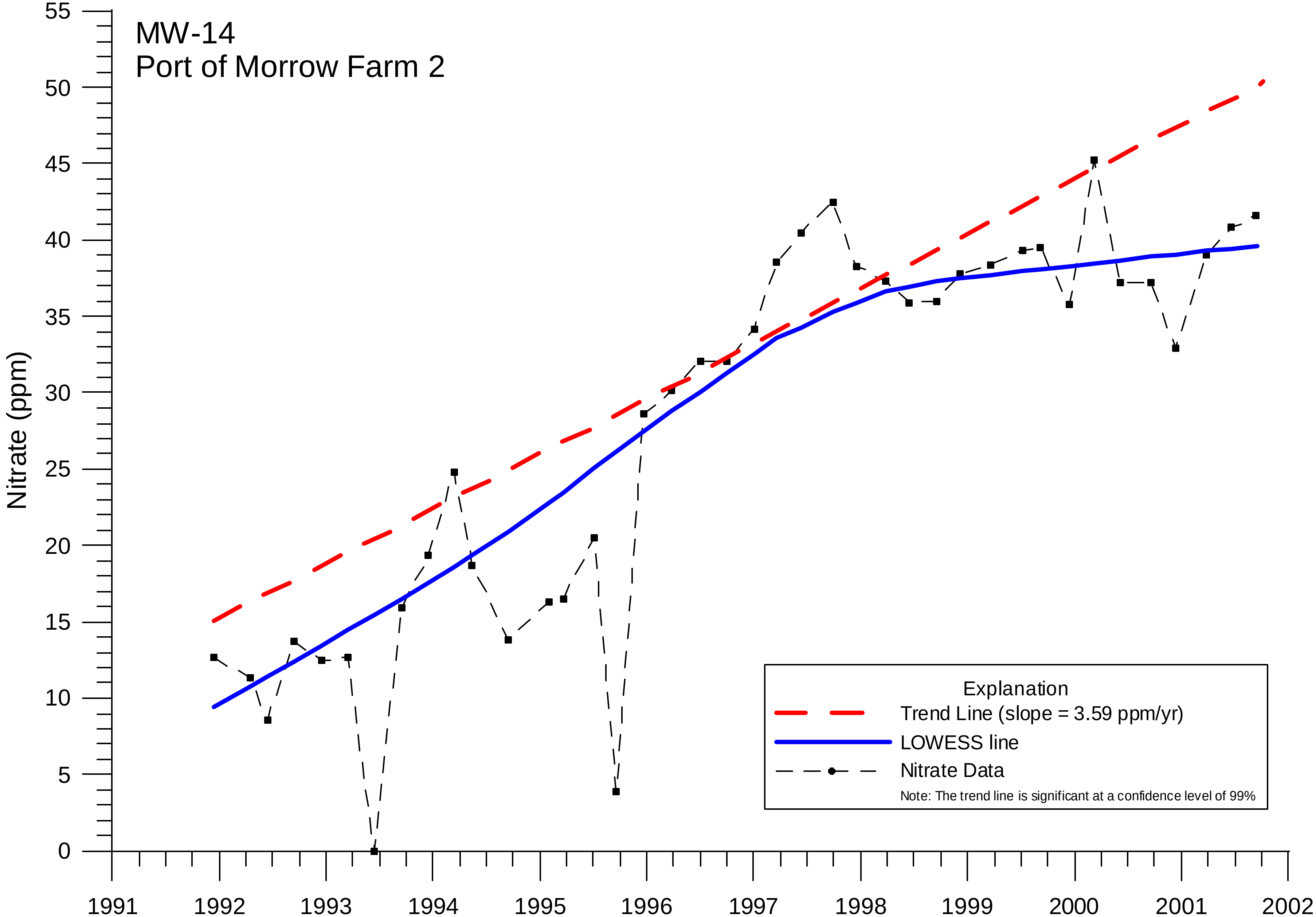
MW-SP1
Port of Morrow Farm 1
Explanation
Trend Line (slope = 0.67 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%
Nitrate (ppm)
55
50
45
40
35
30
1995
1996
1997
1998
1999
2000
2001
2002

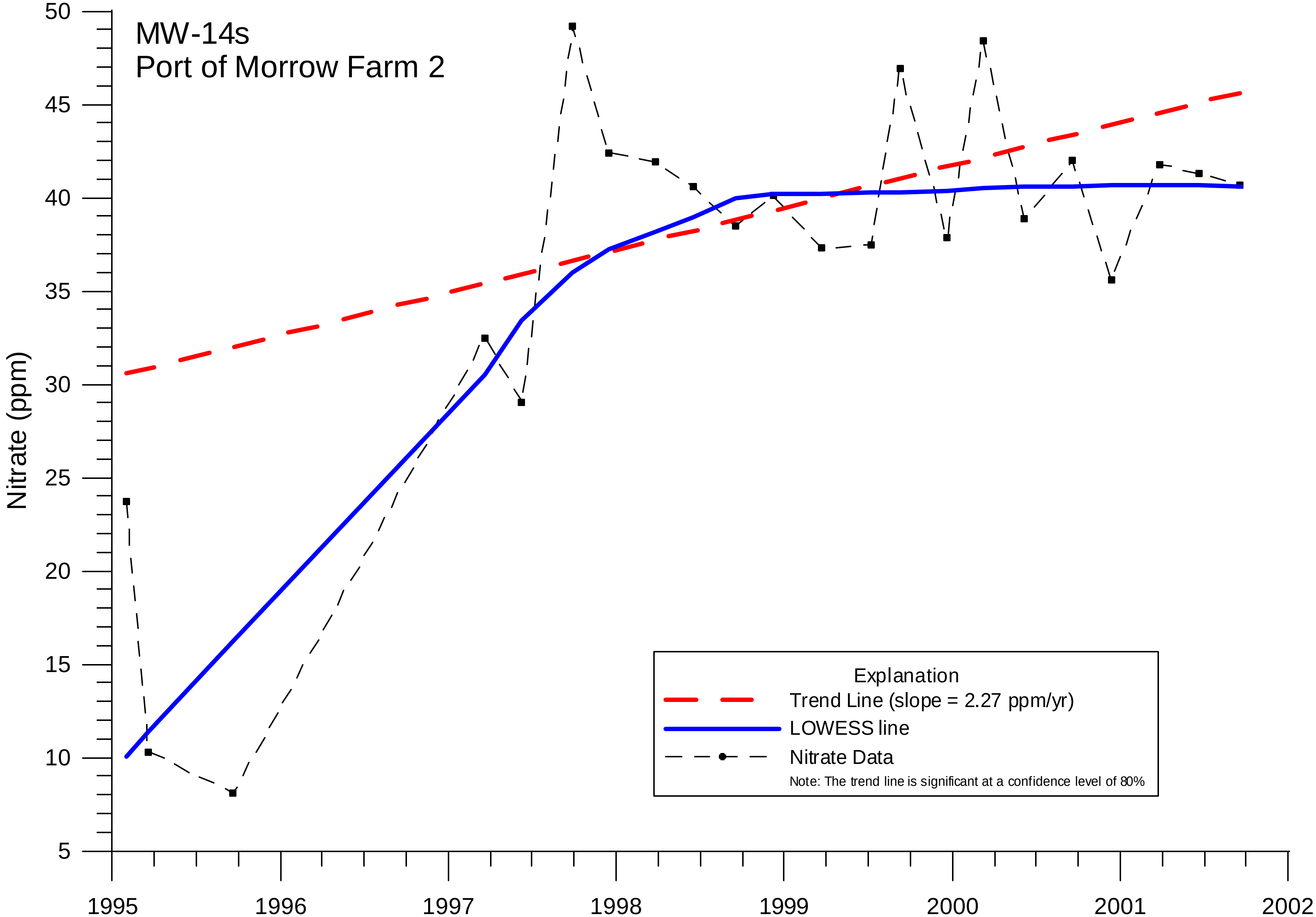


Nitrate (ppm)
50
45
40
35
30
1996
1997
1998
1999
2000
2001
2002
MW-SP2
Port of Morrow Farm 1
Explanation
Trend Line (slope = -0.25 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%

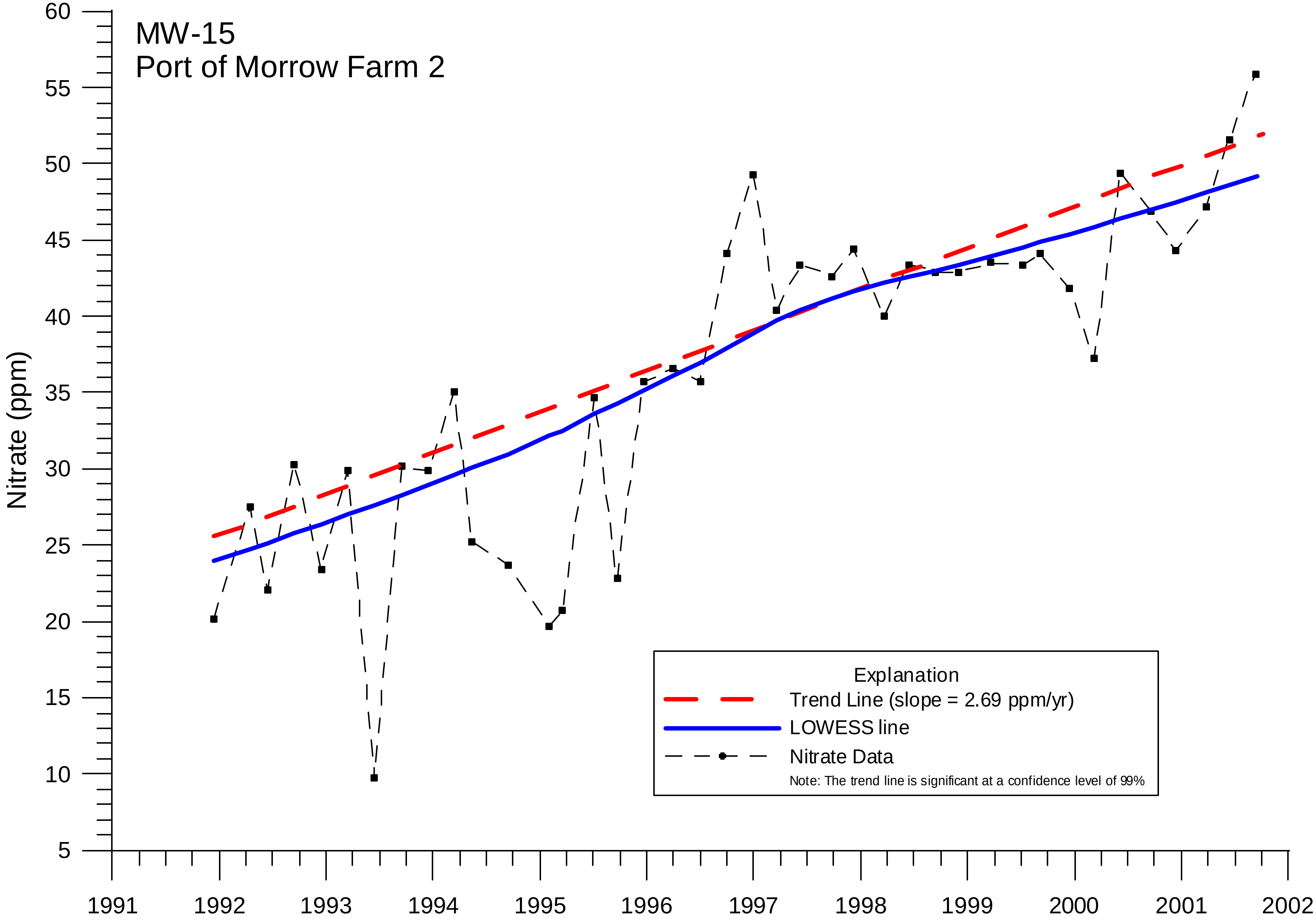

MW-12
Port of Morrow Farm 2
Nitrate (ppm)
50
45
40
35
30
25
20
15
10
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 1.63 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

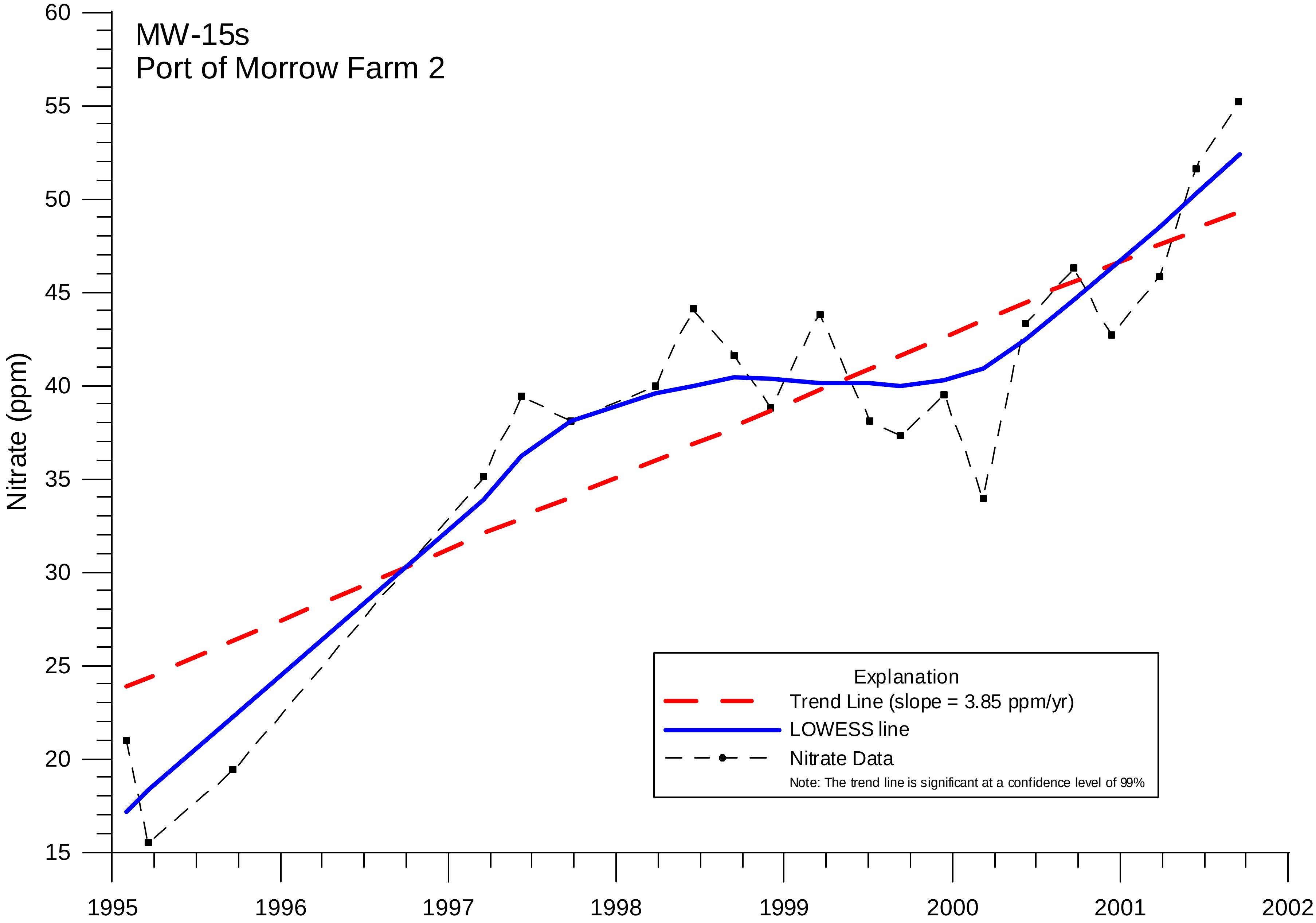

MW-13
Port of Morrow Farm 2
Nitrate (ppm)
65
60
55
50
45
40
35
30
25
20
15
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 2.73 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%


MW-14
Port of Morrow Farm 2
Nitrate (ppm)
0
5
10
15
20
25
30
35
40
45
50
55
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 3.59 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

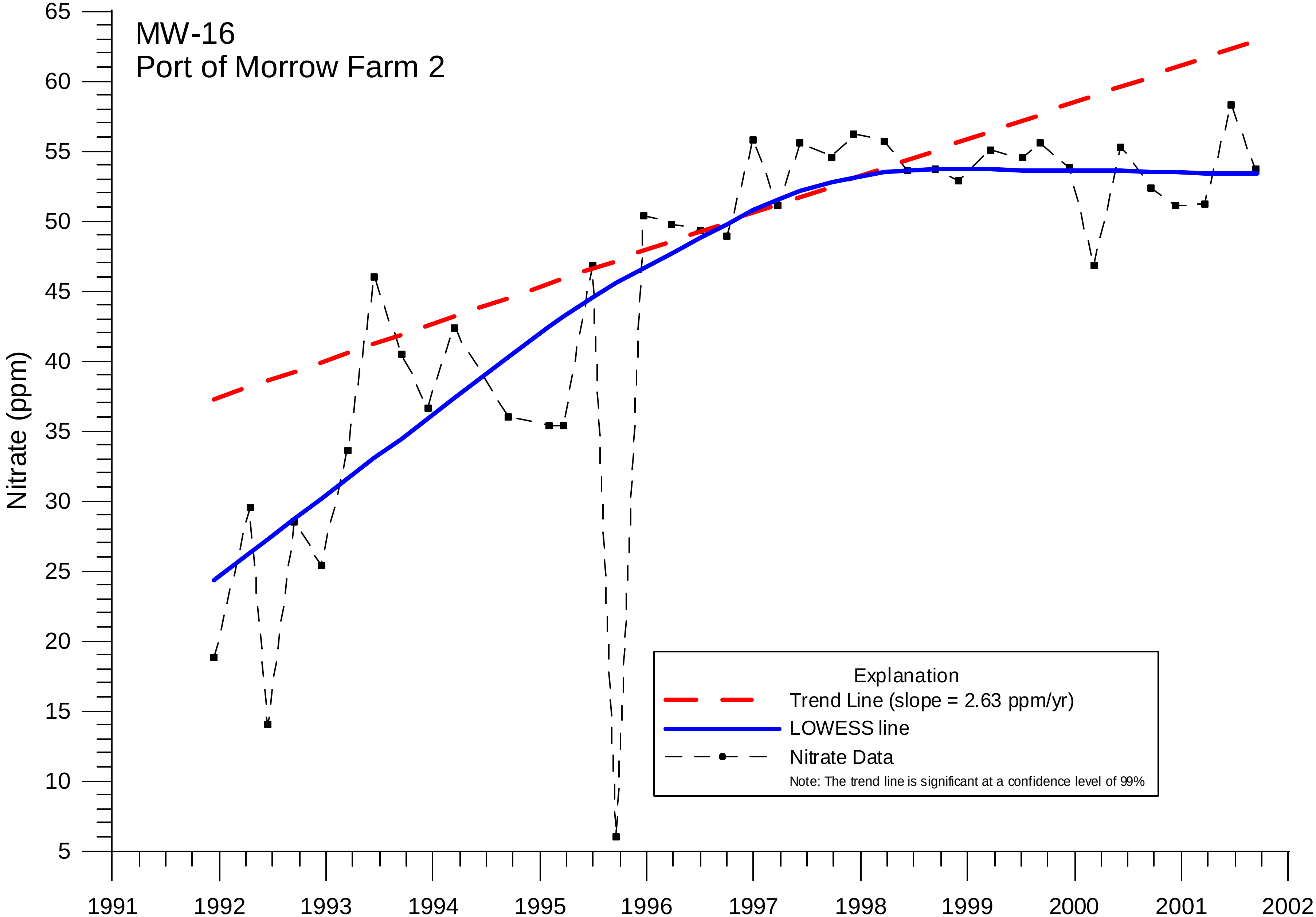


MW-14s
Port of Morrow Farm 2
Nitrate (ppm)
50
45
40
35
30
25
20
15
10
5
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 2.27 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 80%

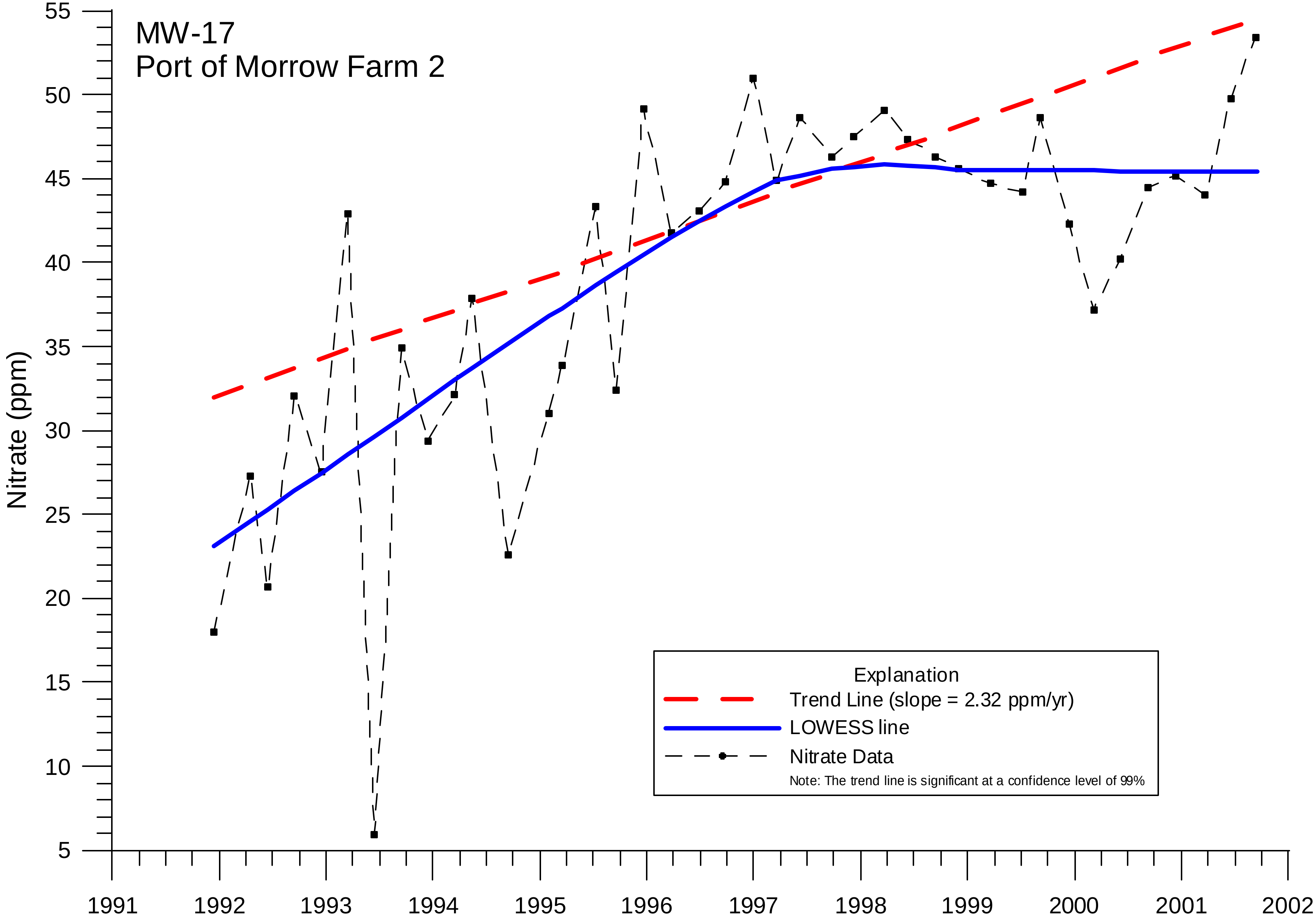

MW-15
Port of Morrow Farm 2
Nitrate (ppm)
60
55
50
45
40
35
30
25
20
15
10
5
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 2.69 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%



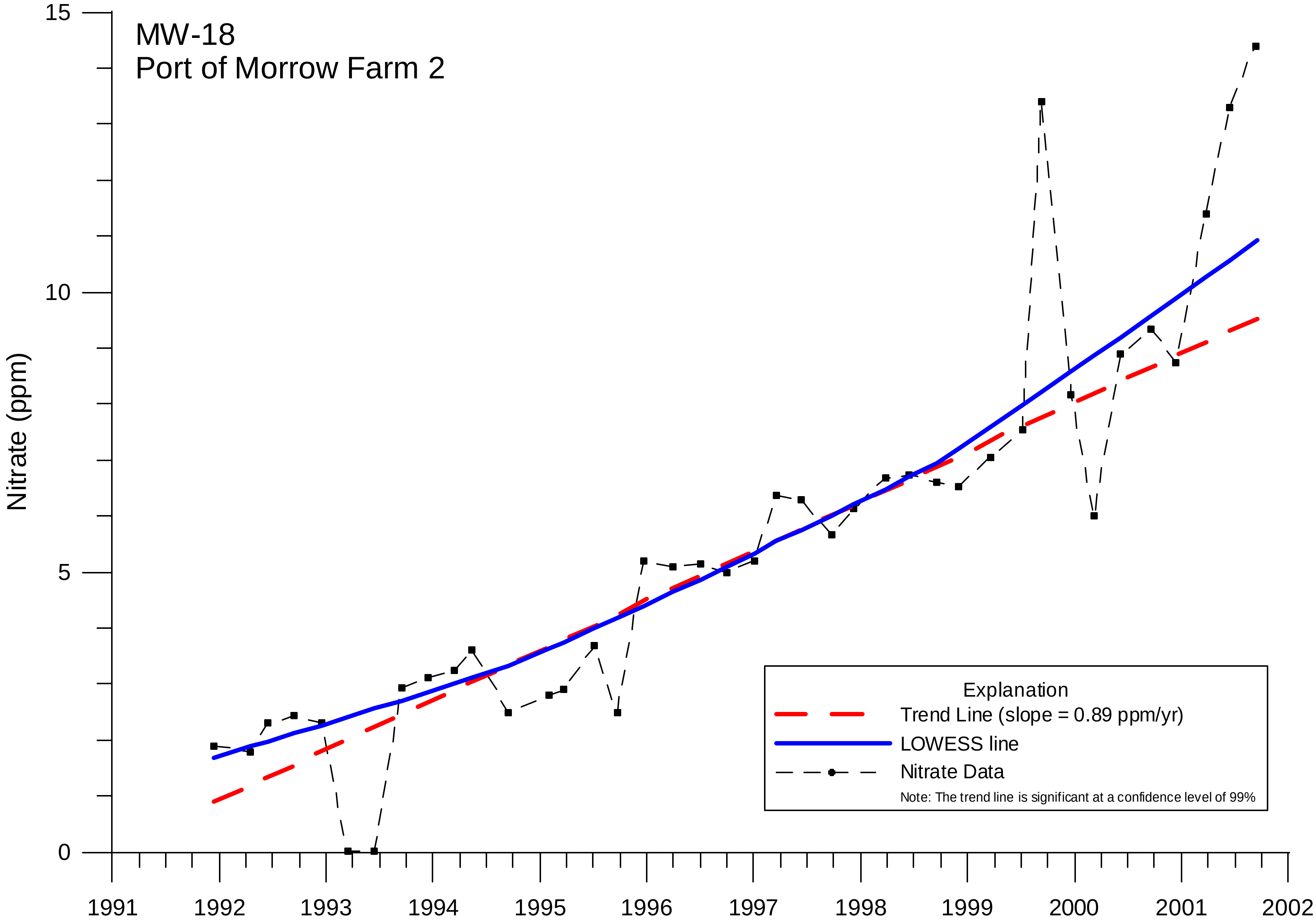
MW-15s
Port of Morrow Farm 2
Nitrate (ppm)
60
55
50
45
40
35
30
25
20
15
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 3.85 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

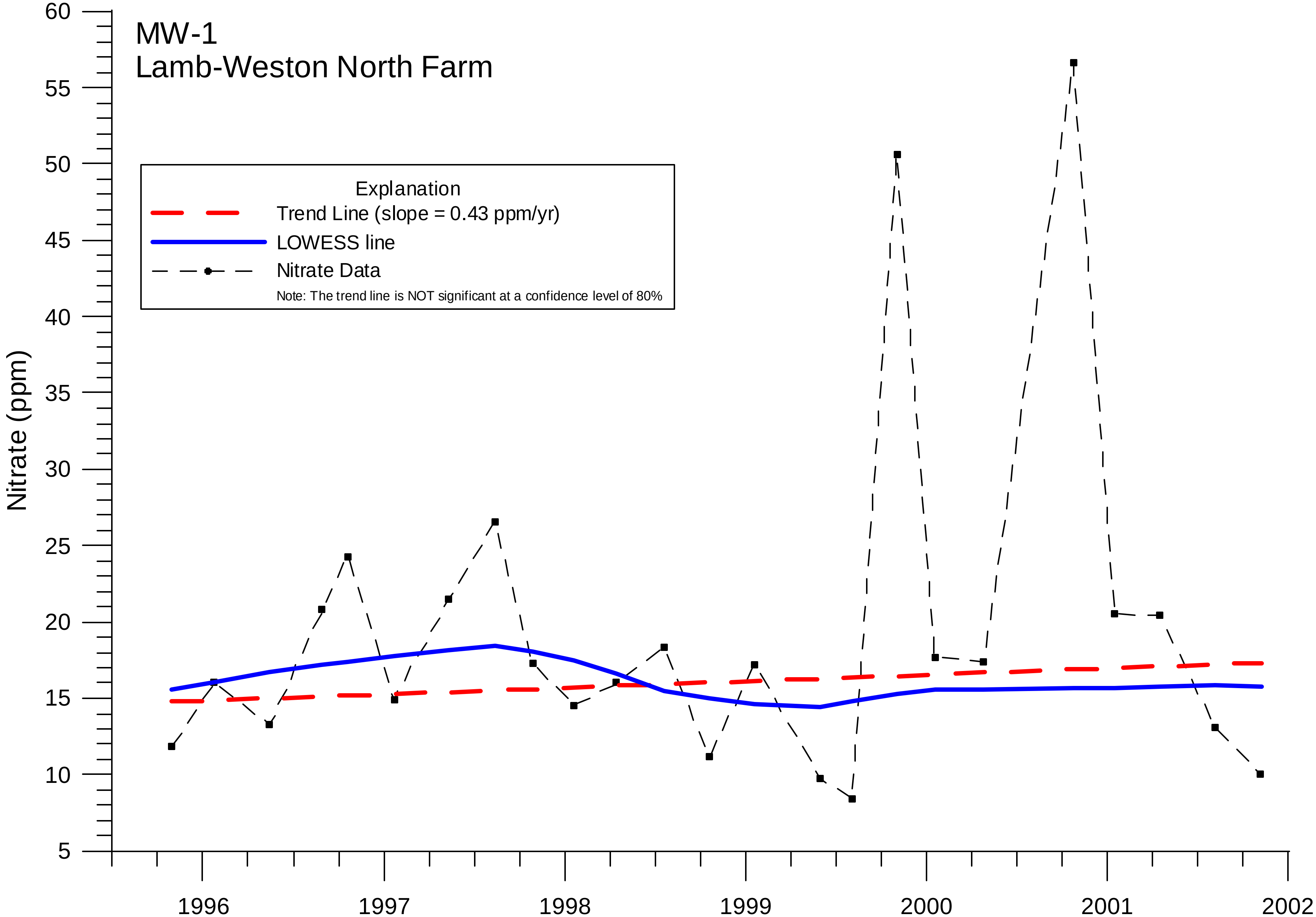


MW-16
Port of Morrow Farm 2
Nitrate (ppm)
65
60
55
50
45
40
35
30
25
20
15
10
5
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 2.63 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

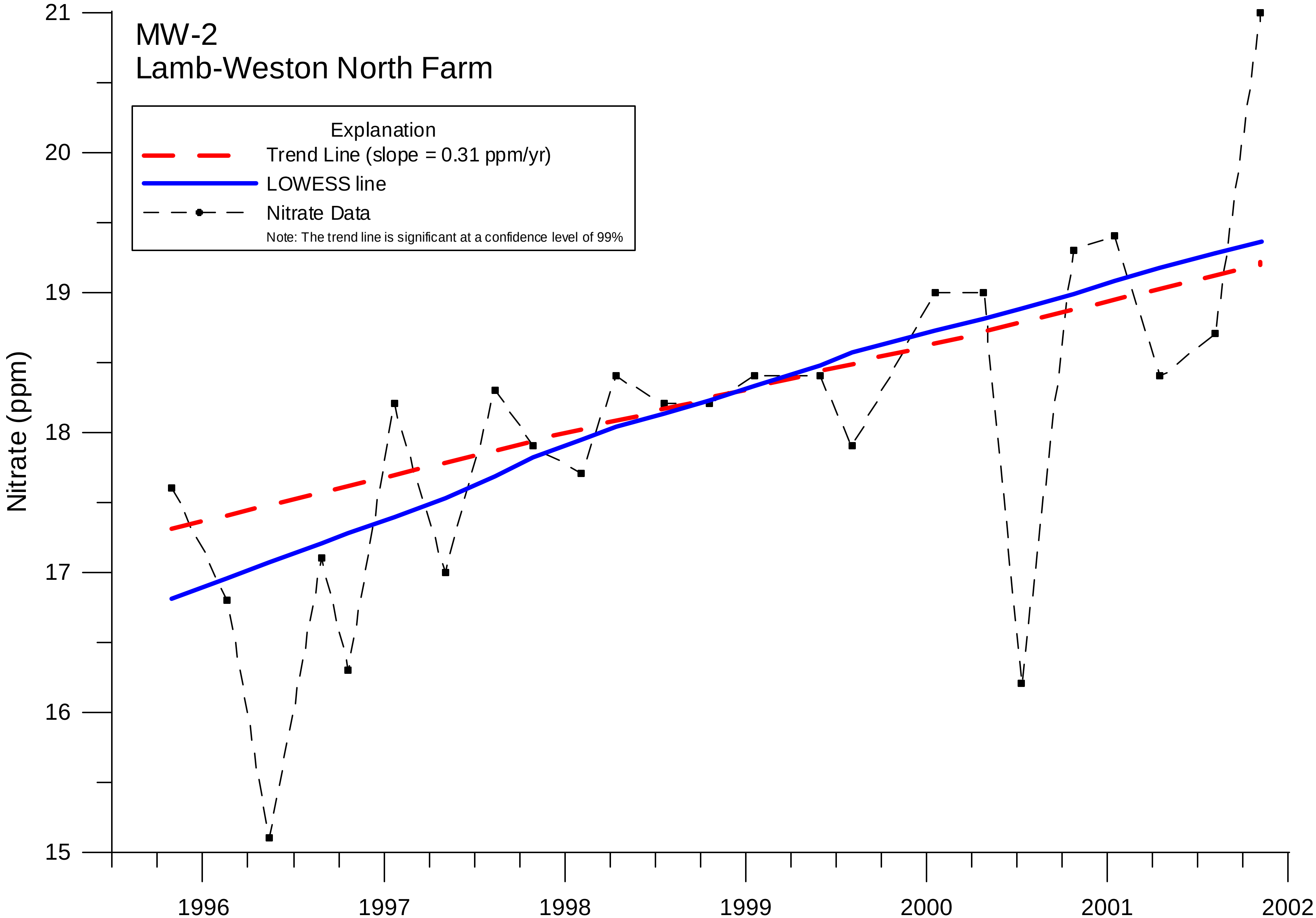


MW-17
Port of Morrow Farm 2
Nitrate (ppm)
55
50
45
40
35
30
25
20
15
10
5
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 2.32 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

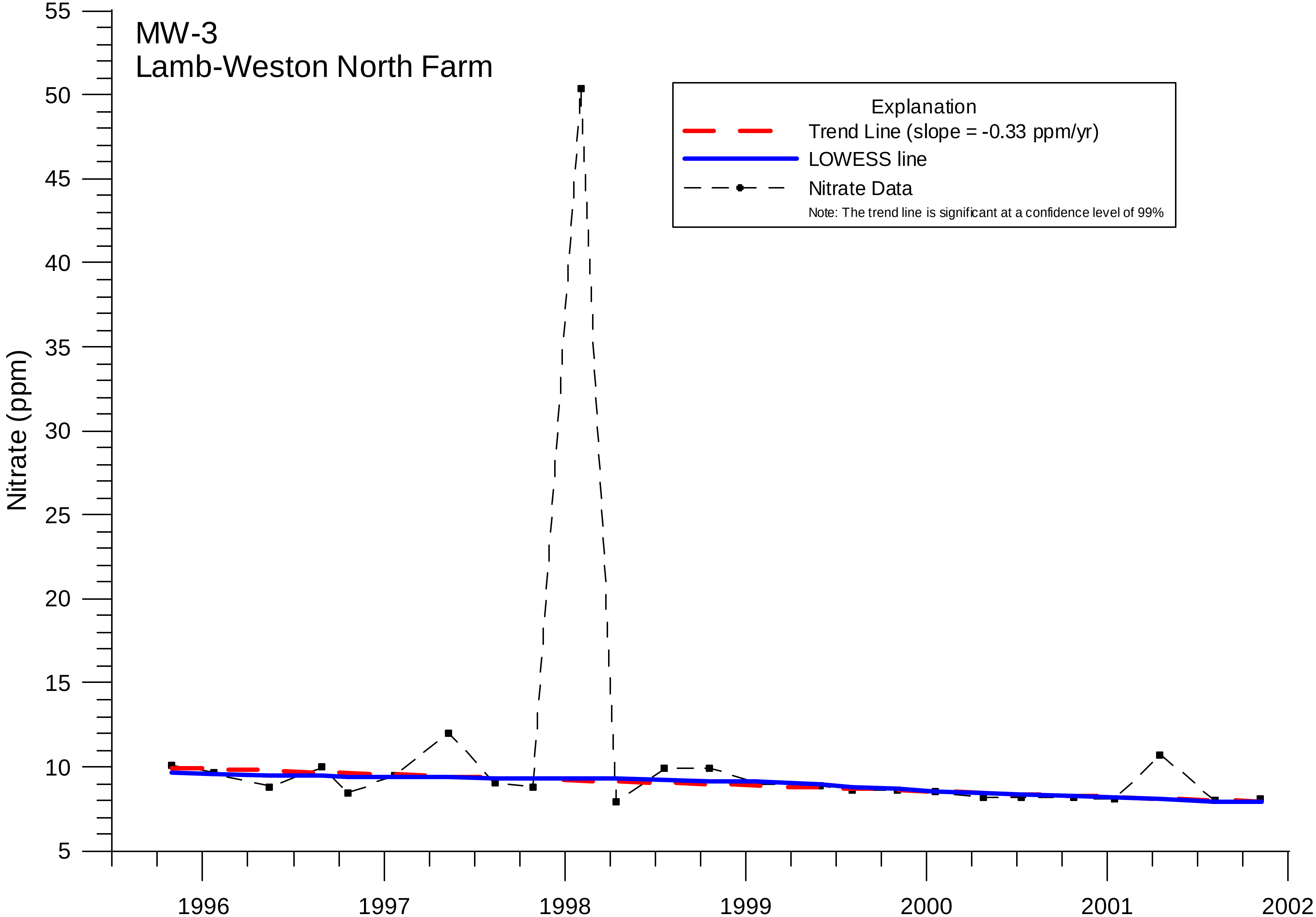

MW-18
Port of Morrow Farm 2
Nitrate (ppm)
15
10
5
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.89 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

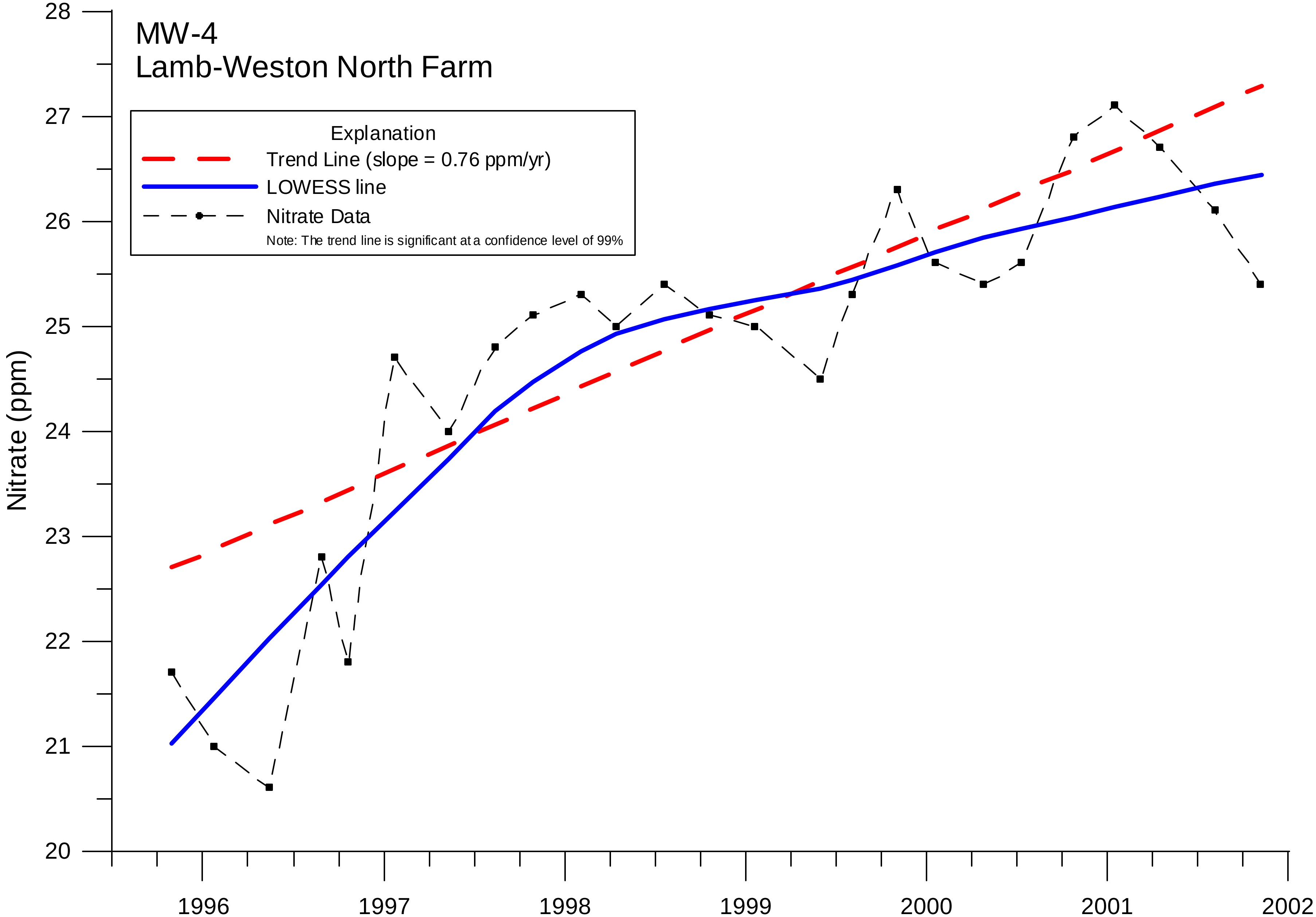


e: lub landapp l-w nf-1.grf

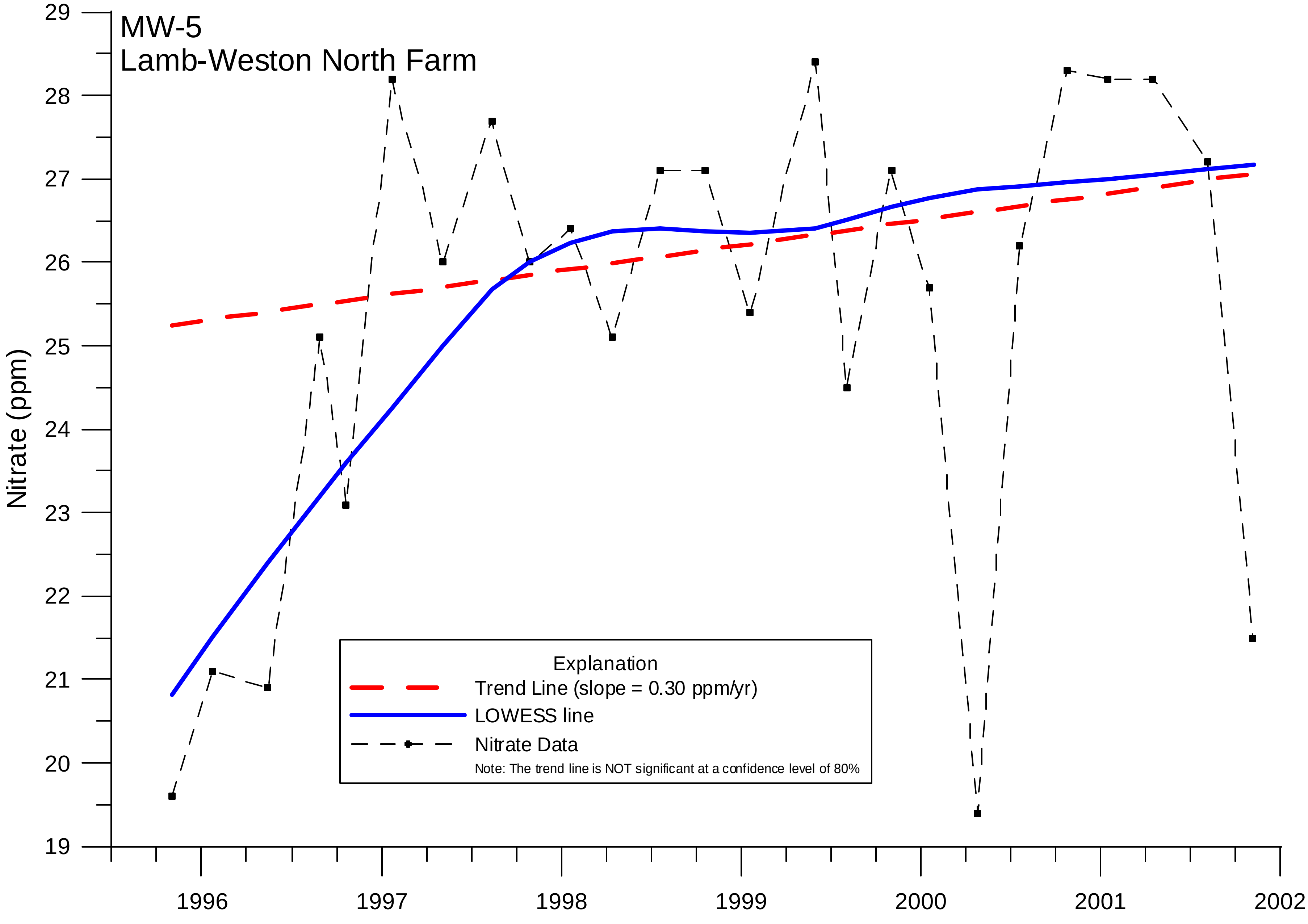


MW-2
Lamb-Weston North Farm
Explanation
Trend Line (slope = 0.31 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%
Nitrate (ppm)
21
20
19
18
17
16
15
1996
1997
1998
1999
2000
2001
2002

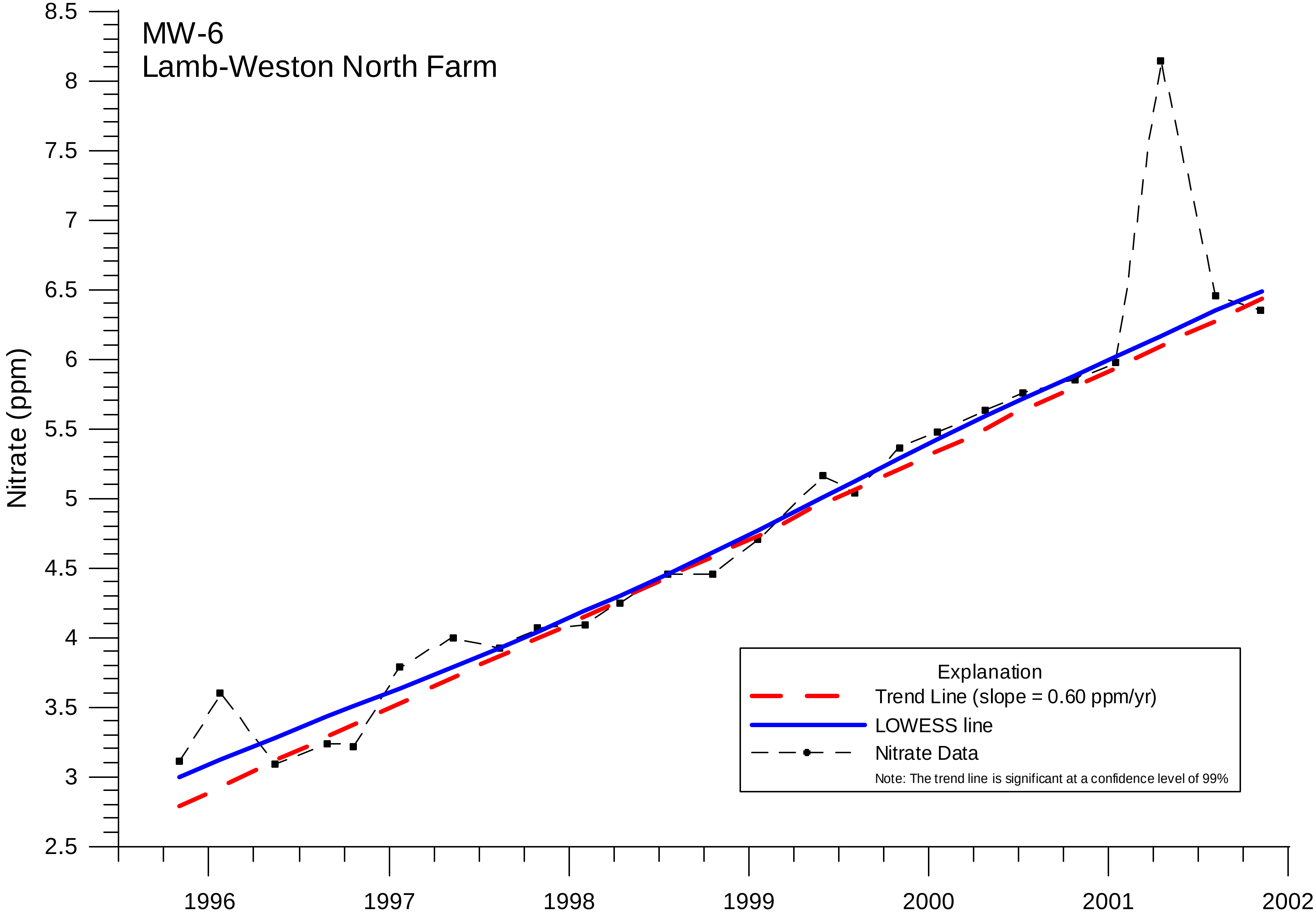

MW-3
Lamb-Weston North Farm
Explanation
Trend Line (slope = -0.33 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%
Nitrate (ppm)
55
50
45
40
35
30
25
20
15
10
5
1996
1997
1998
1999
2000
2001
2002

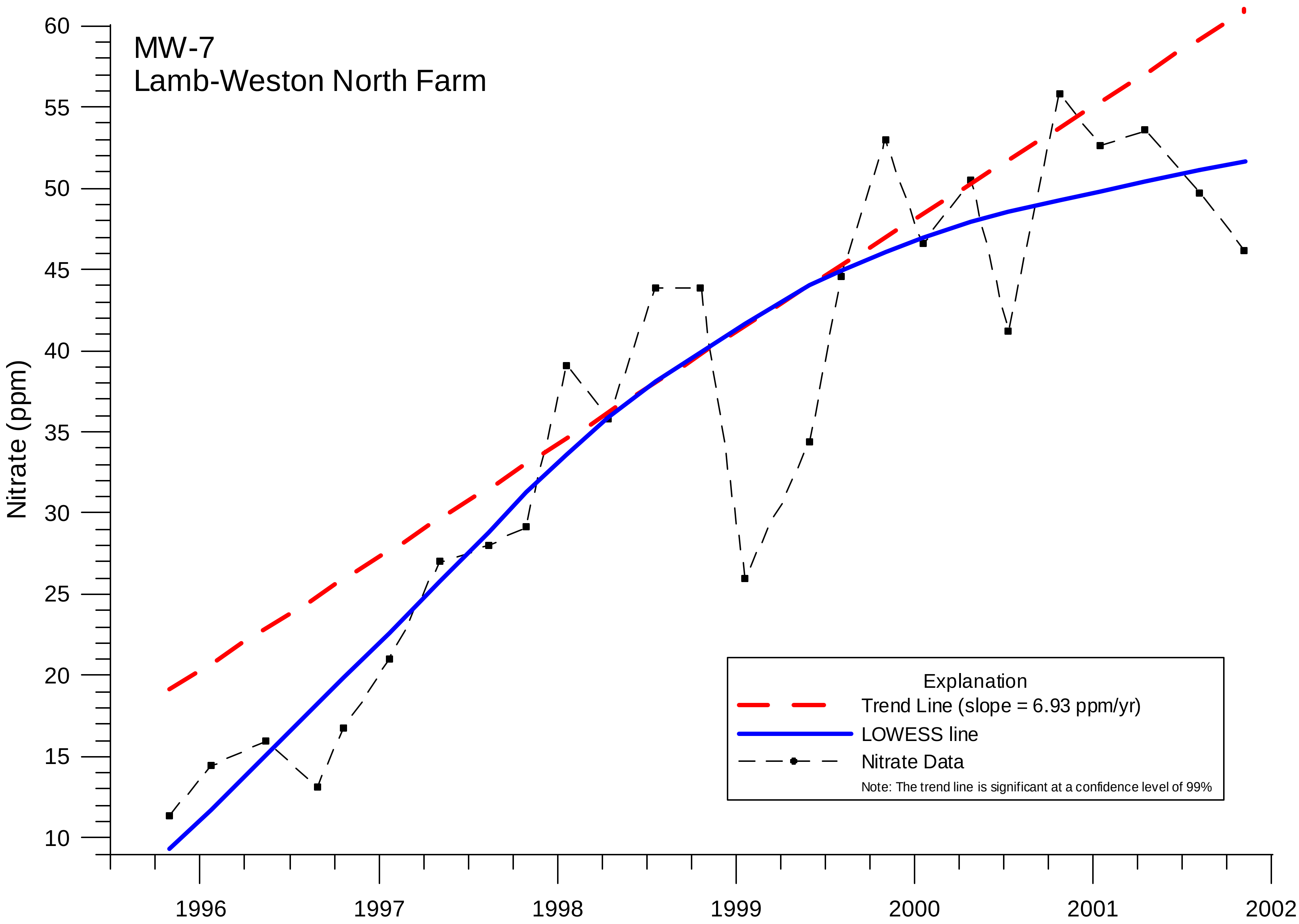


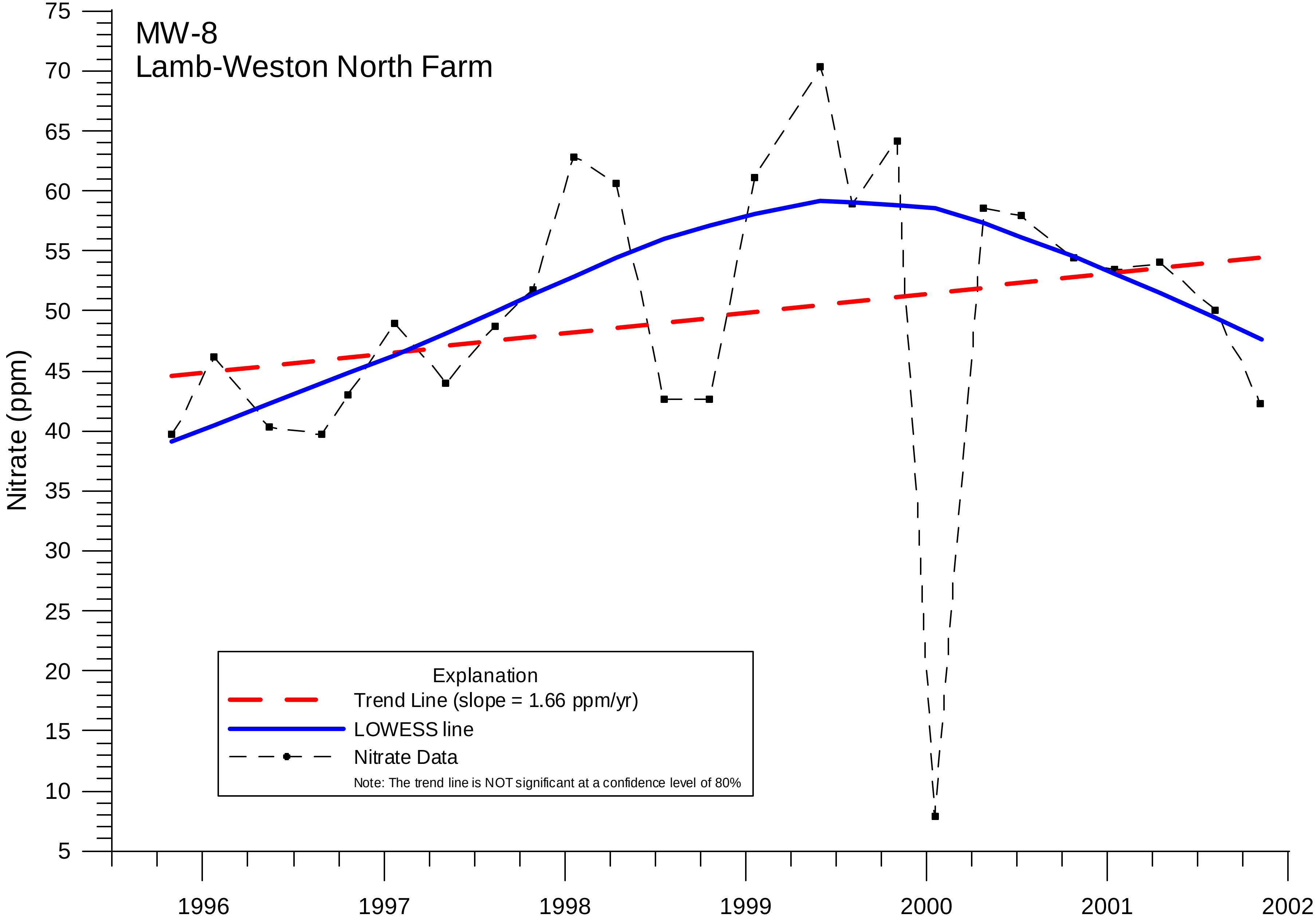
MW-4
Lamb-Weston North Farm
Explanation
Trend Line (slope = 0.76 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%
Nitrate (ppm)
20
21
22
23
24
25
26
27
28
1996
1997
1998
1999
2000
2001
2002

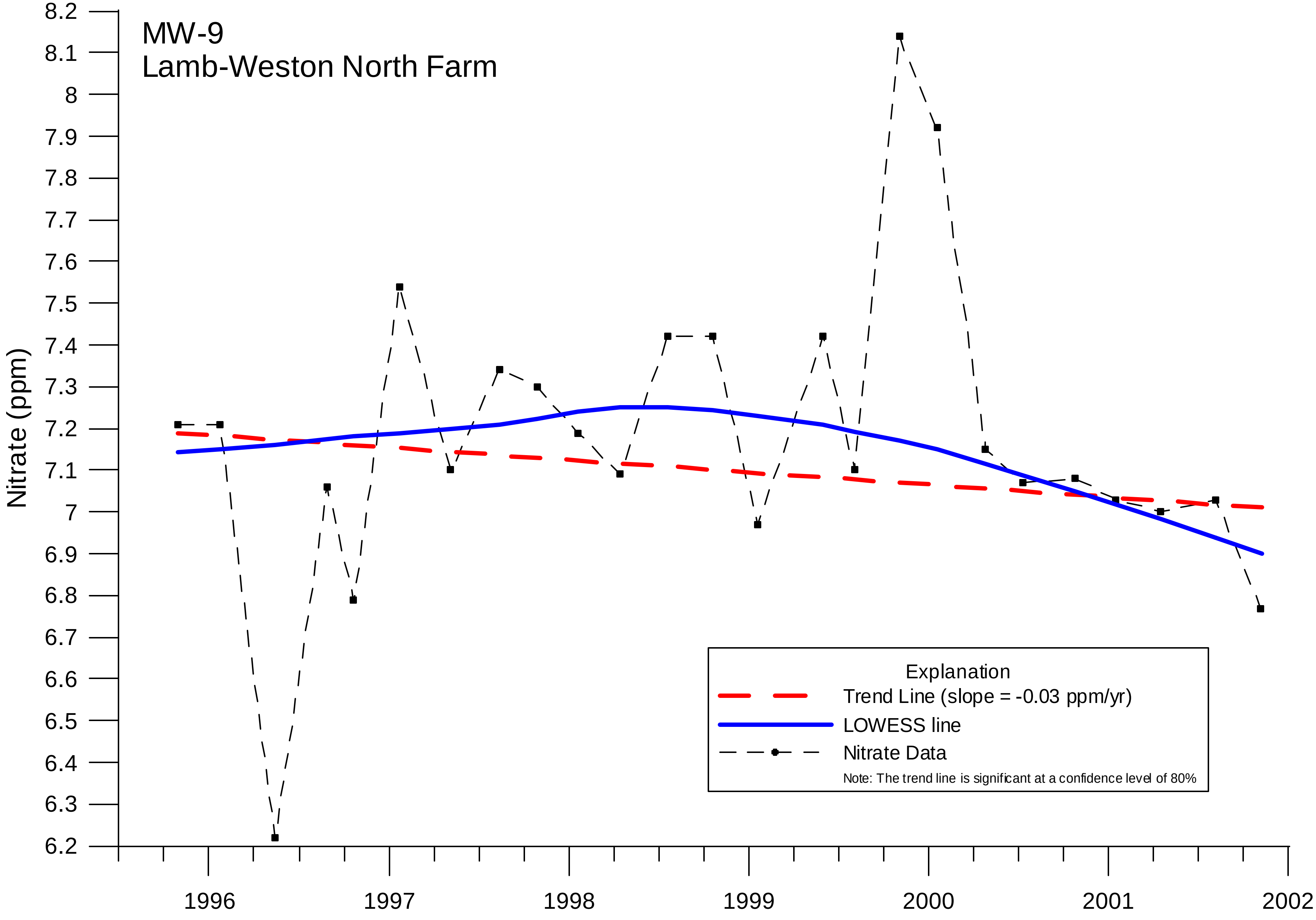


MW-5
Lamb-Weston North Farm
Nitrate (ppm)
29
28
27
26
25
24
23
22
21
20
19
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.30 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%

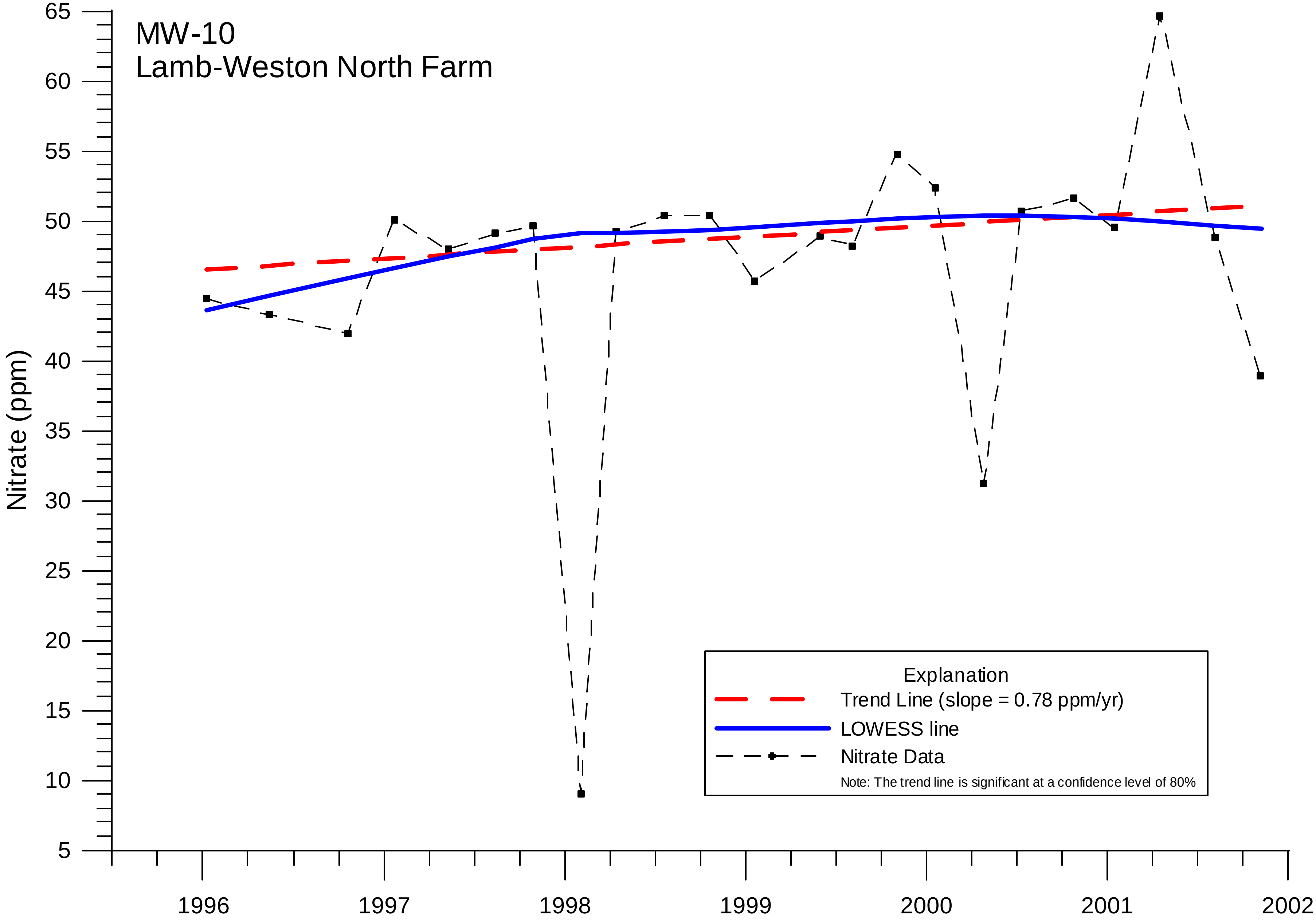

MW-6
Lamb-Weston North Farm
Nitrate (ppm)
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.60 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%


MW-7
Lamb-Weston North Farm
Nitrate (ppm)
60
55
50
45
40
35
30
25
20
15
10
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 6.93 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

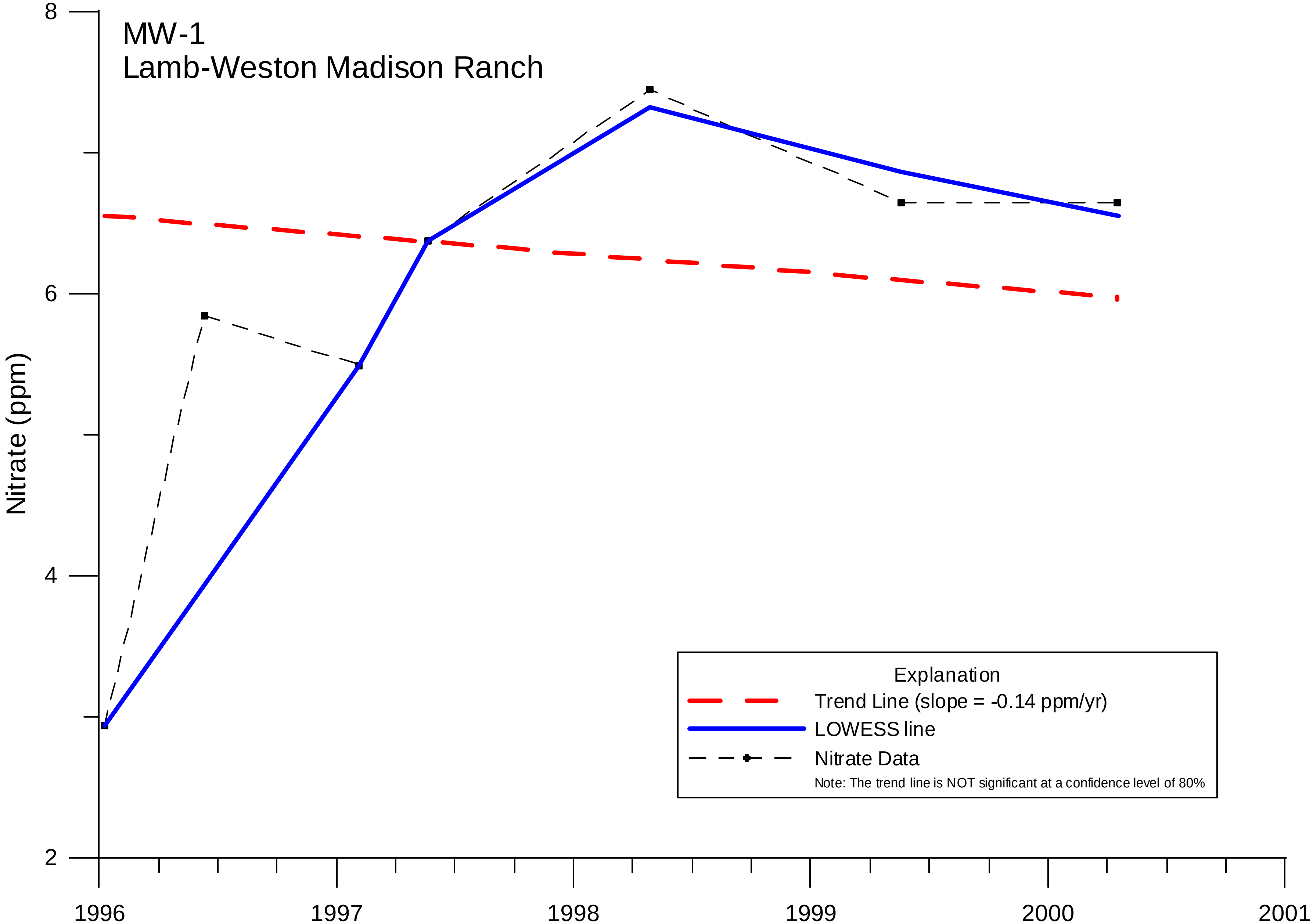

MW-8
Lamb-Weston North Farm
Nitrate (ppm)
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 1.66 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%



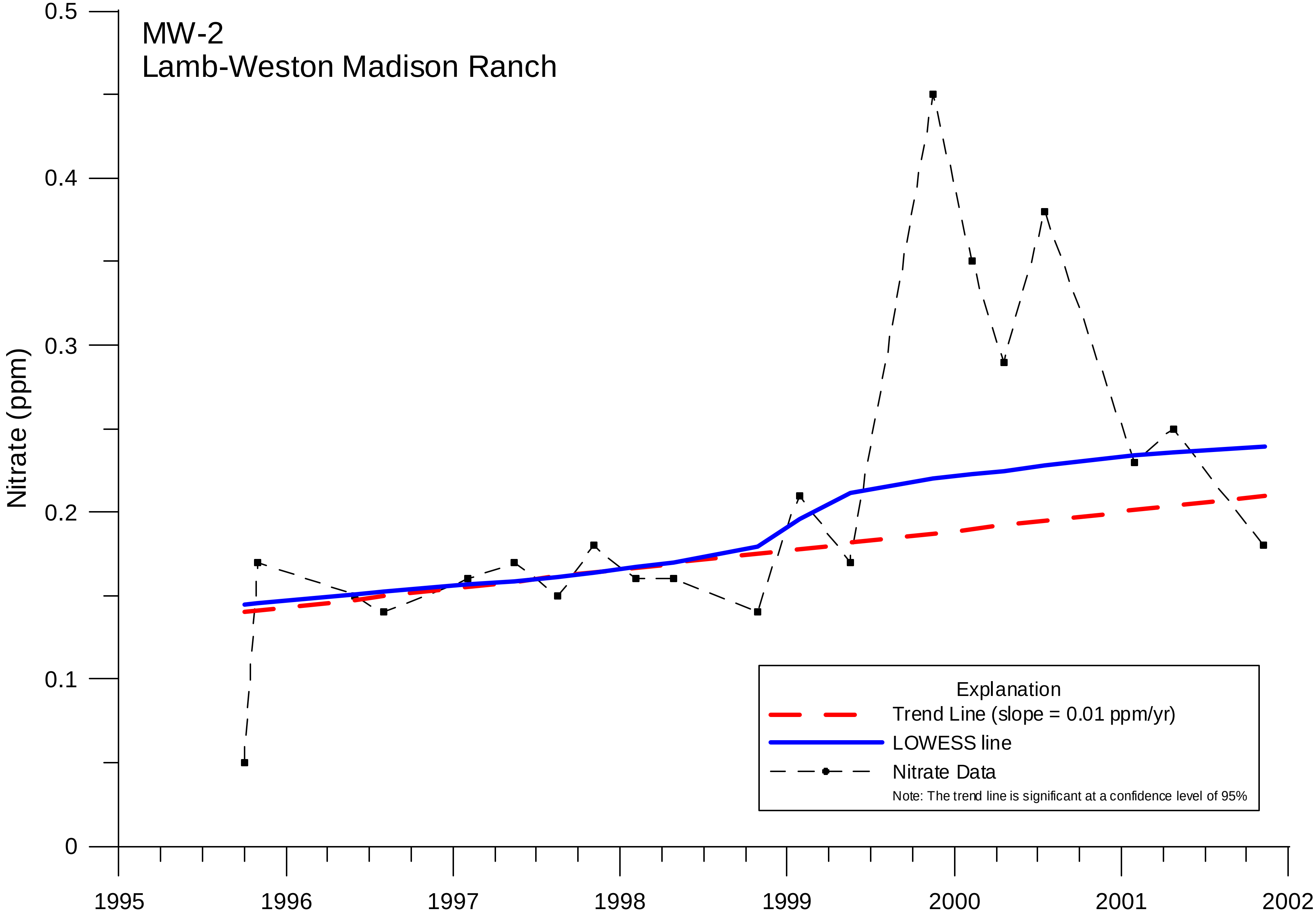
MW-9
Lamb-Weston North Farm
Nitrate (ppm)
8.2
8.1
8
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7
6.9
6.8
6.7
6.6
6.5
6.4
6.3
6.2
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = -0.03 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 80%



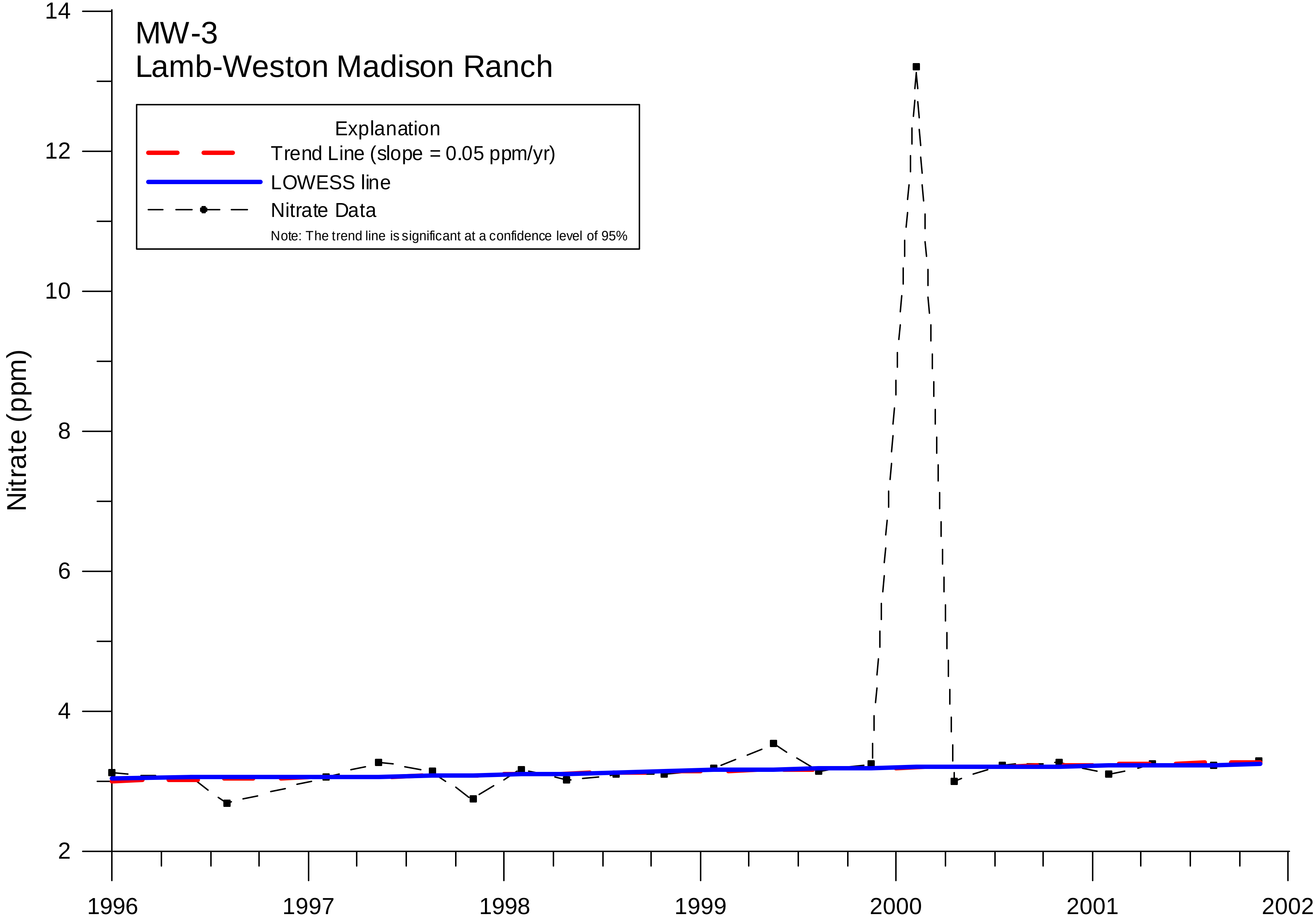
MW-10
Lamb-Weston North Farm
Nitrate (ppm)
65
60
55
50
45
40
35
30
25
20
15
10
5
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.78 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 80%



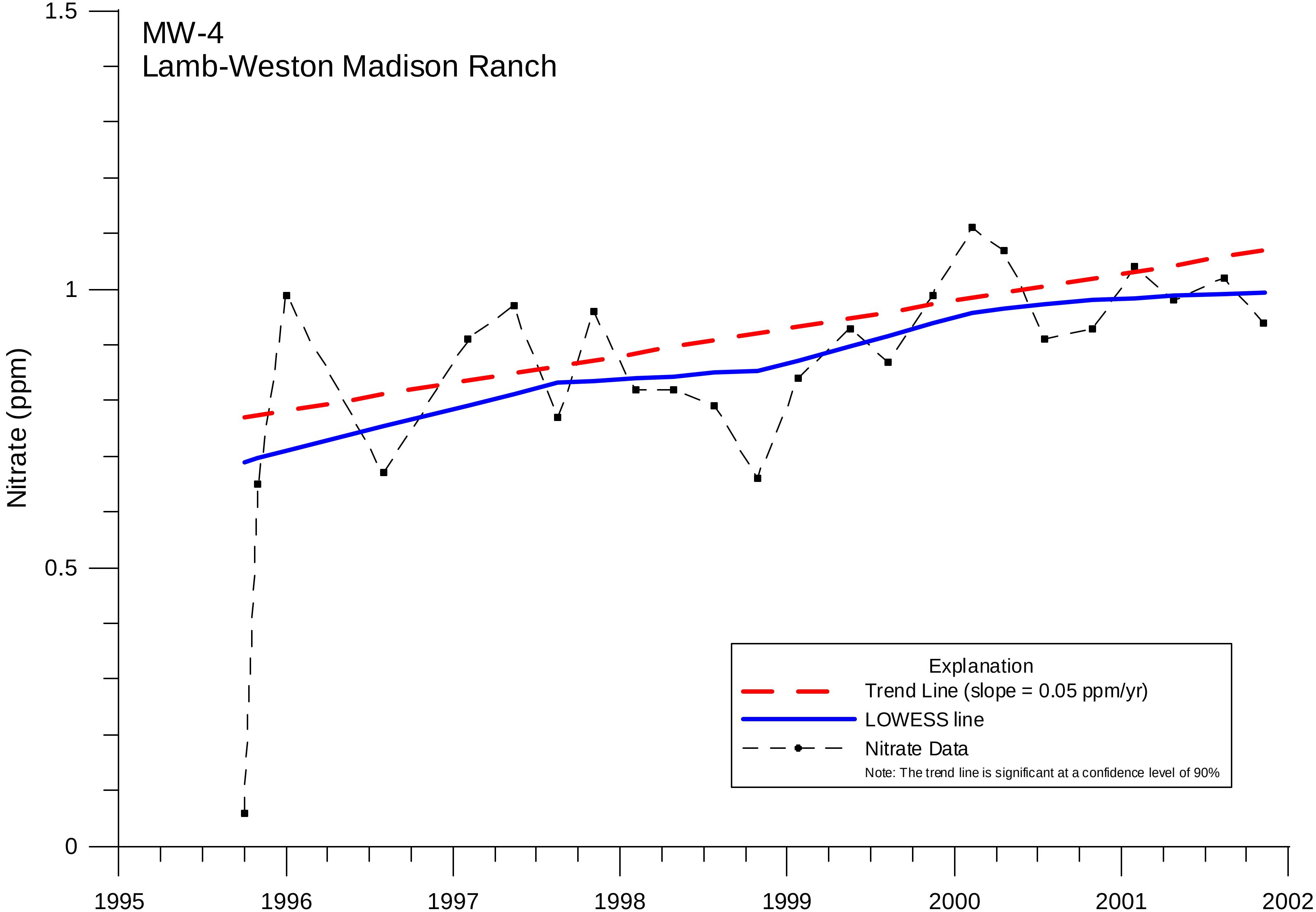
MW-1
Lamb-Weston Madison Ranch
Nitrate (ppm)
8
6
4
2
1996
1997
1998
1999
2000
2001
Explanation
Trend Line (slope = -0.14 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%

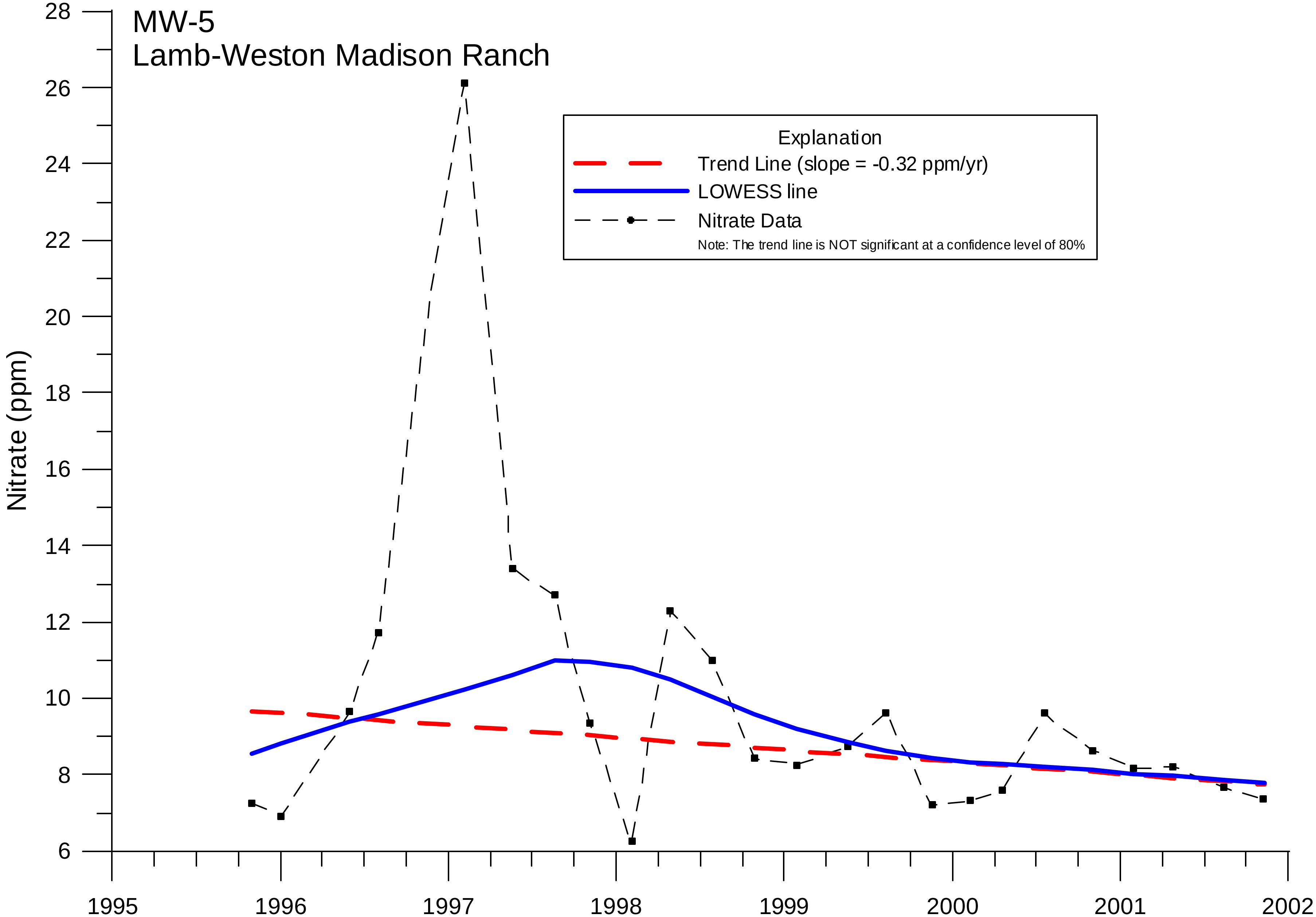


MW-2
Lamb-Weston Madison Ranch
Nitrate (ppm)
0.5
0.4
0.3
0.2
0.1
0
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.01 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 95%

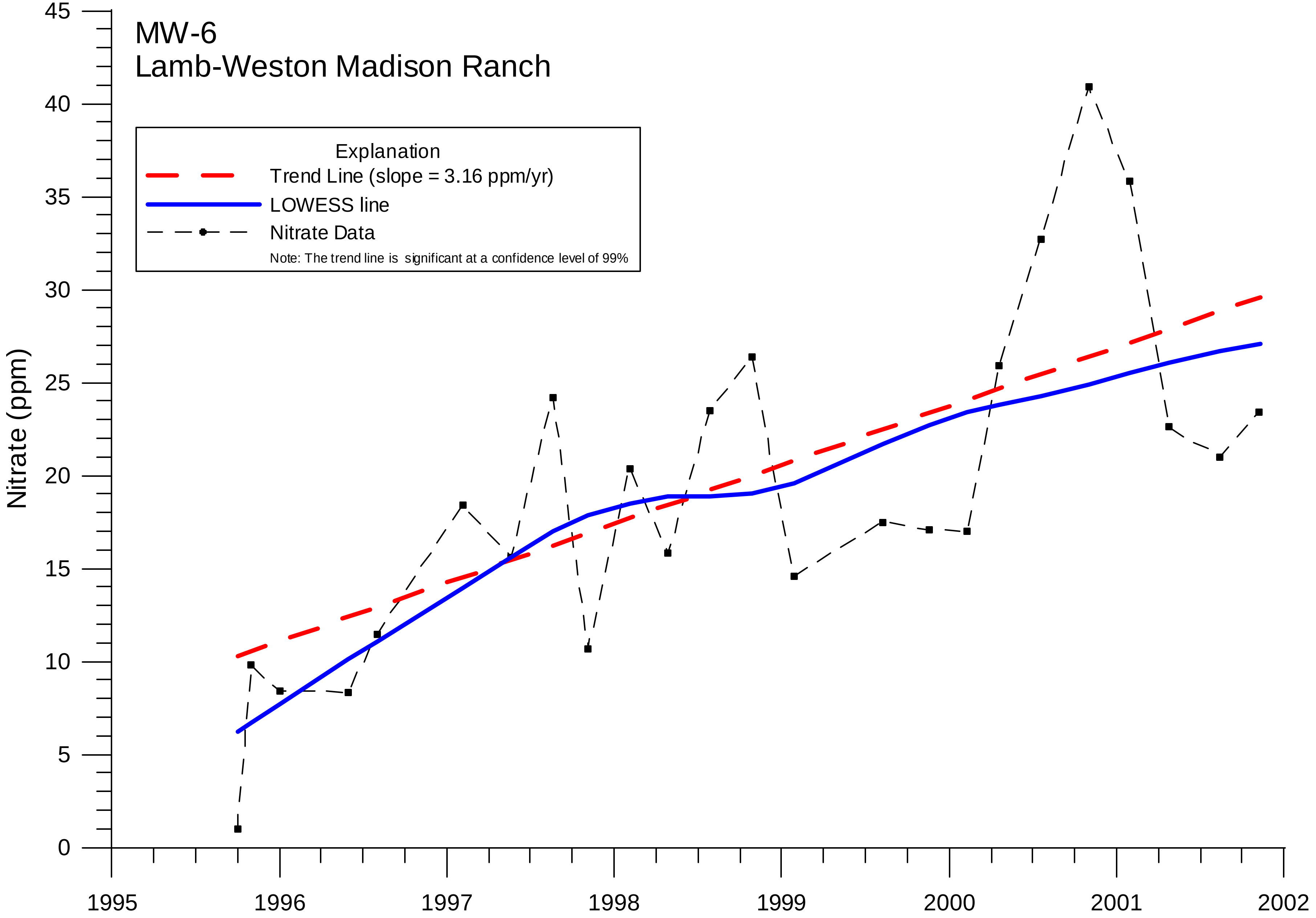


MW-3
Lamb-Weston Madison Ranch
Explanation
Trend Line (slope = 0.05 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 95%
Nitrate (ppm)
14
12
10
8
6
4
2
1996
1997
1998
1999
2000
2001
2002

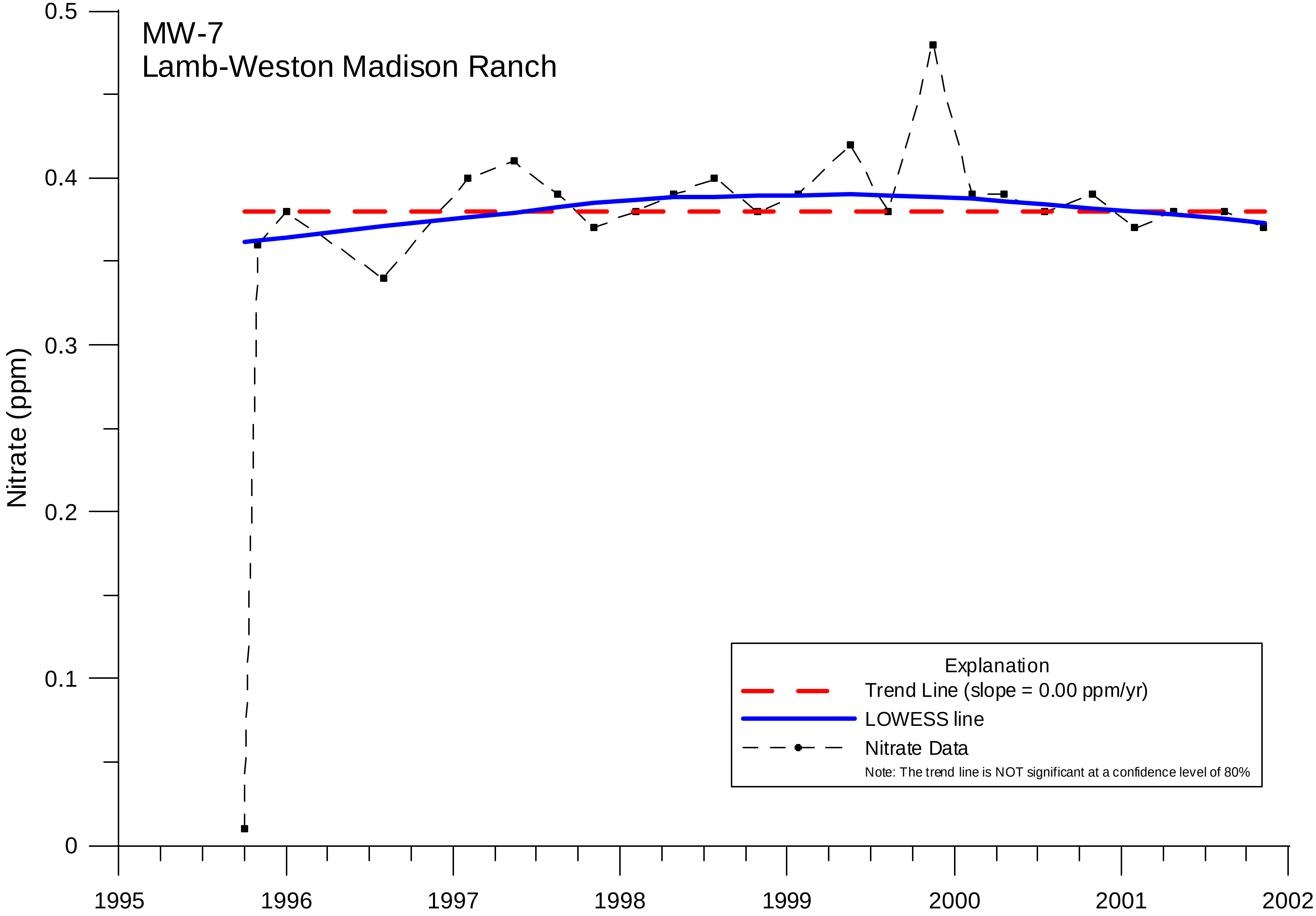

MW-4
Lamb-Weston Madison Ranch
Nitrate (ppm)
1.5
1
0.5
0
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.05 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 90%

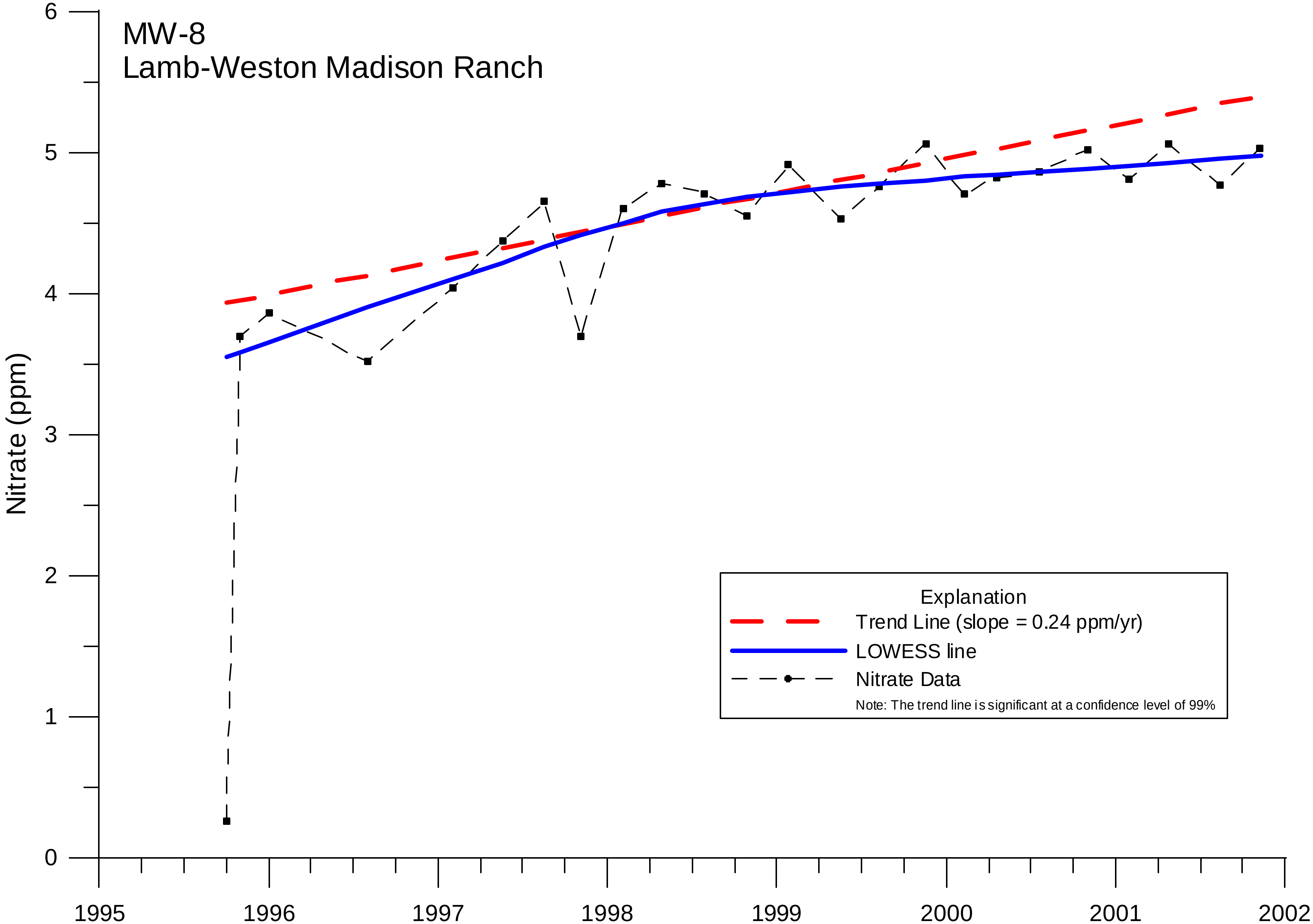


MW-5
Lamb-Weston Madison Ranch
Explanation
Trend Line (slope = -0.32 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%
Nitrate (ppm)
28
26
24
22
20
18
16
14
12
10
8
6
1995
1996
1997
1998
1999
2000
2001
2002

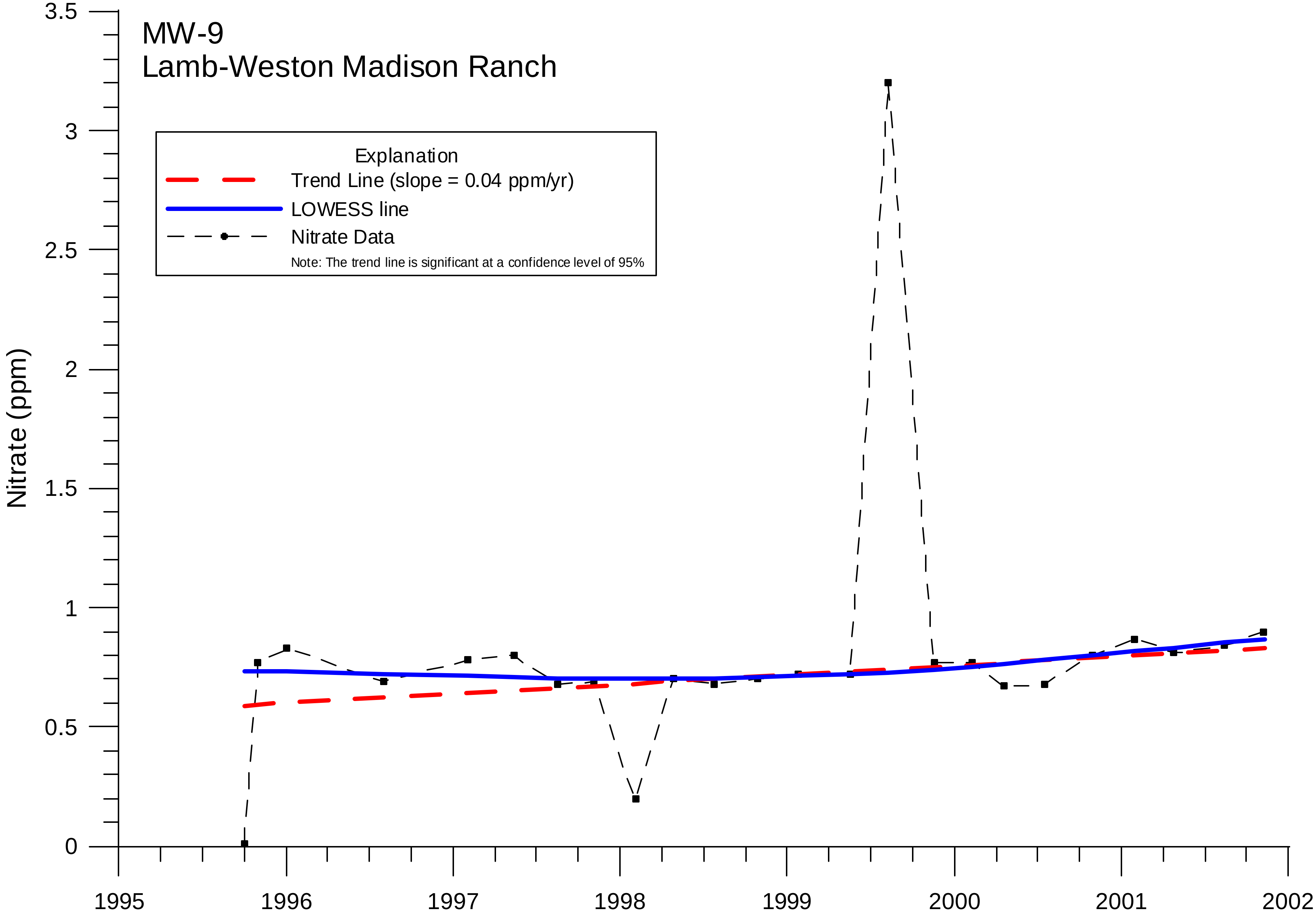


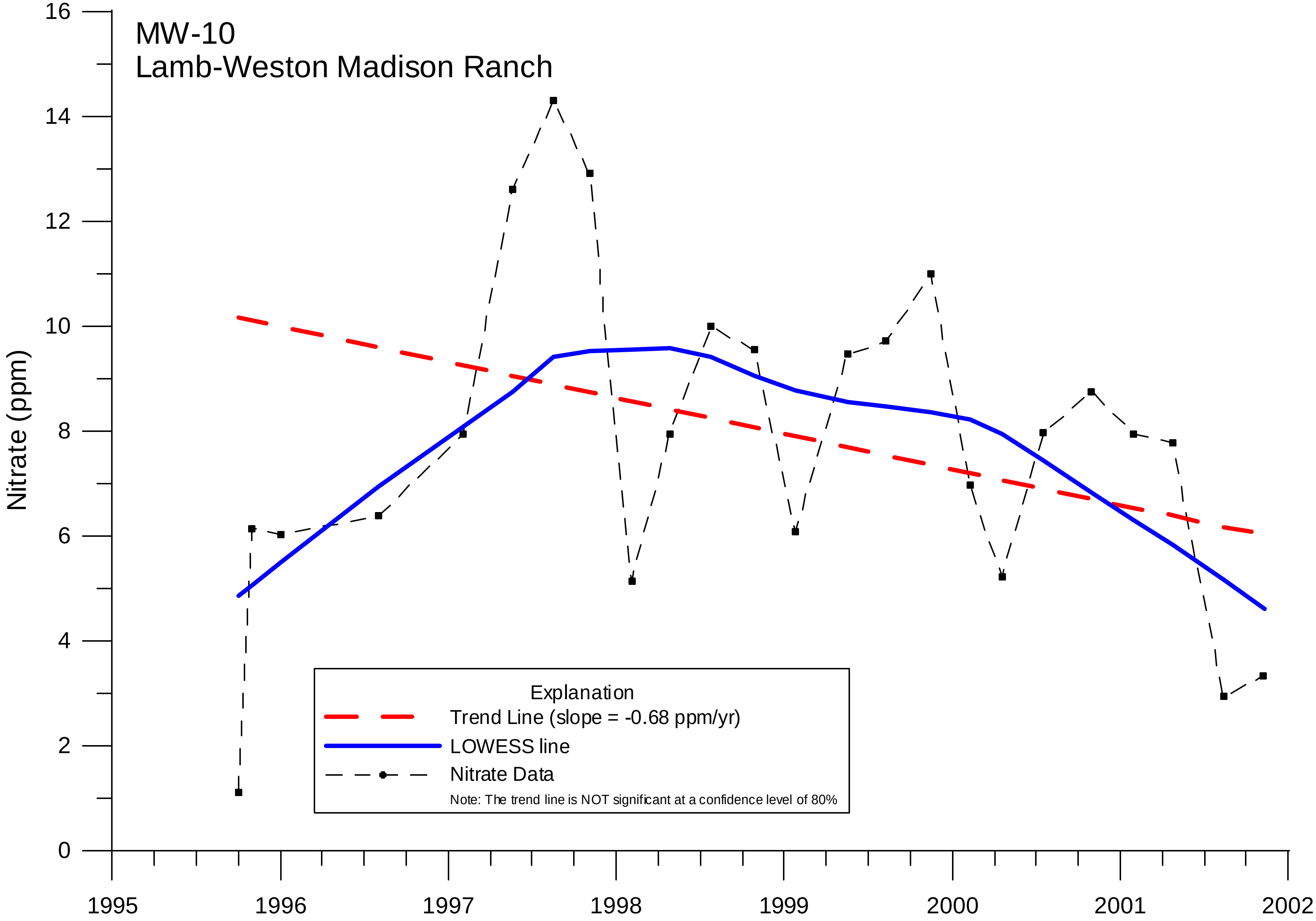
MW-6
Lamb-Weston Madison Ranch
Explanation
Trend Line (slope = 3.16 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%
Nitrate (ppm)
0
5
10
15
20
25
30
35
40
45
1995
1996
1997
1998
1999
2000
2001
2002

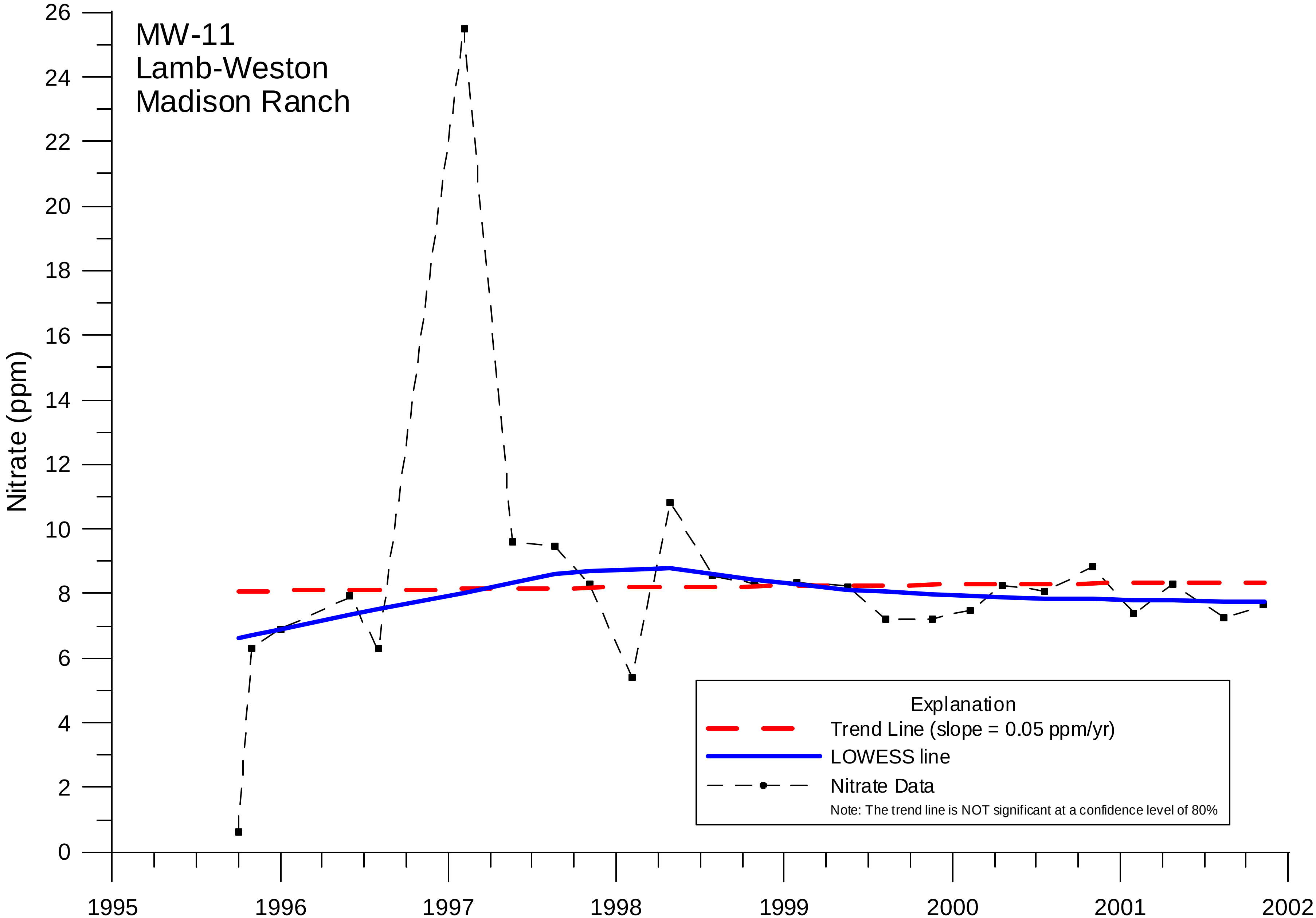

MW-7
Lamb-Weston Madison Ranch
Nitrate (ppm)
0
0.1
0.2
0.3
0.4
0.5
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.00 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%



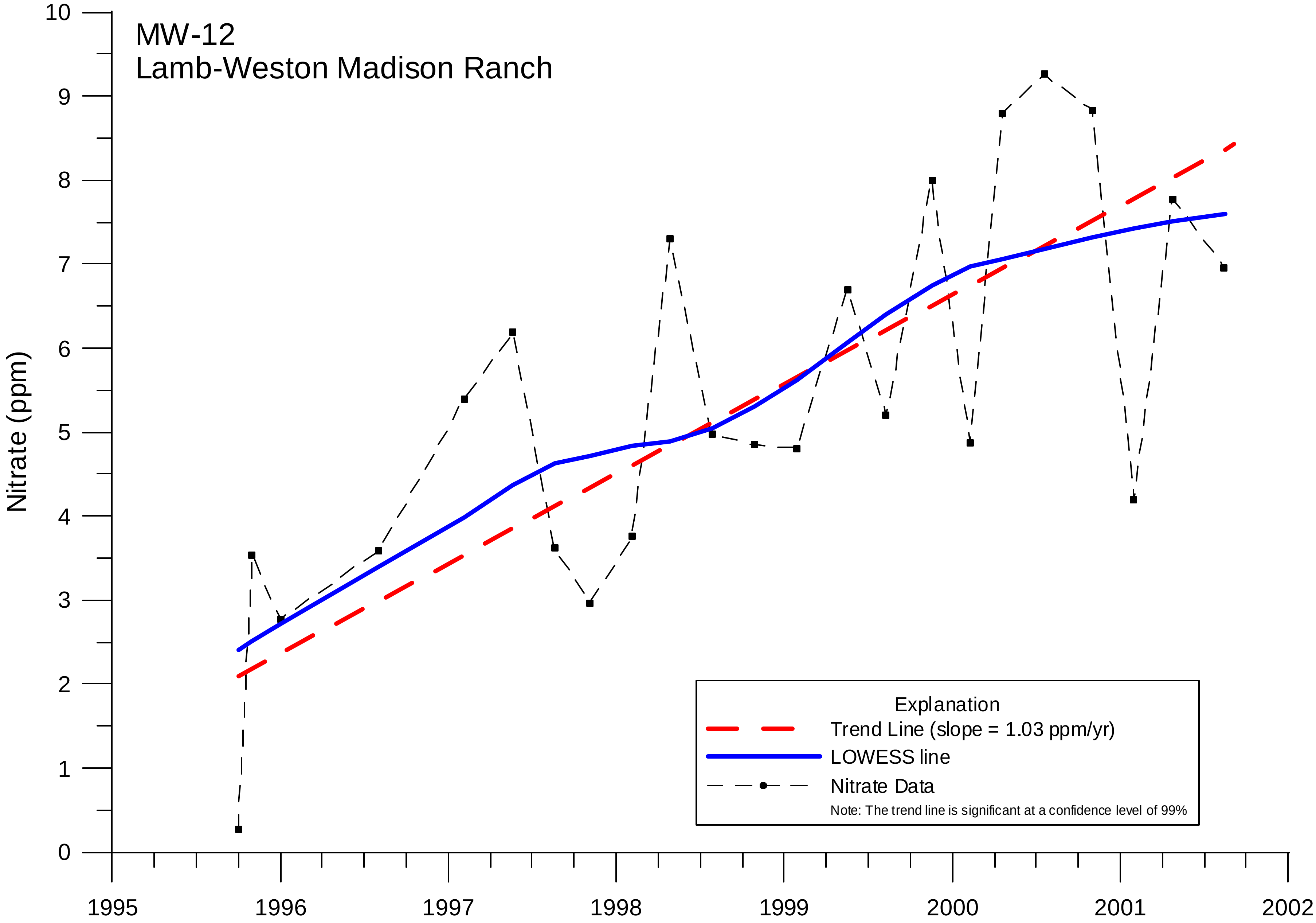
MW-8
Lamb-Weston Madison Ranch
Nitrate (ppm)
0
1
2
3
4
5
6
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.24 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

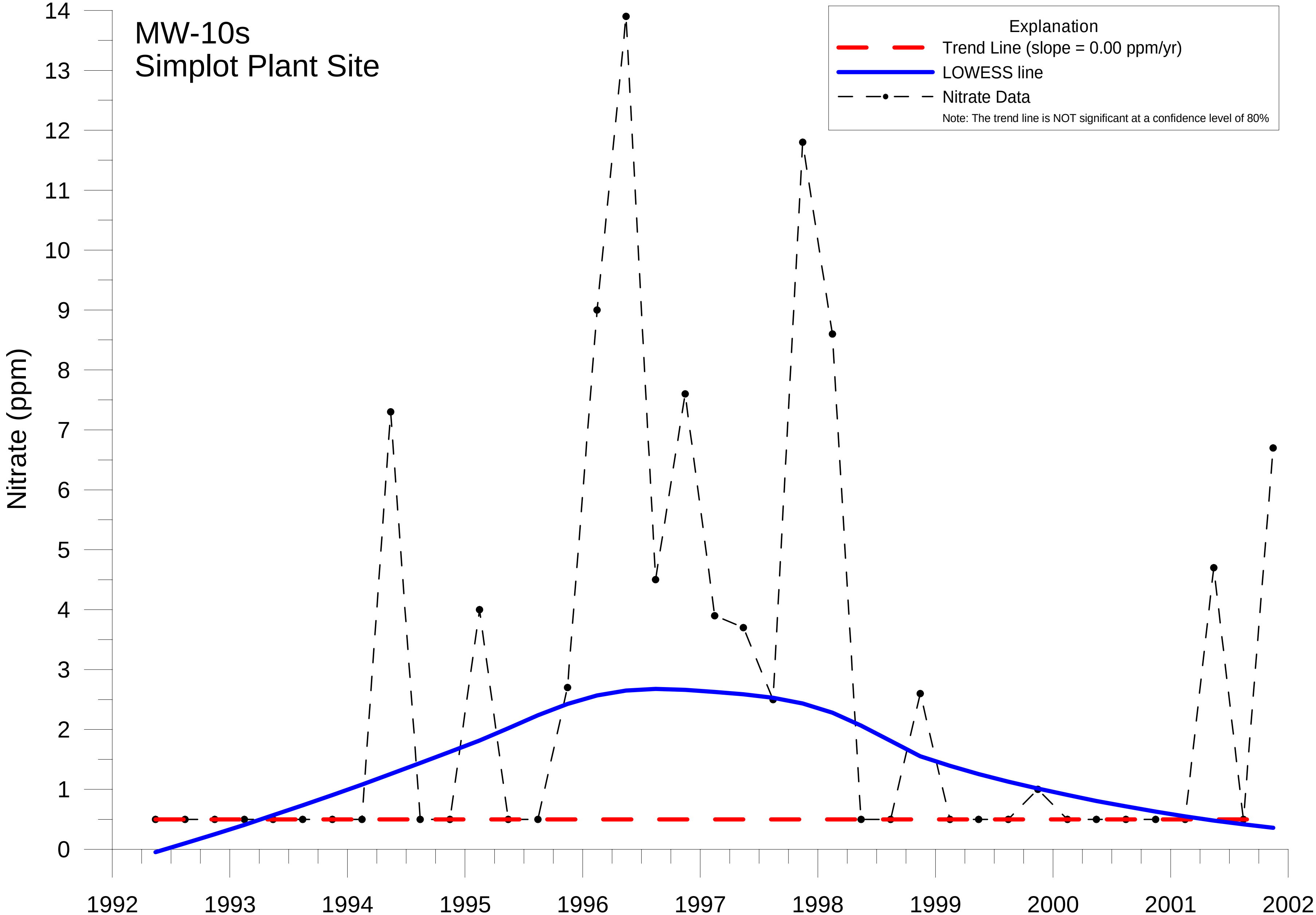

MW-9
Lamb-Weston Madison Ranch
Explanation
Trend Line (slope = 0.04 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 95%
Nitrate (ppm)
3.5
3
2.5
2
1.5
1
0.5
0
1995
1996
1997
1998
1999
2000
2001
2002

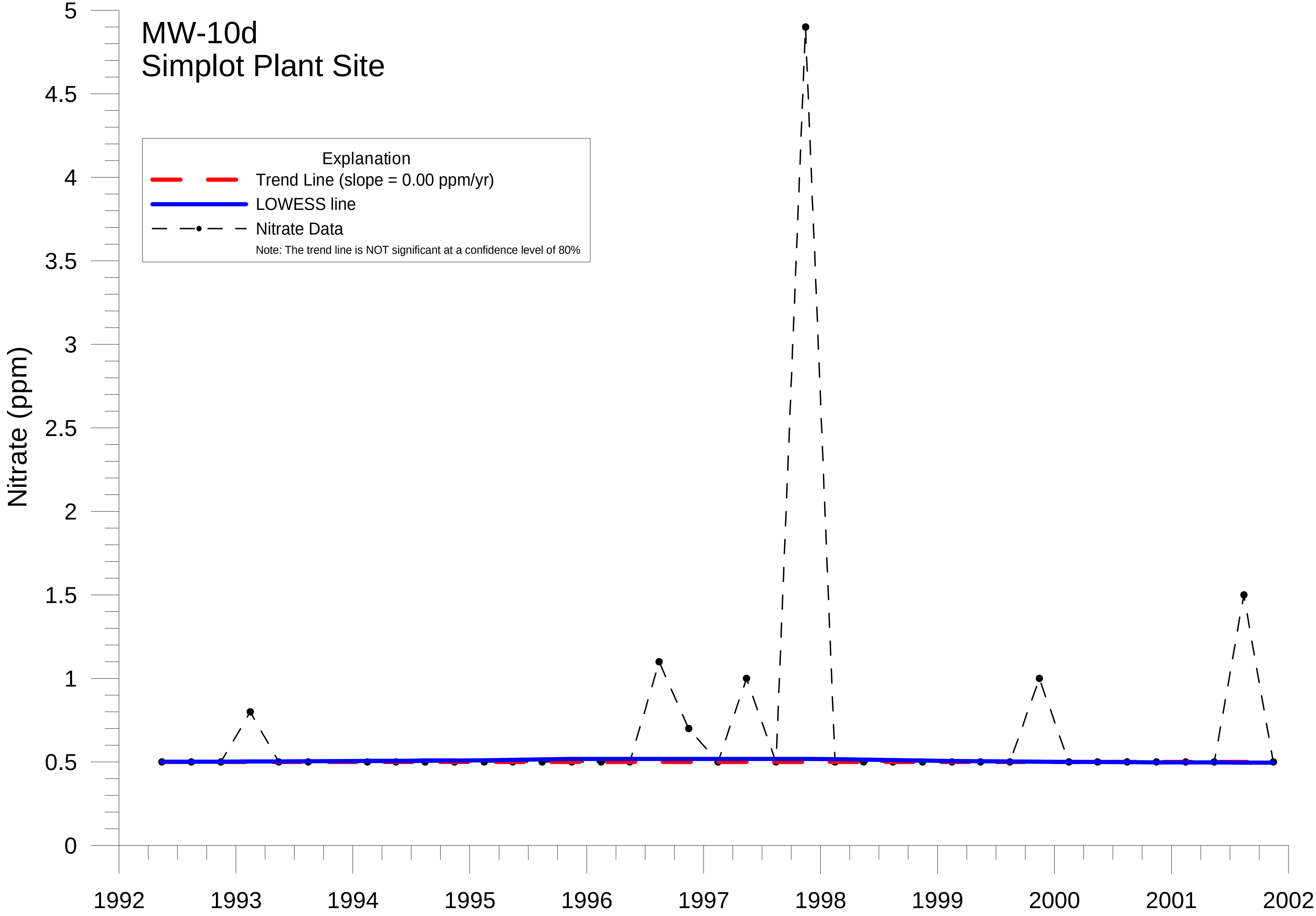

MW-10
Lamb-Weston Madison Ranch
Nitrate (ppm)
0
2
4
6
8
10
12
14
16
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = -0.68 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%



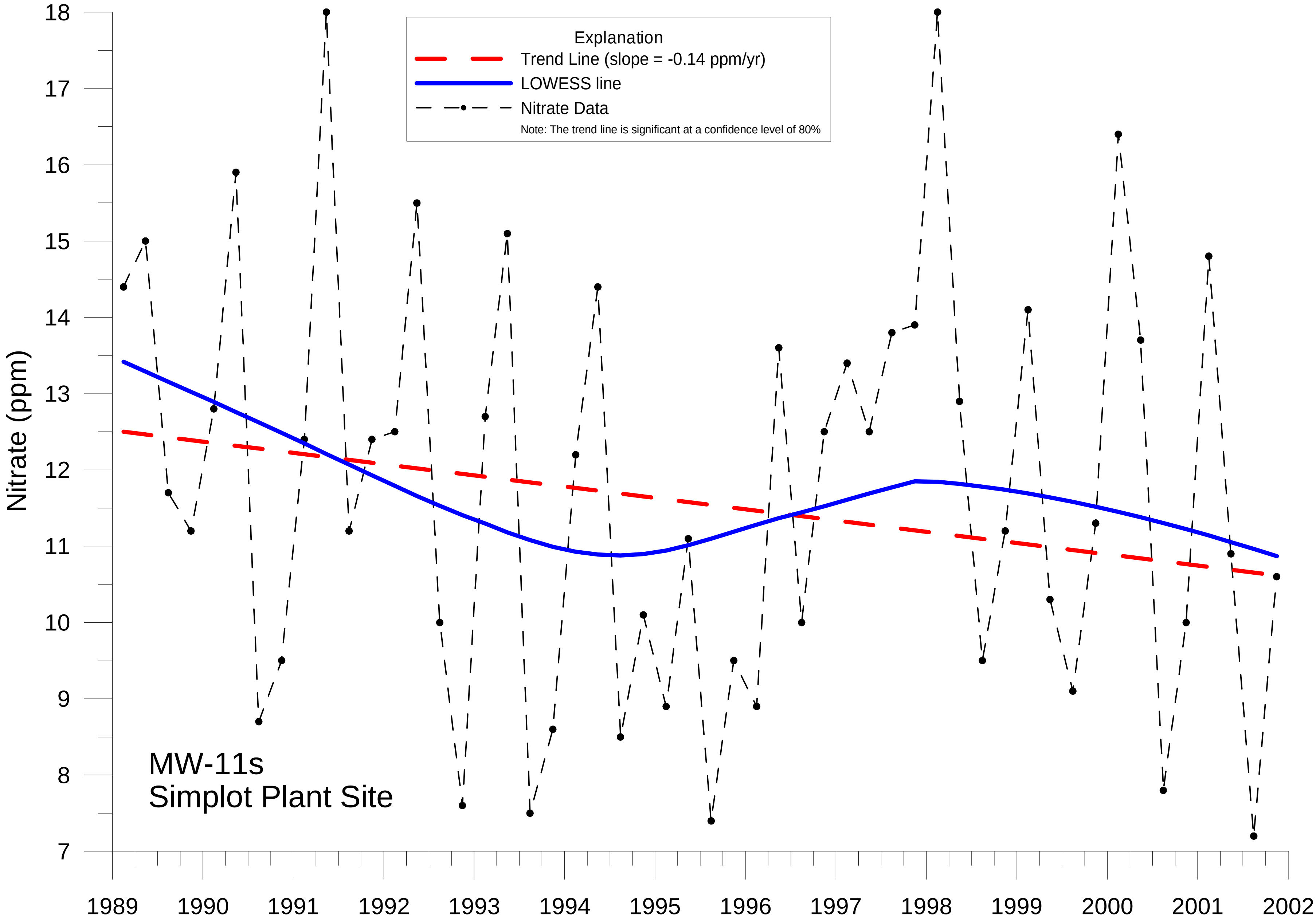
MW-11
Lamb-Weston
Madison Ranch
Nitrate (ppm)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.05 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%


MW-12
Lamb-Weston Madison Ranch
Nitrate (ppm)
0
1
2
3
4
5
6
7
8
9
10
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 1.03 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

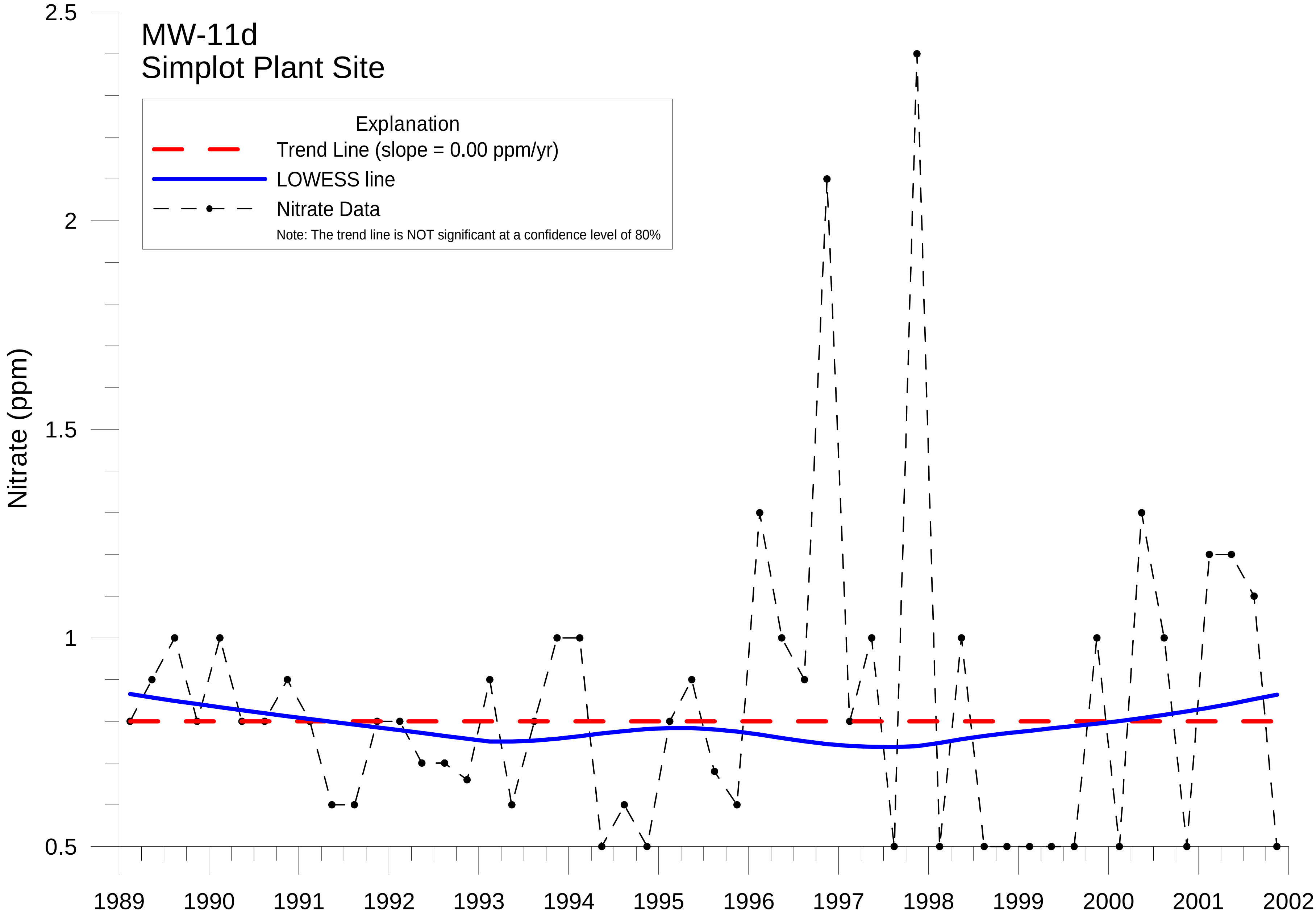

MW-10s
Simplot Plant Site
Explanation
Trend Line (slope = 0.00 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%
Nitrate (ppm)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002



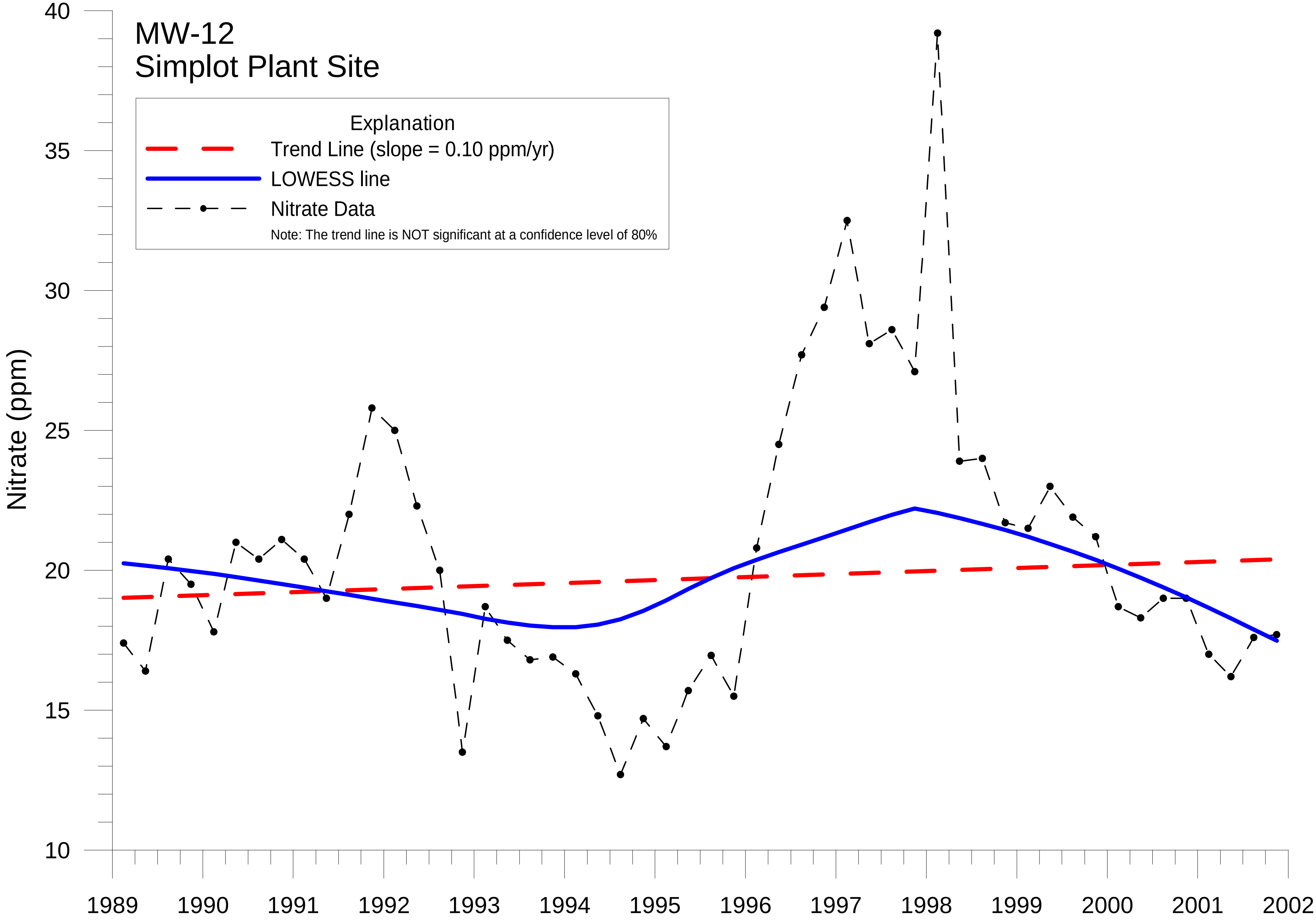
MW-10d
Simplot Plant Site
Explanation
Trend Line (slope = 0.00 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%
Nitrate (ppm)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002



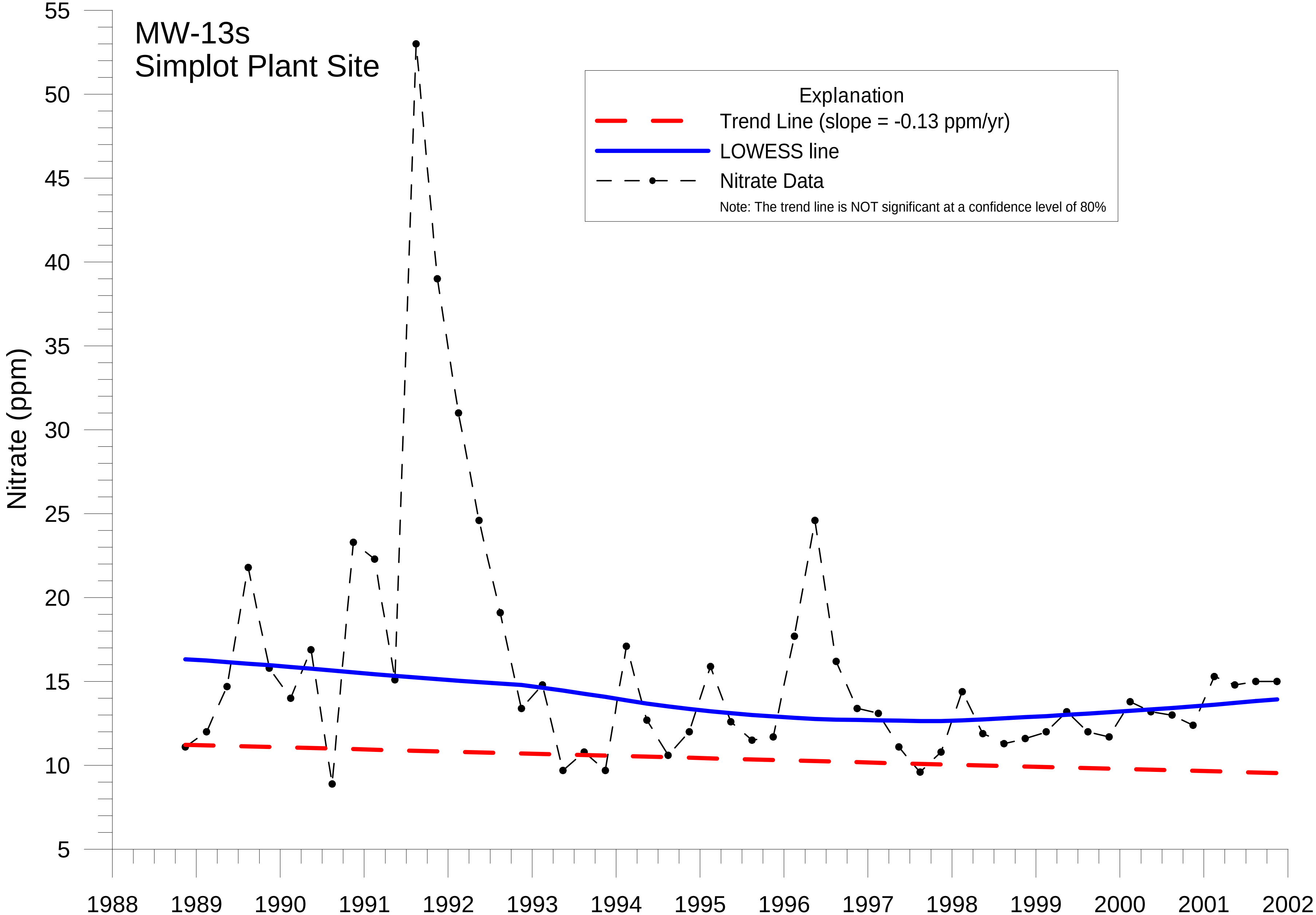
Explanation
Trend Line (slope = -0.14 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 80%
Nitrate (ppm)
18
17
16
15
14
13
12
11
10
9
8
7
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
MW-11s
Simplot Plant Site



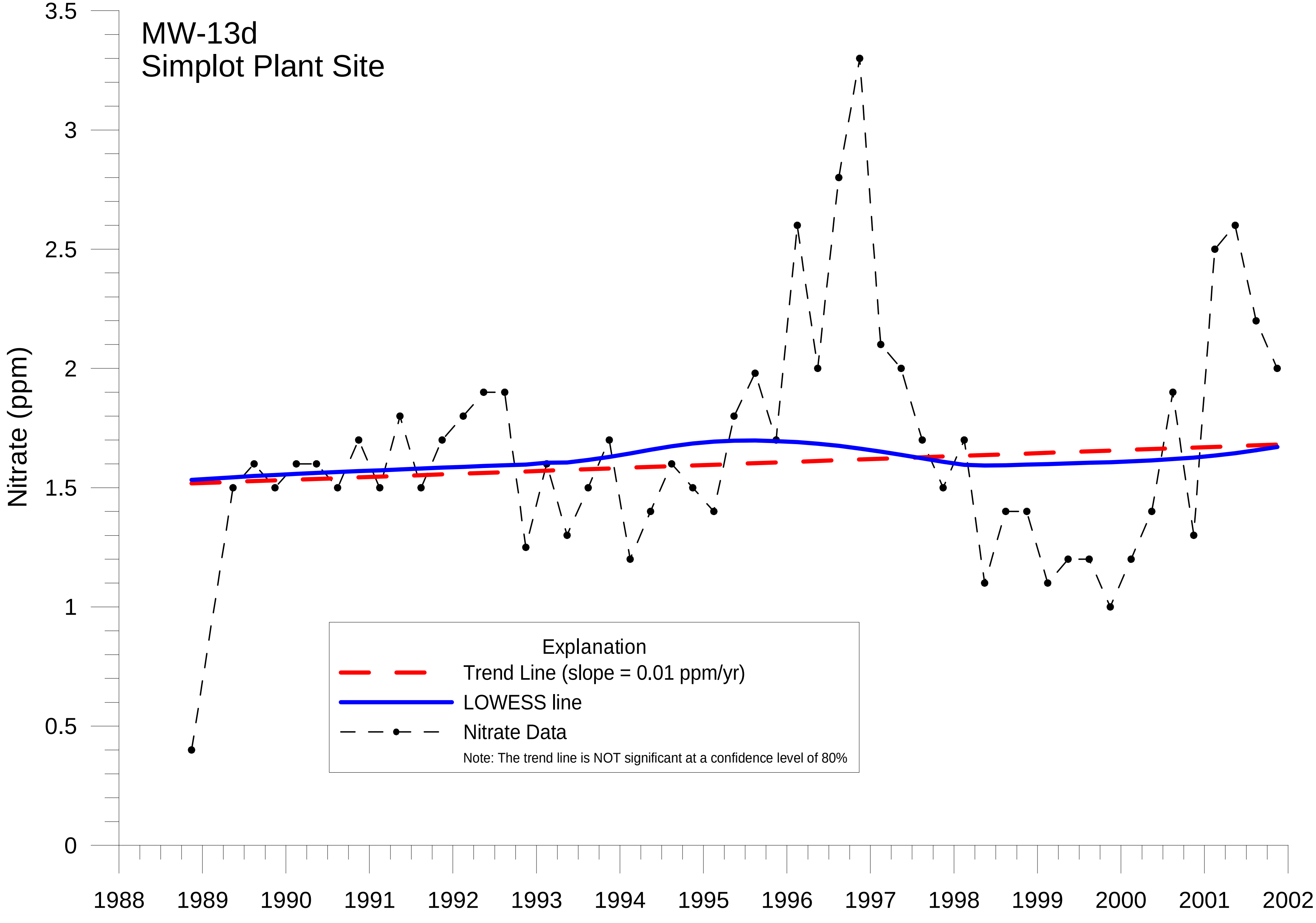
MW-11d
Simplot Plant Site
Explanation
Trend Line (slope = 0.00 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%
Nitrate (ppm)
2.5
2
1.5
1
0.5
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002



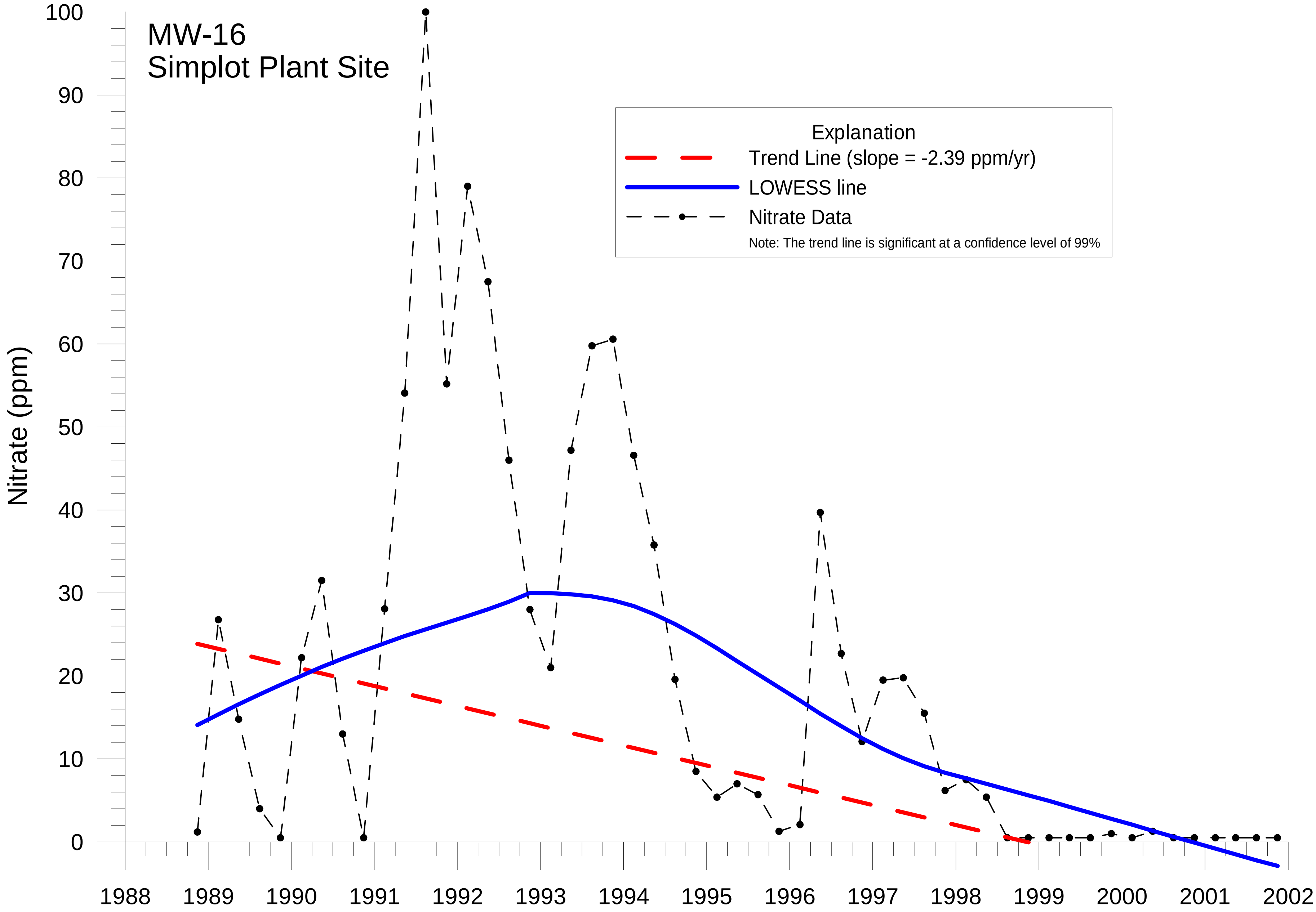
MW-12
Simplot Plant Site
Explanation
Trend Line (slope = 0.10 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%
Nitrate (ppm)
40
35
30
25
20
15
10
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002



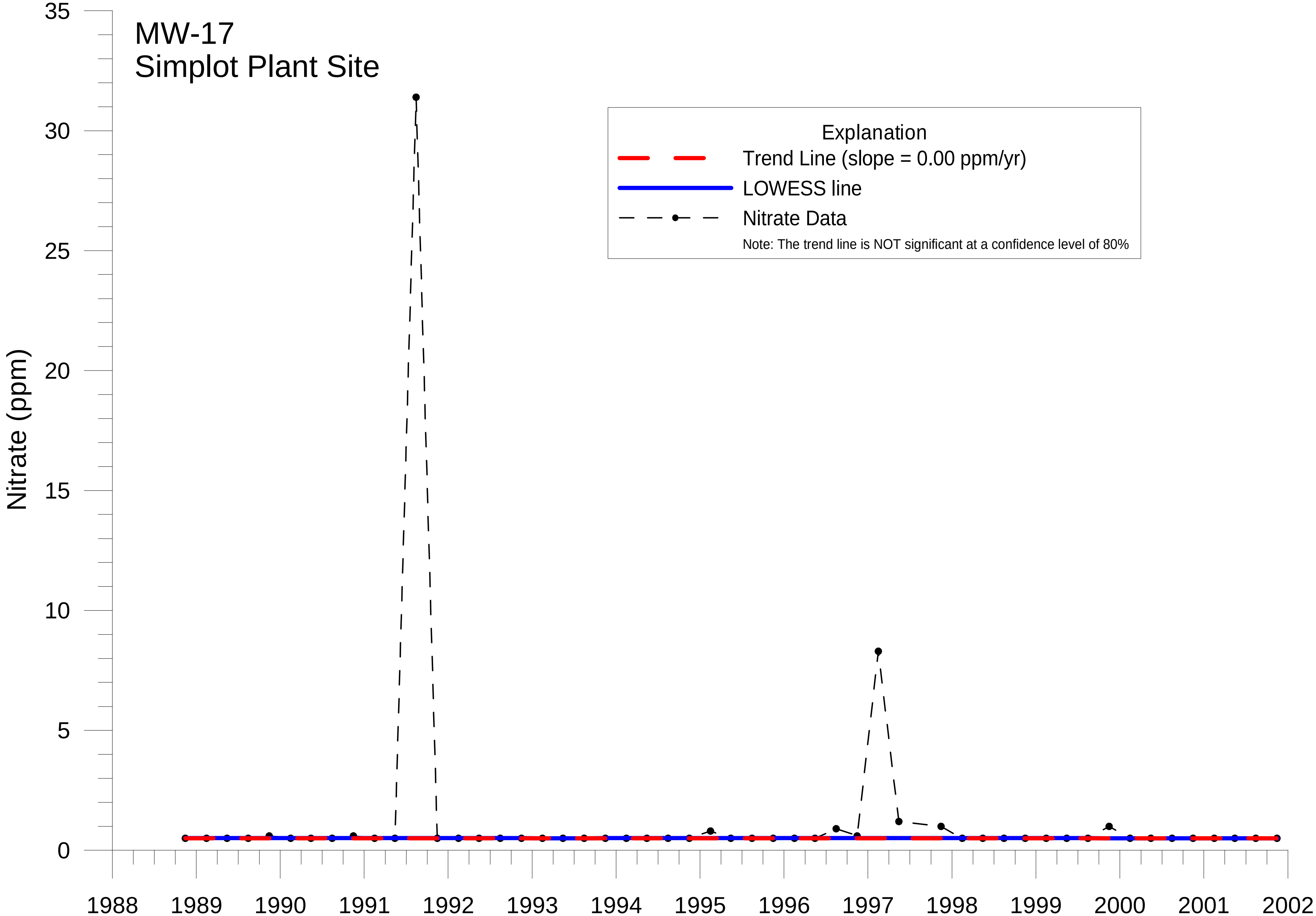
MW-13s
Simplot Plant Site
Explanation
Trend Line (slope = -0.13 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%
Nitrate (ppm)
55
50
45
40
35
30
25
20
15
10
5
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002



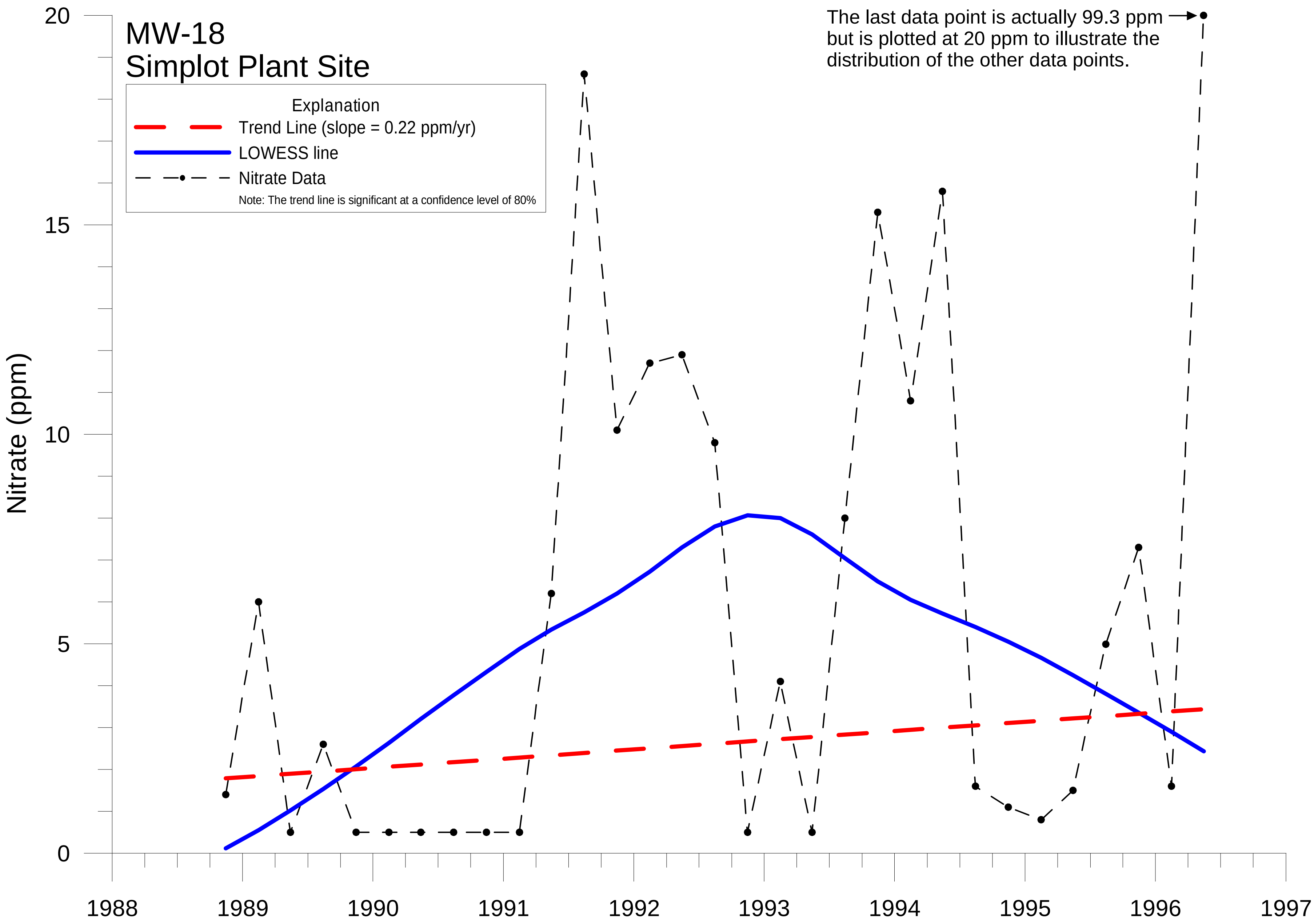
MW-13d
Simplot Plant Site
Nitrate (ppm)
0
0.5
1
1.5
2
2.5
3
3.5
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.01 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%



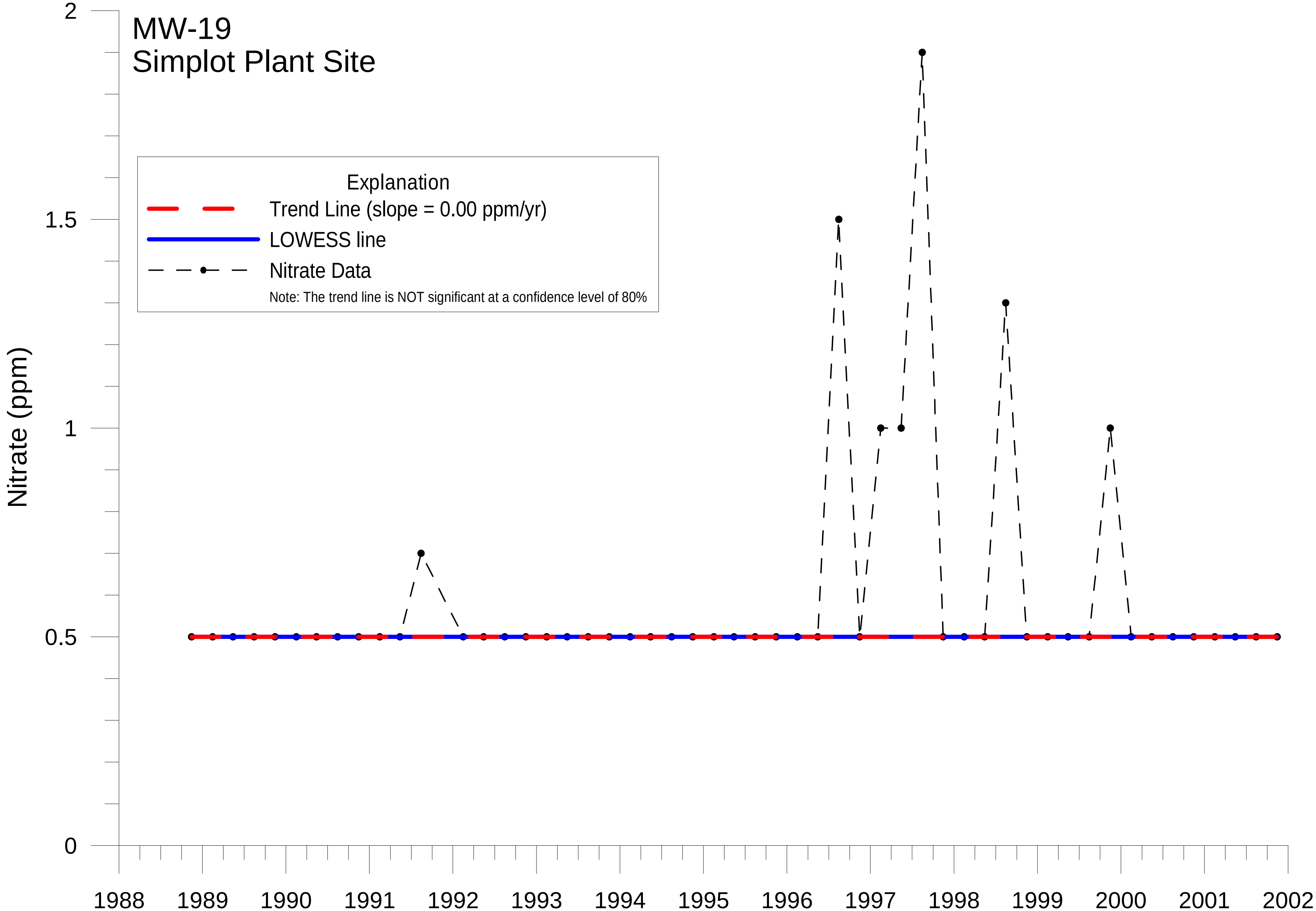
MW-16
Simplot Plant Site
Explanation
Trend Line (slope = -2.39 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%
Nitrate (ppm)
0
10
20
30
40
50
60
70
80
90
100
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002

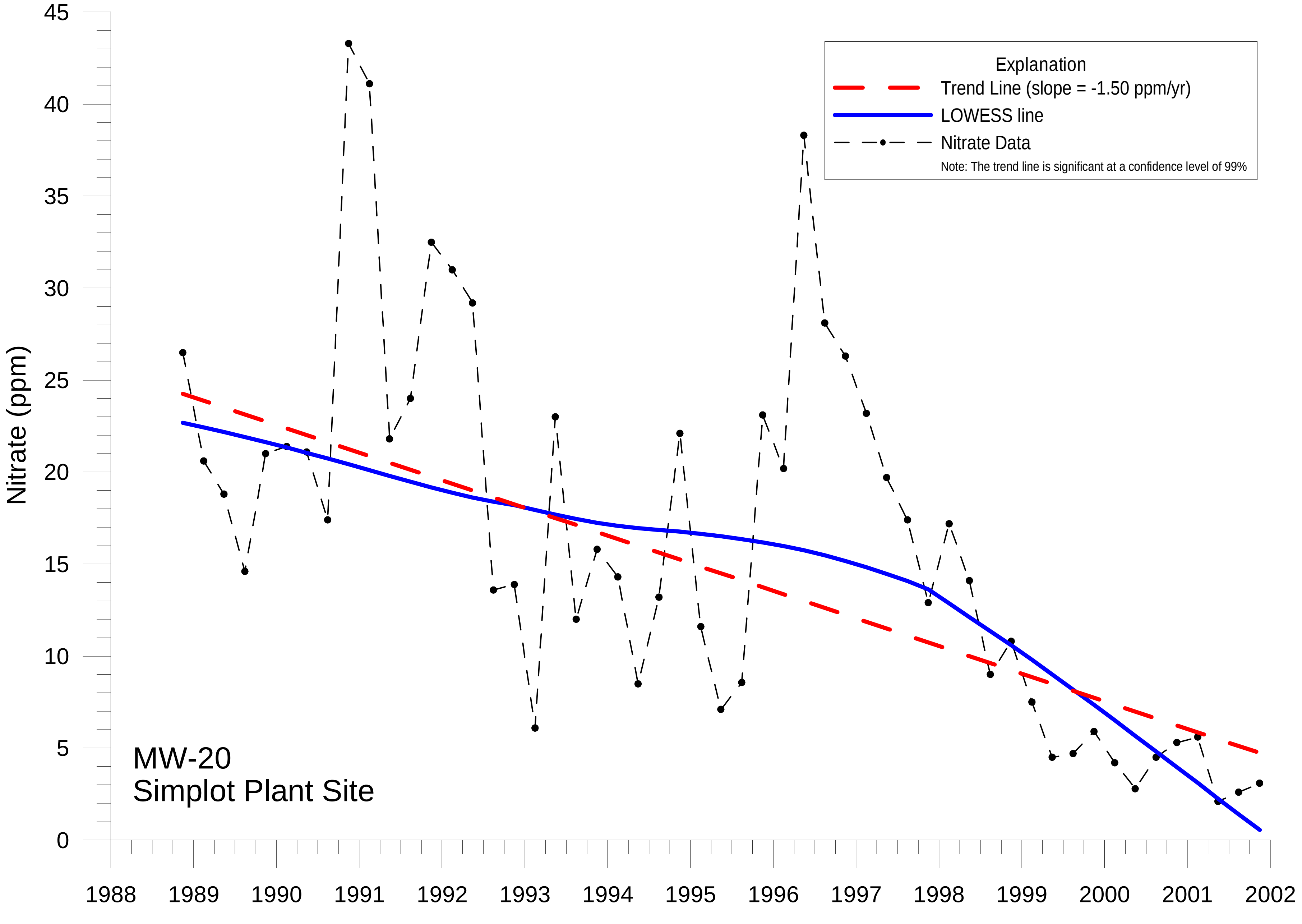


MW-17
Simplot Plant Site
Explanation
Trend Line (slope = 0.00 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%
Nitrate (ppm)
0
5
10
15
20
25
30
35
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002

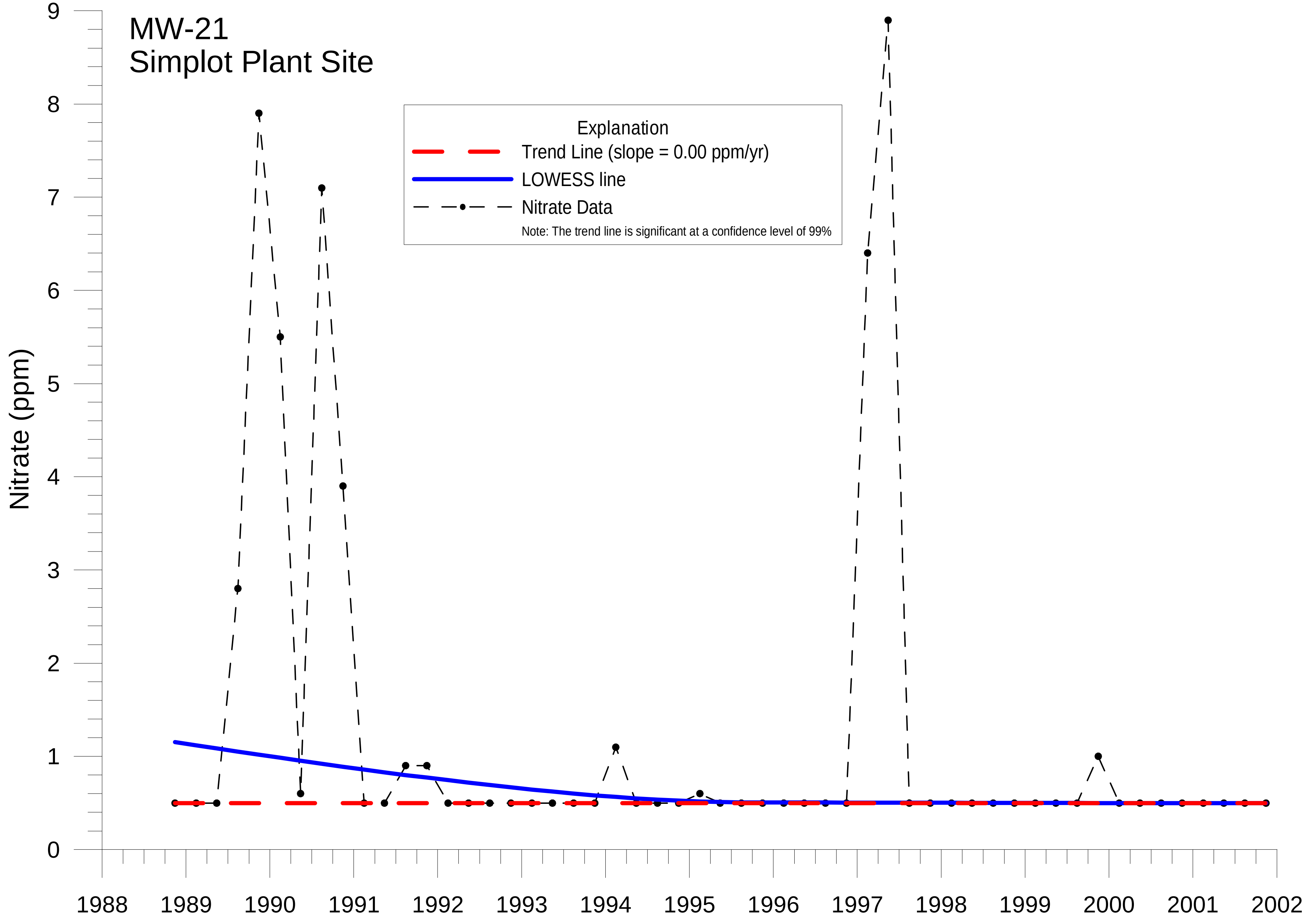


MW-18
Simplot Plant Site
Explanation
Trend Line (slope = 0.22 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 80%
The last data point is actually 99.3 ppm but is plotted at 20 ppm to illustrate the distribution of the other data points.
Nitrate (ppm)
0
5
10
15
20
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997

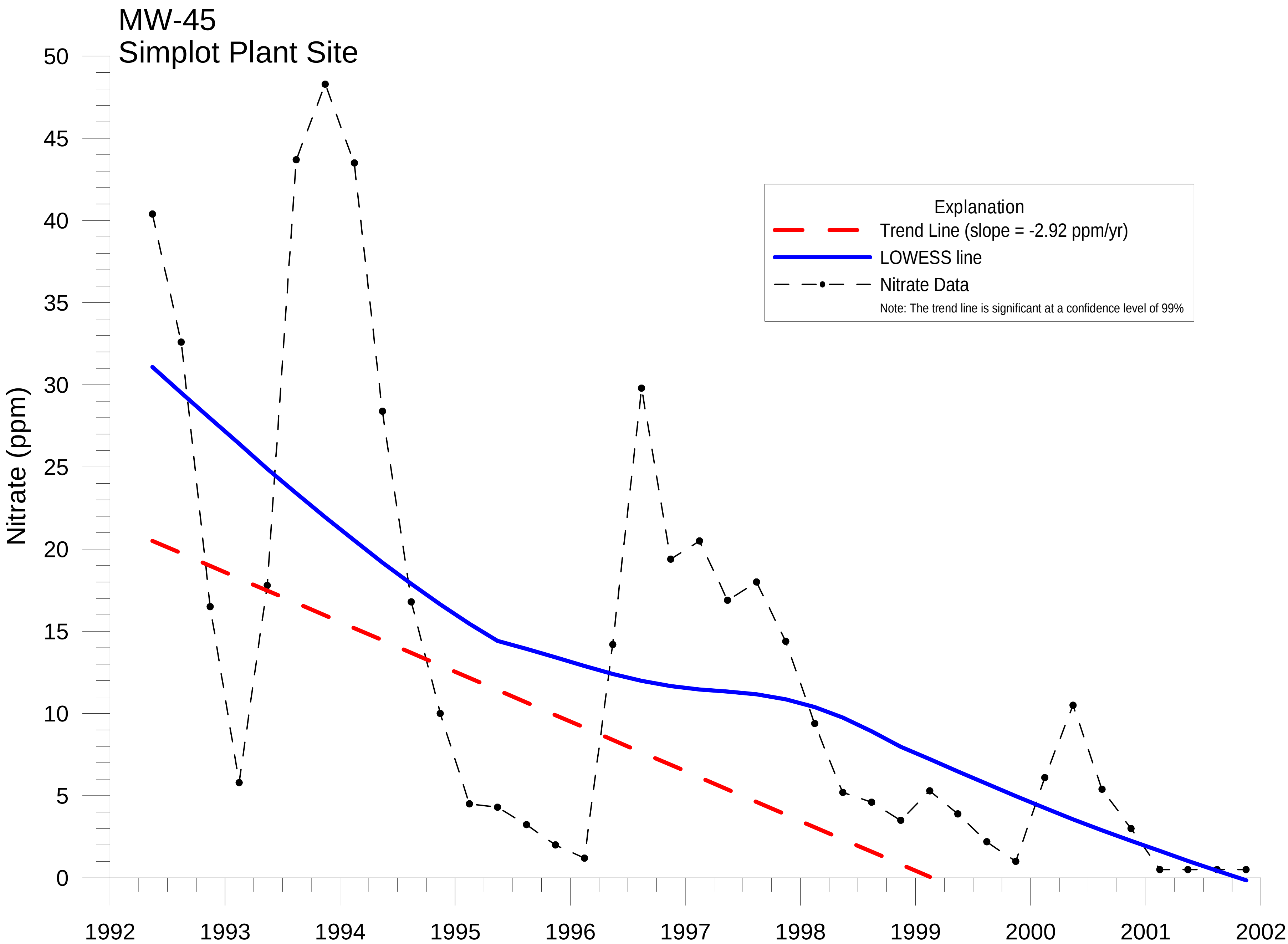

MW-19
Simplot Plant Site
Explanation
Trend Line (slope = 0.00 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%
Nitrate (ppm)
0
0.5
1
1.5
2
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002

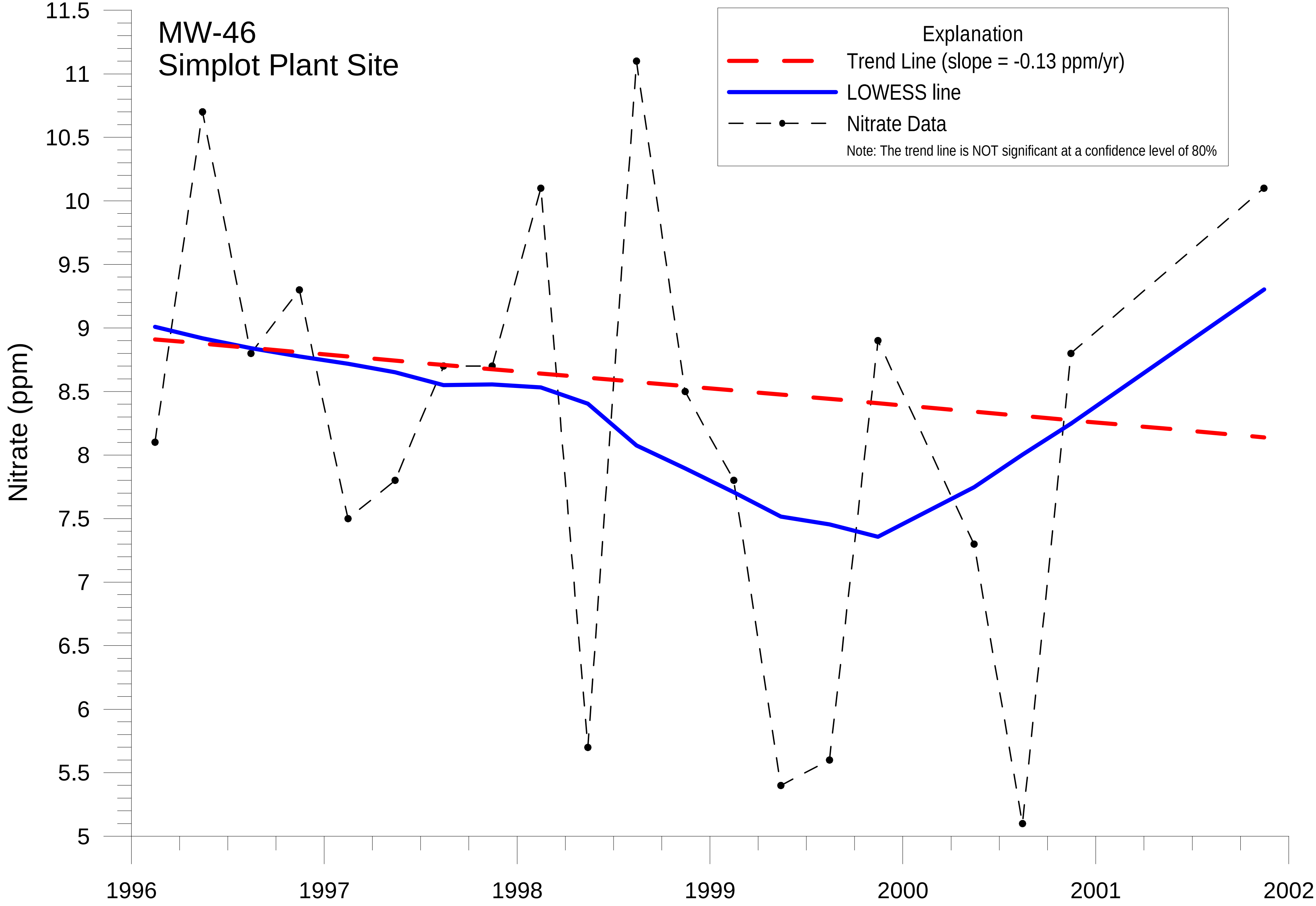


Explanation
Trend Line (slope = -1.50 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%
Nitrate (ppm)
0
5
10
15
20
25
30
35
40
45
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
MW-20
Simplot Plant Site

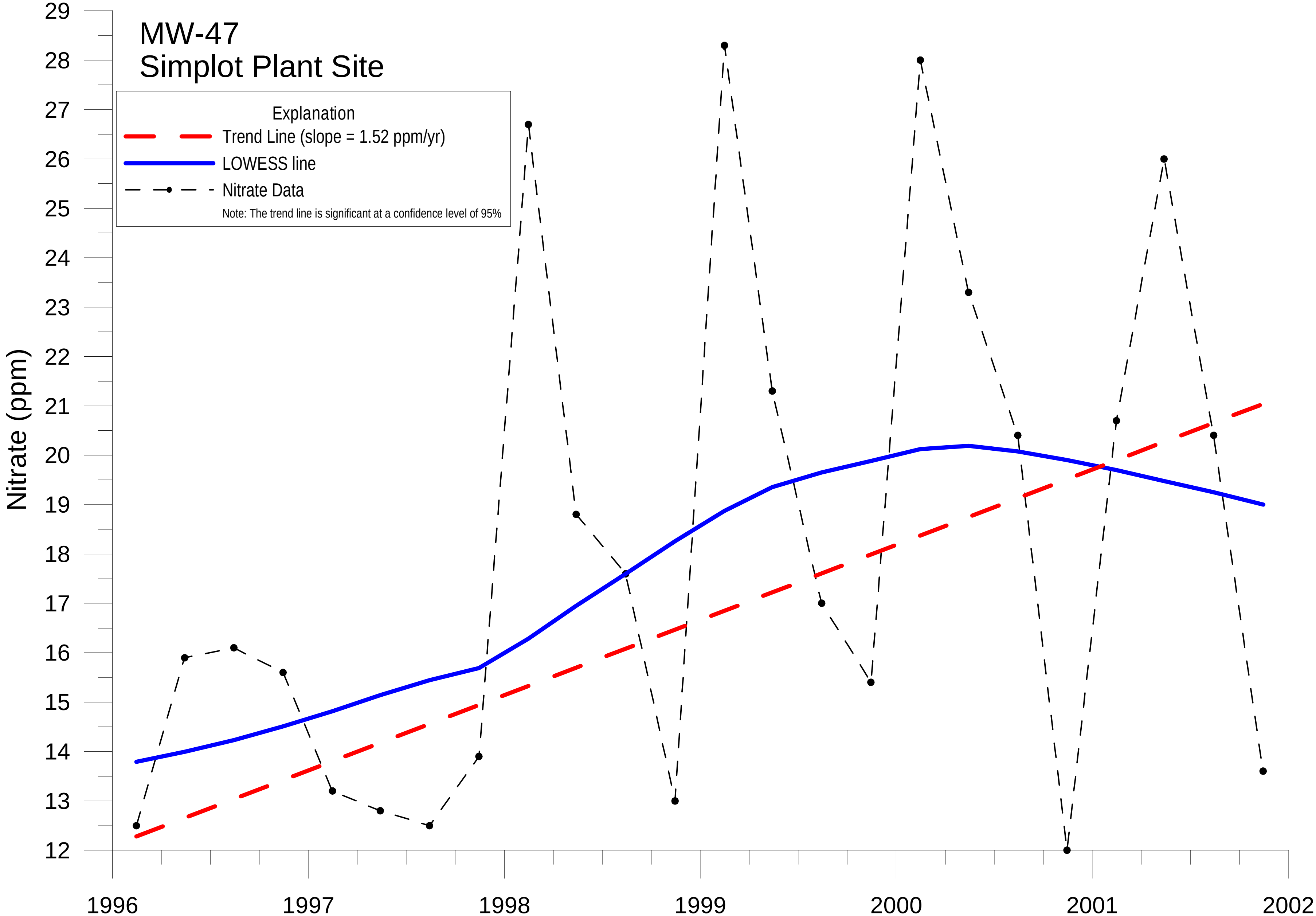


MW-21
Simplot Plant Site
Explanation
Trend Line (slope = 0.00 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%
Nitrate (ppm)
0
1
2
3
4
5
6
7
8
9
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002

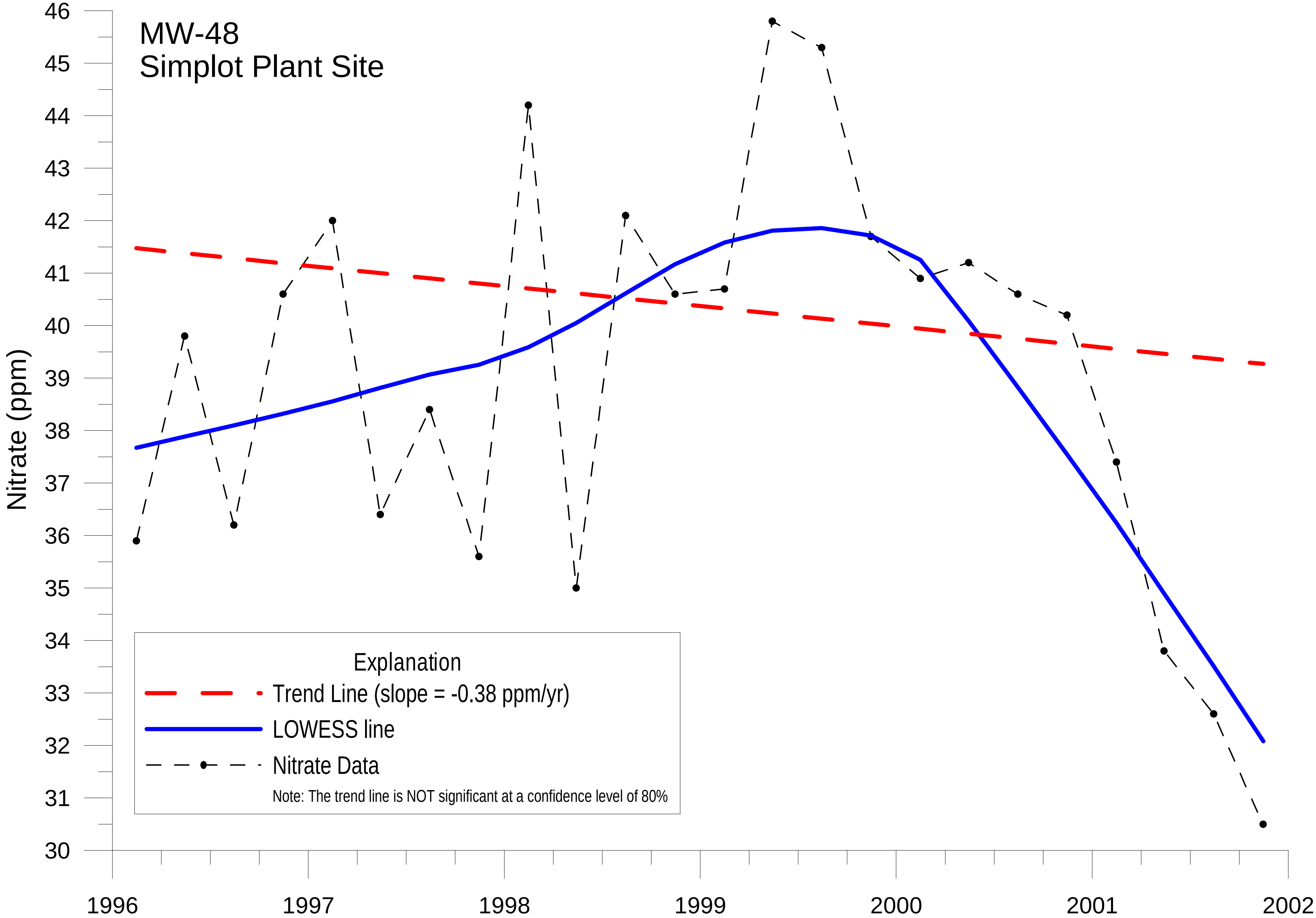

MW-45
Simplot Plant Site
Nitrate (ppm)
0
5
10
15
20
25
30
35
40
45
50
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = -2.92 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%



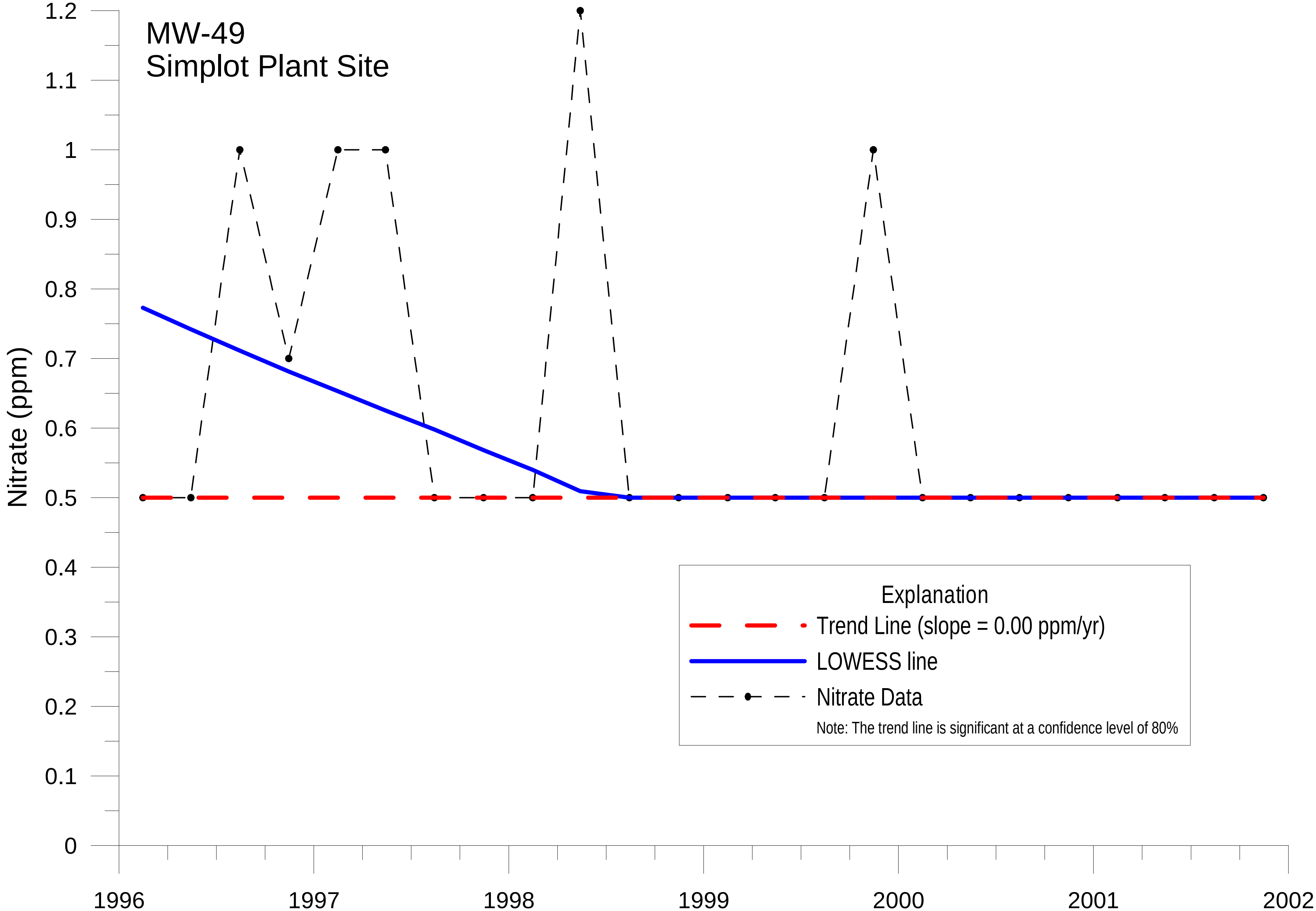
MW-46
Simplot Plant Site
Explanation
Trend Line (slope = -0.13 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%
Nitrate (ppm)
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
1996
1997
1998
1999
2000
2001
2002



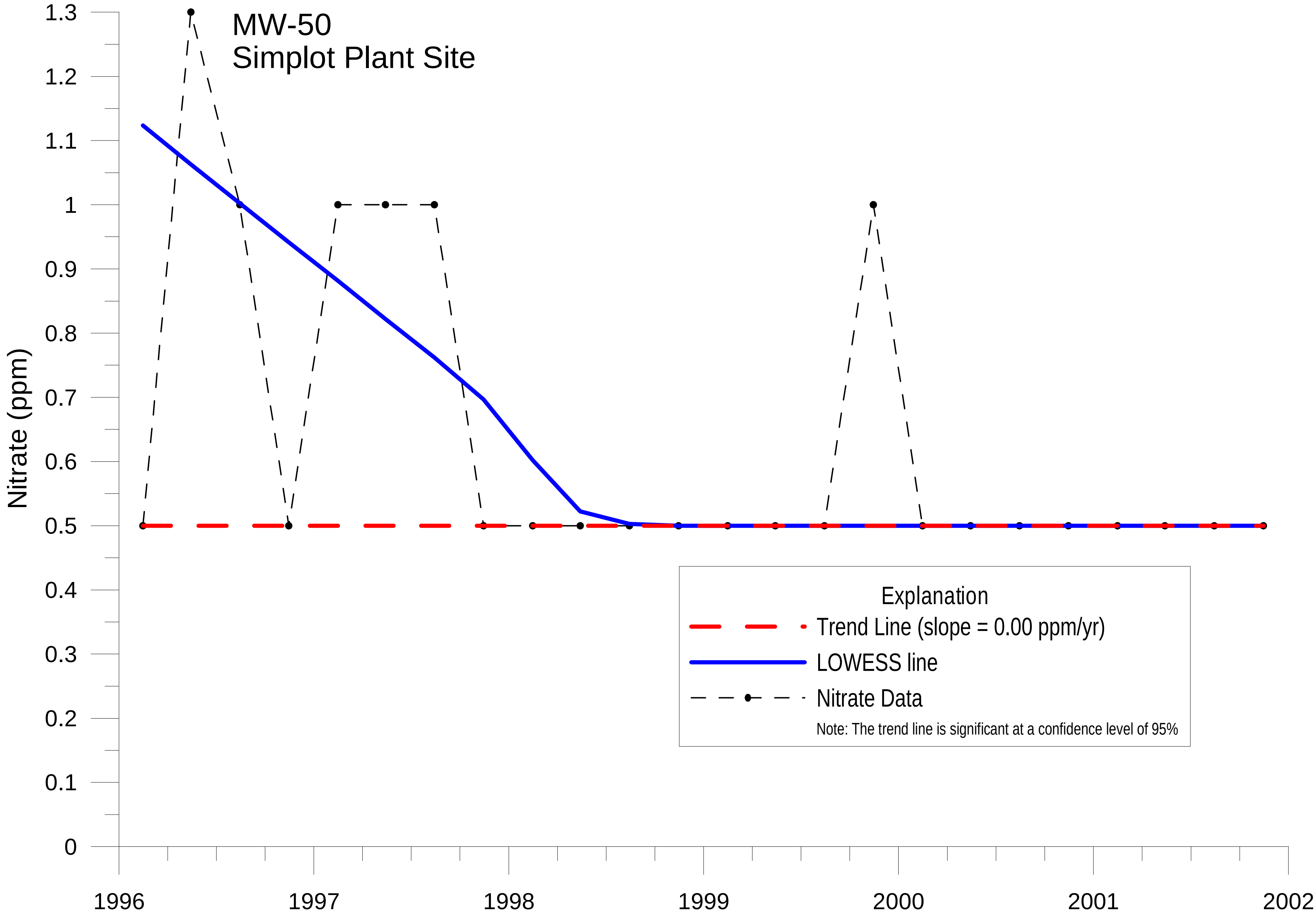
MW-47
Simplot Plant Site
Explanation
Trend Line (slope = 1.52 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 95%
Nitrate (ppm)
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
1996
1997
1998
1999
2000
2001
2002

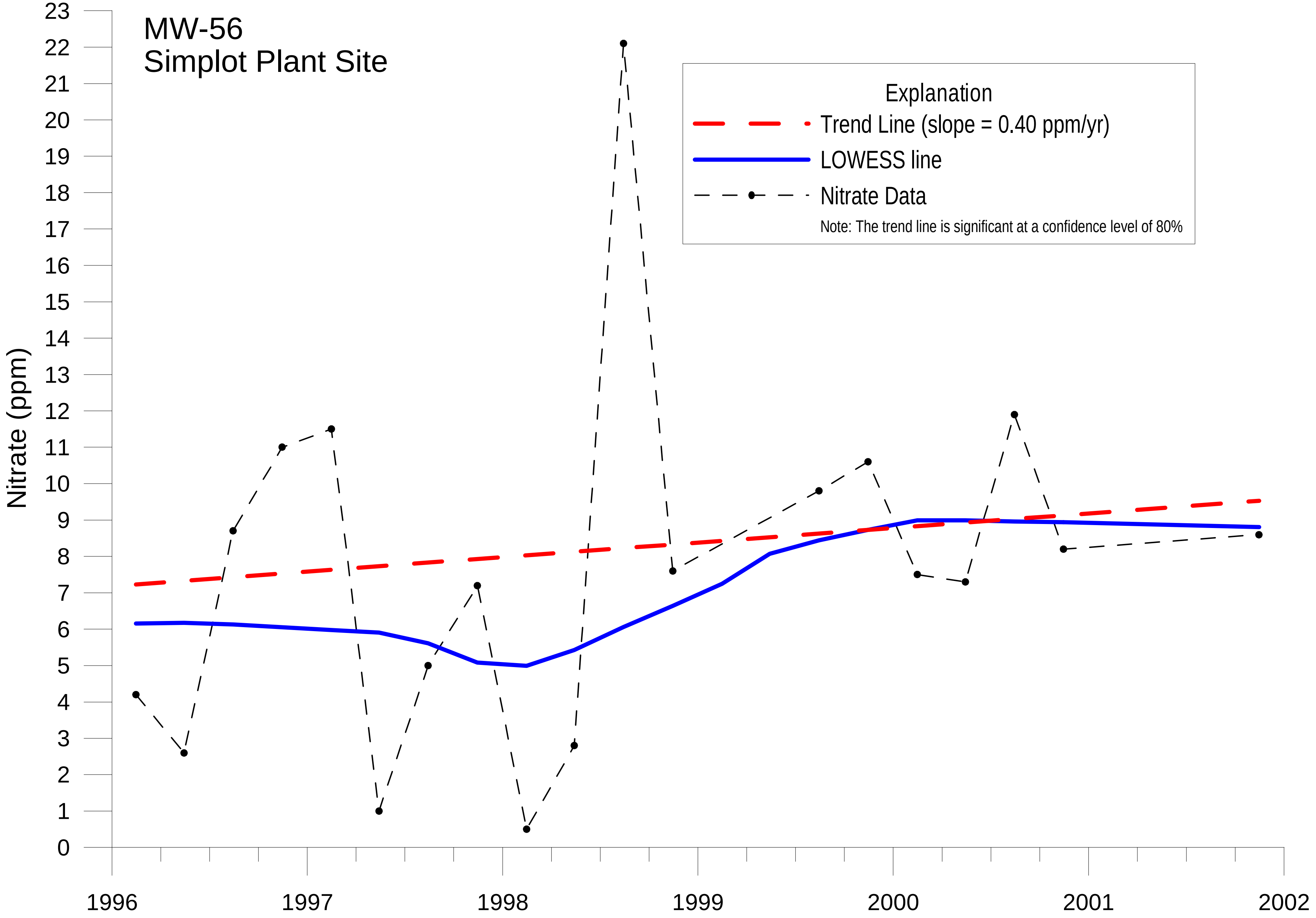


MW-48
Simplot Plant Site
Nitrate (ppm)
46
45
44
43
42
41
40
39
38
37
36
35
34
33
32
31
30
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = -0.38 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%

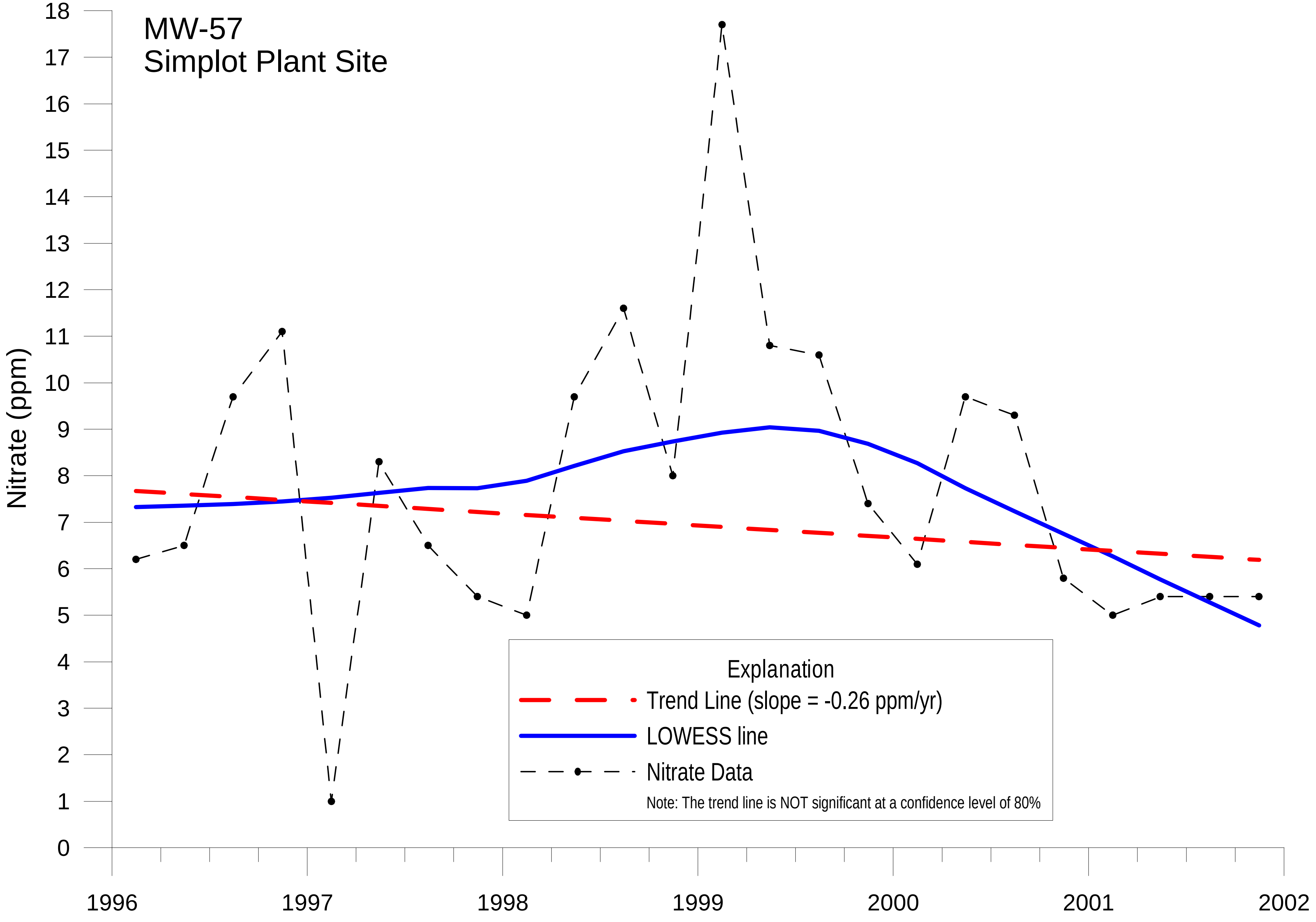


MW-49
Simplot Plant Site
Nitrate (ppm)
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.00 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 80%

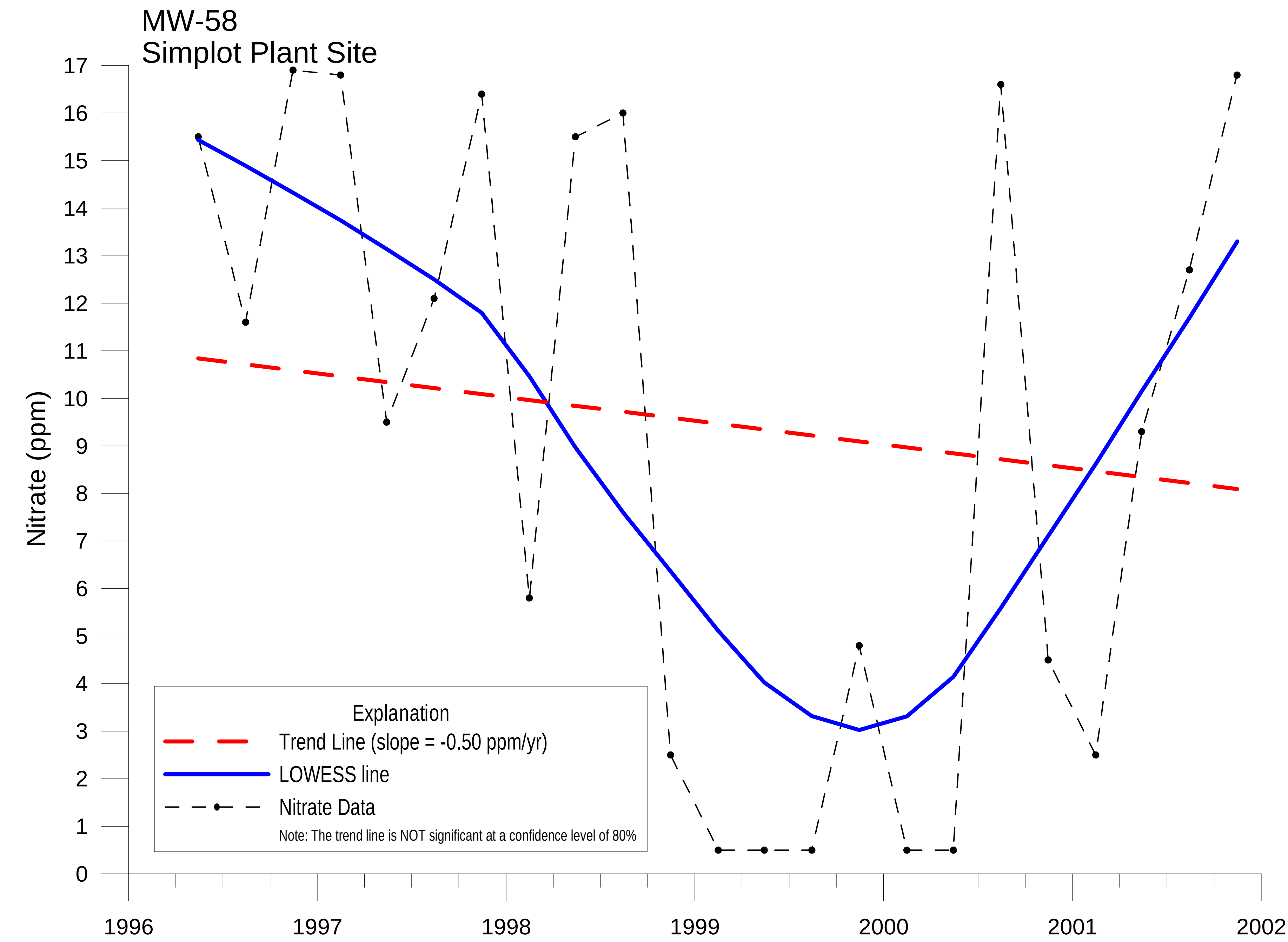

MW-50
Simplot Plant Site
Nitrate (ppm)
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.00 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 95%



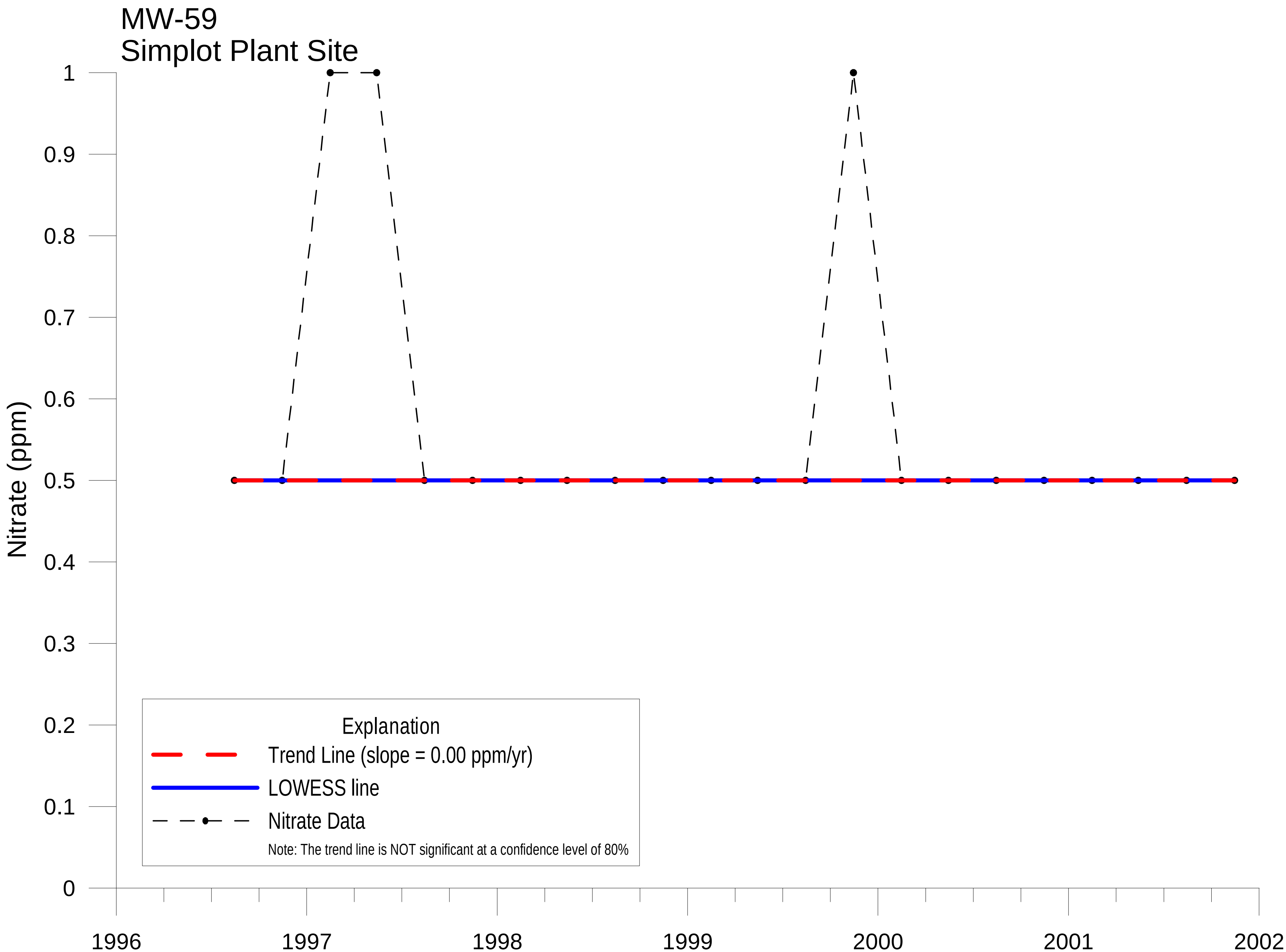
MW-56
Simplot Plant Site
Explanation
Trend Line (slope = 0.40 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 80%
Nitrate (ppm)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
1996
1997
1998
1999
2000
2001
2002

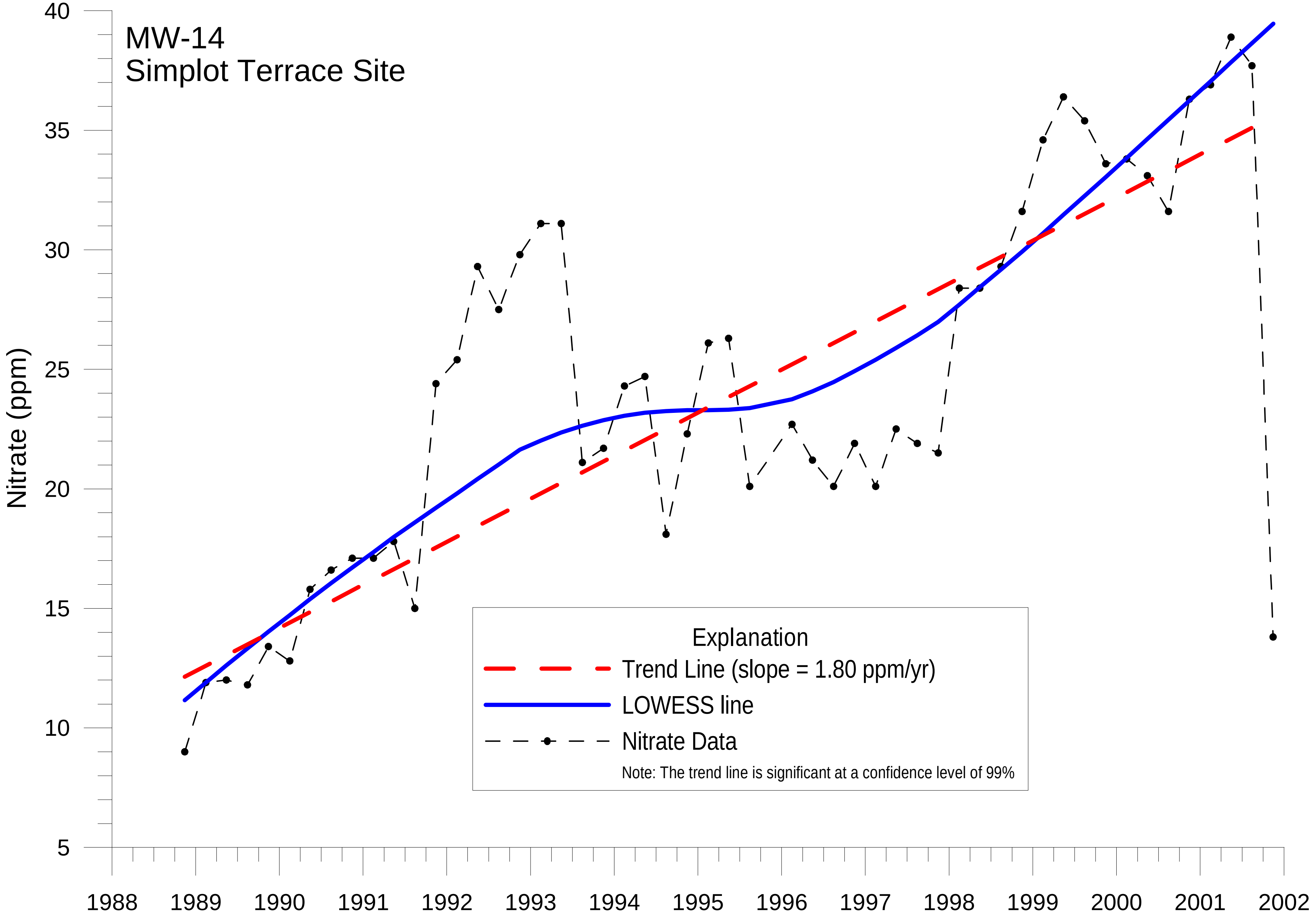


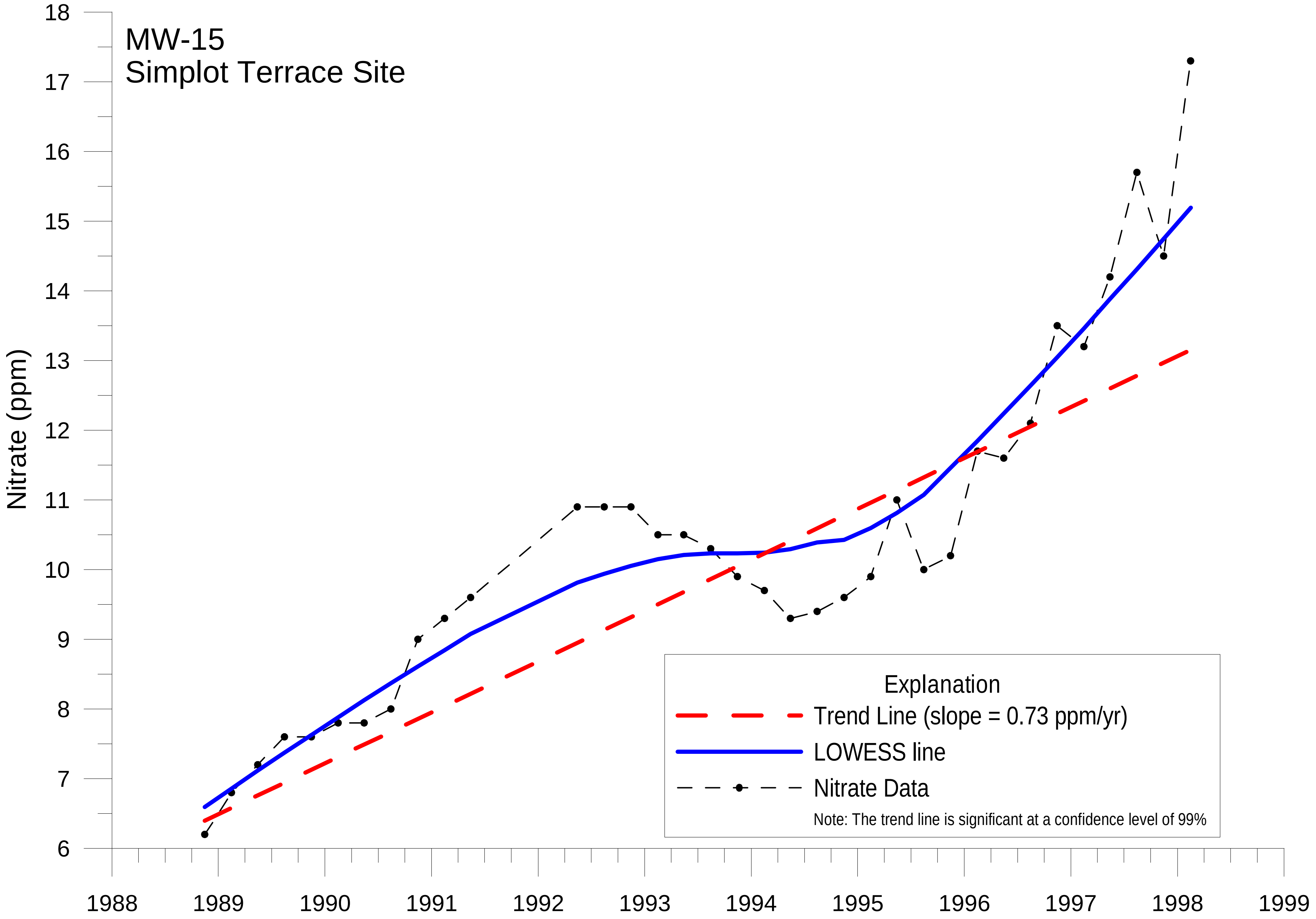
MW-57
Simplot Plant Site
Nitrate (ppm)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = -0.26 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%



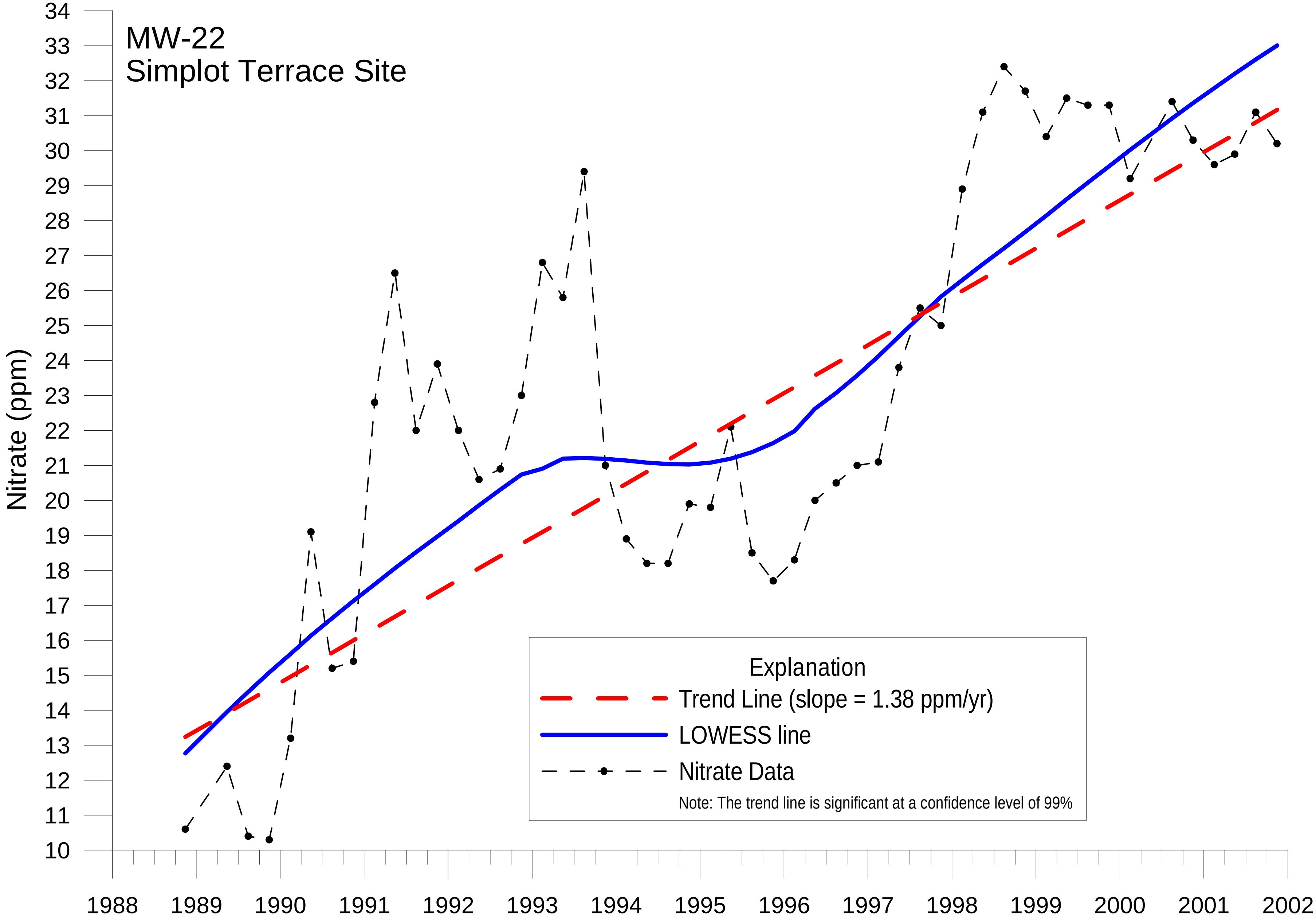
MW-58
Simplot Plant Site
Nitrate (ppm)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = -0.50 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%

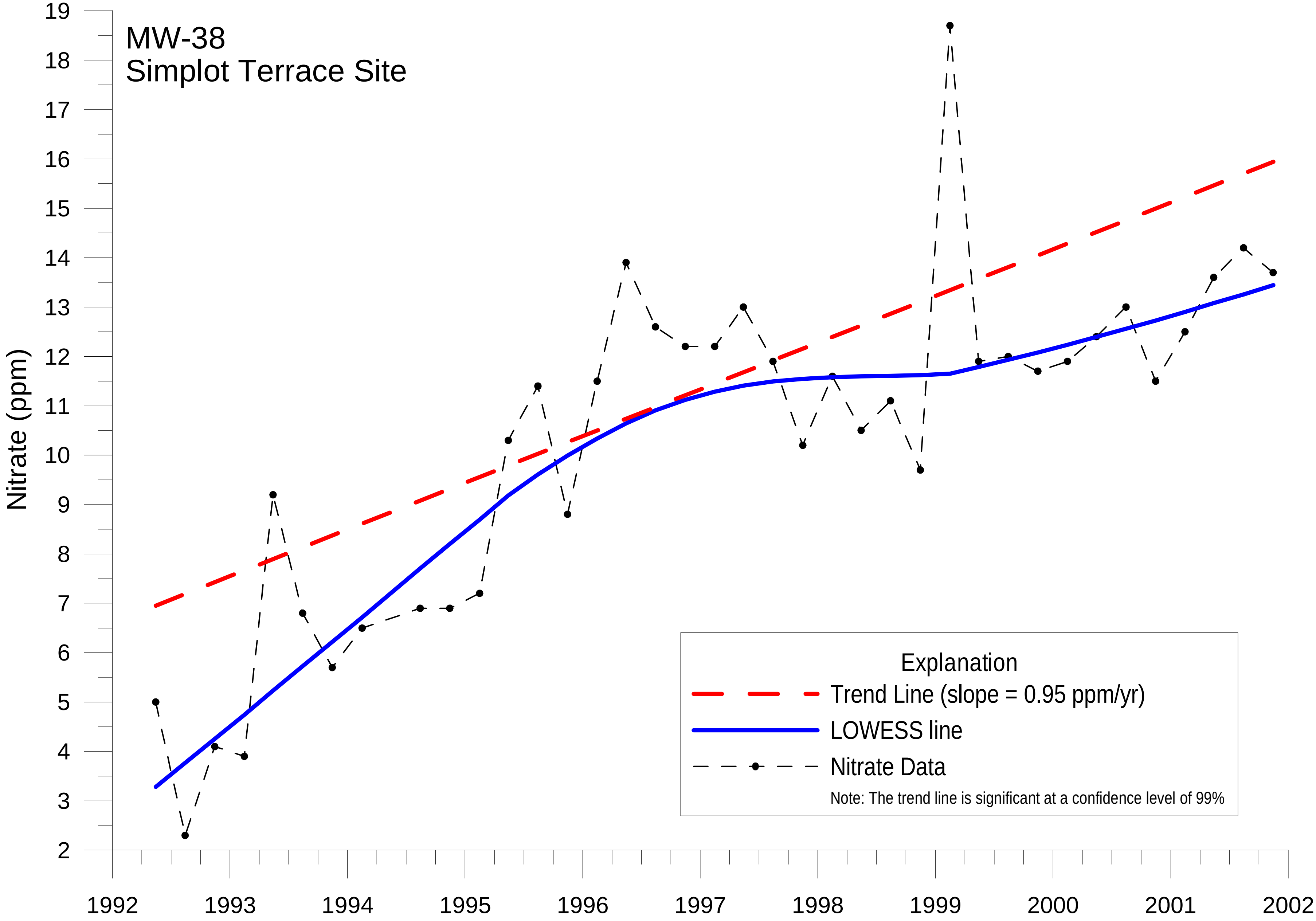

MW-59
Simplot Plant Site
Nitrate (ppm)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.00 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%


MW-14
Simplot Terrace Site
Nitrate (ppm)
40
35
30
25
20
15
10
5
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 1.80 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

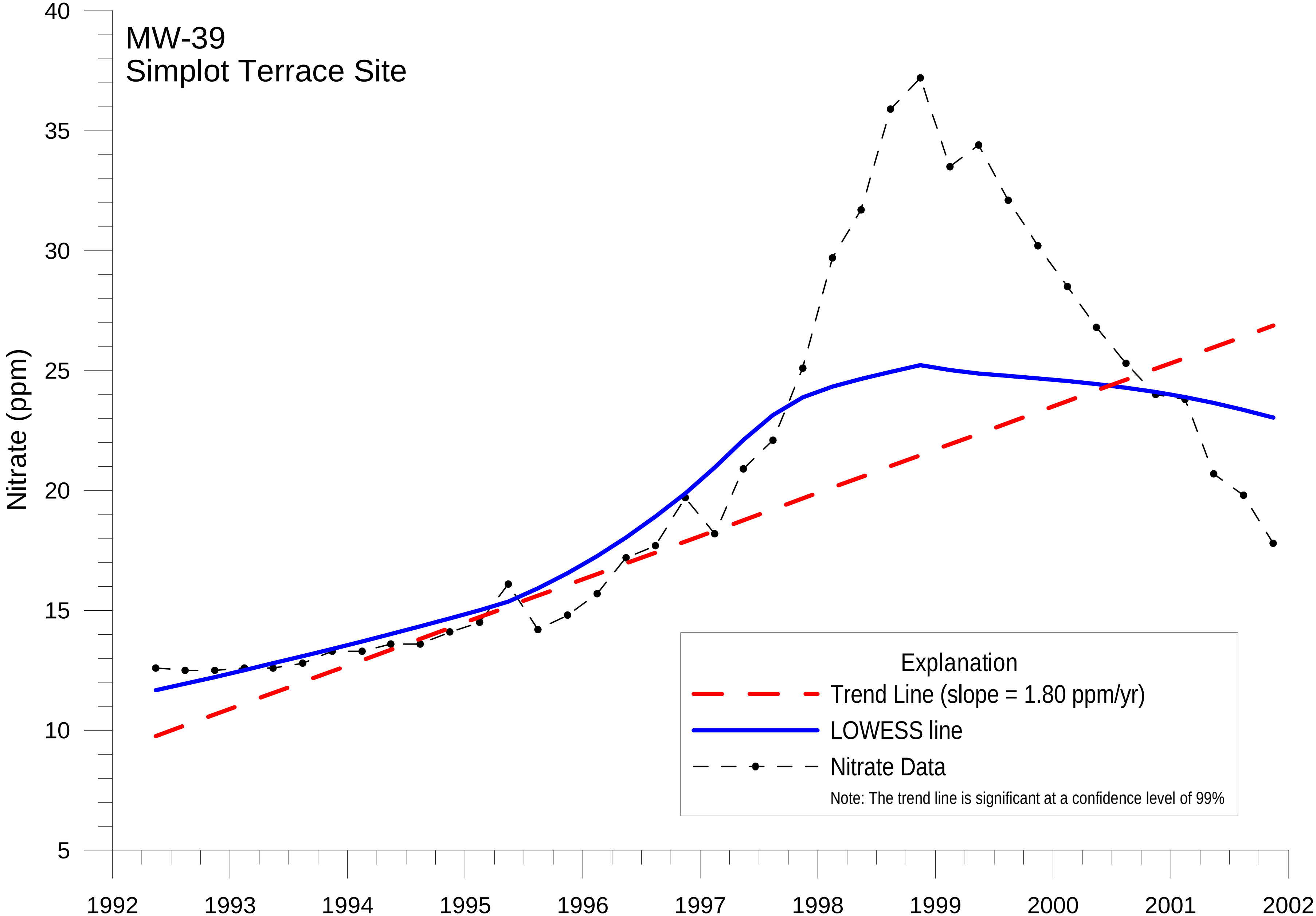


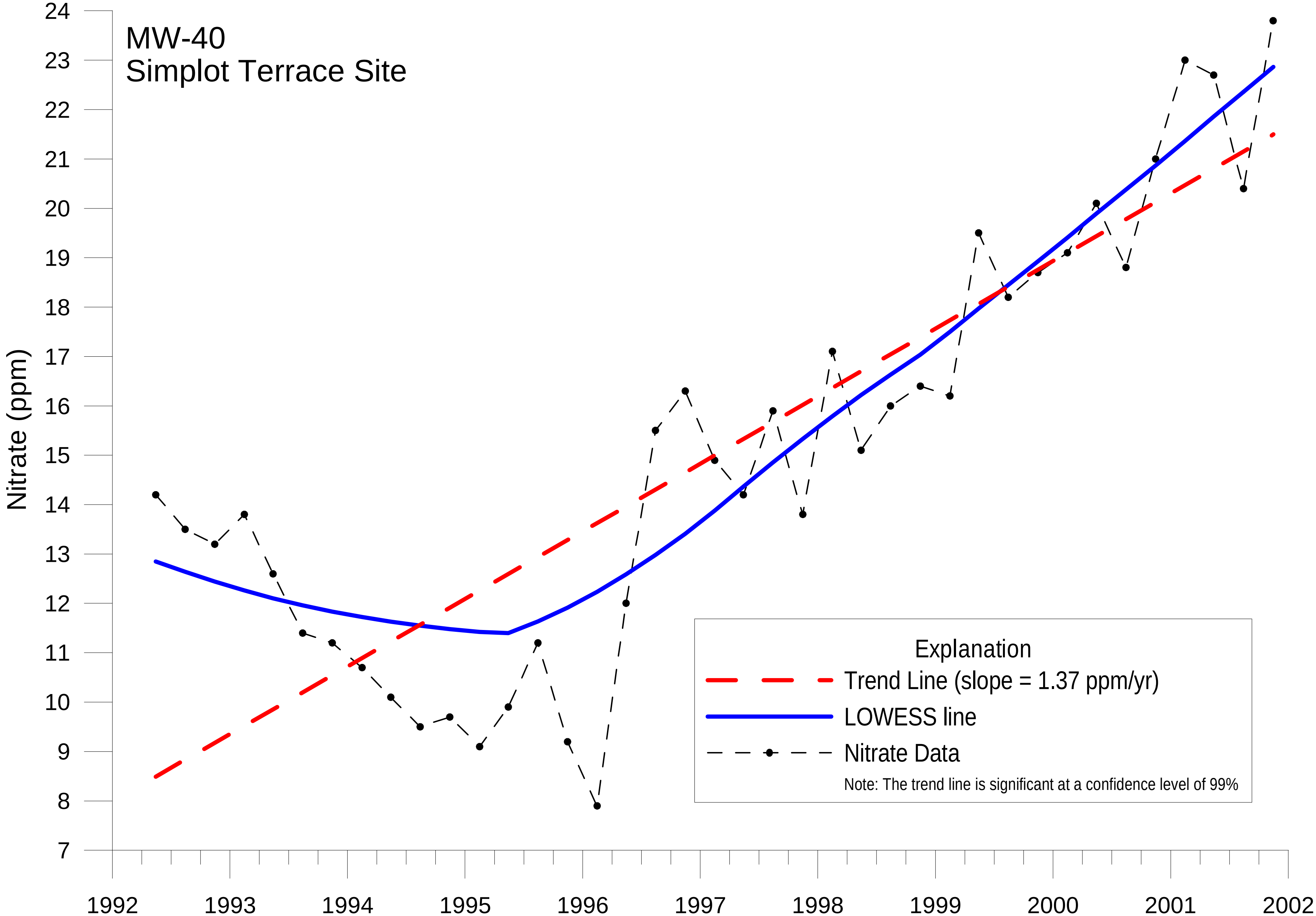
MW-15
Simplot Terrace Site
Nitrate (ppm)
18
17
16
15
14
13
12
11
10
9
8
7
6
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
Explanation
Trend Line (slope = 0.73 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

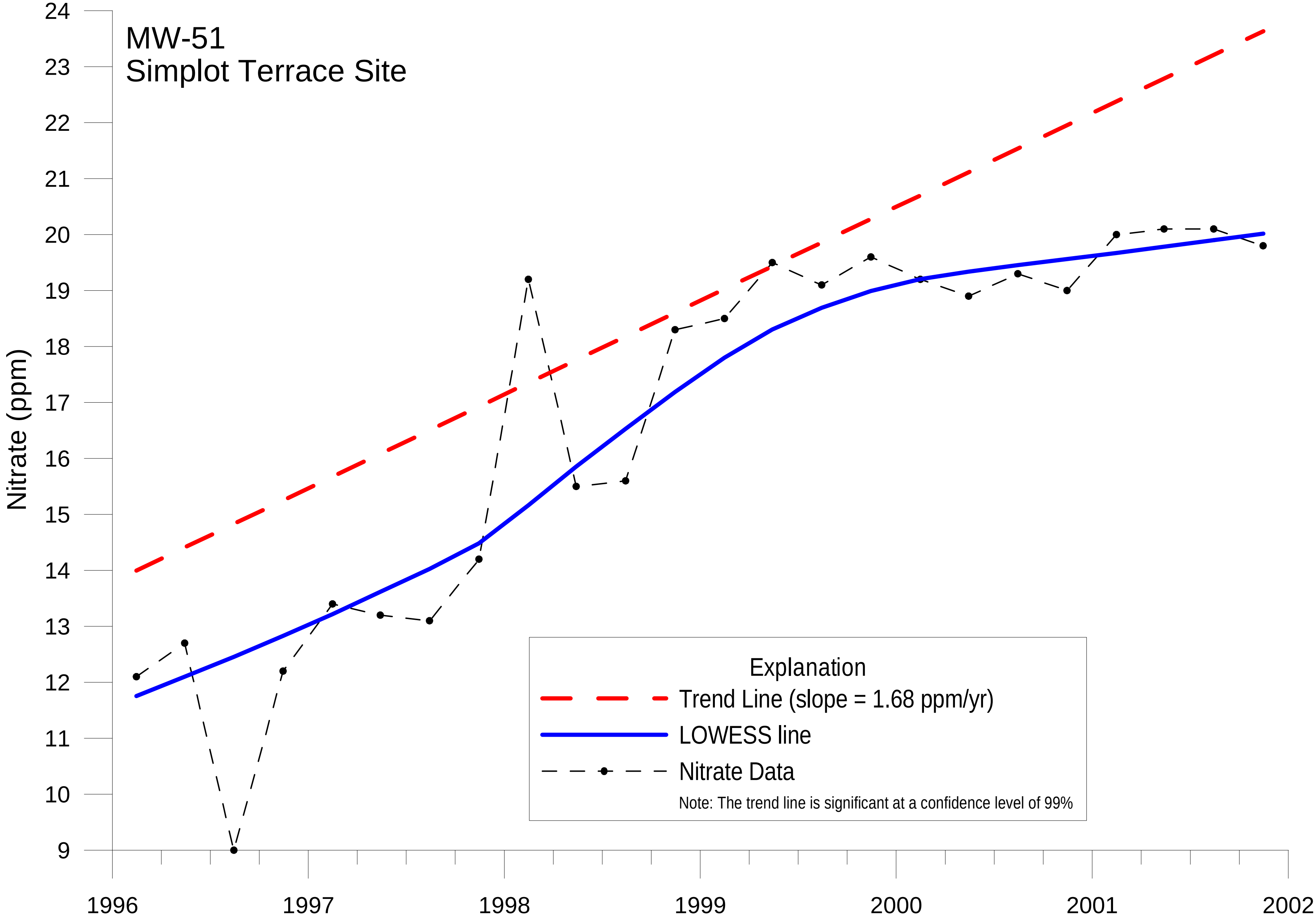

MW-22
Simplot Terrace Site
Nitrate (ppm)
34
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 1.38 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%



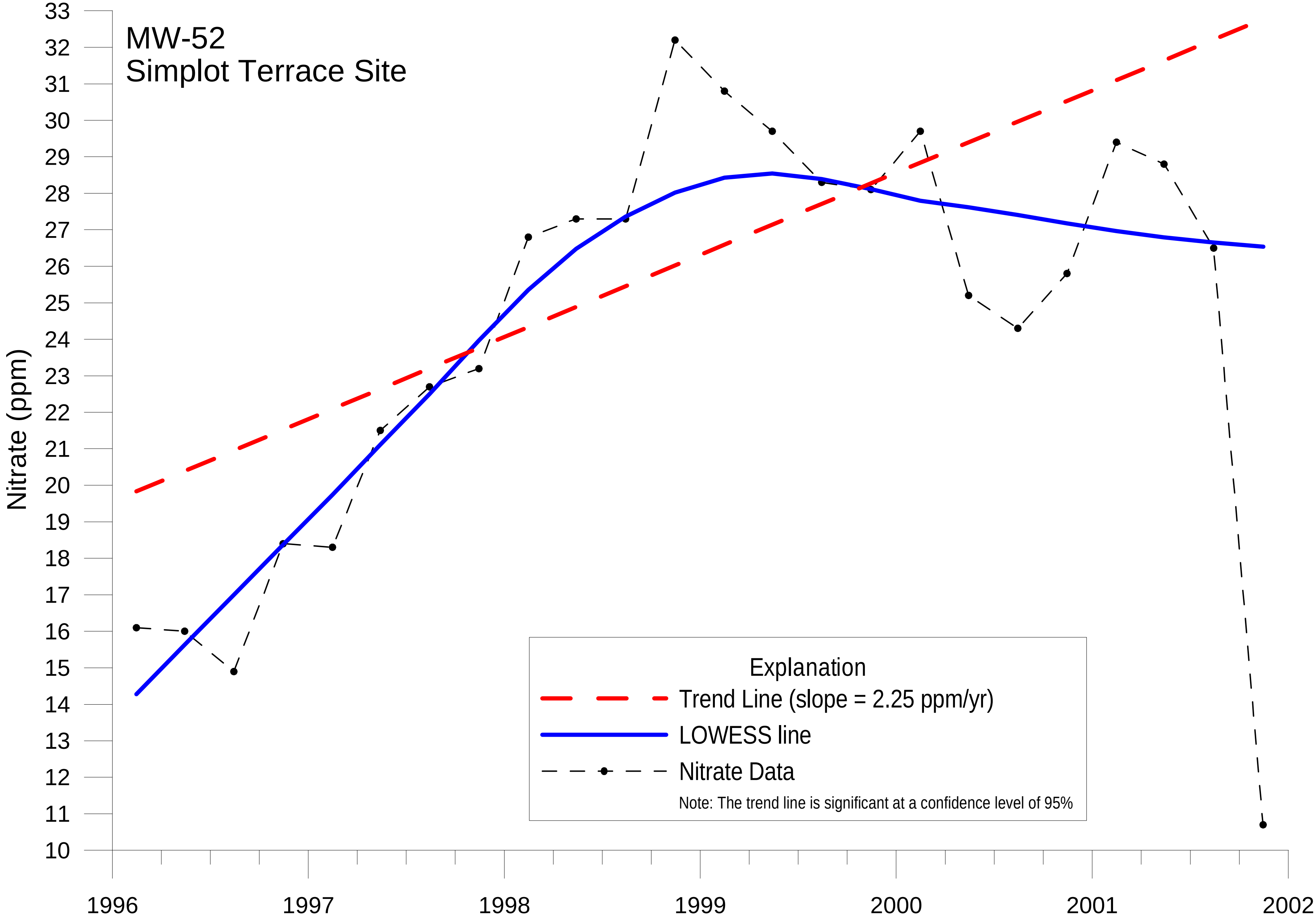
MW-38
Simplot Terrace Site
Nitrate (ppm)
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.95 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

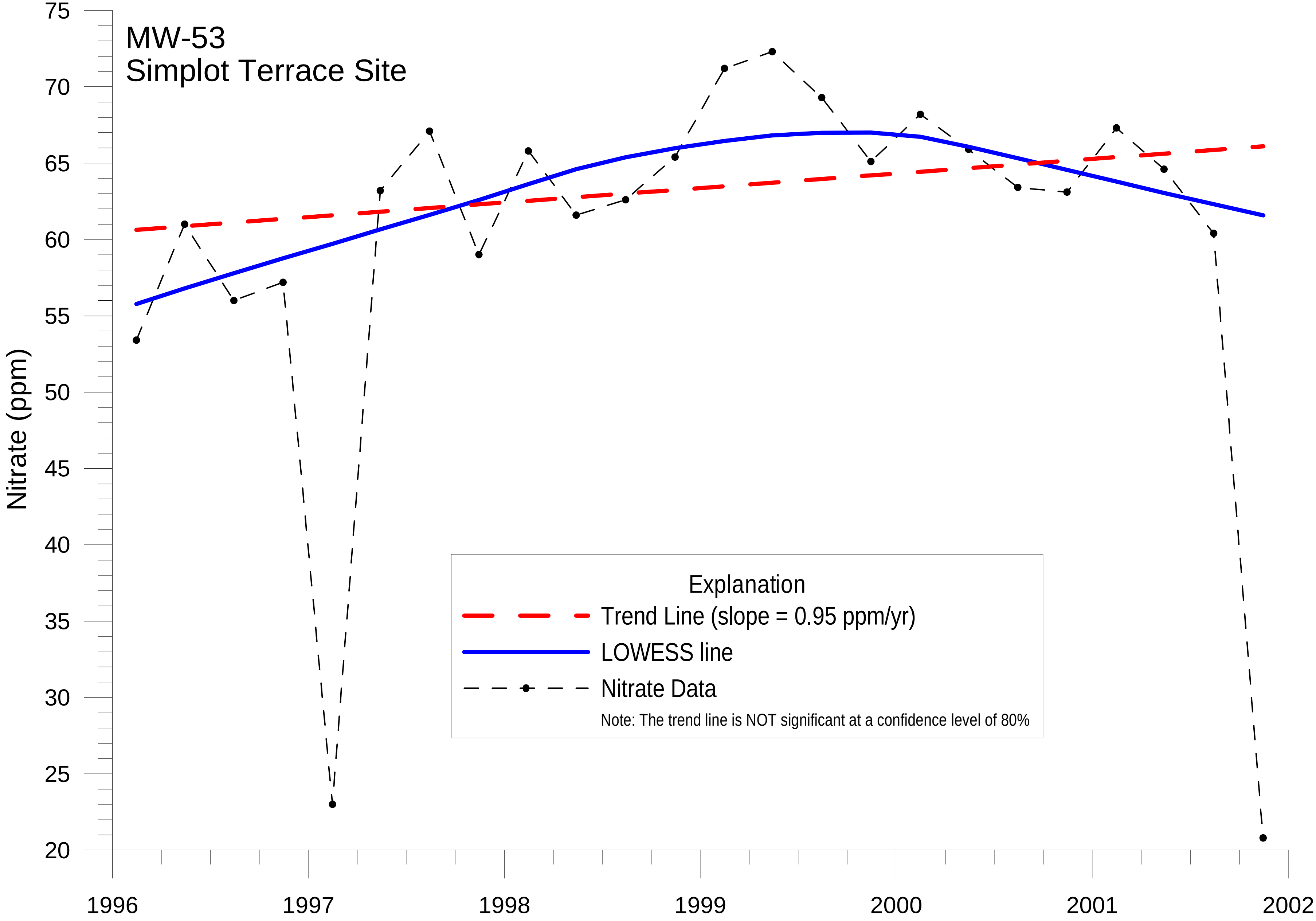

MW-39
Simplot Terrace Site
Nitrate (ppm)
40
35
30
25
20
15
10
5
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 1.80 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

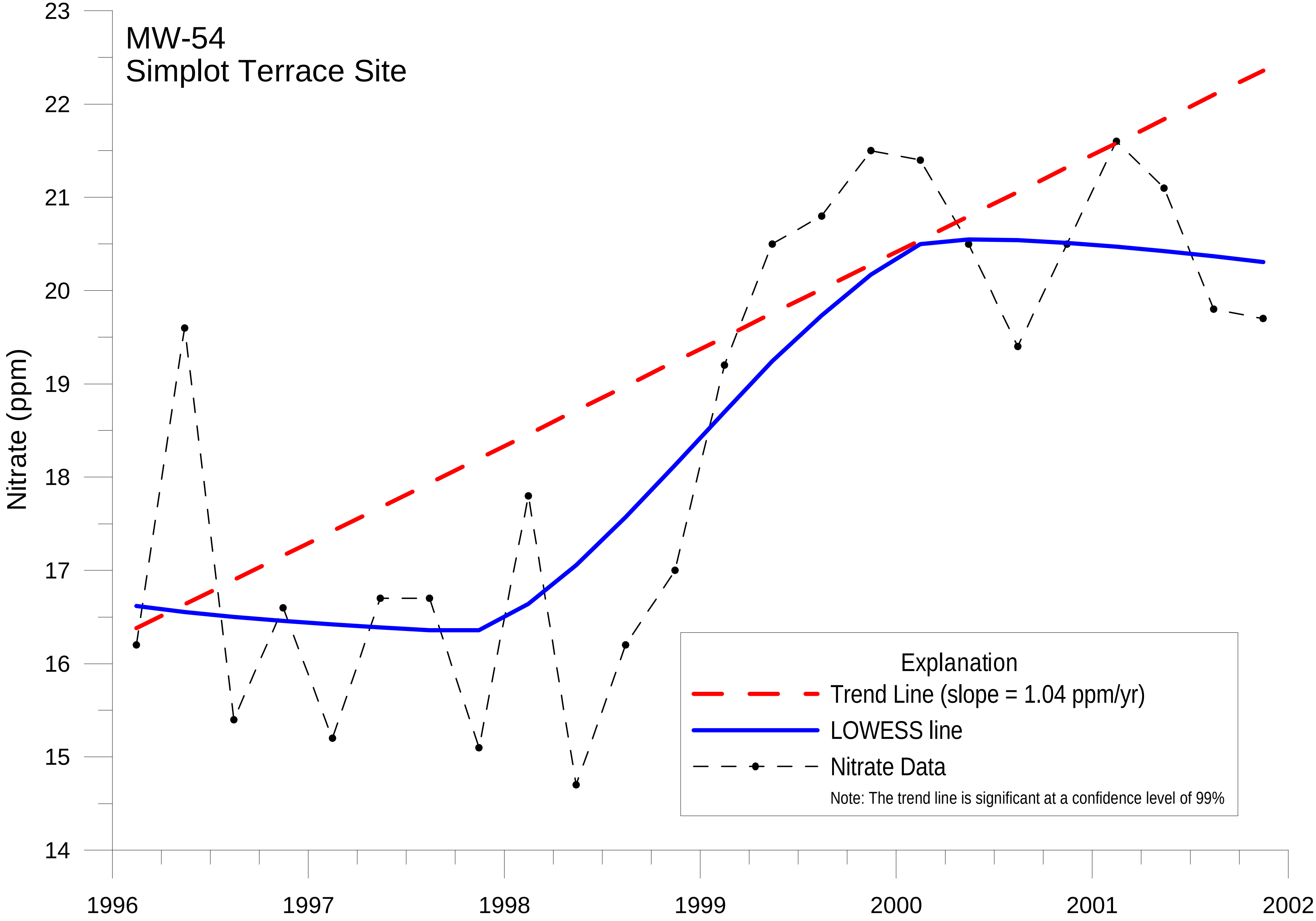

MW-40
Simplot Terrace Site
Nitrate (ppm)
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 1.37 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

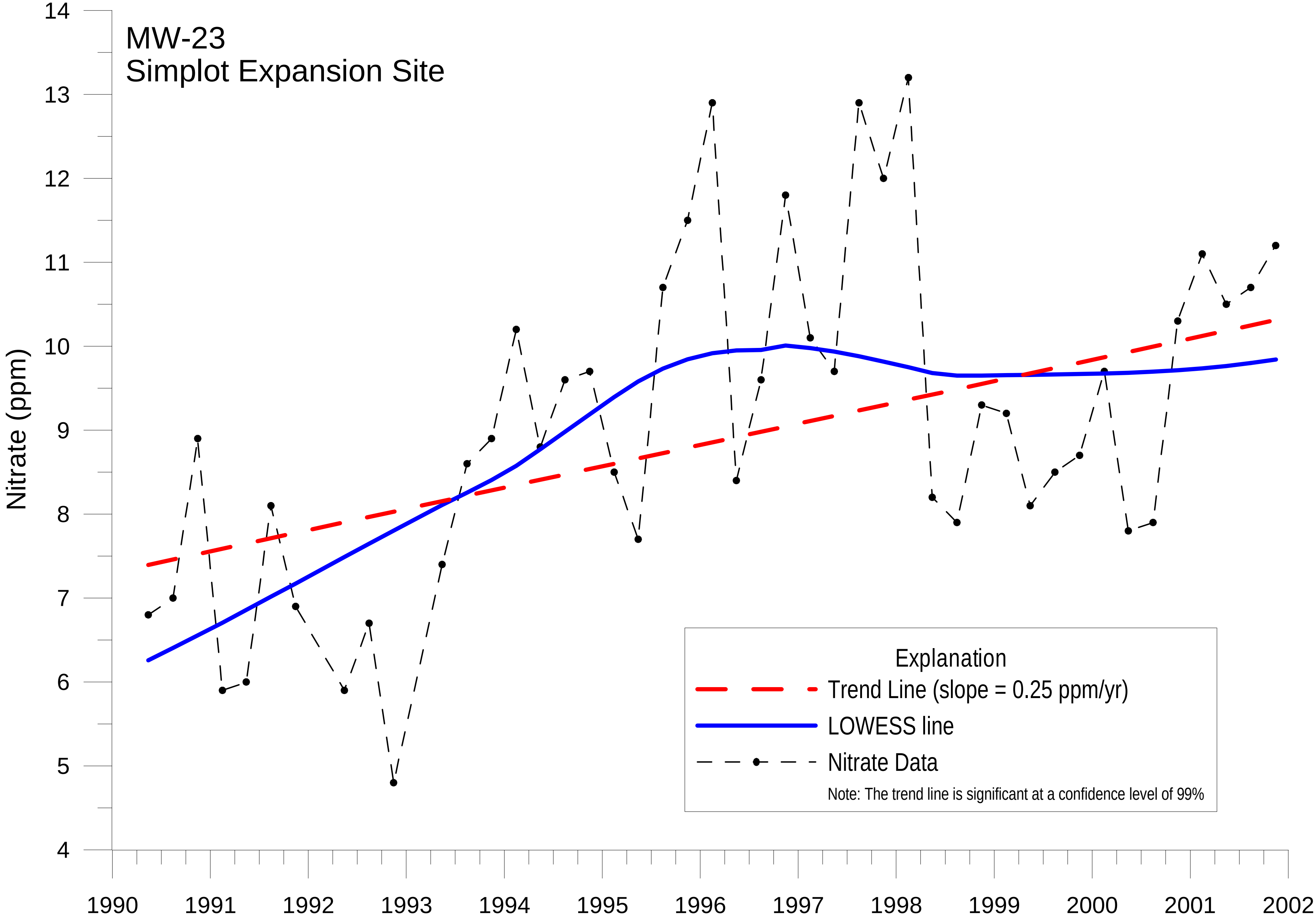


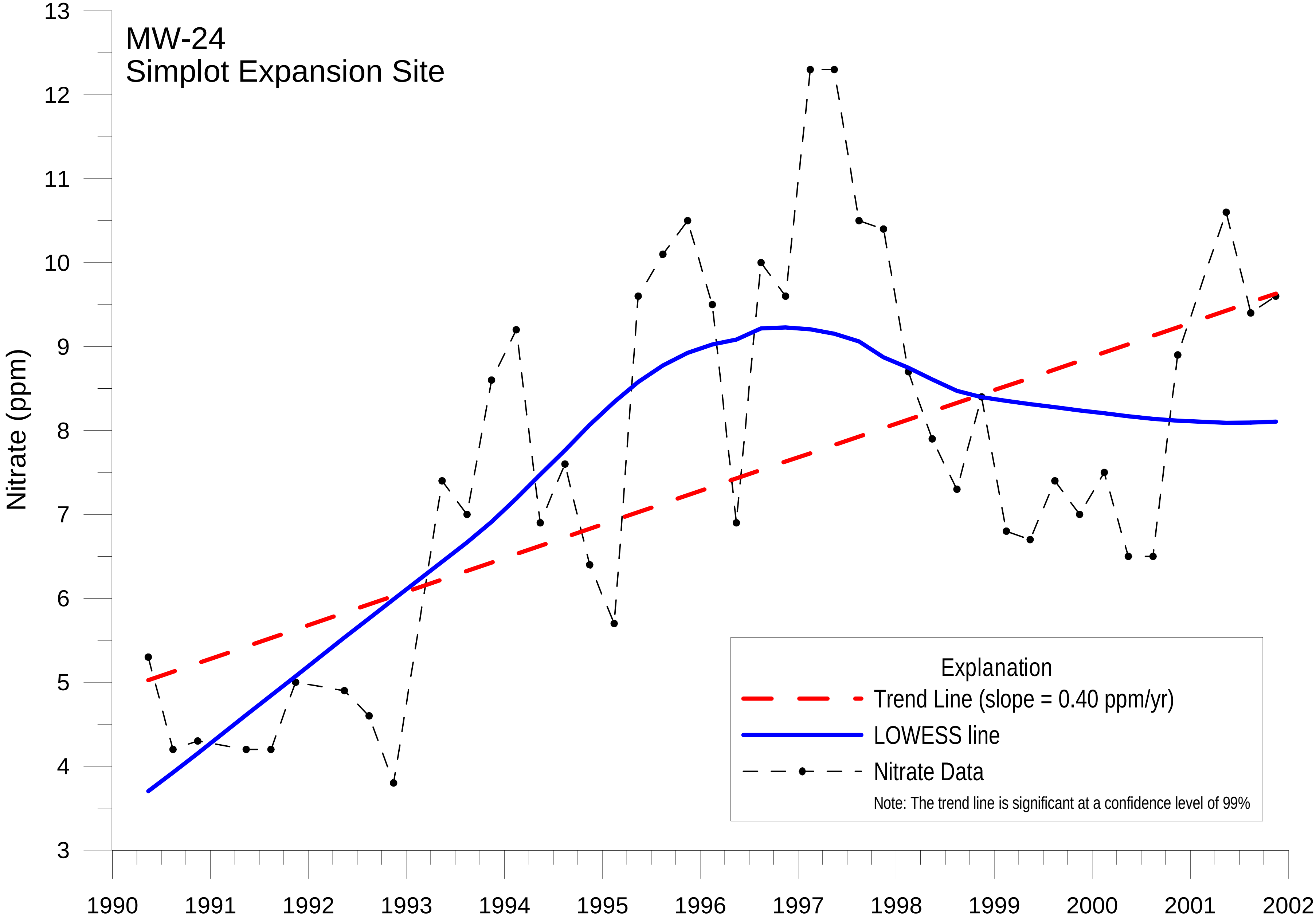
MW-51
Simplot Terrace Site
Nitrate (ppm)
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 1.68 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%


MW-52
Simplot Terrace Site
Nitrate (ppm)
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 2.25 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 95%

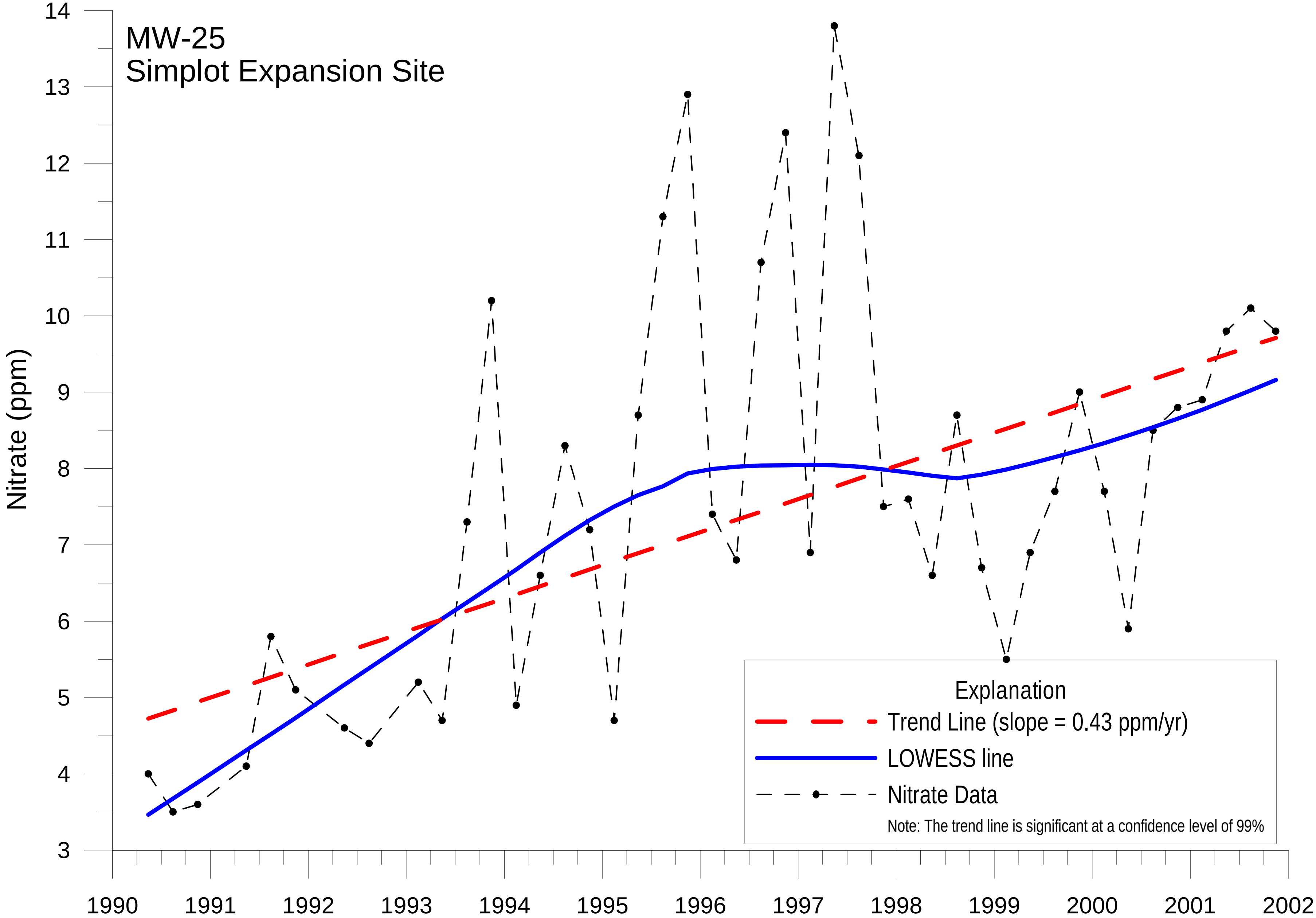

MW-53
Simplot Terrace Site
Nitrate (ppm)
75
70
65
60
55
50
45
40
35
30
25
20
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.95 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%


MW-54
Simplot Terrace Site
Nitrate (ppm)
23
22
21
20
19
18
17
16
15
14
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 1.04 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

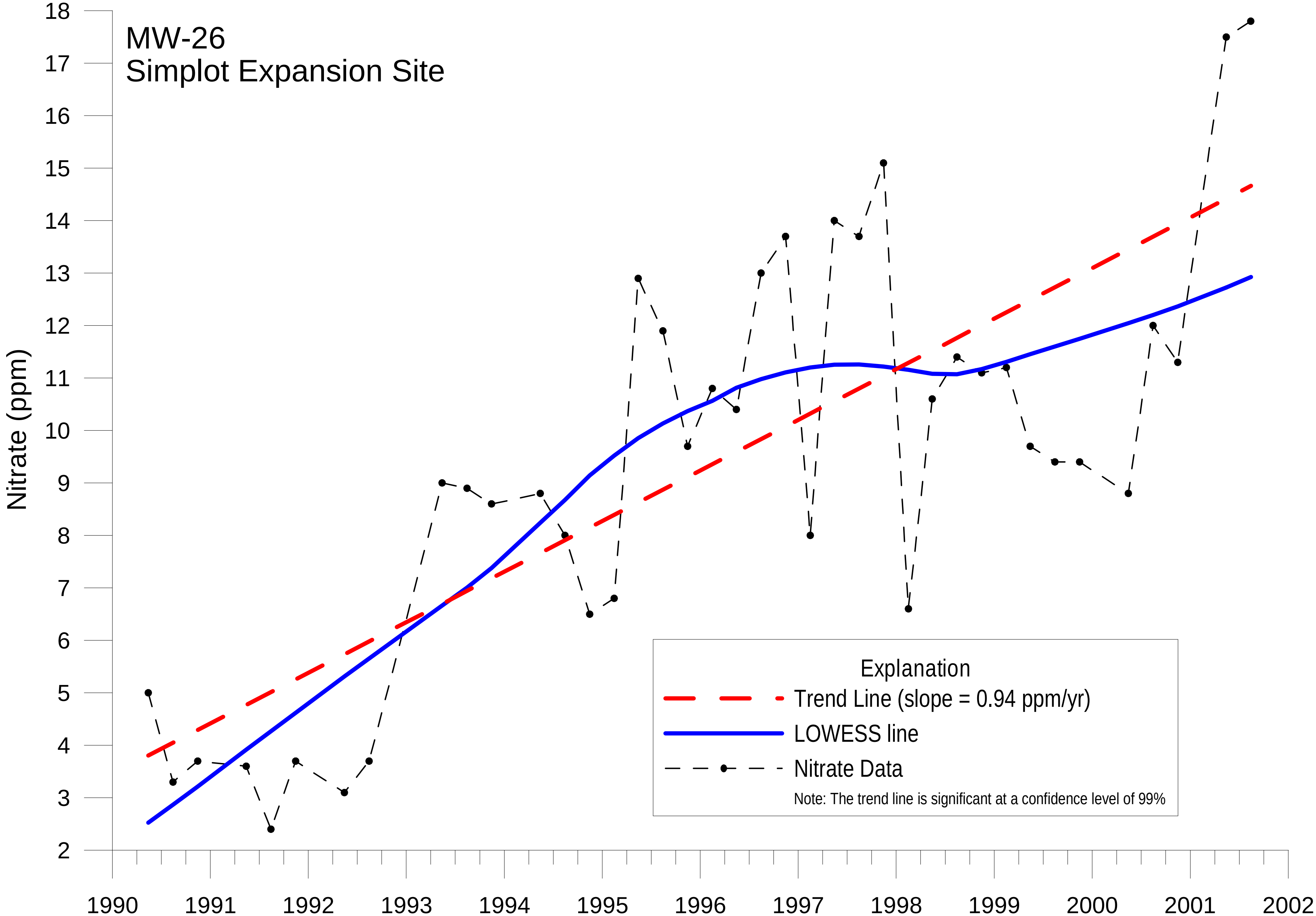

MW-23
Simplot Expansion Site
Nitrate (ppm)
14
13
12
11
10
9
8
7
6
5
4
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.25 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

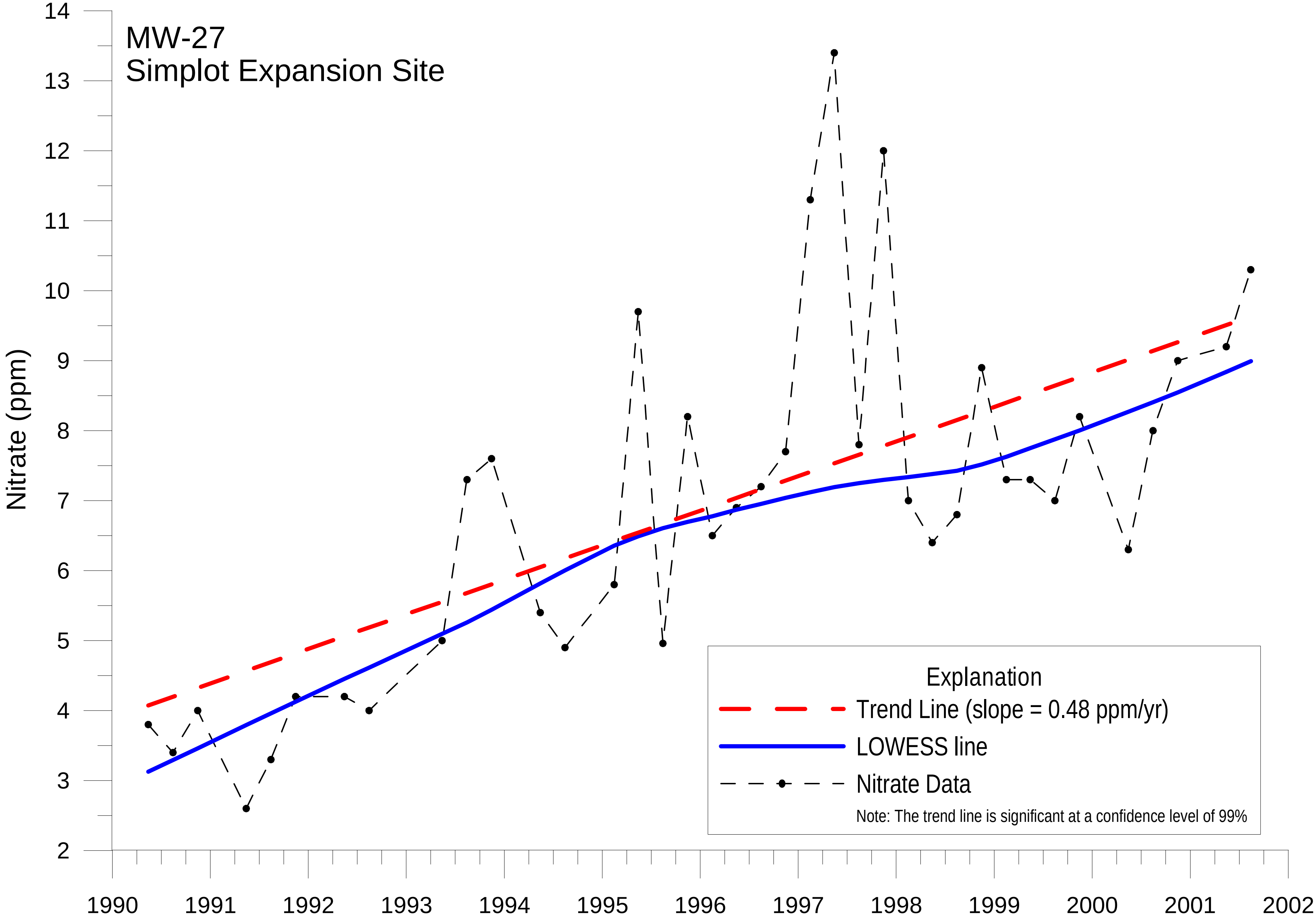


MW-24
Simplot Expansion Site
Nitrate (ppm)
13
12
11
10
9
8
7
6
5
4
3
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.40 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

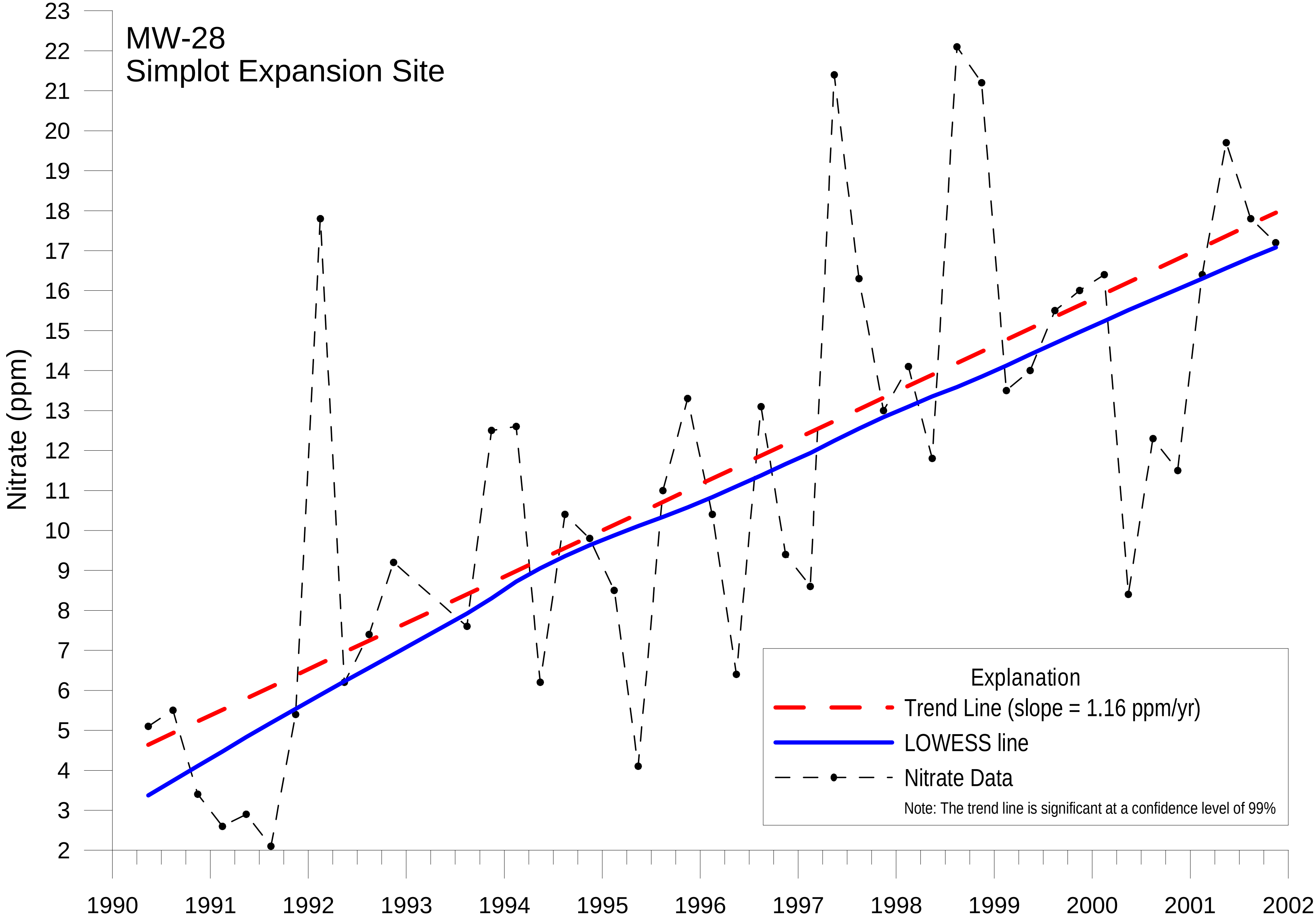


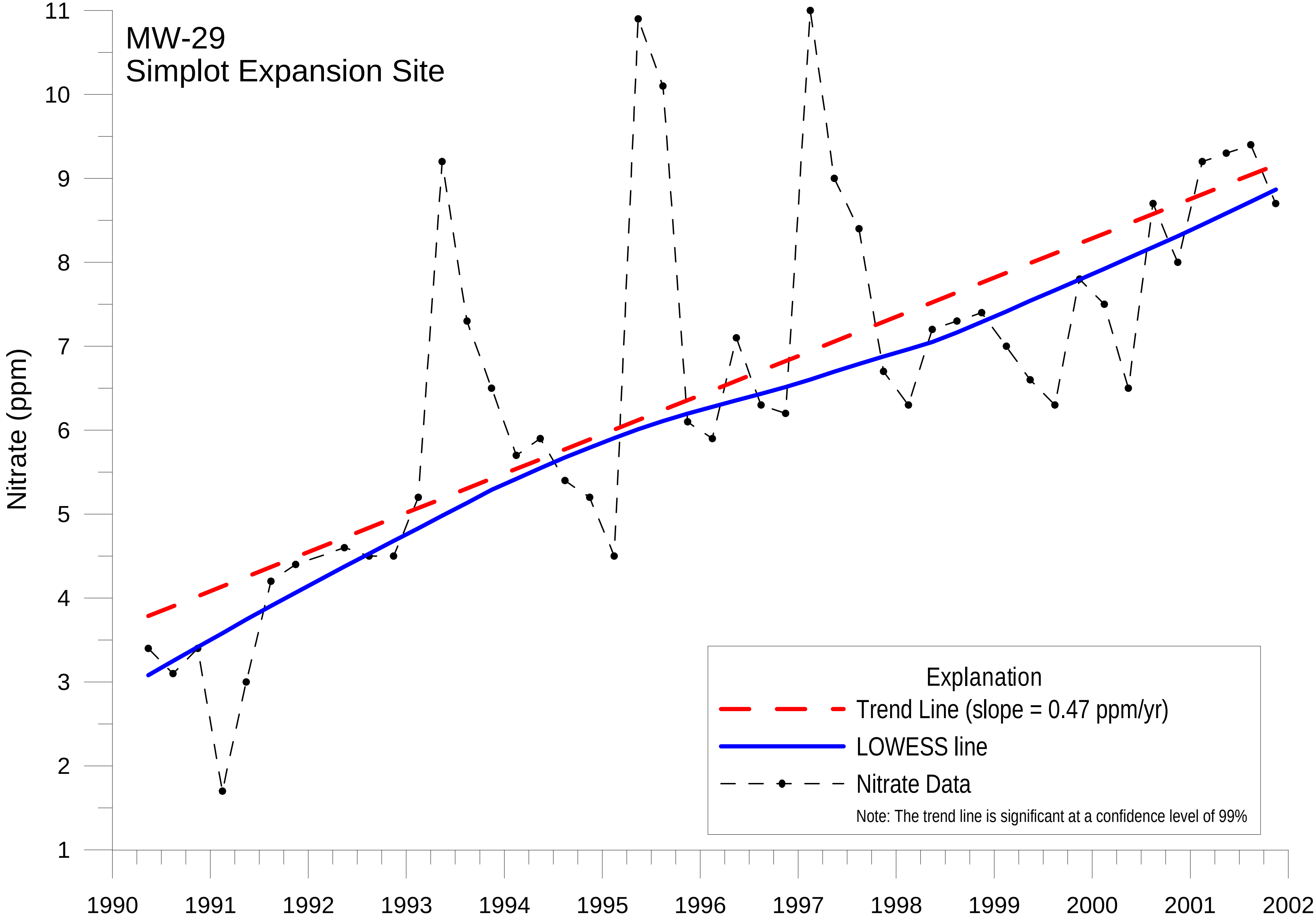
MW-25
Simplot Expansion Site
Nitrate (ppm)
14
13
12
11
10
9
8
7
6
5
4
3
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.43 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

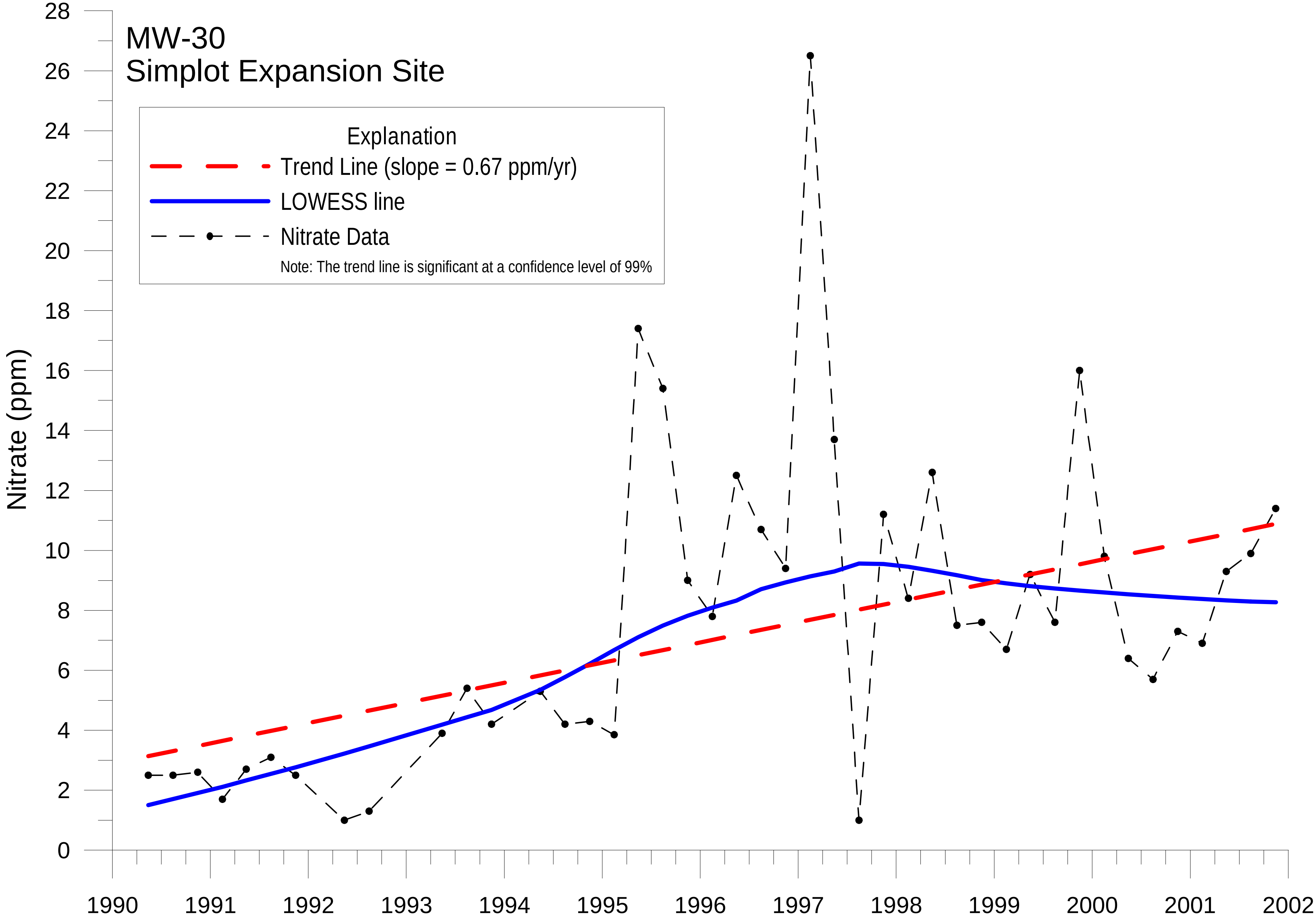

MW-26
Simplot Expansion Site
Nitrate (ppm)
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.94 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

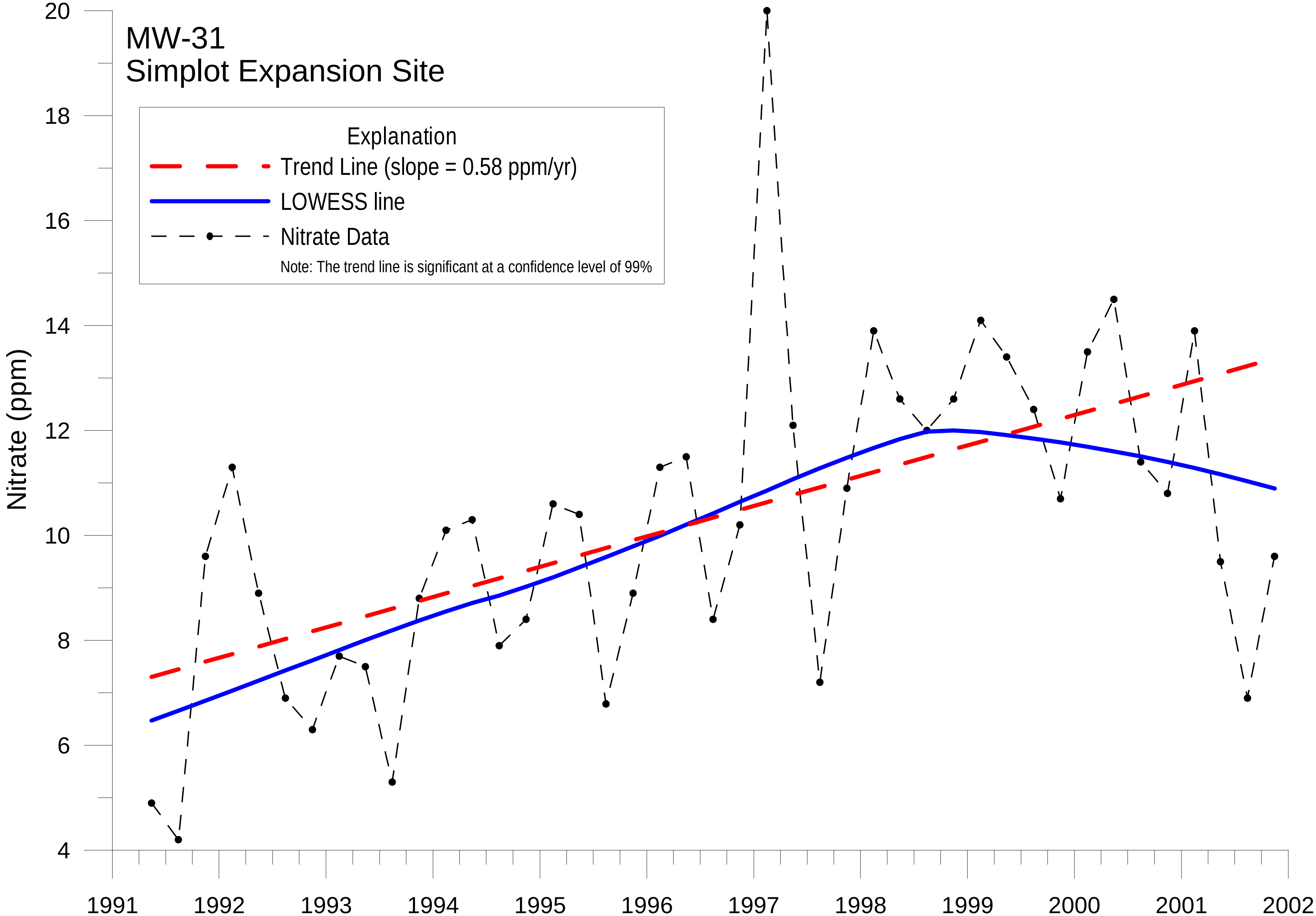


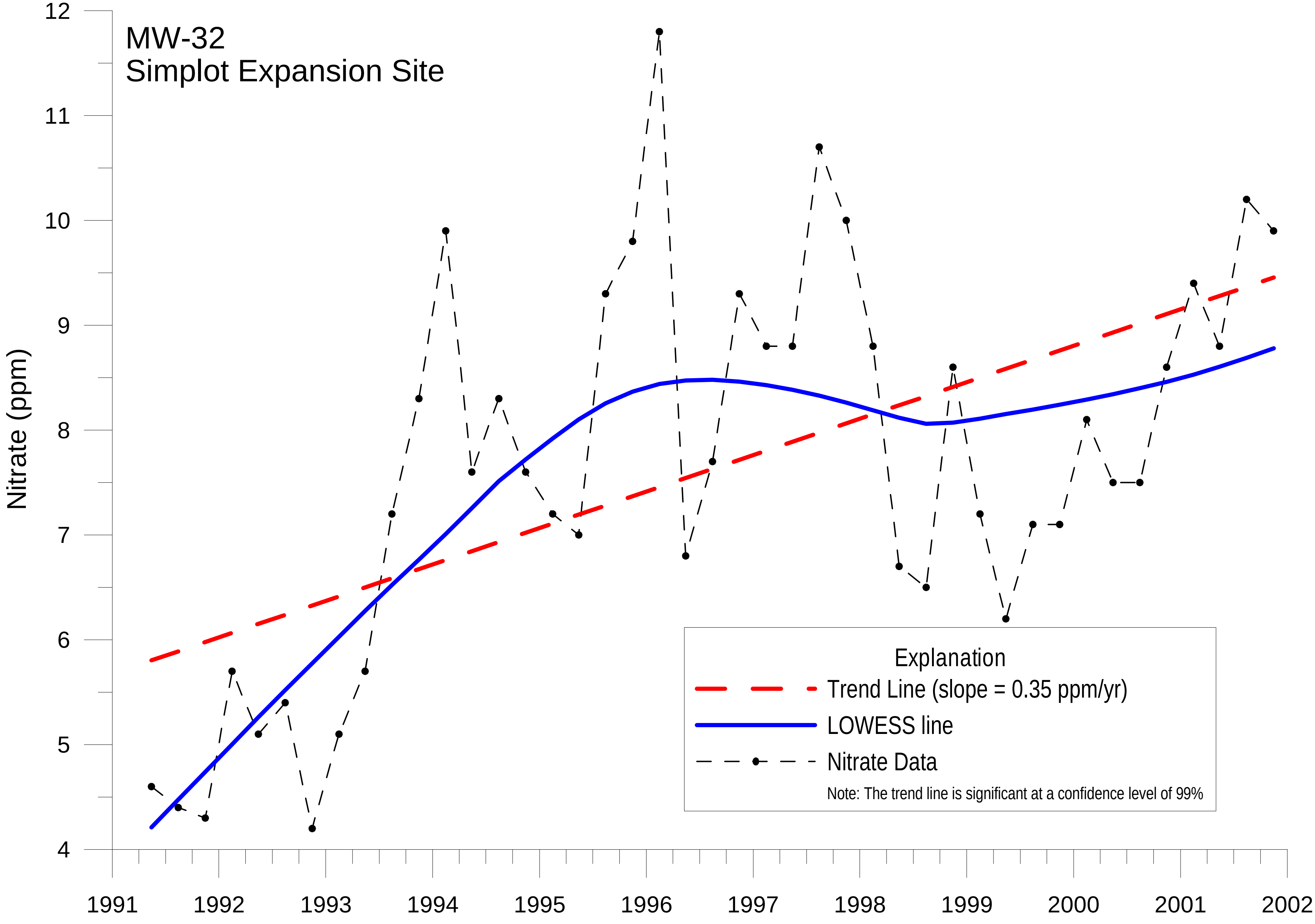
MW-27
Simplot Expansion Site
Nitrate (ppm)
14
13
12
11
10
9
8
7
6
5
4
3
2
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.48 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

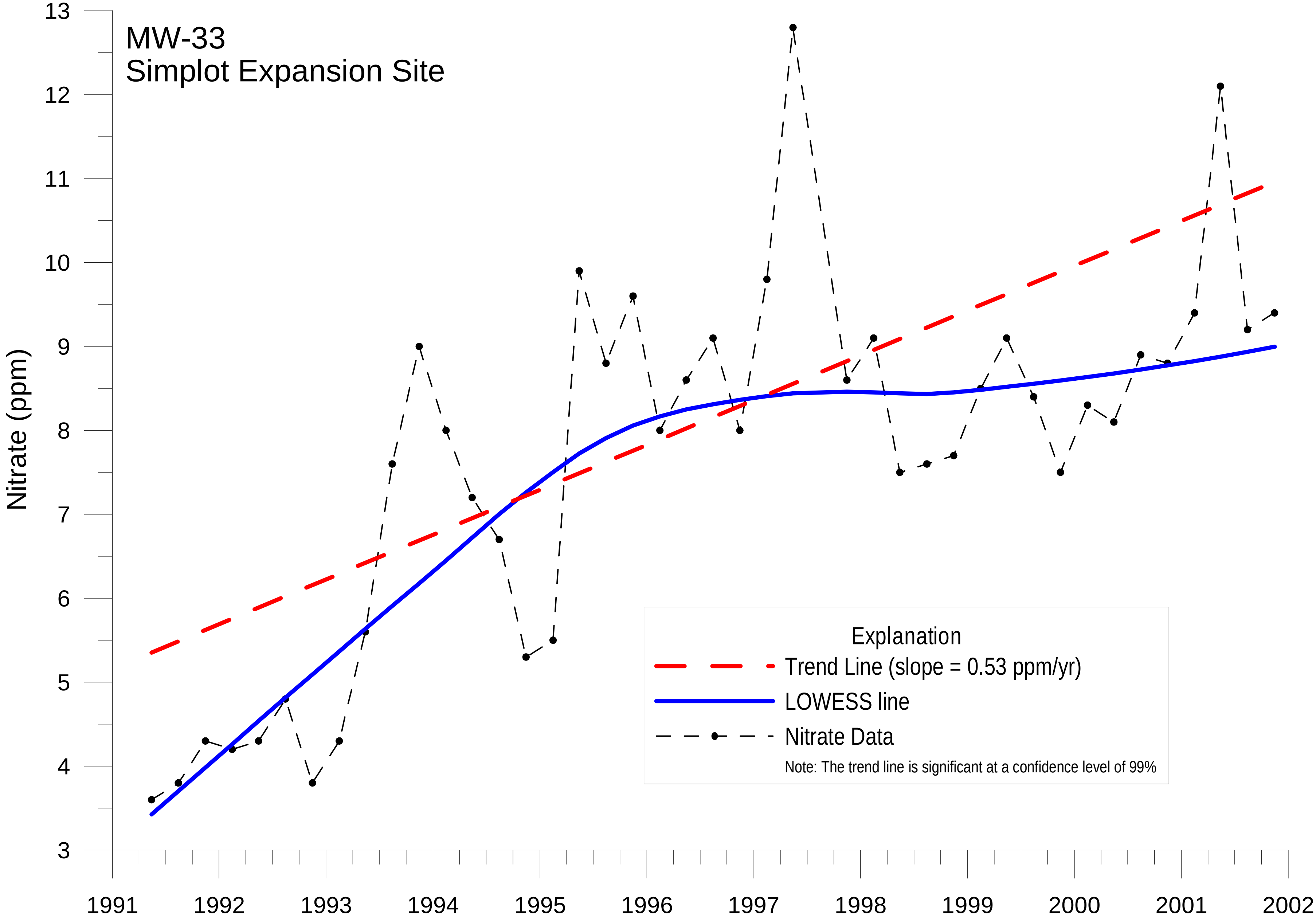

MW-28
Simplot Expansion Site
Nitrate (ppm)
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 1.16 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

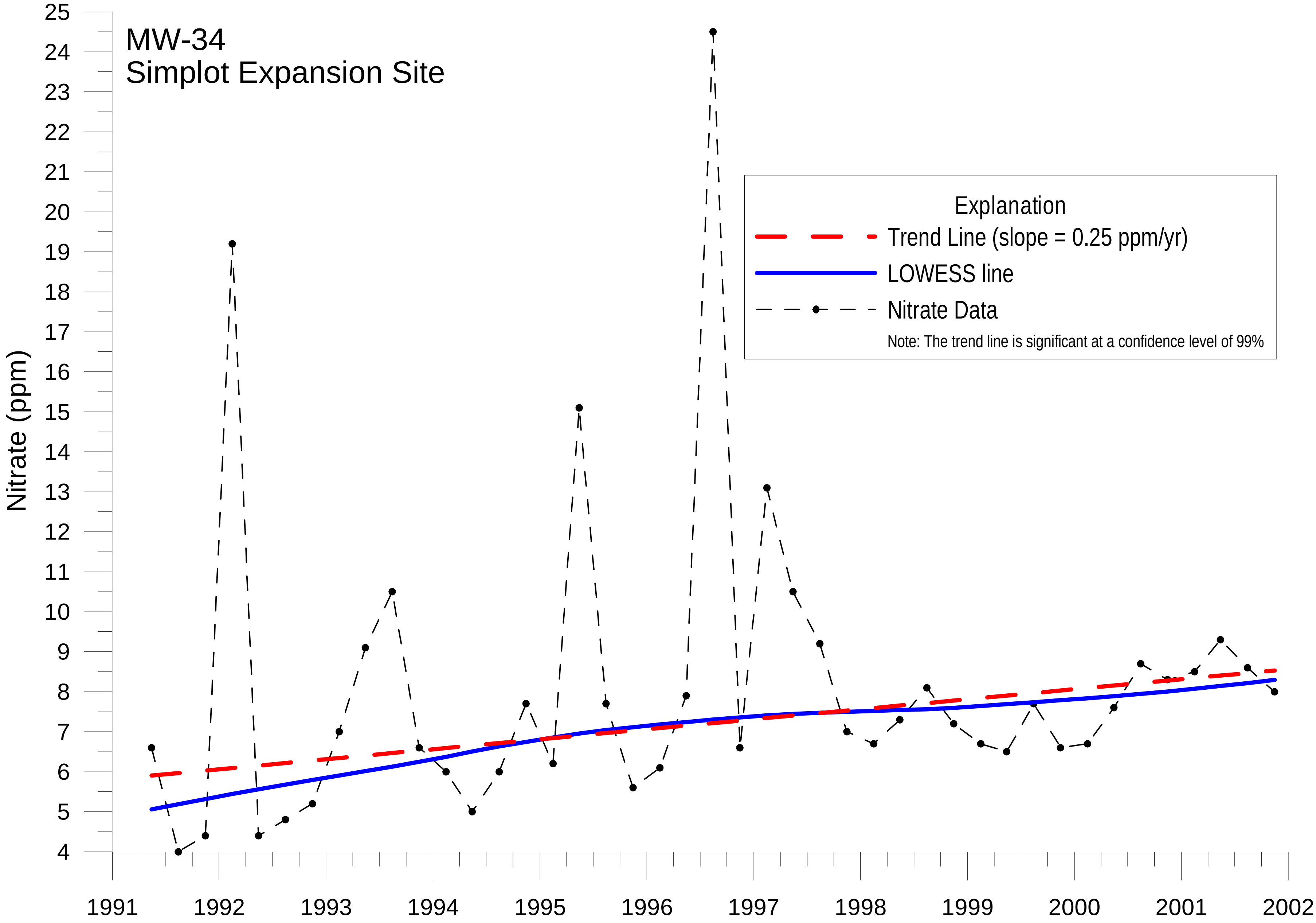

MW-29
Simplot Expansion Site
Nitrate (ppm)
11
10
9
8
7
6
5
4
3
2
1
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.47 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

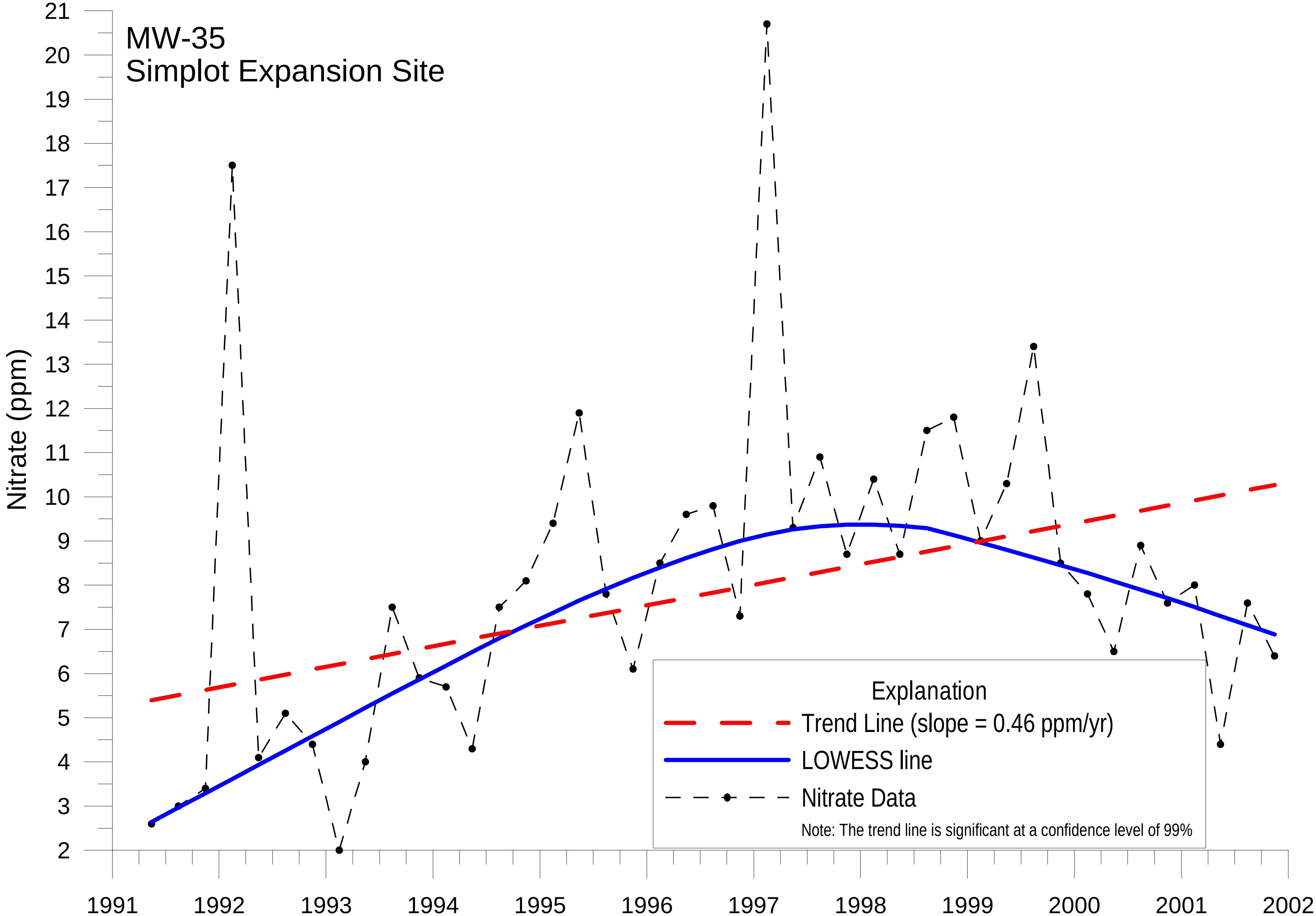

MW-30
Simplot Expansion Site
Explanation
Trend Line (slope = 0.67 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%
Nitrate (ppm)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002

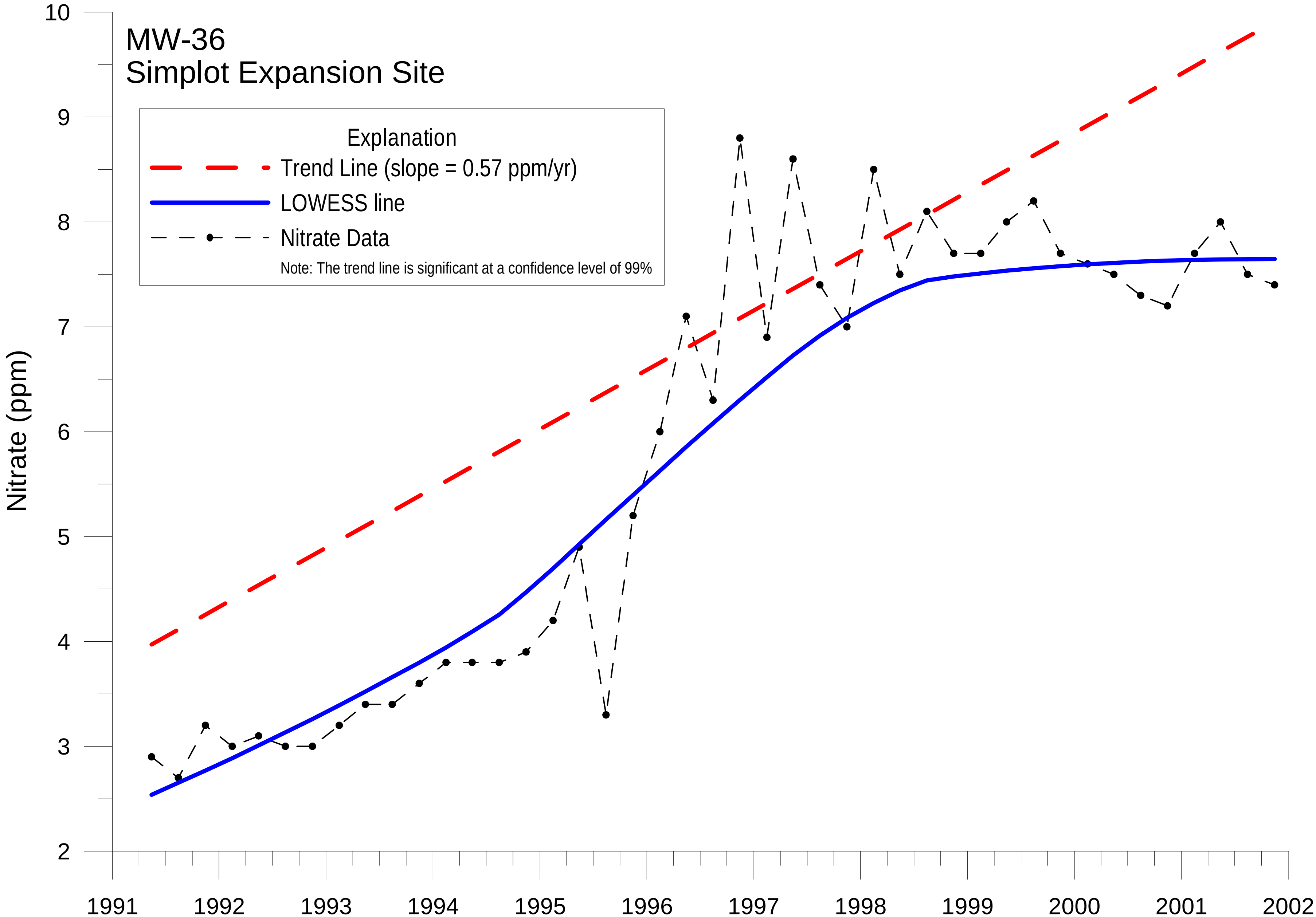

MW-31
Simplot Expansion Site
Explanation
Trend Line (slope = 0.58 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%
Nitrate (ppm)
4
6
8
10
12
14
16
18
20
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002


MW-32
Simplot Expansion Site
Nitrate (ppm)
12
11
10
9
8
7
6
5
4
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.35 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

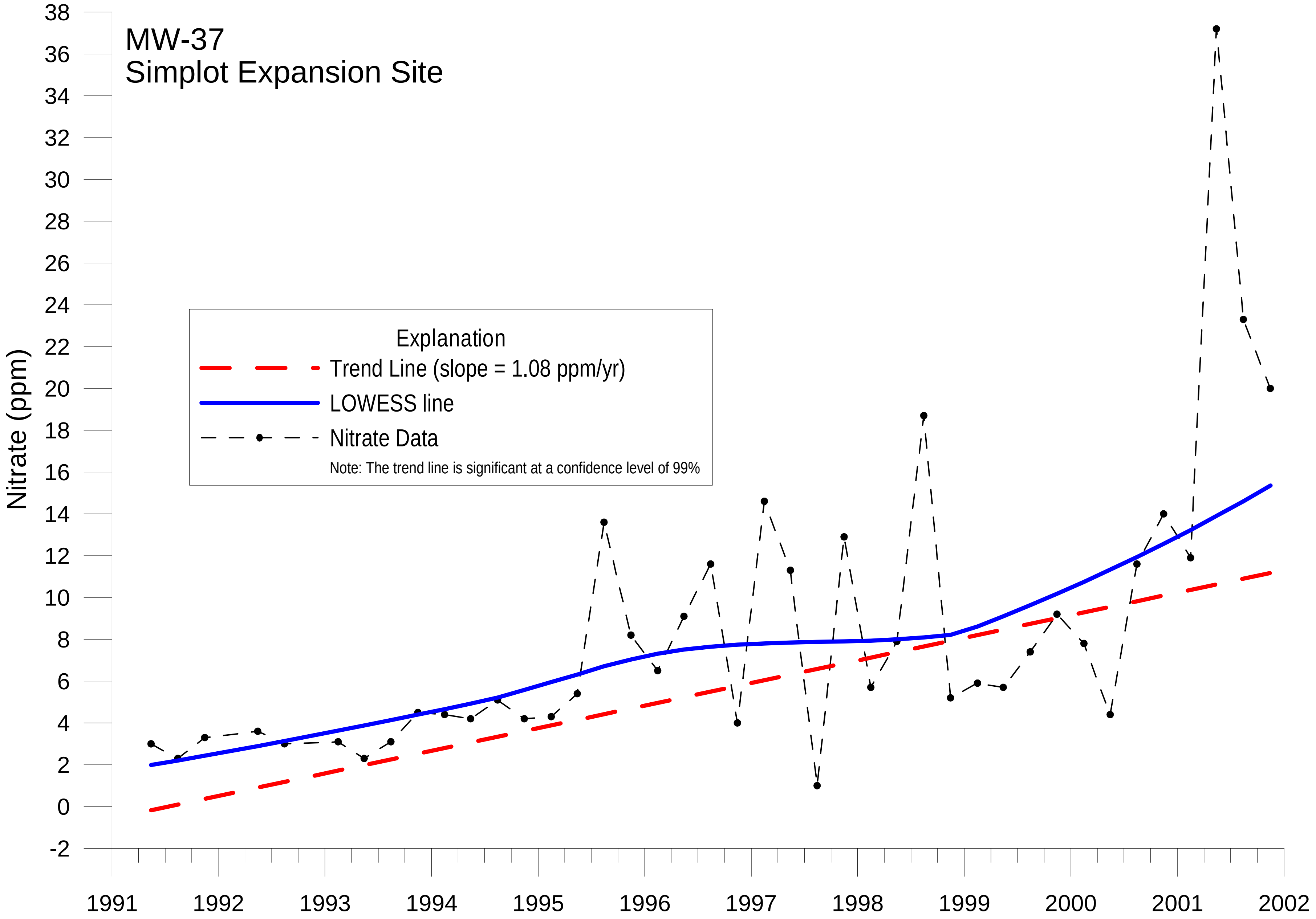

MW-33
Simplot Expansion Site
Nitrate (ppm)
13
12
11
10
9
8
7
6
5
4
3
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.53 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%


MW-34
Simplot Expansion Site
Nitrate (ppm)
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.25 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

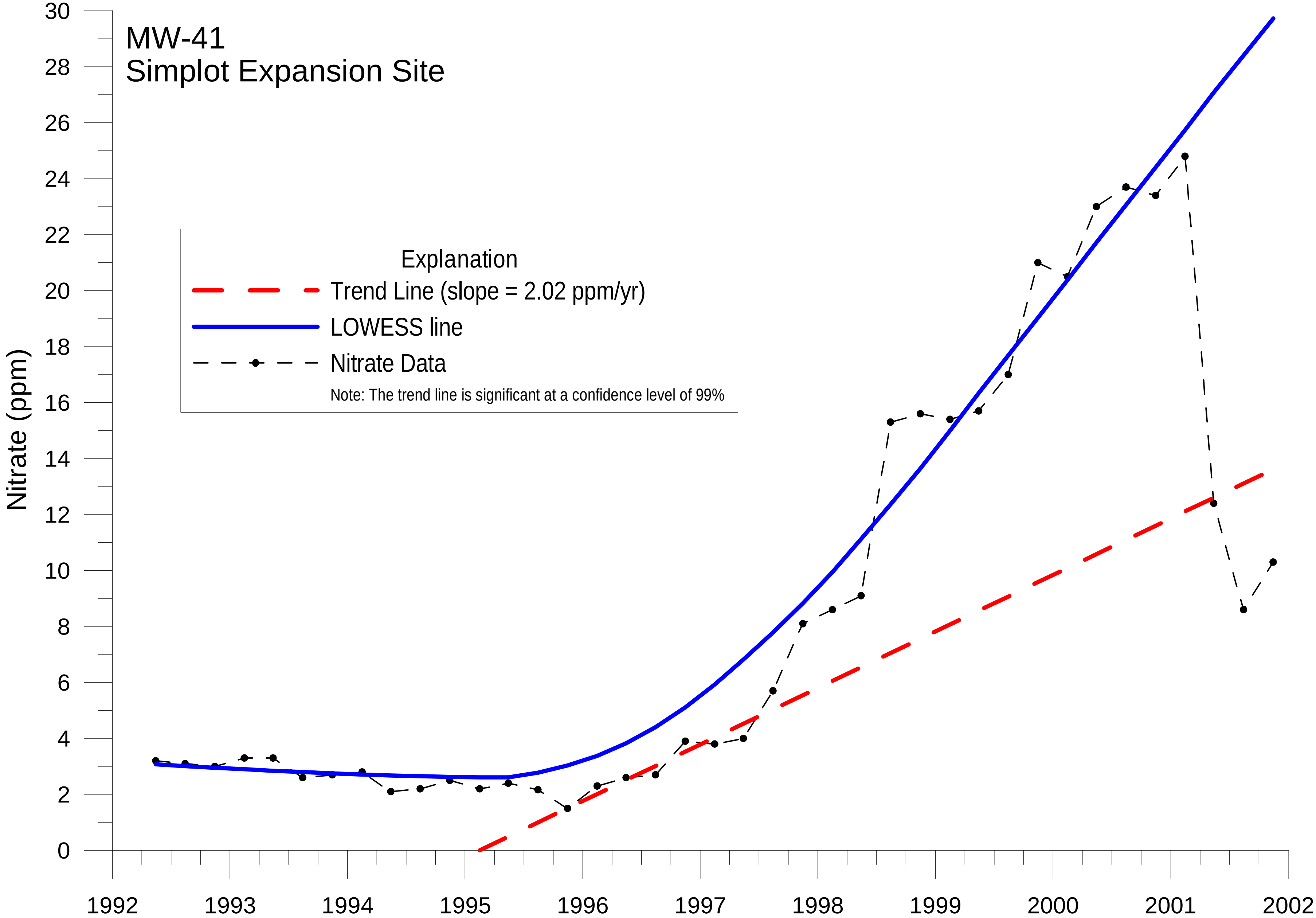

MW-35
Simplot Expansion Site
Nitrate (ppm)
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.46 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

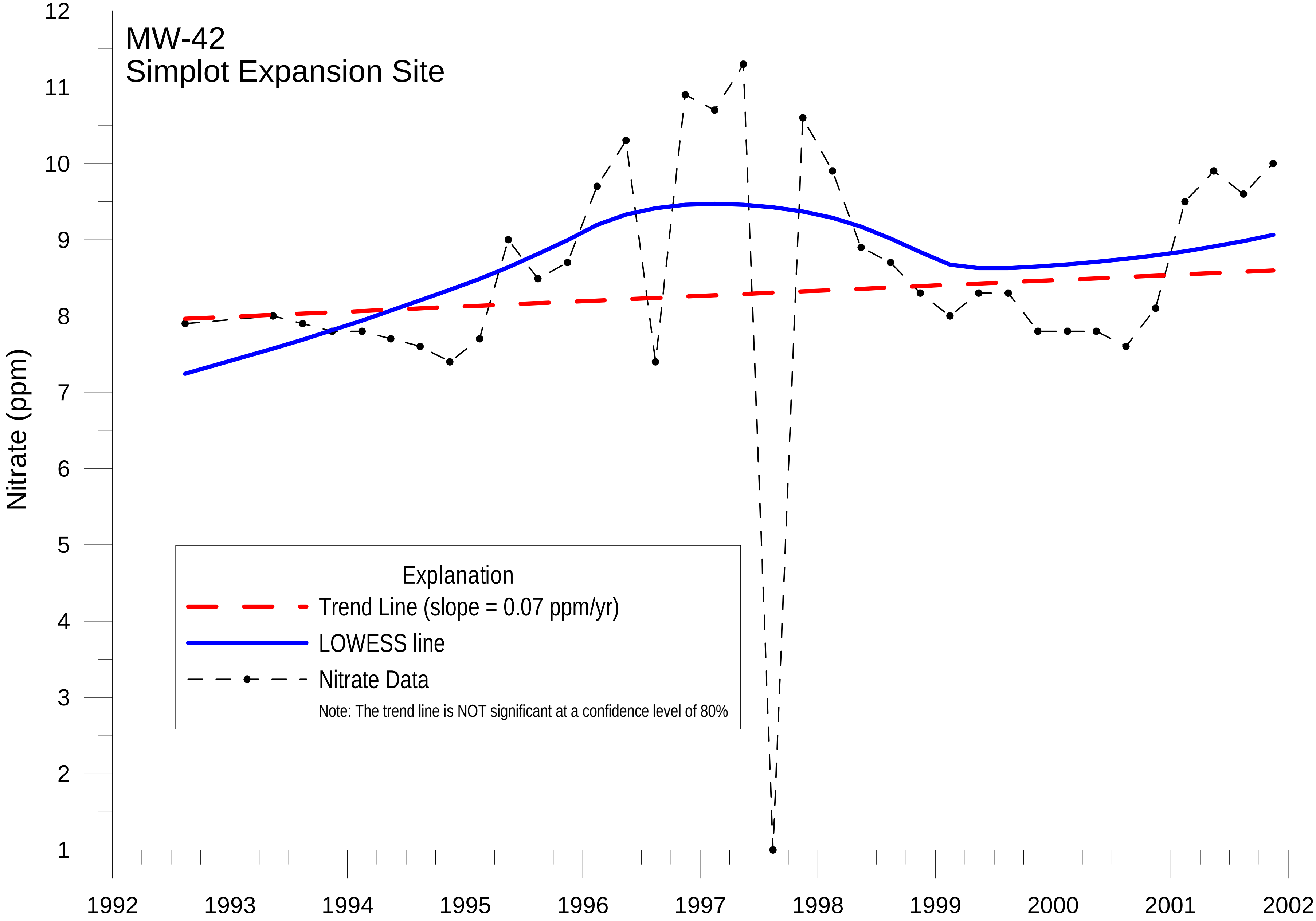


MW-36
Simplot Expansion Site
Explanation
Trend Line (slope = 0.57 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%
Nitrate (ppm)
10
9
8
7
6
5
4
3
2
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002

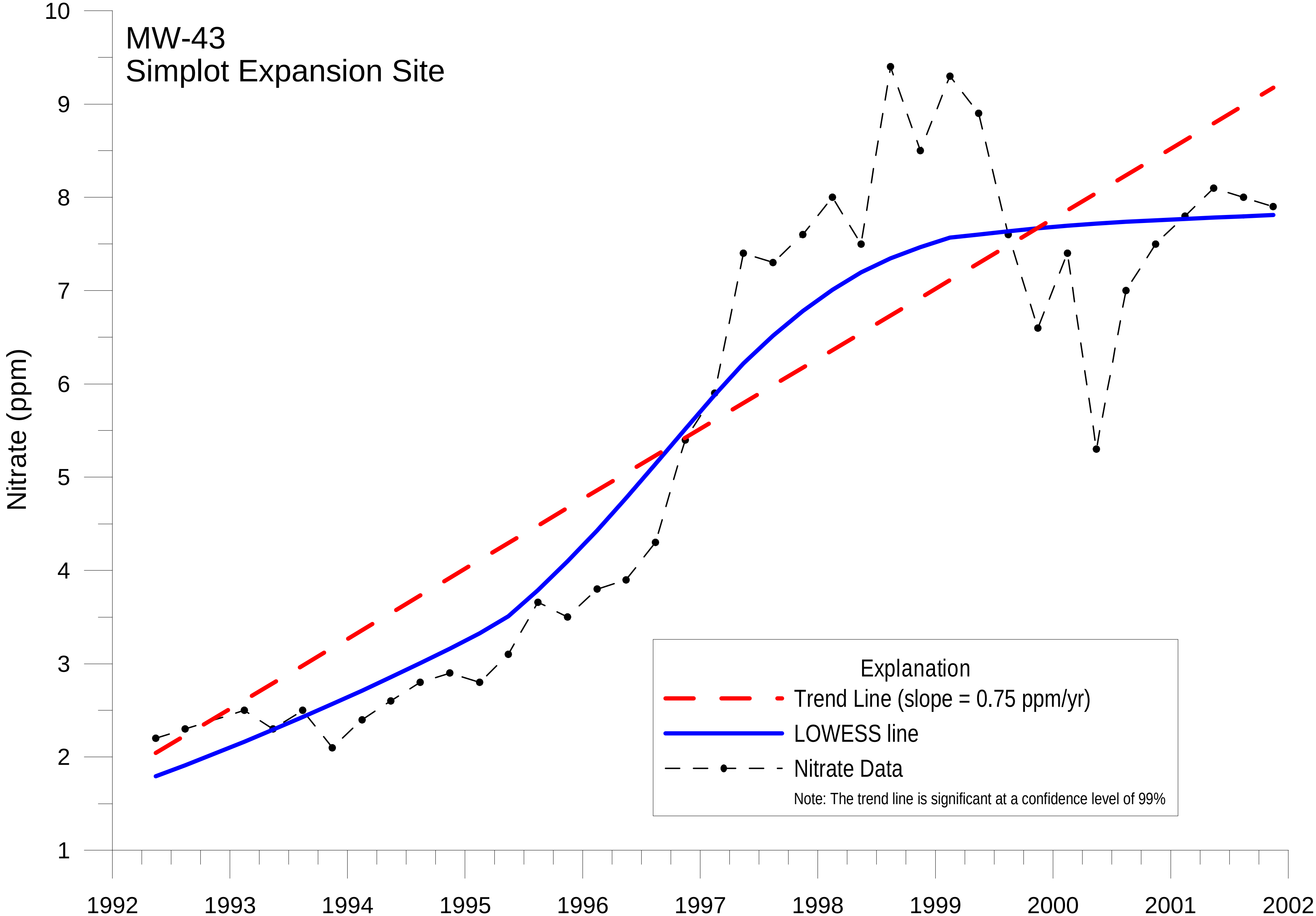


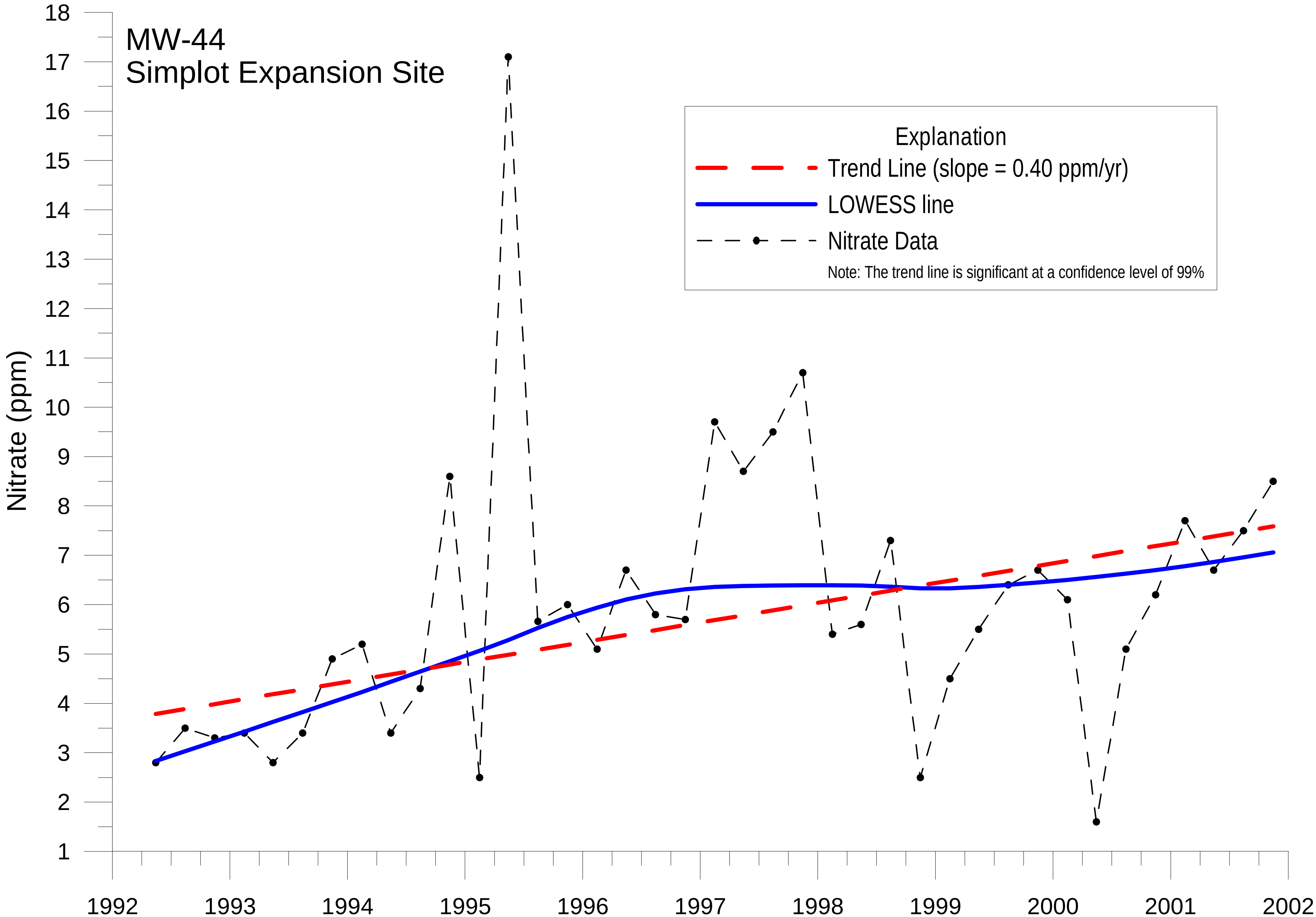
MW-37
Simplot Expansion Site
Explanation
Trend Line (slope = 1.08 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%
Nitrate (ppm)
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002


MW-41
Simplot Expansion Site
Explanation
Trend Line (slope = 2.02 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%
Nitrate (ppm)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002

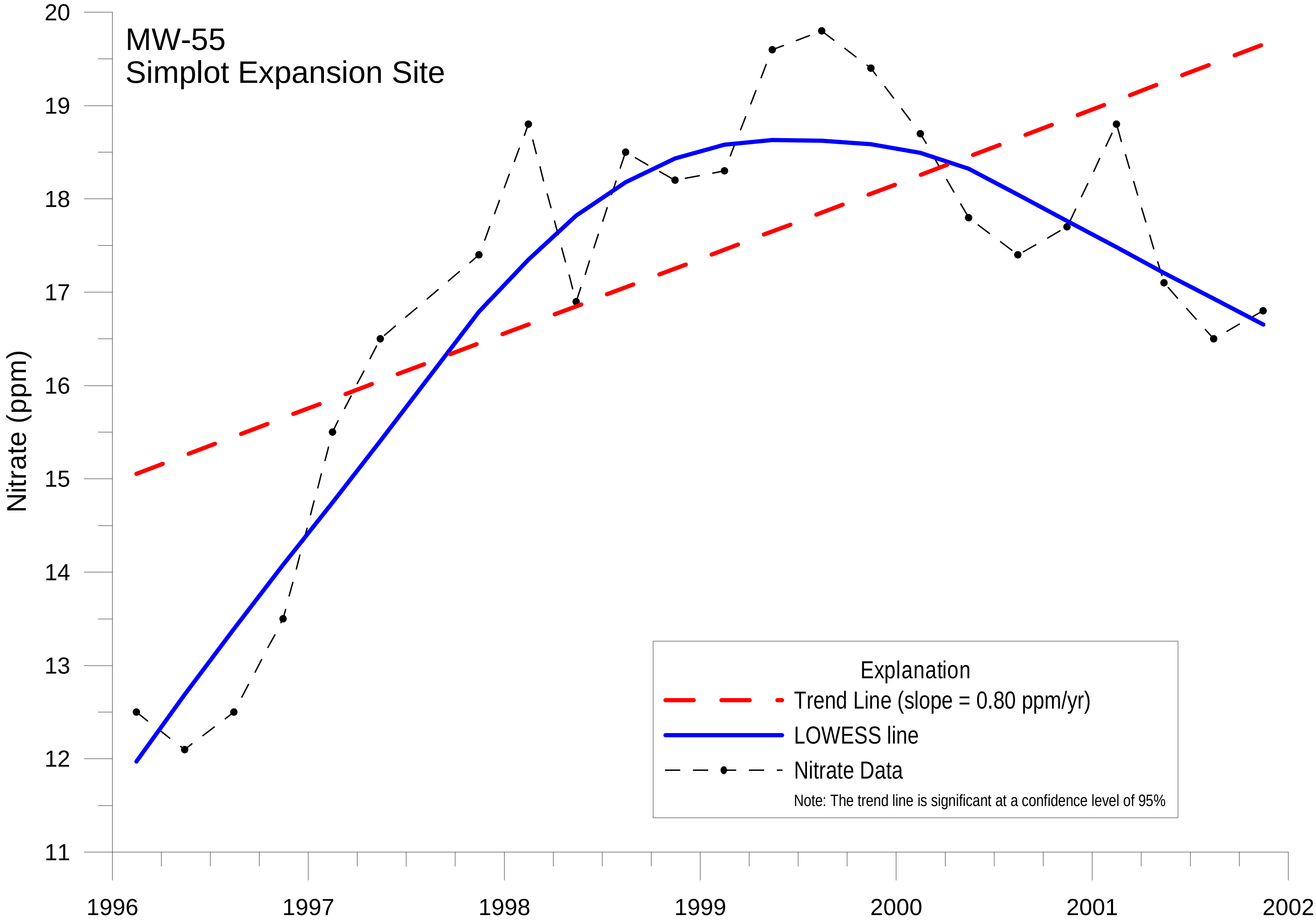


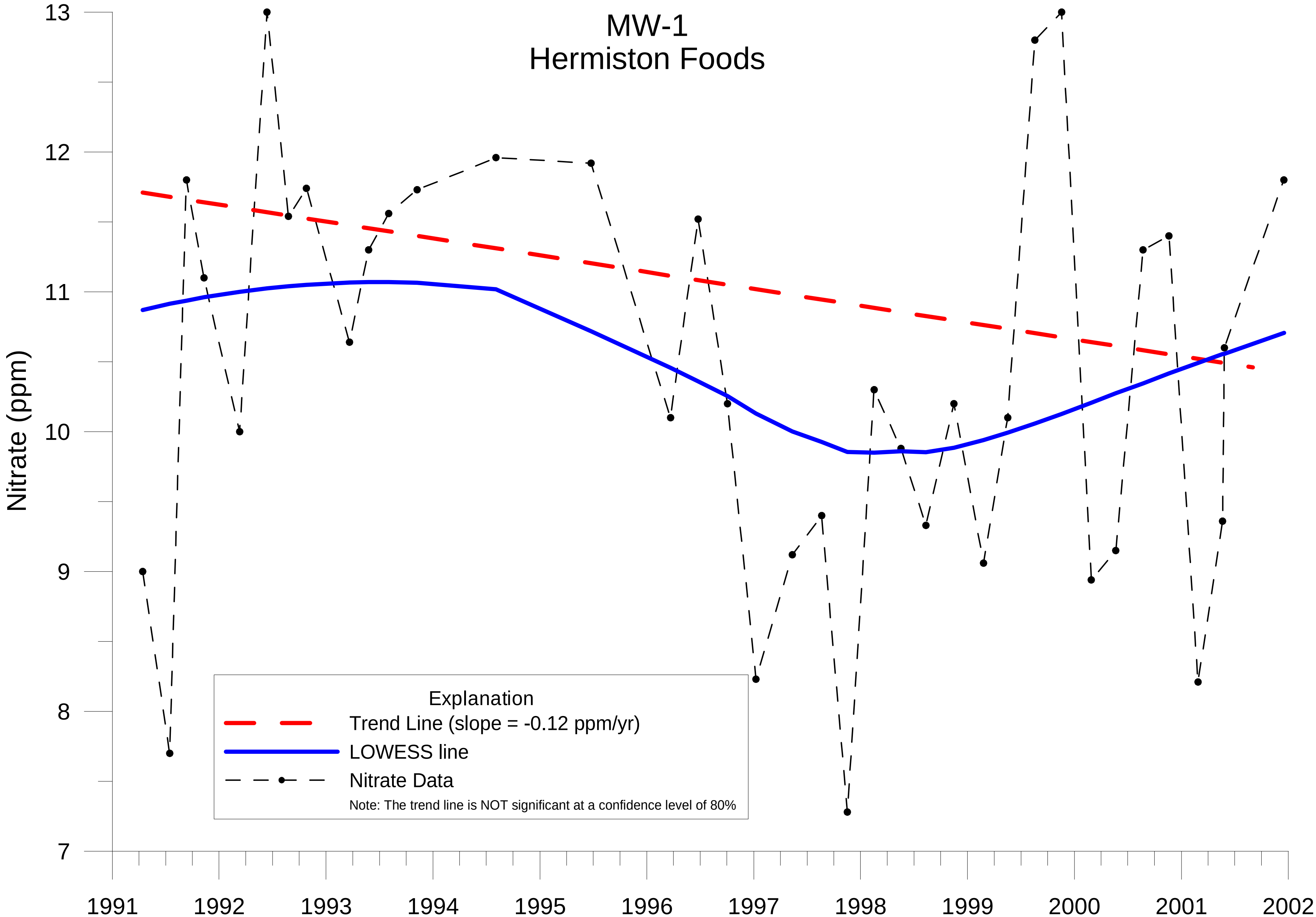
MW-42
Simplot Expansion Site
Nitrate (ppm)
12
11
10
9
8
7
6
5
4
3
2
1
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.07 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%


MW-43
Simplot Expansion Site
Nitrate (ppm)
10
9
8
7
6
5
4
3
2
1
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.75 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

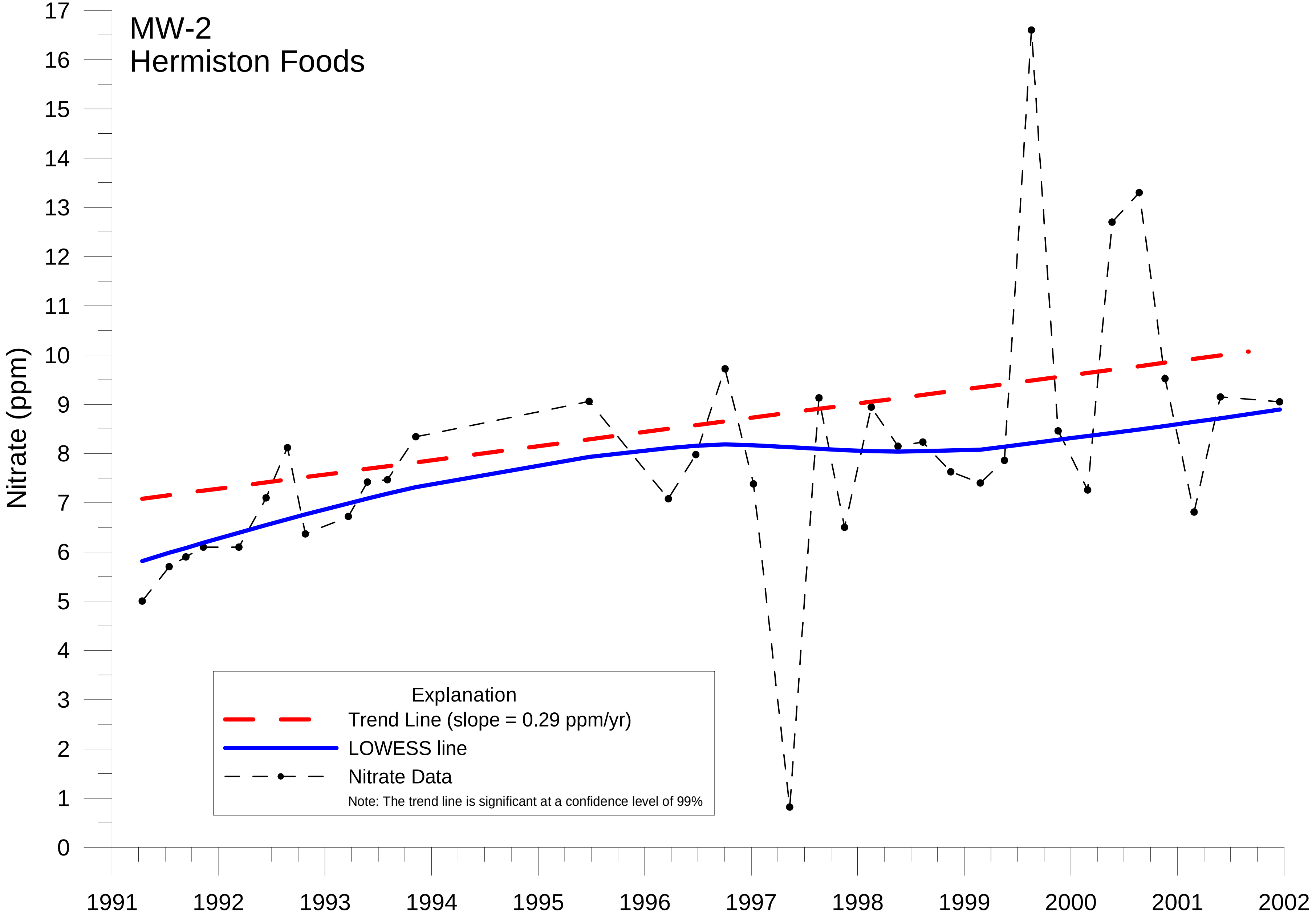


MW-44
Simplot Expansion Site
Explanation
Trend Line (slope = 0.40 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%
Nitrate (ppm)
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002

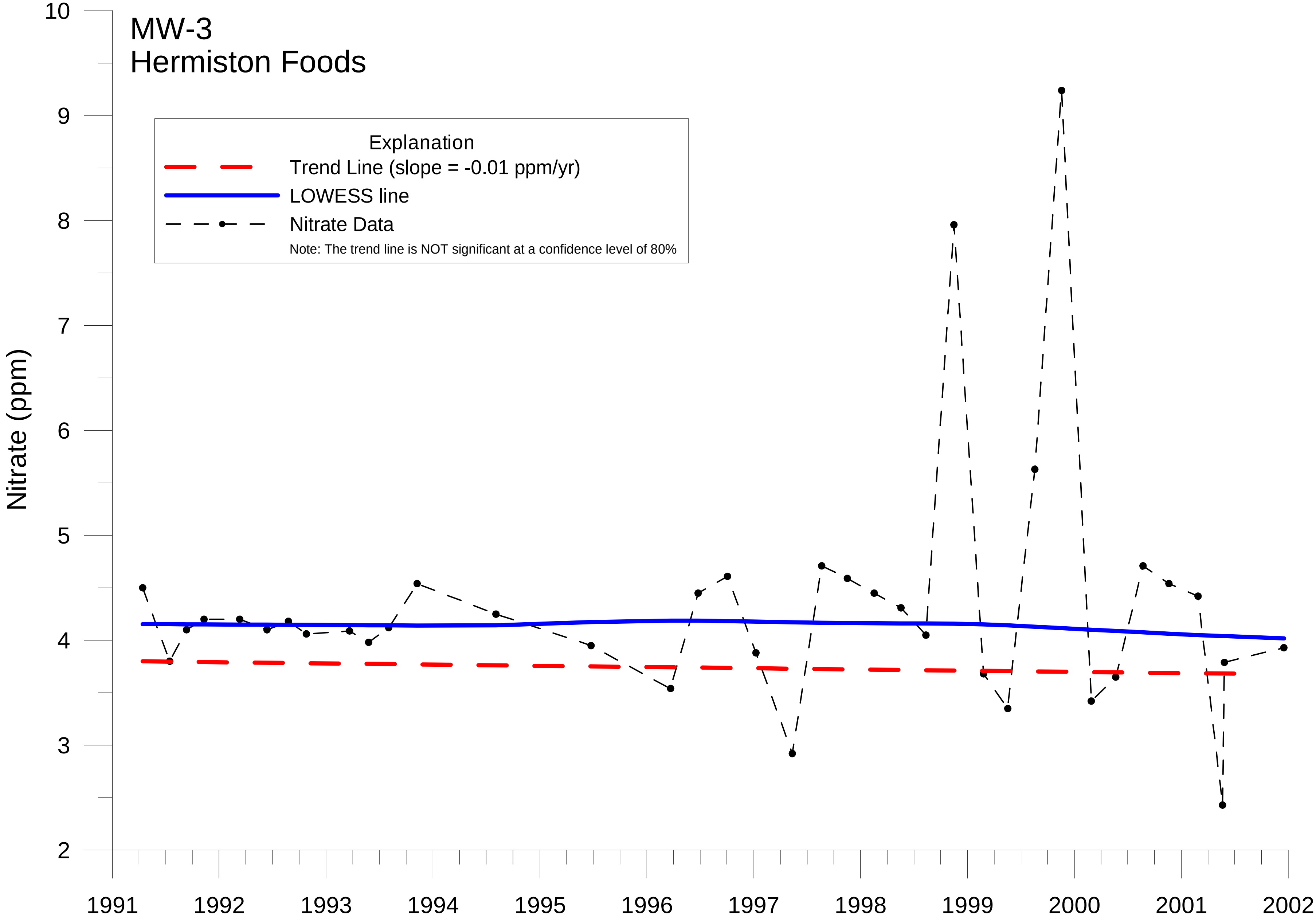

MW-55
Simplot Expansion Site
Nitrate (ppm)
20
19
18
17
16
15
14
13
12
11
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.80 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 95%

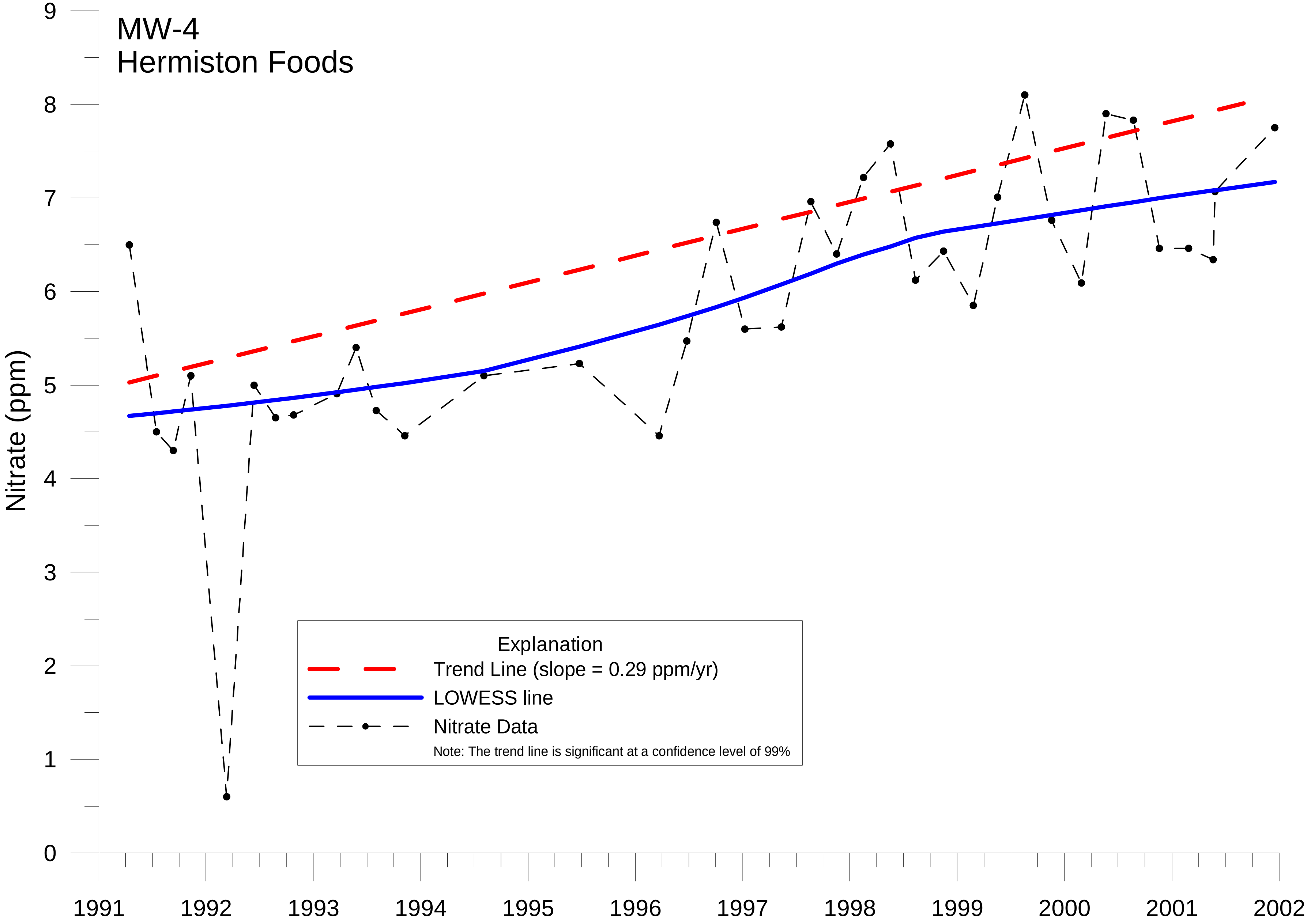


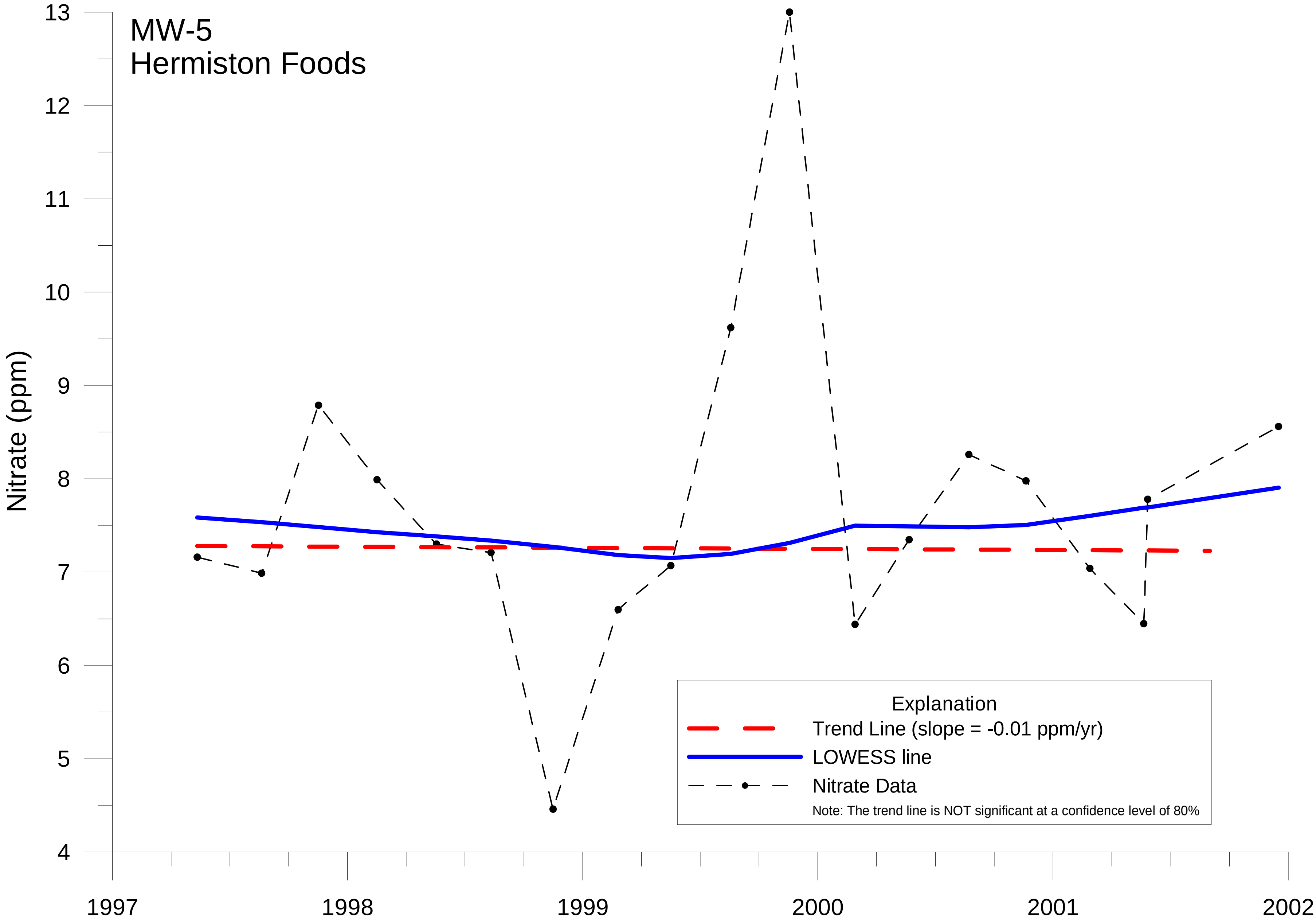
e:\lub\landapp\hermistonfoods\mw-1.grf

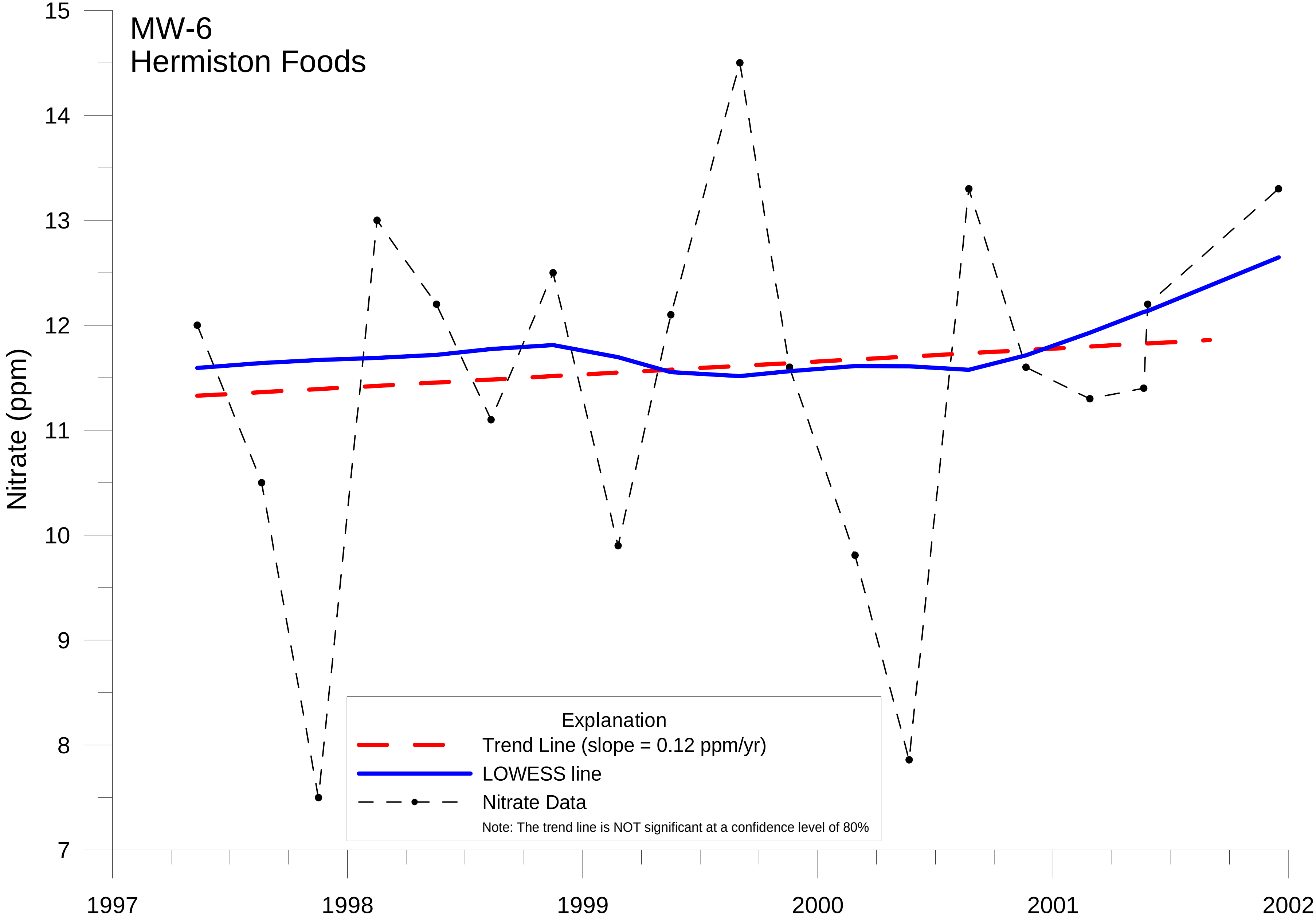


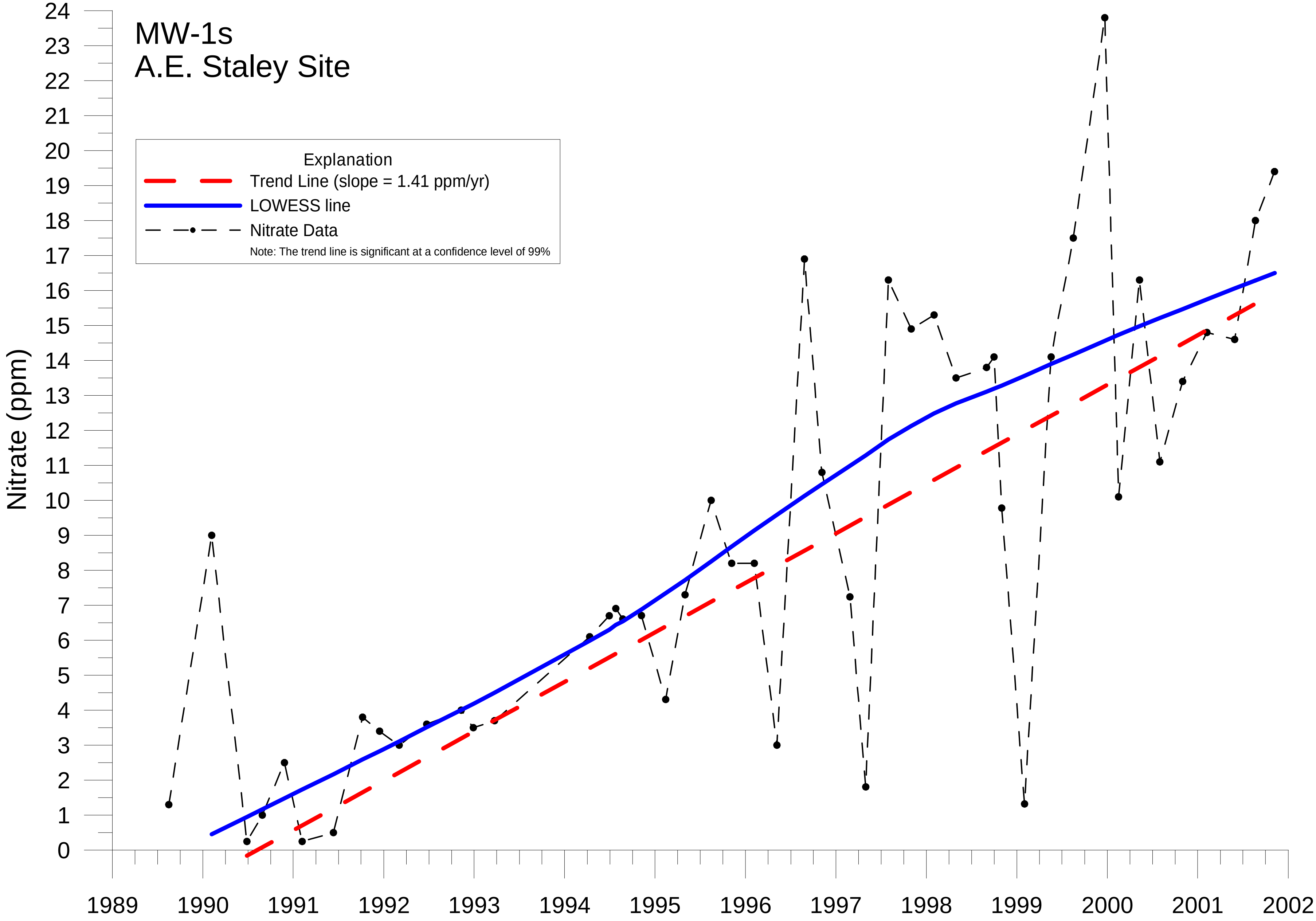
e:\lub\landapp\hermistonfoods\mw-2.grf

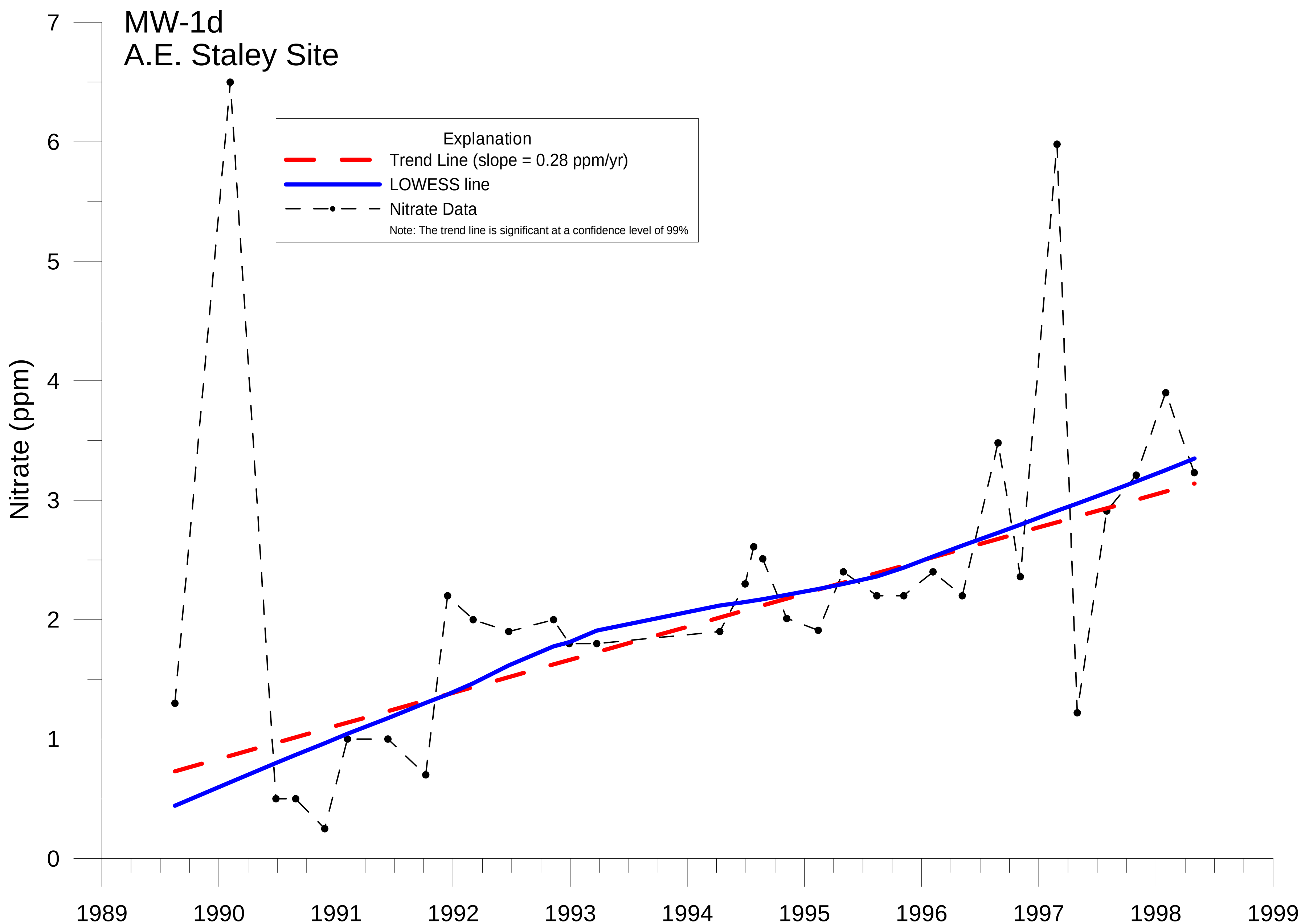

MW-3
Hermiston Foods
Explanation
Trend Line (slope = -0.01 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%
Nitrate (ppm)
10
9
8
7
6
5
4
3
2
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002


MW-4
Hermiston Foods
Nitrate (ppm)
0
1
2
3
4
5
6
7
8
9
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.29 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

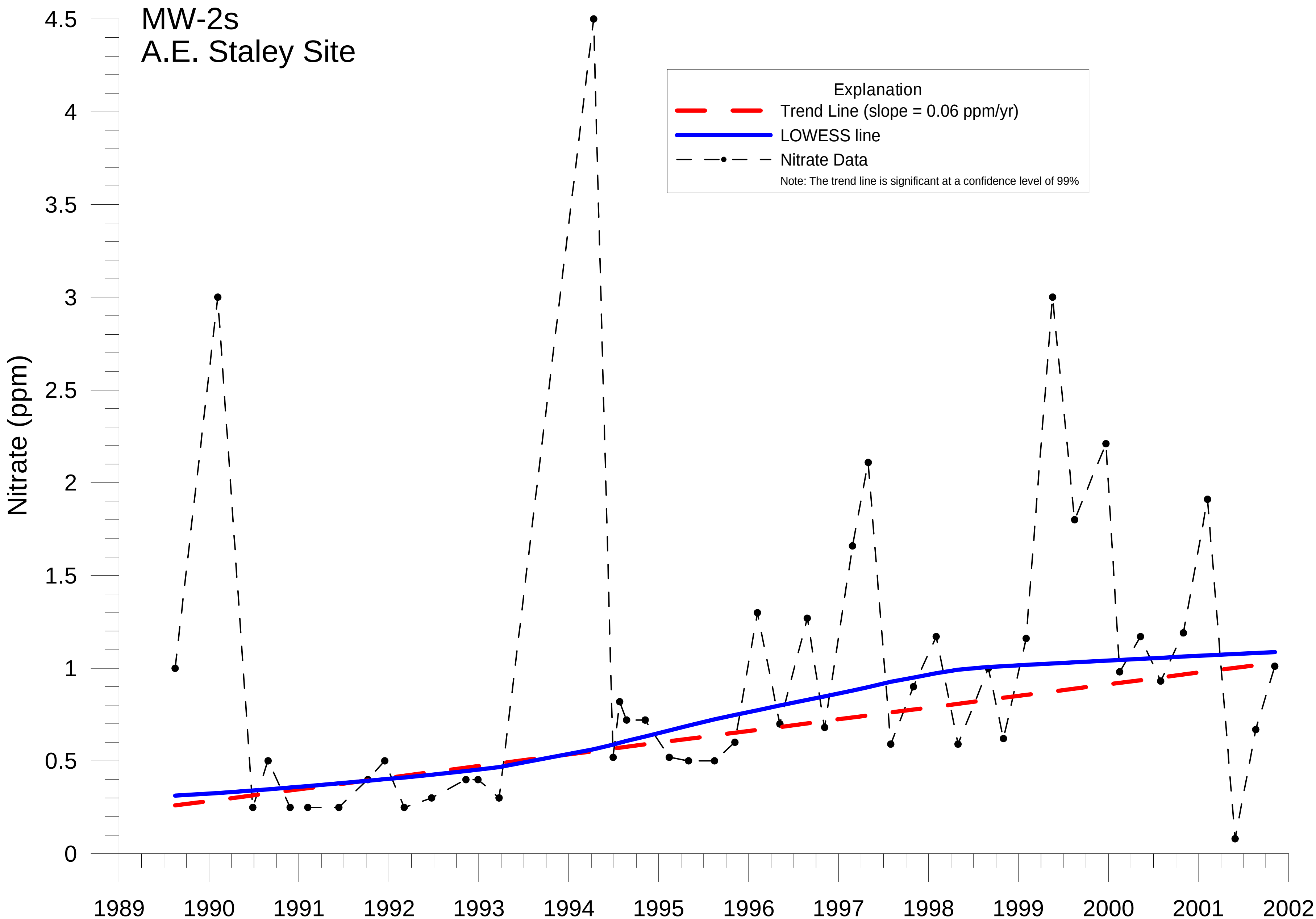

MW-5
Hermiston Foods
Nitrate (ppm)
13
12
11
10
9
8
7
6
5
4
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = -0.01 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%

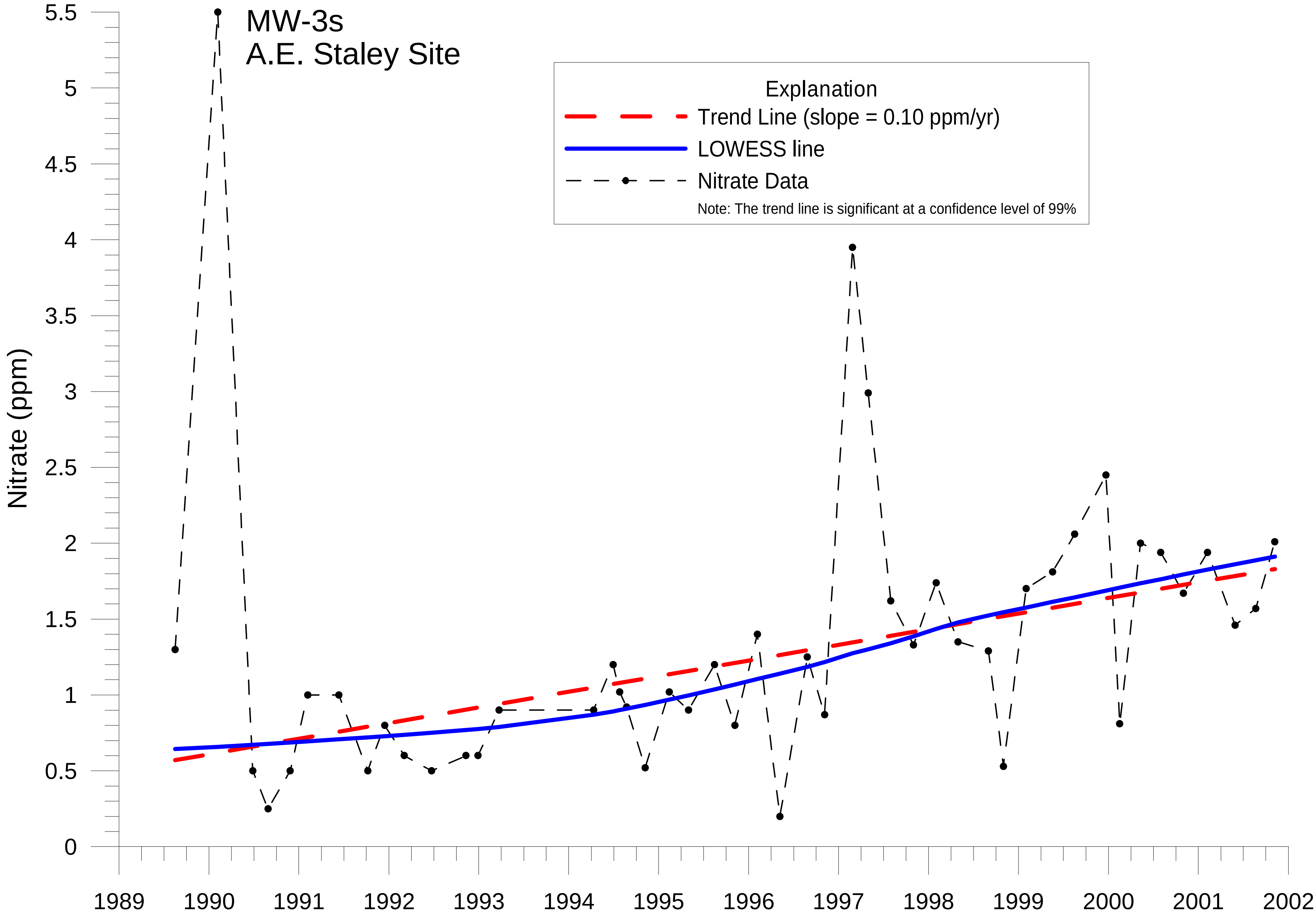

MW-6
Hermiston Foods
Nitrate (ppm)
15
14
13
12
11
10
9
8
7
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.12 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%

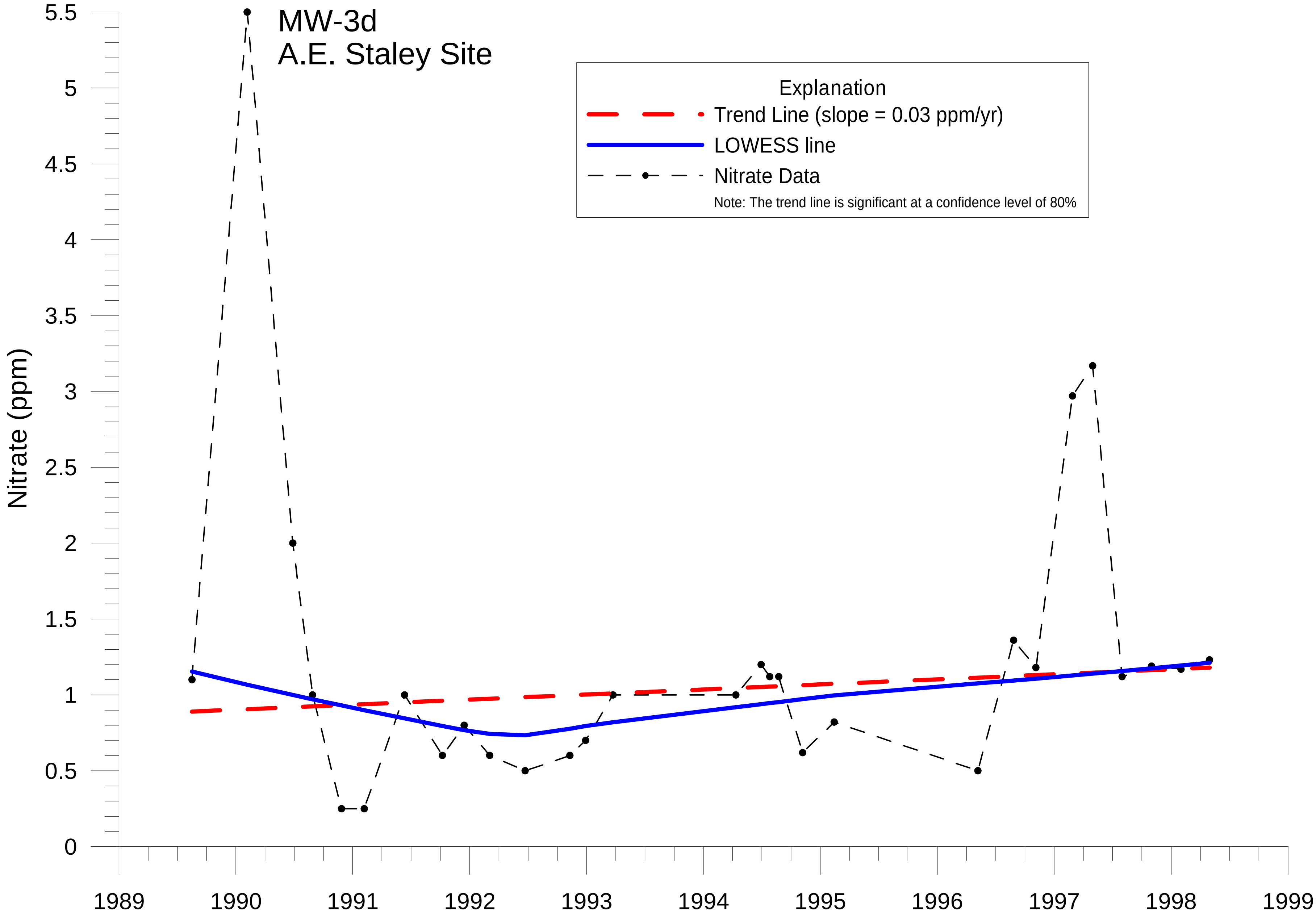

MW-1s
A.E. Staley Site
Explanation
Trend Line (slope = 1.41 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%
Nitrate (ppm)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002

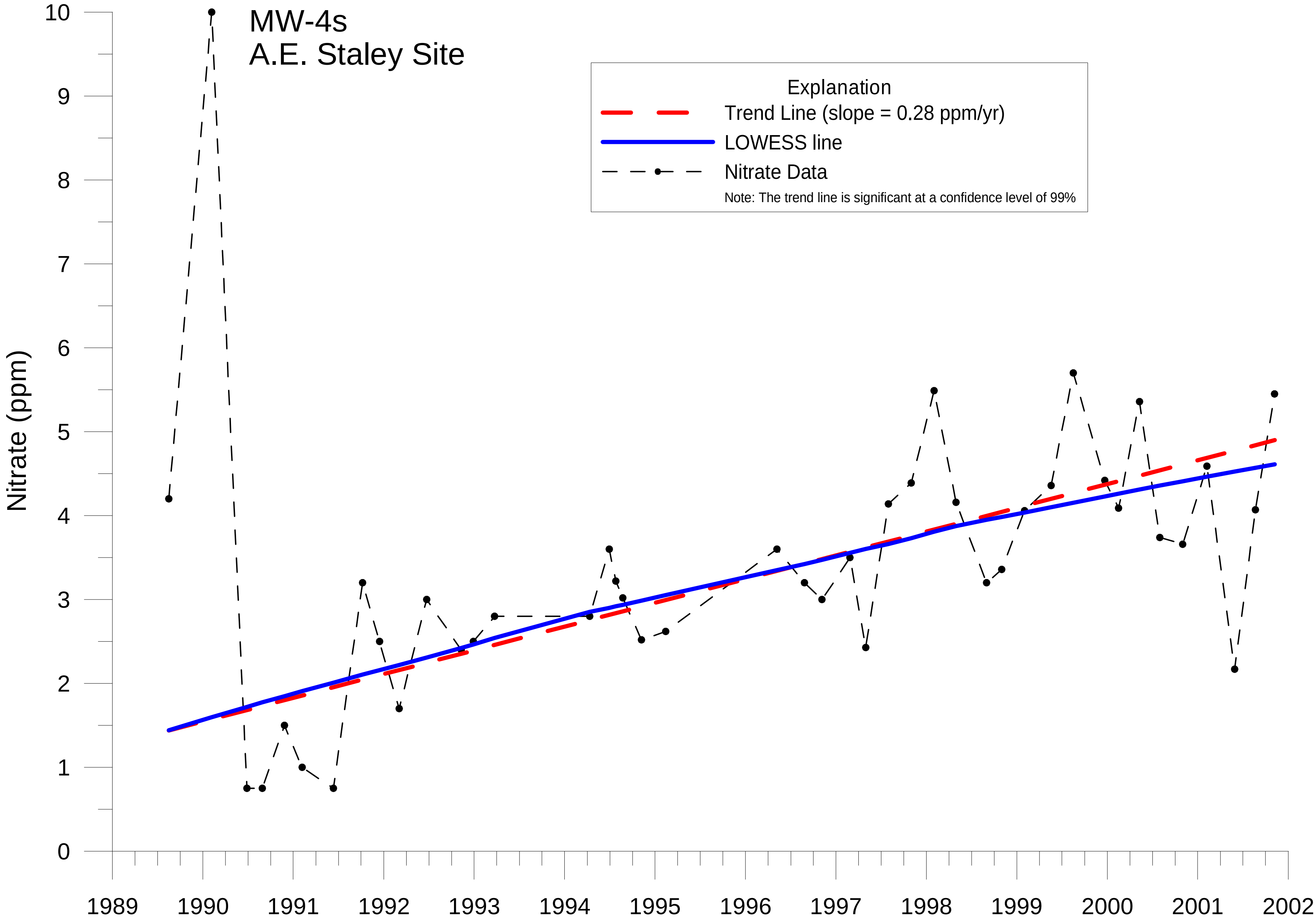


MW-1d
A.E. Staley Site
Explanation
Trend Line (slope = 0.28 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%
Nitrate (ppm)
0
1
2
3
4
5
6
7
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999

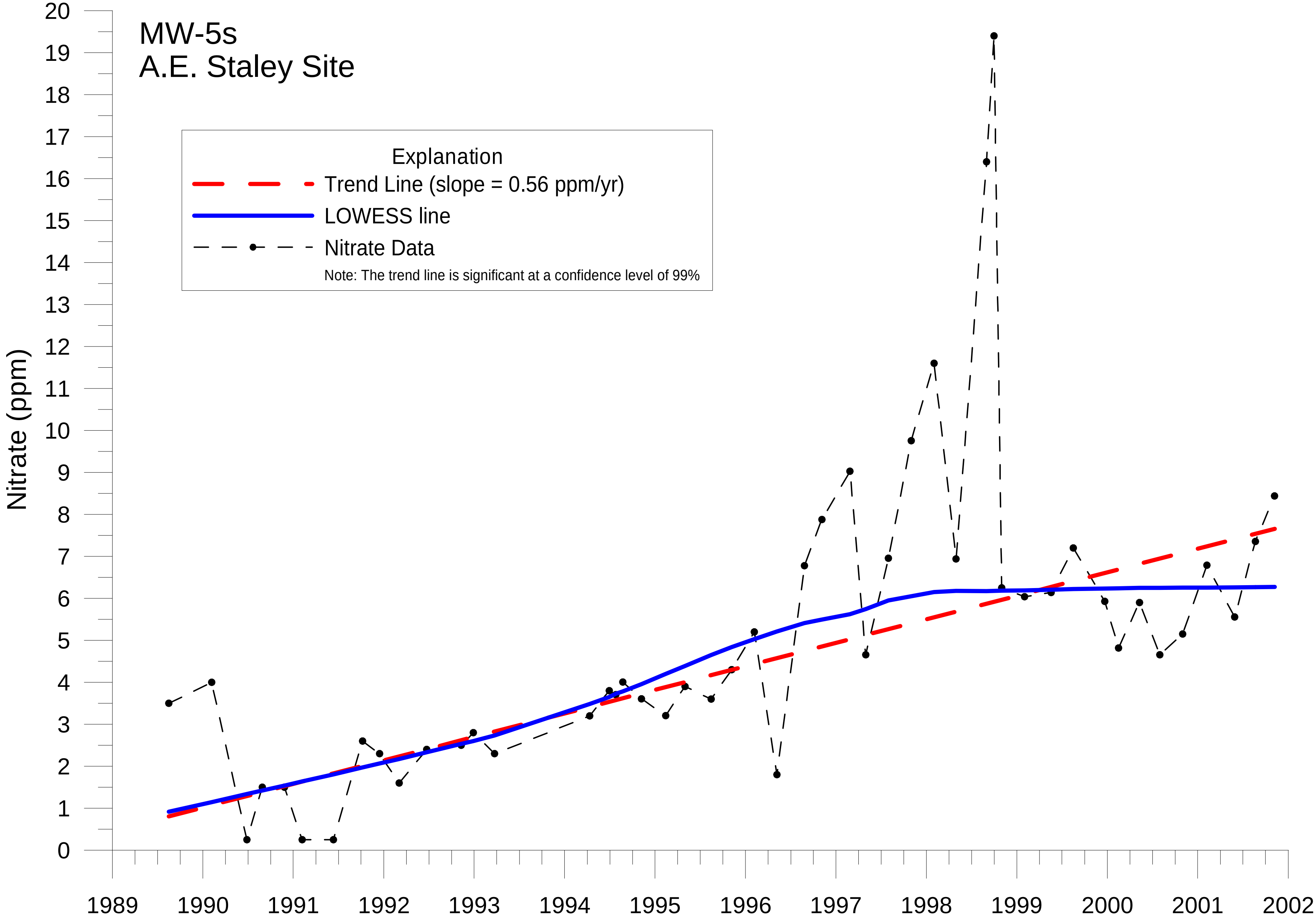

MW-2s
A.E. Staley Site
Explanation
Trend Line (slope = 0.06 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%
Nitrate (ppm)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002


MW-3s
A.E. Staley Site
Explanation
Trend Line (slope = 0.10 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%
Nitrate (ppm)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002

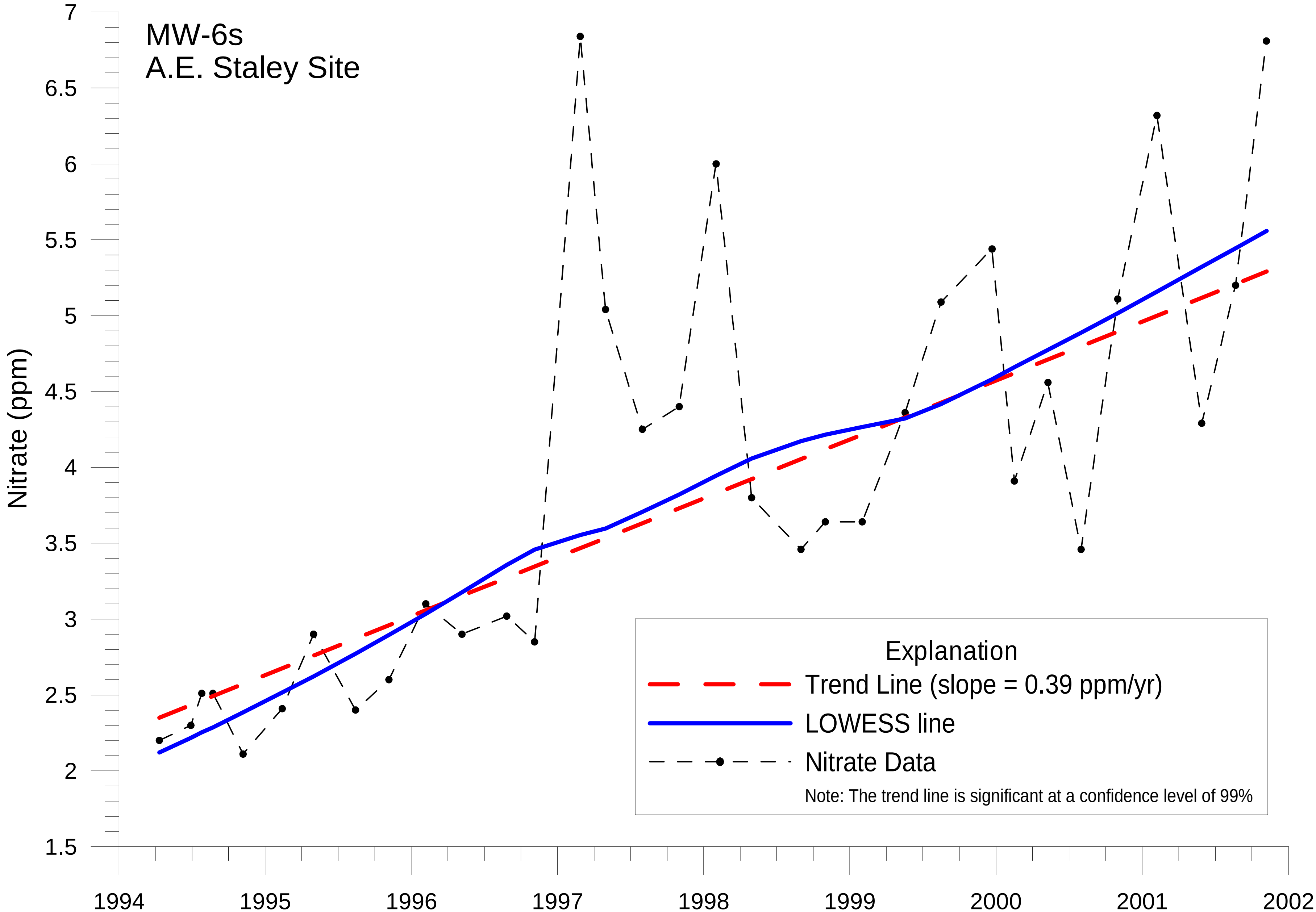

MW-3d
A.E. Staley Site
Explanation
Trend Line (slope = 0.03 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 80%
Nitrate (ppm)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999



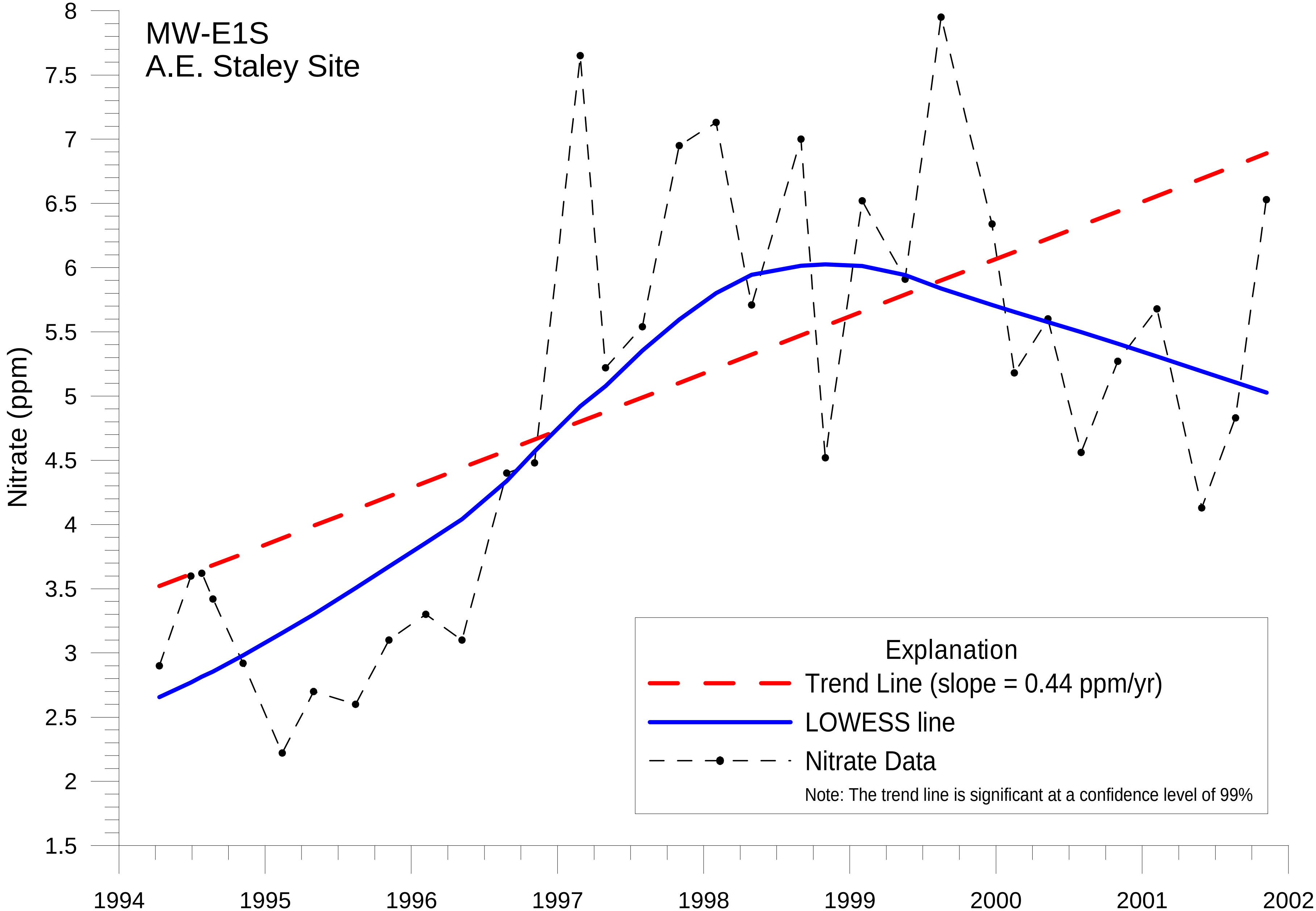
MW-4s
A.E. Staley Site
Explanation
Trend Line (slope = 0.28 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%
Nitrate (ppm)
0
1
2
3
4
5
6
7
8
9
10
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002



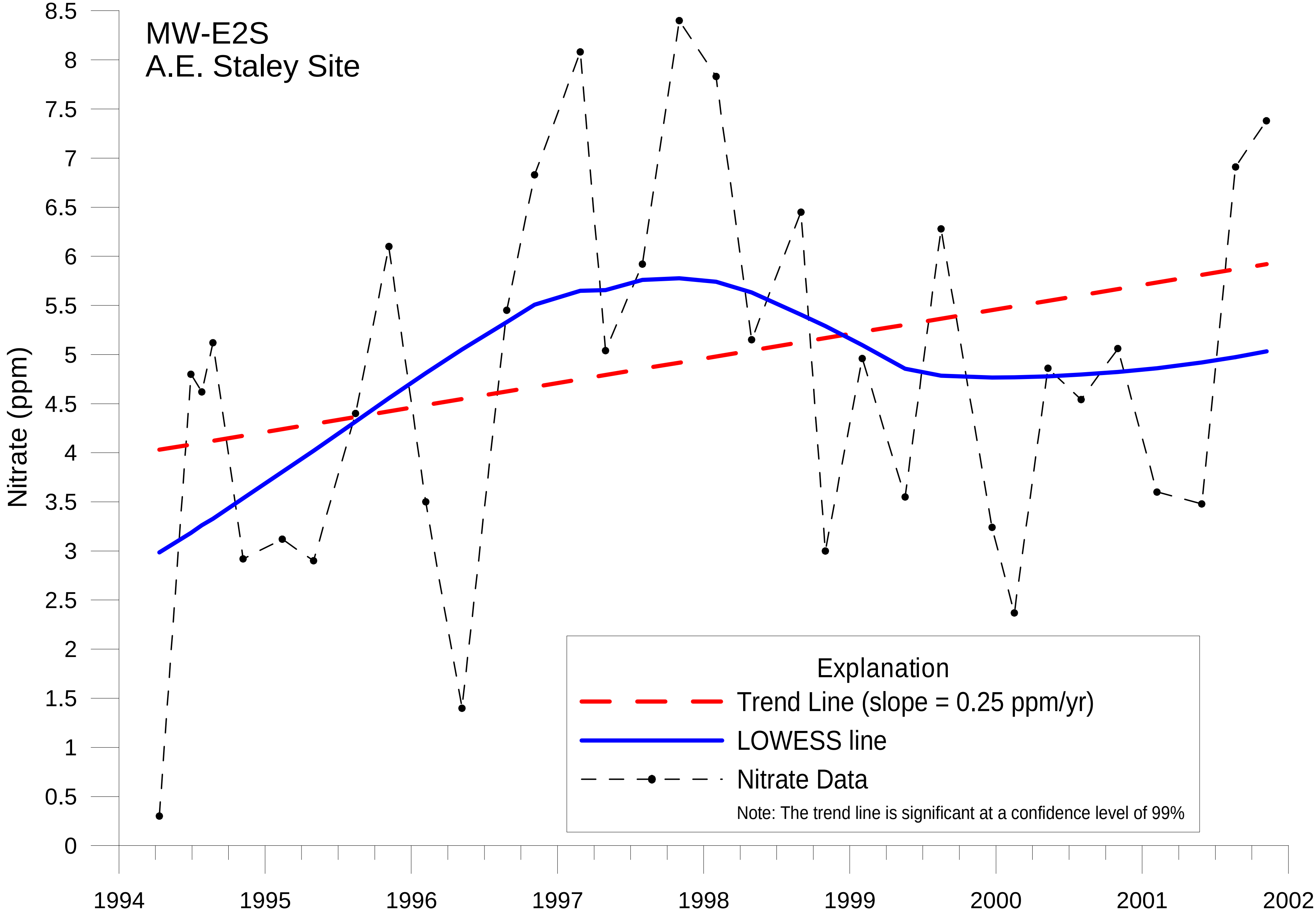
MW-5s
A.E. Staley Site
Explanation
Trend Line (slope = 0.56 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%
Nitrate (ppm)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002



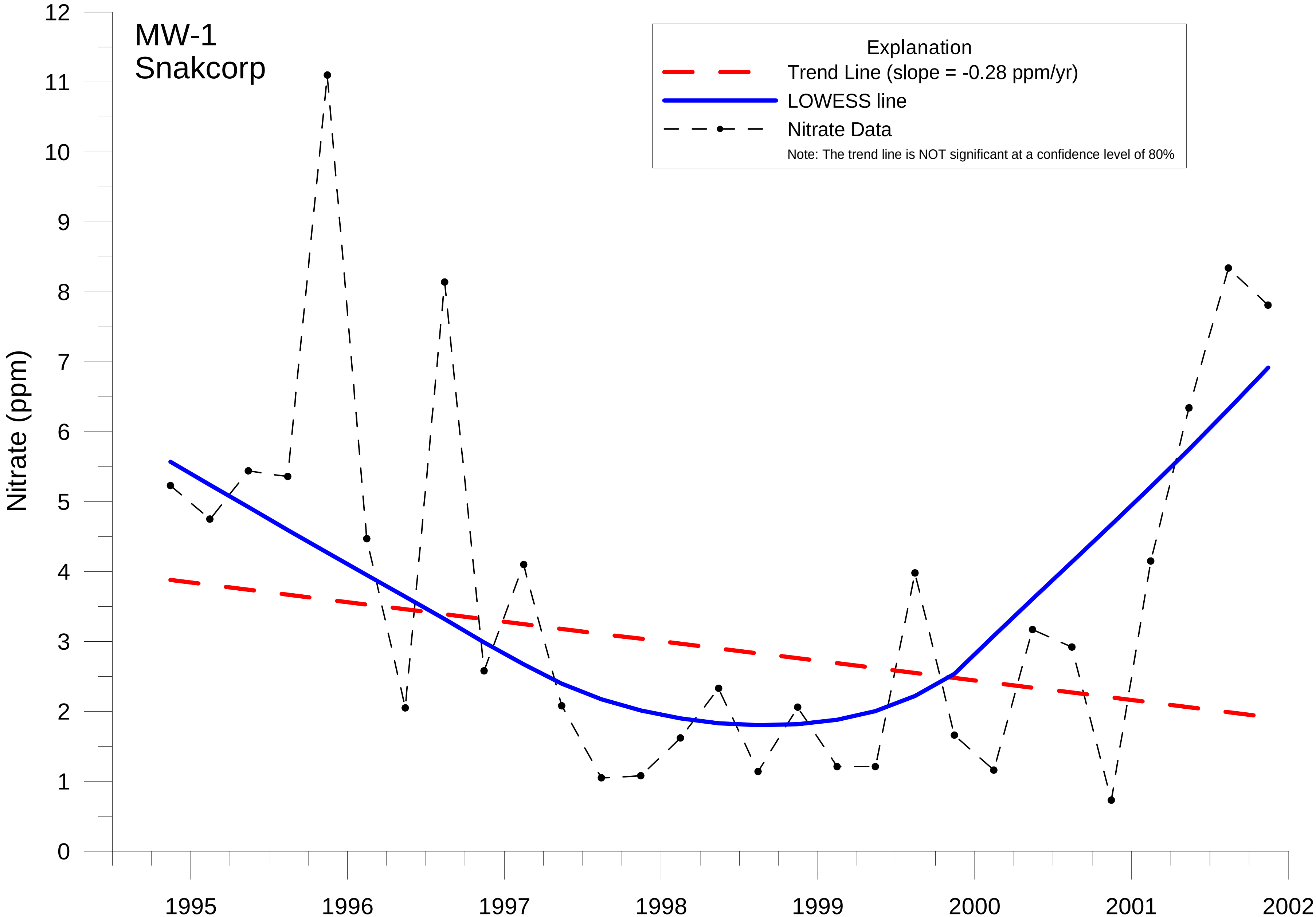
MW-6s
A.E. Staley Site
Nitrate (ppm)
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.39 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%



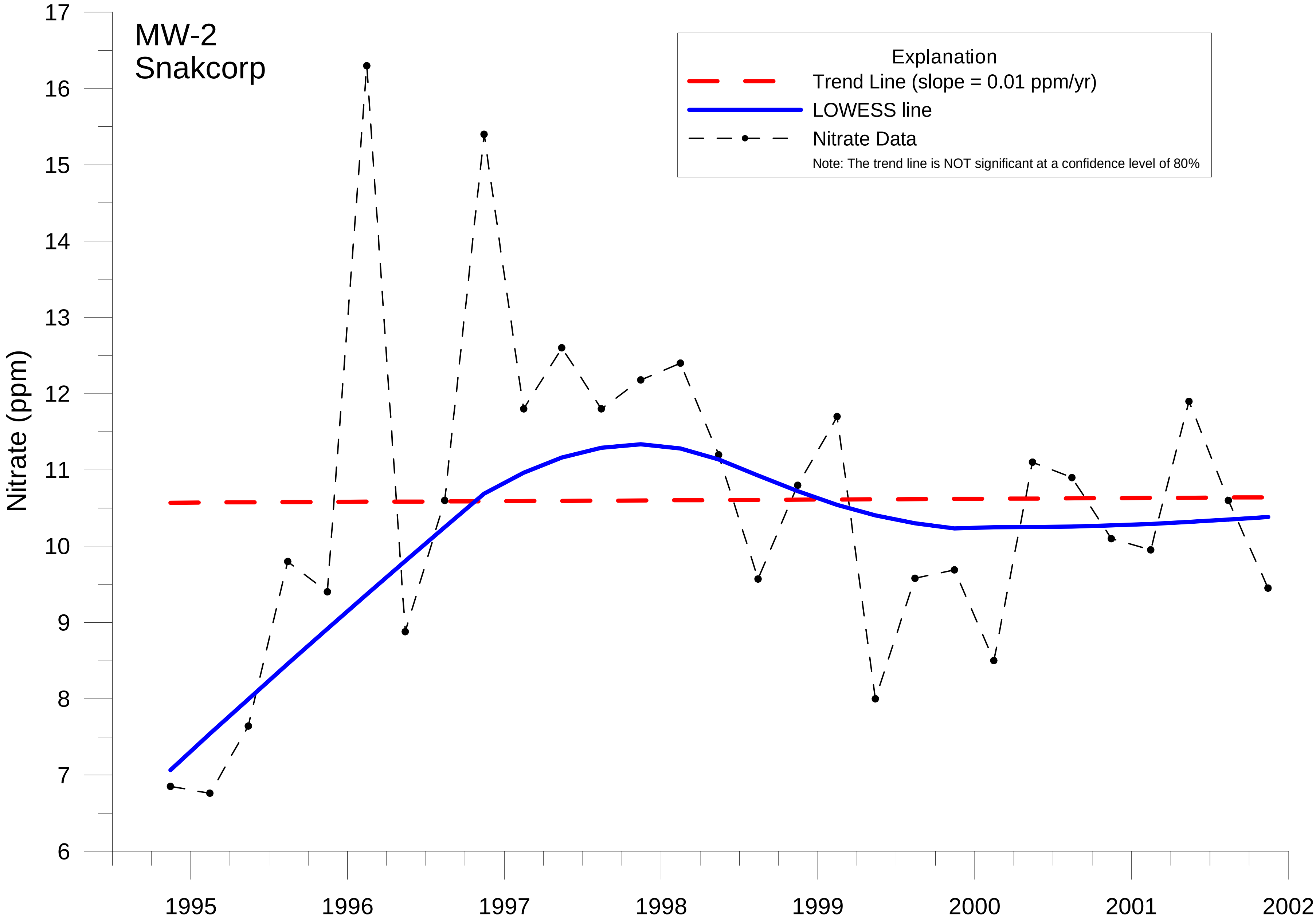
MW-E1S
A.E. Staley Site
Nitrate (ppm)
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.44 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

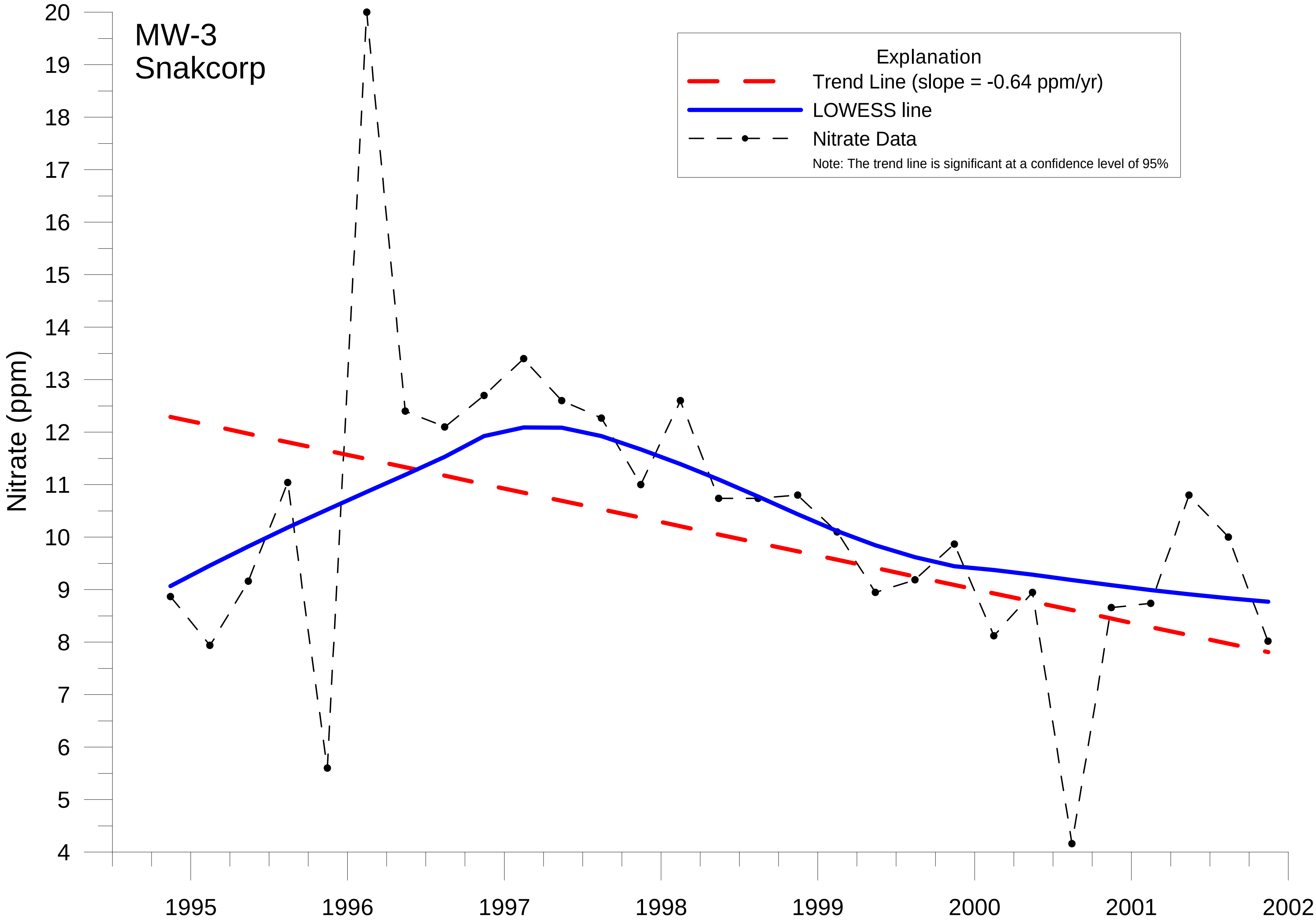


MW-E2S
A.E. Staley Site
Nitrate (ppm)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8
8.5
1994
1995
1996
1997
1998
1999
2000
2001
2002
Explanation
Trend Line (slope = 0.25 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 99%

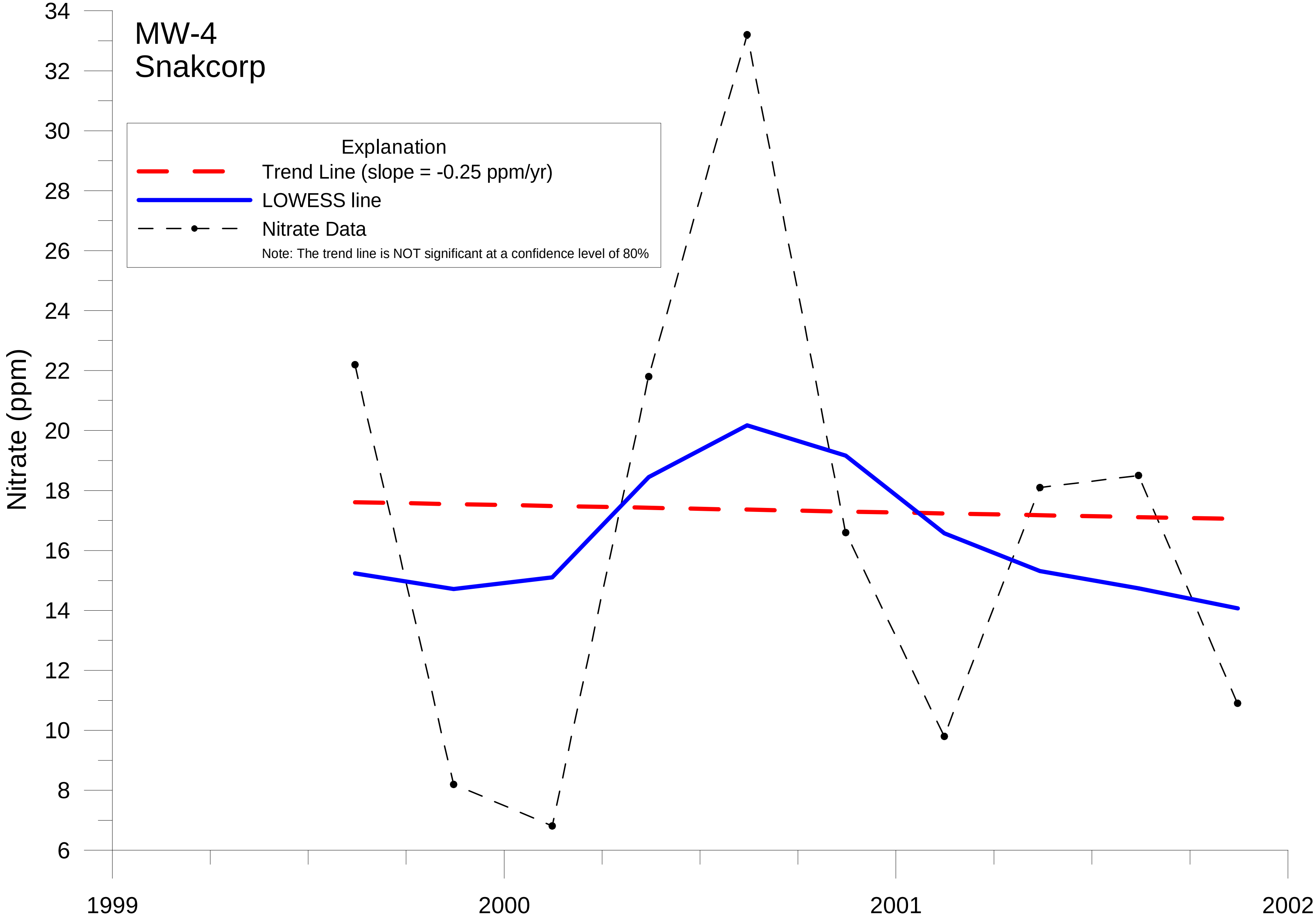


e:\lub\landapp\snakcorp\mw-1.grf


MW-2
Snakcorp
Explanation
Trend Line (slope = 0.01 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%
Nitrate (ppm)
17
16
15
14
13
12
11
10
9
8
7
6
1995
1996
1997
1998
1999
2000
2001
2002



MW-3
Snakcorp
Explanation
Trend Line (slope = -0.64 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is significant at a confidence level of 95%
Nitrate (ppm)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
1995
1996
1997
1998
1999
2000
2001
2002


MW-4
Snakcorp
Explanation
Trend Line (slope = -0.25 ppm/yr)
LOWESS line
Nitrate Data
Note: The trend line is NOT significant at a confidence level of 80%
Nitrate (ppm)
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
1999
2000
2001
2002