DEQ Water Quality Division

Second Northern Malheur County Groundwater Management Area Trend Analysis Report

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State of Oregon
Department of Environmental Quality

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http://www.deq.state.or.us/wq/groundwater/nmcgwma.htm

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LIST OF ACRONYMS

BMP	Best Management Practice
DCPA	Dimethyl tetrachloroterephthalate (sold under the trade name Dacthal)
DEQ	Oregon Department of Environmental Quality
mg/l	milligram per liter
GWMA	Groundwater Management Area
LOWESS	Locally Weighted Scatterplot Smoothing
NMC GWMA	Northern Malheur County Groundwater Management Area
ODA	Oregon Department of Agriculture
OSU	Oregon State University
OWRD	Oregon Water Resources Department
ppm	Part per million

EXECUTIVE SUMMARY

Introduction

The Northern Malheur County Groundwater Management Area (NMC GWMA) was declared in 1989 after widespread groundwater nitrate contamination was identified that had resulted primarily from nonpoint source activities. Oregon DEQ and a citizen's advisory committee created an Action Plan for restoring the groundwater nitrate concentrations to acceptable levels. The Action Plan identifies specific "measures" to gauge the success of changes in the area. The three measures that relate to nitrate concentrations and trends are the subject of this report.

Purpose of the Study

The purpose of this study is to determine, through an analysis of NMC GWMA water quality data, if the three water quality measures of Action Plan success have been met.

Conclusions

The major conclusions drawn from this study are:

- Although not all monitoring stations in the GWMA exhibit decreasing nitrate trends, the multiple lines of evidence suggesting improving water quality (including the statistically significant decreasing area-wide trend) provide sufficient evidence to conclude there has been an overall improvement in groundwater nitrate concentrations from 1991 through 2005. Therefore, the third measure of Action Plan success has been met.
- Continued and perhaps expanded BMP implementation is needed to attain and maintain water quality improvements.

Recommendations

- The recommendations from this report (along with the responsible parties) are:

Groundwater Management Committee and Malheur County SWCD

- By March 2008 produce a report that documents BMP implementation.
- As appropriate and as resources provided allow, evaluate the possibility of point source contributions in the vicinity of wells with increasing nitrate trends.
- As available and appropriate, provide financial and technical support to assist in the continued research, documentation, and implementation of appropriate BMPs in the GWMA as well as projects such as deep soil sampling to evaluate changes in the amount and movement of nitrate within the unsaturated zone.

Groundwater Management Committee and DEQ with support from agencies associated with this project

- Amend the Action Plan to (1) allow the use of the Seasonal Kendall method for the evaluation of water quality trends rather than requiring the use of the ordinary least squares method and (2) remove the unattainable goal of an area-wide nitrate concentration of 7 mg/l by July 1, 2000.

DEQ

- Continue to sample the existing well network (i.e., the 36 wells and 2 surface water bodies) every other month for nitrate to maintain the water quality database.
- Perform another formal trend analysis of nitrate concentrations in 2010 using cadmium reduction nitrate data collected through December 2009.
- Investigate the possibility of point source contamination affecting well MAL126.
- As available and appropriate, provide financial and technical support to assist in the continued research and implementation of appropriate BMPs in the GWMA as well as projects such as deep soil sampling to evaluate changes in the amount and movement of nitrate within the unsaturated zone.

REGISTERED PROFESSIONAL GEOLOGIST SEAL

In accordance with Oregon Revised Statutes (ORS) 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.",

I hereby acknowledge that the document cited below was prepared by me.

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1.0 INTRODUCTION

The Northern Malheur County Groundwater Management Area (NMC GWMA) was declared in 1989 after widespread groundwater nitrate contamination was identified that had resulted primarily from nonpoint source activities. The Oregon Department of Environmental Quality (DEQ) and a citizen's advisory committee created an Action Plan for reducing the groundwater nitrate concentrations to acceptable levels. The Action Plan identifies specific "measures" to gauge the success of changes in the area. The three measures that relate to nitrate concentrations and trends are the subject of this report.

1.1 Establishment of the Northern Malheur County 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.

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 Northern Malheur County GWMA was declared in 1989 after groundwater contamination was identified in an 115,000-acre area in the northeastern portion of the county where land use is dominated by agriculture. The GWMA boundary starts at the mouths of the Malheur and Owyhee Rivers where they converge with the Snake River and extend to the uppermost irrigation canals. The approximate location of the Northern Malheur County GWMA is indicated in Figure 1-1. The locations of the 38 wells and 2 surface water sample locations used to collect water quality data for this trend analysis are indicated in Figure 1-2. Three wells have very few additional data points since the previous trend analysis. One well owner withdrew his well from the sampling program in 2001. The well pump at another well broke in 2000 and was not replaced. The well pump at the third well only works sporadically and has not been replaced. The original selection of the wells was based primarily on an attempt to obtain good geographical coverage of the area while using wells with good well logs and accommodating owners. However, the uneven distribution of wells throughout the GWMA may over-represent some areas while under-representing other areas.

Groundwater samples from private water wells identified nitrate contamination and the presence of the pesticide dacthal[1] and its breakdown products (hereafter known as DCPA & metabolites[2]). Traditional fertilizer and agricultural chemical application practices are believed to be the main source of the contamination. Other possible sources of nitrate identified in the GWMA include residential lawn care, on-site sewage systems (i.e., septic tanks), confined animal feed lot operations, and food processing facilities.

[1] Dacthal is a trade name for dimethyl tetrachloroterephthalate (DCPA). Dacthal is the term used in the Action Plan.
[2] The analytical method used consistently throughout this sampling program does not distinguish between DCPA and its metabolites (i.e., one value representing the sum of the parent and daughter products is reported). However, when a different analytical technique was occasionally used during the sampling program, it was determined that DCPA was not detected but its metabolite(s) were detected. Therefore, concentrations reported as "DCPA & metabolites" are actually representative of only the metabolite(s).

Sampling confirmed that most of the contaminated groundwater is present in the shallow alluvial sand and gravel aquifer which receives a large proportion of its recharge from canal leakage and irrigation water. Therefore, the shallow aquifer is the focus of efforts to restore groundwater quality in Northern Malheur County.

1.2 Northern Malheur County Groundwater Management Area Action Plan

The Northern Malheur County Groundwater Management Action Plan, hereafter referred to as the Action Plan (Malheur County Groundwater Management Committee, 1991) was developed to reduce existing contamination and prevent further contamination of groundwater in the GWMA. The Northern Malheur County Groundwater Management Committee, the Technical Advisory Subcommittee, and representatives from the DEQ, the Oregon Department of Agriculture (ODA), the Oregon Water Resources Department (OWRD), the Oregon Department of Human Services (formerly known as the Oregon Health Division), and Oregon State University (OSU) conducted an 18-month effort ending with approval of an Action Plan focused on reducing groundwater contamination in the GWMA. The Action Plan is available online at http://www.deq.state.or.us/wq/groundwater/docs/nmcgwma/actionplan.pdf

The Action Plan includes detailed information on water quality, identification of contaminant sources, and recommendations for implementation of Best Management Practices (BMPs) to improve groundwater quality. This approach allows farmers to customize a sequence or system of available BMPs to their individual farm operations. The Committee chose 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 and adopt or modify practices and activities to reduce contaminant loading to groundwater.

As part of implementation of the Action plan, a network of 36 wells (mostly private drinking water and irrigation wells) and 2 surface water bodies is currently sampled every other month for analysis of nitrate and DCPA & metabolites. Approximately once a year, these wells and surface water bodies are sampled for a larger list of analytes including major ions, metals, and additional pesticides. The nitrate data provide the basis for this study. The nitrate data (along with the results of the trend analysis) are graphically indicated in Appendix A. A table correlating the DEQ well designation to the Oregon Water Resources Department well designation is also included in Appendix A.

1.3 Purpose of This Study

The purpose of this study is to determine, through an analysis of NMC GWMA nitrate data, if the three water quality measures of Action Plan success have been met.

1.4 Measures of Action Plan Success

The Action Plan specifies four specific ways to gauge success. Three of these are related to water quality concentrations or trends (i.e., changes in groundwater quality over time) in response to adoption of BMPs. The fourth measure of success involves “other indicators of progress” (i.e., the adoption of BMPs). These measures of success are reiterated below.

The Action Plan will be considered successful if:

(1) A trend analysis indicates, at a 75% confidence level, that the level of the nitrate monitoring data for the entire management area is 7 mg/l; or
(2) A trend analysis indicates, at the 80% confidence level, that nitrate levels will reach 7 mg/l by July 1, 2000; or
(3) A statistically significant downward trend can be demonstrated at the 80% confidence level; or
(4) Other indicators show progress toward this goal. Other indicators of progress may include but are not limited to the following:
   - number of producers adopting farm plans;
   - an increase in utilization of soil testing to improve fertilization practices;
   - an increase in efficiency of nitrogen fertilizer application: timing, placement, form, & rate;

- an increase in irrigation efficiency, reducing deep percolation;
- a vadose zone drilling project demonstrating decrease in concentrations of nitrate;
- number of water quality practices being applied; and
- Ontario Hydrologic Unit Area reports and evaluations of progress and effectiveness.

The first three measures of Action Plan success (i.e., those related to water quality trends) are discussed in this report. The fourth measure of success (i.e., the other indicators of progress) will be discussed in a future document titled “Second Northern Malheur County Groundwater Management Area Best Management Practice Implementation Report”. The success of the Action Plan as a whole will be discussed in a future document titled “Second Evaluation of Northern Malheur County Groundwater Management Area Action Plan Success”.

1.5 Principles of Trend Analysis

The principles of trend analysis are discussed in Section 2.0 of the December 2003 document titled “Northern Malheur County Groundwater Management Area Trend Analysis”. This document, as well as other Northern Malheur County GWMA documents, is available at http://www.deq.state.or.us/wq/groundwater/nmcgwma.htm

2.0 DETERMINATION OF ANALYSIS SOFTWARE AND DATA SET

This section of the report provides information on the determination of which software was used, which data were included, and how data were prepared prior to conducting the trend analysis.

2.1 Software Selection

The trend analysis software used in this analysis was Minitab version 14 by Minitab, Inc. and macros written by Dr. Dennis Helsel (with the United States Geological Survey (USGS)) and Dr. Edward Gilroy (retired from the USGS). The use of product names is for information purposes only. DEQ does not advocate the use of any particular software.

2.2 Data Set

The timeframe of the data set (i.e., the inclusive dates), which data to include in the analysis, and the steps taken to prepare the data are discussed in the following sections.

2.2.1 Timeframe of Data Set

The Action Plan requires that nitrate trend analyses include data from July 1, 1991 until the date of the analysis. In accordance with the Action Plan, only data collected after July 1, 1991 were used in this study. This is not necessarily consistent with previous trend analyses (see Appendix C of the December 2003 trend analysis document for more details). This effectively means the first data points from most monitoring stations are from August 1991. The data set for this study includes 14½ years of data from July 1991 through December 2005.

2.2.2 Data To Include In Analysis

The previous trend analysis included an evaluation of nitrate data generated by the cadmium reduction method and the electrode method. That report concluded that only the cadmium reduction method data should be used for trend analysis. Only the cadmium reduction method data are used in this analysis.

The previous trend analysis also included an evaluation of DCPA & metabolites data. During the current analysis, it was concluded that the DCPA & metabolites data generated since 1999 are not adequate to conduct additional trend analyses. This conclusion was reached based on the following aspects of the data:

- DCPA & metabolites data were frequently received by DEQ many months after sample collection with no accompanying analytical quality assurance/quality control (QA/QC) data from the contract lab. Consequently, the quality of the data could not be fully assessed.
- Because no QA/QC data were provided by the contract lab, results were sometimes deemed of unknown quality by the DEQ lab and provided to the data users “for educational purposes only”.
- The standard comparison criterion for field duplicate pairs (i.e., a relative percent difference of 20%) was sometimes exceeded. On at least one occasion, concentrations differed by two orders of magnitude. Because the contract lab did not provide QA/QC data, the cause of the discrepancies could not be determined.
- The analytical procedure used to quantify DCPA & metabolites changed in 2002. The potential effect of this change in procedure is not known.

2.2.3 Data Set Preparation

The starting point for the data used in this evaluation was the input files from the previous trend analysis. Additional data from DEQ’s laboratory database were then added to the electronic files. Certain steps were taken to prepare the data so that the trend analysis could be conducted. These steps included the following:

- Results from duplicate samples were averaged into one value.
- The data were visually examined for obvious outliers and potential transcription errors. If a data point was suspected of being an error, efforts were made to trace the data back to the original laboratory report to confirm the result. Statistical outliers were not deleted from the data set.

3.0 METHODS

The methods selected for evaluation of water quality data were based on the Action Plan, recommendations from previous studies, and literature research. The methods used to evaluate nitrate trends are discussed below.

3.1 Analysis of Non-Detected Data

Results from four wells were sometimes reported as below a detection limit[3] (i.e., <0.05 mg/l). Two wells exhibited a small amount of non-detected values (1 or 2 data points). Two wells exhibited a significant amount of non-detected values (slightly over half of the data points). For those wells with some non-detected values, two values were entered into the electronic files for each result. The first value was the measured concentration for detected concentrations or the detection limit for non-detected values. The second value was a code indicating if the first value represents a detected concentration or the detection limit for a non-detected observation.

The non-detected data were recorded in this manner to allow more statistically robust evaluations of data set characteristics and trends. The procedures recommended in Helsel (2005) for computing summary statistics and calculating trends were followed using macros written by Dr. Helsel for use within Minitab. These include the following:

- For wells with a small amount of non-detected values, the mean and median were calculated by the Kaplan-Meier method using the KMBMean and KMBoot macros.
- For wells with a significant amount of non-detected values, the mean and median were calculated by the Maximum Likelihood Estimation method using the MLEBoot macro.
- Trends at wells with non-detected values were calculated by the Helsel-Turnbull adaptation of the Theil-Sen slope estimate. This is a nonparametric regression line based on Kendall's tau correlation coefficient. The Ckend macro was used for these calculations.
- Seasonality at wells with non-detected values was evaluated using the nonparametric Kruskal-Wallis test for comparing medians. The CensKW macro was used for these calculations.

3.2 Trend Analyses at Individual Wells

Nitrate results from wells with no non-detected values were analyzed for a monotonic trend using the Seasonal Kendall test. The Seasonal Kendall test was developed by the USGS in the 1980s and has become the most frequently used test for trend in the environmental sciences (Helsel, et.al. 2006). The Seasonal Kendall test performs separate tests for trends in each season, and then combines the results into one overall linear trend result.

The Seasonal Kendall test accounts for seasonality by computing the Mann-Kendall test on each season separately, and then combining the results. For example, February data are compared only to February data. No comparisons are made across seasonal boundaries. The overall Seasonal Kendall trend slope is computed as the median of all slopes between data points within the same season. No cross-season slopes contribute to the overall estimate of the Seasonal Kendall trend slope. This slope is the median rate of change over time. This overall result reflects whether there is a trend with time for that location, blocking out all seasonal differences in the pattern of change (Helsel and Frans, 2006). The Seaken macro written by Dr. Helsel for use within Minitab was used to calculate trends at individual wells. Results of the individual well trend analyses are discussed in Section 4.1.

In addition to calculating the monotonic trends at each well, LOWESS lines through the data were also calculated for each well. 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

[3] In the statistical literature, data reported as below or above a detection limit are called "censored" data.

very good graphical depiction of the underlying structure of the data. LOWESS lines are included on each of the NMC GWMA time series plots in Appendix A.

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.

3.3 Evaluation of Area-Wide Trend

The measures of Action Plan success regarding water quality trends relate to changes "for the entire management area." A variation of the Seasonal Kendall test called the Regional Kendall test was used to evaluate the area-wide trend.

Helsel and Frans (2006) describe the test as follows. The Regional Kendall test is a test to determine whether a consistent pattern of trend occurs across an entire area, at multiple locations. The Regional Kendall test substitutes location for season and computes the equivalent of the Seasonal Kendall test. The Regional Kendall test looks for consistency in the direction of trend at each location, and tests whether there is evidence for a general trend in a consistent direction throughout the region. Patterns at an individual location occurring in the same direction as the regional trend provide some evidence toward a significant regional trend, even if there is insufficient evidence of trend for that one location.

The Seaken macro written by Dr. Helsel for use within Minitab was used to calculate the linear area-wide trend. Results of the area-wide trend analysis are discussed in Section 4.2.

4.0 RESULTS

Results of the analysis of nitrate trends at individual wells as well as on an area-wide basis are discussed below. The discussion of individual nitrate trends consists of three aspects: the trend at each well, trends versus geographic location, and trends versus well depth.

4.1 Nitrate Trends at Individual Wells

A basic component of the evaluation of trends at individual wells is the time versus concentration graph. Time versus nitrate concentration graphs at each well are included in Appendix A. Also included on the graphs in Appendix A are the monotonic trends from the previous and current analyses as well as a LOWESS line (which provides an indication of the general pattern of the data).

4.1.1 Nitrate Trends at Each Well

Results of nitrate trend analyses at individual wells include two basic pieces of information for each test performed: a slope value and a confidence level. The slope value indicates the direction and magnitude of the trend while the confidence level indicates the statistical certainty of the result. Trends are either increasing (i.e., have a positive slope), decreasing (i.e., have a negative slope), or flat (i.e., have a slope of zero). For Northern Malheur County GWMA studies, test results with confidence levels less than 80% are considered “statistically insignificant”. This does not mean that the concentrations observed at these wells are insignificant or unworthy of attention. Instead, this means that the statistical test could not identify a linear trend with a high degree of assurance. All statistically insignificant trends are grouped together in this report. Statistically significant trends are divided into increasing or decreasing trends in this report (there were no flat trends identified).

Table 4-1 includes some data set summary statistics for each well and summarizes the nitrate trend at each well. An examination of Table 4-1 reveals 12 increasing trends (32%), 21 decreasing trends (55%), and 5 statistically insignificant trends (13%). Of the statistically significant trends, several trends are approximately 0.1 part per million (ppm) per year or less, and may not be physically meaningful.

Figure 4-1 illustrates the LOWESS lines and trend lines through the nitrate data at all network sampling locations. Each graph on Figure 4-1 is at the same scale to allow a direct comparison of trends between locations. Useful information can be gained by comparing trend lines with LOWESS lines. For example, the monotonic trend at well MAL078 is increasing, but the LOWESS line indicates an increasing then decreasing trend. As another example, the monotonic trend at well MAL126 is increasing, but the LOWESS line indicates the trend is increasing much steeper in the last few years than in previous years.

It is noteworthy that two of the five wells exhibiting statistically insignificant trends have average nitrate concentrations near or above the target concentration of 7 ppm, including the well with the highest average nitrate concentration (46 ppm at well MAL211). Data from well MAL211 end in April 2000 because the well owner decided to end his participation in the sampling program. As previously stated, the fact that a statistically significant linear trend cannot be drawn through the data does not mean the concentrations are insignificant or unworthy of attention. It is also noteworthy that the 10 ppm drinking water standard for nitrate was exceeded at least once at 29 of the 38 wells; and that the average nitrate concentration exceeded the drinking water standard at 20 of the 38 wells.

The fact that statistically significant trends cannot be drawn through the data at some wells indicates that the data are not “well behaved” (i.e., the data exhibit significant variability) and, in one case, may suggest a shift in trend direction within the data set. For example, the LOWESS line through well MAL180 data (page A-30 in Appendix A) displays a flat, then increasing, then decreasing pattern. The trend test is unable to draw a statistically significant line through these data.

In conclusion, the monotonic trends at individual wells are predominately decreasing but also include increasing and statistically insignificant trends. Examination of LOWESS lines through the nitrate data illustrates more subtle changes in concentration over time. Trends are often more complicated than a straight line. Water quality changes seen in the data are smoothed by the LOWESS line and distilled to a straight line by the trend analysis. The smoothing often highlights changes over time while a straight line over-simplifies changes.

Determining why specific wells exhibit high concentrations and/or steeply increasing trends could provide useful information in identifying best management practices that could reduce nonpoint source pollution and/or identifying point source contamination sources that should be addressed. Shallow wells can be affected by both point source and nonpoint source nitrate contamination. For example, well MAL126 located in Vale is potentially affected by a former bulk fertilizer plant located nearby.

4.1.2 Nitrate Trends Versus Geographic Location

Figures 4-2 and 4-3 illustrate the nitrate trends and average nitrate concentrations at each well. Symbols are placed at well locations indicating the trend direction and magnitude on Figure 4-2. Colors and numbers are placed at well locations indicating the average nitrate concentration on Figure 4-3.

An examination of Figures 4-2 and 4-3 illustrates the following observations:

- The Ontario/Cairo Junction area has a mix of increasing and decreasing trends at wells with low, moderate, and elevated nitrate levels,
- The Pioneer School area (the area north of Payette, Idaho) has predominantly decreasing trends at wells with moderate and elevated nitrate levels,
- The area north of Nyssa has a mix of increasing, decreasing, and statistically insignificant trends at wells with low, moderate, and elevated nitrate levels,
- The Vale area has predominantly decreasing trends at wells with predominantly low nitrate levels (one trend is increasing at a well with elevated nitrate concentrations),
- The Owyhee River area wells exhibit increasing and decreasing trends at wells with low to moderate nitrate levels; the surface water samples exhibit either a decreasing or statistically insignificant trend at low nitrate levels, and
- The Annex area has both decreasing and increasing trends at wells with moderate to elevated nitrate levels.

The most dramatic increase and decrease in nitrate concentrations occurred in close proximity to one another, illustrating that large differences in nitrate trends occur over short distances. The largest decreasing trend is 2.63 ppm/yr at well MAL218 located north of Nyssa. Excluding well MAL119 (which exhibited a trend increasing at 1.92 ppm/yr through April 2001 but has not been sampled since then), the largest increasing trend is 0.69 ppm/yr at well MAL078. Wells MAL218 and MAL078 are located a few hundred yards away from each other.

4.1.3 Nitrate Trends Versus Well Depth

Figure 4-4 is a plot of nitrate trends versus well depth. The symbols indicate which aquifer the wells tap. As indicated by Figure 4-4, the shallower wells exhibit the steepest trends (both increasing and decreasing) while the deeper wells exhibit smaller trends. Increasing, decreasing, and statistically insignificant trends are exhibited by wells in each aquifer. The largest decreasing trend is in a well screening a portion of both aquifers. A Sand & Gravel aquifer well has a slightly smaller decreasing trend. The largest increasing trends are in Sand & Gravel Aquifer wells.

In conclusion, shallow wells exhibit the greatest magnitude of trends while deeper wells exhibit smaller trends. This is likely due to the fact that application of nitrate fertilizer and irrigation water, as well as BMP implementation, occurs at land surface thus creating a greater effect in near-surface wells.

4.2 Area-Wide Trends

Figure 4-5 illustrates the data used to evaluate the area-wide trend as well as the results of the evaluation. Figure 4-5 consists of many stacks of data points at two-month intervals. Each of these stacks of data points represents one sampling event and contains one data point for each well sampled that event. An examination of

Figure 4-5 reveals that most data points from all sampling events are less than 30 ppm with many less than 20 ppm. A few data points exceed 50 ppm, with the maximum value of 99 ppm occurring in August 1998. It is also evident from Figure 4-5, that the number of data points greater than 30 ppm declines after about 1999. The mean concentration of all 2,583 data points is 13.9 ppm while the median concentration is 10.9. If the two wells which are no longer sampled are excluded from the data set (i.e., as if they had never been sampled), the mean concentration of all 2,520 data points would be 13.4 and the median concentration would be 10.3 ppm.
The area-wide trend was estimated using the Regional Kendall test for trend. The Regional Kendall test was set up such that each "well / month sampled" combination was defined as a "season." For example, each sample from well MAL005 sampled in February of any year was designated as belonging to season "MAL005Feb." MAL005Feb contains 12 data points. Data points were grouped into 215 "seasons" with enough data to compute slopes. The total number of "seasons" with at least one data point was 226. If all 38 wells had been sampled every other month from July 1991 through December 1999, there would be 3306 data points and 228 "seasons." The data were evaluated to estimate a trend for each "season," then the individual trends were combined into an area-wide trend.

The Regional Kendall test estimated the area-wide trend to be -0.042 ppm/yr at a 99% confidence level. This result is illustrated in Figure 4-5. The area-wide trend calculated without data from wells MAL119 and 211 (to estimate the effects of no longer sampling the wells with the highest average concentration and steepest increasing trend from the previous analysis) was -0.046 ppm/yr. This result is important in that it satisfies the third measure of Action Plan success which calls for a statistically significant downward trend to be demonstrated at the 80% confidence level.

The LOWESS line through all the data is also illustrated in Figure 4-5. The LOWESS line is basically flat through about 1997 then begins to decrease through 2005. The decline of the LOWESS line after about 1997 is consistent with the lack of data points in the 30 to 50 ppm range after about 1999.

EPA (2006) states "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" and "if the stations exhibit approximate trends in the same direction with comparable slopes, then a single summary statement across stations is valid". The author contacted EPA regarding this statement (Warren, 2006) and was told that the comment was written as a precautionary statement since the document was written for non-statisticians. The intent was to ensure that statistical techniques are not misused and that results are not misinterpreted. Although not all monitoring stations in the GWMA exhibit decreasing nitrate trends, the statistically significant decreasing area-wide nitrate trend and decreasing LOWESS line indicates there has been an overall improvement in groundwater nitrate concentrations from 1991 through 2005.

Regional Kendall Trends by Month
Figure 4-6 illustrates the Regional Kendall trend slopes at each well by month in two different ways. Figure 4-6a is a bar chart showing the number of increasing, decreasing, and flat trends per month. Figure 4-6b is a box and whisker plot[4] showing the nitrate trend slope distribution and median per month. Also indicated in Figure 4-6b is the total number of increasing, decreasing, and flat slopes along with their mean and median slope values.

Figure 4-6 illustrates several aspects of the monthly nitrate trends which suggest improving water quality throughout the GWMA. These include:

- there are more decreasing trends than increasing trends (i.e., 132 decreasing trends versus 78 increasing trends),

[4] Box Plot Explanation – The lower limit of the box is the 25th percentile (i.e., 25% of the data is less than this value). The upper limit of the box is the 75th percentile. The height of the box is the interquartile range (IQR). The box contains the middle 50% of the data. A line drawn across the box indicates the median value. Heights of the two box halves depict the skewness (e.g., if the top half is larger the data is positively skewed). Vertical lines are drawn from the top and bottom of the box to the farthest data points within 1.5 times the IQR. Any data point beyond this distance is plotted individually.

- each month exhibits predominantly decreasing trends (e.g., February exhibited 18 decreasing trends, 13 increasing trends, and 2 flat trends), and
- the decreasing trends are steeper than the increasing trends (i.e., the median decrease is -0.35 ppm/yr while the median increase is 0.21 ppm/yr).

Although the numbers of increasing and decreasing trends per month are similar, it is interesting to note that the most decreasing trends occurred in October while the fewest increasing trends occurred in October and December. The largest difference between the number of increasing and decreasing trends also occurred in October (Figure 4-6a). This pattern is interesting because there are reports of a reduction in fall nitrogen fertilization in the GWMA. If this pattern becomes more pronounced in the future, it might be useful to evaluate whether or not water quality improvements are occurring where the reductions in fall fertilization are occurring. The ability to directly link BMP implementation to groundwater quality improvement would be a significant finding and a useful education and outreach tool. As such, it would illustrate the importance and benefit of BMP implementation to growers as well as the general public. However, documentation of the location and timing of fertilizer application over time would be needed to evaluate this possibility.

Conceptual Model of Area-Wide Nitrate Trend

During the previous trend analysis, a conceptual model was developed of how an area-wide trend might develop in response to BMP implementation. This conceptual model is illustrated in Figure 4-7. It is important to note that the axes in Figure 4-7 are relative scales. No values are included or implied.

In the Northern Malheur County GWMA, this conceptual model is best suited to the flood plains closest to perennial streams (e.g., the Malheur and Owyhee Rivers). Areas outside these flood plains that now contain groundwater likely contained little water prior to the introduction of irrigated agriculture.

As illustrated in Figure 4-7, the conceptual model assumes nitrate concentrations were at some low steady-state background concentration prior to the introduction of agriculture. During the early years of agriculture, over-fertilization and over-irrigation cause the accumulation of nitrate in the unsaturated zone beyond the reach of plants and a dramatic increase of nitrate concentrations in groundwater. As BMPs that improve fertilization and irrigation practices are implemented, the nitrate loading at land surface decreases but the nitrate in the unsaturated zone beyond the reach of plants persists. As time progresses under BMP implementation, the nitrate in the unsaturated zone continues to leach, thus maintaining the increase of groundwater nitrate concentrations, but at a slower rate. When a sufficient amount of nitrate has moved through the system and fertilization and irrigation closely approximates crop needs, nitrate concentrations in groundwater stabilize. Eventually, under continued improvement and expansion of BMPs, groundwater quality gradually improves as the majority of remaining nitrate moves out of the unsaturated zone and through the groundwater system. Ultimately, nitrate concentrations are expected to reach a new steady-state concentration likely higher than the original background concentration (Figure 4-7).

An explanation for the slightly decreasing area-wide trend calculated in this study that is consistent with the conceptual model is if these data reflect the portion of the conceptual model curve that is flattening out and beginning to decline (Figure 4-7). The measures of success in the Action Plan requiring area-wide nitrate concentrations of 7 ppm, or even a statistically significant downward trend, within five years of BMP implementation were overly optimistic. It is clear that a longer time frame will be required for both of these measures of success to be met[5].

[5] DEQ reconsidered the five year time frame for improving groundwater quality during preparation of the Action Plan for the second GWMA in Oregon: the Lower Umatilla Basin GWMA. The Lower Umatilla Basin GWMA was declared after the Northern Malheur County GWMA and the LUB Action Plan was finalized in 1997. In the Lower Umatilla Basin GWMA, groundwater quality data is to be collected for 12 years following Action Plan adoption before the first area-wide trend analysis is conducted.

5.0 COMPARISON OF TREND ANALYSES RESULTS

Table 5-1 presents a comparison of the current (1991 through 2005) and previous (1991 through 1999) trend analyses. Changes in data set statistics as well as changes in the nitrate trends are summarized below. These changes are then summarized as indications of improving and worsening water quality.

5.1 Changes in Data Set Statistics

For each sample location identified in Table 5-1, five changes in data set statistics are provided:

1. The difference between the current and previous minimum value detected is indicated. If the current minimum equals the previous minimum, a value of zero is indicated. If the current minimum is less than the previous minimum, the difference between the two values is indicated. For example, the minimum value observed at well MAL030 in the previous trend analysis was 26 ppm. The minimum value observed at well MAL030 in the current trend analysis was 15.4 ppm. The difference between the two values (i.e., 10.6 ppm) is indicated in Table 5-1.
2. The difference between the current and previous maximum value detected is indicated. If the current maximum equals the previous maximum, a value of zero is indicated. If the current maximum is higher than the previous maximum, the difference between the two values is indicated. For example, the maximum value observed at well MAL016 in the previous trend analysis was 19 ppm. The maximum value observed at well MAL016 in the current trend analysis was 29.5 ppm. The difference between the two values (i.e., 10.5 ppm) is indicated in Table 5-1.
3. The difference between the current and previous mean value is indicated. If the current mean is higher than the previous mean, a positive value is indicated. Conversely, if the current mean is lower than the previous mean, a negative value is indicated.
4. The difference between the current and previous median value is indicated. If the current median equals the previous median, a value of zero is indicated. If the current median is higher than the previous median, a positive value is indicated. If the current median is lower than the previous median, a negative value is indicated.
5. The number of additional samples analyzed since the previous trend analysis is indicated. Most locations have more than 32 additional samples. Three locations have less than 10 additional samples.

The changes in data set statistics are summarized at the bottom of Table 5-1 and reiterated below.

New Minimum and Maximum Values
42% of the stations (15 wells and both drains) exhibited new minimum values (0.015 to 10.6 ppm lower).
32% of the stations (12 wells and 1 drain) exhibited new maximum values (0.2 to 31.1 ppm higher).
4 wells and 1 drain exhibited both a new maximum and minimum value.

Changes in Mean Values
65% of stations (24 wells and both drains) exhibited lower mean values (0.01 to 13.51 ppm lower).
35% of stations (14 wells) exhibited higher mean values (0.03 to 6.5 ppm higher).

Changes in Median Values
60% of stations (22 wells and both drains) exhibited lower median values (0.02 to 18.02 ppm lower).
10% of stations (4 wells) exhibited no change in median values.
30% of stations (12 wells) exhibited an increase in median values (0.01 to 1.5 ppm higher).

5.2 Trend Comparison

For each sample location identified in Table 5-1, results from the current and previous trend analyses are presented along with a summary of the change in trend. The change in trend is expressed in two ways: (1) as a slope and confidence level, and (2) as a description of the change in calculated trends. For example, the trend at well MAL030 during the previous trend analysis was 0.22 ppm/yr at a 95% confidence level while the trend during the current trend analysis was -0.56 ppm/yr at a 99% confidence level. Therefore, the change in trend is expressed both as a change in slope of -0.78 ppm/yr and “from increasing trend to decreasing trend”. It should be noted that the numbers in the spreadsheet used to create Table 5-1 contain more than two digits but are typically displayed to two significant figures. The resulting rounding can cause the appearance of incorrect math. The changes in nitrate trends are summarized at the bottom of Table 5-1 and reiterated below.

Trend Slope
66% of stations (23 wells and both drains) exhibited improving trends.
34% of stations (13 wells) exhibited worsening trends.

Results from wells MAL119 and MAL211 are not included in the percentages cited above because no more than 3 additional samples were collected from these wells since the previous analysis. Trends at these two wells increased with the addition of these few additional samples, which would make 15 (rather than 13) locations at which nitrate levels worsened.

The locations of changes in nitrate trends between the two trend analyses are presented in Figure 5-1. Observing different trends in different geographic regions is consistent with expectations made during preparation and implementation of the Action Plan. For example, it was anticipated that groundwater quality would first improve in the upper reaches of the valleys as BMPs were implemented near the beginning of groundwater flow paths, and take longer for groundwater quality to improve at lower elevations near the end of groundwater flow paths. As expected, many of the locations exhibiting worsening nitrate trends are located towards the end of ground water flow paths (i.e., along the lower reaches of the Malheur River and towards the Snake River). However, some locations exhibiting worsening nitrate trends are in the upper portions of the GWMA which were expected to respond quickest to BMP implementation. This highlights the importance of continued, and perhaps, expanded implementation of BMPs.

5.3 Indications of Improving and Worsening Water Quality

Some of the changes in nitrate data set statistics and trends discussed above have been summarized in Table 5-2 as indications of improving or worsening water quality. Table 5-2 includes more indications of improving water quality than worsening water quality. Furthermore, the indications considered most important (e.g., the area-wide trend, the number of individual increasing and decreasing trends) all suggest improving water quality.

The information in Table 5-2 can also be stated as follows:

- the overall area-wide nitrate trend changed from a statistically insignificant flat trend to a statistically significant slightly declining trend,
- the area-wide nitrate trends by month exhibit more decreasing trends than increasing trends, and the decreasing trends are steeper than the increasing trends,
- more wells show overall decreasing trends than increasing trends,
- the average slope of all trends decreased,
- more monitoring stations exhibited new minimum concentrations (42%) than new maximum concentrations (32%),
- more monitoring stations show a decrease in trend slope (66%) than an increase in trend slope (34%),
- more monitoring stations exhibited lower mean and median concentrations than higher mean and median concentrations, and
- the area-wide mean and median concentrations were lower.

Although not all monitoring stations in the GWMA exhibit decreasing nitrate trends, the multiple lines of evidence suggesting improving water quality discussed above (including the statistically significant decreasing area-wide trend) provide sufficient evidence to conclude there has been an overall improvement in groundwater nitrate concentrations from 1991 through 2005.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Based on the information presented in this report, the following conclusions were drawn from this study:

- The Action Plan goal of achieving an area-wide nitrate concentration of 7 mg/l with a 75% confidence level has not yet been met. The area-wide mean and median concentrations are 13.9 and 10.9 mg/l, respectively.
- The Action Plan goal of achieving area-wide nitrate concentration of 7 mg/l by July 1, 2000 was not met.
- Although not all monitoring stations in the GWMA exhibit decreasing nitrate trends, the multiple lines of evidence suggesting improving water quality (including the statistically significant decreasing area-wide trend) provide sufficient evidence to conclude there has been an overall improvement in groundwater nitrate concentrations from 1991 through 2005. Therefore, the third measure of Action Plan success has been met.
- Continued and perhaps expanded BMP implementation is needed to attain and maintain water quality improvements.

6.2 Recommendations

Based on the conclusions stated above, the following recommendations are made. These recommendations are grouped according to the responsible parties.

Groundwater Management Committee and Malheur County SWCD

- By March 2008 produce a report that documents BMP implementation.
- As appropriate and as resources provided allow, evaluate the possibility of point source contributions in the vicinity of wells with increasing nitrate trends.
- As available and appropriate, provide financial and technical support to assist in the continued research, documentation, and implementation of appropriate BMPs in the GWMA as well as projects such as deep soil sampling to evaluate changes in the amount and movement of nitrate within the unsaturated zone.

Groundwater Management Committee and DEQ with support from Federal, State, and County Agencies associated with this project

- Amend the Action Plan to allow the use of the Seasonal Kendall method for the evaluation of water quality trends rather than requiring the use of the ordinary least squares method.
- Amend the Action Plan to remove the unattainable goal of an area-wide nitrate concentration of 7 mg/l by July 1, 2000.

DEQ

- Continue to sample the existing well network (i.e., the 36 wells and 2 surface water bodies) every other month for nitrate to maintain the water quality database.
- Perform another formal trend analysis of nitrate concentrations in 2010 using cadmium reduction nitrate data collected through December 2009.
- Investigate the possibility of point source contamination affecting well MAL126.
- As available and appropriate, provide financial and technical support to assist in the continued research and implementation of appropriate BMPs in the GWMA as well as projects such as deep soil sampling to evaluate changes in the amount and movement of nitrate within the unsaturated zone.

7.0 REFERENCES

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Table 4-1
Summary of Individual Well Nitrate Trends
Second Northern Malheur County GWMA Trend Analysis Report

Sample Location	Data Set Statistics								Trend Analysis Results		Trend Direction	Are the Data Seasonal?	LOWESS Pattern
	Starting Date	Ending Date	Minimum	Maximum	Mean	Median	n	% BDL	Slope (ppm/yr)	Confidence Level			
MAL005	Feb-92	Dec-05	4.25	8.6	6.39	6.75	76	0%	0.14	99%	Increasing	No	Increasing, decreasing, then increasing
MAL012	Aug-91	Dec-05	9.39	36	23.80	23.7	76	0%	-0.76	99%	Decreasing	No	Decreasing, increasing, then decreasing
MAL016	Aug-91	Oct-05	8.55	29.5	14.91	13	66	0%	0.20	84%	Increasing	No	Decreasing then increasing
MAL030	Aug-91	Dec-05	15.4	31	26.28	27.15	76	0%	-0.56	99%	Decreasing	No	Increasing then decreasing
MAL035	Aug-91	Dec-05	19	35.7	28.33	29	79	0%	-0.38	99%	Decreasing	No	Increasing then decreasing
MAL041	Aug-91	Oct-05	15.5	21.8	18.06	18	74	0%	0.03	94%	Increasing	Yes	Flat, increasing, then decreasing
MAL044	Aug-91	Dec-05	14.7	22	17.81	18	78	0%	-0.15	99%	Decreasing	No	Flat, decreasing, then increasing
MAL047	Aug-91	Dec-05	18.2	48	31.13	31	80	0%	-1.23	99%	Decreasing	No	Increasing then decreasing
MAL062	Aug-91	Oct-05	11.5	54	25.45	36	61	0%	-0.99	99%	Decreasing	No	Increasing, decreasing, then starting to level off
MAL064	Aug-91	Dec-05	0.0107	22	6.95	7.04	76	0%	-0.11	53%	NS80	Yes	Decreasing then flat
MAL078	Feb-93	Dec-05	<0.0050	74.7	15.37	7.68	72	1%	0.69	99%	Increasing	Yes	Increasing then decreasing
MAL079	Feb-93	Dec-05	3.51	21	9.83	9.9	75	0%	0.03	29%	NS80	No	Basically flat
MAL083	Feb-93	Dec-05	3.18	47	21.51	3.18	71	0%	-1.36	99%	Decreasing	No	Decreasing, increasing, then decreasing
MAL101	Oct-91	Dec-05	1.3	43.6	10.13	7.94	77	0%	0.41	91%	Increasing	No	Increasing, decreasing, then increasing
MAL105	Aug-91	Jun-05	15	33	25.89	25.15	80	0%	0.14	82%	Increasing	No	Increasing then decreasing
MAL106	Apr-93	Oct-05	0.0057	31	16.51	19.5	46	0%	-2.57	99%	Decreasing	No	Increasing then decreasing
MAL108	Aug-91	Dec-05	0.07	4	1.15	0.64	81	0%	0.003	19%	NS80	Yes	Decreasing, increasing, then decreasing
MAL116	Aug-91	Dec-05	2.16	19	5.04	3.91	51	0%	-0.15	94%	Decreasing	Yes	Decreasing, increasing, then decreasing
MAL119	Aug-91	Apr-01	9.3	26.7	20.13	22.15	30	0%	1.92	99%	Increasing	No	Increasing then flat
MAL121	Aug-91	Dec-05	10.1	15	12.71	13	79	0%	-0.06	99%	Decreasing	No	Flat then decreasing
MAL125	Aug-91	Dec-05	2.35	24	8.27	7.1	57	0%	-0.60	99%	Decreasing	Yes	Flat, decreasing, then increasing
MAL126	Feb-93	Oct-05	4.9	99	29.26	20.25	72	0%	0.65	92%	Increasing	Yes	Increasing, decreasing, then increasing
MAL129	Feb-93	Dec-05	0.606	8.1	3.22	3.4	74	0%	-0.30	99%	Decreasing	No	Decreasing, then decreasing steeper
MAL136	Aug-91	Dec-05	7.78	14	9.37	8.82	78	0%	-0.21	99%	Decreasing	No	Decreasing then increasing
MAL147	Aug-91	Dec-05	<0.0050	0.36	0.02	0.006	77	53%	-0.002	89%	Decreasing	No	Decreasing then flat
MAL152	Jun-93	Oct-05	4.21	16	9.49	9.7	47	0%	-0.42	99%	Decreasing	No	Increasing then decreasing
MAL164	Aug-91	Oct-05	1.85	8.45	3.83	3.32	55	0%	-0.14	99%	Decreasing	Yes	Decreasing, increasing, then decreasing
MAL172	Aug-91	Dec-05	2	14	7.68	7.65	76	0%	-0.48	99%	Decreasing	No	Decreasing then leveling off
MAL175	Aug-91	Dec-05	7.09	22	12.95	13	78	0%	-0.50	99%	Decreasing	No	Increasing then decreasing
MAL180	Apr-93	Dec-05	2.21	6.36	3.96	3.955	74	0%	-0.02	60%	NS80	Yes	Decreasing, increasing, then decreasing
MAL189	Feb-93	Oct-05	7.4	11.2	8.84	8.8	62	0%	0.05	99%	Increasing	No	Increasing then increasing less steeply
MAL211	Aug-91	Apr-00	16.2	76	46.07	48	33	0%	0.29	40%	NS80	No	Basically flat
MAL216	Aug-92	Dec-05	<0.0050	0.36	0.02	0.0056	72	54%	-0.003	99%	Decreasing	No	Basically flat
MAL217	Apr-93	Dec-05	12	21.7	16.53	16.5	73	0%	0.49	99%	Increasing	No	Increasing then decreasing
MAL218	Apr-95	Dec-05	1.8	46.5	17.26	14.8	63	0%	-2.63	99%	Decreasing	No	Decreasing then flat
OWY002	Aug-91	Dec-05	1.4	6.93	4.18	4.5	77	0%	-0.10	97%	Decreasing	No	Increasing then decreasing
OWY009	Apr-93	Oct-02	<0.0050	7.1	3.14	3.3	35	6%	0.33	99%	Increasing	No	Increasing then increasing less steeply
OWY101	Aug-91	Oct-05	2.54	12	9.54	9.2	76	0%	0.16	99%	Increasing	No	Increasing then beginning to level off
OWYDRN001	Feb-93	Dec-05	0.38	7.05	3.89	4.05	74	0%	0.01	25%	NS80	Yes	Slight increase then slight decrease
OWYDRN002	Feb-93	Dec-05	0.94	6.9	3.95	4.88	74	0%	-0.05	99%	Decreasing	Yes	Basically flat

# of Increasing Trends at wells ==>	12 (32%)
# of Decreasing Trends at wells ==>	21 (55%)
# of Flat Trends at wells ==>	0 (0%)
# of Insignificant Trends at wells==>	5 (13%)

Average slope of significant trends at the 38 wells ==>	-0.25
Average slope of all trends at the 38 wells ==>	-0.22

Notes:
n = number of samples; BDL = below detection limit
NS80 = not significant at an 80% confidence level

E:\Malheur\2006 Trend Analysis\[all trends.xls]Nitrate Trends thru 2005

Table 5-1
Comparison of Nitrate Data and Trends Between Analyses
Second Northern Malheur County GWMA Trend Analysis Report

Sample Location	Change In Data Set Statistics					1991 Through 1999 Trend		1991 Through 2005 Trend		Change in Trend	Change in Calculated Trends
	Minimum	Maximum	Mean	Median	n	Slope (ppm/yr)	Confidence Level	Slope (ppm/yr)	Confidence Level	Slope (ppm/yr)	
MAL005	0	0.9	0.22	0.05	35	0.38	99%	0.14	99%	-0.25	From increasing trend to less steep increasing trend
MAL012	0	0	-1.57	-1.30	31	-0.89	95%	-0.76	99%	0.13	From decreasing trend to less steep decreasing trend
MAL016	0	10.5	1.60	0.00	25	-0.75	99%	0.20	84%	0.95	From decreasing trend to increasing trend
MAL030	10.6	0	-2.05	-0.85	32	0.22	95%	-0.56	99%	-0.78	From increasing trend to decreasing trend
MAL035	0	0	-1.26	-1.00	35	1.00	99%	-0.38	99%	-1.37	From increasing trend to decreasing trend
MAL041	0.5	0.2	0.13	0.00	30	0.20	95%	0.03	94%	-0.17	From increasing trend to less steep increasing trend
MAL044	0.3	0	-0.74	-0.60	34	0.09	NS80	-0.15	99%	-0.24	From SI increasing trend to decreasing trend
MAL047	3.6	0	-3.58	-4.00	34	-0.99	NS80	-1.23	99%	-0.24	From SI decreasing trend to steeper decreasing trend
MAL062	10.6	0	-13.51	-4.00	18	1.33	80%	-0.99	99%	-2.32	From increasing trend to decreasing trend
MAL064	0	0	-0.42	-0.76	32	-0.30	NS80	-0.11	NS80	0.19	From SI decreasing trend to less steep SI decreasing trend
MAL078	>0.575	31.1	6.50	1.18	29	0.53	80%	0.69	99%	0.16	From increasing trend to steeper increasing trend
MAL079	0	3.0	0.55	0.40	35	-0.54	80%	0.03	NS80	0.56	From decreasing trend to SI increasing trend
MAL083	5.7	0	-2.91	-18.02	33	-3.30	99%	-1.36	99%	1.94	From decreasing trend to less steep decreasing trend
MAL101	0	21.6	1.55	0.64	34	-0.62	80%	0.41	91%	1.04	From decreasing trend to increasing trend
MAL105	0	0	-0.24	-2.85	33	1.51	99%	0.14	82%	-1.37	From increasing trend to less steep increasing trend
MAL106	0	0	-8.70	-8.50	20	0.63	90%	-2.57	99%	-3.20	From increasing trend to decreasing trend
MAL108	0	0	0.10	0.12	35	-0.04	95%	0.003	NS80	0.04	From decreasing trend to SI increasing trend
MAL116	0	0	-0.19	0.01	21	-0.25	NS80	-0.15	94%	0.11	From SI decreasing trend to less steep decreasing trend
MAL119	0	0.7	0.43	1.15	3	1.99	99%	1.92	99%	-0.07	From increasing trend to less steep increasing trend
MAL121	1.9	0	-0.32	0.00	34	0.00	NS80	-0.06	99%	-0.06	From SI flat trend to decreasing trend
MAL125	2.8	0	-2.63	-1.70	25	-0.60	NS80	-0.60	99%	-0.001	From SI decreasing trend to decreasing trend
MAL126	0	0	1.68	0.35	32	0.55	NS80	0.65	92%	0.10	From SI increasing trend to steeper increasing trend
MAL129	2.0	0	-0.99	-0.50	33	-0.05	NS80	-0.30	99%	-0.25	From SI decreasing trend to steeper decreasing trend
MAL136	0	0	-0.51	-0.98	34	-0.76	99%	-0.21	99%	0.55	From decreasing trend to less steep decreasing trend
MAL147	0	0	-0.01	0.00	33	0.00	99%	-0.002	89%	-0.002	From flat trend to decreasing trend
MAL152	0.3	0	-1.58	-1.30	21	0.49	NS80	-0.42	99%	-0.91	From SI increasing trend to decreasing trend
MAL164	0	0	-0.27	-0.28	23	-0.59	99%	-0.14	99%	0.45	From decreasing trend to less steep decreasing trend
MAL172	0	0	-1.49	-1.85	35	-0.21	NS80	-0.48	99%	-0.27	From SI decreasing trend to steeper decreasing trend
MAL175	2.9	0	-1.91	-1.00	34	0.49	95%	-0.50	99%	-0.99	From increasing trend to decreasing trend
MAL180	0.1	0.8	-0.01	-0.04	34	0.08	NS80	-0.02	NS80	-0.10	From SI increasing trend to SI decreasing trend
MAL189	0	1.2	0.14	0.20	24	0.10	99%	0.05	99%	-0.05	From increasing trend to less steep increasing trend
MAL211	0	0	0.03	-0.50	1	-0.50	NS80	0.29	NS80	0.80	From SI decreasing trend to SI increasing trend
MAL216	0	0	-0.10	-0.09	31	0.00	95%	-0.003	99%	-0.003	From flat trend to decreasing trend
MAL217	0	1.7	1.10	1.50	33	0.97	99%	0.49	99%	-0.47	From increasing trend to less steep increasing trend
MAL218	0	0	-9.21	-12.20	34	-2.52	95%	-2.63	99%	-0.12	From decreasing trend to steeper decreasing trend
OWY002	2.0	0.9	-0.47	-0.20	35	0.10	99%	-0.10	97%	-0.20	From increasing trend to decreasing trend
OWY009	0.015	0	0.25	0.40	9	0.40	90%	0.33	99%	-0.07	From increasing trend to less steep increasing trend
OWY101	0	2.0	0.71	0.30	32	0.04	NS80	0.16	99%	0.12	From SI increasing trend to steeper increasing trend
OWYDRN001	0.6	0.2	-0.02	-0.15	35	0.20	99%	0.01	NS80	-0.20	From increasing trend to less steep SI increasing trend
OWYDRN002	0.5	0	-0.16	-0.02	35	-0.03	NS80	-0.05	99%	-0.02	From SI decreasing trend to steeper decreasing trend

Summary of Differences

Minimum and Maximum
42% of stations (15 wells and both drains) exhibited new minimum (0.015 to 10.6 ppm lower).
32% of stations (12 wells and 1 drain) exhibited new maximums (0.2 to 31.1 ppm higher).
4 wells and 1 drain exhibited both a new maximum and minimum concentration

Mean
65% of stations (24 wells and both drains) exhibited lower means (0.01 to 13.51 ppm lower)
35% of stations (14 wells) exhibited higher mean values (0.03 to 6.5 ppm higher).

Median
60% of stations (22 wells and both drains) exhibited lower median (0.02 to 18.02 ppm lower).
10% of stations (4 wells) exhibited no change in median values
30% of stations (12 wells) exhibited an increase in median values (0.01 to 1.5 ppm higher).

Trend Slope
66% of stations (23 wells and both drains) exhibited improving trends
34% of stations (13 wells) exhibited worsening trends.
This does not include wells MAL119 and MAL211 since these have only
1 or 3 additional data points since the previous trend analysis.

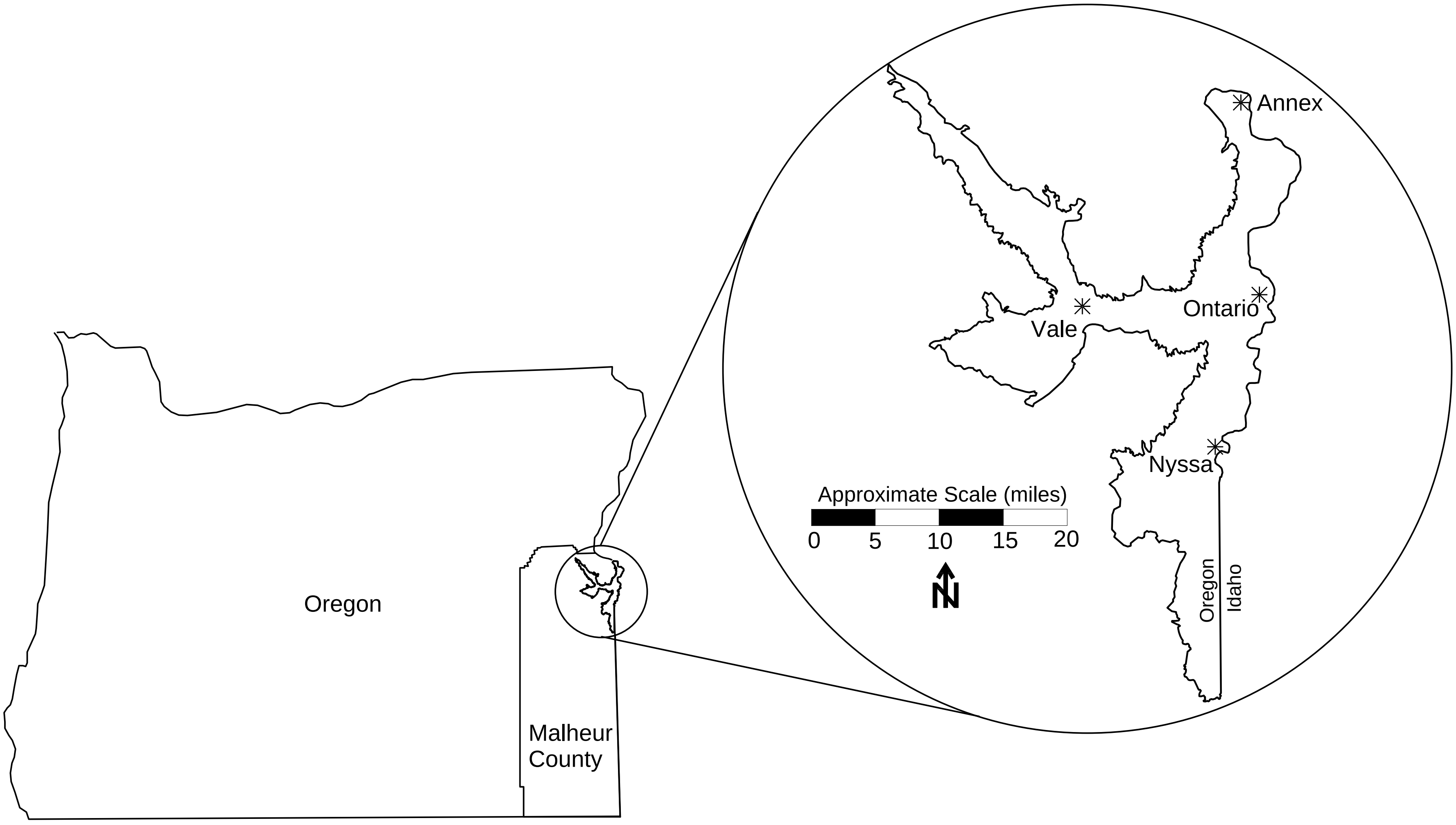
E:\Malheur\2006 Trend Analysis\[all trends.xls]Differences 1999-2005

Table 5-2
Indications of Improving and Worsening Water Quality
Second Northern Malheur County GWMA Trend Analysis Report

Variable	Indications of Improving Water Quality*	Indications of Worsening Water Quality*
Overall area-wide nitrate trend	Changed from flat to decreasing *(from 0.0 to -0.04 ppm/yr)*	
Area-wide trends by month	Overall, there are more decreasing trends than increasing trends; Every month exhibits predominantly decreasing trends; Decreasing trends are steeper than increasing trends	
LOWESS line through all data	Changed from flat from 1991 through late 1990s to slightly declining through 2005	
Number of decreasing trends at individual locations	More wells show decreasing trends *(from 9 to 21)*	
Number of increasing trends at individual locations	Fewer wells show increasing trends *(from 15 to 12)*	
Average slope of all trends	Decreased *(from -0.01 to -0.25 ppm/yr for significant trends)* *(from -0.05 to -0.22 ppm/yr for all 38 wells)*	
New minimum concentrations	42% of monitoring stations exhibited new minimum concentrations *(ranging from 0.015 to 10.6 ppm lower)*	
New maximum concentrations		32% of monitoring stations exhibited new maximums *(ranging from 0.2 to 31.1 ppm higher)*
Change in trend line slope	66% of monitoring stations show a decrease in trend slope *(slope changes range from -3.20 to 1.94 ppm/yr;* *average slope change = -0.17 ppm/yr;* *median slope change = -0.06 ppm/yr)*	34% of monitoring stations show an increase in trend slope
Mean concentrations	65% of monitoring stations exhibited lower mean concentrations *(0.01 to 13.51 ppm lower)* Area-wide mean concentration was lower *(1.1 ppm lower; from 15.0 to13.9)* *[it is1.6 ppm lower if data from wells MAL119 and MAL211 are excluded]*	35% of monitoring stations exhibited higher mean concentrations *(0.03 to 6.5 ppm higher)*
Median concentrations	60% of monitoring stations exhibited lower median concentrations *(0.2 to 18.02 ppm lower)* Area-wide median concentration was lower *(1.1 ppm lower; from 12.0 to 10.9)* *[it is 1.7 ppm lower if data from wells MAL119 and MAL211 are excluded]*	30% of monitoring stations exhibited higher median concentrations *(0.01 to 1.5 ppm higher)*

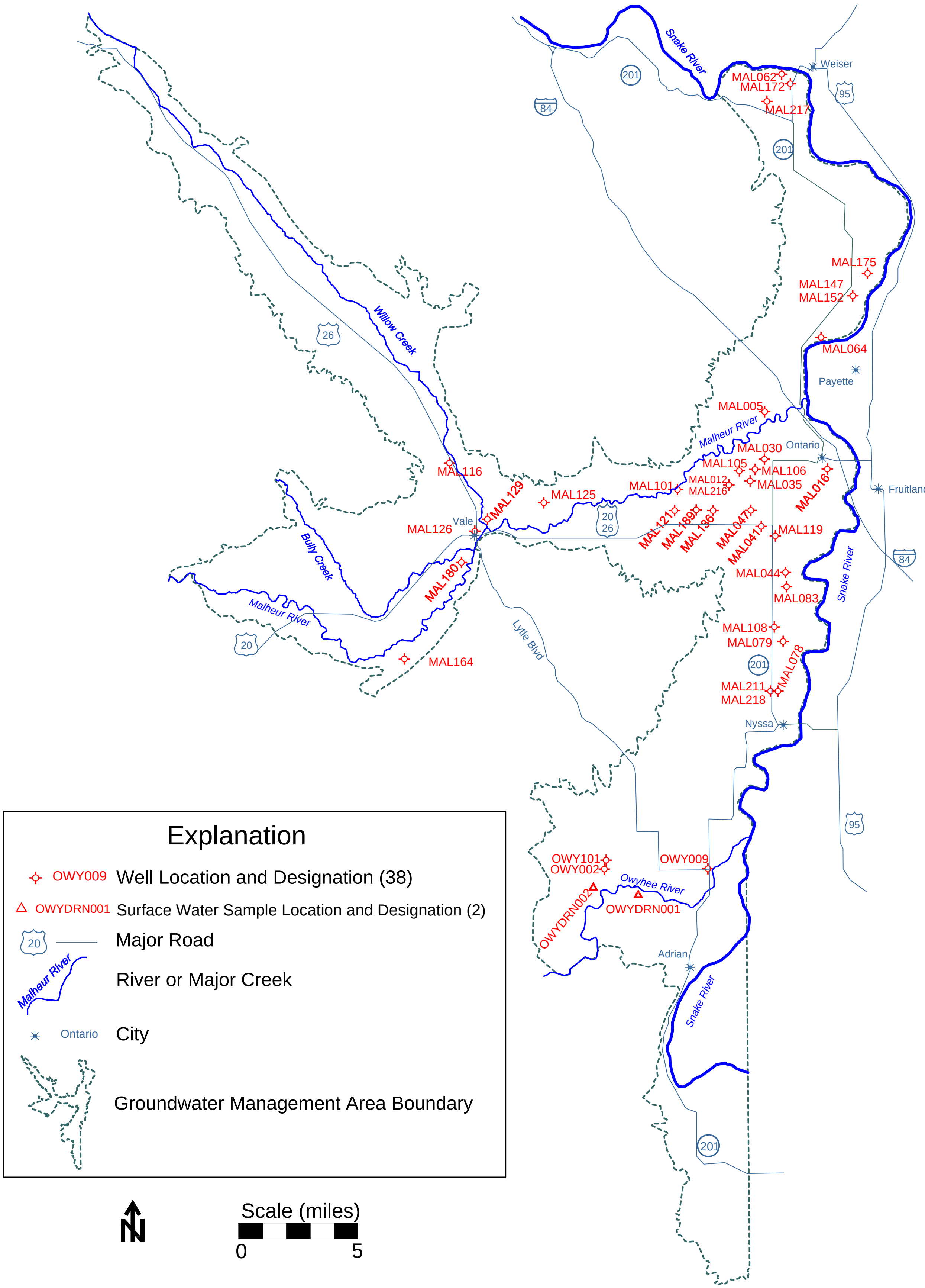
* = when the 1991 through 1999 data set is compared to the 1991 through 2005 data set

Figure 1-1
Location of Northern Malheur County Groundwater Management Area
Second Northern Malheur County GWMA Trend Analysis Report



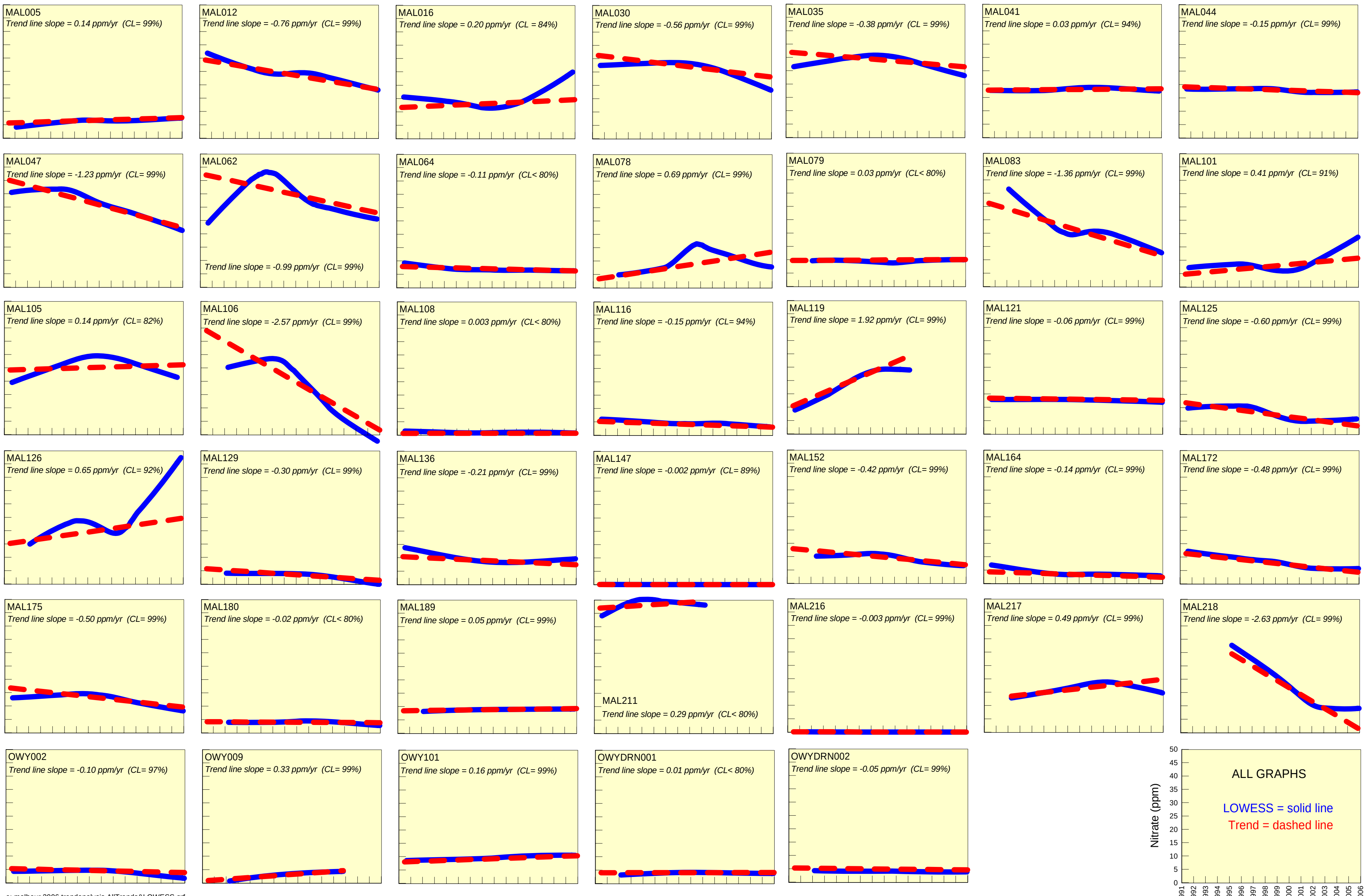
e: malheur 2006 trend analysis figure 1-1.srf

Figure 1-2
Well Location Map
Second Northern Malheur County GWMA Trend Analysis Report



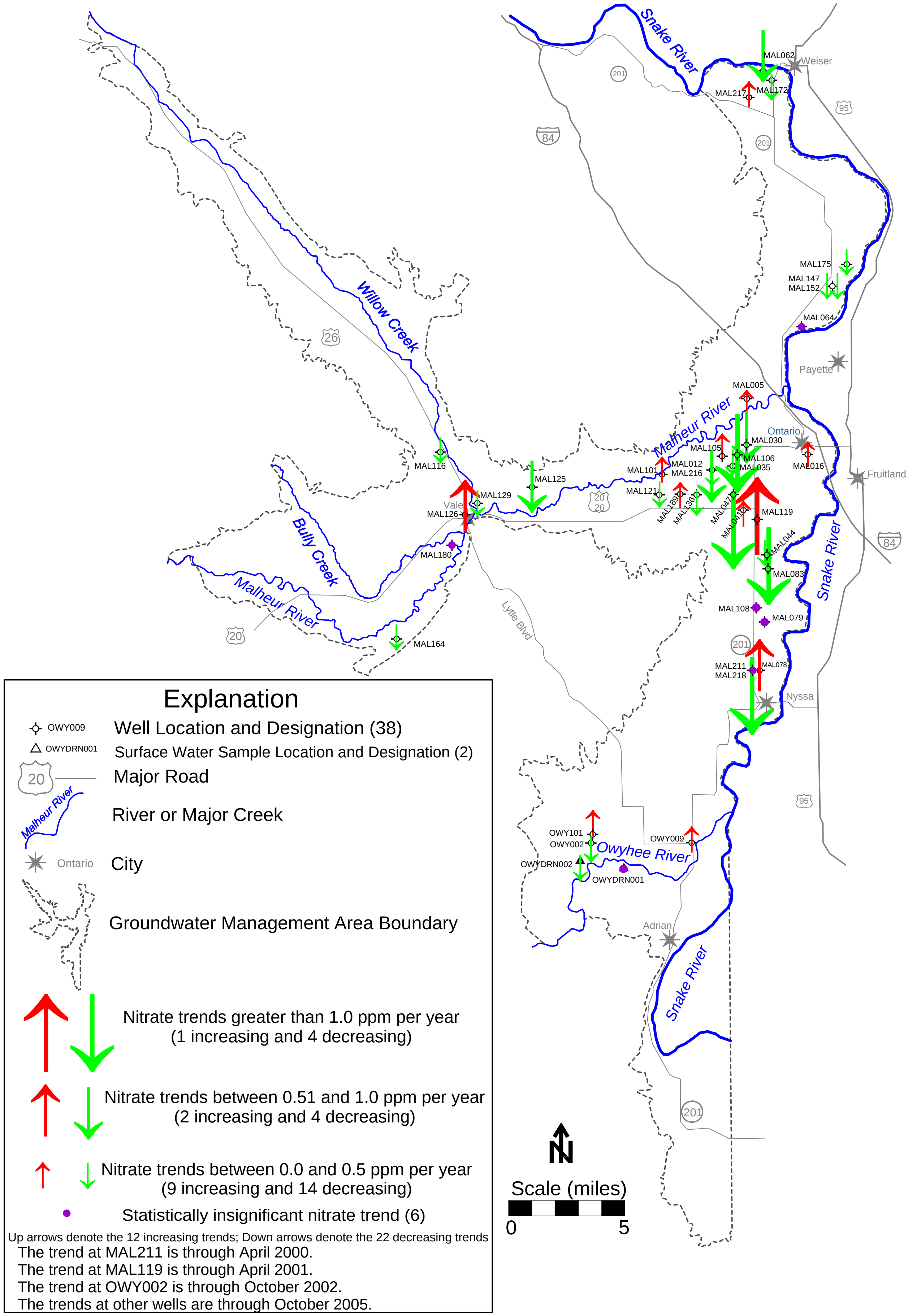
e: malheur 2006trendanalysis figure 1-2.srf

Figure 4-1
LOWESS Lines and Trend Lines Through Nitrate Data
Second Northern Malheur County GWMA Trend Analysis Report



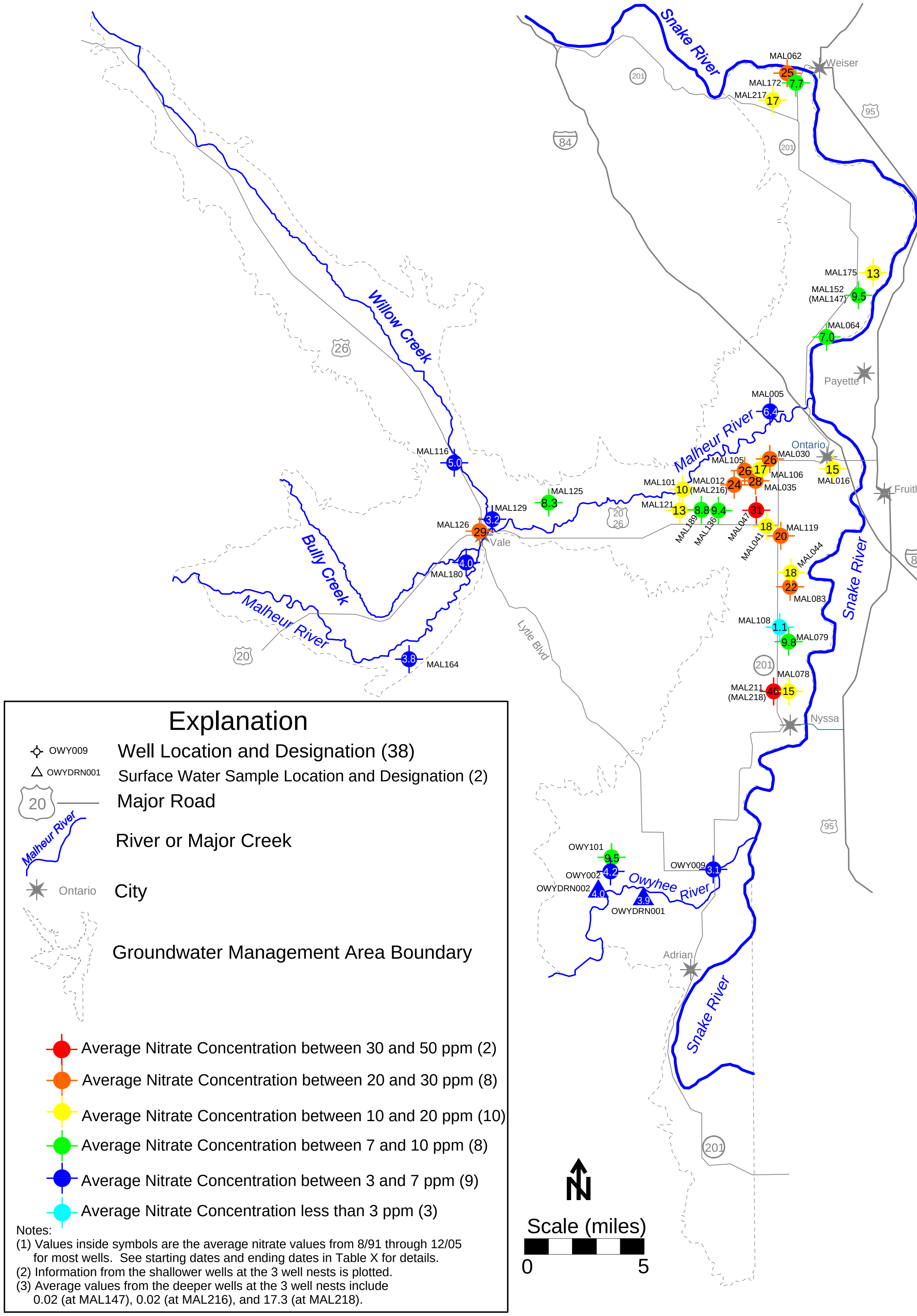
e: malheur 2006 trendanalysis AllTrends&LOWESS.grf

Figure 4-2
Nitrate Trends at Individual Wells
Second Northern Malheur County GWMA Trend Analysis Report



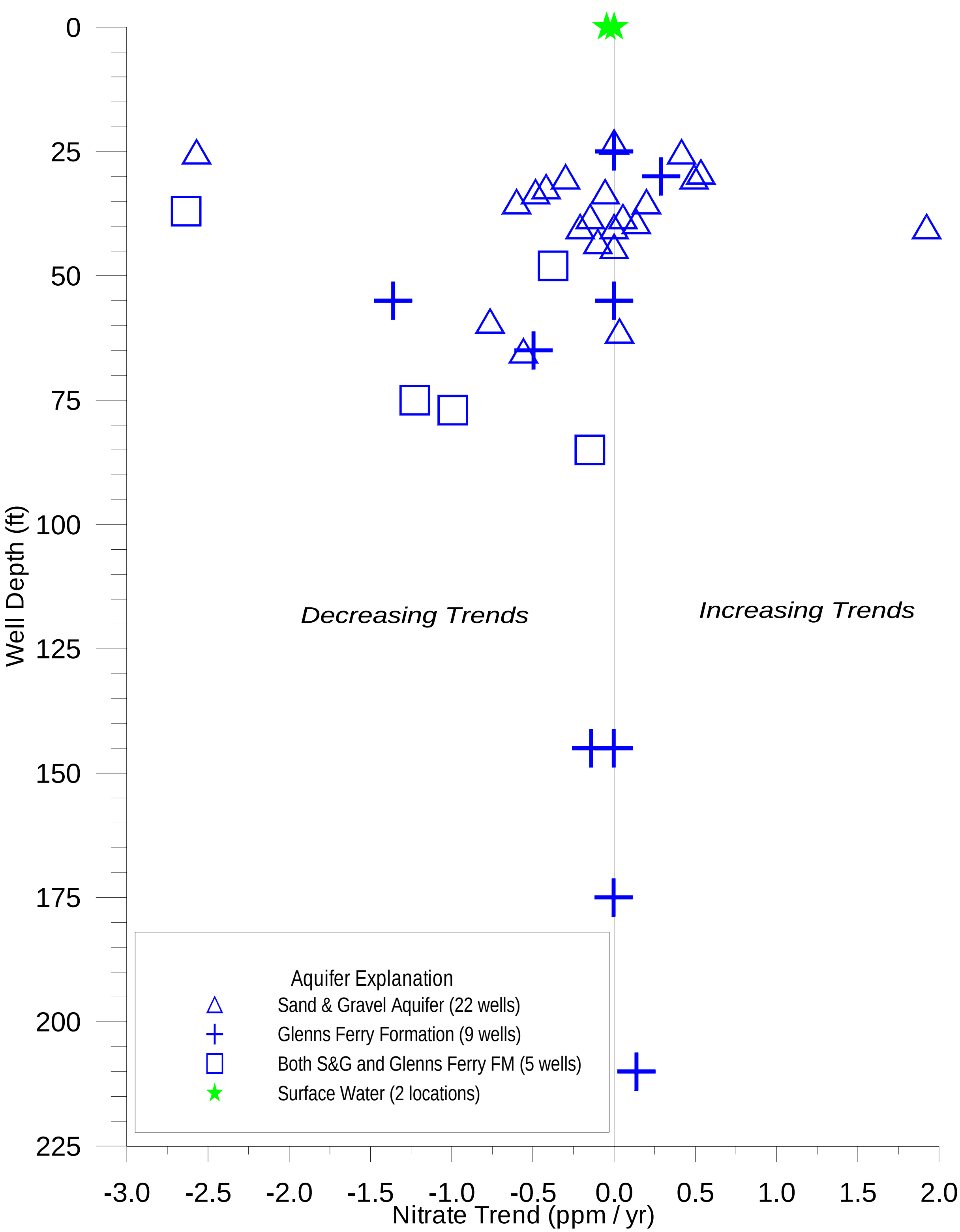
e: malheur 2006 trend analysis no3trnd.srf

Figure 4-3
Average Nitrate Concentrations at Individual Wells
Second Northern Malheur County GWMA Trend Analysis Report



e: malheur 2006 trend analysis no3avg.srf

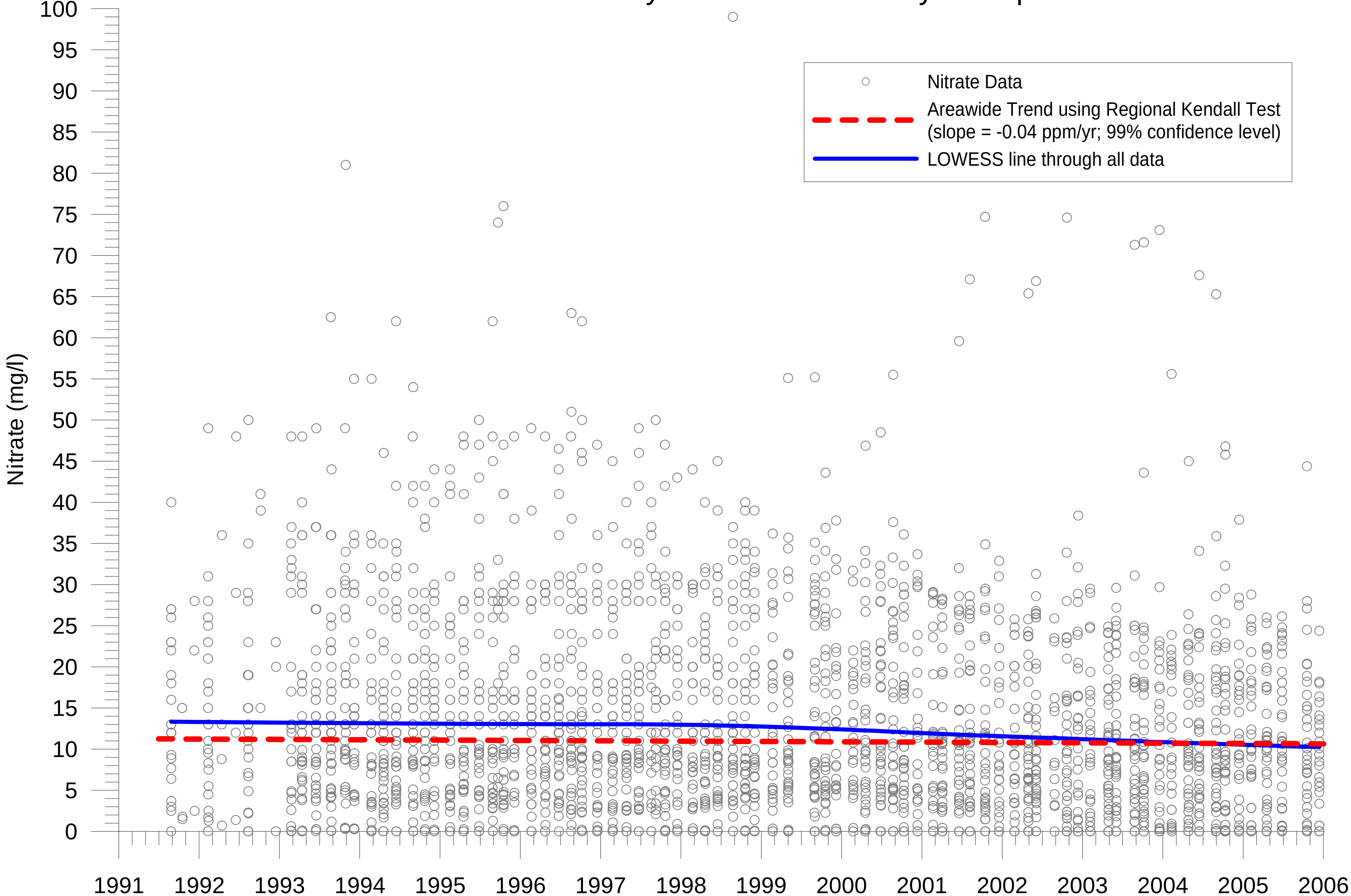
Figure 4-4
Nitrate Trend vs. Well Depth
Second Northern Malheur County GWMA Trend Analysis Report



Notes:
(1) Two wells of unknown depth are assumed to be S&G AQ wells and are not plotted.
Both have increasing trends (0.16 ppm/yr and 0.65 ppm/yr).
(2) Wells with no significant trend are plotted with a 0.0 ppm/yr trend.

e: malheur 2006 trend analysis Trend vs Depth.grf

Figure 4-5
Area-Wide Nitrate Trend
Second Northern Malheur County GWMA Trend Analysis Report



e: malheur 2006 trend analysis areawide nitrate trend.grf

Figure 4-6
Nitrate Trends By Month
Second Northern Malheur County GWMA Trend Analysis Report

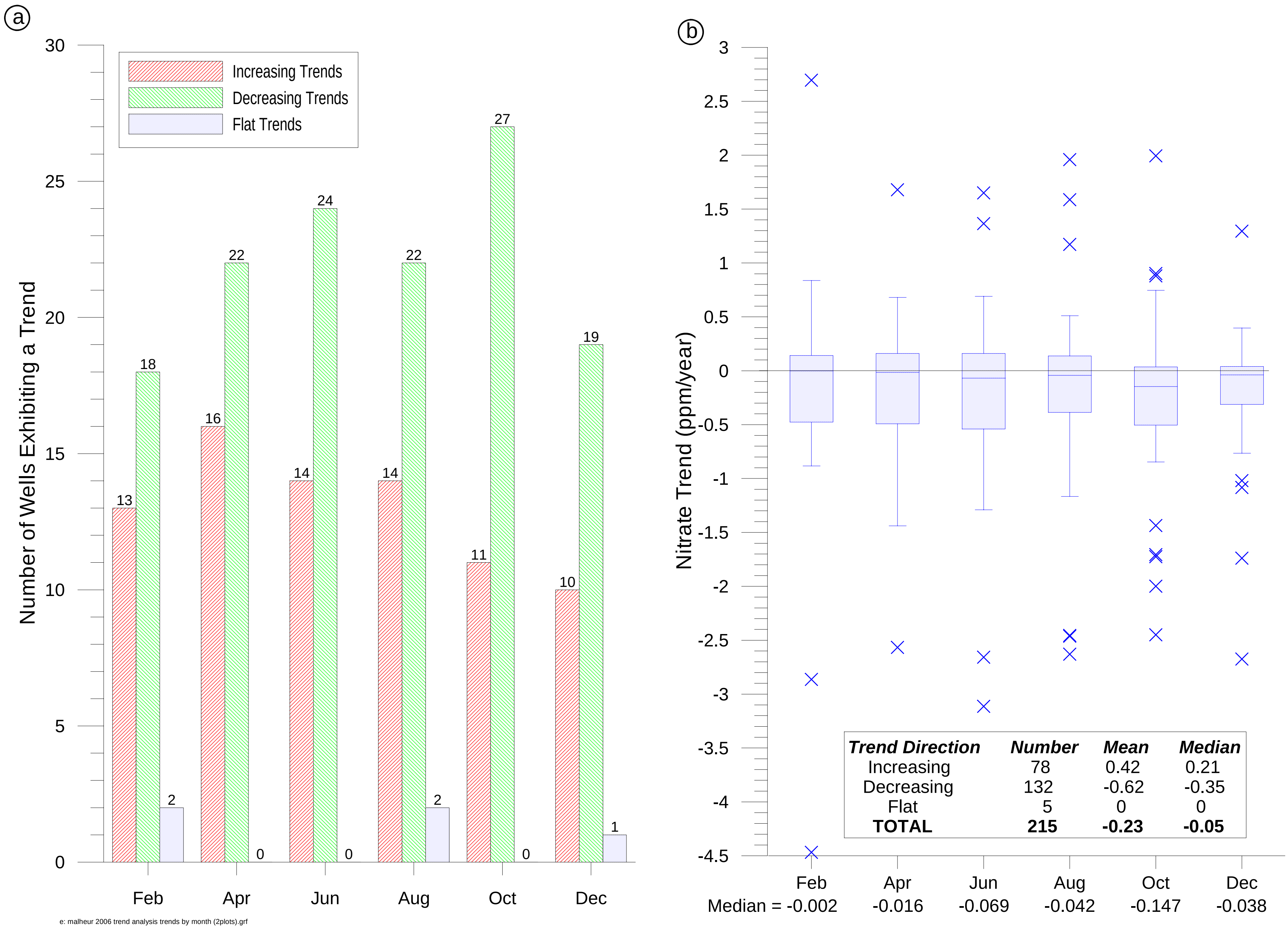
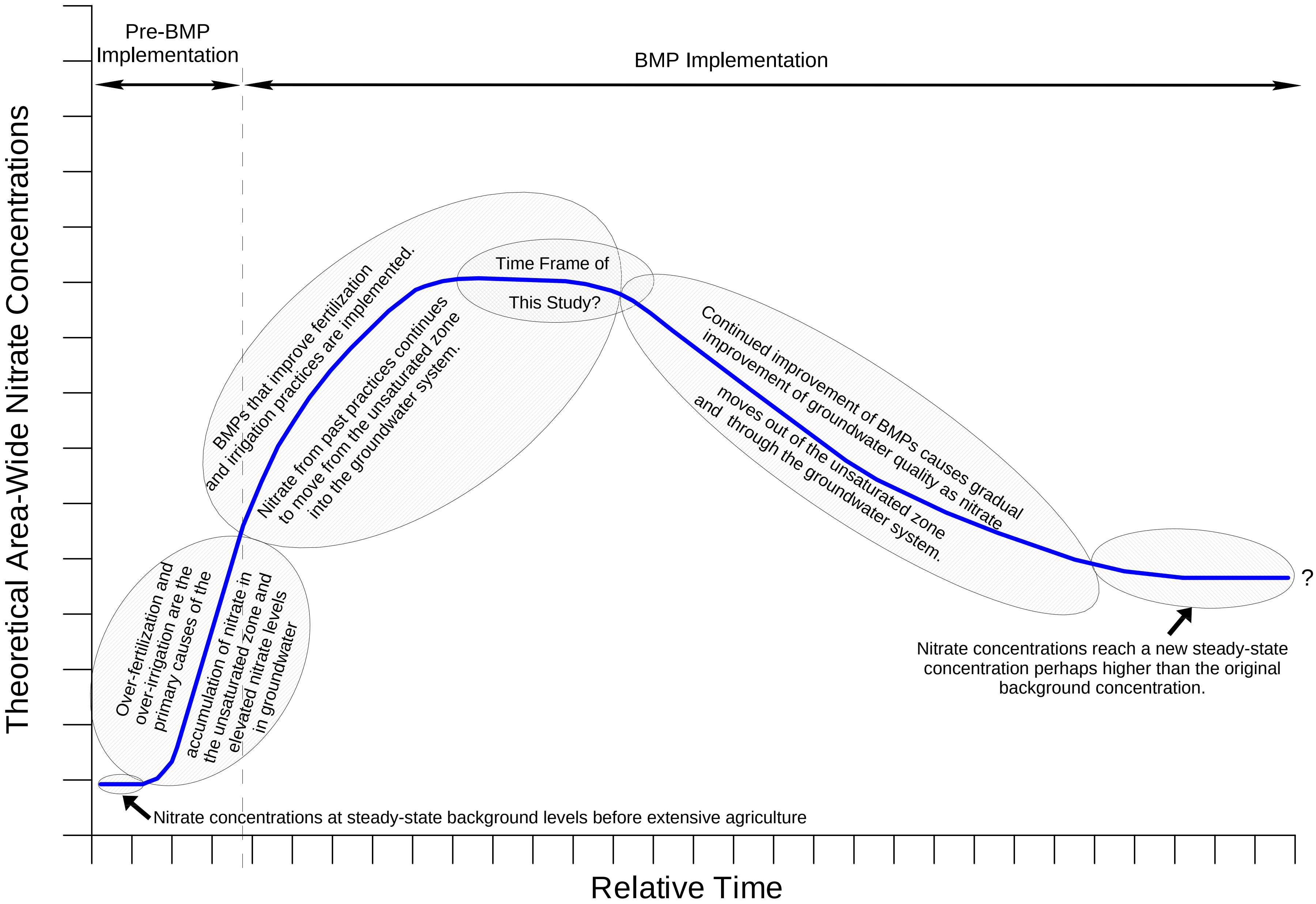
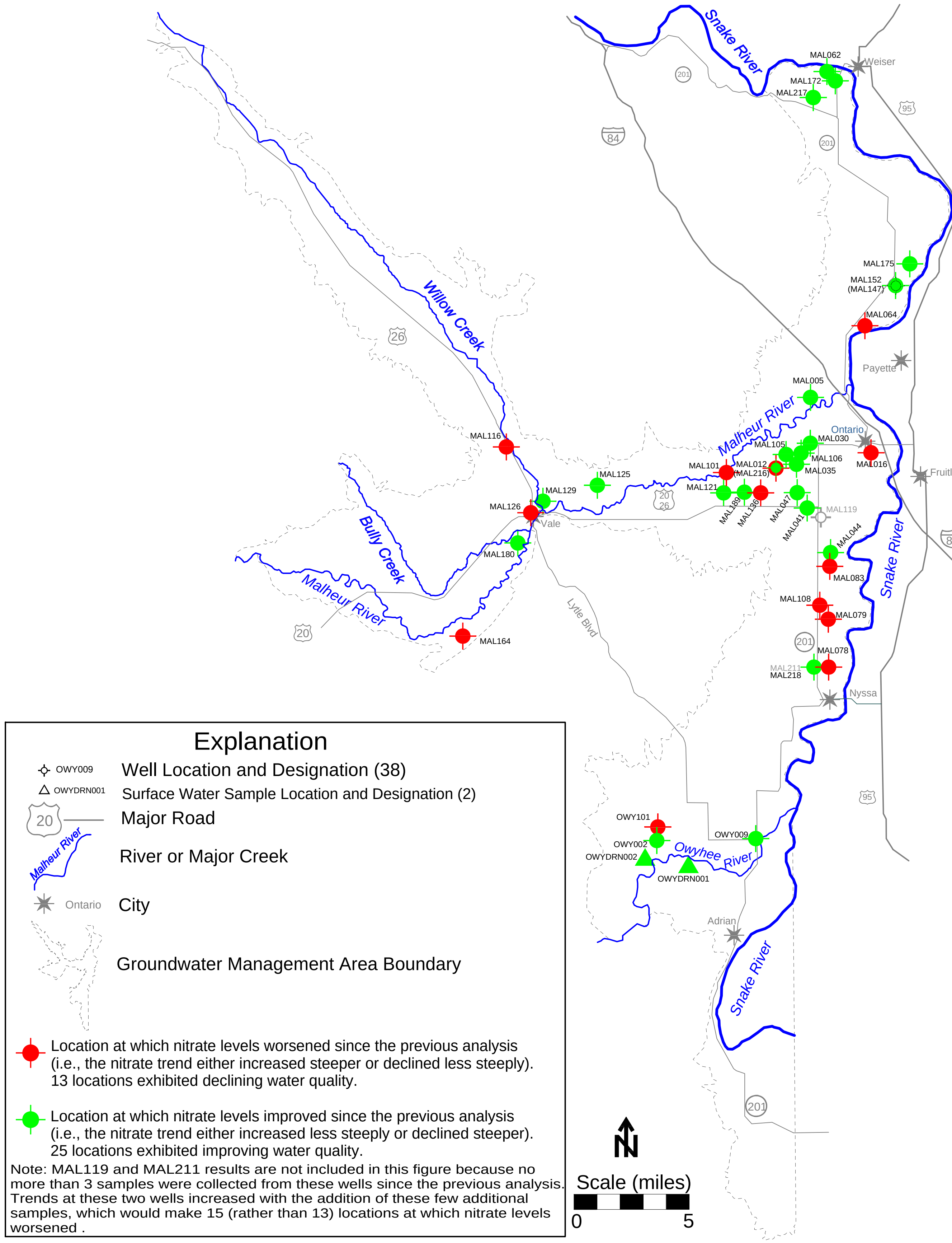


Figure 4-7
Conceptual Model of an Area-Wide Nitrate Trend
Second Northern Malheur County GWMA Trend Analysis Report



e: malheur 2006trendanalysis model.grf

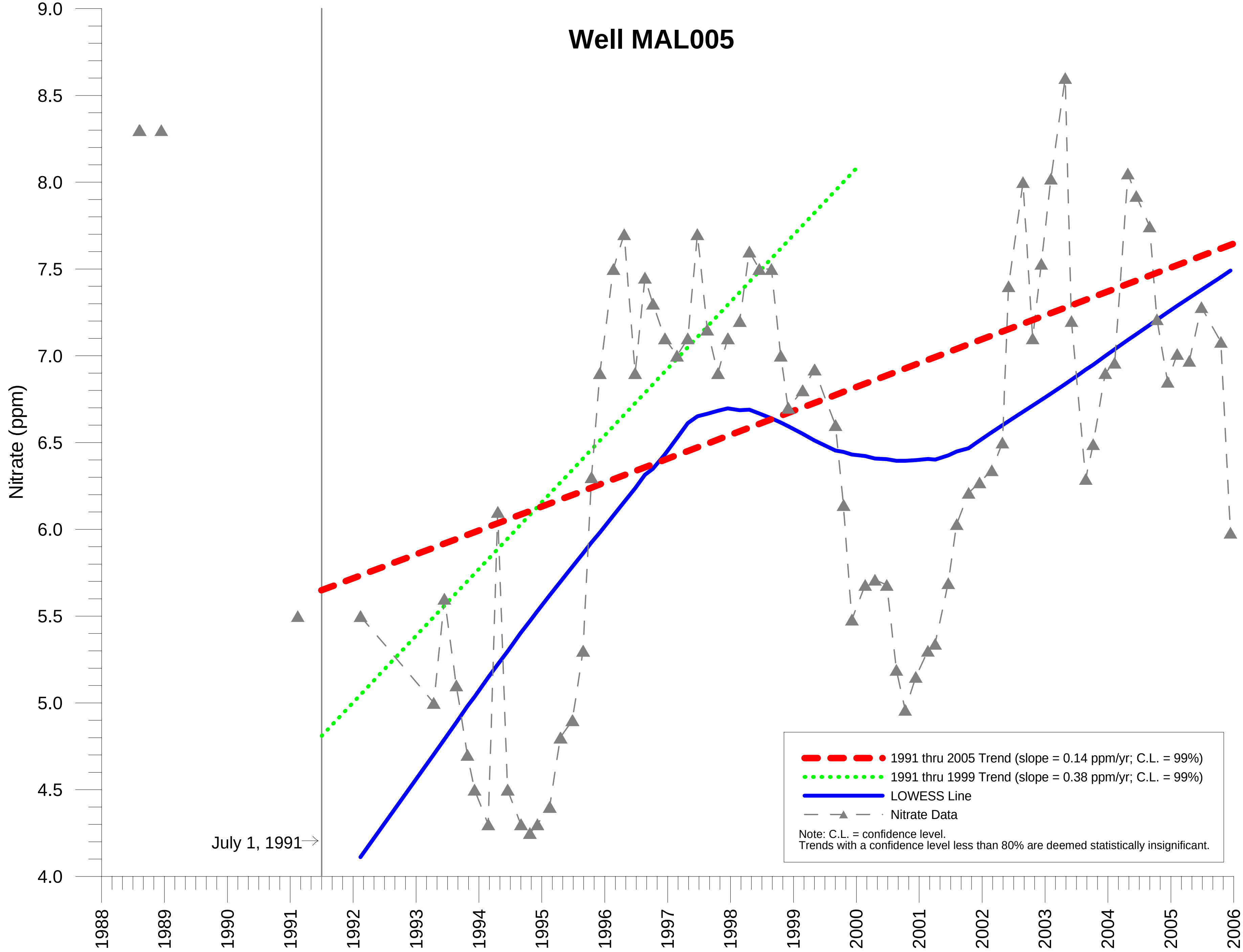
Figure 5-1
Change in Nitrate Trends Since Previous Analysis
Second Northern Malheur County GWMA Trend Analysis Report



e: malheur 2006 trend analysis DeltaNO3Trend.srf

Appendix A

Time versus Concentrations Graphs
&
DEQ and OWRD Well Designation Table



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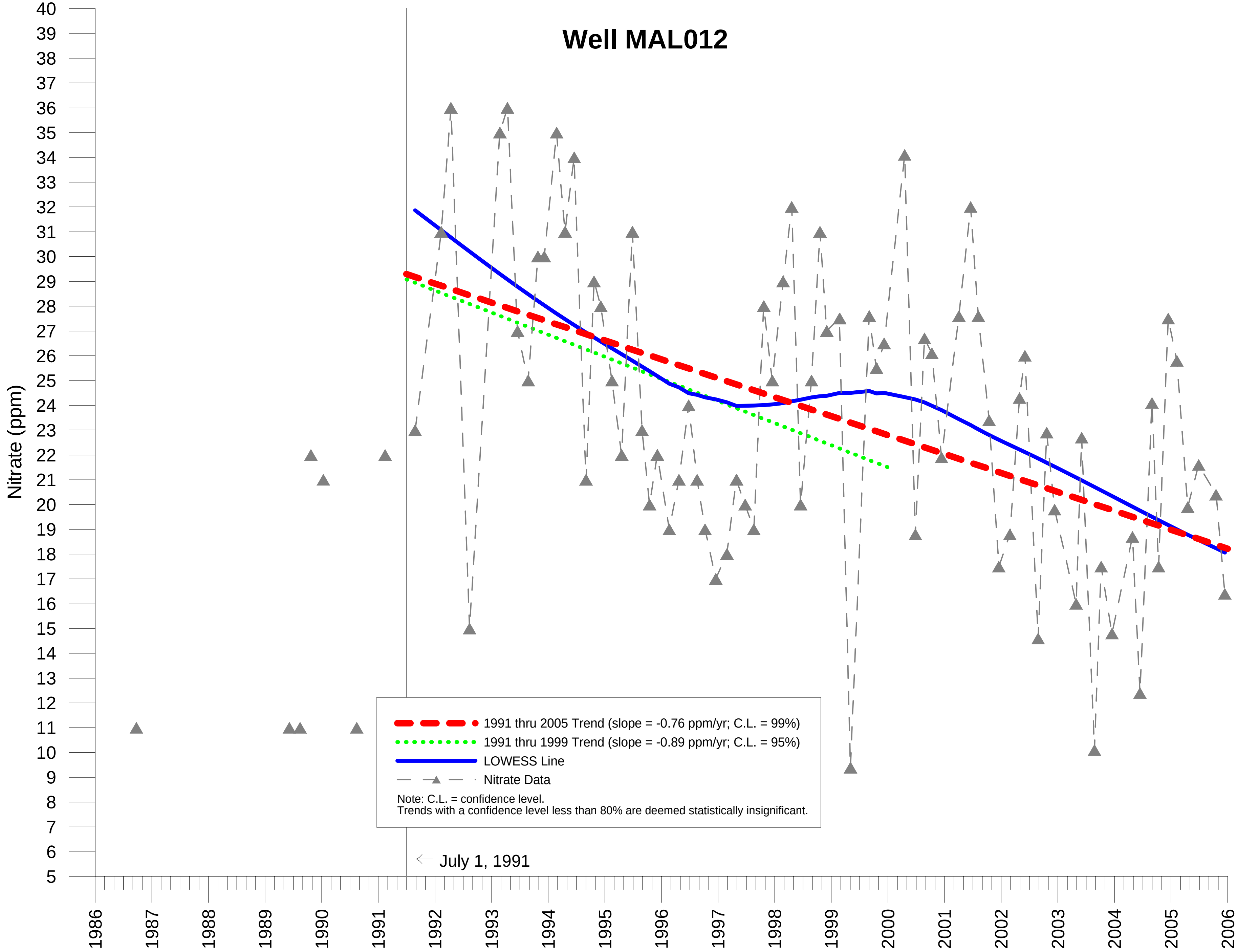

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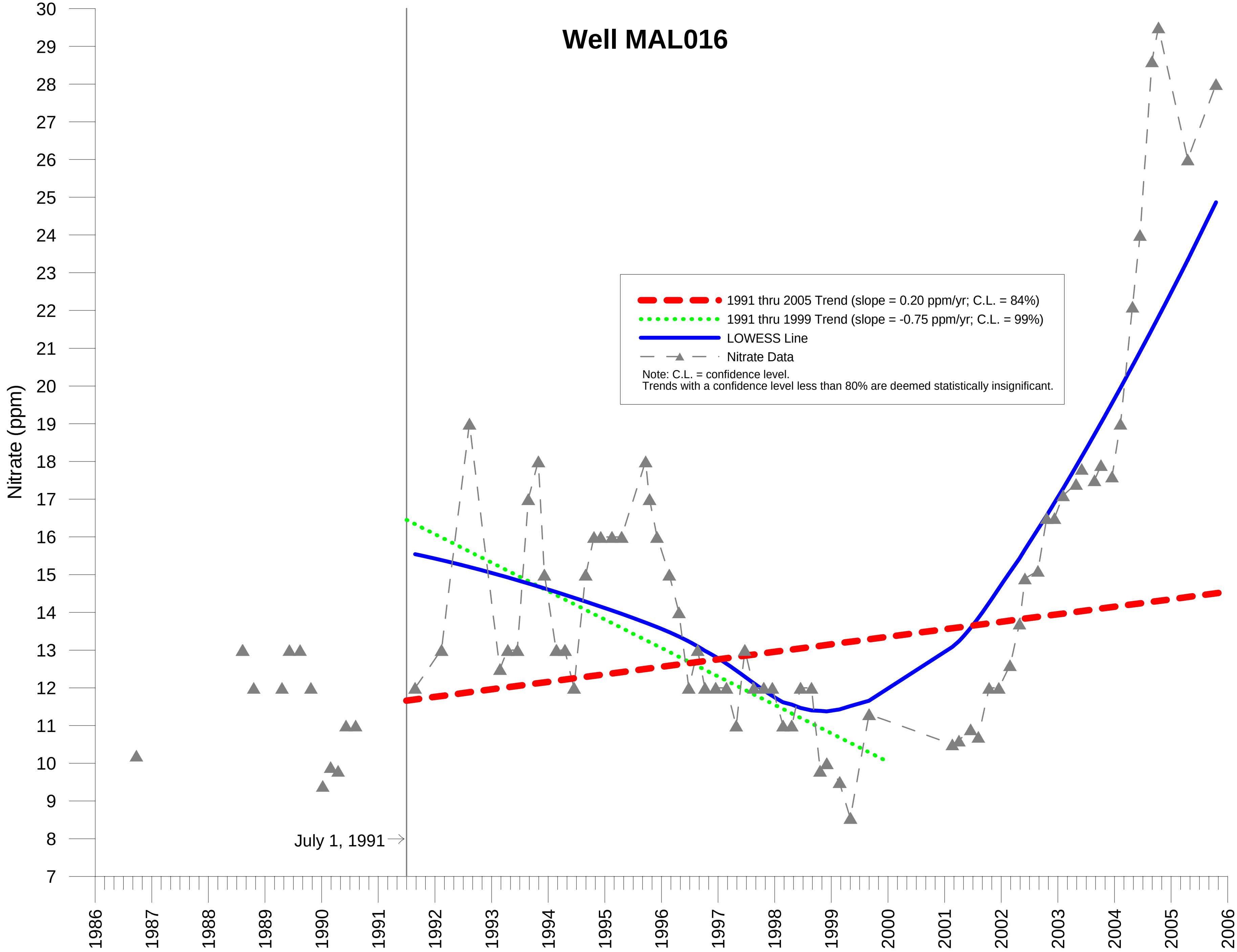

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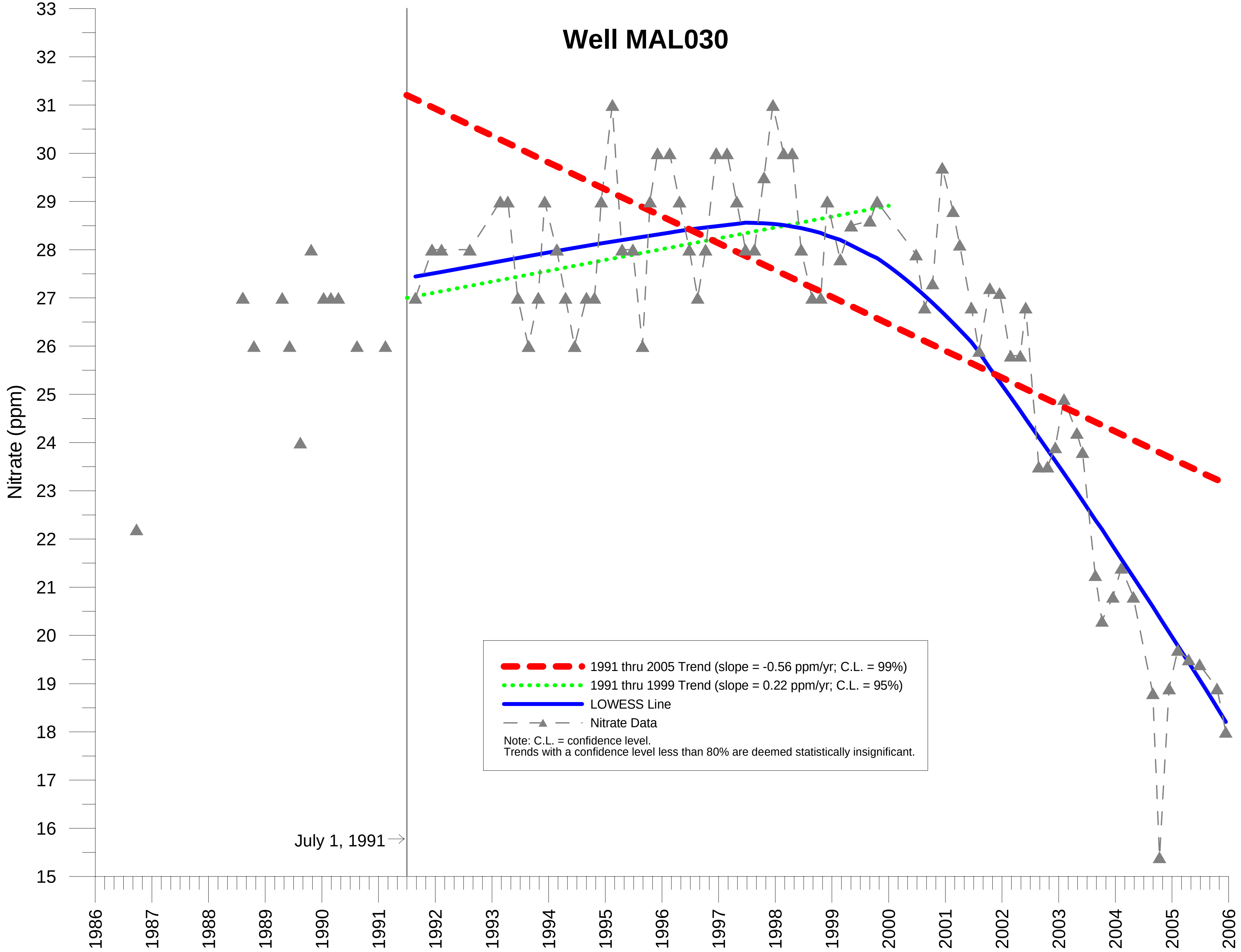

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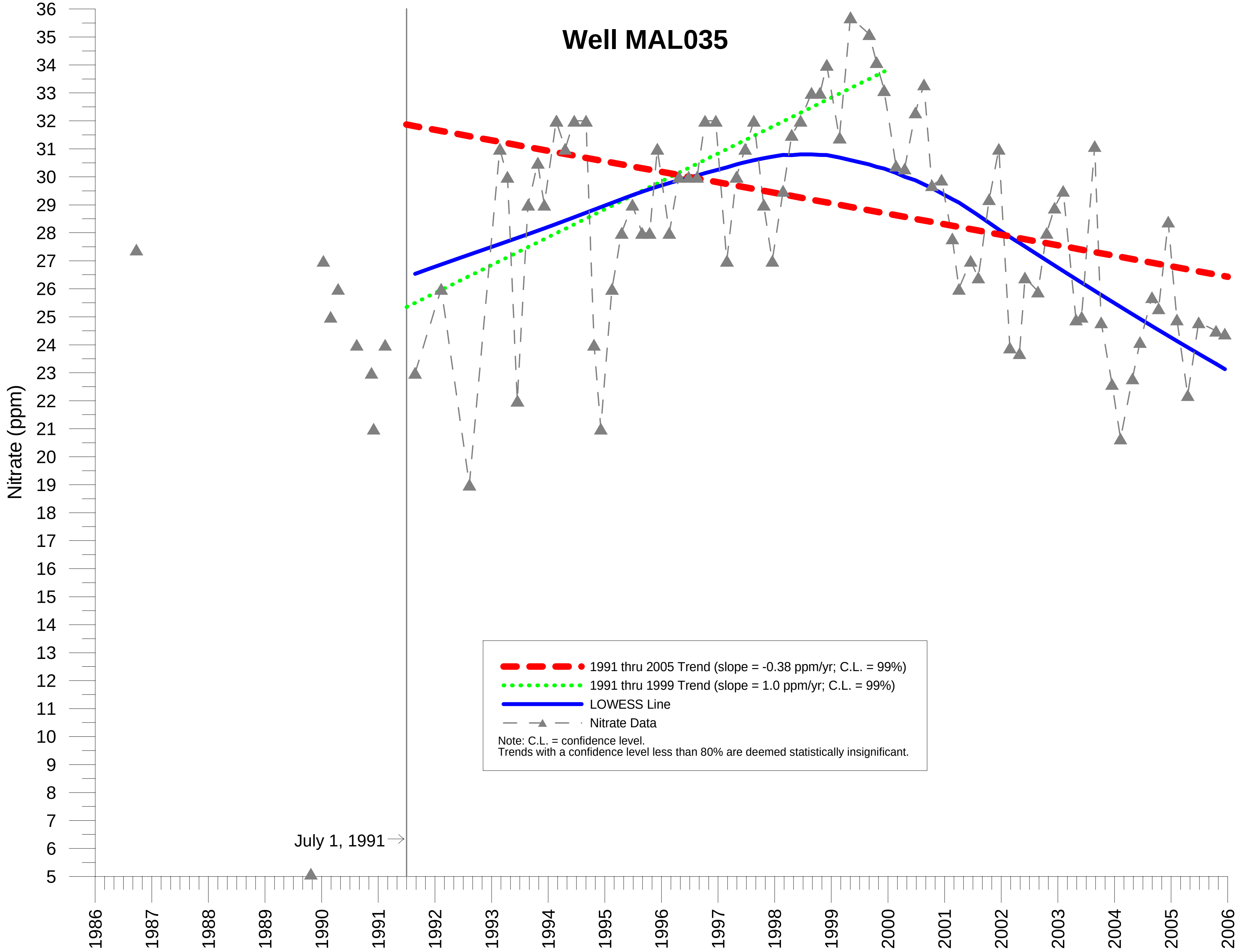

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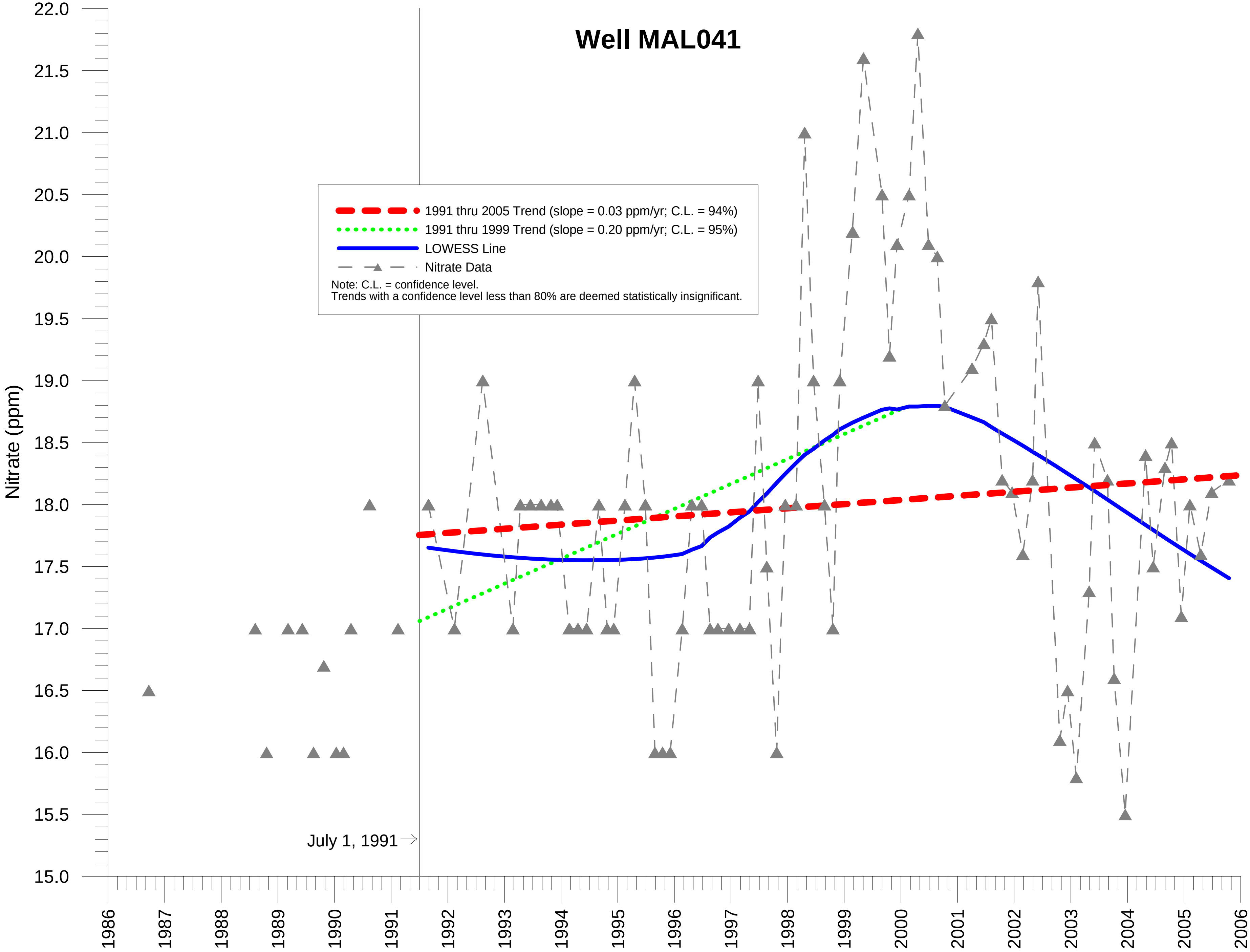

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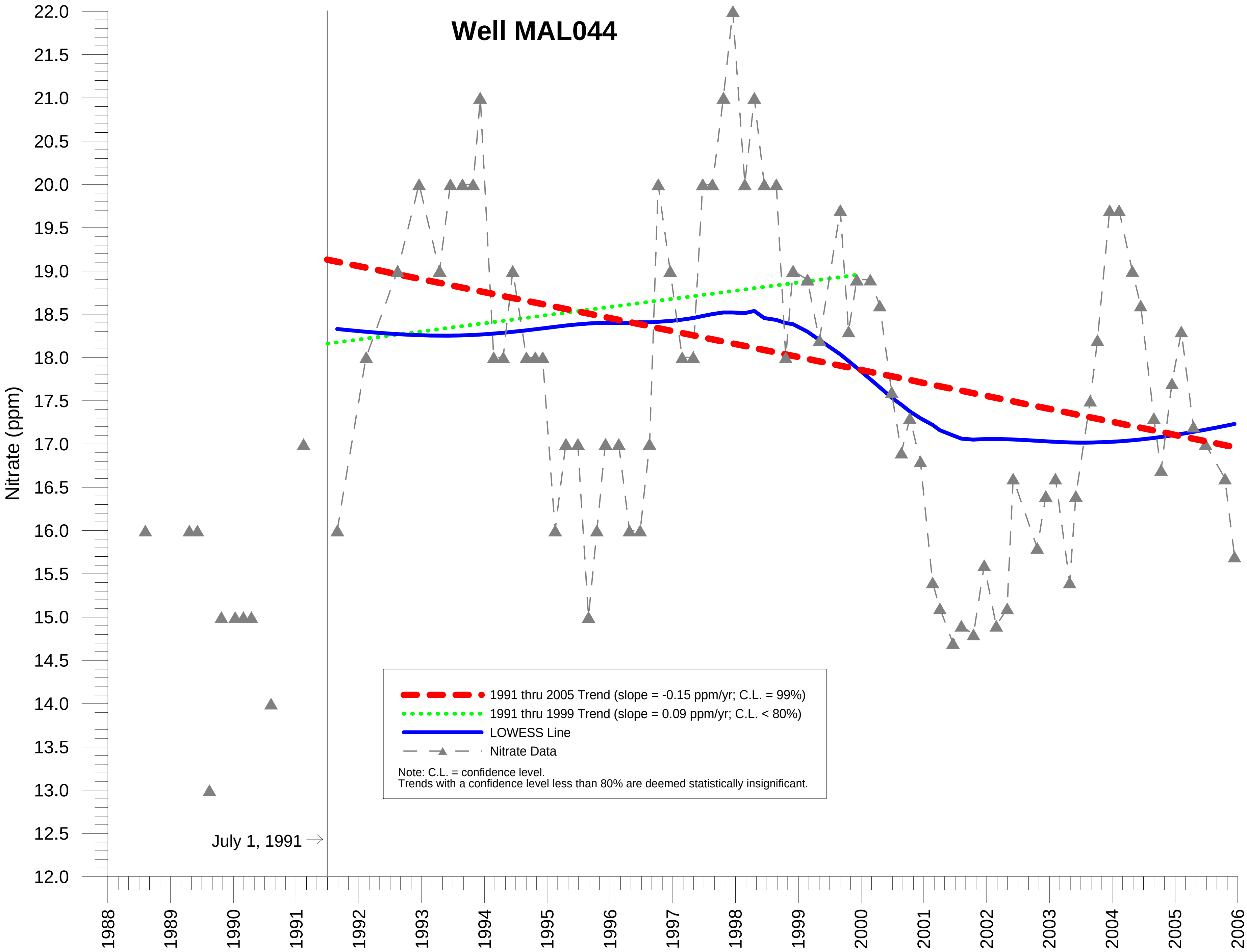

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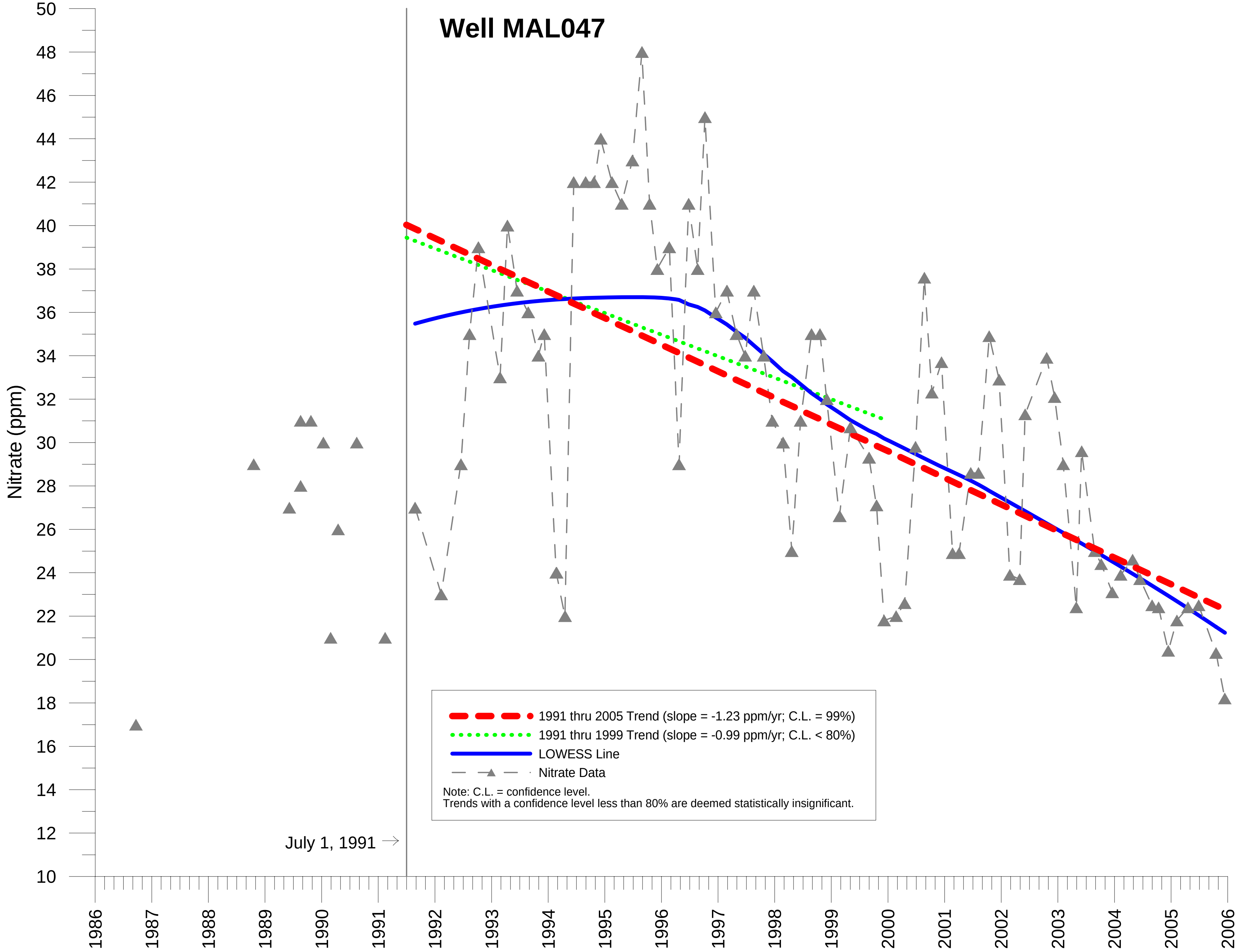

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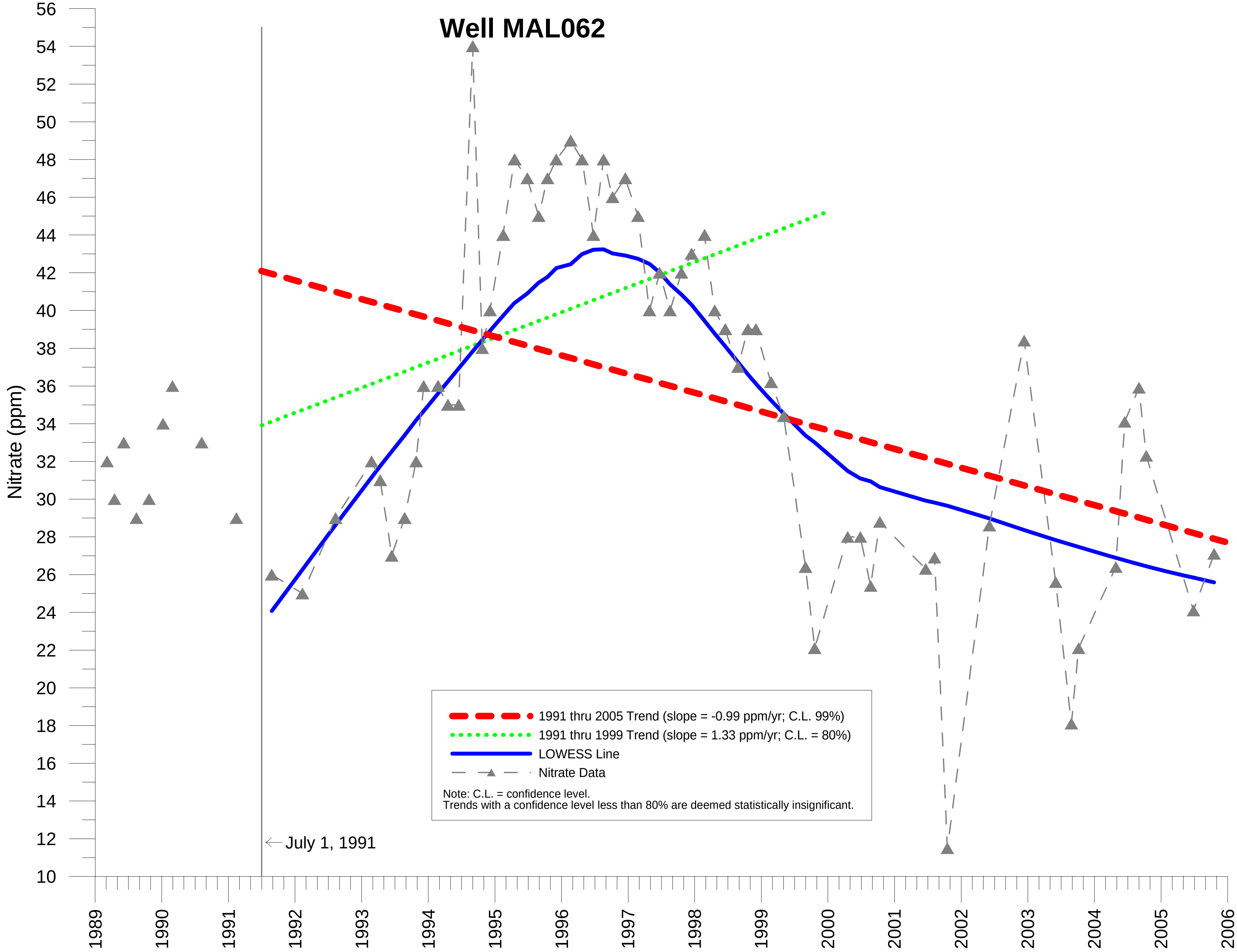

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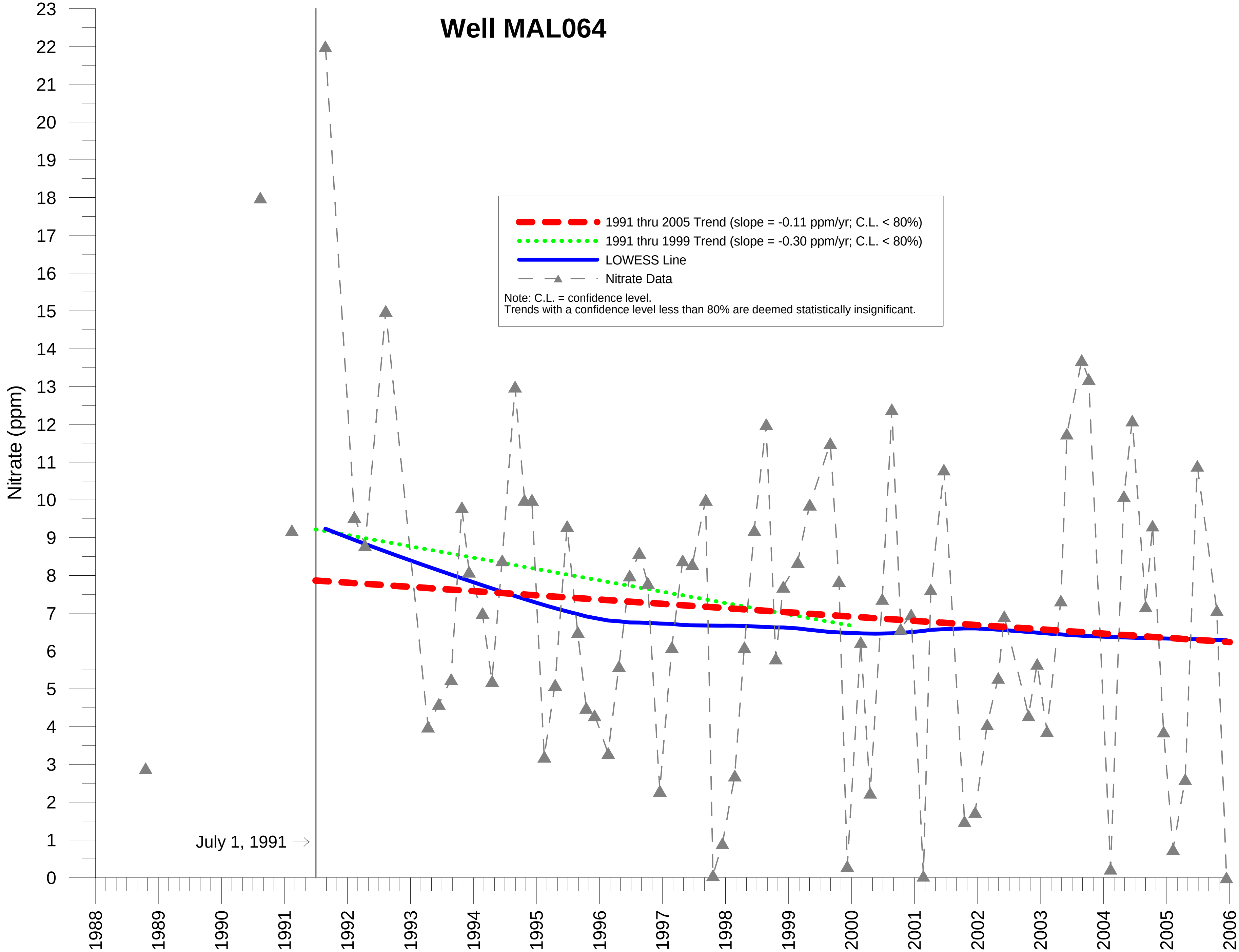

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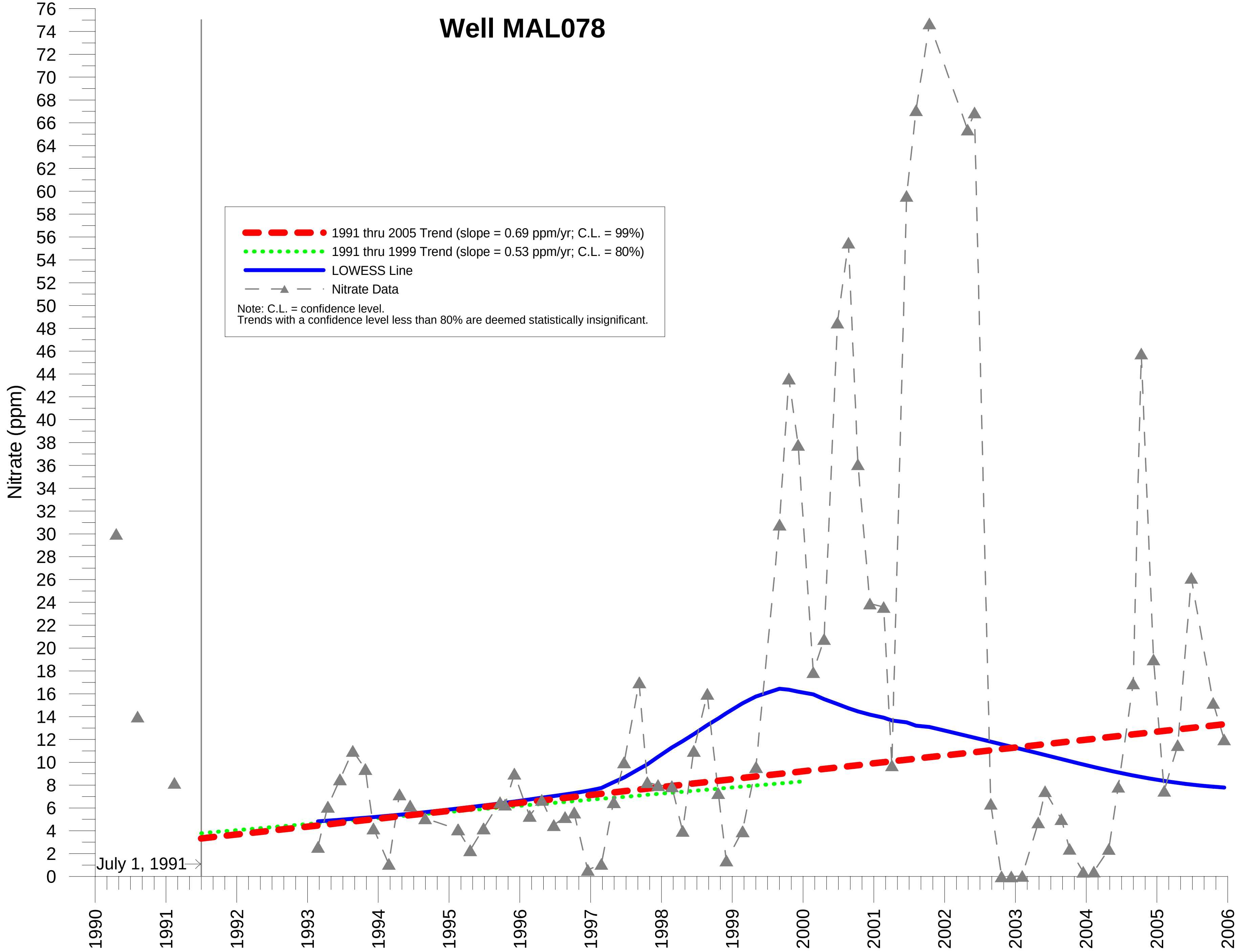

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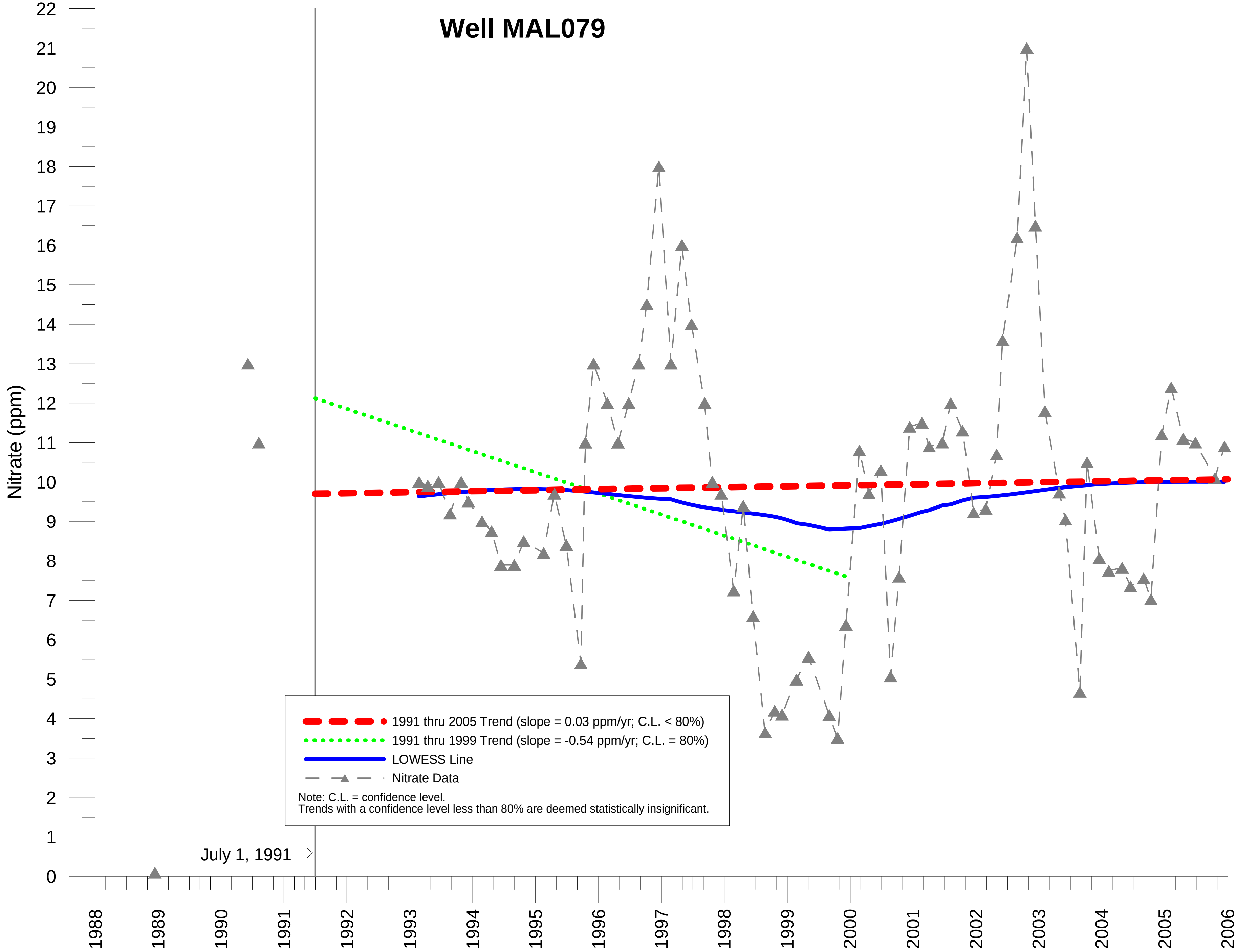

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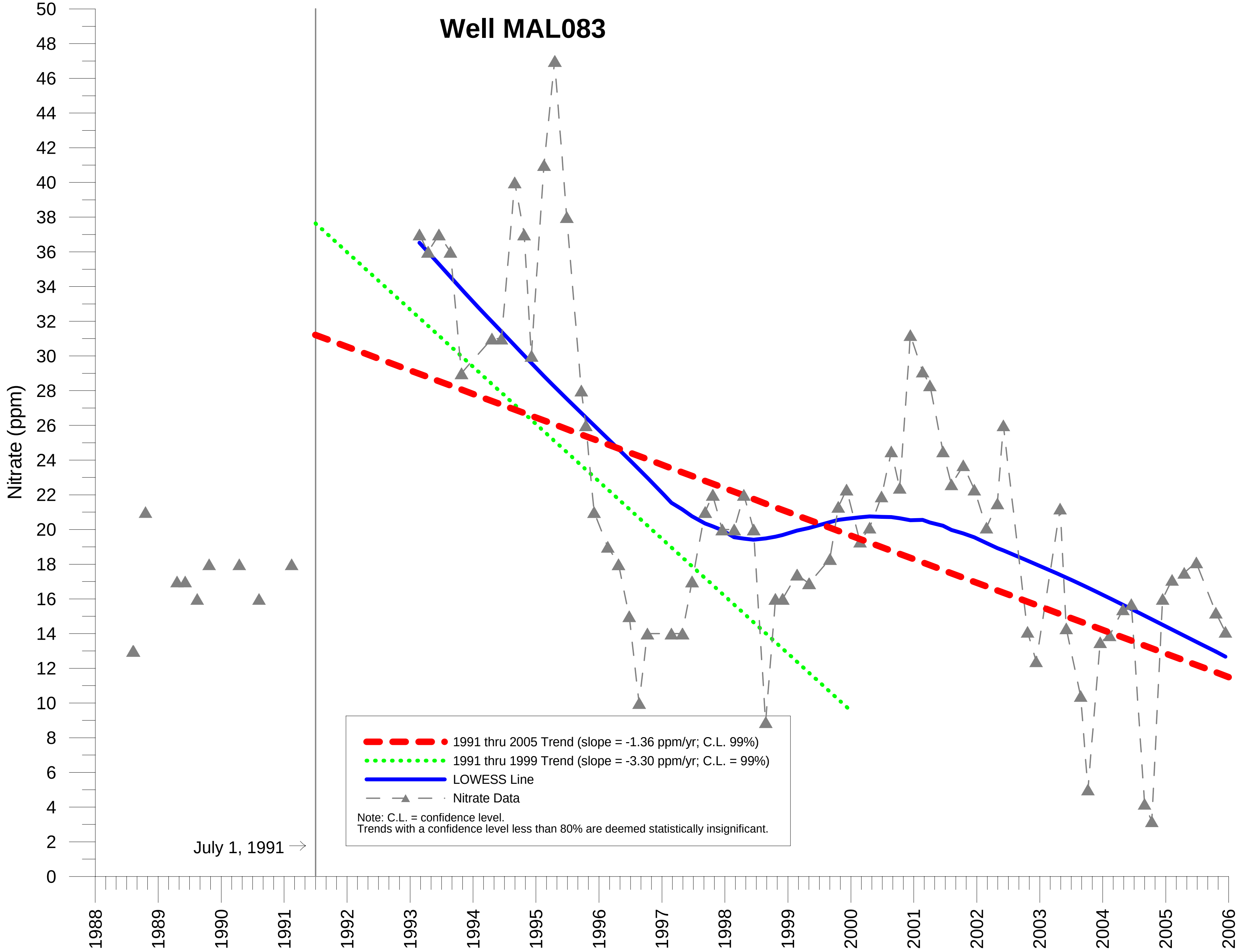
Well MAL083



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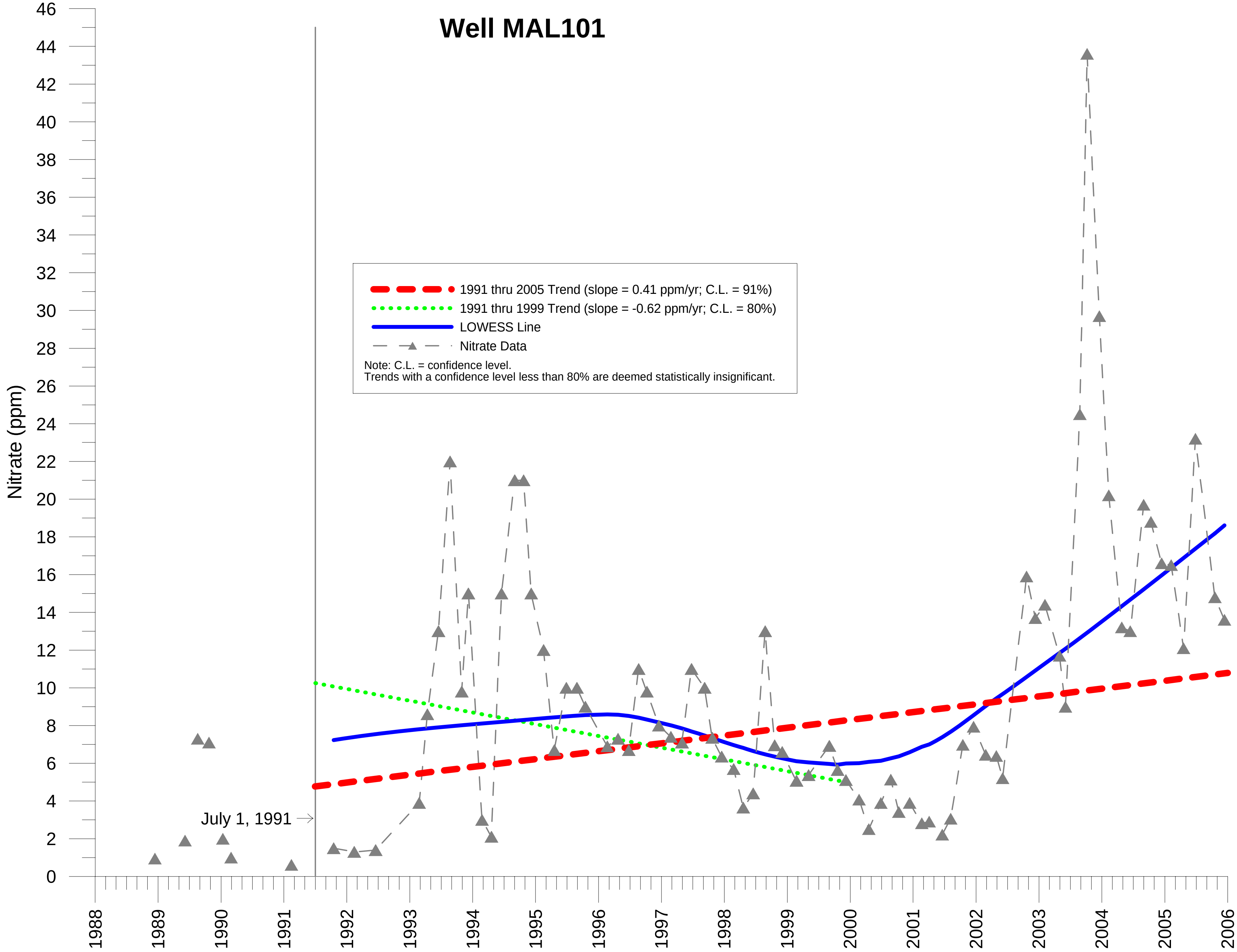

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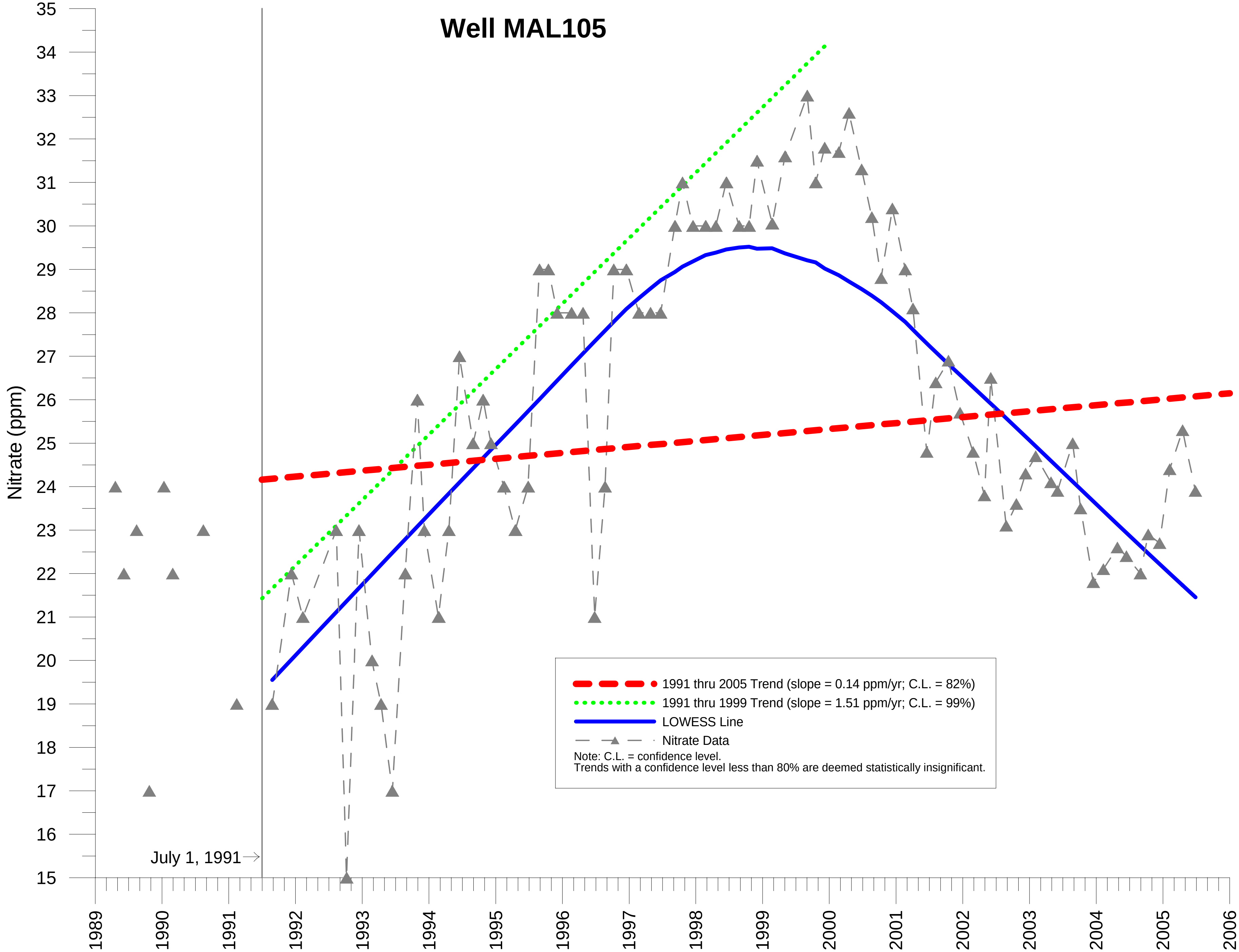

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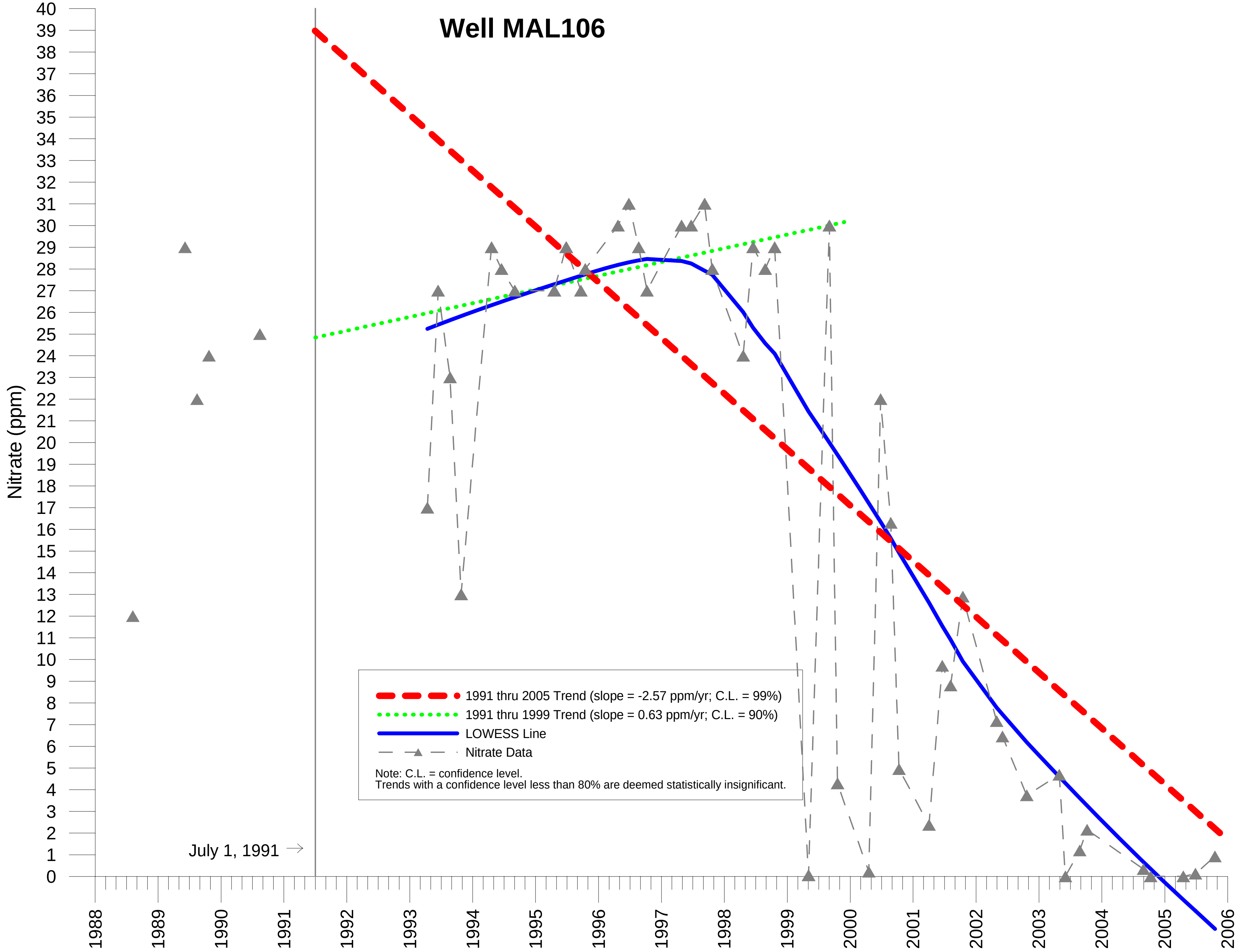

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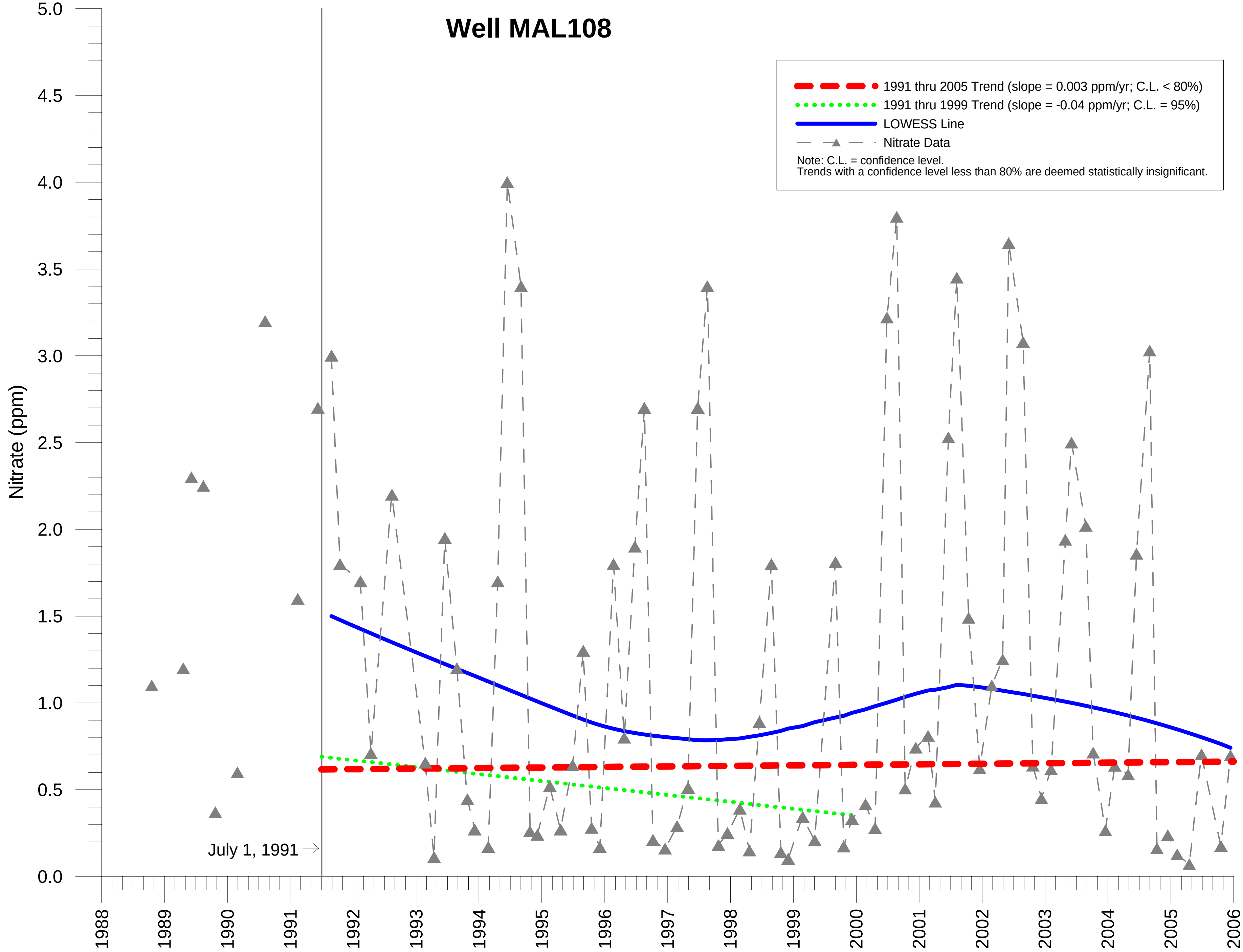

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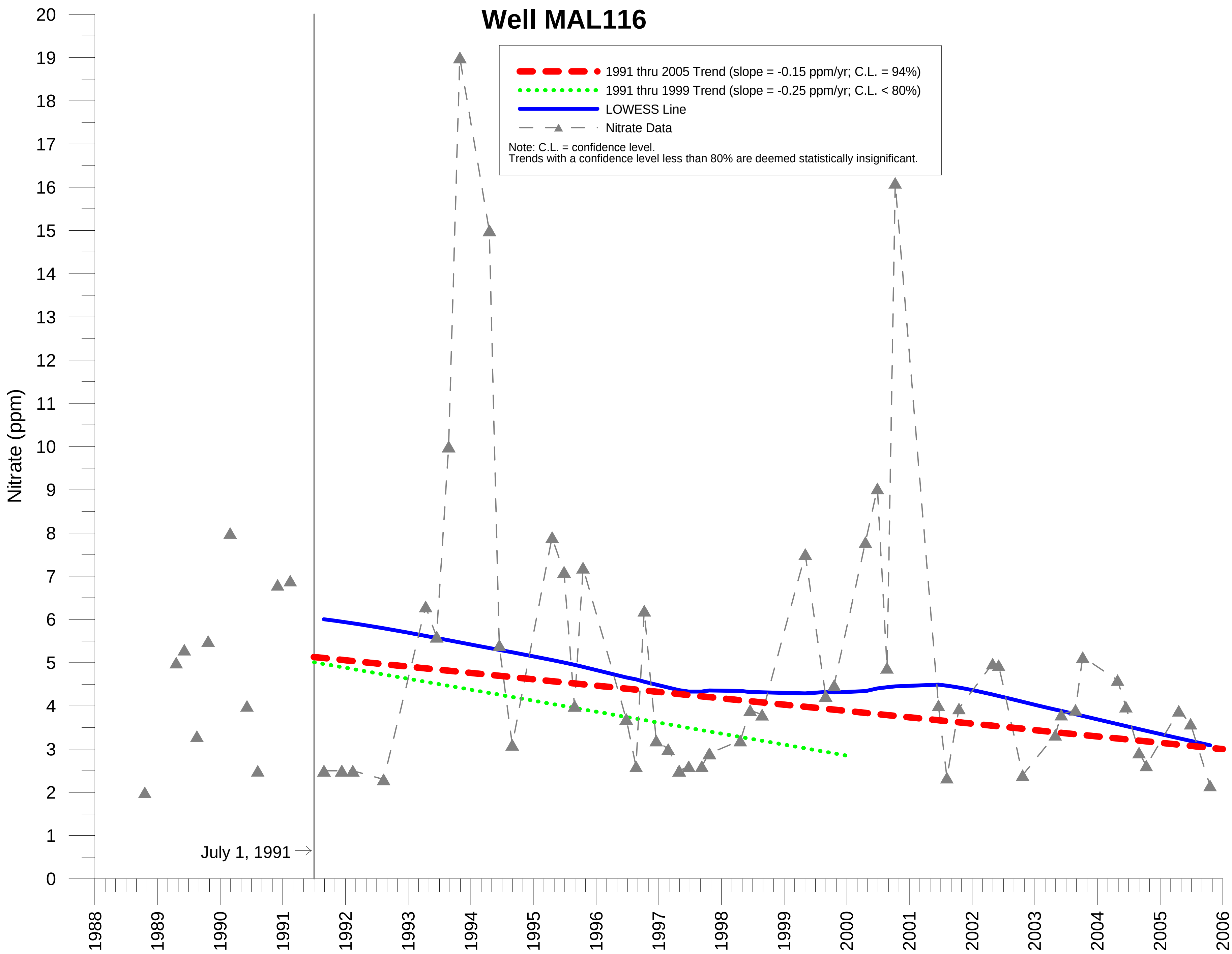

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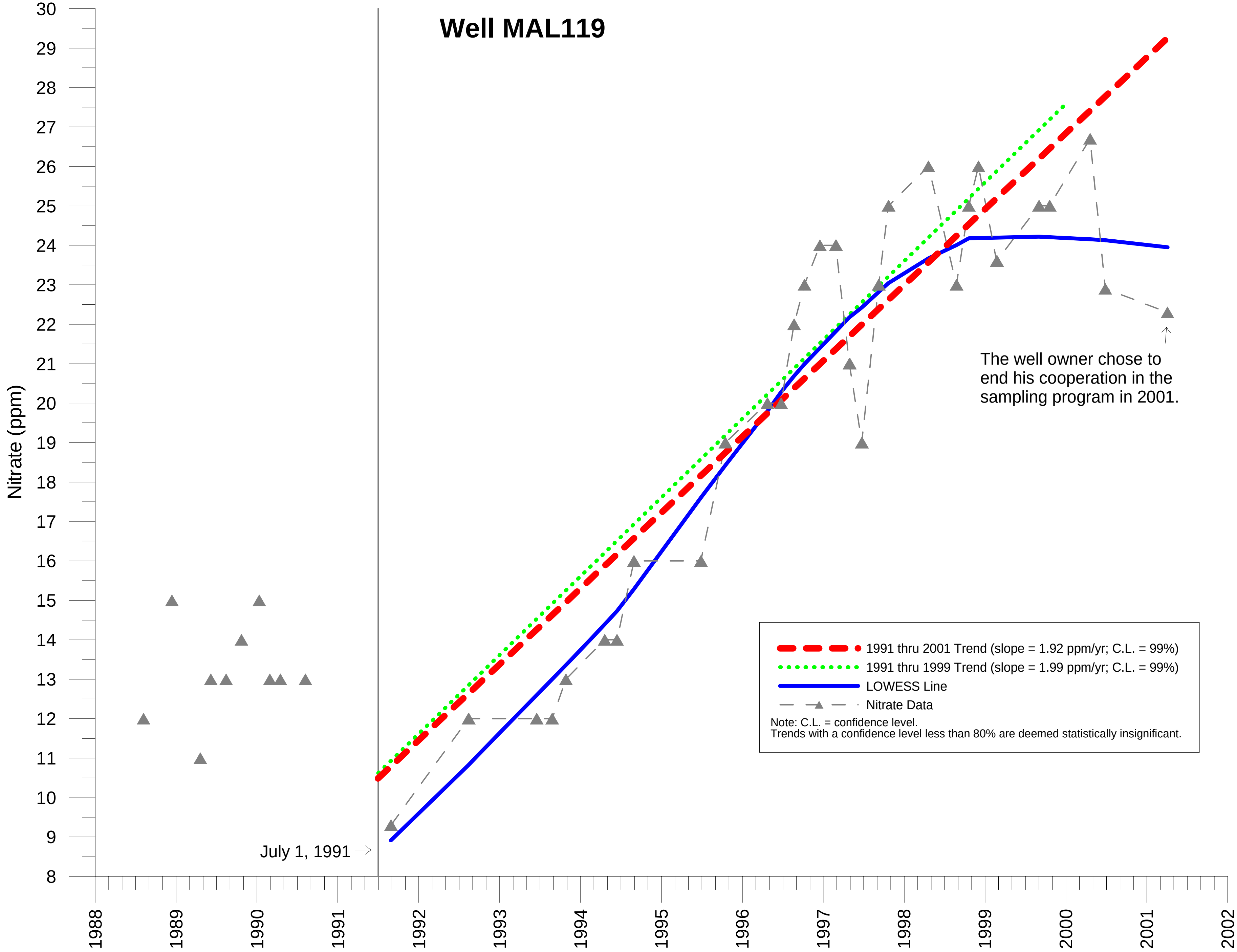

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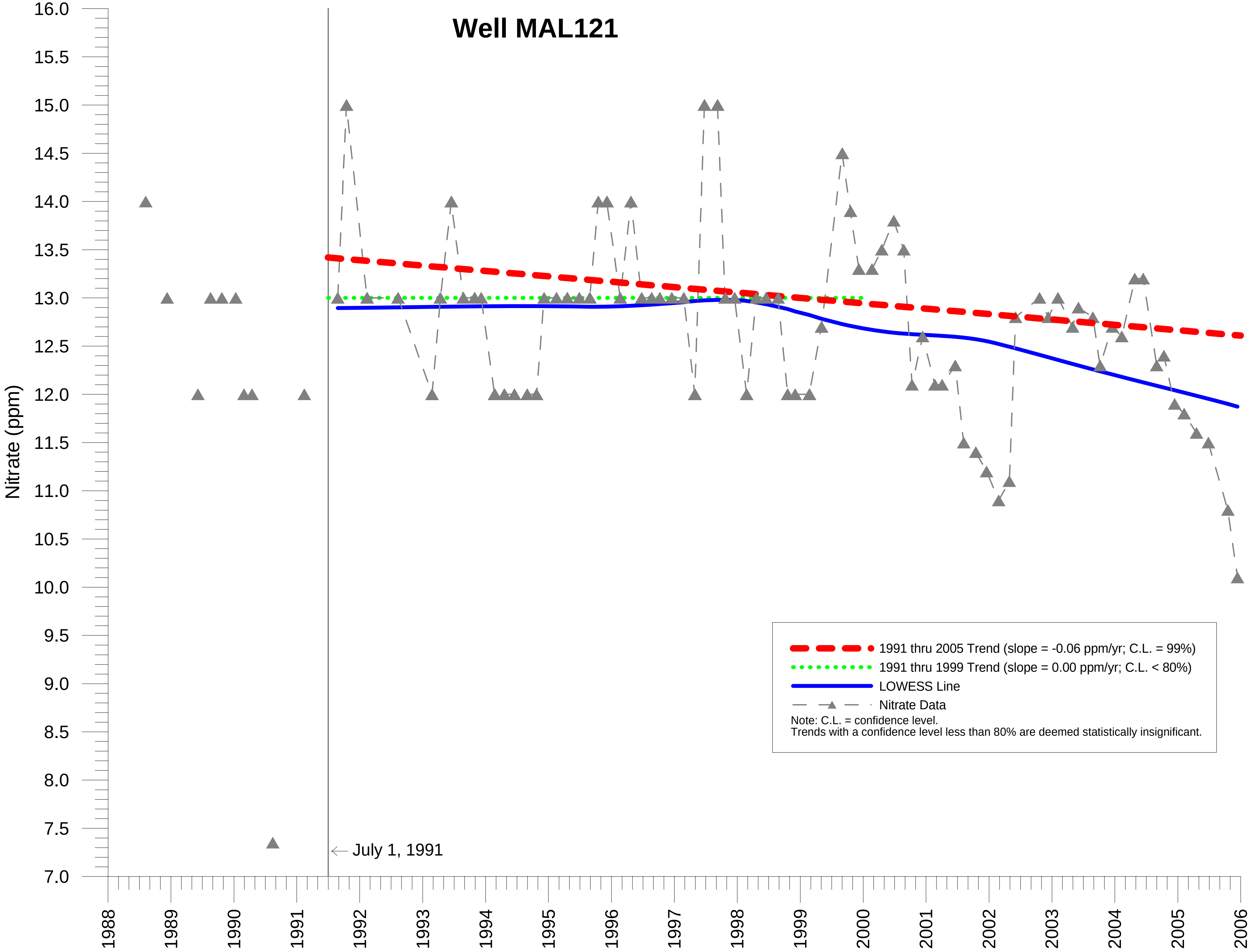

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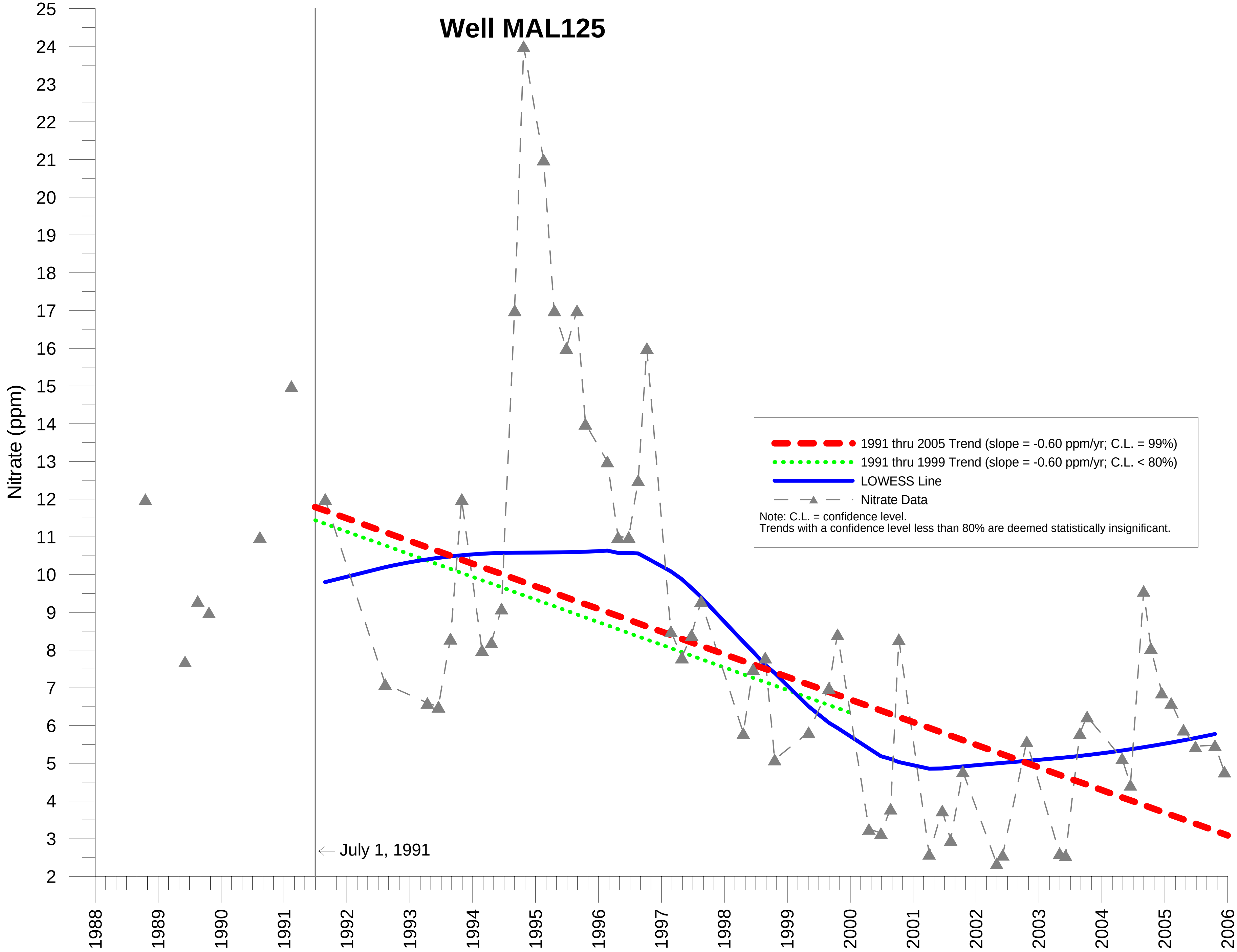

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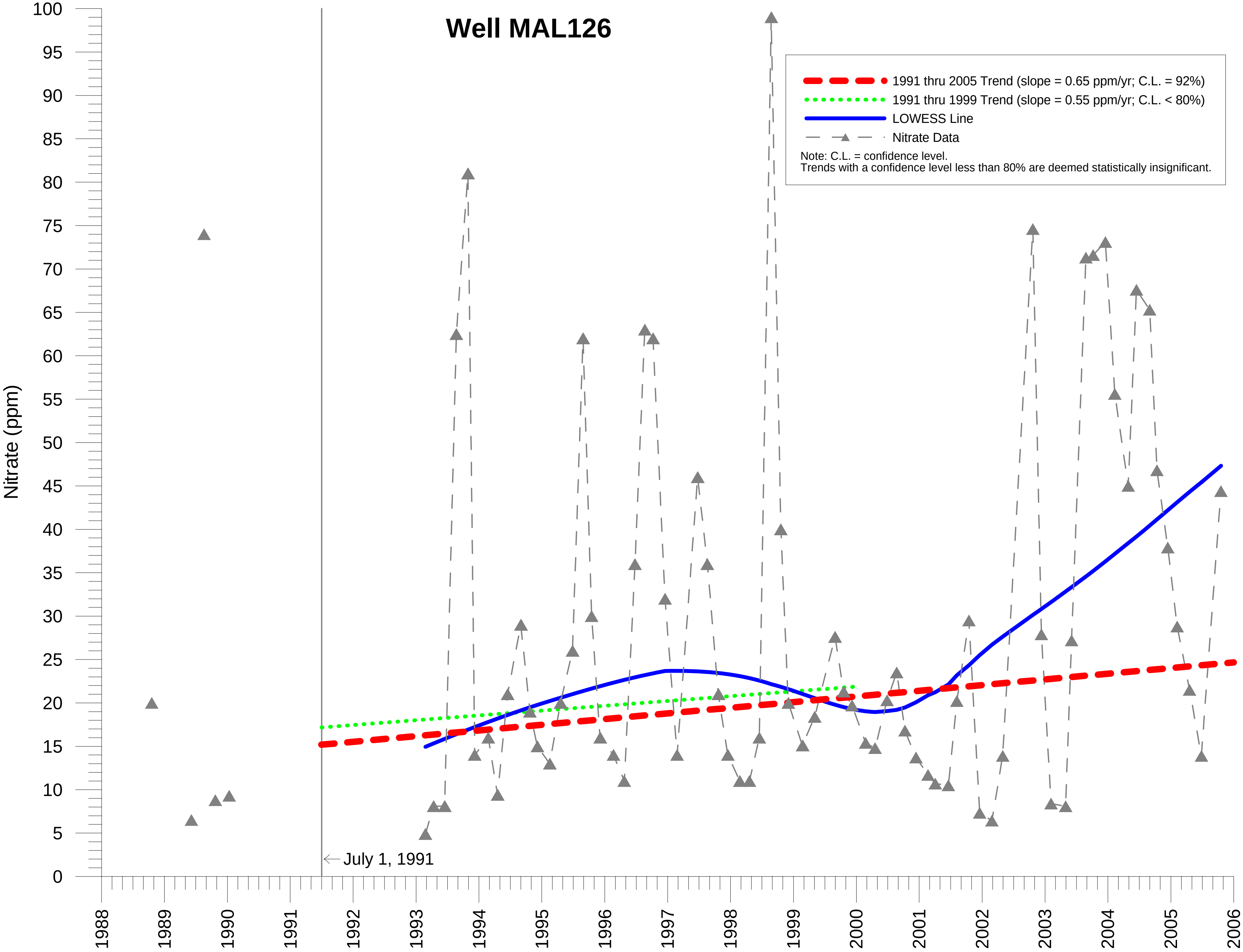

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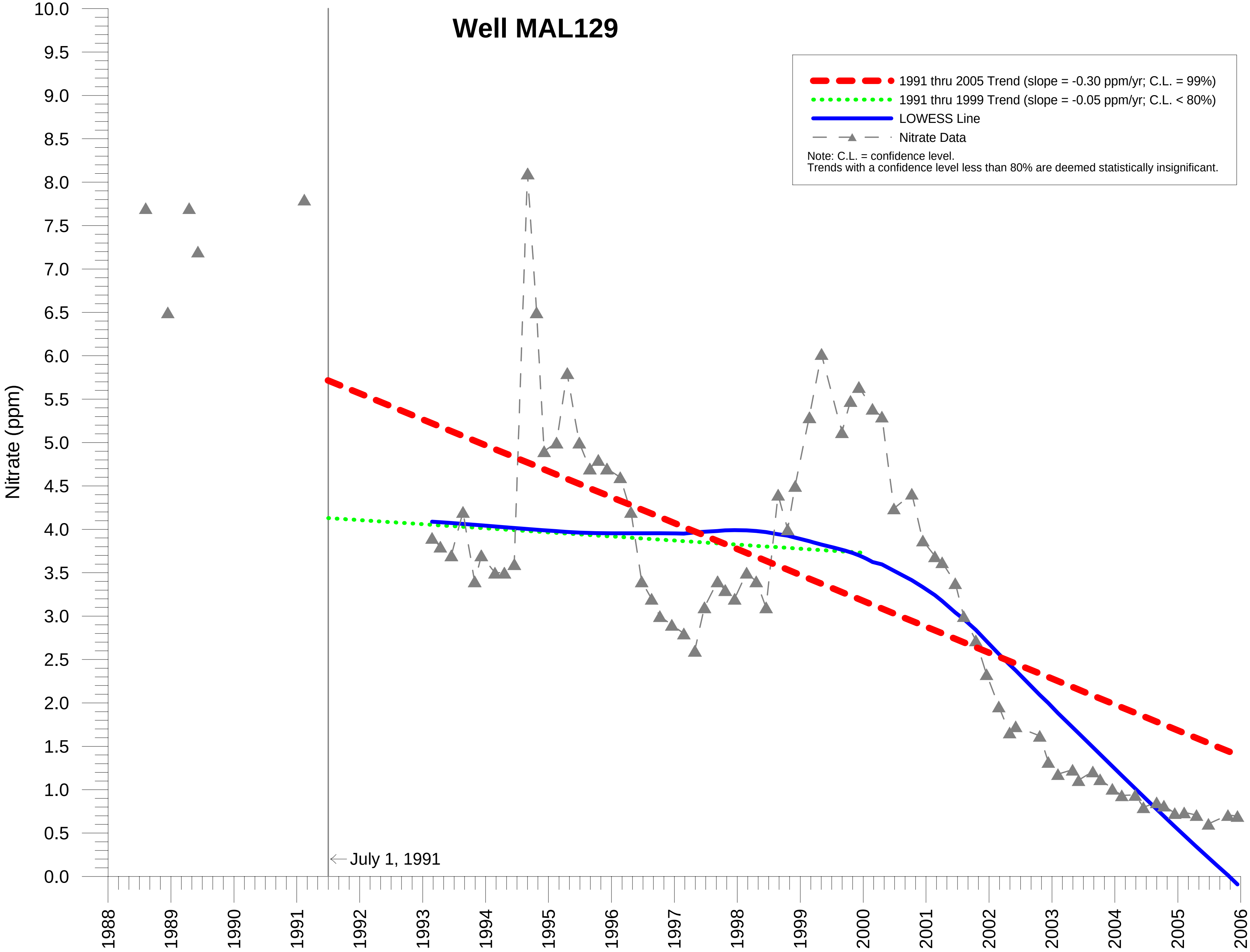

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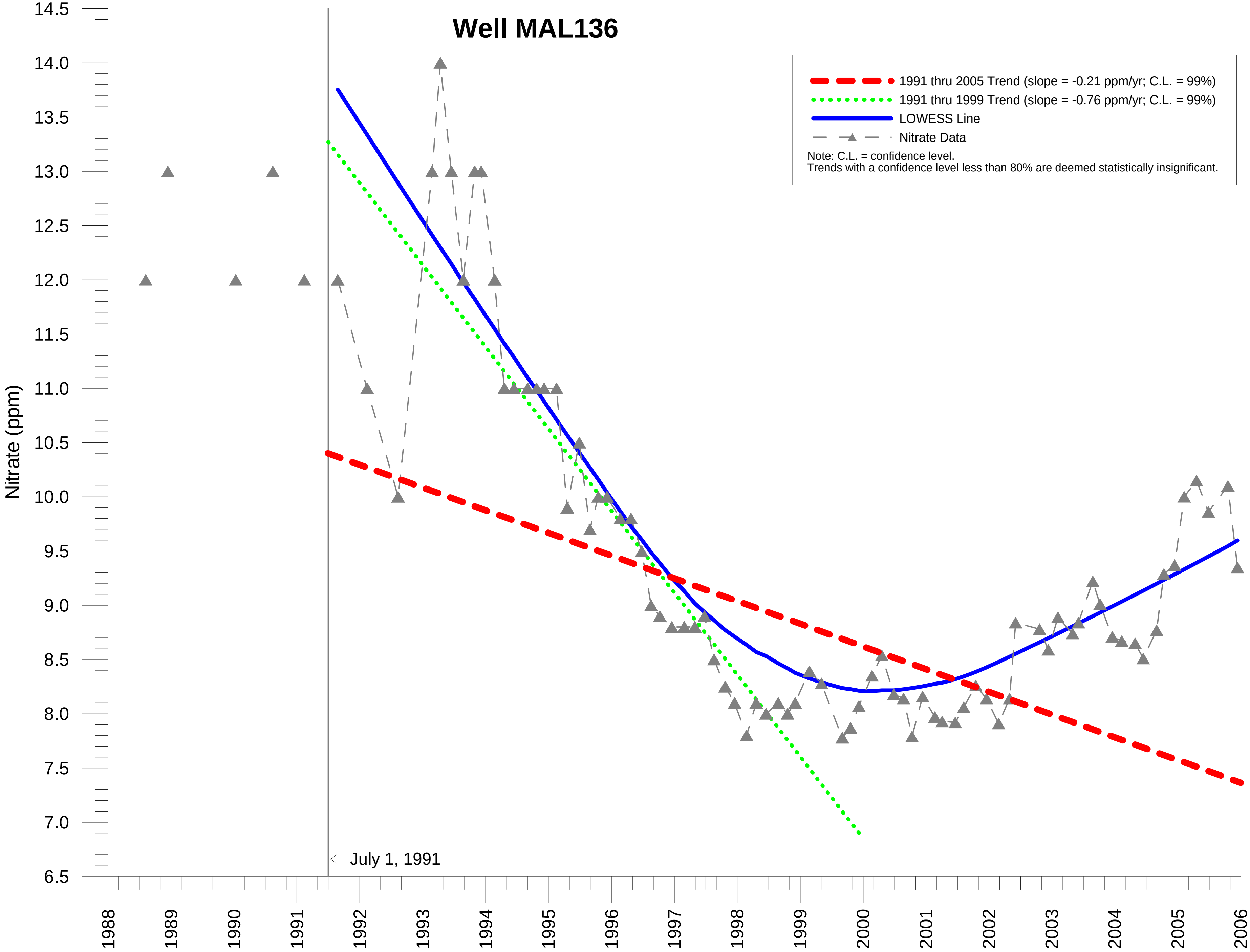

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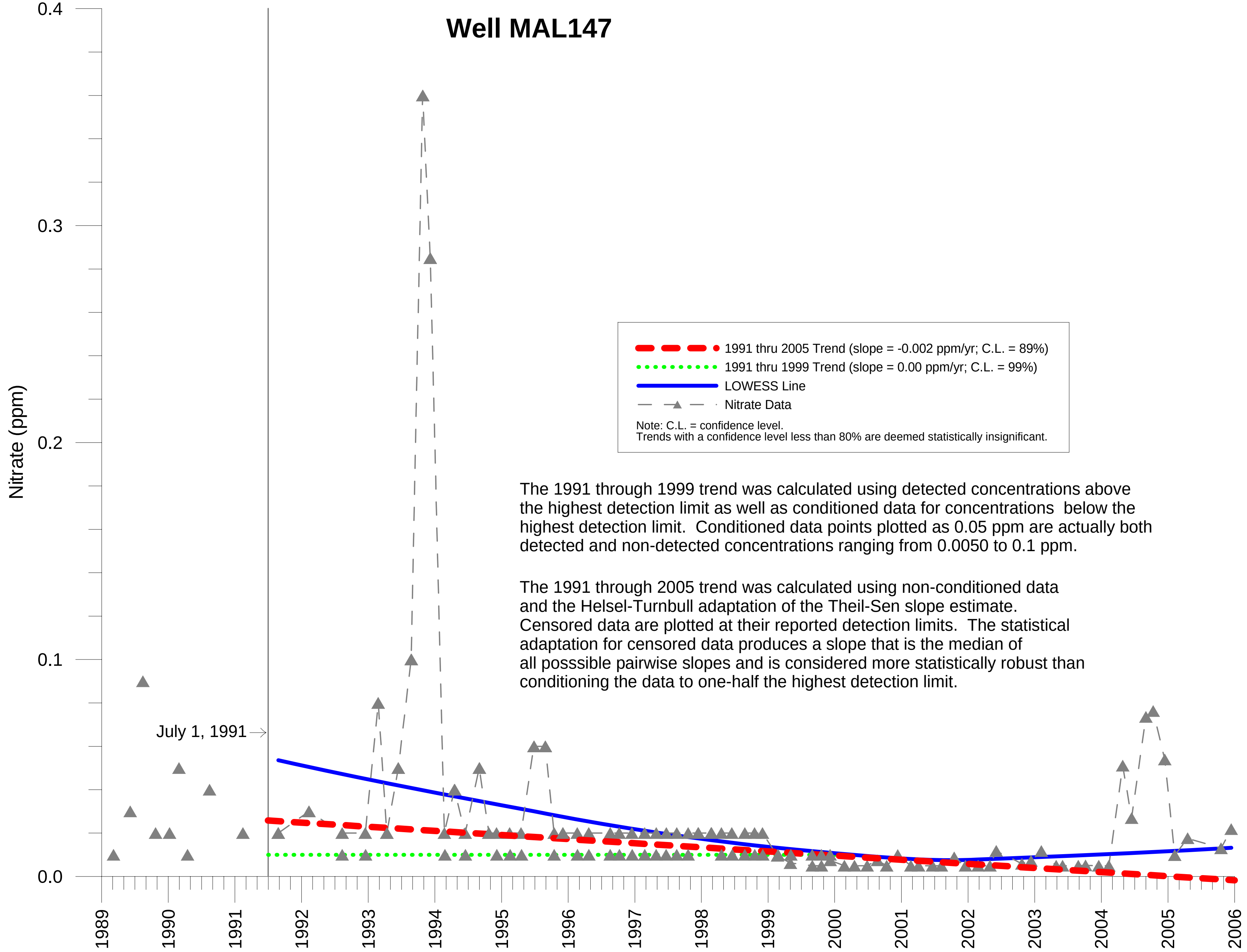

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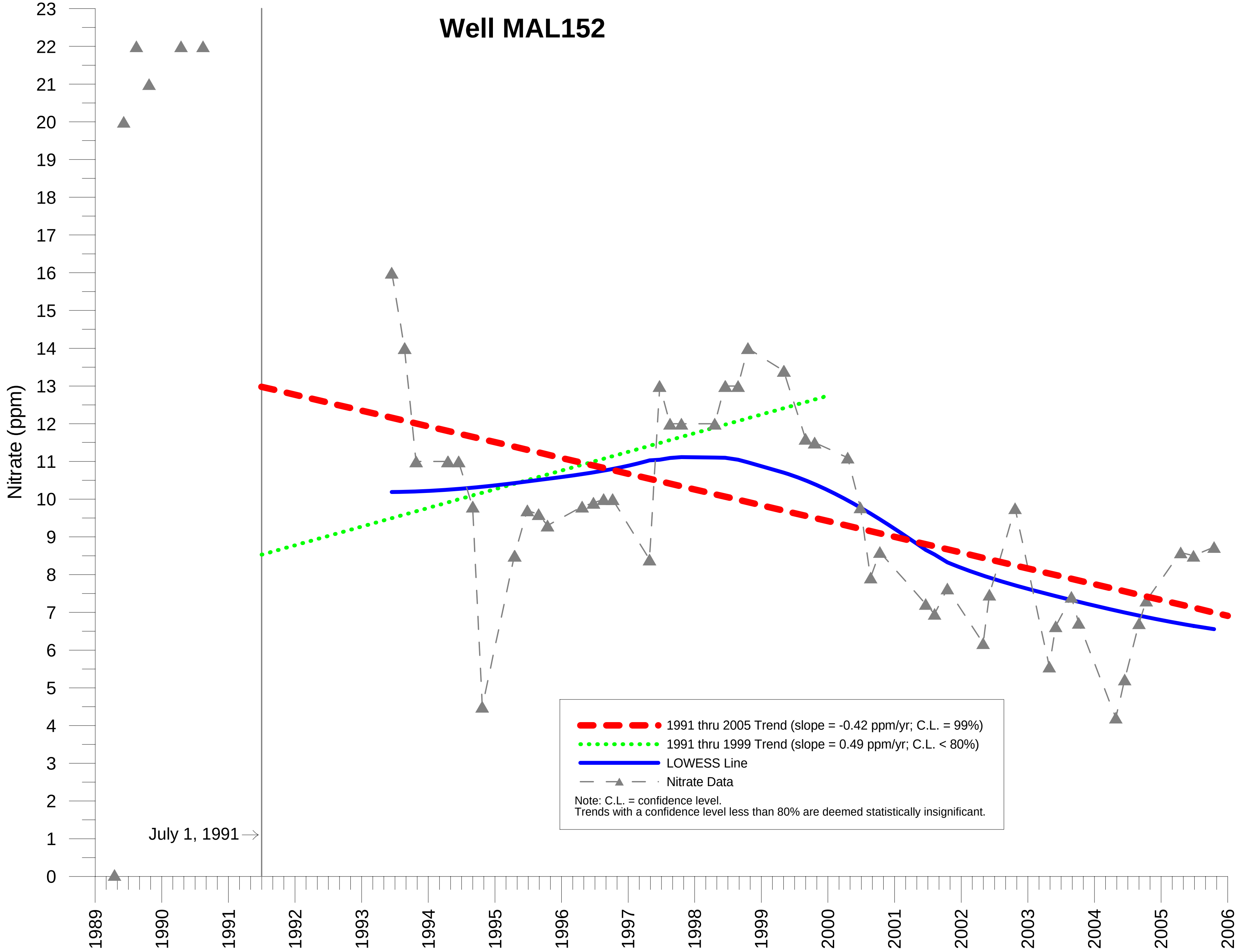

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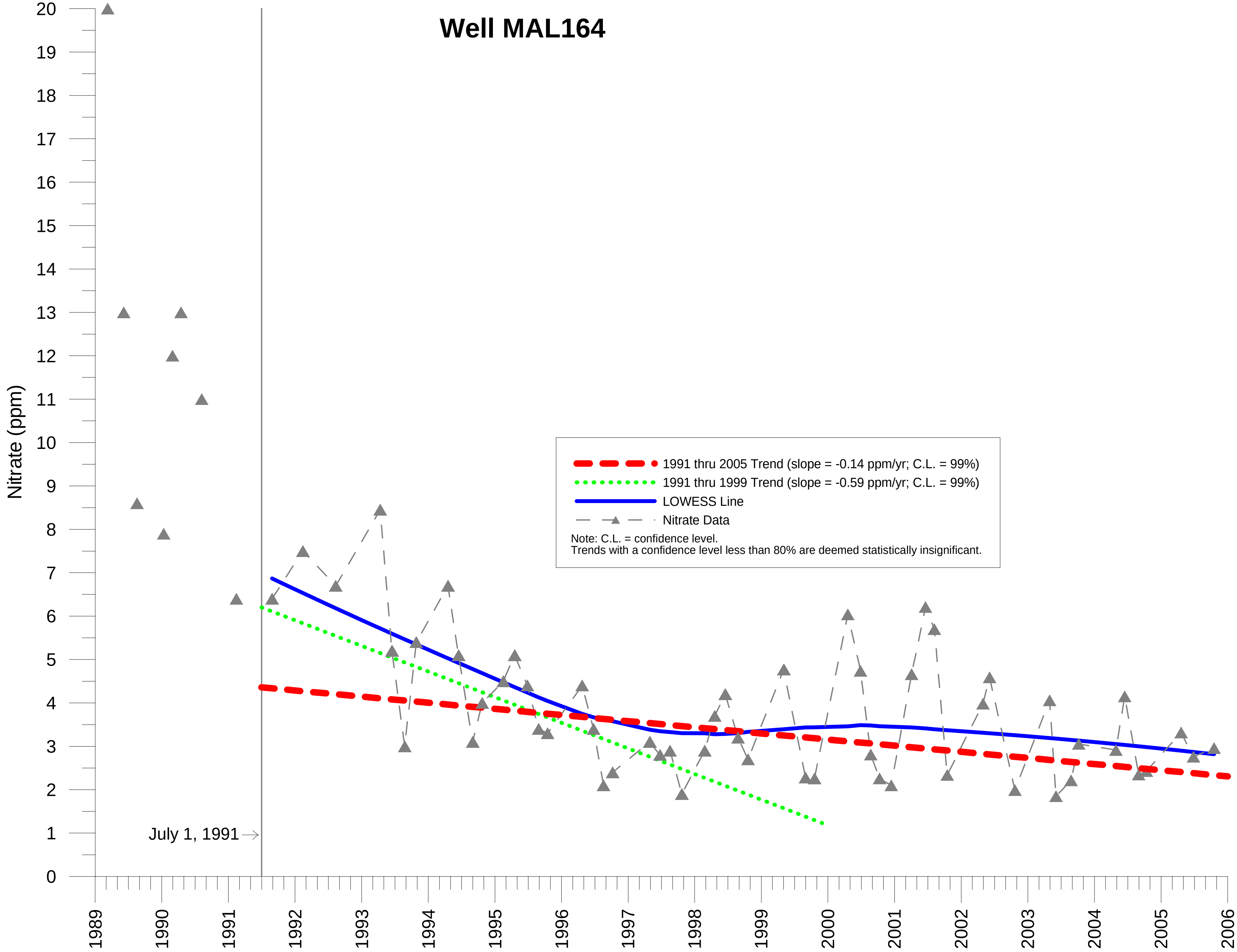

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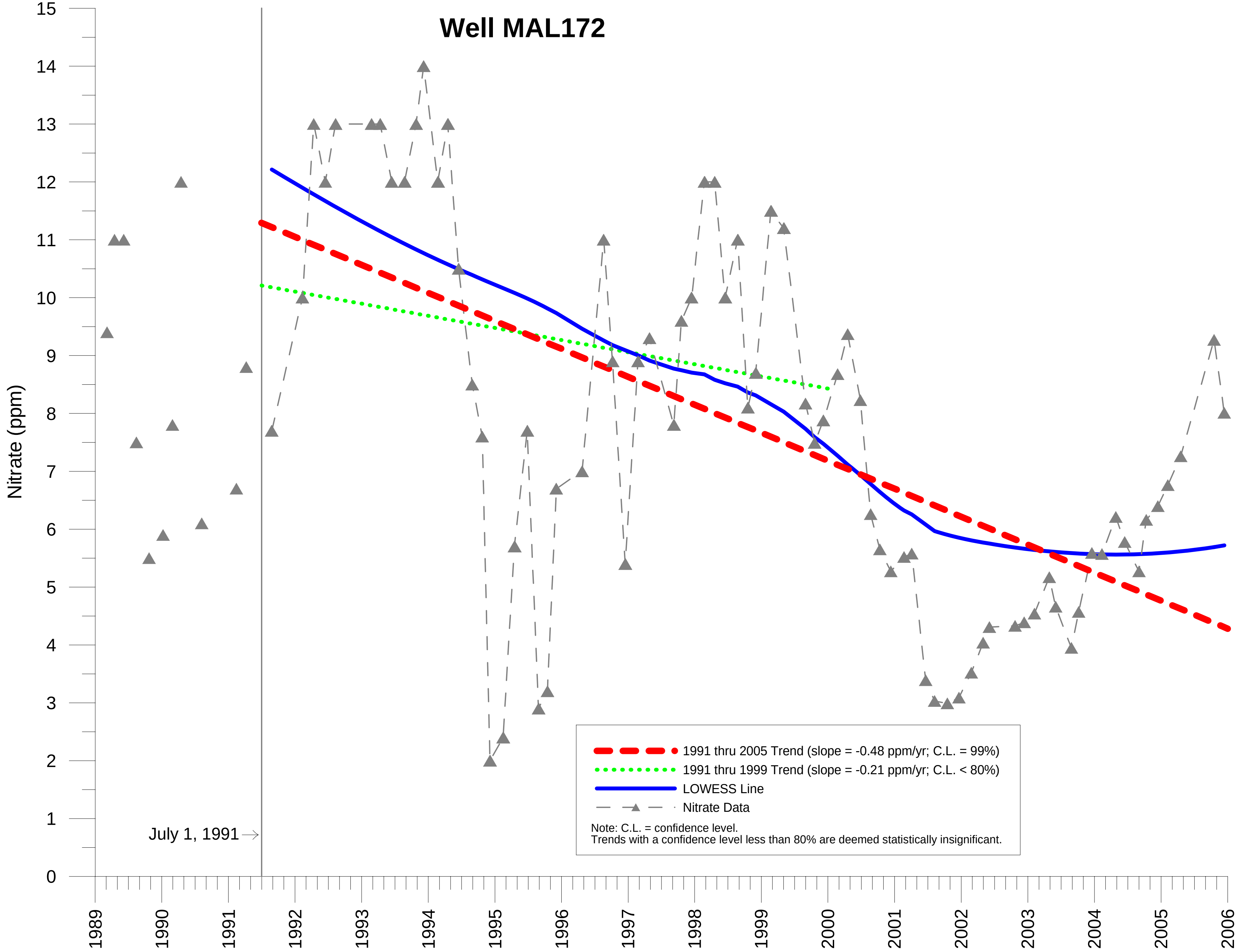

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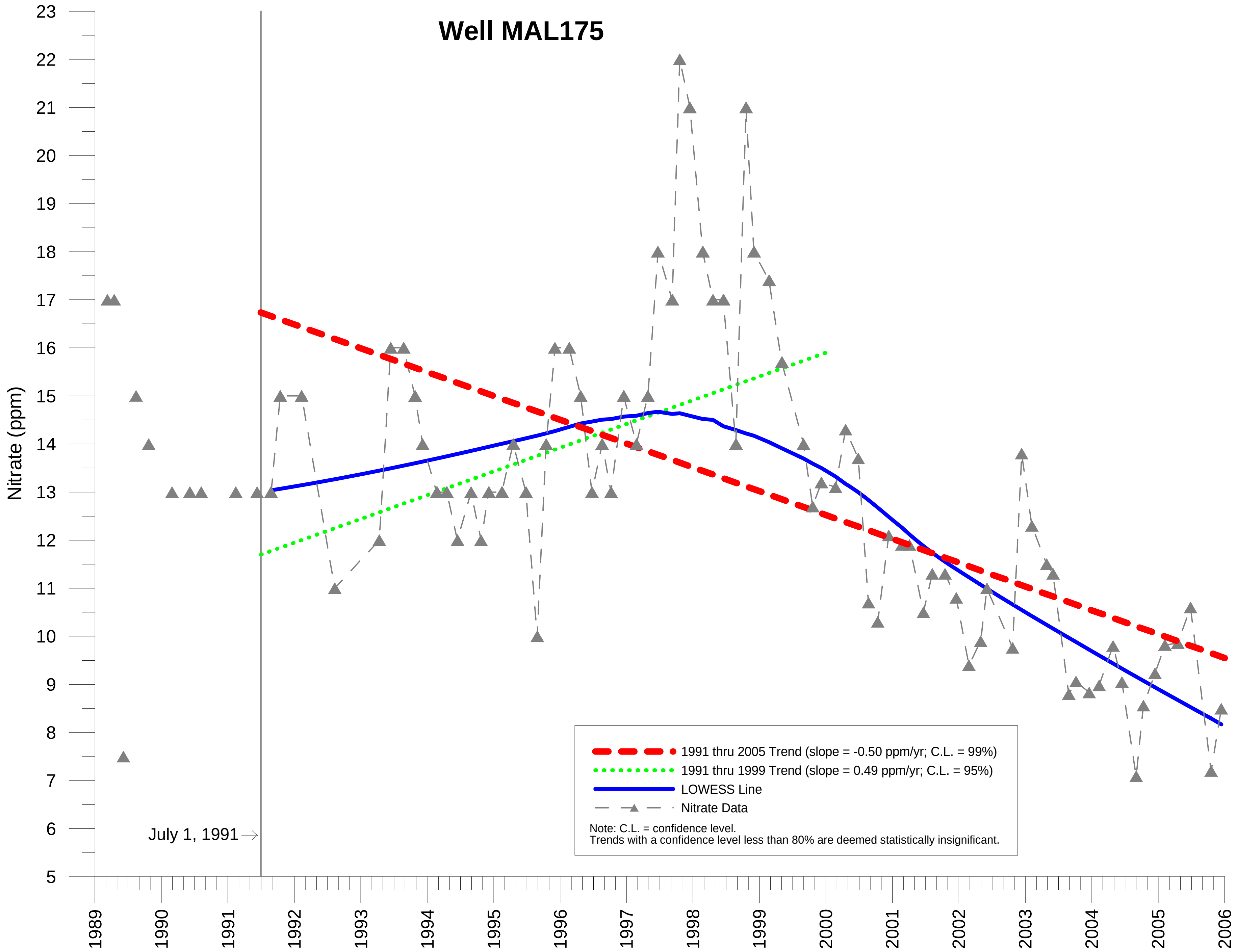

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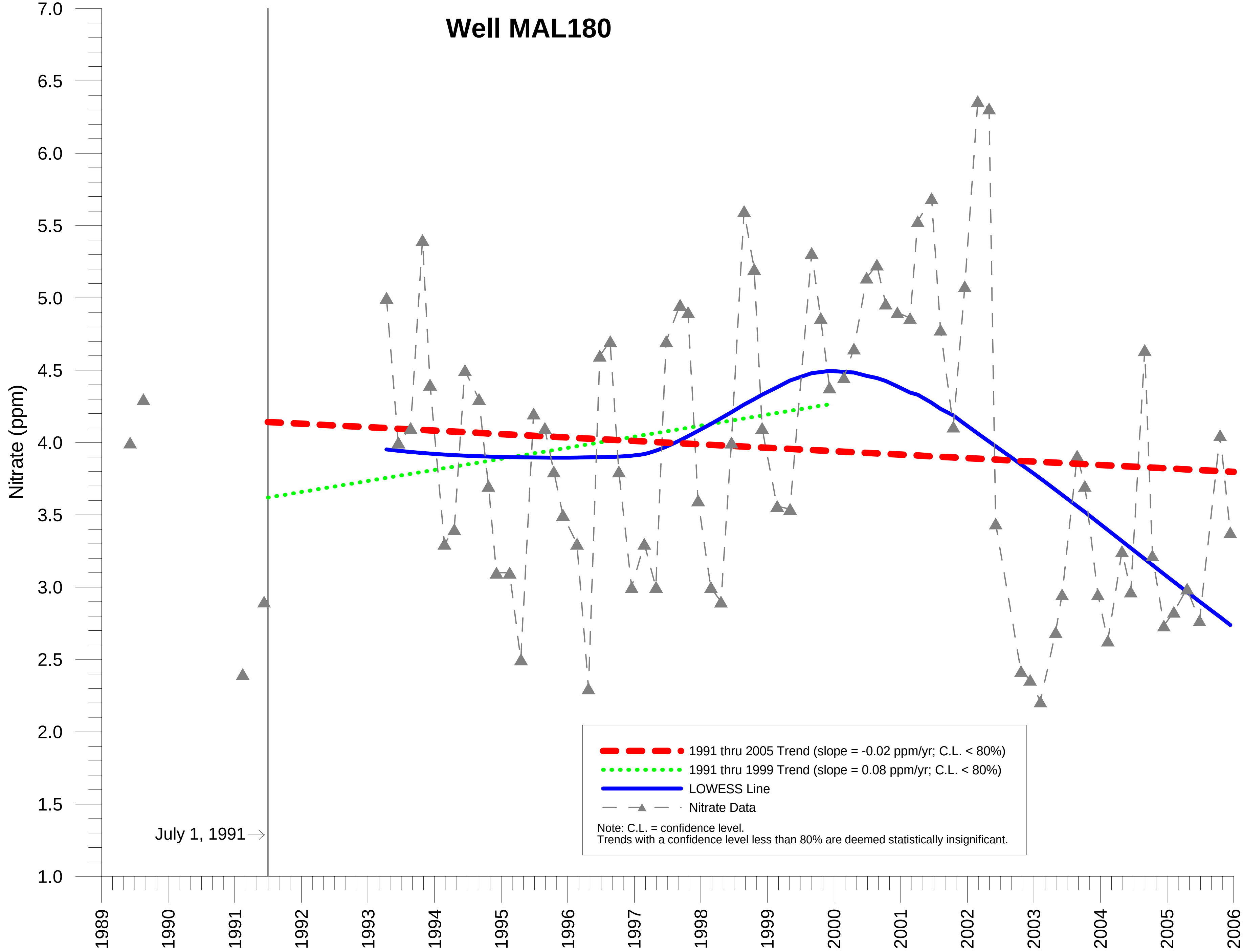

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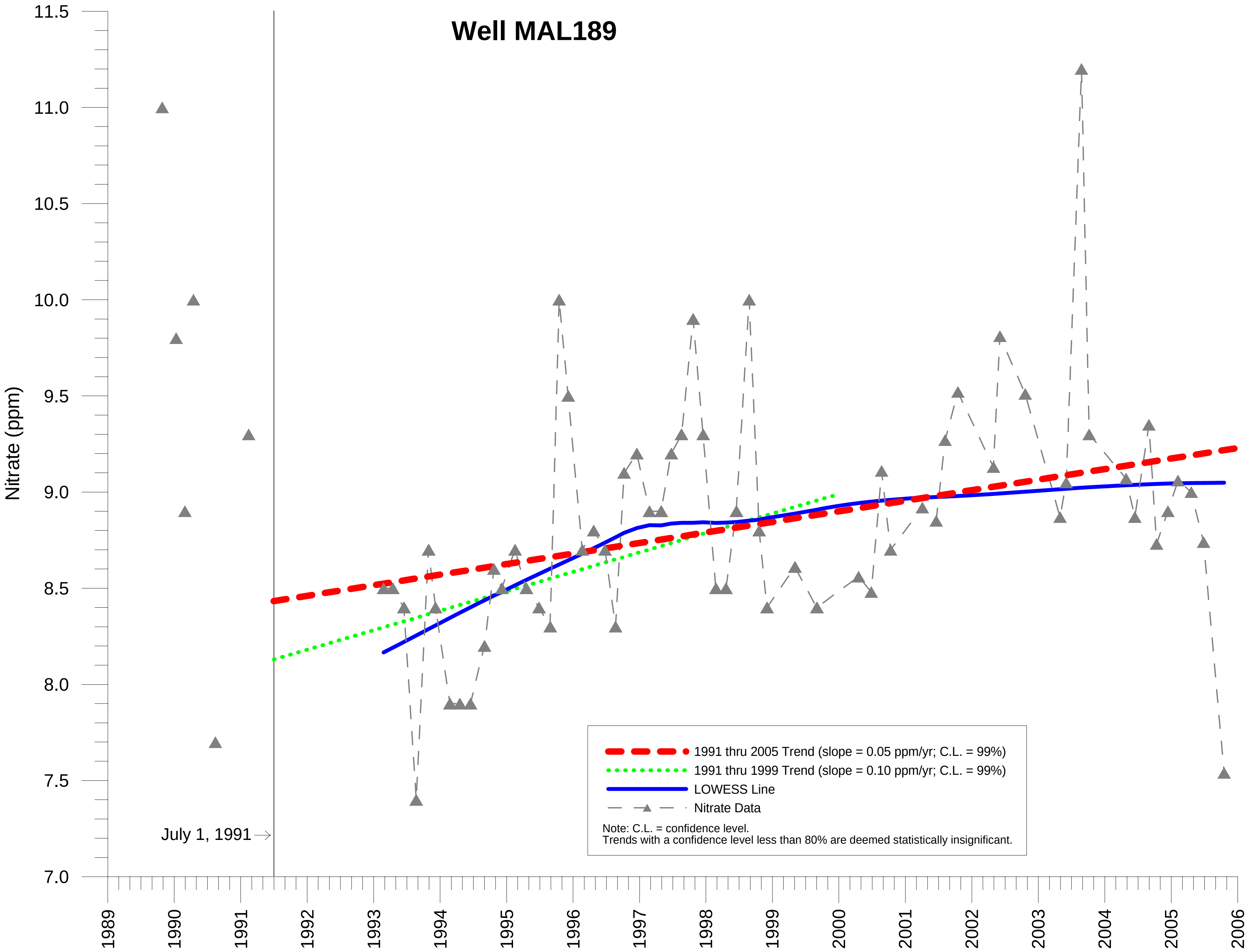

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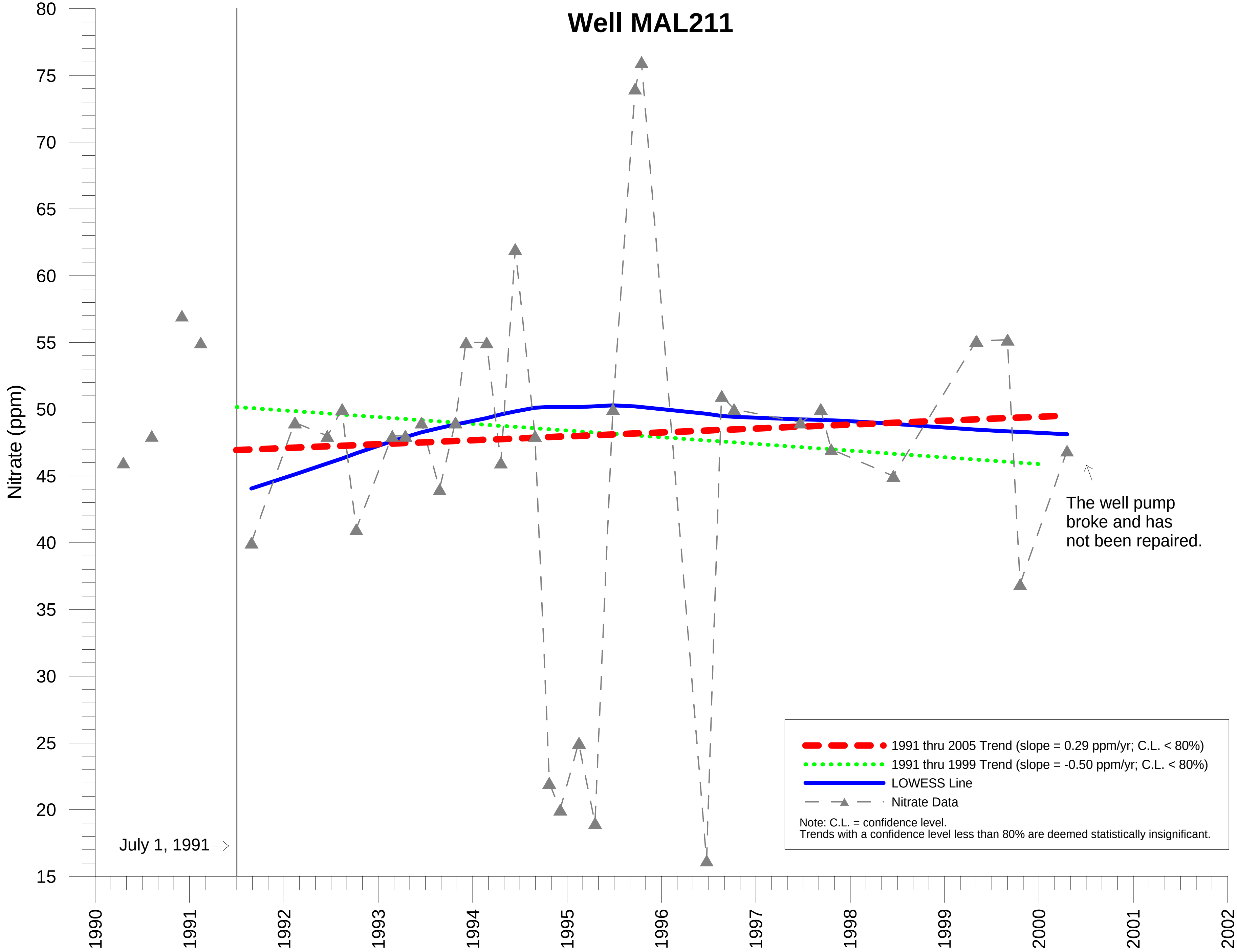

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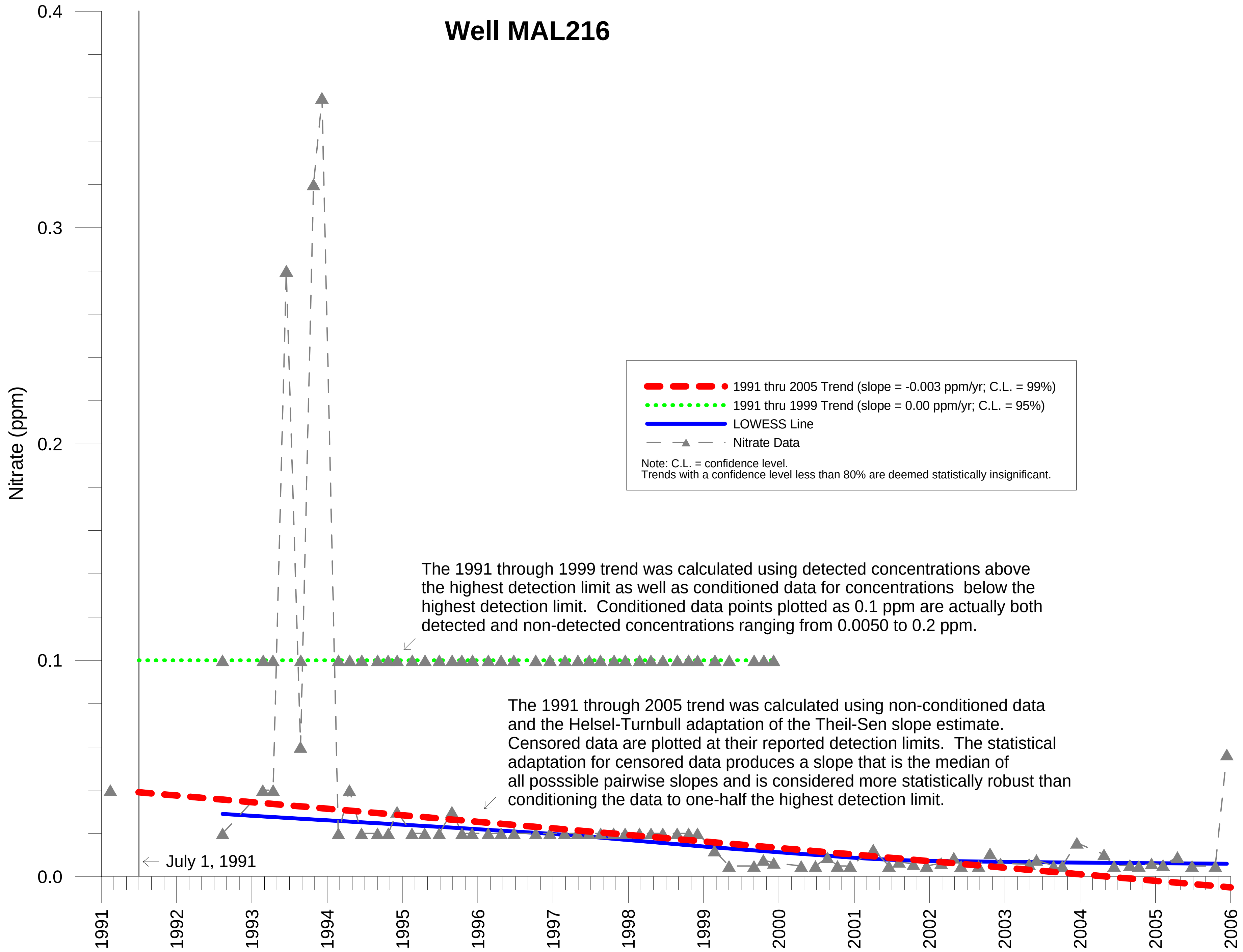

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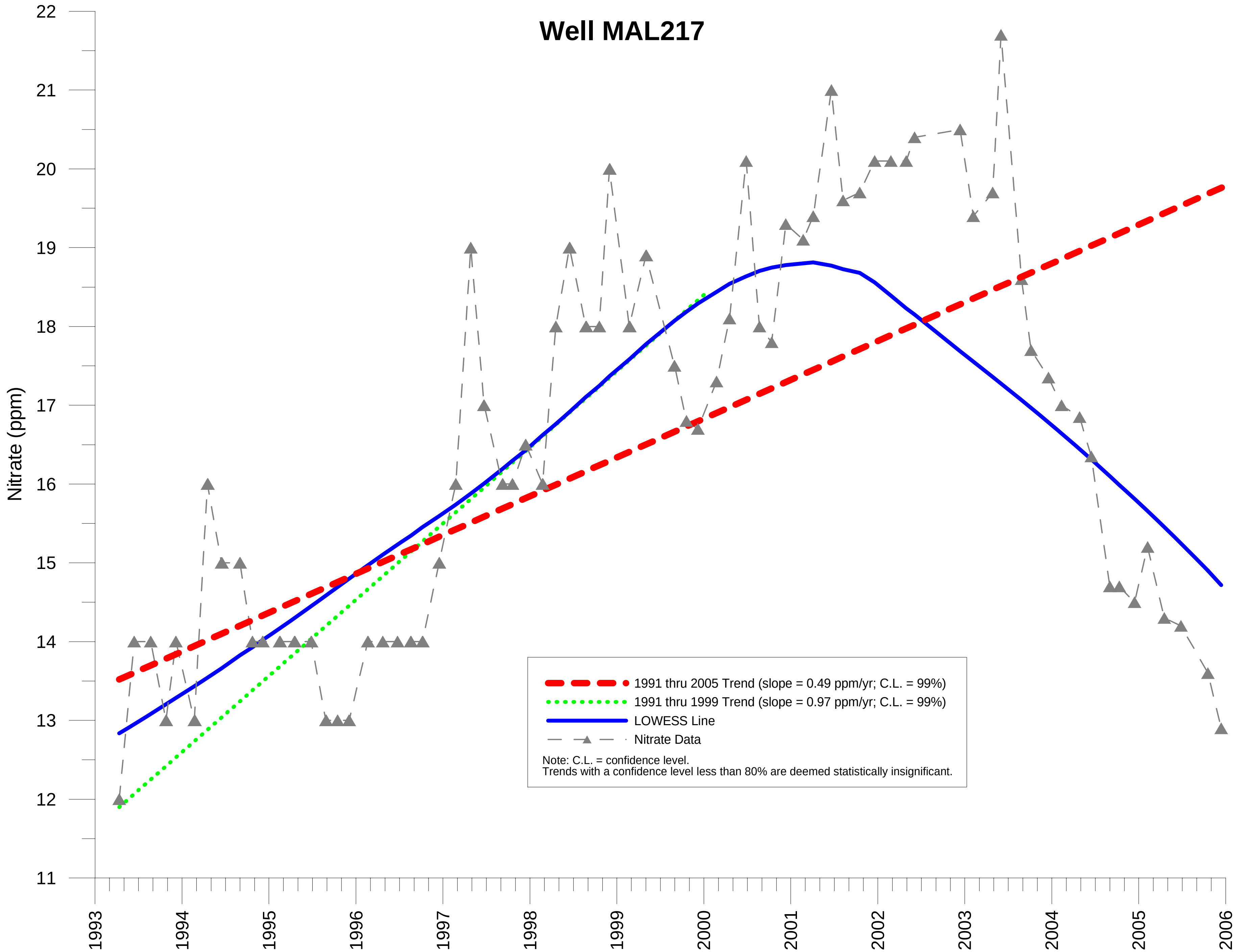

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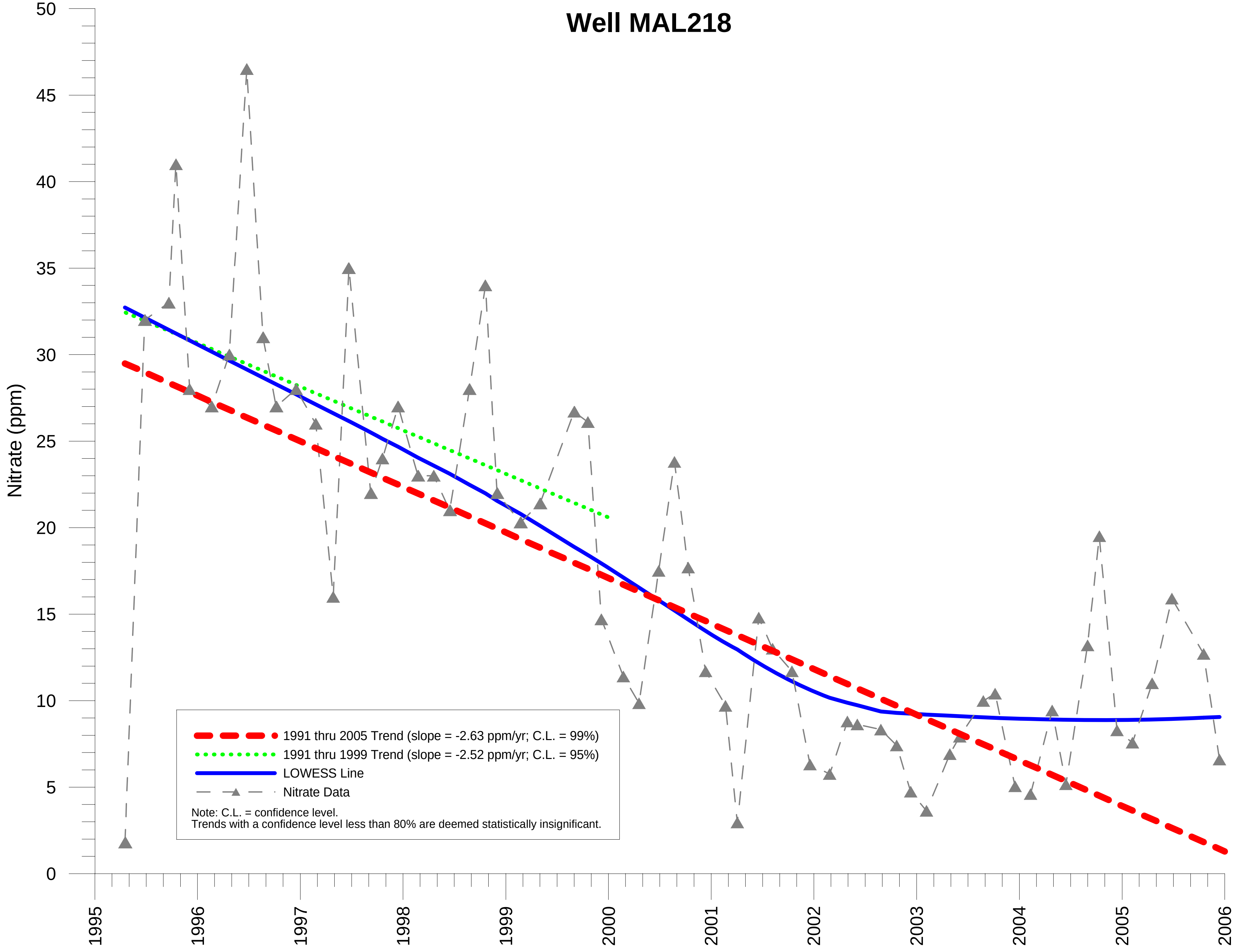

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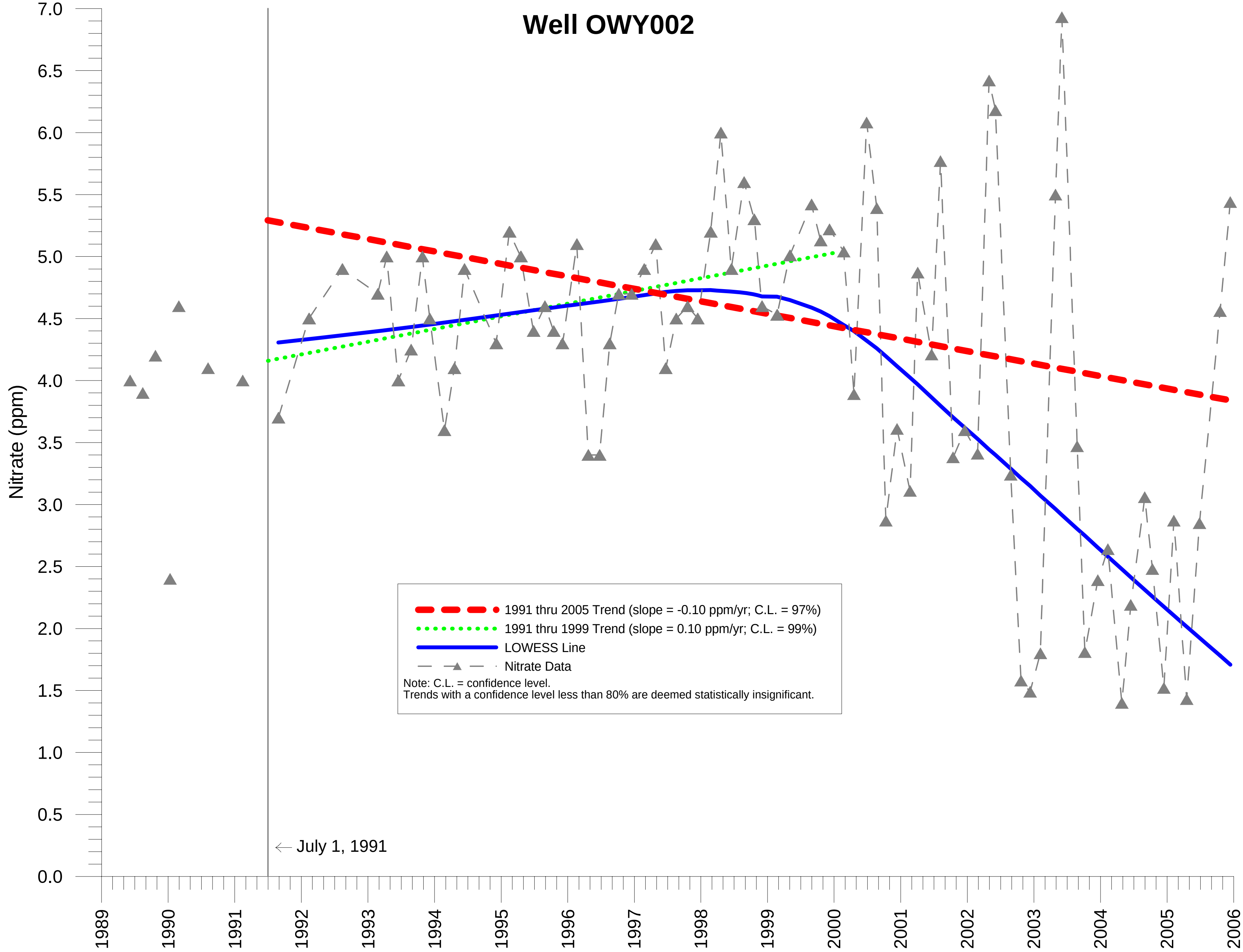

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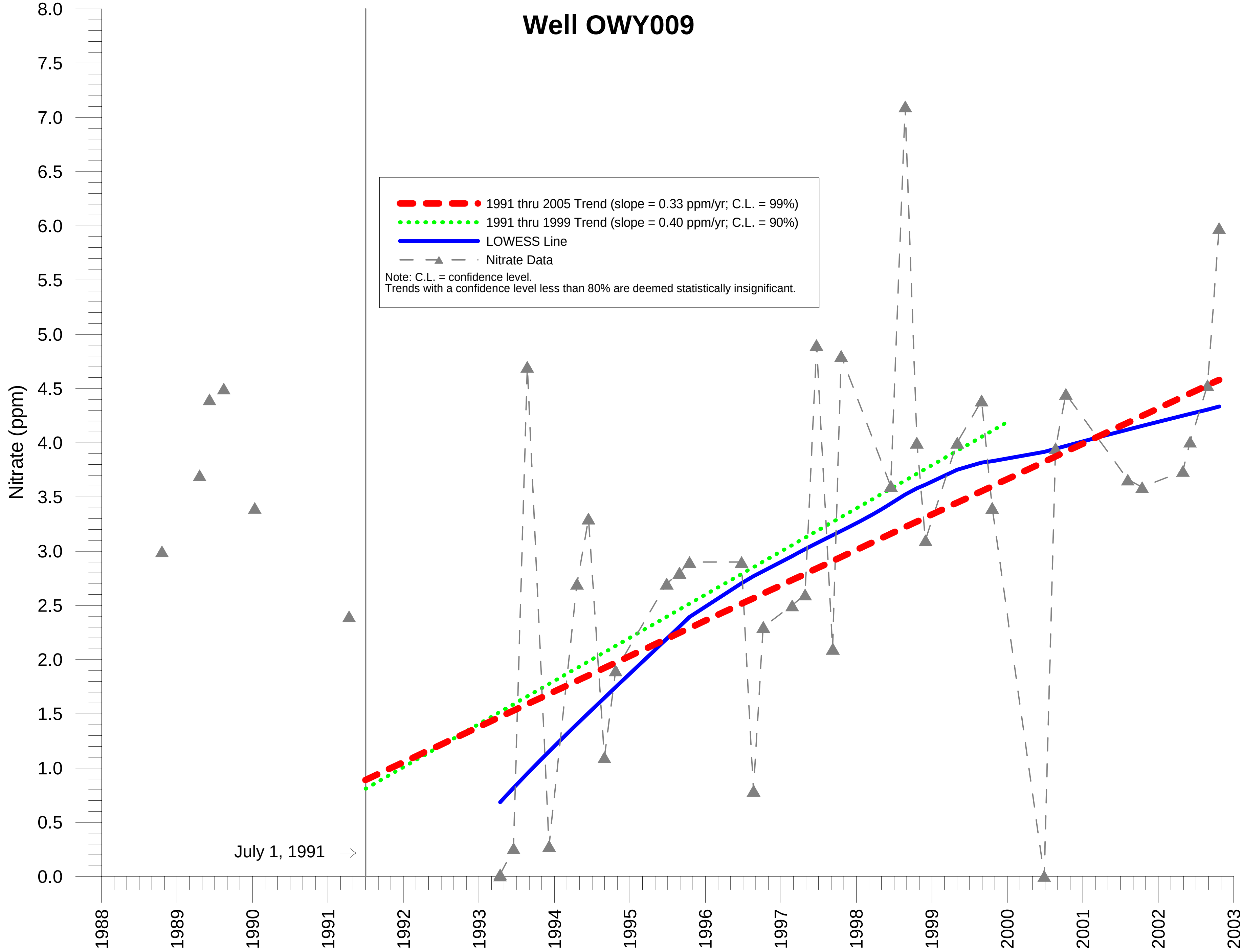

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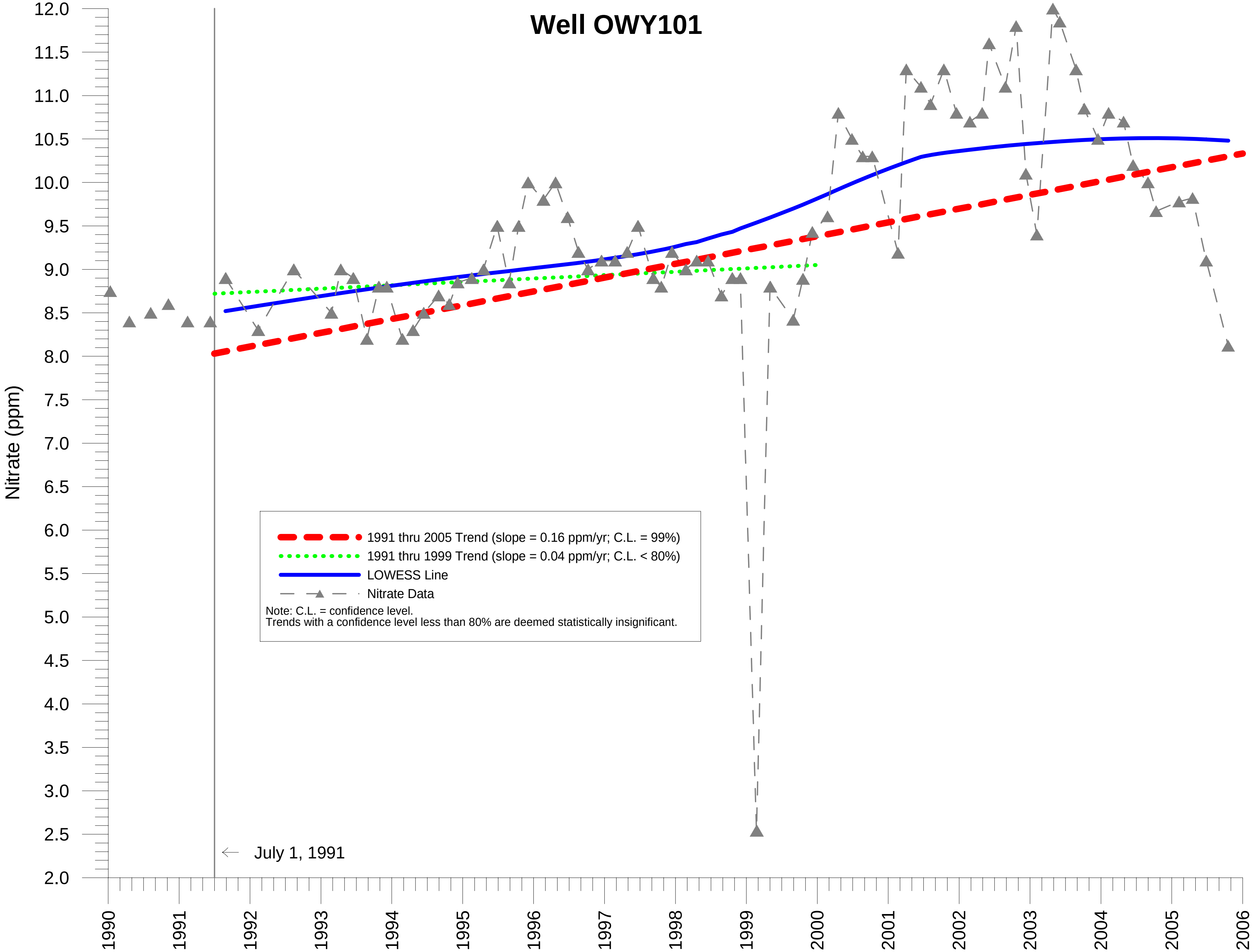

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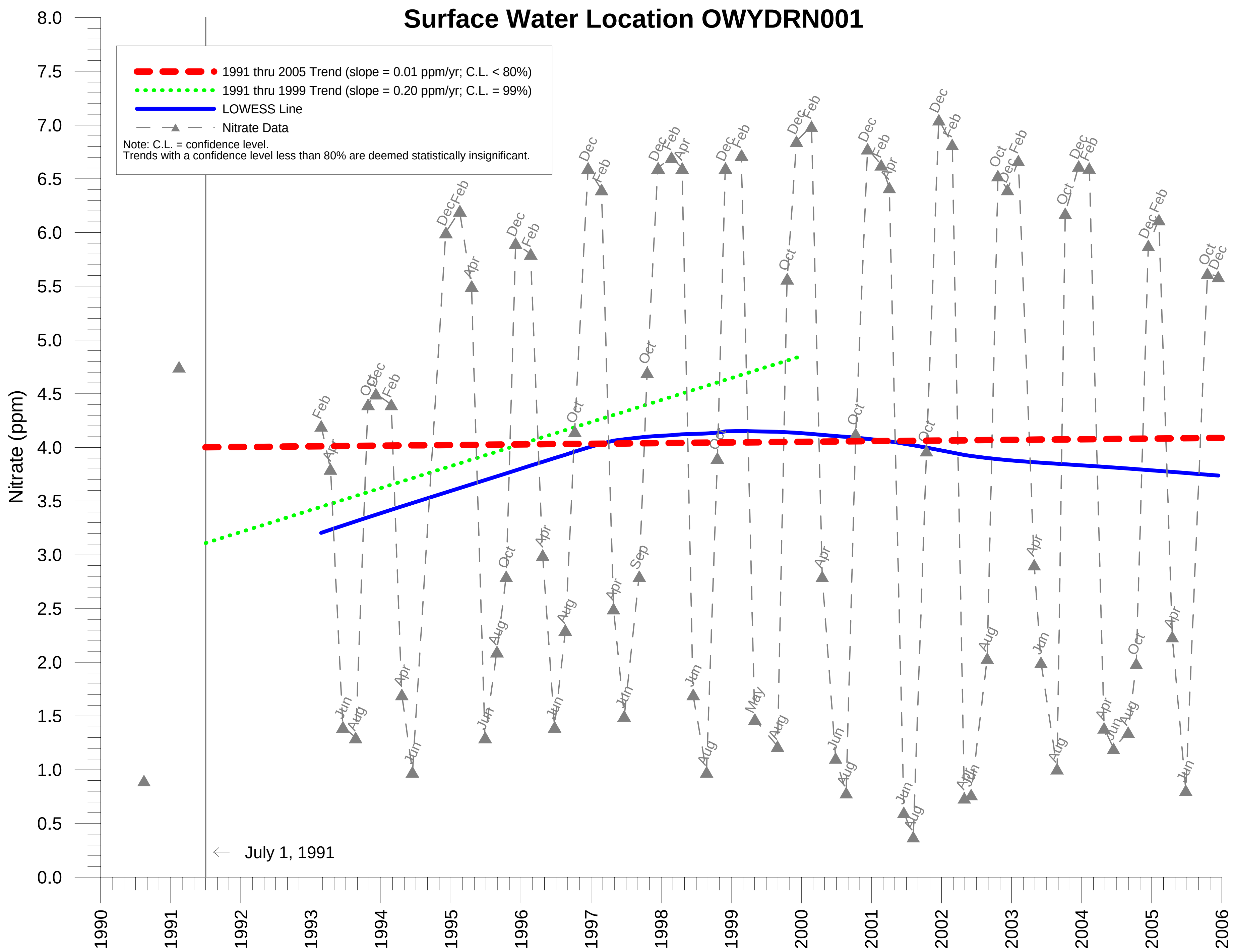

Surface Water Location OWYDRN001
1991 thru 2005 Trend (slope = 0.01 ppm/yr; C.L. < 80%)
1991 thru 1999 Trend (slope = 0.20 ppm/yr; C.L. = 99%)
LOWESS Line
Nitrate Data
Note: C.L. = confidence level.
Trends with a confidence level less than 80% are deemed statistically insignificant.
Nitrate (ppm)
July 1, 1991

Surface Water Location OWYDRN002

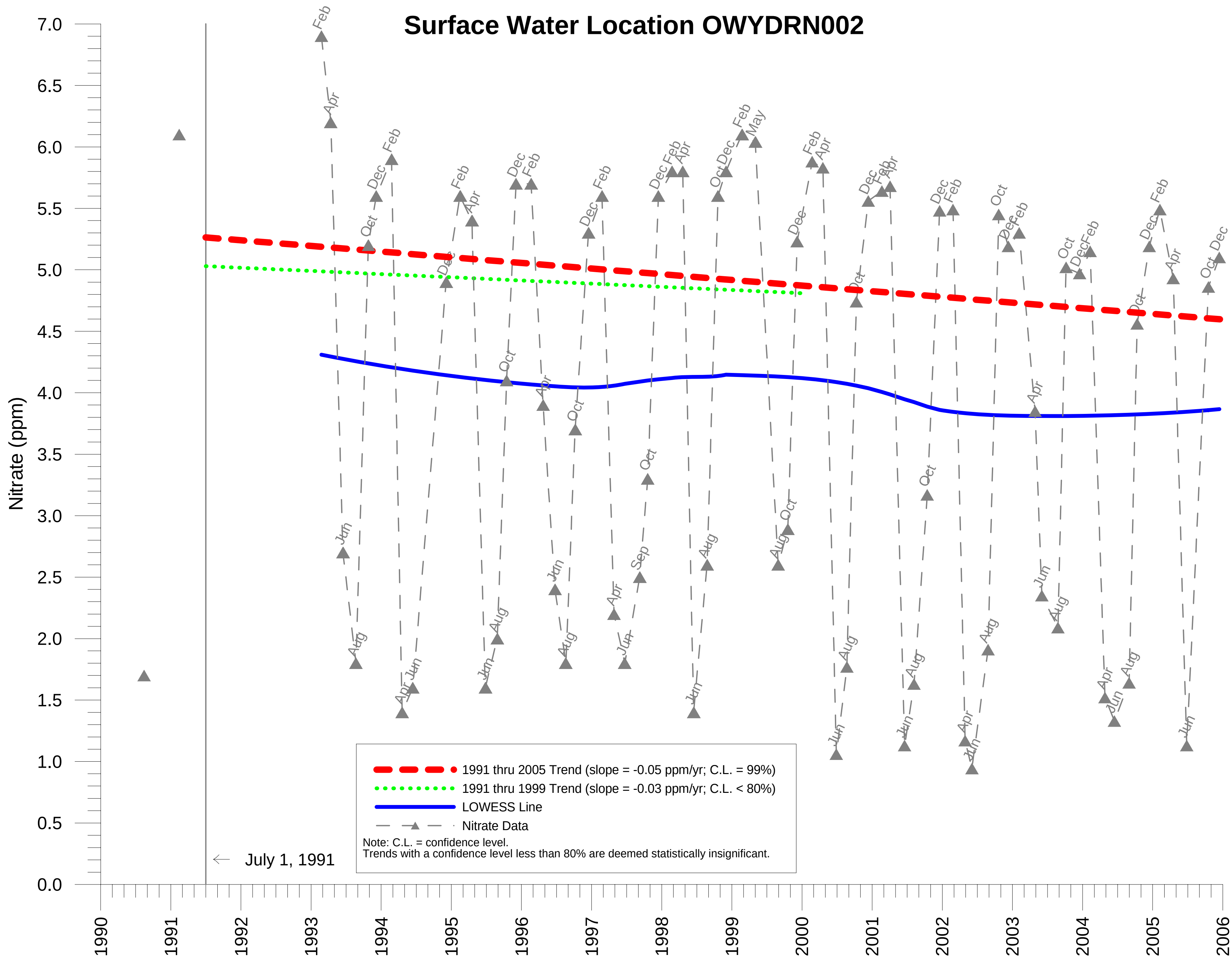

Table A-1
DEQ and OWRD Well Designations
Second Northern Malheur County GWMA Trend Analysis Report

DEQ Well ID	OWRD Well ID
MAL005	MALH 626
MAL012	MALH 1188
MAL016	MALH 1606
MAL030	MALH 1496
MAL035	?
MAL041	MALH 1703
MAL044	MALH 1718
MAL047	MALH 1695
MAL062	?
MAL064	MALH 539
MAL078	MALH 1936
MAL079	?
MAL083	MALH 1731
MAL101	MALH 1212
MAL105	MALH 1195
MAL106	?
MAL108	MALH 1927
MAL116	MALH 898
MAL119	MALH 1706
MAL121	MALH 1213
MAL125	MALH 923
MAL126	?
MAL129	MALH 1004
MAL136	MALH 1207
MAL147	MALH 461
MAL152	MALH 469
MAL164	?
MAL172	MALH 190
MAL175	MALH 334
MAL180	MALH 1154
MAL189	MALH 1211
MAL211	?
MAL216	MALH 2526
MAL217	?
MAL218	MALH 3044
OWY002	?
OWY009	MALH 2143
OWY101	MALH 51463