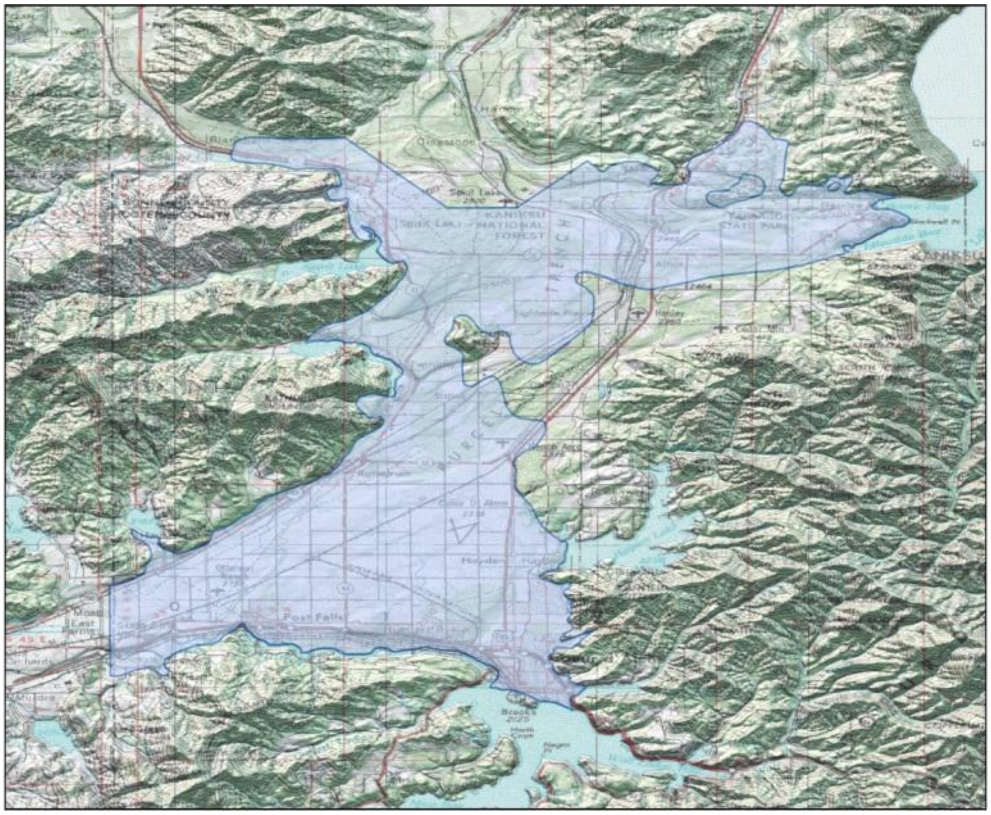
Trend Analysis of Selected Ground Water Constituents of the Rathdrum Prairie Aquifer, Kootenai County, Idaho

Ground Water Investigation Report DEQ-CRO-01-15



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Prepared by
Gary R. Stevens, P.G.
Idaho Department of Environmental Quality
Coeur d’Alene Regional Office
2110 Ironwood Parkway
Coeur d’Alene, Idaho 83814

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1 Introduction

The Panhandle Health District (PHD) is one of seven health districts in Idaho that provides a number of services to protect human health, including the protection and provision of safe drinking water supplies. The sole aquifer used to provide drinking water to Kootenai County is the Rathdrum Prairie aquifer (RPA), and monitoring the water quality is an important step in ensuring safe drinking water.

The PHD has been collecting water quality information from a number of wells completed in the RPA since 1975. When the well sampling program was initiated, the emphasis was on monitoring the potential of water quality impacts from subsurface wastewater disposal predominantly in the southern portion of the aquifer. In subsequent years, the well sampling program has evolved to investigate other constituents and different geographical areas of the aquifer. The water quality data consist of a variety of inorganic and organic constituents that represent general aquifer ground water quality, along with some that may indicate contamination from land surface activities.

2 Rathdrum Prairie Aquifer

The RPA covers approximately 200 square miles in Idaho and extends from Lake Pend Oreille south to Coeur d'Alene and Post Falls and west to the Idaho-Washington border (Figure 1). The RPA is part of the larger Spokane Valley-Rathdrum Prairie aquifer that extends into Washington State.

The alluvium that forms the RPA was deposited 8,000–18,000 years ago by southerly drainage from the continental Cordilleran Ice Sheet along with enormous catastrophic floods from Lake Missoula (Alt 2005). The large volume and flow rate of the floods deposited the gravel, cobbles, and boulders into the Rathdrum Prairie and carried away most of the smaller silt and sand, leaving behind the very permeable aquifer that is the area's source of drinking water today. The bedrock basement of the RPA is composed predominantly of Precambrian age medisediments and Cretaceous age granitic rocks (Lewis at al. 2002).

The water that recharges the RPA is mainly seepage from the Spokane River and adjacent lakes along with precipitation (Hsieh et al. 2007). Ground water from the northern areas of the aquifer starts at a water elevation of about 2,100 feet, and at the state line the water elevation is about 1,970 feet. Depths to water from land surface range from approximately 150 feet to 550 feet.

3 Groundwater Monitoring

3.1 Monitoring Wells

PHD's monitoring well network used for this analysis consists of 34 wells distributed across the RPA that were typically sampled three to four times per year (Figure 2, Table 1). Most of the wells are clustered around the cities of Coeur d'Alene and Post Falls, with fewer located in the central and northern portions of the aquifer. The monitoring wells are almost all municipal or community wells (except wells 114 and 116) and have been sampled for a number of years and a variety of constituents (Table 1). The range of sampling dates vary; most had sampling initiated in the mid-1970s to early 1980s and were sampled through 2014—the last year used for this analysis. A few wells had sampling terminated earlier. The analytical data can be obtained at the Panhandle Health District's office at 8500 N Atlas Rd, Hayden, Idaho or through PHD's website (*http://www2.phd1.idaho.gov/welltest/default.aspx*).

3.2 Water Quality Constituents

The water quality constituents chosen for statistical analysis were those that could be indicators of anthropogenic activities: (1) nitrate as nitrogen, (2) chloride, (3) sodium, (4) magnesium, and (5) conductivity. The sources of these constituents are many and include septic waste, fertilizer, road deicers, stormwater, and landfill leachate (Fernando and Lerner 2005; Morris et al. 1994; Paul et al. 2007; Recay 2004; Watson et al. 2002). No attempt was made to distinguish the specific sources and locations for any of these constituents. Such an effort is beyond the scope of this investigation.

4 Statistical Methods

The water quality data sets were analyzed for various statistical parameters and trends: (1) arithmetic mean, (2) median, (3) standard deviation, (4) Mann-Kendall trend, and (5) Theil-Sen trend. These analyses provide information regarding each constituent data set in relation to the drinking water standards and potential contributions from anthropogenic activities.

4.1 Summary Statistics

The arithmetic mean and median provide a measure of central tendency, which is a single value that describes an entire set of data by identifying the central position within that data set. The arithmetic mean is the average of a set of values and is equal to the sum of all the values divided by the number of values in the data set. The median is also a measure of central tendency. The median is the middle number for a set of data that has been arranged in order of magnitude. The median is typically used to describe environmental data because it is less affected by outliers and skewed data.

The standard deviation is a measure of the dispersion of a set of data from its mean. The more spread apart the data, the higher the deviation. The first step in determining the standard deviation is to determine the variance. The variance is the average of the squared differences of each measure from the mean. The standard deviation is then calculated as the square root of the variance.

4.2 Trend Analysis

The Mann-Kendall test (EPA 2009; Helsel and Hirsch 2002; Singh 2013) is used to detect a monotonic trend (concentrations tend to change over time) in time-series data. The Mann-Kendall test uses the difference between pairs of data points rather than the data values themselves. Each value is compared to all the other values in the data set. If the difference between the two values is positive (indicating an increase), the difference is scored as a positive one (1). If the difference is negative (indicating a decrease), the difference is scored as a negative one (-1). If there is no or little difference, then the difference is scored as a zero (0). All the scored differences are summed (designated by S). A positive S indicates an increasing trend, while a negative S indicates a decreasing trend. If S is near or equal to zero, there is no trend.

The Theil-Sen test (EPA 2009; Helsel and Hirsch 2002; Singh 2013) is another method to determine monotonic trends in time-series data. The Theil-Sen test also uses the difference between pairs of data points rather than the data values themselves. Each value is compared to all the other values in the data set, but instead of the arithmetic difference between the two values, the slope is calculated. The slopes can be positive, negative, or zero. All the slopes are then arranged in numerical order—either high to low or low to high—and the center value (median) is selected and designated β. If β is positive there is an increasing trend, and if β is negative there is a decreasing trend. If β is near or equal to zero then there is no trend.

Both the Mann-Kendall and Theil-Sen tests were completed with a confidence coefficient of 95%. A 95% confidence coefficient means there is only a 5% chance of obtaining a data set indicating a trend when there is actually no trend present. The determination of a 95% confidence coefficient was completed through a statistical method called hypothesis testing. There are two hypotheses or outcomes of the method; (1) there is no trend (2) or the trend is either increasing or decreasing. The hypothesis that there is no trend is called the null hypothesis and the hypothesis that the trend is either increasing or decreasing is called the alternative hypothesis. The assumption is that the null hypothesis is true (no trend is present) unless there is strong enough evidence to support the alternate hypothesis (a trend is present). If the data set indicates that the confidence coefficient is equal to or greater than 95% then there is strong enough evidence to support the alternate hypothesis and not the null hypothesis.

The results of the Mann-Kendall analysis were evaluated by determining the probability value (p-value) for each data set. The p-value is the probability of obtaining a data set that indicates that a trend is present if the null hypothesis were true (no trend is present). A 95% confidence coefficient equates to a significance level of 0.05 (1.00-0.95). The significance level is the threshold level that will be used to compare the p-value for each data set. If the p-value is greater than 0.05 indicating that there is greater than a 5% chance that the data set indicates a trend when no trend is actually present then we assume the null hypothesis is true (no trend). If the p-value is equal to or less than 0.05 then we assume the alternate hypothesis is true (a trend is present), indicating that there is less than a 5% chance that the data set indicates a trend when no trend is actually present. The greater the p-value is above 0.05 the more confident we are that we have no trend. The greater the p-value is below 0.05 the more confident we are that we have a trend. The p-value is determined by referencing a table of p-values based on the number of samples and the S value of each data set (Gilbert, 1987)

The null or alternative hypothesis was evaluated with a 95% confidence coefficient for the Theil-Sen analysis by calculating the confidence intervals of the slope. The Theil-Sen analysis determined the median slope (β) between all the slope measurements in the data set. If each well had been repeatedly sampled at the same dates and over the same period of time we would expect a range of median slope values from each unique data set. The upper and lower slope values that are expected to bracket our median value of β 95% of the time are the upper confidence limit (UCL) and the lower confidence limit (LCL). If sampling results tightly group about the median slope (small standard deviation) you would expect a small difference between the UCL and the LCL. If we only have sampling results that exist over a large range of median slope values (large standard deviation) you would expect a large difference between the UCL and the LCL.

The UCl and LCL were calculated with a 95% confidence coefficient for each of our median slopes values. For each of our measured data sets, if a slope of 0 (zero) was bracketed between the UCL and LCL at the 95% confidence coefficient then there is no trend. If both the UCL and LCL are positive or negative then we can conclude with e 95% confidence there is trend (positive of negative).

The ProUCL software (Singh 2013) was used to determine the statistical values and trends in this study. The ProUCL software was developed to compute rigorous statistics to aid decision makers regarding sample analysis. Nondetect values used for the Mann-Kendall and Theil-Sen trend tests were replaced with the minimum reporting limit (MRL) associated with each constituent data set for each well. If multiple MRL's were present, then the greatest MRL was used to replace all the nondetect values associated with each constituent data set for each well. It is also recommend (USEPA, 2009) that the non-detect values be assigned a common value lower than any of the detected concentrations. If the greatest MRL's in the data set were above the lowest detected concentration, then all the MRL values were replaced with the lowest detected concentration. Using a single value for the nondetect concentrations eliminates the potential to affect the resulting trend. These data sets were also used to compute the summary statistics.

Seasonality could potentially affect constituent concentrations over a year. In order to detect and correct seasonal trends a number of measurements are necessary per year with usually monthly sampling recommended (Hirsch et al 1982). The PHD data sets vary between one and four measurements per year. The number and consistency of the data sets are not considered sufficient for modeling seasonality. No seasonal analysis or corrections were applied in this study and most likely do not affect the long term (multi-year) trends identified in this study.

5 Results

5.1 Mean, Median, Standard Deviation

The mean values for nitrate as nitrogen and chloride are all well below primary and secondary drinking water standards (Table 2). Magnesium, sodium, and conductivity do not have drinking water standards but were considered as indicators of potential anthropogenic impacts to water quality. The mean and median values have very little difference for most wells and constituents, which indicates there is little variation in sample results. Additional evidence is the relatively small standard deviation computed for each well and constituent. Well 108 appears to have significant differences between the mean and median values along with a relatively large standard deviation. A previous study (Riley 1999) indicates that the aquifer water quality on the south side of the Spokane River in this area can be affected by the stage and flow of the Spokane

River. The significant differences between the mean and median values along with a relatively large standard deviation are most likely reflections of the associated changes in water quality.

The median values for nitrate as nitrogen and chloride are all well below primary and secondary drinking water standards (Figure 3, Figure 4 and Table 2). Wells were determined to have elevated concentrations of a constituent by relative comparison of the median value to all the other wells. Some wells may have elevated median concentrations of multiple constituents and are more likely to be impacted by anthropogenic activities (Figure 3 – Figure 7).

A measure of the cumulative impact from all the constituents on each well was determined by summing the normalized median values for each constituent of each well. For each constituent, the median concentration for each well was normalized relative to the median concentrations in all the other wells. Normalization was completed through a ranking system of 0 through 10. The well with the greatest median concentration for a constituent was given a score of 10 and the well with the least concentration was given a score of 0. All other wells were given a score between 0 and 10 depending on where the median value fell between the maximum and minimum values. The normalization was completed for each constituent and provides for an equal measure of all the median values of each constituent between the different wells. The normalized values for each constituent were then summed for each well giving a cumulative normalized value (CNV) that indicates the relative impact on each well. The normalized value for each well and constituent along with the cumulative values can be seen in Table 3. Figure 8 shows the CNV for all the monitoring wells.

Two general areas, as indicated by multiple wells, appear to have elevated CNVs: (1) an area north-northwest of the city of Coeur d'Alene and (2) an area immediately west of the city of Post Falls. These areas may have elevated CNVs due to a combination of sources such as road deicers, stormwater discharges, and lawn fertilizers, based on the median values. The area west of Post Falls may have additional contributions potentially from subsurface septic systems and agricultural fertilizers.

Four wells outside of these areas also demonstrate elevated CNVs: Well 108, Well 111, Well 122, and Well 126. Wells 108 and 111 appear to be located downgradient from areas with high densities of subsurface septic systems relative to the rest of the RPA. The elevated CNV of Well 122 is most likely due to a combination of sources such as road deicers, stormwater discharges, and lawn fertilizers. The potential water quality impacts from the surface activities described in Well 99 (elevated area north of Coeur d'Alene) and Well 122 are consistent with results from a previous study (Stevens 2013). The potential source causing the elevated CNV for Well 126 is unknown and may be related to the inability to sufficiently purge the well due to the plumbing configuration.

5.2 Trend Analysis

The trend analysis for both the Mann-Kendall and Theil-Sen analysis resulted in wells with constituents that were increasing, decreasing or exhibited no trend. Examples of ProUCL output trend plots for both analysis can be seen in Figure 9 - Figure 11. The Mann-Kendall trends indicate a number of wells with increasing trends for all the constituents (Figure 12 – Figure 16, Table 4, and Appendix A). The Theil-Sen trends also indicate a number of wells with increasing trends for all the constituents (Figure 17 – Figure 21, Table 4, and Appendix A). There are some discrepancies between the two trend analysis method results. It appears the discrepancies are from wells with constituent or conductivity trends that are very minor.

The two constituents with the greatest number of wells with increasing trends are chloride and sodium, followed by magnesium (Table 4). Conductivity also shows an increasing trend in many wells, which is most likely related to the sodium, magnesium, and chloride trends.

6 Conclusion

The mean and median values of the nitrate as nitrogen and chloride sampled by PHD from wells completed in the RPA are well below the drinking water standards. The CNVs for all the constituents indicate two areas—one north-northwest of Coeur d'Alene and one west of Post Falls—that appear to have elevated values that maybe indicative of anthropogenic impacts. In addition to these two areas, three individual wells have elevated CNVs that may reflect anthropogenic impacts.

The trend analysis completed with both the Mann-Kendall and Theil-Sen tests indicate a number of wells with increasing trends. Chloride and sodium, followed by magnesium, are the constituents with the most wells showing an increasing trend and most likely reflect anthropogenic impacts.

References

Alt, L. 2005. *Glacial Lake Missoula and the Humongous Floods*. Missoula, MT: Mountain Press.

EPA (US Environmental Protection Agency). 2009. *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance*. Washington, DC: EPA. EPA530/R-09-007.

Fernando, W. and D. Lerner. 2005. "Non-Agricultural Sources of Groundwater Nitrate: A Review and Case Study." *Water Research* 39:3-16.

Gilbert, R., 1987. "*Statistical Methods for Environmental Pollution Monitoring*". John Wiley & Sons, New York.

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

Helsel, D., and R. Hirsch, R. 2002. "Statistical Methods in Water Resources." In *Techniques of Water Resources Investigations of the United States Geological Survey, Book 4, Hydrologic Analysis and Interpretation*. US Geological Survey.

Hsieh, P., M. Barber, C. Bryce, A. Hossain, G. Johnson, J. Jones, and A. Wylie. 2007. *Ground-Water Flow Model for the Spokane Valley-Rathdrum Prairie aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho*. Reston, VA: US Geological Survey. Scientific Investigations Report 2007-5044.

Lewis, R., R. Burmester, R. Breckenridge, M. McFadden, and J. Kauffman. 2002. "Geologic Map of the Coeur d'Alene 30 × 60 Minute Quadrangle, Idaho." Moscow, ID: Idaho Geological Survey. GM-33.

Morris, B., A. Lawrence, and M. Stuart. 1994. *The Impact of Urbanization on Groundwater Quality (Project Summary Report)*. British Geological Survey Report. Technical Report WC/94/56, Overseas Geology Series.

Paul, A., R. Seiler, T. Rowe, and M. Rosen. 2007. *Effects of Agriculture and Urbanization on Quality of Shallow Ground Water in the Arid to Semiarid Western United States, 1993 – 2004*. US Geological Survey. Scientific Investigations Report 2007-5179.

Recay, W. 2004. "Septic Tank Impacts on Ground Water Quality and Nearshore Sediment Nutrient Flux." *Ground Water* 42(7):1079–1089.

Riley, J. 1999. "Investigation of Nitrate in Ground Water in a Small Aquifer South of Post Falls, Idaho." Prepared for the State of Idaho's Department of Health and Welfare, Division of Environmental Quality.

Singh, A., and A.K. Singh. 2013. ProUCL Version 5.0.00 Technical Guide, Statistical Software for Environmental Applications for Data Sets With and Without Nondetect Observations. EPA/600/R-07/041.

Stevens, G. 2013. *A Hydrogeochemical Investigation of the Rathdrum Prairie Aquifer, Kootenai County, Idaho*. Boise, ID: Idaho Department of Environmental Quality. Ground Water Investigation Report DEQ-CRO-03-13.

Watson, L., E. Bayless, P. Buszka, and J. Wilson. 2002. *Effects of Highway-Deicer Application on Ground-Water Quality in a Part of the Calumet Aquifer, Northwestern Indiana*. USGS WRI 01-4260.

Table 1. Sampling history of Panhandle Health District's Rathdrum Prairie aquifer monitoring wells.

Well	Arsenic	Bromodichloromethane	Bromoform	Cadmium	Calcium	Calcium Carbonate	Carbon Tetrabromide	Carbon Tetrachloride	Chloride	Chloromethane	Dibromochloromethane	Dichloromethane	Iron	Fluoride	Lead	Magnesium	Manganese	Nitrate as Nitrogen	Nitrate	Orthophosphate	Potassium	Sodium	Sulfate	1,1,1-Trichloroethane	Tetrachloroethylene	Toluene	Trichloroethylene	VOC	Zinc	Temperature	pH	Conductivity	Date Range
99 CDA-4th Street	x	x	x		x	x			x		x		x	x		x		x	x	x	x	x	x					x	x	x	x	x	8/7/1975–6/3/2014
100 CDA-Locust Street	x				x	x		x	x			x	x	x		x		x	x	x	x	x	x				x	x	x	x	x	x	8/7/1975–6/3/2014
101 CDA-Linden Street	x				x	x		x	x				x	x		x		x	x	x	x	x	x		x		x	x	x	x	x	x	8/7/1975–5/1/2001
102 CDA-Atlas Well	x				x	x			x				x	x		x		x	x	x	x	x	x					x	x	x	x	x	8/7/1975–6/3/2014
103 Post Falls #4 Greensferry	x				x	x			x			x	x	x		x	x	x	x	x	x	x	x					x	x	x	x	x	8/7/1975–6/3/2014
104 Post Falls #3 Idaho Rd	x			x	x	x			x				x	x	x	x		x	x	x	x	x	x				x	x	x	x	x	x	8/7/1975–6/3/2014
105 Post Falls #5 Poleline	x				x	x			x				x	x		x		x	x	x	x	x	x					x		x	x	x	7/26/1982–6/2/2014
106 Post Falls #1 N. Tennis				x	x				x				x	x		x	x	x	x	x	x	x	x					x	x	x	x	x	8/1/1975–10/30/2000
107 Post Falls #2 S. Tennis					x		x		x				x	x		x		x	x	x	x	x	x		x			x	x	x	x	x	8/1/1975–10/30/2000
108 South River Water Association	x				x	x			x				x	x		x		x	x	x	x	x	x							x	x	x	1/28/1981–6/2/2014
109 N Kootenai Water #1 Hayden	x	x			x	x			x	x	x		x	x		x		x	x	x	x	x	x					x	x	x	x	x	9/15/1980–6/3/2014
110 Avondale Well					x				x				x	x		x	x	x	x	x		x	x				x	x	x	x	x	x	8/27/1975–10/24/1988
111 Dalton Gardens #1 E	x				x	x			x				x	x		x		x	x	x	x	x	x				x	x	x	x	x	x	7/30/1975–6/3/2014
112 East Greenacres	x				x	x			x				x	x	x	x	x	x	x	x	x		x				x	x	x	x	x	x	4/11/1976–6/2/2014
113 Mtn. View Terrace	x			x	x	x			x			x	x	x	x	x		x	x	x	x	x	x					x	x	x	x	x	8/11/1975–6/2/2014
114 CHS	x				x	x			x			x	x	x		x		x	x	x	x	x	x				x	x	x	x	x	x	7/28/1975–6/2/2014
115 Ross Point - Syringa	x				x	x			x				x	x		x	x	x	x	x	x	x	x					x	x	x	x	x	7/31/1975–6/2/2014
116 Turrel Well	x		x		x	x			x				x			x		x	x	x	x	x					x	x		x	x	x	7/25/1983–2/11/2008
117 USFS Nursery	x				x	x			x			x	x	x		x		x	x	x	x	x	x				x		x	x	x	x	7/28/1982–6/3/2014
118 Farragut #3	x				x	x			x				x	x		x		x	x	x	x	x	x					x	x	x	x	x	7/30/1975–6/3/2014
119 Athol #1 Grove Ave	x				x	x			x				x	x		x		x	x	x	x	x	x					x	x	x	x	x	8/5/1975–6/3/2014
120 Spirit Lake Well #3					x				x					x		x		x	x	x	x	x	x					x	x	x	x	x	8/5/1975–1/25/2000
121 Rathdrum - Pine Street	x				x	x			x				x	x		x		x	x	x	x	x	x				x	x	x	x	x	x	7/30/1975–6/2/2014

Well	Arsenic	Bromodichloromethane	Bromoform	Cadmium	Calcium	Calcium Carbonate	Carbon Tetrabromide	Carbon Tetrachloride	Chloride	Chloromethane	Dibromochloromethane	Dichloromethane	Iron	Fluoride	Lead	Magnesium	Manganese	Nitrate as Nitrogen	Nitrate	Orthophosphate	Potassium	Sodium	Sulfate	1,1,1-Trichloroethane	Tetrachloroethylene	Toluene	Trichloroethylene	VOC	Zinc	Temperature	pH	Conductivity	Date Range
122 Rathdrum - Grange	x	x	x		x	x			x		x		x	x		x		x	x	x	x	x	x		x			x			x	x	5/26/1981–6/2/2014
123 Ross Point - Hwy 41	x				x	x			x				x	x		x		x	x	x		x	x				x	x	x	x	x	x	7/31/1975–1/30/2012
124 CDA Airport					x				x				x	x	x	x		x		x	x	x	x				x	x	x	x	x	x	7/28/1982–10/31/1994
125 L.A. Aluminum	x				x	x			x	x			x	x		x		x	x	x	x	x	x	x	x	x		x	x	x	x	x	8/6/1975–6/3/2014
126 Silver Water Association	x	x	x		x	x			x		x		x	x		x		x	x	x	x	x	x	x	x		x	x	x	x	x	x	8/12/1975–6/3/2014
127 CDA-Hanley	x				x	x			x			x	x	x		x		x	x	x	x	x	x	x			x			x	x	x	7/29/1992–6/3/2014
128 Post Falls #7 Majestic	x				x	x			x				x	x		x		x	x	x	x	x								x	x	x	1/24/1994–6/1/2009
129 Post Falls #6 - Mullan	x				x	x			x				x	x		x		x	x	x	x	x	x					x		x	x	x	10/28/1996–6/2/2014
130 CDA-Honeysuckle	x				x	x			x				x	x		x		x	x	x	x	x	x							x	x	x	1/27/1998–1/28/2014
131 Spirit Lake #4	x				x	x			x				x	x		x		x	x	x	x	x	x							x	x	x	4/24/2000–6/2/2014
132 Hauser	x				x	x			x				x		x	x		x		x			x							x	x	x	1/27/2003–6/2/2014

Note: VOC = volatile organic compounds

Table 2. Statistical results of Panhandle Health District's water quality data.

Well	Nitrate as Nitrogen (mg/L) *Primary Drinking Water Standard = 10 mg/L*			Chloride (mg/L) *Primary Drinking Water Standard = 250 mg/L*			Magnesium (mg/L) *No Drinking Water Standard*			Sodium (mg/L) *No Drinking Water Standard*			Conductivity (µmhos/cm) *No Drinking Water Standard*		
	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation
99 CDA 4th St.	1.06	1.01	0.38	4.82	3.20	4.06	12.90	12.60	2.79	2.75	2.70	0.37	249.7	236.5	72.6
100 CDA Locust St.	0.70	0.70	0.18	2.57	2.05	1.33	7.40	7.32	0.85	2.44	2.40	0.23	189.9	178.1	50.8
101 CDA Linden St.	0.44	0.41	0.16	1.77	1.30	1.47	5.03	4.80	0.63	2.18	2.20	0.22	131.2	125.0	2.8
102 CDA Atlas St.	0.86	0.82	0.29	3.32	2.89	2.56	7.99	7.60	1.60	2.84	2.80	0.40	200.7	191.5	42.7
103 Post Falls #4	0.80	0.68	0.52	1.68	1.50	1.04	6.81	7.05	3.22	2.20	2.20	0.38	139.5	130.0	64.3
104 Post Falls #3	1.29	1.25	0.29	2.19	2.00	1.17	10.11	9.95	1.63	2.19	2.20	0.27	179.5	160.0	53.8
105 Post Falls #5 Poleline	1.13	1.09	0.36	2.42	2.10	1.20	9.71	9.10	1.66	2.63	2.50	0.76	184.6	150.0	82.6
106 Post Falls #1 N. Tennis Courts	1.49	1.39	0.54	2.25	2.00	1.80	10.55	10.70	1.64	2.36	2.35	0.51	171.8	165.0	38.4
107 Post Falls #2 S. Tennis	1.17	0.98	0.54	1.61	1.30	1.05	8.16	7.90	1.27	2.21	2.20	0.28	155.6	145.0	28.4
108 South River Water Association	2.35	1.65	2.59	4.23	3.40	2.98	3.45	3.32	1.14	4.00	3.60	1.17	167.8	158.0	64.1
109 N Kootenai Water #1 Hayden	0.24	0.21	0.13	1.80	1.00	0.65	3.38	2.90	2.31	2.08	2.05	0.37	113.1	100.0	37.5
110 Avondale Well	0.22	0.17	0.32	1.56	0.81	1.95	3.11	2.30	3.18	1.90	1.85	0.44	54.5	46.5	37.0
111 Dalton Gardens #1 E	1.79	1.94	0.64	4.09	3.60	2.01	12.61	13.50	3.38	4.04	4.10	0.69	274.7	250.0	97.0
112 East Greenacres	1.36	1.34	0.23	1.97	1.76	0.96	15.83	15.80	1.37	2.83	2.80	0.27	247.2	217.5	68.5
113 Mtn. View Terrace	1.64	1.65	0.54	2.65	2.50	1.28	14.37	14.40	1.43	2.81	2.80	0.30	235.8	220.0	57.7
114 CHS	1.26	1.23	0.83	1.94	1.70	1.01	13.71	13.80	1.51	2.81	2.80	0.26	226.6	198.0	60.8
115 Ross Point - Syringa	1.42	1.29	0.91	2.52	2.05	1.49	9.22	8.40	3.55	2.47	2.40	0.41	170.8	182.0	44.9
116 Turrel Well	0.14	0.13	0.04	0.77	0.70	0.59	2.44	2.50	0.21	2.05	2.10	0.13	70.3	60.0	20.3
117 USFS Nursery	0.53	0.49	0.34	3.34	2.58	2.94	7.13	6.60	1.90	2.82	2.75	0.38	199.4	172.5	77.1
118 Farragut St. Pk. #3	0.19	0.15	0.18	1.30	1.10	0.96	13.40	13.50	0.86	2.99	3.00	0.19	221.5	197.5	57.6
119 Athol #1 Grove Ave.	0.56	0.43	0.41	1.73	1.50	1.18	13.02	13.20	1.92	3.00	3.00	0.17	220.6	185.0	63.0
120 Spirit Lake Well #3	0.22	0.19	0.12	0.84	0.50	0.89	0.60	0.60	0.23	2.14	2.20	0.24	33.8	30.0	26.9
121 Rathdrum - PIne	1.25	1.16	0.56	3.01	2.70	1.64	7.70	7.30	1.89	3.18	2.90	0.83	194.6	180.0	62.2

Well	Nitrate as Nitrogen (mg/L) *Primary Drinking Water Standard = 10 mg/L*			Chloride (mg/L) *Primary Drinking Water Standard = 250 mg/L*			Magnesium (mg/L) *No Drinking Water Standard*			Sodium (mg/L) *No Drinking Water Standard*			Conductivity (µmhos/cm) *No Drinking Water Standard*		
	Mean	**Median**	**Standard Deviation**	**Mean**	**Median**	**Standard Deviation**	**Mean**	**Median**	**Standard Deviation**	**Mean**	**Median**	**Standard Deviation**	**Mean**	**Median**	**Standard Deviation**
Street															
122 Rathdrum Grange	1.80	1.78	0.72	3.69	3.55	1.66	7.62	7.60	0.93	4.68	4.90	0.82	180.2	160.0	58.1
123 Ross Point - Hwy 41	0.98	0.79	0.63	2.60	2.00	1.77	7.45	6.50	2.99	2.54	2.50	0.28	156.5	162.5	48.1
124 CDA Airport	1.43	1.44	0.32	1.60	1.50	0.55	11.01	11.20	0.89	2.75	2.70	0.34	162.9	165.0	23.6
125 L.A. Aluminum	0.70	0.65	0.26	1.72	1.50	0.95	6.68	6.40	1.34	2.42	2.40	0.30	148.5	149.0	42.0
126 Silver Water Association	1.56	1.46	0.82	4.55	3.70	4.10	17.47	17.70	3.15	5.12	5.20	0.91	384.7	330.0	128.1
127 CDA-Hanley	1.00	1.06	0.42	4.68	4.04	1.73	14.41	14.50	2.80	3.76	3.80	0.23	250.5	251.0	55.1
128 Post Falls #7 Majestic	0.23	0.16	0.23	0.97	1.00	0.60	1.89	1.60	1.67	2.46	1.90	1.44	75.8	60.6	60.9
129 Post Falls #6 - Mullan	0.79	0.77	0.26	3.44	2.50	4.84	6.20	5.83	1.64	3.70	2.75	4.30	184.3	179.0	54.8
130 CDA-Honeysuckle	0.97	0.89	0.30	3.44	3.51	0.78	13.95	14.20	1.44	2.93	2.95	0.25	277.0	285.0	46.2
131 Spirit Lake #4	0.33	0.31	0.12	1.44	1.11	0.58	3.57	3.57	0.54	2.13	2.20	0.12	128.9	118.0	40.5
132 Hauser	1.09	1.10	0.22	4.19	4.02	1.09	9.31	9.34	0.44	NA	NA	NA	363.5	373.0	49.7

Notes: NA = not available, µmhos/cm = micromhos per centimeter, mg/L = milligrams per liter

Table 3. Normalized and cumulative normalized values.

Well	Normalized Values					Cumulative Normalized Value
	NO_3-N	Cl	Na	Mg	Conductivity	
99 CDA 4th St.	5	8	3	7	6	29
100 CDA Locust St.	3	4	2	4	4	17
101 CDA Linden St.	2	2	1	2	3	10
102 CDA Atlas St.	4	7	3	4	5	23
103 Post Falls #4	3	3	1	4	3	14
104 Post Falls #3	6	4	1	5	4	20
105 Post Falls #5 Poleline	5	5	2	5	3	20
106 Post Falls #1 N. Tennis Courts	7	4	1	6	4	22
107 Post Falls #2 S. Tennis	5	2	1	4	3	15
108 South River Water Association	8	8	5	2	4	27
109 N Kootenai Water #1 Hayden	0	1	1	1	2	5
110 Avondale Well	0	1	0	1	0	2
111 Dalton Gardens #1 E	10	9	7	8	6	40
112 East Greenacres	7	4	3	9	5	28
113 Mtn. View Terrace	8	6	3	8	6	31
114 CHS	6	3	3	8	5	25
115 Ross Point - Syringa	6	4	2	5	4	21
116 Turrel Well	0	1	1	1	1	4
117 USFS Nursery	2	6	3	4	4	19
118 Farragut State Park #3	0	2	3	8	5	18
119 Athol #1 Grove Ave.	2	3	3	7	5	20
120 Spirit Lake Well #3	0	0	1	0	0	1
121 Rathdrum - PIne Street	6	6	3	4	4	23
122 Rathdrum Grange	9	9	9	4	4	35
123 Ross Point - Hwy 41	4	4	2	3	4	17
124 CDA Airport	7	3	3	6	4	23
125 L.A. Aluminum	3	3	2	3	3	14
126 Silver Water Association	7	9	10	10	9	45
127 CDA-Hanley	5	10	6	8	6	35
128 Post Falls #7 Majestic	0	1	0	1	1	3
129 Post Falls #6 - Mullan	4	6	3	3	4	20
130 CDA-Honeysuckle	4	9	3	8	7	31
131 Spirit Lake #4	1	2	1	2	3	9
132 Hauser	5	10	NA	5	10	30

Notes: NA = not available, NO_3-N = nitrate as nitrogen, Cl = chloride, NA = sodium, Mg = magnesium

Table 4. Number of wells with increasing, decreasing, or no trend.

Constituent	Mann-Kendall			Theil-Sen		
	Increasing	Decreasing	No Trend	Increasing	Decreasing	No Trend
NO_3-N	11	10	13	11	9	14
Cl	23	3	8	22	3	9
Mg	13	4	17	11	2	21
Na	18	1	14	12	2	19
Conductivity	25	0	9	22	0	12
Total	**90**	**18**	**61**	**78**	**16**	**75**

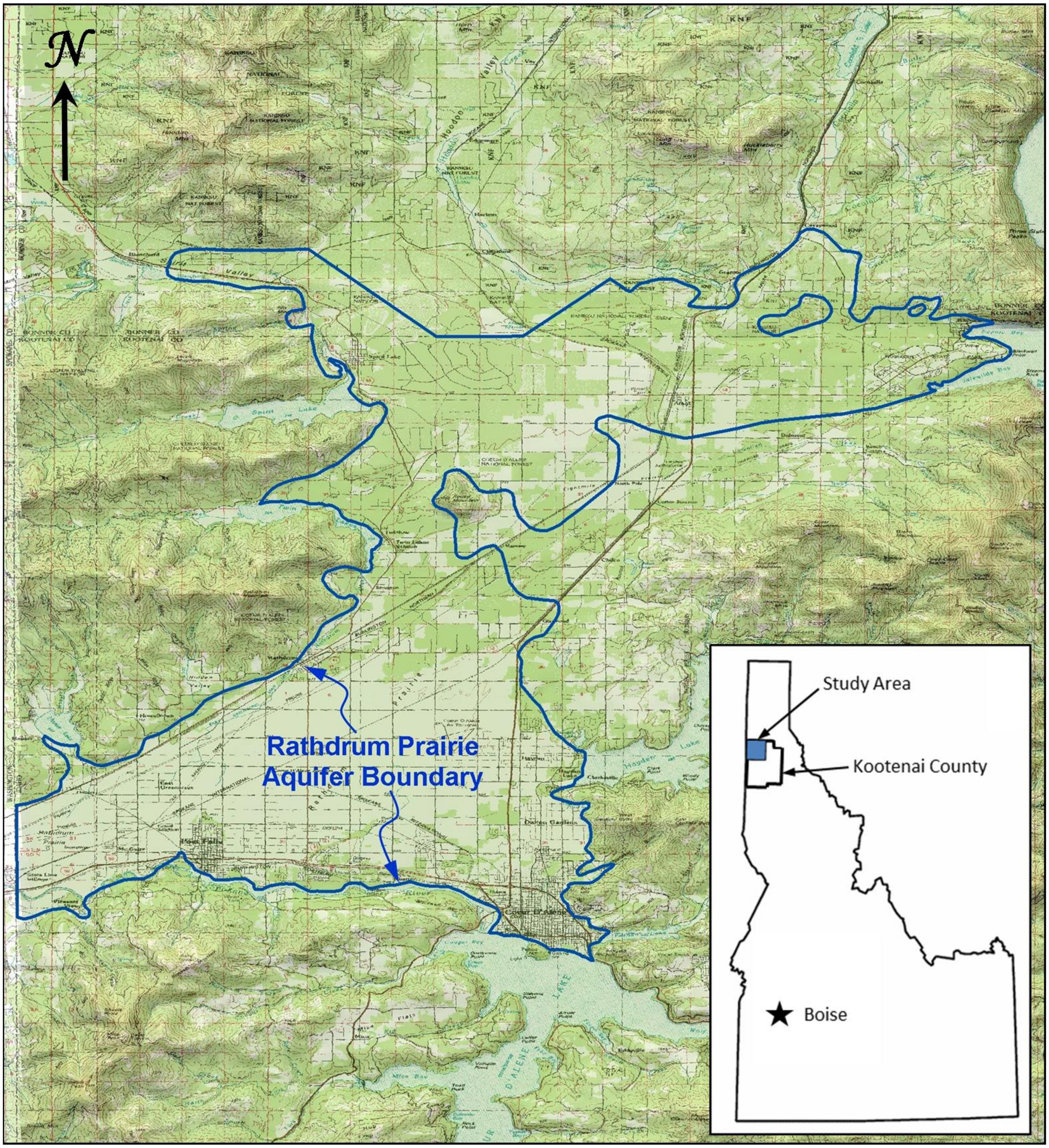

Figure 1. Rathdrum Prairie aquifer area map.

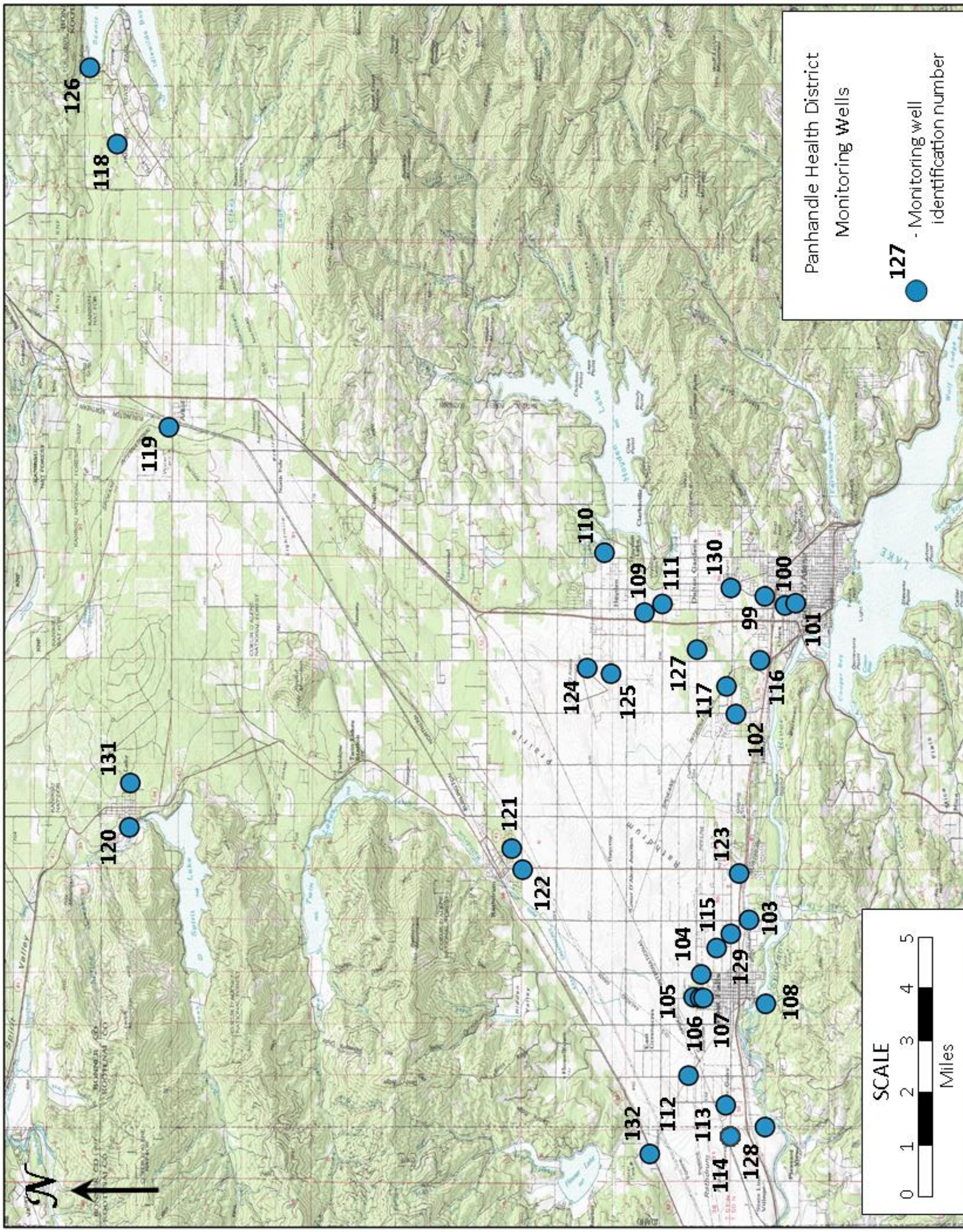

Figure 2. Panhandle Health District monitoring well locations.

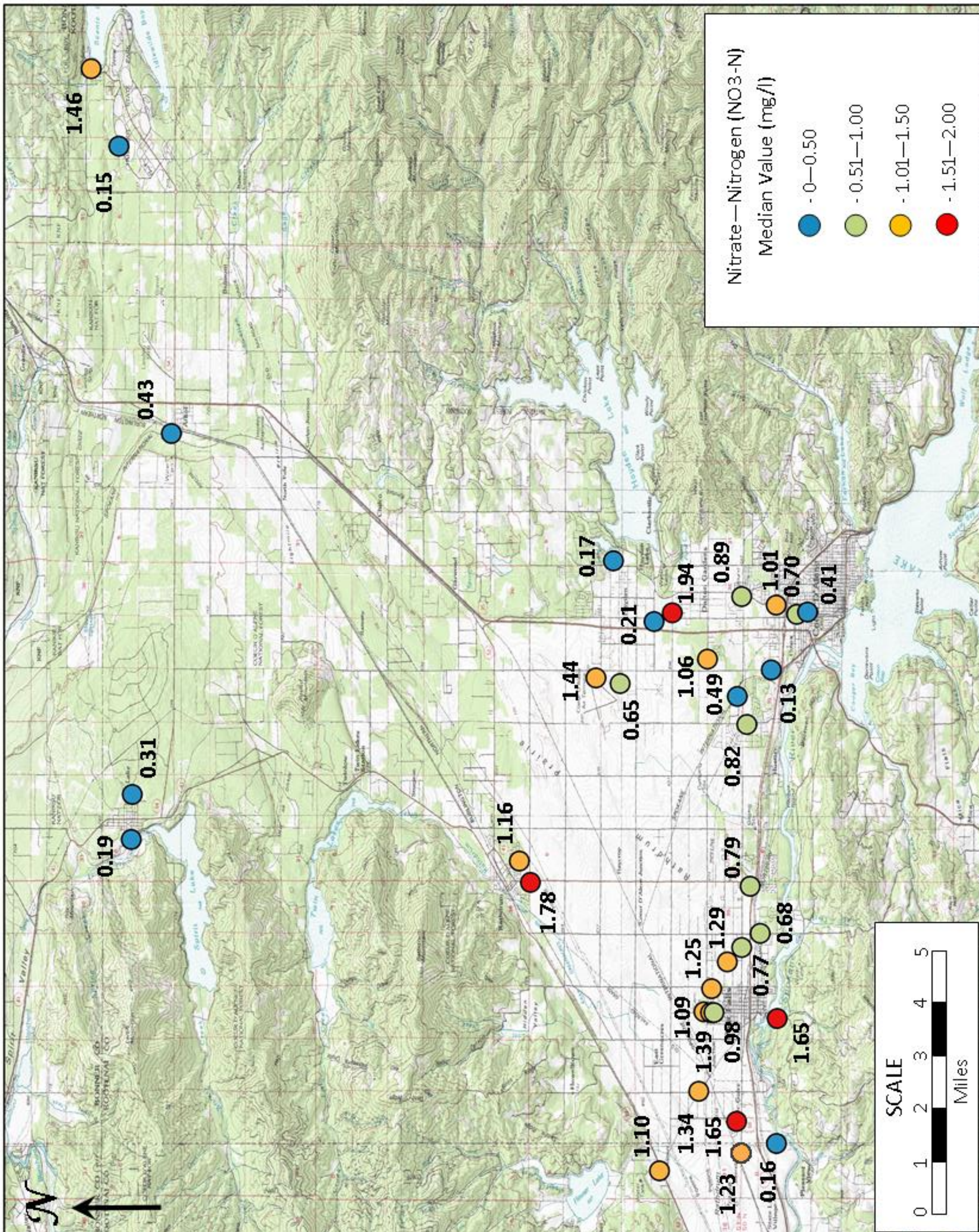

Figure 3. Median values for nitrate—nitrogen.

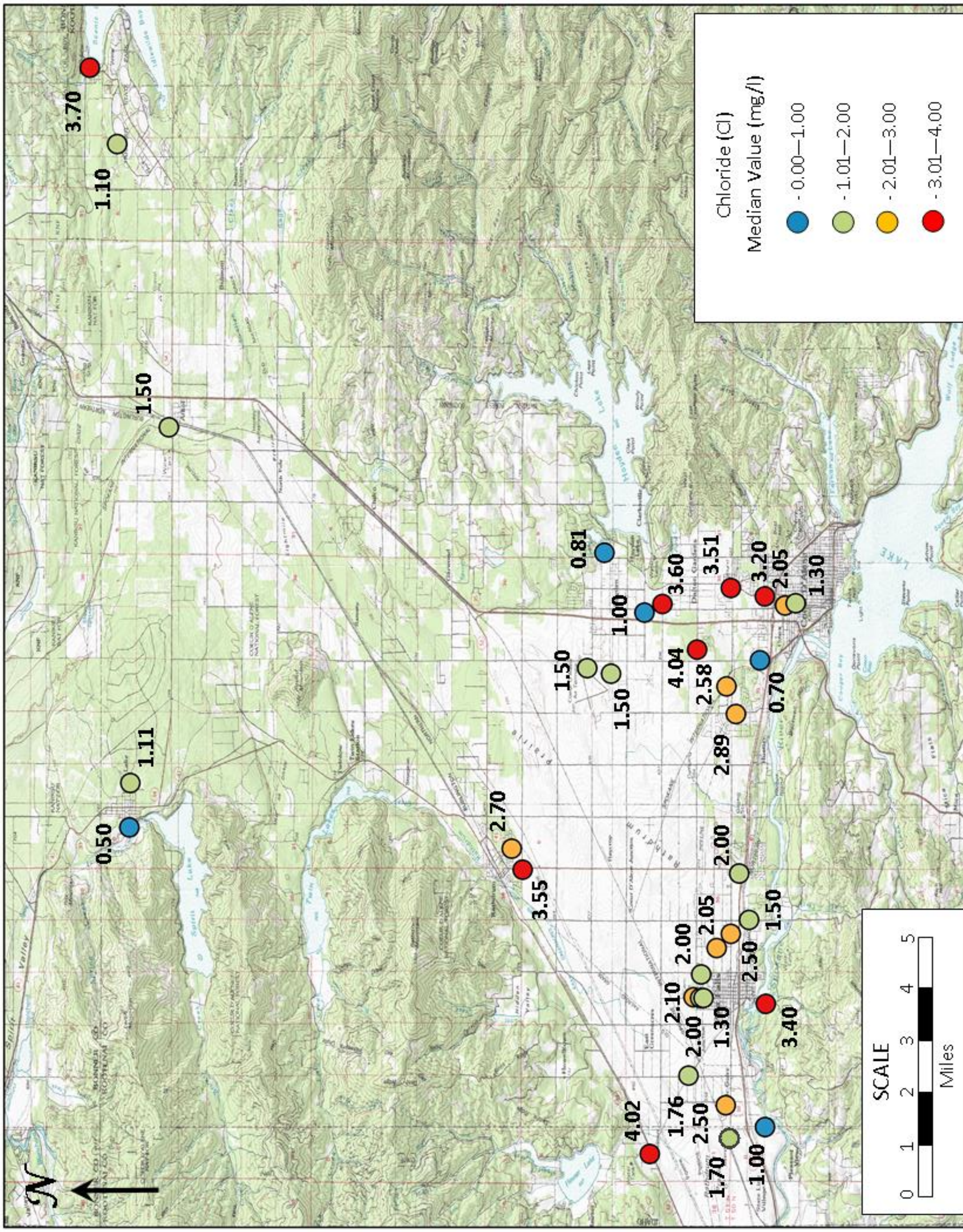

Figure 4. Median values for chloride.

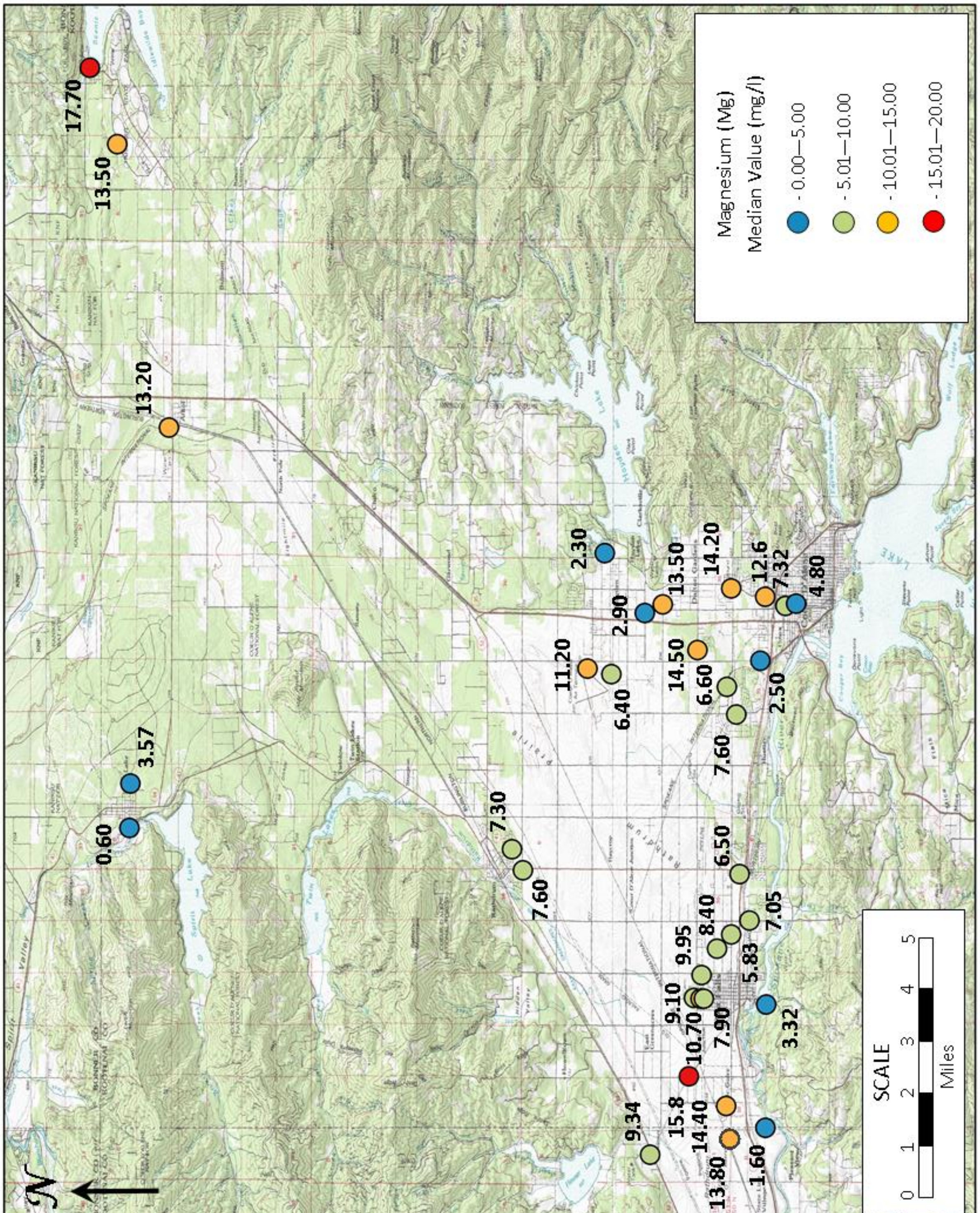

Figure 5. Median values for magnesium.

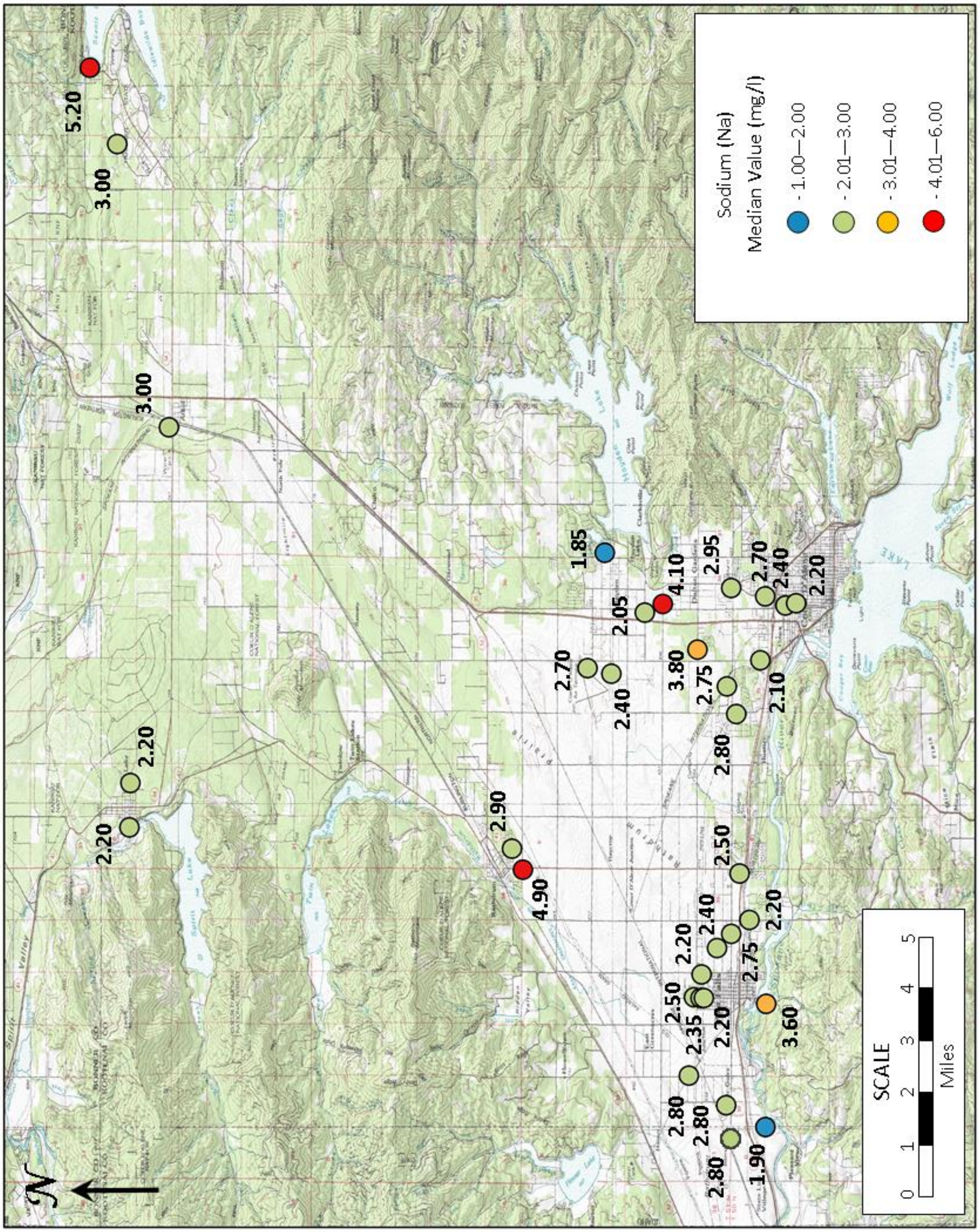

Figure 6. Median values for sodium.

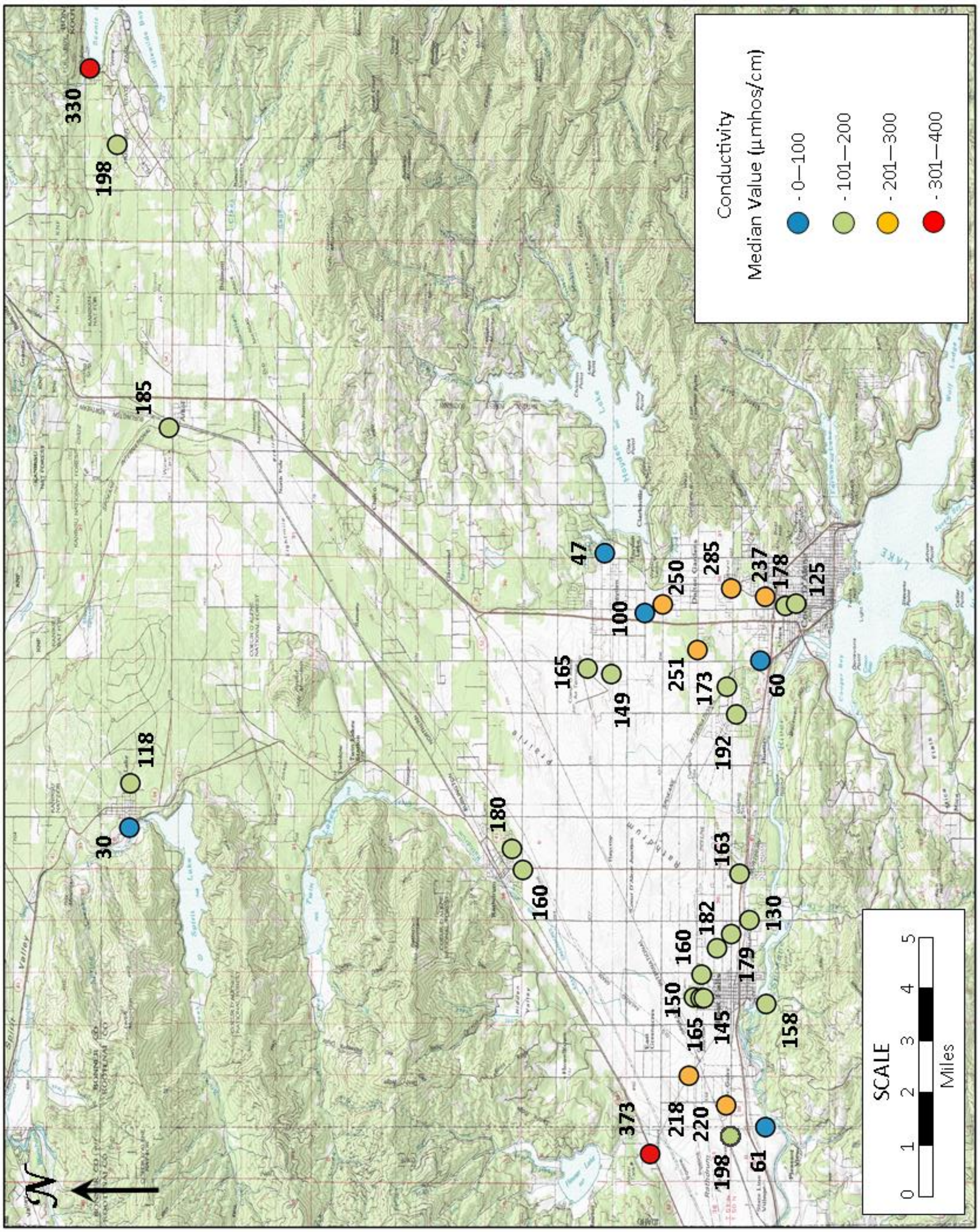

Figure 7. Median values for conductivity.

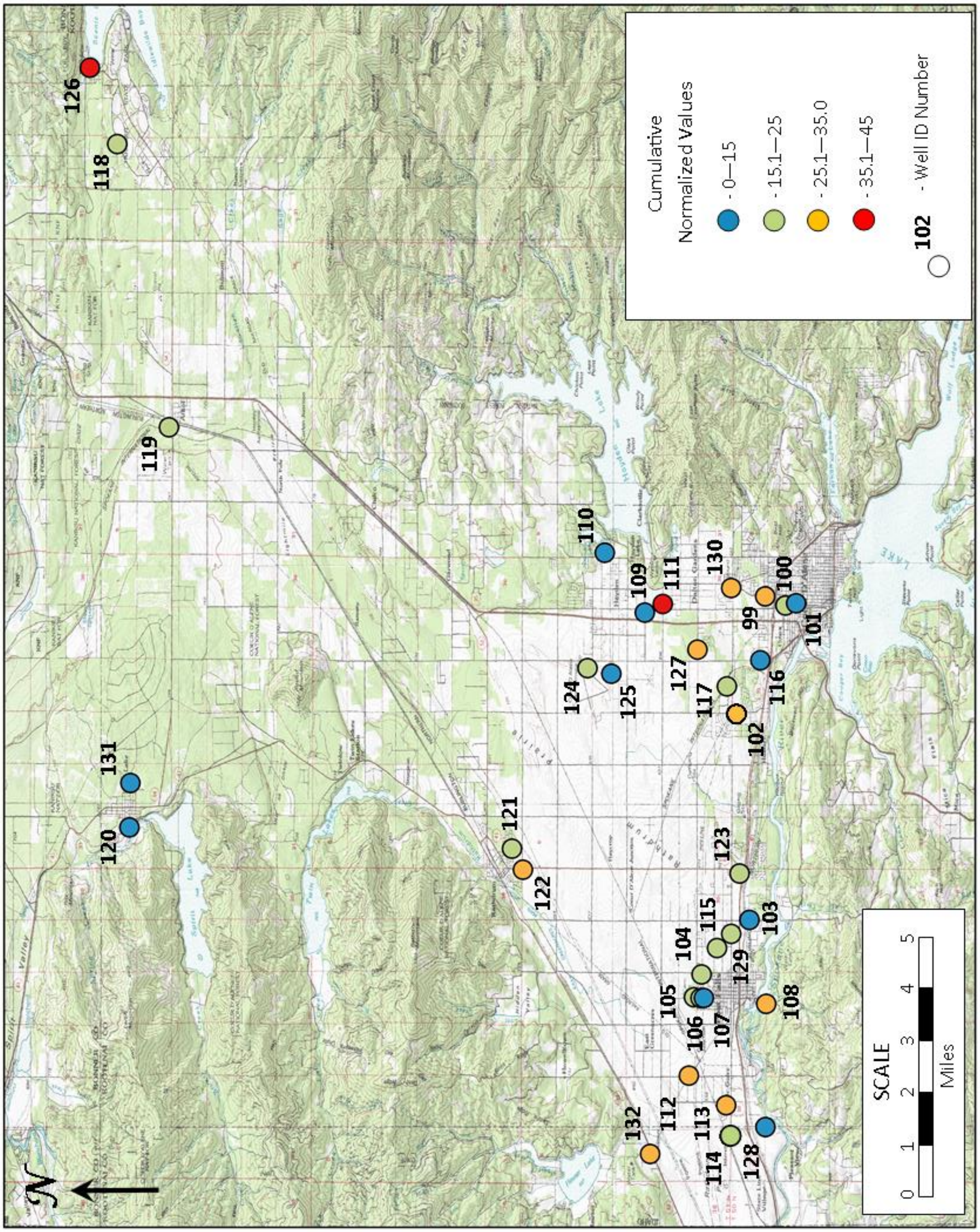

Figure 8. Cumulative normalized values for NO3-N, Cl, Na, Mg and conductivity.

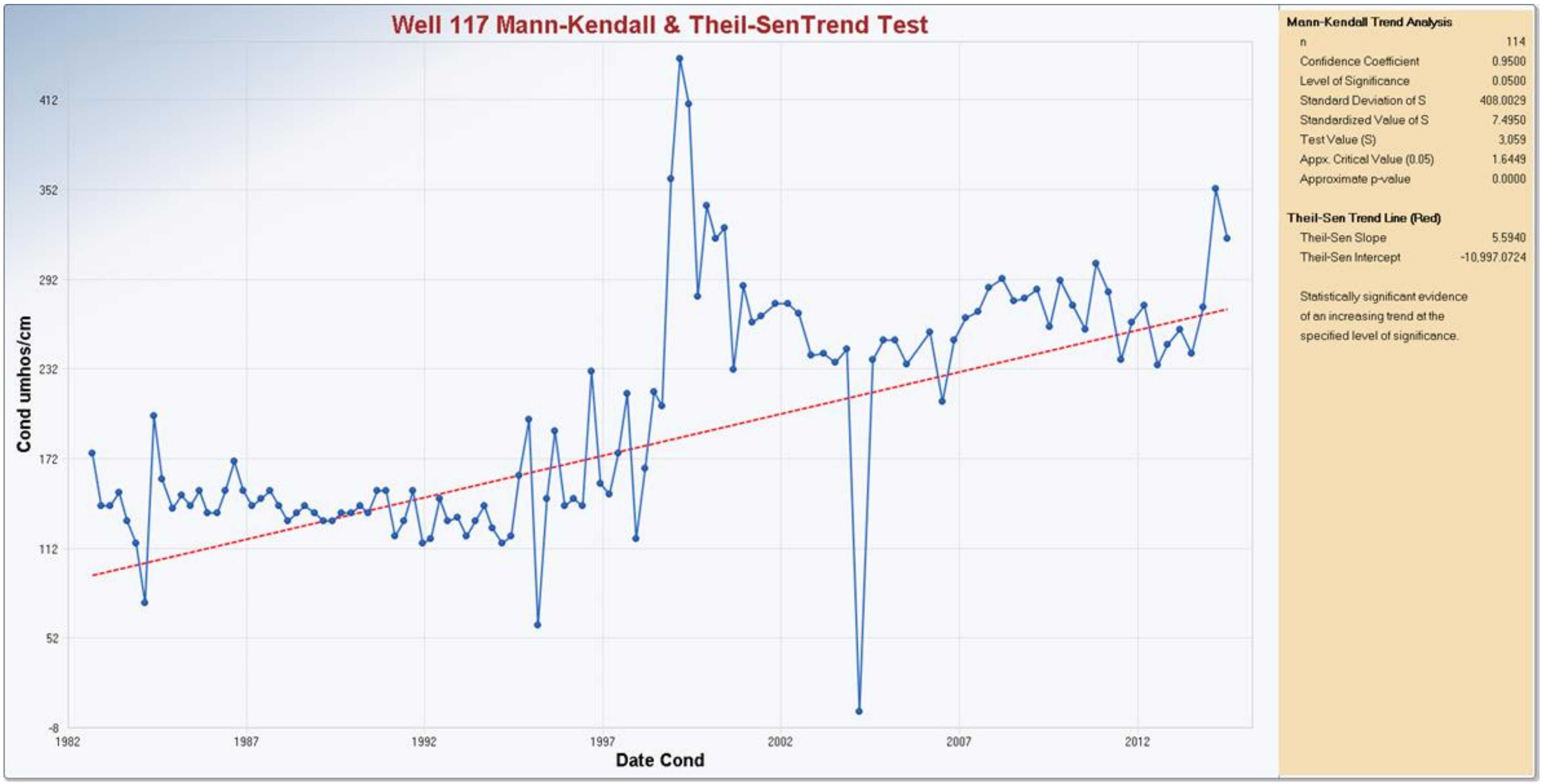

Figure 9. Example conductivity dataset of increasing Mann-Kendall and Theil-Sen trend.

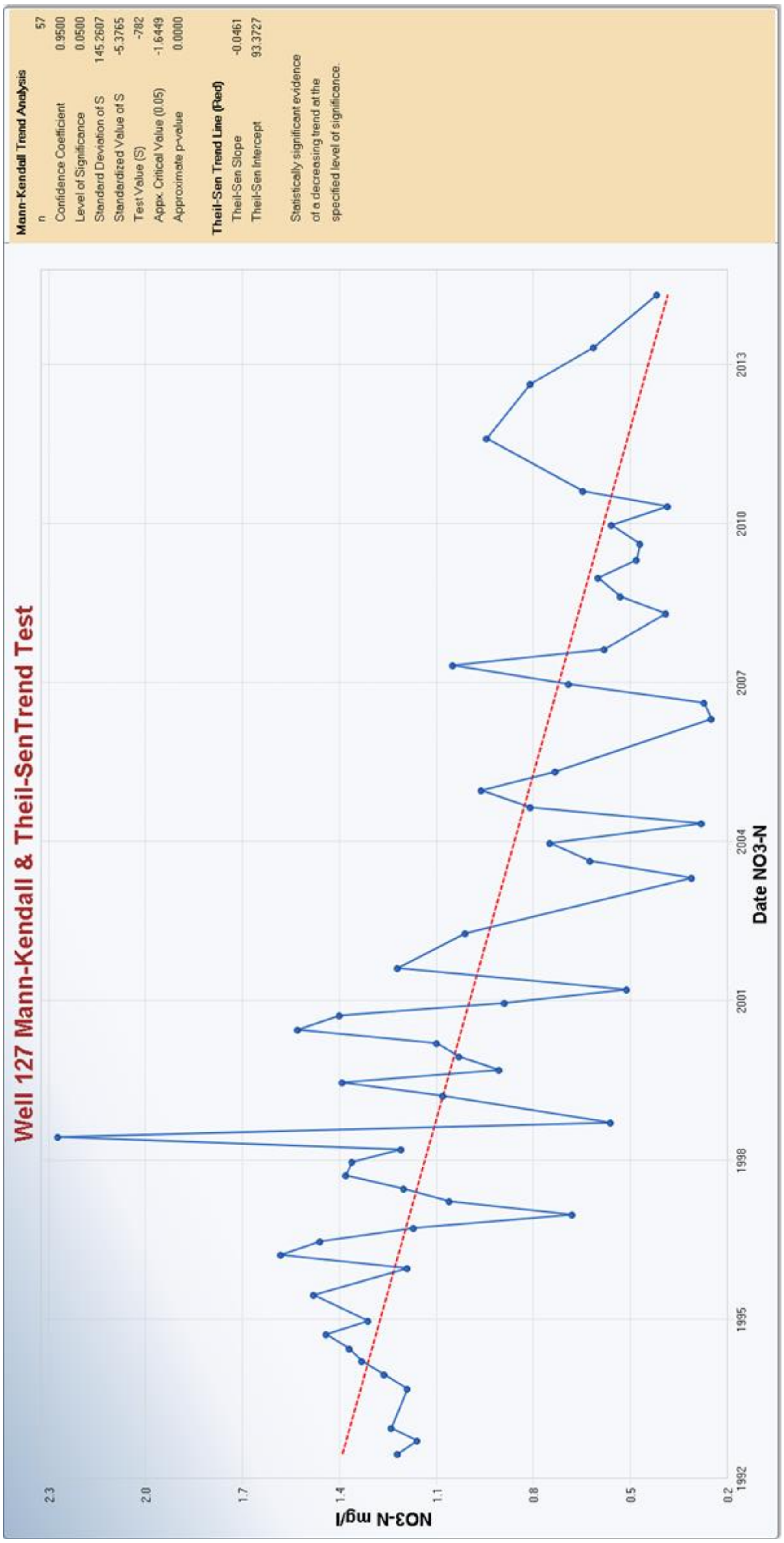

Figure 10. Example nitrate -nitrogen dataset of decreasing Mann-Kendall and Theil-Sen trend.

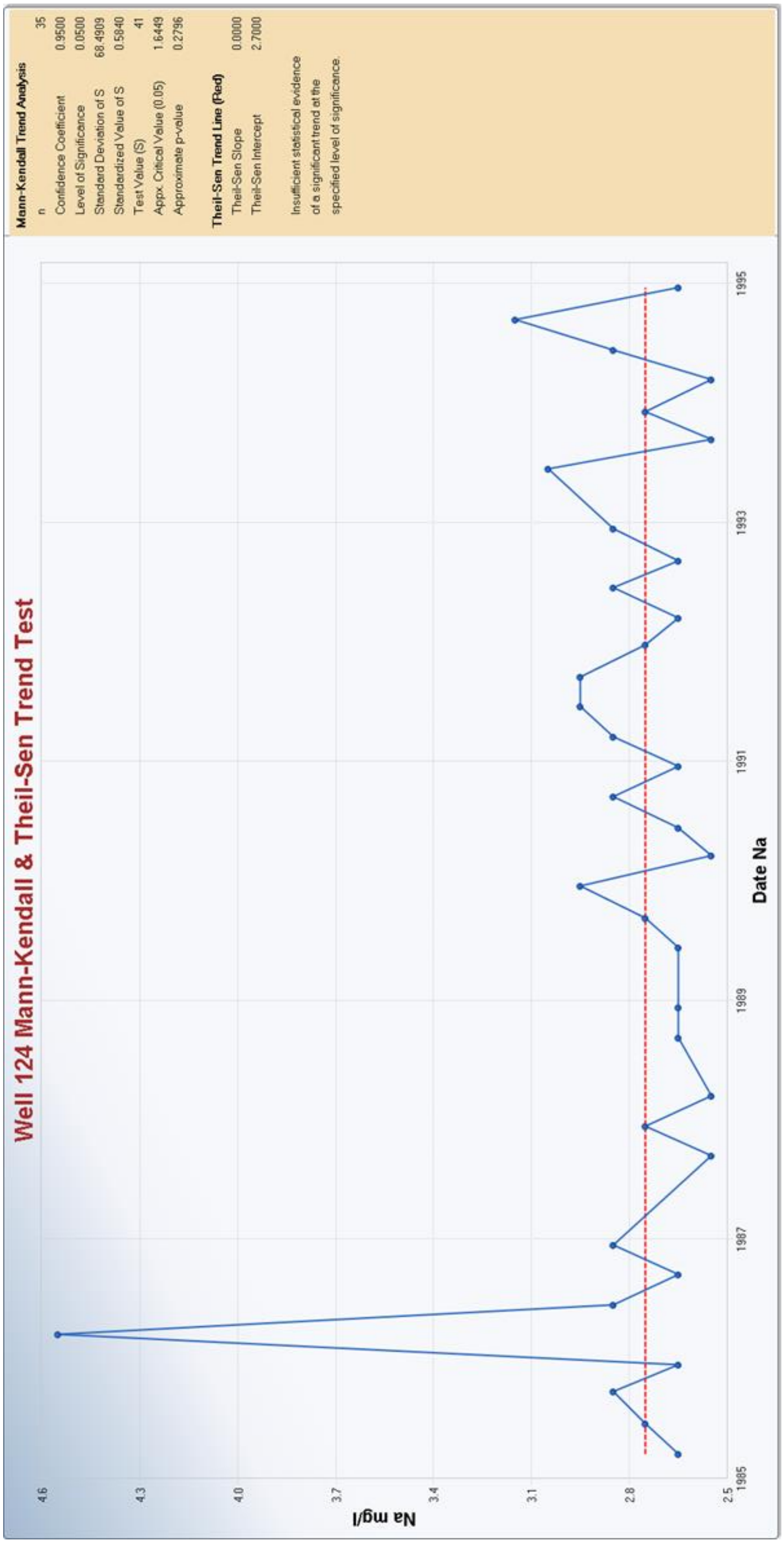

Figure 11. Example sodium dataset exhibiting no Mann-Kendall and Theil-Sen trend.

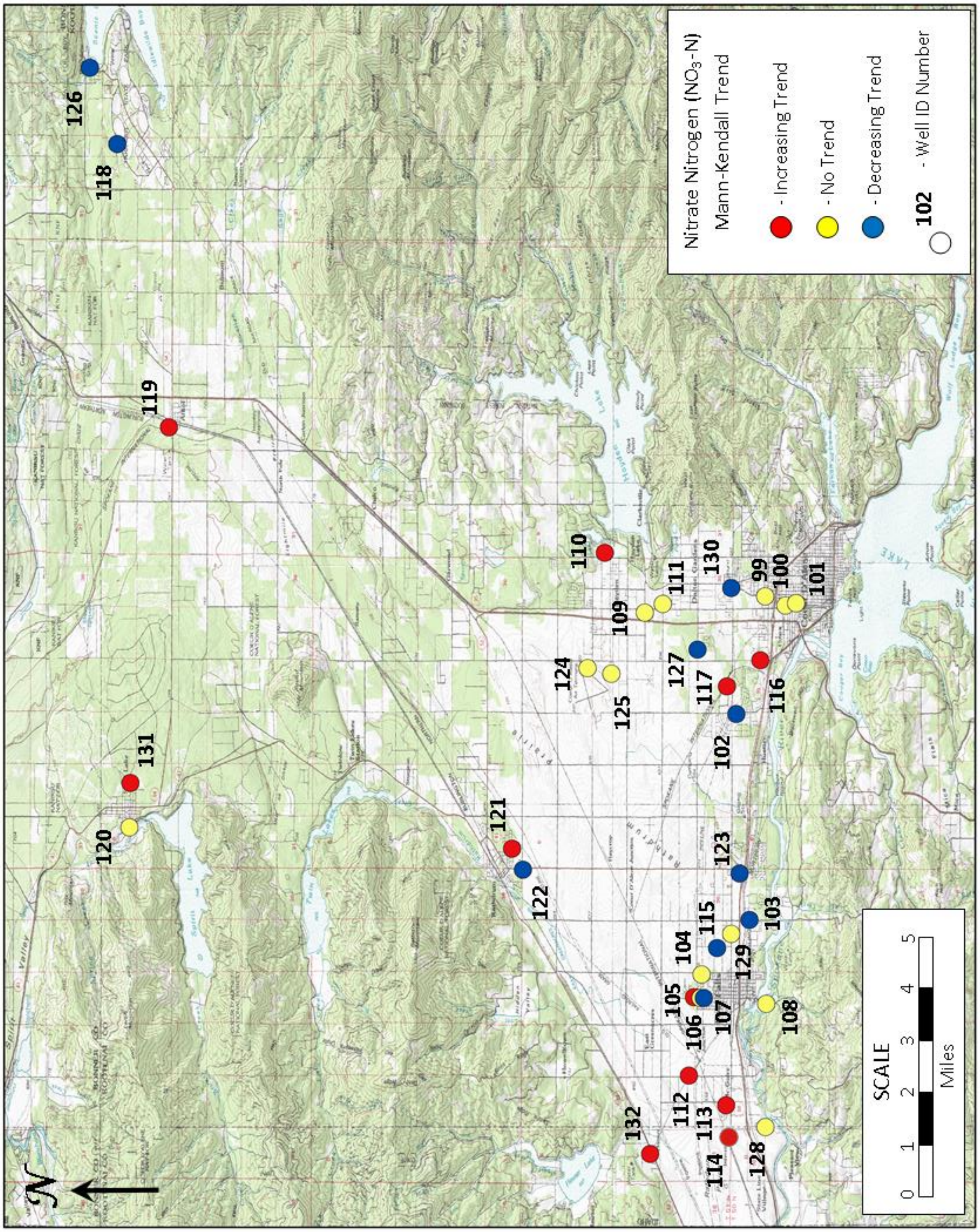

Figure 12. Mann-Kendall trend for nitrate-nitrogen.

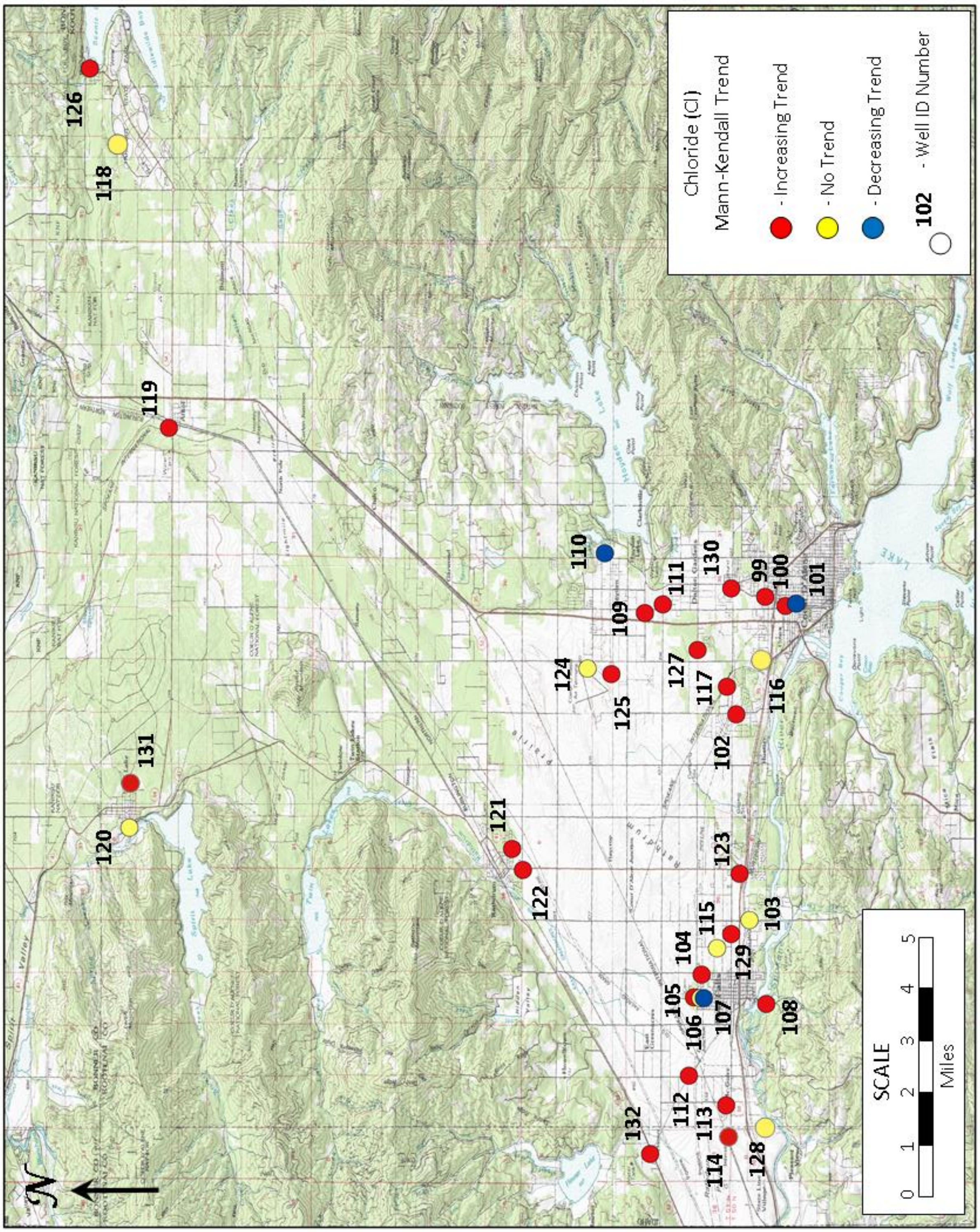

Figure 13. Mann-Kendall trend for chloride.

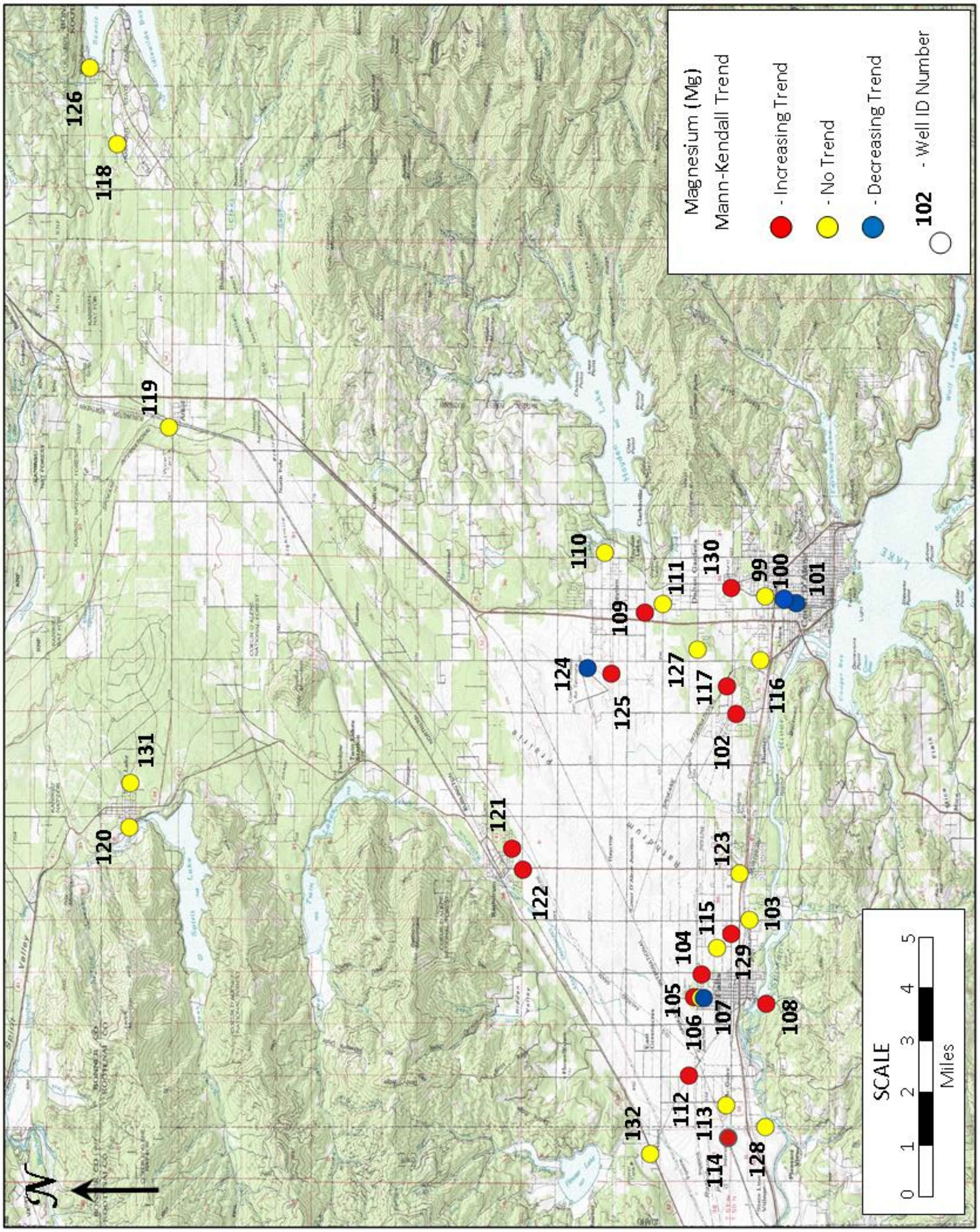

Figure 14. Mann-Kendall trend for magnesium.

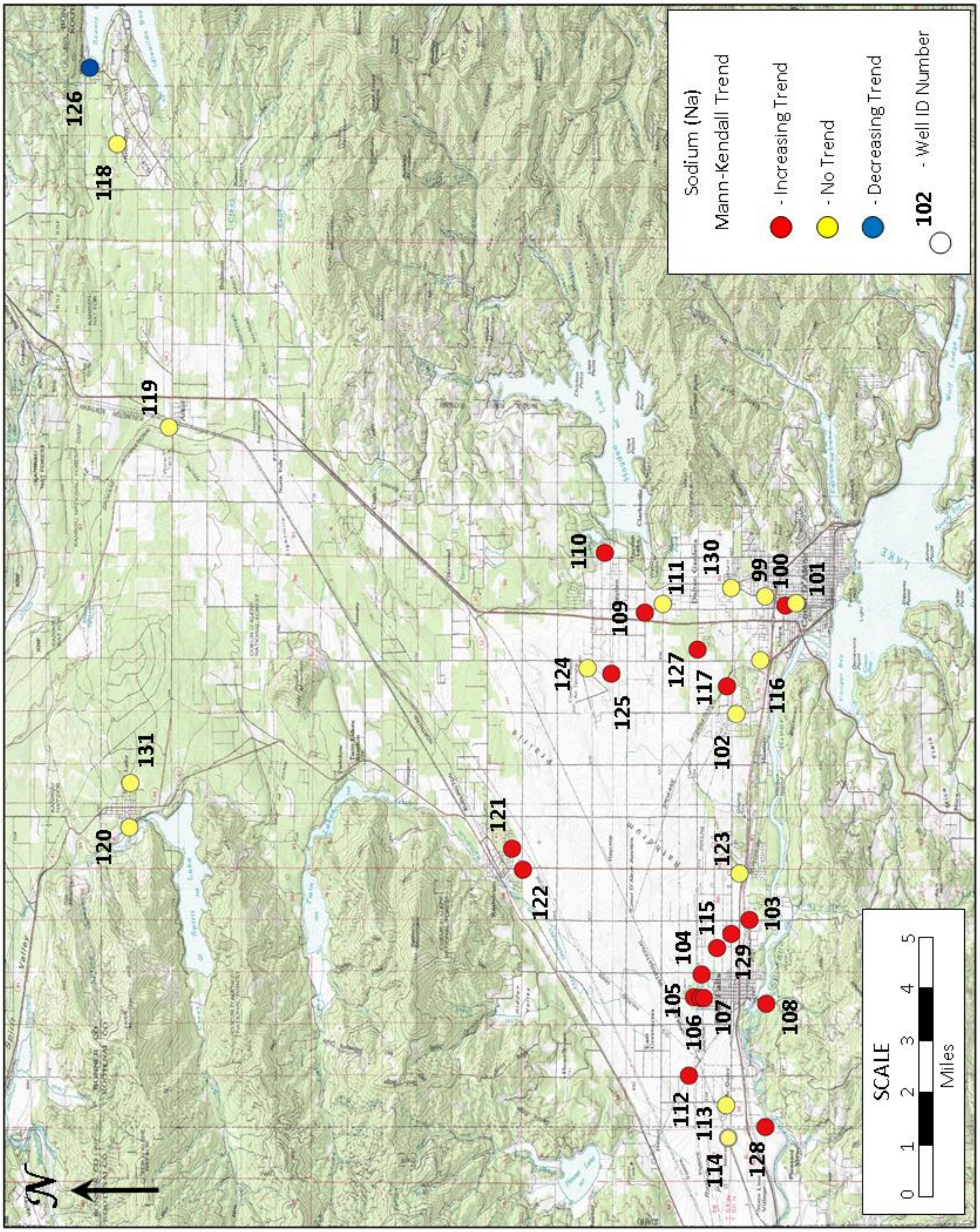

Figure 15. Mann-Kendall trend for sodium.

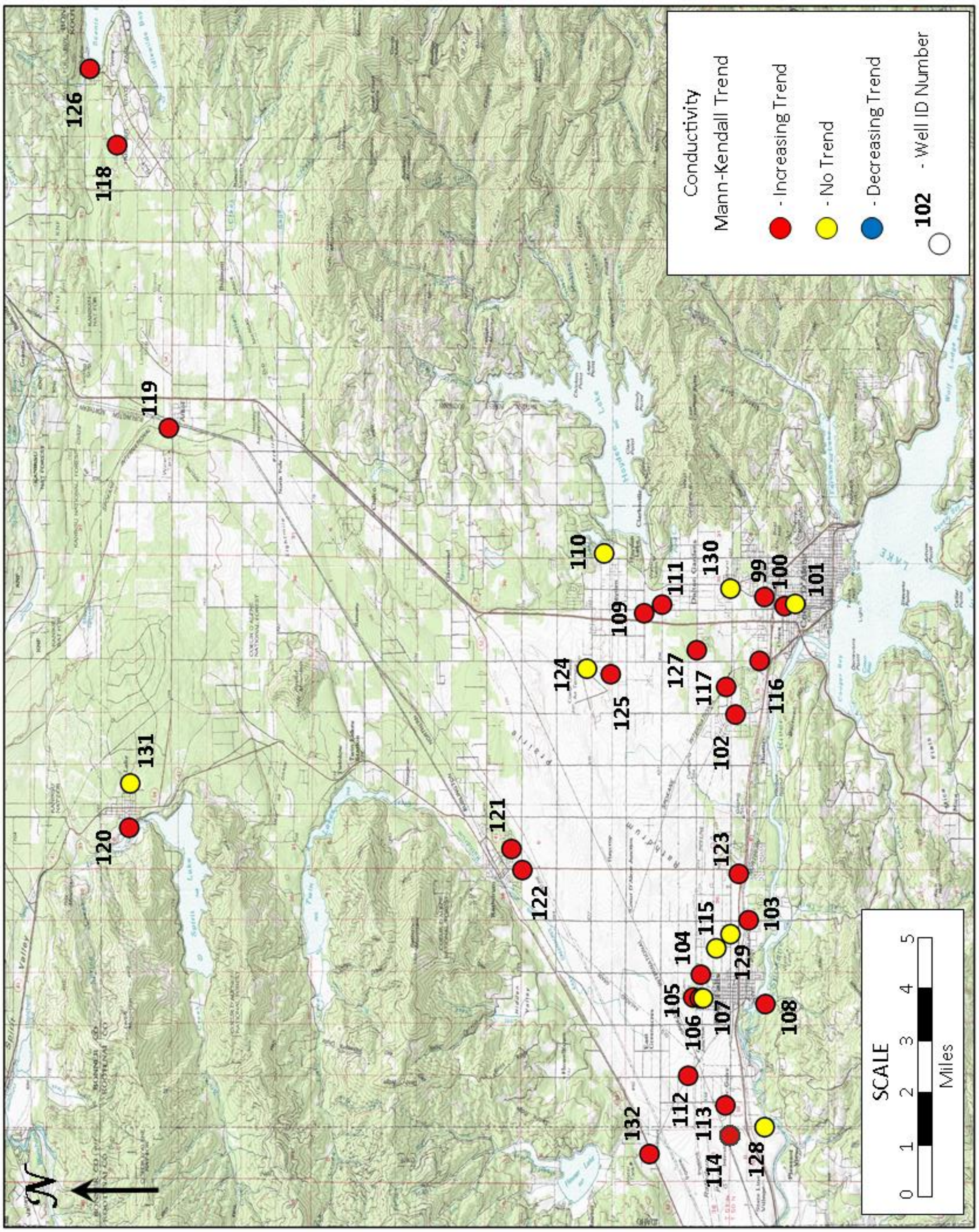

Figure 16. Mann-Kendall trend for conductivity.

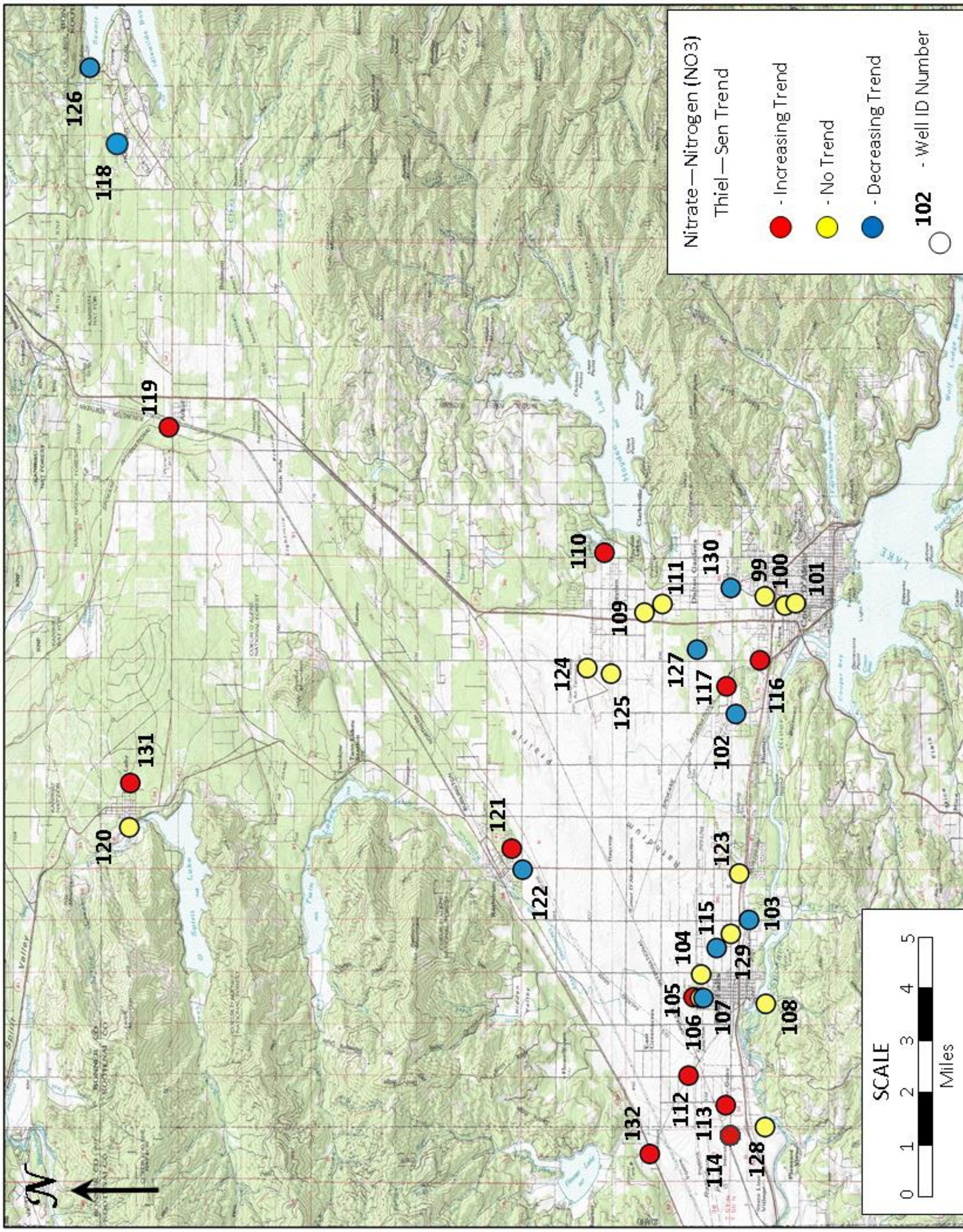

Figure 17. Theil-Sen trend for nitrate-nitrogen.

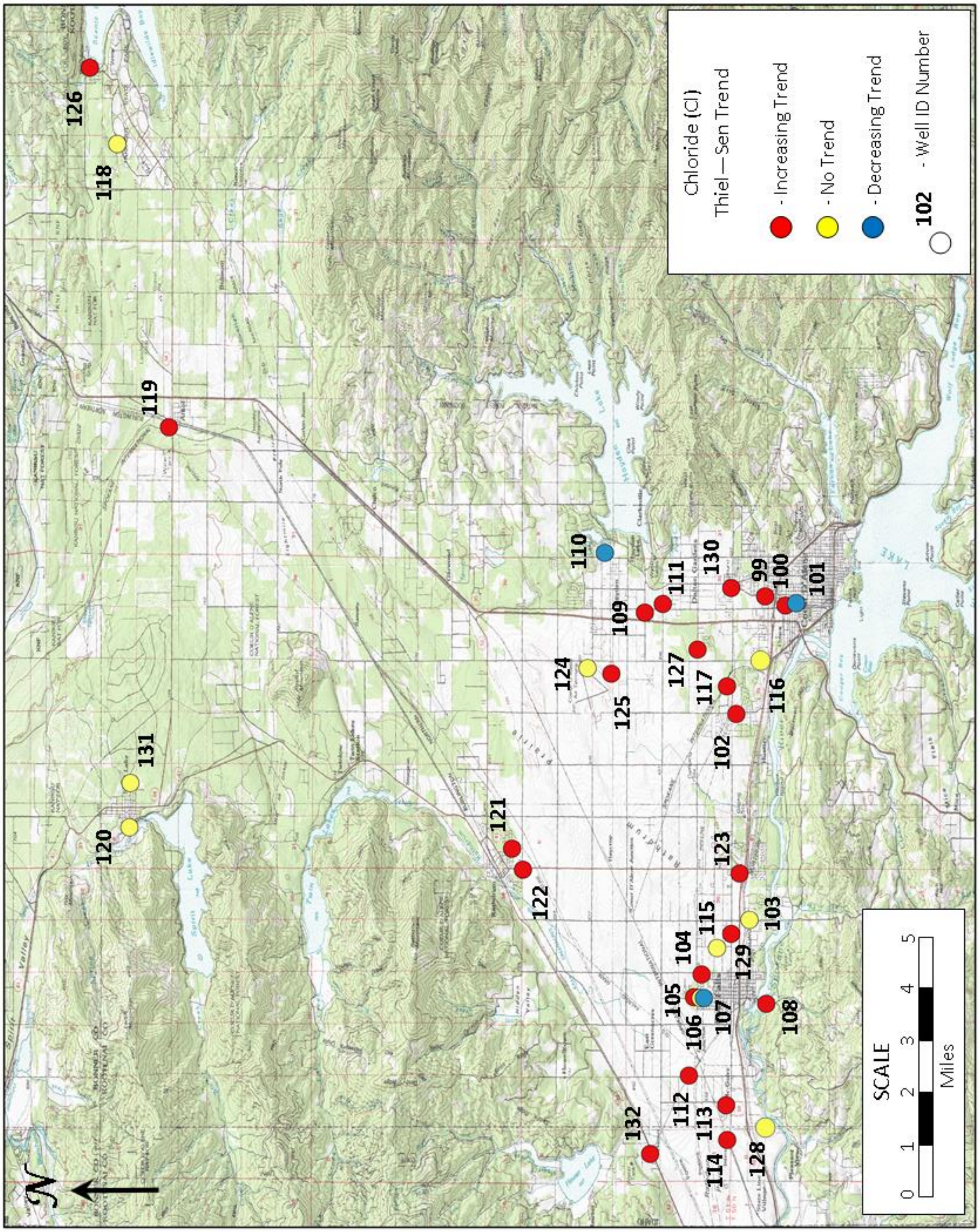

Figure 18. Theil-Sen trend for chloride.

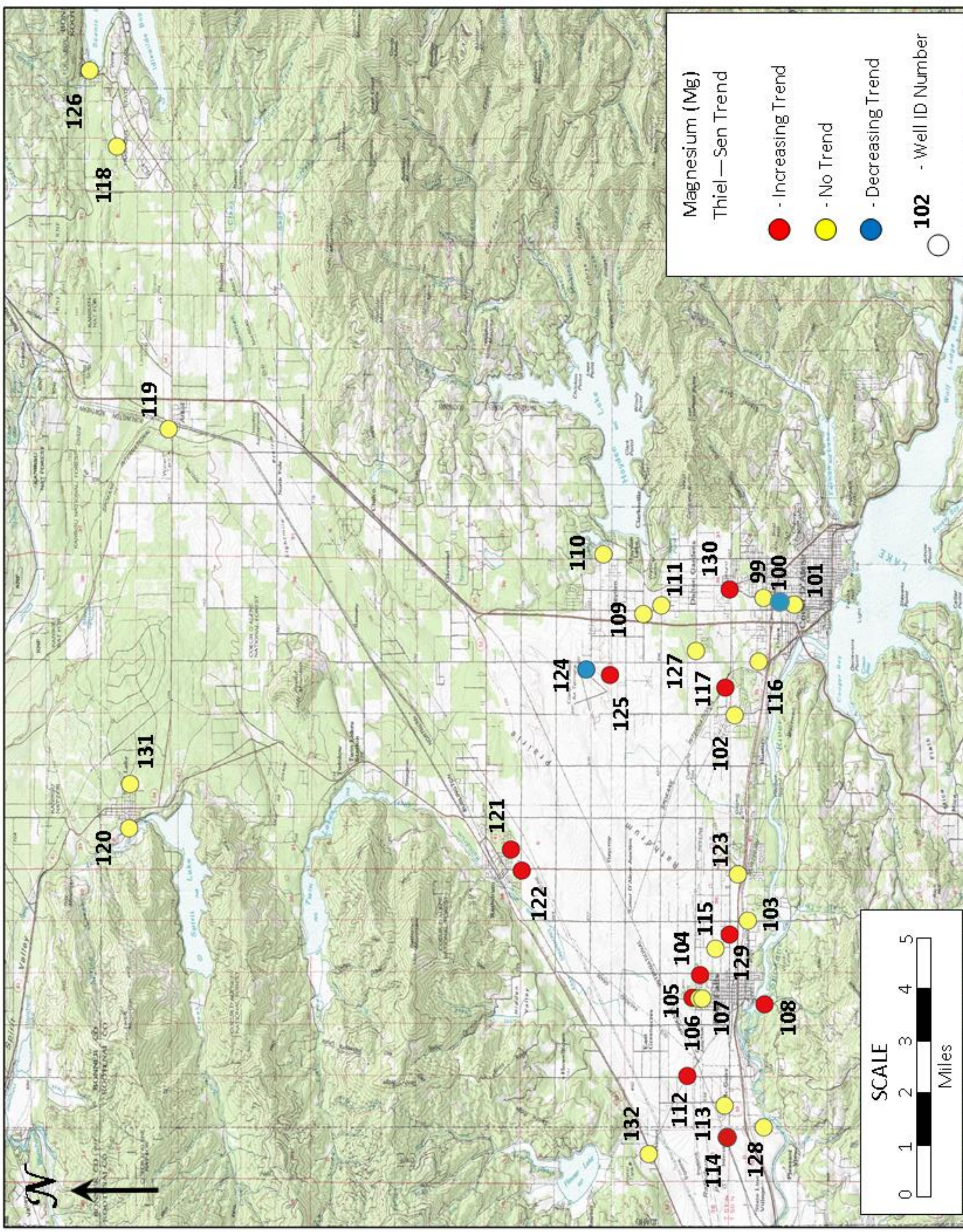

Figure 19. Theil-Sen trend for magnesium.

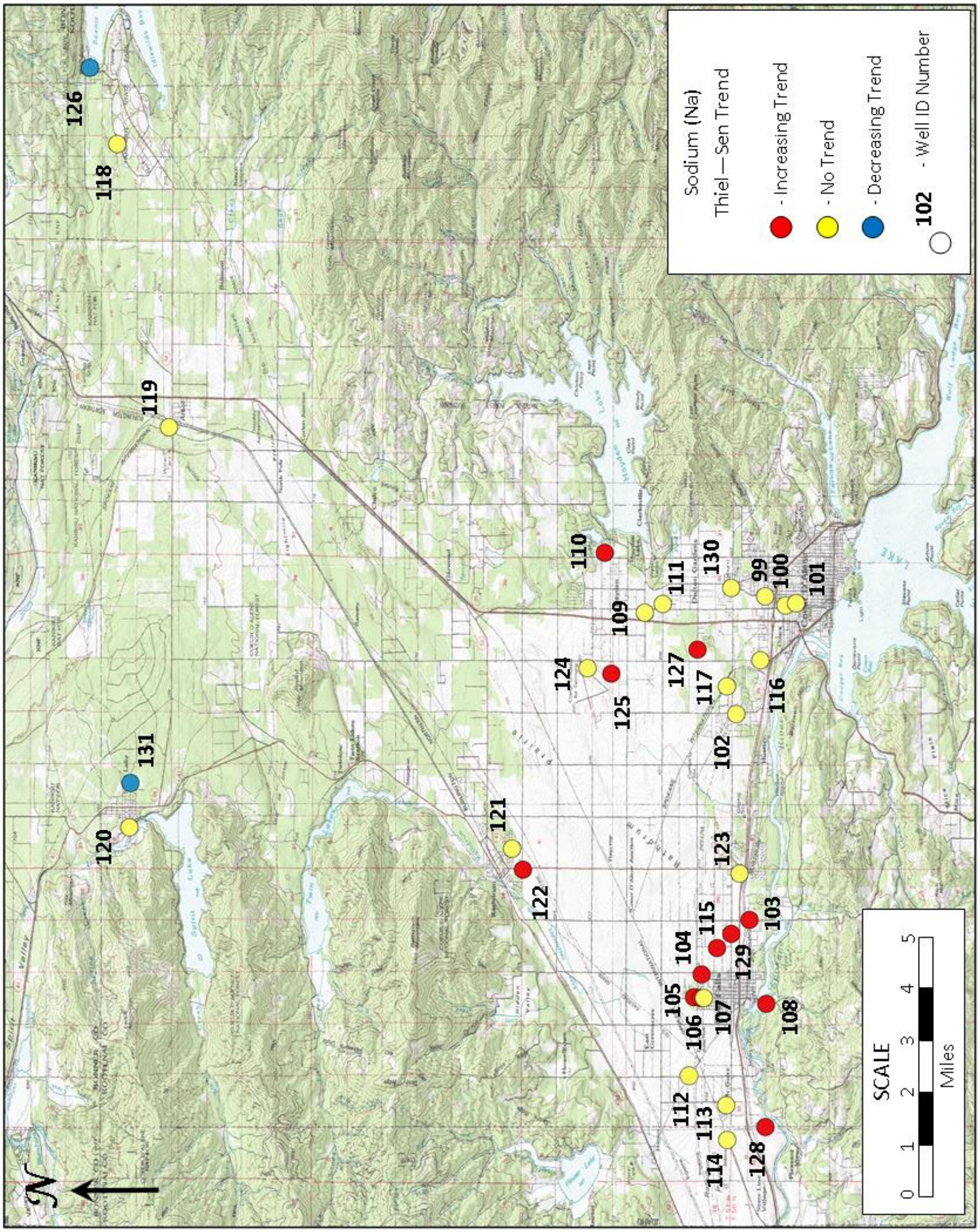

Figure 20. Theil-Sen trend for sodium.

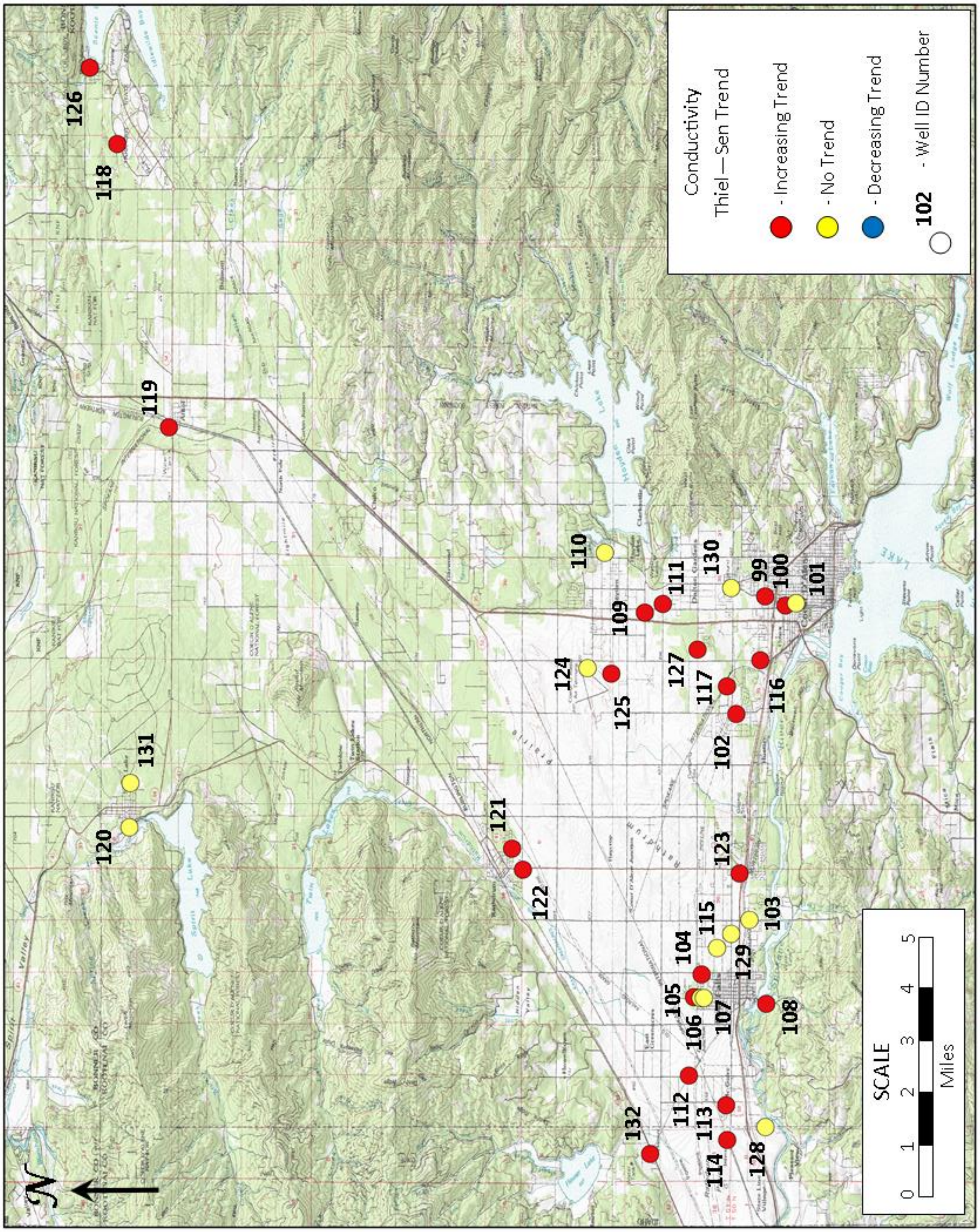

Figure 21. Theil-Sen trend for conductivity.

Appendix A. Trend analysis results.

Well	Mann-Kendall (calculated p-value)			Theil-Sen (calculated median slope)		
	Increasing	Decreasing	No Trend	Increasing	Decreasing	No Trend
99 Coeur d'Alene 4th St.						
NO_3-N			0.364			-0.002
Cl	9.5213E-7			0.142		
Na			0.230			0.000
Mg			0.238			0.044
Conductivity	7.775E-06			3.885		
100 Coeur d'Alene Locust St.						
NO_3-N			0.382			0.000
Cl	3.258E-06			0.053		
Na	0.014					0.009
Mg		0.016			-0.026	
Conductivity	1.129E-08			2.177		
101 Coeur d'Alene Linden St.						
NO_3-N			0.421			0.000
Cl		4.372E-4			-0.056	
Na			0.094			-0.007
Mg		0.032				-0.036
Conductivity			0.354			0.000
102 Coeur d'Alene Atlas St.						
NO_3-N		7.226E-04			-0.008	
Cl	7.745E-04			0.051		
Na			0.385			0.000
Mg	0.033					0.036
Conductivity	2.734E-07			2.589		
103 Post Falls #4						
NO_3-N		2.940E-3			-0.012	
Cl			0.383			0.000
Na	2.054E-04			0.020		
Mg			0.056			-0.098
Conductivity	0.033					0.888
104 Post Falls #3						
NO_3-N			0.302			0.001
Cl	1.121E-05			0.041		
Na	4.410E-08			0.019		
Mg	1.234E-04			0.092		
Conductivity	0.000			3.890		

Well	Mann-Kendall (calculated p-value)			Theil-Sen (calculated median slope)		
	Increasing	Decreasing	No Trend	Increasing	Decreasing	No Trend
105 Post Falls #5 Poleline						
NO_3-N	1.874E04			0.012		
Cl	0.000			0.115		
Na	4.178E-06			0.035		
Mg	1.106E-11			0.143		
Conductivity	0.000			5.128		
106 Post Falls #1 N. Tennis Courts						
NO_3-N			0.484			0.000
Cl			0.151			-0.007
Na	3.991E-07			0.026		
Mg			0.063			0.068
Conductivity	0.037					1.252
107 Post Falls #2 S. Tennis						
NO_3-N		1.056E-07			-0.030	
Cl		5.176E-04			-0.030	
Na	0.043					0.005
Mg		0.031				-0.055
Conductivity			0.377			0.000
108 South River Water Association						
NO_3-N			0.361			-0.006
Cl	6.197E-07			0.112		
Na	3.614E-05			0.142		
Mg	3.100E-03			0.050		
Conductivity	1.096E-06			2.860		
109 N Kootenai Water #1 Hayden						
NO_3-N			0.398			0.000
Cl	4.798E-6			0.022		
Na	1.890E-02					0.010
Mg	9.390E-03					0.009
Conductivity	1.659E-11			2.111		
110 Avondale Well						
NO_3-N	2.833E-04			0.007		
Cl		6.624E-05			-0.146	
Na	9.770E-03			0.025		
Mg			0.175			-0.008
Conductivity			0.325			0.000

Well	Mann-Kendall (calculated p-value)			Theil-Sen (calculated median slope)		
	Increasing	Decreasing	No Trend	Increasing	Decreasing	No Trend
111 Dalton Gardens #1 E						
NO_3-N			0.051			-0.005
Cl	9.827E-10			0.096		
Na			0.130			-0.011
Mg			0.336			-0.018
Conductivity	1.412E-9			6.036		
112 East Greenacres						
NO_3-N	0.000			0.016		
Cl	4.075E-13			0.054		
Na	9.000E-03					0.008
Mg	5.732E-04			0.049		
Conductivity	0.000			4.593		
113 Mtn. View Terrace						
NO_3-N	1.688E-07			0.019		
Cl	5.884E-15			0.070		
Na			0.082			0.000
Mg			0.057			0.027
Conductivity	1.110E-16			3.692		
114 CHS						
NO_3-N	0.000			0.011		
Cl	6.949E-07			0.040		
Na			0.282			0.000
Mg	1.236E-07			0.049		
Conductivity	0.000			4.247		
115 Ross Point – Syringa						
NO_3-N		4.216E-4			-0.024	
Cl			0.226			-0.005
Na	1.441E-04			0.021		
Mg			0.111			-0.115
Conductivity			0.398			0.000
116 Turrel Well						
NO3-N	8.054E-04			0.001		
Cl			0.074			0.026
Na			0.150			0.000
Mg			0.280			0.000
Conductivity	2.952E-11			1.309		

Well	Mann-Kendall (calculated p-value)			Theil-Sen (calculated median slope)		
	Increasing	Decreasing	No Trend	Increasing	Decreasing	No Trend
117 U.S. Forest Service Nursery						
NO3-N	4.254E-10			0.014		
Cl	0.000			0.248		
Na	0.027					0.022
Mg	2.363E-04			0.058		
Conductivity	3.308E-14			5.594		
118 Farragut State Park #3						
NO3-N		0.011			-0.001	
Cl			0.154			0.046
Na			0.073			0.000
Mg			0.142			-0.009
Conductivity	9.867E-13			4.089		
119 Athol #1 Grove Ave.						
NO3-N	4.520E-03			0.009		
Cl	6.331E-9			0.050		
Na			0.110			0.000
Mg			0.061			0.027
Conductivity	0.000			5.347		
120 Spirit Lake Well #3						
NO3-N			0.121			-0.002
Cl			0.203			0.000
Na			0.235			0.000
Mg			0.255			0.000
Conductivity	0.050					0.000
121 Rathdrum - PIne Street						
NO3-N	2.484E-04			0.009		
Cl	6.344E-06			0.044		
Na	0.038					0.021
Mg	4.190E-13			0.181		
Conductivity	0.000			4.690		
122 Rathdrum Grange						
NO3-N		2.993E-08			-0.040	
Cl	7.709E-06			0.066		
Na	3.927E-04			0.053		
Mg	9.455E-04			0.034		
Conductivity	0.000			4.573		
123 Ross Point - Hwy 41						
NO3-N		0.042				-0.011
Cl	5.185E-06			0.066		
Na			0.059			0.010
Mg			0.329			0.022
Conductivity	1.774E-06			2.485		

Well	Mann-Kendall (calculated p-value)			Theil-Sen (calculated median slope)		
	Increasing	Decreasing	No Trend	Increasing	Decreasing	No Trend
124 Coeur d'Alene Airport						
NO3-N			0.400			-0.003
Cl			0.062			0.037
Na			0.280			0.000
Mg		4.720E-03			-0.100	
Conductivity			0.388			0.000
125 L.A. Aluminum						
NO3-N			0.154			-0.001
Cl	1.140E-04			0.026		
Na	4.014E-4			0.013		
Mg	1.102E-10			0.111		
Conductivity	2.354E-14			3.036		
126 Silver Water Association						
NO3-N		1.133E-11			-0.043	
Cl	5.370E-03			0.047		
Na		3.248E-07			-0.070	
Mg			0.133			0.056
Conductivity	1.514E-13			9.047		
127 Coeur d'Alene – Hanley						
NO3-N		3.797E-08			-0.046	
Cl	2.868E-05			0.125		
Na	1.370E-03			0.057		
Mg			0.104			-0.129
Conductivity	9.261E-06			3.883		
128 Post Falls #7 Majestic						
NO3-N			0.059			0.002
Cl			0.260			0.000
Na	2.100E-03			0.131		
Mg			0.226			0.000
Conductivity			0.088			0.865
129 Post Falls #6 – Mullan						
NO3-N			0.450			0.001
Cl	2.144E-08			0.148		
Na	8.290E-03			0.213		
Mg	8.250E-03			0.069		
Conductivity			0.265			0.776
130 CDA-Honeysuckle						
NO3-N		7.468E-04			-0.040	
Cl	1.025E-04			0.100		
Na			0.350			-0.020
Mg	5.020E-03			0.160		
Conductivity			0.265			0.352

Well	Mann-Kendall (calculated p-value)			Theil-Sen (calculated median slope)		
	Increasing	Decreasing	No Trend	Increasing	Decreasing	No Trend
131 Spirit Lake #4						
NO3-N	8.180E-03			0.009		
Cl	5.620E-03					-0.016
Na			0.270		-0.387	
Mg			0.083			0.057
Conductivity			0.081			3.572
132 Hauser						
NO3-N	6.430E-03			0.016		
Cl	2.983E-11			0.308		
Na	--	--	--	--	--	--
Mg			0.310			0.040
Conductivity	6.490E-05			3.013		