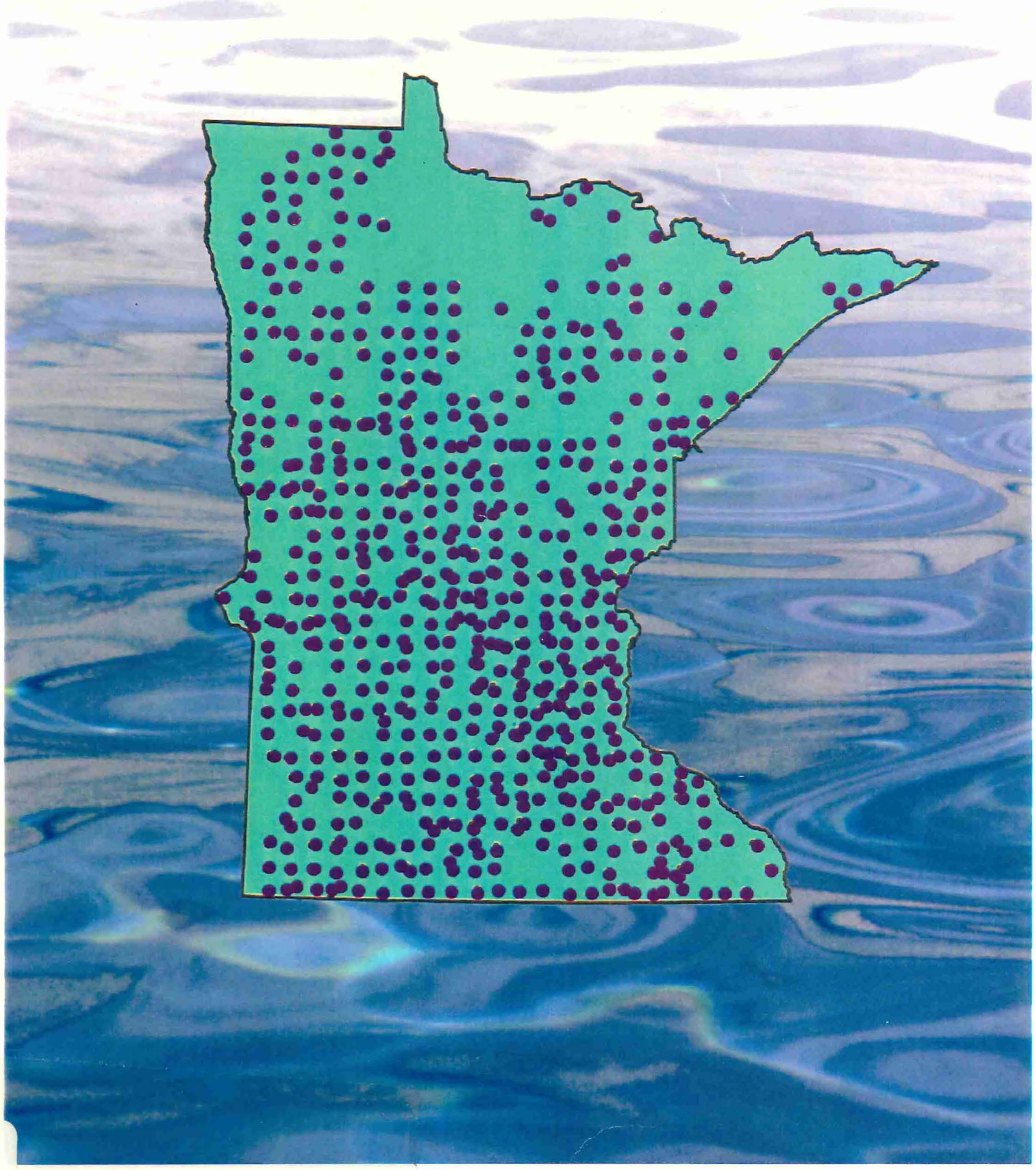
Baseline Water Quality of Minnesota's Principal Aquifers



Minnesota Pollution Control Agency

ERRATA - MARCH 1998

1. Nitrate concentrations in this report should be listed as nitrate-nitrogen. This change does not affect any values or interpretations presented in the report, since nitrate-nitrogen is the standard method of reporting nitrate results and evaluating health effects.
2. Phosphate concentrations in the report should be listed as phosphate-phosphorus. To get concentrations of phosphate, multiply concentrations presented in the report by 3. This does not affect any statistical tests performed for the baseline report.
3. Sulfate concentrations in the report are incorrectly listed as "sulfate." The concentrations provided are actually sulfate-sulfur. Since the standard format for reporting sulfate is as sulfate, not sulfate-sulfur, all concentrations in the report would increase by a factor of 3. This change has no effect on correlation tests, hypothesis tests, and geochemical interpretations. However, in addition to concentrations provided in Tables D.6 through D.44, the information provided in Table D.112 would change. These changes are summarized below.

Aquifer	No. of exceedances of MCL reported in baseline report	No. of actual exceedances of MCL (corrected data)
Cretaceous (KRET)	6	17
Precambrian crystalline (PCCR)	1	1
Precambrian undifferentiated (PCUU)	0	1
Sioux Quartzite (PMSX)	2	2
buried, artesian Quaternary (QBAA)	24	42
buried, unconfined Quaternary (QBUA)	2	3
buried, undifferentiated Quaternary (QBUU)	1	4
undifferentiated Quaternary (QUUU)	2	2
water-table Quaternary (QWTA)	1	1

4. Historically, reports prepared by the Ground Water Monitoring and Assessment Program (GWMAP) have reported data in a variety of ways. Regardless of what is indicated in previous GWMAP reports, all data for nitrate, sulfate, and phosphate actually represent nitrate-nitrogen, sulfate-sulfur, and phosphate-phosphorus. In addition, oxidation-reduction potential may have been reported as Eh in some previous documents. All values for oxidation-reduction potential or Eh represent field measured oxidation-reduction potential, which is not corrected for temperature nor is referenced to the standard hydrogen electrode. The current report presents field-measured oxidation-reduction potentials and Eh. The value for Eh is referenced to the standard hydrogen electrode and is temperature corrected.

Baseline Water Quality of Minnesota's Principal Aquifers

March 1998

Published by

Minnesota Pollution Control Agency
Ground Water and Solid Waste Division
Program Development Section
Ground Water Unit
520 Lafayette Road
St. Paul, Minnesota 55155-4194
(612)296-6300 or 1(800)657-3864

Prepared by

Don Jakes: Supervisor

Tom Clark: Program Coordinator
Yuan-Ming Hsu: Data Coordinator
Curt Hoffman: Pollution Control Specialist
Jennifer Maloney: Hydrologist
Jim Stockinger: Field Coordinator
Mike Trojan: Hydrologist

This material may be made available in other formats,
such as Braille, large type or audio, upon request.
TDD users call (612)282-5332.

Printed with soy-based inks on recycled paper containing
at least 10 percent fibers from paper recycled by consumers.

Foreword

Ground Water Monitoring and Assessment Program (GWMAP) staff believe the enclosed report represents the most comprehensive study, to date, of water quality in Minnesota's principal aquifers. Information in this report can be used by water resource managers to identify baseline or background water quality conditions in areas or aquifers of concern, prioritize ground water problems, and assist in site decision-making, provided the limitations and assumptions outlined in the document are understood. Although data have been carefully analyzed, compiled, and reviewed independently, mistakes are inevitable with a dataset this large. If mistakes are found in this report, please forward them to GWMAP staff. Errata sheets will be prepared as needed.

The report is divided into five parts. Part I summarizes the history of the baseline study, including sample design and collection. Part II describes analysis methods. Results are provided in Part III. Part IV includes a summary of results and application examples and problems. Future objectives of GWMAP and some suggested program improvements are presented in Part V.

Acknowledgments

This report represents the efforts of many people to whom the authors wish to express their gratitude. Ground Water Unit Supervisor Don Jakes has overseen the Ground Water Monitoring and Assessment Program (GWMAP) since its inception and his guidance and support over the years have been a key to its growth and development. The heart of the success of the baseline monitoring program rests with the 13 student assistants who were employed full-time during the field season (generally, May through September) and part-time during the academic year throughout the study. Their many responsibilities included assisting with the well selection process, contacting well owners for permission to sample, planning sampling trips, collecting and delivering samples for analysis, cleaning and maintaining equipment, and making sure the field vehicles were serviced. Two of the 13 who worked during the period 1992-1996, Jennifer Maloney and Jim Stockinger, have gone on to become full-time members of the GWMAP team. Student assistants who served GWMAP to complete the statewide baseline network, their school and years of service are:

1992--Madonna Cehota, University of Minnesota
Melonie Elvebak, Winona State University
Jennifer Maloney, Macalester College

1993--Lilla Bartko, Macalester College
Madonna Cehota, University of Minnesota
Melonie Elvebak, Winona State University

1994--Madonna Cehota, University of Minnesota
Tim Kelley, Century College (formerly Northeast Metro Technical College)
Becky Straub, University of Minnesota

1995--Dan Dammann, University of Minnesota
Karen Earley, Century College and University of Minnesota
John Samuelson, University of Wisconsin, River Falls
Jim Stockinger, University of Wisconsin, River Falls

1996--Jeannie Goette, University of Wisconsin, River Falls
Brad Pierskalla, University of Minnesota
Slade Smith, University of Wisconsin, River Falls

The redesign of Minnesota's ambient ground water monitoring program which led to development of the statewide baseline network component of GWMAP was accomplished by Ground Water Unit staff Georgianna Myers, Suzanne Magdalene and Eric Porcher under funding provided by the Legislative Commission on Minnesota Resources. The early development of the baseline network benefited from the input of several representatives of academic institutions. Dr. Nancy Jannik of Winona State University, Dr. Calvin Alexander and Scott Alexander of the University of Minnesota, and Bob Tipping of the University of Minnesota (State Geological Survey) provided valuable assistance and feedback in development of sampling network design, the well selection process, and the field sampling protocol. A reliable and responsive water quality lab is a key to any ground water monitoring effort and we thank Roger Eliason and Marilyn Flaws of the University of Minnesota's Research Analytical Lab which performed the major cation and anion and trace metal analyses, and the Minnesota Department of Health Lab which analyzed the volatile organic compounds. County Water Plan Coordinators and others at the local level too numerous to mention by name contributed greatly to success of the program.

Julie Pedersen deserves special recognition for compiling and organizing the enclosed report. Finally, to the 954 well owners who participated in the baseline network, 1992-1996, our sincere thanks. Without your cooperation, a program like ours would be impossible. Your assistance has allowed us to gain valuable information about the aquifers Minnesotans depend on.

Abbreviations

ANOVA - Analysis of Variance

CFCs - Chlorofluorocarbons

CWI - County Well Index

DNAPL - Dense Non-aqueous Phase Liquid

FDES - Field Data Entry System

GIS - Geographic Information System

GPS - Global Positioning System

GWMAP - Ground Water Monitoring and Assessment Program

GWSWD - Ground Water and Solid Waste Division

HBV - Health Based Value

HI - Hazard Index

HQ - Hazard Quotient

HRL - Health Risk Limit

LCMR - Legislative Commission on Minnesota Resources

LHA - Lifetime Health Advisory

LNAPL - Light Non-aqueous Phase Liquid

LSD - Least Significant Difference

MCL - Maximum Contaminant Level

MCLG - Maximum Contaminant Level Guideline

MS_E - Mean Square for Error

MPCA - Minnesota Pollution Control Agency

PLS - Public Land Survey

QA/QC - Quality Assurance/Quality Control

RLs - Reporting Limits

SMCL - Secondary Maximum Contaminant Level

THMs - Trihalomethanes

USGS - United States Geological Survey

UTM - Universal Trans Mercator

VOC - Volatile Organic Compound

TABLE OF CONTENTS

FOREWORD i

ACKNOWLEDGMENTS ii

ABBREVIATIONS iii

EXECUTIVE SUMMARY 1

PART I: BASELINE DESIGN AND IMPLEMENTATION 3

1.1 PROGRAM HISTORY 3
1.2 HYDROGEOLOGIC SETTING 4
1.3 WELL SELECTION USING GIS 5
1.4 FIELD SAMPLING PROTOCOL 6
1.5 ANALYTICAL PARAMETERS 7
1.6 SUMMARY OF SAMPLING LOCATIONS 7

PART II: DATA ANALYSIS METHODS 9

2.1. QUALITY ASSURANCE ANALYSIS 9
2.2. INORGANICS 10
2.2.1. DESCRIPTIVE SUMMARIES 11
2.2.2. FACTOR ANALYSIS 15
2.2.3. HEALTH AND RISK 17
2.2.4. GEOCHEMICAL INTERPRETATIONS FOR INDIVIDUAL PARAMETERS 19
2.3. ORGANICS - VOLATILE ORGANIC COMPOUNDS (VOCS) 22
2.3.1. DESCRIPTIVE SUMMARIES 24
2.3.2. FACTOR ANALYSIS 24
2.3.3. HEALTH AND RISK 25
2.3.4. GEOCHEMICAL INTERPRETATIONS FOR INDIVIDUAL PARAMETERS 25

PART III: RESULTS 27

3.1. QUALITY ASSURANCE ANALYSIS 27
3.2. INORGANICS 29
3.2.1. DESCRIPTIVE SUMMARIES 29
3.2.2. FACTOR ANALYSIS 34
3.2.3. HEALTH AND RISK 47
3.2.4. GEOCHEMICAL INTERPRETATIONS FOR INDIVIDUAL PARAMETERS 49
3.3. ORGANICS - VOLATILE ORGANIC COMPOUNDS 84
3.3.1. DESCRIPTIVE SUMMARIES 84
3.3.2. FACTOR ANALYSIS 85
3.3.3. HEALTH AND RISK 86
3.3.4. GEOCHEMICAL INTERPRETATIONS FOR INDIVIDUAL PARAMETERS 86

PART IV: SUMMARY AND EXAMPLES 87

4.1. INORGANICS 87
4.1.1. CHEMICAL DISTRIBUTIONS 87
4.1.2. FACTOR ANALYSIS 99
4.1.3. HEALTH AND RISK 114
4.1.4. GEOCHEMICAL INTERPRETATIONS FOR INDIVIDUAL PARAMETERS 118
4.2. ORGANICS - VOLATILE ORGANIC COMPOUNDS 122
4.3. PROBLEMS 123

PART V: ADDITIONAL PRODUCTS AND FUTURE OF THE PROGRAM 137

5.1 DEVELOPMENT OF SPECIAL STUDIES/PROGRAM DESIGN 137
5.2 ADDITIONAL GWMAP SERVICES 138
5.3 DATA AND INTERPRETATION 139
5.4 PROGRAM IMPROVEMENTS 140

REFERENCES 143

TABLE 1 12
TABLE 2 23
TABLE 3 30
TABLE 4 31
TABLE 5 33
TABLE 6 35
TABLE 7 89
TABLE 8 91
TABLE 9 123
TABLE 10 124
TABLE 11 125
TABLE 12 127
TABLE 13 127
TABLE 14 132
TABLE 15 134
TABLE 16 139

FIGURES

FIGURE 1 36
FIGURE 2 95
FIGURE 3 120
FIGURE 4 130
FIGURE 5 133
FIGURE 6 133
FIGURE 7 134
FIGURE 8 137

APPENDICES

APPENDIX A .... TECHNICAL SPECIFICATIONS FOR THE HANDHELD GLOBAL POSITIONING SYSTEM (GPS)
APPENDIX B .... SAMPLE BOTTLE DESCRIPTIONS
APPENDIX C .... INORGANIC CHEMISTRY AND VOLATILE ORGANIC COMPOUNDS
APPENDIX D .... TABLES OF RESULTS
APPENDIX E .... SAMPLING PROTOCOL AND MAPS OF WELLS SAMPLED

Executive Summary

Understanding baseline or background water quality and chemistry of important aquifers is a powerful tool which allows resource managers to identify potential ground water problems, compare site concentrations with background concentrations, and develop studies of regional ground water quality. In 1991, a study was begun within the Minnesota Pollution Control Agency's (MPCA) Ground Water Monitoring and Assessment Program (GWMAP) to establish baseline ground water quality in Minnesota's principal aquifers. A randomized grid design was established across the state, with a grid node spacing of 11 miles. A well from each principal aquifer used as a source of drinking water was selected within a nine-mile target area centered on each grid node Between 1992 and 1996, 954 drinking water wells were sampled for major cations and anions, trace inorganics, volatile organic compounds (VOCs), total organic carbon, total and dissolved solids. Field measurements were made for pH, oxidation-reduction potential, dissolved oxygen, temperature, alkalinity, and specific conductivity. Mean, median, minimum, maximum, 95th percentile, and 95th upper confidence limit concentrations were determined for all inorganic parameters for thirty individual aquifers, seven age-based aquifer groups, and four hydrology-based aquifer groups. Effects of well diameter, sampling year and month, presence or absence of VOCs or tritium, well depth, static water elevation, geographic location, and redox parameters (dissolved oxygen, total iron and manganese concentrations, and oxidation-reduction potential) on concentrations of each chemical parameter were determined for all aquifers and aquifer groups. Concentrations were compared with drinking water criteria and a risk analysis was completed. A geochemical analysis was also completed for each parameter. Chemicals were divided into six categories based on the potential for ground water to become contaminated under equilibrium conditions. Results are presented in *Baseline Water Quality of Minnesota's Principal Aquifers* (MPCA, 1998). GWMAP is using the results of the baseline study to design additional studies to investigate the effects of human activity on ground water quality. These studies focus on identifying the primary human activities which affect ground water, quantifying risk to human and ecological receptors, and determining the effectiveness of management practices.

Design

Part I: Baseline Design and Implementation

The mission of the Minnesota Pollution Control Agency's (MPCA) Ground Water Monitoring and Assessment Program (GWMAP) is to examine the quality of ground water in the state's principal aquifers, establish baseline conditions, assess changes in these conditions with time, evaluate effects of human activity on ground water quality, and communicate results to the public in a meaningful way. This report is a compilation and analysis of ground water quality data for 954 primarily domestic wells collected in 86 counties between 1992 and 1996. Together, the dataset comprises the Ambient Statewide Baseline Study (hereafter, baseline study) as originally envisioned in the redesign of Minnesota's ambient ground water monitoring program (Myers et al., 1992). **GWMAP staff feel the results of the baseline study provide information about "background" water quality in Minnesota's principal aquifers provided limitations and assumptions outlined in this document are understood.**

1.1 Program History

Minnesota's first ambient ground water monitoring network was designed in the late 1970's by the United States Geological Survey (USGS) under contract to the MPCA (Hult, 1979). The program was designed to improve knowledge of the quality of the state's principal aquifers by studying them on a continuing basis. Between 1978 and 1990, the program collected approximately 1100 samples from 314 points, including wells and some springs, across the state. Wells were selected to represent, to the best extent possible, the state's principal aquifers. Selection was not random, but was skewed toward areas of greater population density and increased ground water use. Inadequate funding, shifting priorities, and inconsistencies in sampling methods and parameters analyzed made data collection and interpretation difficult. However, MPCA published several compilations of this data throughout the program and the chemistry data for the 314 stations established during the 12 years the program operated are stored in the national water quality database, STORET.

In 1989, the MPCA received a $196,000 grant from the Legislative Commission on Minnesota Resources (LCMR). Part of this grant was used to redesign Minnesota's ambient ground water monitoring program (Myers et al., 1992). Three components of GWMAP were established: baseline assessment, trend monitoring, and development of regional cooperatives. The baseline component was intended to establish ambient or "background" water quality of Minnesota's principal aquifers. Specific objectives of the baseline component were to establish median and 95th percentile concentrations for the chemistry of the principal aquifers, quantify the spatial distribution of water quality parameters in these aquifers, and identify potential ground water quality concerns.

During 1990 and 1991, most of the ground water monitoring staff effort was directed toward the redesign, including developing what was to become GWMAP's ground water sampling protocol. The 1991 field season included testing and calibrating field procedures. The sampling protocol has been refined over the years and the most recent version (Revision 3.0) has been published as the GWMAP Field Guidance Manual (MPCA, 1996). Beginning in the fall of 1992, the sampling protocol was in place and a budget was established in support of sampling activities. A technical services contract for analytical support was negotiated with the University of Minnesota Research Analytical Laboratory and a Quality Assurance/Quality Control (QA/QC) Policy was established (Research Analytical Laboratory, 1997). Sampling began with collection of 158 samples from six bedrock aquifers in cooperation with water resource managers from nine southeast Minnesota counties (Tipping, 1994). During the 1993 field season, 206 samples were collected in the southern one-quarter of the state and a portion of the Red River Valley. Results from the combined dataset of 364 wells are found in MPCA, 1994.

During the 1994 field season, an additional 197 samples were collected in 19 counties. Results of the baseline study to that point are found in MPCA, 1995. Sampling to complete statewide coverage continued during the 1995 and 1996 field seasons. By September 1996, sample collection was completed. Although the redesign report somewhat overestimated the availability of wells in some areas of the state, the 954 wells comprising the statewide baseline component of GWMAP meet the state's needs for a dataset of baseline ground water quality of Minnesota's principal aquifers.

1.2 Hydrogeologic Setting

Minnesota, the twelfth largest state, obtains its ground water from 14 principal aquifers (Adolphson, et al., 1981) which span over four billion years of geologic history. Although Minnesota is widely known for its 10,000 lakes, nearly all the rural population of the state depends on ground water for a water supply. Buried and surficial sand and gravel aquifers left by several glacial advances over much of the state in the last million years are composed of outwash, beach ridge, and ice contact deposits. Sandstone and carbonate rocks of Paleozoic and late Precambrian age comprise aquifers which support the population of much of the southeast part of the state, including the metropolitan areas of the Twin Cities and Rochester. Early Precambrian aquifers of granite, basalt and quartzite are locally important, although they generally yield relatively small amounts of water. Part II of this report contains a list of individual aquifers, arranged by geologic age. The interpretation of ground water chemistry data in Part II includes a comparison among age groups and individual aquifers.

1.3 Well Selection Using GIS

Minnesota has over 200,000 active water wells, so choosing a representative group of these wells to define water quality of the principal aquifers is a formidable job. GWMAP chose a geographic information system (GIS) as an automated prescreening mechanism to facilitate well selection. GIS allows a sampling grid to be layered over hydrogeologic criteria and well location information to ensure an efficient and cost-effective selection process for designating wells that are useful for evaluating baseline ground water quality conditions. Grid-based sampling was first implemented in GWMAP during the 1991 protocol test phase using a manually-generated spatial grid defined by the Public Land Survey (PLS). Although the PLS is not 100 percent geographically uniform, it originally was selected as a basis of the grid to expedite well selection from existing digital databases in which wells are located by PLS section. GWMAP has since developed an improved automated grid overlay combining use of ARC/INFO[1] (Environmental Systems Research Institute, 1993) and global positioning system (GPS) technology (Hsu et al., 1993; Hsu et al., 1996).

The statewide sampling grid, generated from a randomly selected origin, consisted of about 700 square cells, each comprised of an 11-by-11 mile square, or 121 square miles (Figure E.1). The centroid of each cell was extracted to produce the origin of each sampling zone, a three-by-three mile square, from which the wells chosen as candidates for sampling were selected. The sampling zones were then made into a GIS coverage and overlaid on top of the PLS coverage to extract those sections which were associated with each of the sampling zones. The County Well Index (CWI), a statewide electronic well log database (Wahl and Tipping, 1991), was imported as a point coverage and overlaid with the selected PLS section coverage so that wells falling within the sampling zones could be identified electronically as potential candidates for sampling. For wells that fall within the zones, actual well construction records were pulled for review, or, as has been the case more recently, reviewed electronically on CWI. Typically, five to ten percent of all selected wells meeting the location criteria were sampled. This accounted for hydrogeologic and well construction criteria and the cooperation by well owners participating in the program. Selecting wells in this manner provides a water quality analysis which predominantly reflects the natural composition of ground water, but also includes some overlay of human activity. Distinguishing between these two is difficult and was not a specific objective of the baseline study. For a complete discussion of how CWI was used and wells were selected, see MPCA, 1994.

[1] Mention of a particular product or company does not imply endorsement or preference over similar products not mentioned.

1.4 Field Sampling Protocol

GWMAP's field sampling protocol is discussed in detail in the GWMAP Field Guidance Manual (MPCA, 1996), so only some of the major features are highlighted here. The on-site well sampling procedure used for obtaining all the baseline samples is shown by the flow chart in Figure E.2. The primary selection criterion for a well was that it be located within the target grid cell. This involved two checks, first, that the well to be sampled matched the selected well log and owner description, and second, that the well log had the correct location information with it so that the sample location could be verified as being within the grid cell. The Field Sampling Protocol requires that two people be in the field to collect a sample: the Recorder and the Operator. The Recorder's primary responsibilities were taking and recording GPS readings, operating the data logger, completing the well sampling field form (including a site map) on the back of the well owner calling checklist, ensuring that the well met the stabilization criteria prior to sample collection, and ensuring that all samples were collected in properly labeled and preserved bottles. The Operator's primary responsibilities were to set up and calibrate the equipment, ensure that the equipment was functioning properly, observe all measurements, collect the samples, and pack up the equipment.

GWMAP employed GPS technology in the field to locate its wells with five-meter accuracy. A description of the equipment used and specifications are listed in Appendix A. Data were downloaded to personal computers using the Pathfinder software package supplied with the receiver (Hsu et al., 1993). At the sampling site, the receiver was typically placed on the wellhead and continuously logged for about five minutes. This technology is suitable for any program that is designed to conduct either large-area or intensive monitoring activities. In 1995, efficiency was further increased by the addition of three data loggers and bar coders which replaced the need for paper field forms and the need to manually label and track sample bottles. Operation of the data logger/bar coder system is discussed in detail in GWMAP's Field Data Entry System (FDES) Operating Manual (MPCA, 1997).

Sample bottle descriptions and preservatives used are summarized in Appendix B. The filling of sample bottles requires only a few minutes, but samplers spent anywhere from 30 minutes to as long as two hours at a site, depending upon how much time was required to purge and stabilize the well. The amount of time required at each site depended upon the diameter and depth of water column in the well, since a minimum of three well volumes needed to be removed from the well casing. During collection of the baseline sample dataset (1992-1996), the instrument display was observed and recorded at three minute intervals for at least nine minutes. Parameters measured in the field included alkalinity (titration), dissolved oxygen, pH, specific conductivity, oxidation-reduction potential, and temperature. The sampler watched for stability of pH ($\pm$ 0.1 pH units), specific conductivity ($\pm$ five percent for three consecutive readings), and temperature ($\pm$ 0.1 degree Celsius) readings. Alkalinity titration was performed on-site by the Recorder as the Sampler filled the sample bottles. Samples were immediately placed in a cooler and iced to four degrees Celsius until being placed in a dedicated refrigerator at the MPCA field operations center. From there, they were delivered to the appropriate analytical laboratory to meet holding time requirements.

1.5 Analytical Parameters

One of the desired goals of the baseline network was to develop an analytical parameter list which would be applied consistently throughout the duration of the five-year project. Addition or deletion of parameters was done only by careful consideration and consensus of the team. Of the 52 inorganic parameters analyzed for the baseline network and listed in Appendix C, 41 have ten or fewer missing results. Four metals—bismuth, cesium, tin and zirconium—were added to the analytical list at the start of fiscal year 1996. One parameter, mercury, was dropped from the analytical list at the end of the 1994 field season for the reasons described in MPCA, 1995. A complete synopsis of chemical parameters analyzed by GWMAP, number of detections, and any censoring values applied may be found in Part II of this report. Appendix C also contains a list of the 68 Volatile Organic Compounds (VOCs) analyzed by GWMAP.

1.6 Summary of Sampling Locations

Well sampling, by year, is summarized in Figure E.3. Well sampling, by aquifers, is summarized in Figures E.4 through E.10. Aquifers are grouped by age of the deposit, such as Cambrian and Ordovician, except for the Quaternary aquifers, which are divided into buried and surficial Quaternary aquifers. Information on the number of samples collected from each aquifer is summarized in Tables D.6 through D.44.

Methods

Part II: Data Analysis Methods

Following completion of sample collection and laboratory analysis, the task of data analysis began. Data analysis methods employed within GWMAP are discussed in *Data Analysis Protocol for the Ground Water Monitoring and Assessment Program* (MPCA, 1998). Prior to conducting specific statistical analysis of the data, quality assurance analyses were completed. Following analyses of quality assurance, statistical analysis was performed, including descriptive summaries, hypothesis tests, and correlation tests between chemical concentrations and various factors. General procedures for conducting these analyses are summarized below.

2.1. Quality Assurance Analysis

The objective of quality assurance analysis is to evaluate the accuracy and precision of laboratory and field sample results. Erroneous or questionable data may occur as a result of sample preparation and collection in the field, sample storage and transport prior to delivery at the laboratory, laboratory procedures (including reporting), and data entry. Data which fail quality assurance guidelines may require re-sampling, flagging of questionable data, eliminating questionable data from the data set, and changing sample collection or analysis procedures. Routine Quality Assurance/Quality Control (QA/QC) procedures which are now implemented by GWMAP staff are described below in bold.

- **Samples exceeding recommended holding times are flagged. Re-sampling may occur but is not required. Results may be discarded.** No well was re-sampled and no data were discarded due to holding time requirements. Laboratory turnaround times for sample analysis were typically four to six weeks for inorganics and two to four weeks for Volatile Organic Compounds (VOCs). These turnaround times include report generation. It is unlikely holding times were exceeded for inorganic samples. VOC samples were typically brought to the laboratory in batches. Some VOC samples in these batches may have been collected a few days prior to sample delivery. With a VOC holding time of fourteen days, it is possible holding times may have occasionally been exceeded. The holding time requirement is most critical for highly volatile or degradable VOCs.
- **Samples in which reporting limits (RLs) are raised during laboratory analysis are flagged.** RLs were not raised for the baseline data.
- **Charge balances exceeding ± 5 percent are flagged and samples are re-analyzed once**. This procedure was implemented after 1994. In most cases, re-analyzing the sample did not improve the charge balance. Possible reasons for this are presented in Section 3.1.

- **Concentrations in primary and field duplicate samples which differ by more than ten percent in any individual sample are flagged and possibly re-analyzed.** These samples were not flagged by GWMAP staff during the course of baseline sampling. This analysis was performed for this report.
- **Concentrations in field samples and laboratory duplicates which differ by more than ten percent in any individual sample are flagged and possibly re-analyzed.** These samples were not flagged by GWMAP staff during the course of baseline sampling. This analysis was performed for this report.
- **Surrogate and spike recoveries which are not within acceptable limits are flagged and the sample batch may be re-analyzed.** Surrogate recoveries for organic and inorganic compounds should be greater than 80 percent and less than 120 percent. Recoveries were within acceptable limits for all baseline samples.
- **Total dissolved solid concentrations (mg/L) less than 55 percent or greater than 76 percent of the conductivity (umhos/cm) are flagged.** For flagged data, ratios of conductivity to meq of cations less than 50 or greater than 150 are flagged. For these flagged data, the value for conductivity is considered invalid and is removed from the data set. This procedure was not applied during baseline sampling, although the ratios were computed.
- **If a common organic laboratory contaminant (methylene chloride, phthalates, acetone) is found in a laboratory or trip blank at a concentration greater than ten percent of the concentration reported in a sample, the sample is flagged.** GWMAP considers these samples to represent false positives and they are treated as a non-detect. For uncommon organic laboratory contaminants, a value of 20 percent is used.

Other data quality tests which are sometimes utilized for data analysis and may indicate potential problems with the data are summarized below.

- (Mg/(Mg+Ca)) greater than 40 percent;
- (Na/(Na+Cl)) less than 50 percent;
- (Ca/(Ca+SO_4)) less than 50 percent; and
- (K/(K+Na)) greater than 20 percent.

These were not performed during baseline sampling but have been calculated for this report.

2.2. Inorganics

Analysis for synthetic organic compounds (pesticides and VOCs) and inorganics differs in two respects. First, inorganic chemicals are found naturally in ground water, although sometimes at very low concentrations. Concentrations in ground water may increase as a result of human activity, but it is difficult to differentiate between natural and anthropogenic contributions. Most of the organic compounds sampled as part of the baseline assessment are not naturally occurring and result from industrial use of chemicals (including disposal), agriculture, spills and leaks, atmospheric fallout and subsequent leaching, landfills, and so on. Second, detection frequencies are much lower for most organic chemicals. Because of the low frequency of detection and the anthropogenic nature of most organics, the distribution of organics can be treated as a binomial population where the chemical is either present or absent. Inorganic chemicals are treated as a normally or log-normally distributed chemical in which parametric and nonparametric statistical methods may be used to describe and predict the distribution of these chemicals. Inorganics are discussed in this section and organics are discussed in Section 2.3.

2.2.1. Descriptive Summaries

Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) Version 6.1.2. Descriptive statistical analysis was performed for individual aquifers and combinations of aquifers. All sampled wells were selected from the County Well Index (CWI) (Wahl and Tipping, 1991). CWI is a database containing information for thousands of wells drilled in Minnesota. Within CWI, each well is assigned a four-letter code corresponding with the most likely geologic formation in which the well is completed. The first letter in the sequence defines the geologic time in which the deposit formed. Thirty aquifer designations were encountered during sampling. These are summarized in Table 1. A detailed discussion of CWI and how it was used in well selection is described in MPCA, 1994. Statistical methods are discussed further in MPCA (1998), SPSS Inc. (1996), Adkins (1993), United States Environmental Protection Agency (USEPA) (1989), and Montgomery (1984).

Table 1.: Summary of aquifers and aquifer groups.

CWI Code	Aquifer	Aquifer Age Group	Aquifer Hydrologic Group
CFIG	Franconia-Ironton Galesville	Cambrian	Franconia-Ironton-Galesville
CFRN	Franconia	Cambrian	Franconia-Ironton-Galesville
CIGL	Ironton-Galesville	Cambrian	Franconia-Ironton-Galesville
CJDN	Jordan	Cambrian	St. Peter-Prairie du Chien-Jordan
CMSH	Mount Simon-Hinckley	Cambrian	Mount Simon-Hinckley
CMTS	Mount Simon	Cambrian	Mount Simon-Hinckley
CSLF	St. Lawrence-Franconia	Cambrian	-
CSTL	St. Lawrence	Cambrian	-
DCVA	Cedar Valley	Devonian	Upper Carbonate
KRET	Cretaceous	Cretaceous	-
OGAL	Galena	Ordovician	Upper Carbonate
OMAQ	Maquoketa-Galena	Ordovician	Upper Carbonate
OPDC	Prairie du Chien Group	Ordovician	St. Peter-Prairie du Chien-Jordan
OPVL	Platteville	Ordovician	Upper Carbonate
OSPC	St. Peter - Prairie du Chien	Ordovician	St. Peter-Prairie du Chien-Jordan
OSTP	St. Peter	Ordovician	St. Peter-Prairie du Chien-Jordan
PCCR	Crystalline rocks	Precambrian	-
PCUU	Undifferentiated	Precambrian	-
PEBI	Biwabik Iron Formation	Precambrian	-
PMDC	Duluth Complex	Precambrian	-
PMFL	Fond du Lac Formation	Precambrian	-
PMHN	Hinckley Sandstone	Precambrian	Mount Simon-Hinckley
PMNS	North Shore Volcanic Group	Precambrian	-
PMSX	Sioux Quartzite	Precambrian	-
PMUD	Middle Proterozoic rocks, undifferentiated	Precambrian	-
QBAA	Buried artesian aquifer	Buried Quaternary	-
QBUA	Buried unconfined aquifer	Buried Quaternary	-
QBUU	Buried unconfined undifferentiated	Buried Quaternary	-
QUUU	Unconfined undifferentiated	Surficial Quaternary	-
QWTA	Water table aquifer	Surficial Quaternary	-

Descriptive statistics were generated for each of these thirty aquifers for 52 chemical parameters. Descriptive statistics include the mean and upper 95th percent confidence limit of the mean for data which fit a normal or log-normal distribution, the median, 95th percentile, minimum, and maximum concentrations for each chemical parameter. Parametric analysis (mean and 95th percent mean concentrations) was performed for data which fit a normal or log-normal distribution. The procedure for calculating descriptive statistics is summarized below.

1. Calculate nonparametric statistics (median, minimum, maximum, and for sample sizes of 20 or greater, the 95th percentile).
2. Censor data at the highest reporting limit. All non-detections and detections below the highest reporting limit were assigned the same value. This value was less than the highest reporting limit. Censored values are treated as missing data for parametric analysis and equal values for nonparametric analysis.
3. For uncensored data, Kolmogorov-Smirnov and Shapiro-Wilk statistics were calculated. If either of these values was greater than 0.05, the data were assumed to be normally distributed. If both values were less than 0.05, the statistics were calculated for log-transformed data. If the values were less than 0.05 for transformed data, the data were assumed to be non-normally distributed and parametric statistics were not calculated.
4. For censored data, parametric statistics were calculated using Helsel's Robust method (Newman et al., 1995). This method employs curve-fitting techniques to "fill in" censored data using information from the detections. The data are assumed to follow a log-normal distribution described by the z distribution.

The above procedure has the following limitations.

- Data were not examined for outliers (an outlier is defined as the upper 95th percent confidence level plus 1.5 times the standard deviation). Outliers do not have an effect on nonparametric descriptives unless percentiles are being calculated near the maximum and minimum values in the data and these data are not representative of the overall population. Outliers may have a significant effect on parametric descriptive statistics, particularly for small sample sizes.
- Only normal and log-normal distributions were considered.
- All data were considered to be derived from a single population. When considering a single aquifer such as Quaternary water table aquifers (QWTA), this assumption is valid because the effect of individual factors on the data distribution are not being considered. Combining all data into a single sample population will "smooth out" variability associated with factors which may have significant effects on the distribution of data. More detailed factor analysis for individual aquifers will be performed in subsequent reports.
- Aquifer designations within CWI are subject to interpretations by geologists. There are at least four concerns with this. First, QWTA wells are classified as such because they have less than ten feet of confining material between the land surface and the potentiometric surface. A check of water levels in QWTA wells reveals that many of these wells could be classified as confined. Second, many individual aquifers are in hydrologic connection and can be treated as a single

aquifer. For example, in many places, the Prairie du Chien (OPDC) and Jordan (CJDN) aquifers behave as a single aquifer, while in other areas they behave as independent aquifers. Third, no distinction is made between unconfined and confined aquifers for the same bedrock unit. The Prairie du Chien aquifer may be the uppermost aquifer in some areas but may be well protected in others. Although spatial analysis cannot be performed on the baseline data due to the large grid spacing, visual inspection of analytical results indicates water quality in areas where bedrock aquifers are the uppermost geologic unit differs from areas where these aquifers are confined. Fourth, the effect of karst is ignored. A single sample collected from a karst aquifer may not accurately represent overall water quality in that well because of large temporal variations in water quality. This same concern exists, to a lesser extent, for shallow outwash aquifers. These factors were not considered in well selection because the objective was to assess baseline ground water quality. Selecting wells based on geologic criteria would introduce a bias into the sampling procedures. Subsequent studies conducted by GWMAP which focus on specific hydrologic problems or effects of human activity on ground water quality will require careful screening of individual wells, because understanding local geology and hydrology are critical for these types of studies.

- For some chemical parameters, there were multiple reporting limits. Censoring at the highest reporting limit resulted in a loss of data for some parameters.

These limitations were partly imposed because individual wells were not selected based on geologic criteria (other than having the appropriate four-letter designation) and because data were not rigorously analyzed until all samples had been collected. Despite these limitations, the sampling methodology (Meyers et al., 1991), the shear mass of data, and the conservative assumptions used in the analysis are considered to result in an analysis which provides meaningful descriptive information **provided these limitations are kept in mind**.

In addition to the individual aquifer analysis, two aquifer groupings were considered. The first grouping was based on age of deposit. This was an analysis which could be quickly implemented because of the CWI designation in which the first letter represents the age of the deposit. All Cambrian, Ordovician, Precambrian, buried Quaternary, and surficial Quaternary samples were combined as separate groups (see Table 1). Devonian and Cretaceous aquifers also represent age-related groups, but only one aquifer contributed to these groups. Note that a single age-based group, the Quaternary aquifer group, was divided into two groups - surficial and buried. Before descriptive analysis was conducted, hypothesis testing was performed to determine which parameters were appropriate for analysis. The Kruskal-Wallis test was used for more than two independent samples to determine if concentrations for a chemical parameter differed between the individual aquifers comprising the group. If concentrations differed (at the 0.05 level), descriptive analysis was not performed for that parameter. This means, for example, if nitrate concentrations in the Jordan (CJDN) and Mount Simon-Hinckley (CMSH) aquifers differed (at the 0.05 level), then an overall nitrate concentration for the Cambrian group was not computed. Such a calculation would have no meaning since nitrate levels in two of the aquifers contributing to the group differ and represent different populations.

The second grouping was based on aquifers considered to be hydrologically connected. Four aquifer groups were identified: the St. Peter-Prairie du Chien-Jordan aquifer (OSTP-OPDC-CJDN); the Franconia-Ironton-Galesville aquifer (CFIG-CFRN-CIGL); the Mount Simon-Hinckley aquifer (CMSH-CMTS-PMHN); and the Upper Carbonate aquifer. Individual aquifers comprising these aquifer groups are summarized in Table 1. The Kruskal-Wallis test was used for more than two independent samples to determine if concentrations for a chemical parameter differed between the individual aquifers comprising the group. If concentrations differed (at the 0.05 level), descriptive analysis was not performed for that parameter.

A third grouping which was not utilized in this study would be between similar geologic deposits. For example, limestone-dolomite aquifers, sandstone aquifers, sand and gravel aquifers, aquifers of volcanic origin, and aquifers of metamorphic origin may comprise different groups. This analysis may prove insightful when conducting regional analysis of the data in subsequent reports.

2.2.2. Factor Analysis

Factor analysis involved hypothesis testing and correlation analysis. Hypothesis tests involve a comparison of concentrations between two or more factors. The factors are therefore discrete rather than continuous variables. An example of a hypotheses test is determining if concentrations of lead in Quaternary water-table aquifers (QWTA) wells differ between wells with diameters of four and twelve inches (at the 0.05 level). If they do, then wells should be divided into well diameter classes when conducting additional analysis because each diameter class (discrete variables) represents a different population. Correlation analysis involves evaluating a response in concentration to a continuous variable. An example of a correlation analysis is determining if the concentration of lead in QWTA wells changes in a predictable manner with well diameter. In this case, well diameter is treated as a continuous variable ranging from four to twelve inches. If the relationship between lead concentration and well diameter is significant, we can predict the concentration of lead for a particular well diameter.

The number of potential factors and factor combinations that affect water quality is very large. Some of these will be discussed in subsequent reports. In this report, hypothesis tests were performed to determine if concentrations of each chemical parameter varied within the following factors, which were divided into discrete classes:

- aquifer (for all chemicals) - thirty aquifer classes (see Table 1);
- aquifer groups (for all chemicals) - seven age-based classes and four hydrology-based classes (see Table 1);
- well diameter (by aquifer group and overall for all chemicals) - nine diameter classes (4, 5, 6, 7, 8, 12-16, 24, 30, and 36 inches);
- presence of detectable tritium (by aquifer group and overall for all chemicals) - two classes, detected or not detected;
- presence of detectable VOCs (by aquifer group and overall for all chemicals) - two classes, detected or not detected;
- year of sampling (by aquifer group and overall for all chemicals) - five year classes (1992, 1993, 1994, 1995, 1996); and
- month of sampling (by aquifer group and overall for all chemicals) - twelve month classes (January through December).

Hypothesis tests were conducted by stating a null hypothesis, which was rejected if the test significance was 0.05 or less. The null hypothesis in all cases was that chemical concentrations did not differ between the factor categories being compared. Nonparametric tests were conducted, including the Mann-Whitney test for pairwise comparisons and the Kruskal-Wallis test for multiple comparisons. If the null hypothesis was rejected using the Kruskal-Wallis test, the Least Significance Difference method was used to determine which variables differed (Montgomery, 1984). For the aquifer groups, hypothesis tests were performed only for those parameters in which concentrations did not differ between the aquifers comprising the group.

All hypothesis tests involved single factor analysis. This means that combinations of two or more factors, such as well type and well diameter, were not considered. Single factor analysis emphasizes differences in concentration associated with a particular factor, but weakens the ability to predict a concentration. This is because the concentration of a chemical in any given well is a function of many factors. Analysis was limited to those aquifers and aquifer groups with sufficient sample size.

Spearmann rho correlations were calculated between each chemical parameter and well depth, depth to water, Universal Trans Mercator (UTM) east coordinate, and UTM-north coordinate. Correlations were calculated for each aquifer group. A test value of 0.05 was used to identify significant correlations. The correlation coefficient (R^2) describes the fraction of variability accounted for by the factor being considered. Spearmann rho correlations were also calculated between each chemical parameter and dissolved oxygen, oxidation-reduction potential, iron, and manganese. These four factors provide an indication of redox conditions in ground water. Many chemicals, such as arsenic, nitrate, sulfate, and volatile organic compounds (VOCs) are redox-sensitive.

2.2.3. Health and Risk

The number and frequency of samples exceeding water quality criteria was calculated for each chemical parameter having a water quality criteria. This analysis was performed for all aquifers and aquifer groups. Criteria, in priority order of use, were the Health Risk Limit (HRL), Health Based Value (HBV), Maximum Contaminant Level (MCL), and Secondary Maximum Contaminant Level (SMCL) (Federal Register, January 30, 1991, p. 3526-3614; and July 1, 1991, p. 30266-30281).

The primary utility of calculating the number or percentage of wells which exceed a water quality criteria is identifying the capacity of an aquifer to support a drinking water use. Water quality exceedances do not reflect ambient water quality in an aquifer. Conversely, mean and median background concentrations do reflect ambient water quality but do not provide an indication of risk to ground water receptors. Considering only the mean or median concentrations or the percent of samples exceeding drinking criteria ignores chemical additivity. This is because there are some chemicals which have the same toxic endpoint. Consequently, the combination of these chemicals needs to be considered when assessing potential risk to ground water receptors.

Risk analysis provides useful information about the potential risk posed to ground water receptors. A risk analysis is performed in two stages. First, a hazard quotient is calculated for each chemical in a well. A hazard quotient (HQ) is defined by:

$$HQ = \text{concentration/risk criteria} \qquad [1].$$

Appropriate risk criteria include the HRL or HBV. HRLs are defined in the following manner: *HRLs are promulgated concentrations of a ground water contaminant, in ug/L, which estimates the long-term exposure level which is unlikely to result in deleterious effects to humans. HRLs strictly incorporate factors related to human health* (Minn. R., Pts. 4717.7100 to 4717.7800). HBVs have a similar definition, with the exception that they are not promulgated and have not undergone rigorous external peer review. Drinking water criteria are calculated based on a standard adult (70 kg) ingestion rate of two liters of water per day. Uncertainty and other exposure pathways, such as showering, cooking, and inhalation of water vapor, are addressed through the use of safety factors. Lifetime exposure is assumed to apply to baseline data, since the sampled wells are used for domestic supply.

MCLs and SMCLs are not strictly health-based and are therefore not used in calculations of risk. The exception was use of arsenic, which has an MCL, in calculations affecting the cancer endpoint. SMCLs are not enforceable and do not consider additivity.

The second step is calculation of a hazard index (HI), which is the sum of hazard quotients for chemicals with the same endpoint:

$$HI = HQ_1 + HQ_2 + \ldots HQ_n \qquad [2]$$

where 1, 2, ... *n* are chemicals with the same target endpoint. Hazard indices were calculated for each of the following target endpoints:

- cardiovascular or blood system (CV/BLD);
- central or peripheral nervous system (CNS/PNS);
- immune system (IMMUN);
- kidney (KID);
- gastrointestinal system or liver (GI/LIV);
- reproductive system including teratogenic and developmental effects (REPRO);
- respiratory system (RESP);
- skin irritation or other effects (SKIN);
- skeletal system (SKEL);
- endocrine system (ENDO);
- cancer; and
- whole body (BODY).

As an example, barium and nitrate both have the cardiovascular system as their target endpoint. If the concentrations of barium and nitrate in a well are 500 and 1000 ug/L, respectively, the hazard quotient for barium is (500/HRL = 500/2000 = 0.25) and the hazard quotient for nitrate is (1000/HRL = 1000/10000 = 0.10). The overall hazard index for the cardiovascular system is the sum of the individual hazard quotients or (0.25 + 0.10 = 0.35), assuming no other chemicals affect the cardiovascular system. For this example, the hazard index indicates there are no likely deleterious effects associated with these concentrations.

Hazard indices are not linear and should not be interpreted as quantitative estimates of risk. If the HI exceeds 1.0 for an endpoint, further investigation is recommended to evaluate the potential factors controlling chemical concentrations and the validity of the exposure assumptions.

Median hazard indices were calculated for each target endpoint for each aquifer and aquifer group. The percentage of samples for which the HI would be expected to exceed a value of 1.0 were calculated for each endpoint and aquifer or aquifer group in which there was a sufficient number of samples to make this calculation. There were no chemicals affecting the respiratory, immune system, skeletal, and endocrine endpoints and these endpoints are not included in the tables.

These calculations represent interpretations at the time of this report. Drinking water criteria are updated by the Minnesota Department of Health periodically and interpretations therefore are subject to change. Also, ecological receptors were not considered in this report. Ground water which discharges to surface water has the potential to impact ecological receptors. Ground water concentrations can be compared to aquatic life standards to evaluate potential impacts to ecological receptors.

2.2.4. Geochemical Interpretations for Individual Parameters

The water chemistry of an aquifer is influenced by many factors, including interaction with the unsaturated zone and over- or underlying aquifers, presence of microorganisms, and chemistry of source rocks. Despite these, geochemical controls on solubility and chemical form exist for many sampled parameters. Within ground water, geochemical reactions are primarily influenced by kinetic constraints on dissolution and ion exchange reactions and by oxidation-reduction conditions, since temperature and pH are generally within narrow ranges. The objectives of conducting geochemical analysis of ground water data are to identify chemical forms likely to exist within an aquifer, particularly those which represent a potential health concern, to determine the potential for an aquifer to support chemical concentrations which may represent a health risk, and to identify likely source rocks when chemical concentrations represent a potential health concern.

Theoretical concentrations of a chemical can be calculated knowing geochemical conditions in an aquifer and making some simple assumptions about potential source rocks. These concentrations can then be compared to drinking water criteria to determine if an aquifer is potentially sensitive to contamination with this chemical and to measured concentrations to determine if concentration is potentially being limited by availability of source rocks. To calculate the theoretical concentration of a chemical A in solution, indicated as C_A in ug/L, the following general equations are applied:

$$AB \rightarrow A^{n+} + B^{n-} \qquad [3]$$

$$K \rightarrow [A^{n+}][B^{n-}]/[AB] \qquad [4]$$

$$\Delta G^{o}_{r} = \Delta G^{o}_{B} + \Delta G^{o}_{A} - \Delta G^{o}_{AB} \qquad [5]$$

$$\log K \rightarrow -\Delta G^{\circ}_{r}/1.364 \qquad [6]$$

$$C_A \rightarrow K*1000000*MWt*[AB]/[B] \qquad [7]$$

where ΔG^{o}_{r} represents the Gibbs Free Energy of Formation (kcal/mol), K is the equilibrium or dissociation constant, *Mwt* is the molecular weight of chemical *A*, and [] represents the molar concentration. In actuality, [] represents an activity, but ionic strength effects are ignored in this analysis. The activity of the solid, *AB*, is taken as 1 and it thus falls out of Eq. [4]. Equations 3 and 4 are used to calculate *K*, Eq. [6] is rearranged into Eq.[5] to get the concentration in ug/L. Gibbs Free Energy values were obtained from Garrels and Christ (1965). The values reported in this text are somewhat out of date, but the tables from this text were used because they encompass all chemicals sampled during the baseline assessment.

Equations [3] through [7] are simplistic. They assume the free form of *A* will be the form present in solution. Many chemicals form oxides or hydroxides. Eq. [3] can be modified to reflect these forms:

$$AB + nOH^{-} \rightarrow [A(OH)_n] + Bn^{-} \qquad [8]$$

$$AB + 0.5n(H_2O) \rightarrow [AO] + B^{n-} + nH^{+} \qquad [9].$$

Equations [8] and [9] are pH-sensitive, while equations [4], [7], [8], and [9] are sensitive to concentrations of *B* (assuming the activity of *AB* is unity). *B* typically represents a carbonate, sulfate, or sulfide, but may also represent a silicate, chloride, or phosphate. Considering carbonates, the ratio of bicarbonate to carbonate is given by:

$$[HCO3]/[CO3] = 10^{-pH}/10^{-10.3} \qquad [10].$$

Even for relatively high-pH ground water (about 8.0), the concentration of bicarbonate is much greater than that of carbonate. Eq. 8 therefore needs to be rewritten to reflect the dominance of bicarbonate:

$$ACO_3 + H^{+} \rightarrow A^{2+} + HCO_3^{-} \qquad [11].$$

Theoretical concentrations for individual chemicals were calculated using the above principles and median values for the entire data set for bicarbonate, sulfate, chloride, silica, pH, and iron. Mean molar concentrations for hydrogen (pH), bicarbonate (alkalinity), and sulfate were $10^{-7.24}$, $10^{-2.32}$, and 10^{-4}, respectively. A value of 10^{-4} was used for sulfide.

As an example, consider the theoretical dissolved concentration of cadmium in equilibrium with solid cadmium carbonate:

$$CdCO_{3(s)} + H^{+} \rightarrow Cd^{2+} + HCO3^{-}$$

Using published values for $\Delta G°$:

$$\Delta G°_r = \Delta G°_B + \Delta G°_A + \Delta G°_{AB} = (-140.31) + (-18.58) - (-160.2) = 1.31$$

$$\log K = -1.31/1.364 = -0.960$$

$$C_{Cd2+} = 10^6 MWt*[H^+][K]/[HCO3-] = 10^6*112.4*[10^{-7.24}][10^{-0.96}]/[10^{-2.32}] = 135 \text{ ug/L}$$

This theoretical dissolved concentration is well above the HRL of 4 ug/L. Field measured Cd concentrations are much less than the calculated theoretical value, indicating the availability of cadmium-bearing carbonates may be limiting the distribution of cadmium, assuming a system in equilibrium with cadmium carbonate. An aquifer in which cadmium solubility is controlled by carbonates is susceptible to contamination with cadmium.

Some simplifying assumptions are utilized in applying Equations [3] through [11]. These are discussed below.

- Activity coefficients are assumed to be equal to 1. This implies that ions in solution behave ideally and do not interact with each other or with the solvent, which is water. This assumption is reasonable for monovalent chemicals up to ionic strengths of about 0.03, for divalent chemicals up to ionic strengths of about 0.003, and trivalent chemicals up to ionic strengths of about 0.0003. The ionic strength of a solution is a measure of the electrostatic field caused by the ions. Consequently, the greater the ionic strength of a solution, the more ions interact with each and deviate from ideal behavior. The overall median ionic strength for the baseline data was about 0.01. At this ionic strength, activity coefficients for monovalent, divalent, and trivalent species will be about 0.90, 0.65, and 0.40, respectively. Although these values represent substantial corrections in solubility calculations, the effect of activity coefficient is relatively small compared to effects of differences in pH and solubility products utilized in the calculations. Nevertheless, theoretical equilibrium concentrations should be considered with these potential adjustments in mind. Additional discussion of activity and ionic strength can be found in standard geochemical texts.

- Overall median concentrations were used in the calculations. Ideally, calculations of potential equilibrium concentrations should be done for individual wells, considering concentrations of relevant ions, pH, and ionic strength for each well. An analysis of relative saturation can then be computed for each well in a particular aquifer, followed by an analysis for the entire aquifer. (Neve et al., 1996) completed this analysis for a small set of selected parameters for the data set through 1995. Such a procedure is somewhat time intensive and is not warranted for this broad overview. However, this analysis procedure is warranted for individual chemicals which may represent a potential health concern in an aquifer or aquifers. This analysis will be conducted and presented for these chemicals of concern in subsequent reports.
- Ammonia and carbonate were not measured and were considered to be negligible. All reported concentrations were assumed to represent dissolved concentrations, which is not true since the samples were not filtered. The effect of filtering will be most important for iron and manganese.
- Complexation was ignored. For chemicals which tend to be highly complexed in solution, the calculated theoretical concentrations will underestimate the true theoretical concentration.

Because the objective of this geochemical analysis is to generally categorize individual chemicals in terms of potential aquifer sensitivity, these assumptions have a minor effect on the overall evaluation for each chemical. However, the reader should be aware that chemicals do not always fit nicely into these aquifer sensitivity categories. Consequently, there is some discussion in Part III of the factors which may lead to increased sensitivity for individual chemicals.

2.3. Organics - Volatile Organic Compounds (VOCs)

Organic compounds sampled included Volatile Organic Compounds (VOCs), base-neutral pesticides, and total organic carbon. Pesticides were only sampled in wells considered to be hydrologically sensitive (e.g., outwash aquifers) and were detected in only two samples. Both detections were of atrazine and concentrations were well below the Health Risk Limit (HRL) of 20 ug/L. Total organic carbon is naturally-occurring organic material in ground water. It is discussed with the inorganic chemical parameters, which are also naturally-occurring. The discussion of organics is therefore restricted to VOCs.

VOCs are carbon-containing compounds that readily evaporate at normal air temperature and pressure (USGS, 1996). Statistical analysis of VOCs is confounded by several factors. First, frequency of VOC detection is typically very small for a randomly selected population of wells (less than 15 percent of sampled wells). Second, presence of VOCs is usually the result of human activity, but in domestic wells the source of the VOC(s) is difficult to identify. Third, there are several classes of VOCs. Seven classes of VOCs were established for this report based on chemical and physical properties. These are summarized in Table 2. Additional classes of VOCs not detected in any sample and not included in Table 2 include alcohols, nonhalogenated aliphatics, amides, amines, carboxylic acids, phthalates, and heterocyclic compounds.

Table 2: Classes of VOCs used in analysis of VOC data.

VOC Class	Typical Properties	Common Sources	Compounds Detected
Class 1. Nonhalogenated aromatics	Lighter than water, degraded in presence of oxygen, high HRLs (except benzene), mobile in ground water	Gasoline and fuel oils, paints, solvents, detergents	Benzene, toluene, ethylbenzene, styrene, xylene, trimethylbenzenes, isopropyl, propyl, and butyl benzenes, isopropyltoluene
Class 2. Halogenated aliphatics (not THMs or CFCs)	Denser than water, persistent except in strongly reducing environments, low HRLs, mobile in ground water	Solvents, degreasers, dry cleaners, paints, varnishes, paint stripping, organic synthesis	Di-, tri, and tetrachloroethenes and ethanes, 1,2-dichloropropane, methylene chloride
Class 3. Ketones and aldehydes	Lighter than water, not persistent, high HRLs, extremely mobile in ground water	Dyestuffs, solvents, paints, paint removers, adhesives, lacquers	Methyl ethyl ketone (2-butanone), acetone
Class 4. Trihalomethanes (THMs)	Heavier than water, persistent, low HRLs, mobile in ground water	Well disinfection, solvents, refrigerants	Chloroform, chlorodibromomethane, dichlorobromomethane
Class 5. Chloro-fluorocarbons (CFCs)	Heavier than water, moderate persistence, high HRLs, mobile in ground water	Solvents, refrigerant, dry-cleaning, fire extinguishers	Trichlorofluoromethane, dichlorofluoromethane, dichlorodifluoromethane
Class 6. Ethers (including furans)	Lighter than water, persistent if ringed structure, low to moderate HRLs, very mobile in ground water	Solvents, fuel oils and gasoline, glues, chemical manufacturing	Tetrahydrofuran, ethyl ether
Class 7. Polynuclear aromatic hydrocarbons	Variable density, persistence increases and mobility decreases with increasing molecular weight	Gasoline, lubricants, solvents, coal and combustion by-products	Naphthalene

The following generalizations should be considered in reviewing Table 2.

- Chemical persistence is strongly influenced by geochemical conditions in an aquifer.
- Chemical density is relatively unimportant in domestic wells since concentrations never approached the solubility product for any chemical. However, presence of a VOC in a well at low concentration does not preclude existence of a dense non-aqueous phase liquid (DNAPL) or light non-aqueous phase liquid (LNAPL) source upgradient of the well.
- The list of common sources for these chemicals is not all encompassing.
- Nonhalogenated aliphatics, amines and amides, and many alcohols are not included in the Minnesota Department of Health Method 465 analysis.
- Many degradation products, particularly for the halogenated compounds, are not included in Table 2 because they were not detected during this study. These compounds are generally more volatile and often more toxic and persistent than the parent material.

2.3.1. Descriptive Summaries

Most VOCs are not natural constituents of ground water. Their background concentration is therefore assumed to be zero. However, a sample below the reporting limit may not contain VOCs, or VOCs may be present at a concentration below the reporting limit. Since it is impossible to know which condition applies to a sample, analysis of distribution of VOCs in ground water is limited to reporting the number of samples and detections above the reporting limit, overall, by aquifer, aquifer group, and chemical class.

2.3.2. Factor Analysis

Distribution of VOCs may be viewed as a binomial population distributed among non-detections and detections. Non-detections are thus treated as zeroes. This approach emphasizes environmental conditions which are related to increased likelihood of VOCs being present in a well. This approach will underestimate the number of wells impacted with VOCs, since a chemical may be present below the reporting limit but counted as a zero, or a chemical may be present which is not included in the analytical method. It is assumed that the database is of sufficient size to allow identification of those factors correlated with increased incidence of a VOC detection in ground water.

Treating the population of VOCs as a binomial population allows for relatively easy analysis. Hypothesis tests (Mann-Whitney test) were conducted to determine if the concentration of any sampled chemical or chemical parameter, well depth, static water elevation, UTM coordinate, or sampling time was equal in wells containing a detected VOC compared to wells with no detection. The null hypothesis was that there were no differences between the two groups. A significance level of 0.05 was used to identify differences.

Comparison of chemical concentrations for all sampled wells was discussed in Section 2.2.2. An additional analysis was to determine, by chemical class, if chemical concentrations or other factors (e.g., well depth, sampling location) differed in wells with a VOC detection compared to wells with no VOC detection.

2.3.3. Health and Risk

The discussion of exceedances and hazard indices presented in Section 2.2.3. applies to VOCs. Each VOC has one or more target endpoints. Calculations of hazard indices include contributions of VOCs, but the contribution of individual VOCs to overall hazard indices are not discussed because they are minor relative to the contribution from inorganic chemicals.

2.3.4. Geochemical Interpretations for Individual Parameters

The quantity of VOC present in a ground water sample is a function of inputs and attenuation processes. If there is no continuous source for the VOC(s) detected in a ground water sample, the following assumptions can be made to evaluate fate of VOCs in an aquifer.

- Adsorption of VOCs is negligible. This assumption may fail for highly chlorinated VOCs (tetra-chlorinated species) and in aquifers which have high concentrations of organic carbon.
- The primary mechanism for attenuation is biological degradation. Chemical degradation is unlikely within the ranges of pH and oxidation-reduction potential observed in sampled wells.
- Transient effects are negligible. Most sampled wells are sufficiently deep to not be highly responsive to surface processes, such as recharge.

Considering these assumptions, degradation pathways and mechanisms can be hypothesized for each VOC class.

Nonhalogenated aromatics are degraded in the presence of oxygen. Adjacent hydrogens on the ring are replaced with hydroxyl groups. Cleavage of the ring then occurs between the two hydroxyl groups, resulting in formation of a bicarboxylic acid. Some nonhalogenated aromatics may also be degraded under anaerobic conditions. Anaerobic degradation involves saturation of the benzene ring to a cyclohexane, which is then oxidized to a ketone, and finally cleaved to form a carboxylic acid. Anaerobic degradation proceeds more slowly than aerobic degradation (Fetter, 1993).

Chlorinated aliphatic compounds are relatively recalcitrant in ground water, being degraded only under reducing conditions. The primary mechanism of degradation is through co-metabolism, typically at oxidation-reduction potentials which occur within methanogenic environments. Degradation proceeds through a series of dechlorination reactions, eventually leading to formation of vinyl chloride. Vinyl chloride is then degraded under oxidizing conditions. Chemical classes 2 (halogenated aliphatics), 4 (THMs), and 5 (CFCs) would be degraded by this mechanism (Fetter, 1993).

Ethers and furans (Class 6), despite having oxygen present in their molecular structure, are relatively resistant to degradation. They may be slowly oxidized to form peroxides, which are then quickly degraded (Fetter, 1993).

Ketones and aldehydes are relatively oxidized organic compounds and will degrade rapidly within reducing environments. Even under oxidizing conditions they are not likely to persist for long. Their presence in ground water may reflect recent contamination or be the result of degradation of nonhalogenated aromatic compounds.

Results

Part III: Results

The objective of this part of the report is to provide a cursory analysis of the baseline data. In addition to compilation of summary statistics, factors affecting ground water chemistry are identified. Some of these factors will be analyzed and discussed in greater detail in subsequent reports.

3.1. Quality Assurance Analysis

A charge balance was calculated on each sample. Results are presented in Table D.1 in Appendix D. The percent of samples exceeding a ten percent balance was 23.8. The absolute value of the overall charge balance was 6.9 percent. Field alkalinity was used to estimate bicarbonate concentration in the calculations. Five samples were not included in the charge balance due to a missing value for field alkalinity. Iron was not included in the calculation because samples were not filtered.

Samples from Cretaceous (KRET), undifferentiated surficial Quaternary (QUUU), and Sioux Quartzite (PMSX) aquifers showed the greatest discrepancies in charge balance. This accounts for the greater values for charge balance in 1993, when most of these wells were sampled. Overall, there was a strong positive correlation ($p = 1.3X10^{-207}$; $R^2 = 0.62$) between values for charge balance and meq of cations. The reason for this relationship cannot be explained with existing data. Potential contributing factors include:

- presence of organic acids which were not analyzed;
- overestimates of cation concentration due to acidification of unfiltered samples, which results in metal associated with colloidal material being analyzed as free metal; and
- underestimates of anion concentration due to gaseous loss of bicarbonate as carbon dioxide prior to field titration.

The ratio of total dissolved solids to specific conductance for all samples was 0.68, which is within the acceptable range of 0.55 to 0.76 (Hounslow, 1995). Results are presented in Table D.1. There were 290 individual sample ratios outside the acceptable range. The accuracy of field measurements of specific conductance may be limited by the precision of the field instrument. The ratio of specific conductance to meq of cations was 86.4 overall. This ratio should be close to 100, but values between 50 and 150 were considered acceptable. Sixty-seven samples were outside of this range and were considered to have erroneous values for specific conductance. The overall difference between lab-measured total dissolved solids and calculated total dissolved solids (sum of ions and silica) was 2.3 percent.

Various ratios of major ions are illustrated in Table D.2. A high percentage of wells showed large magnesium to calcium ratios for the Platteville (OPVL), Precambrian crystalline (PCCR), and Precambrian North Shore Volcanics (PMNS) aquifers. The Platteville aquifer consists largely of dolomite, while the high magnesium signatures in the Precambrian aquifers may reflect mafic silicate weathering. There were many aquifers with high proportions of chloride relative to sodium. Many of these are surficial aquifers [Quaternary water table aquifers (QWTA) and Quaternary undifferentiated aquifers (QUUU)] or may locally represent an unconfined bedrock aquifer [Prairie du Chien (OPDC) and Platteville (OPVL) aquifers]. These aquifers may be impacted by road salts. There were few aquifers with low ratios of calcium to sulfate. The PMSX and KRET aquifers had relatively low ratios of calcium to sulfate. Within these aquifers, calcium may be involved in ion exchange reactions because concentrations of sodium are relatively high. Many aquifers showed ratios of potassium to (potassium+sodium) exceeding the target values of 0.20. However, the median ratios are generally between 0.20 and 0.30, which does not reflect a significant deviation from the target value.

Field primary and duplicate samples were compared for each parameter. For samples with detectable concentrations of a chemical, means, medians, and standard deviations were calculated. Results are illustrated in Table D.3. Differences between primary samples and field duplicates were within acceptable ranges (ten percent) for all parameters.

Field samples and laboratory duplicates were compared for each parameter. The overall field duplicate rate was 8.6 percent. For samples with detectable concentrations of a chemical, means, medians, and standard deviations were calculated. Results are illustrated in Table D.4. Differences between samples and lab duplicates were within acceptable ranges for all parameters except for chromium (10.2 percent).

VOCs were detected in 109 wells, nine (8.3 percent) of which had a field duplicate sample collected. Twelve VOC detections occurred in these nine wells. Primary samples had an overall VOC concentration which was 27.9 percent lower than the duplicate sample. Three primary samples had non-detectable VOC concentrations when the duplicate had a detectable concentration.

The MPCA Ground Water and Solid Waste Division (GWSWD) Laboratory Quality Assurance/Quality Control Coordinator collects routine information for spike recoveries for VOC analysis from the Minnesota Depart of Health (MDH) Laboratory. Spike recoveries have routinely been within acceptable limits (QA/QC Coordinator, personal communication). Additional information related to calibration results for laboratories utilized by GWMAP during the baseline assessment is also kept on file within the GWSWD.

One set of trip blanks was transported with each set of VOCs collected in the field. Consequently, a single set of trip blanks frequently was used for multiple sampling events conducted over successive days. Trip blanks were not collected for two sample events in 1993. VOCs were detected in trip blanks for two events in 1996. These included a detection of 100 ug/L of acetone and 0.6 ug/L of toluene. These compounds were not detected in any sample for these two events and both detections are suspected of being caused by laboratory contamination.

3.2. Inorganics

Inorganic chemicals and chemical parameters were treated as continuous populations which followed some sort of distribution within an aquifer. Non-detections were consequently treated as either missing data (in descriptive statistical analysis) or equal values (in hypothesis and correlation tests) in the statistical analyses.

3.2.1. Descriptive Summaries

Summary statistics provide information to ground water managers and planners about the distribution of chemicals in Minnesota's principal aquifers. This includes central tendencies and variability in concentrations. Summary statistics for all data combined are shown in Table D.5. Summary statistics for each chemical and sample parameter are illustrated by aquifer and aquifer group in Tables D.6 through D.44.

Distributions of a chemical in an aquifer or aquifer group can be established for any chemical for which there was a sufficient sample size. These distributions include percentiles, which are based on the distribution of data collected during the baseline assessment, and probabilities, which are based on the variability in the data collected. Probabilities can only be developed for chemicals which had normal, log-normal, or log-censored distributions. For normal and log-normal distributions, a distribution can be established knowing the standard deviation (σ) and the sample size (n) and assuming a t-distribution:

$$C = \mu \pm t_{\alpha}\sigma/\sqrt{n} \qquad [12]$$

where C is the concentration (ug/L) at some value of t at a probability α and μ is the mean concentration (ug/L). Standard deviations and sample sizes calculated from the baseline data are illustrated in Table D.45, with the values for standard deviation being log-transformed for log-distributed parameters. Values for t vary with sample size. Complete tables for the distribution of t over a range of sample sizes can be found in standard statistics texts. Values of t are summarized in Table 3 for three sample sizes.

The value of t decreases slowly as sample size increases beyond 60. The values shown in Table 3 are two-tailed. This means the probabilities consider both low and high values. If just an upper tail is desired, then the appropriate t value corresponds with $\alpha/2$. **For log-transformed data, concentrations must be log-transformed prior to calculations.**

Table 3: Values of *t* for a range of sample sizes and probabilities.

α	t for n=10	t for n=25	t for n = 60
0.40	0.260	0.256	0.254
0.25	0.700	0.684	0.679
0.10	1.372	1.316	1.296
0.05	1.812	1.708	1.671
0.025	2.228	2.060	2.000
0.01	2.764	2.485	2.390
0.005	3.169	2.787	2.660
0.0025	3.581	3.078	2.915
0.001	4.144	3.450	3.232
0.0005	4.587	3.725	3.460

As an example, suppose we want to establish a distribution of chloride and calcium in the Jordan aquifer. Using Tables D.9 and D.45, calcium has a normal distribution, a mean concentration of 67964 ug/L, a standard deviation of 25020, and a sample size of 31. Chloride has a log distribution, a log-transformed mean concentration of 3.06 ug/L, a standard deviation of 0.39, and a sample size of 39. Using these values, Eq. [12], and t-values from Table 3 for a sample size of 25, distributions of calcium and chloride can be generated. These are shown in Table 4. The table allows a user to determine the likelihood of a concentration being equal to the overall mean concentration. For example, the probability of exceeding chloride concentrations of 1000 and 2000 ug/L is approximately 0.80 and 0.001, respectively.

Table 4: Calculated distributions of calcium and chloride in the Jordan aquifer. Concentrations are in ug/L.

α	Calcium	Chloride
0.9995	51225	630
0.9900	52461	658
0.9975	54132	699
0.9950	55440	732
0.9900	56797	769
0.9750	58707	824
0.9500	60289	872
0.9000	62050	929
0.7500	64890	1028
0.6000	66814	1102
0.5000	67964	1148
0.4000	69114	1197
0.2500	71038	1282
0.1000	73878	1420
0.0500	75639	1512
0.0250	77221	1601
0.0100	79131	1714
0.0050	80488	1800
0.0025	81796	1886
0.0010	83467	2003
0.0005	84703	2094

Percentiles and confidence limits for uncensored data can also be calculated directly in a statistical software package. For example, assume a user wants to know the concentration of bicarbonate (alkalinity) in Quaternary water-table aquifers (QWTA) aquifers at the 90th and 99th percentiles and at a confidence limit of 90 and 99 percent. Using the baseline data for the QWTA aquifer within a statistical software package, the user can specify the 90th and 99th percentile and confidence limits. The resulting values are 371900 and 521920 ug/L for the 90 and 99 percentiles and 261674 and 270405 ug/L for the 90 and 99 percent confidence limits. Generally, it is best to use a software package in these calculations because additional assumptions about normality and outliers can be addressed quickly and accurately.

For log-censored data, confidence limits must be calculated indirectly. A log-censored population is one in which the data are assumed to follow a log distribution, but for which there were values below the reporting limit. The Helsel method which was used to calculate means assumes the concentrations follow a log distribution which can be described by the *z* distribution (Newmann et al., 1995). This method fits a regression line to the log transformed values above the reporting limit. The regression is then used to "fill in" the values for the non-detections. Output from this method includes the slope (*b*) and intercept (*a*) of the regression line:

$$C = \exp(a + bz) \qquad [13]$$

where *C* is the concentration in ground water (ug/L) and *z* is the *z* score. All correlation coefficients from regression analysis were greater than 0.800. With *a* and *b* known, the user can either determine the concentration at a particular value of *z* or determine the value of *z* at a particular concentration. Values of *z* correspond with a probability value, such as the percentile or confidence limit. Values for *z* are illustrated in Table 5. Intercepts and slopes from the analysis using Helsel's method are shown in Table D.46. As an example, consider lead in QWTA aquifers. Table D.35 indicates the distribution of lead was log-censored, with ten of 117 samples being below the maximum reporting limit. Table D.46 indicates the intercept and slope for Helsel's method were -1.638 and 1.583, respectively. Assume we want to know the concentrations at the 99 percent confidence limit. The *z* score from Table 5 is about 2.33 at this probability level. Inserting these values into Eq. [13] gives a concentration of 7.77 ug/L. Conversely, assume we had a concentration of 1.0 ug/L and wanted to know the probability of having this concentration in a QWTA aquifer. Inserting values for *a*, *b*, and *C* into Eq. [13] gives a value of 1.04 for z, which from Table 5 corresponds to a probability of about 0.85. This means we could expect the concentration of 1.0 ug/L to exceed about 85 percent of the observed concentrations in samples collected from this aquifer. These procedures can be used to calculate a concentration distribution across a range of probabilities, such as was done in Table 4. Additional examples are provided in Part 4.

Use of descriptive statistics and corresponding analysis models should be used as a tool in supporting decisions, not as the basis for a decision. Users must have a thorough understanding of the physical system they are evaluating to determine how representative the data they have collected is for the system they are considering. When used properly, analysis of the distribution of a chemical can provide powerful information to aid in the understanding of a hydrologic system.

Table 5: Values of *z* for a range of probabilities.

z	probability
0.0	0.50000
0.1	0.53983
0.2	0.57926
0.3	0.61791
0.4	0.65542
0.5	0.69146
0.6	0.72575
0.7	0.75803
0.8	0.78814
0.9	0.81594
1.0	0.74134
1.1	0.76433
1.2	0.88493
1.3	0.90320
1.4	0.91924
1.5	0.93319
1.6	0.94520
1.7	0.95543
1.8	0.96407
1.9	0.97128
2.0	0.97725
2.1	0.98214
2.2	0.98610
2.3	0.98928
2.4	0.99180
2.5	0.99379
2.6	0.99534
2.7	0.99653
2.8	0.99744
2.9	0.99813
3.0	0.99865
3.1	0.99903
3.2	0.99931
3.3	0.99952
3.4	0.99966
3.5	0.99977
3.6	0.99984
3.7	0.99989
3.8	0.99993
3.9	0.99995

3.2.2. Factor Analysis

Factor analysis tests the relationships between chemical concentration and hydrologic, physical, geologic, or other variables. The purpose of factor analysis is to identify factors which affect the concentration or distribution of a chemical. Two categories of factor analysis were conducted for the baseline assessment. Hypothesis or group tests are used to compare concentrations of a chemical between two or more independent treatments (i.e., groups). An example is a comparison of nitrate concentrations between the St. Peter, Prairie du Chien, and Jordan aquifers. The factor in this example is aquifer and the three treatments or groups are the three aquifers. A second category of factor analysis is correlation testing, which involves determining the relationship between an independent and dependent variable. For example, if nitrate concentrations vary with well depth, nitrate is the dependent variable and well depth is the independent variable.

Results of hypothesis tests are presented in Tables D.47 through D.87. Nonparametric methods were employed for all factor analyses. This means the relative ranks of chemical concentrations were used for comparisons rather than the actual concentrations. Mean ranks are therefore indicated in all tables. An example of a nonparametric analysis is illustrated in Table 6. Concentrations are provided for two aquifers, A and B. The concentrations are then ranked from low to high. In the cases of ties, each tied well is assigned the same rank. The results in Table 6 show that the mean concentration in aquifer A is equal to the concentration in aquifer B, but that concentrations are generally greater in individual wells in aquifer B. In this nonparametric procedure, well six in aquifer A has a small impact on the overall comparison of ranks, whereas it has a large effect when comparing average concentrations. Statistical analysis of this data is done by comparing ranks. In the final reporting of this data, medians are displayed as summary information and the comparison of ranks is used as the basis for comparing concentrations in individual wells from the two aquifers. The results are significant ($p = 0.03$), with concentrations being assumed to be greater in aquifer B.

Tables D.47 through D.87 include p-values and the Least Significant Difference (LSD). The p-value estimates the probability that the null hypothesis was true. In each case, the null hypothesis was that chemical concentrations were equal in the different groups being compared. A low p-value therefore indicates that it is likely the null hypothesis is not true and that concentrations do differ between the factor groups. In the example in Table 6, the null hypothesis was that concentrations in aquifers A and B were equal. Using nonparametric methods comparing ranks, the p-value was 0.03, which indicates there is a 0.03 or three percent chance the null hypothesis is true. Typically, a p-value of 0.05 or less is used to reject the null hypothesis. In the case of Table 6, concentrations in aquifers A and B are not equal because p is less than 0.05.

Table 6: Example of nonparametric procedure for comparing concentrations in wells from two hypothetical aquifers.

Well	Concentrations		Ranks	
	Aquifer A	Aquifer B	Aquifer A	Aquifer B
1	100	100	2	2
2	121	351	4	15
3	129	249	5	11
4	135	267	6	12
5	100	198	2	10
6	991	167	16	8
7	188	270	9	13
8	149	311	7	14
Mean	239	239	6.9	10.1
Median	132	258	5.5	11.5

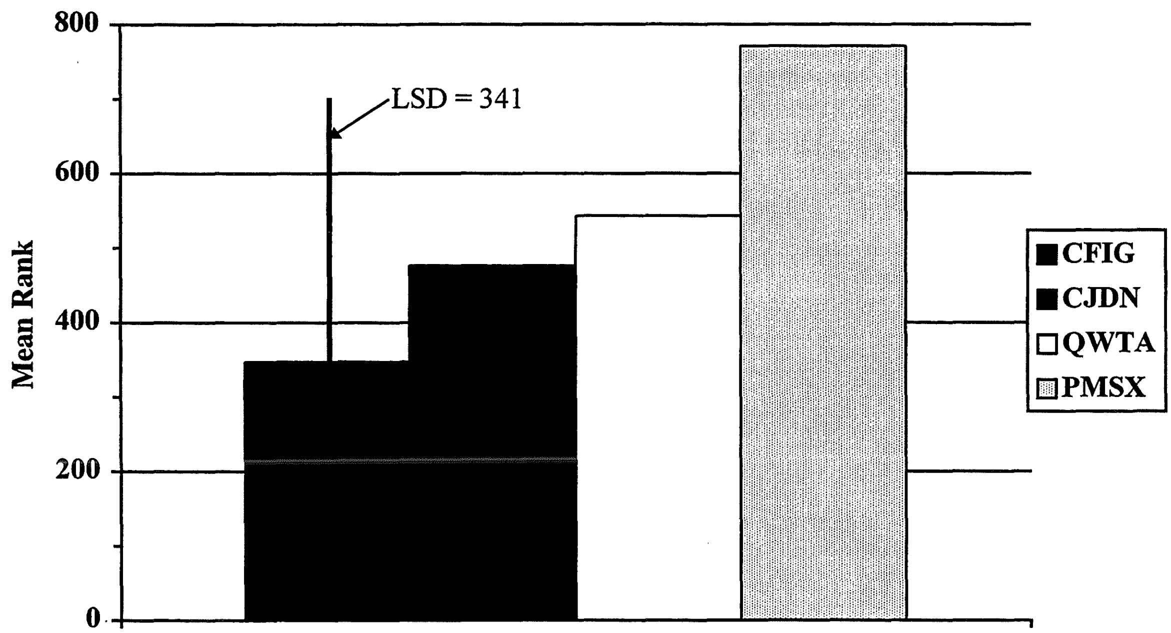
The LSD is the amount by which two populations would be expected to differ if the population means were truly different. The formula for computing the LSD is:

$$\mathrm{LSD} = t_{\alpha/2,N\text{-}y}\sqrt{MS_E}(1/n_i + 1/_{nj} + \ldots + 1/n_z) \qquad [14]$$

where MS_E is the expected mean square for error, N is the total number of samples, y is the number of treatments (i.e., aquifers in the example of Table 6), n is the number of samples in treatments i through z, and α is the probability. In the example of Table 6, n is equal to 8 for both aquifers A and B, y is equal to two (two aquifers are being compared), and N is equal to 16 (the total number of wells). By choosing α, the corresponding value of t can be determined from Table 3. The MS_E represents a measure of the variability in the data. It is produced as standard output generated during the statistical analysis comparing different treatments. LSDs were computed for all aquifer-aquifer comparisons at an α value of 0.05. These are illustrated in Tables D.47 through D.87.

As an example, consider nickel concentrations in different aquifers. Using Table D.47, the probability that nickel concentrations in all 30 aquifers are equal is 0.001. We conclude that nickel concentrations do differ between some aquifers, but which ones? Let us compare nickel concentrations in the Franconia-Ironton-Galesville (CFIG) aquifer with those in the Jordan (CJDN), Sioux Quartzite (PMSX), and Quaternary water-table (QWTA) aquifers. Mean ranks were 347, 476, 771, and 543, respectively, for the CFIG, CJDN, PMSX, and QWTA aquifers. The LSD was 341. The difference in ranks between the CFIG aquifer and any of the other aquifers is given by the absolute value of {Mean $\text{rank}_{\text{CFIG}}$ - Mean $\text{rank}_{\text{CJDN, PMSX, or QWTA}}$}. This value is then compared to the LSD. The differences between the CFIG and CJDN, PMSX, and QWTA aquifers were 129, 424, and 196, respectively. The difference is less than the LSD for the CJDN and QWTA aquifers and greater for the PMSX aquifer. We conclude, therefore, with a confidence of 95 percent, that nickel concentrations in the PMSX aquifer are greater than in the CFIG aquifer, while nickel concentrations in the CJDN and QWTA aquifers are not. This example is illustrated in Figure 1. Mean ranks are shown as bars and the LSD is shown as a vertical line. In Figure 1, the top of the LSD line is below the top of the bar for the PMSX aquifer, reflecting the difference in nickel concentrations between the CFIG and PMSX aquifers.

Figure 1: Illustration of aquifer comparisons using the Least Significant Differences.



We could also use established values for LSD to calculate a probability that concentrations are equal. For example, we concluded that concentrations of nickel differed between the PMSX and CFIG at the 0.05 level. What is the exact probability that the concentrations of nickel in these two aquifers are equal? First, we would have to determine the MS_E, use the observed difference between the two aquifers (424) as the LSD, and then compute t. We would then look up this value of t in a statistics text to find the corresponding α value. For this example, we rearrange Equation [14] to solve for MS_E:

$$MSE = 1/(1/n_i + 1/_{nj} + \ldots + 1/n_z)(\mathrm{LSD}/t)^2 \qquad [15].$$

LSD is equal to 341, a value of two was used for t, and values for 1/n can be determined from Tables D.6 through D.35. The value for 1/n was computed as 5.97. The resulting MSE was calculated as 4869. Now substituting the observed difference of 424 for the LSD and rearranging to solve for t gives:

$$t = \mathrm{LSD}/\sqrt{MS_E}(1/n_i + 1/_{nj} + \ldots + 1/n_z) \qquad [16].$$

The resulting t value is 2.48. The corresponding probability, using Table 3, is between 0.005 and 0.01. Running through the same procedure for the QWTA aquifer, where the observed difference in nickel concentrations was 196, gives a t value of 1.15, which corresponds to a probability of about 0.15.

Aquifer Effects

Results of hypothesis tests for aquifers are illustrated in Table D.47. There were significant differences between aquifers for all chemicals and sampled parameters except tin. The number of potential comparisons for each chemical is very large and only the following general conclusions are offered. More detailed analysis will follow in subsequent reports.

- Cambrian aquifers generally had low to moderate concentrations of most chemicals compared to other aquifers. Temperature, zinc, and cobalt appeared to be elevated in some Cambrian aquifers compared to other aquifers. Other instances of elevated concentrations included thallium and manganese in the St. Lawrence-Franconia (CSLF) aquifer and alkalinity and lead in the St. Lawrence (CSTL) aquifer.
- The Devonian (DCVA) aquifer had elevated concentrations of barium, cadmium, phosphorus, and total organic carbon compared to other aquifers.
- The Cretaceous (KRET) aquifer had elevated concentrations of many parameters, including alkalinity, bromide, fluoride, orthophosphate, potassium, sodium, specific conductivity, strontium, sulfate, temperature, and total dissolved solids.
- Within the Ordovician aquifers, two distinct groupings were evident. The first consisted of those aquifers which were included in the Upper Carbonate aquifer group. These were the Galena (OGAL), Maquoketa (OMAQ), and Platteville (OPVL) aquifers. These aquifers showed elevated concentrations for many chemicals compared to other aquifers, including arsenic, barium, cadmium, copper, dissolved oxygen, magnesium, nickel, nitrate, oxidation-reduction potential, selenium, silica, temperature, thallium, titanium, total organic carbon, and zinc. The second grouping included the Prairie du Chien (OPDC), St. Peter-Prairie du

Chien (OSPC), and St. Peter (OSTP) aquifers. These aquifers generally had low to moderate concentrations of most chemicals compared to other aquifers.

- The Precambrian aquifers showed a diverse range of concentrations compared to other aquifers. This is not surprising, considering the wide range of geologic formations and geographic distribution which comprise this aquifer group. The Sioux Quartzite (PMSX) and Duluth Complex (PMDC) aquifers had elevated concentrations of many parameters. For the PMDC aquifer, most of these appeared to be related to geology (through dissolution of parent rock). Aluminum, antimony, beryllium, chromium, copper, lead, molybdenum, selenium, silver, titanium, and zinc were among the chemicals with elevated concentrations in this aquifer compared to other aquifers. The PMSX aquifer also had elevated concentrations of many chemicals which appear to be related to geology, including antimony, copper, lead, lithium, molybdenum, nickel, rubidium, strontium, titanium, and vanadium. However, nitrate, sulfur, sulfate, and sodium were also greater in this aquifer compared to other aquifers, and this may be due to human influences on the aquifer. The PMSX aquifer is generally used only when it is located near the land surface and therefore comprises a sole-source aquifer. Concentrations of most chemicals were low to moderate in the Precambrian crystalline (PCCR), Precambrian undifferentiated (PCUU), and Hinckley (PMHN) aquifers. The Biwabik (PEBI), Fond du Lac (PMFL), and North Shore Volcanics (PMNS) aquifers have elevated concentrations for many parameters, including antimony, arsenic, beryllium, manganese, selenium, zinc, and sulfate in the PEBI aquifer, aluminum, chromium, lead, and silver in the PMFL aquifer, and aluminum, beryllium, boron, and titanium in the PMNS aquifer. There were very small sample sizes for many of the Precambrian aquifers.
- Among the Quaternary aquifers, the buried artesian (QBAA), buried unconfined (QBUA), and water table (QWTA) aquifers had low to moderate concentrations for most chemicals. This is opposite of the undifferentiated aquifers (QBUU and QUUU), which had elevated concentrations of many parameters, including alkalinity, antimony, boron, calcium, cobalt, copper, dissolved oxygen, lithium, magnesium, molybdenum, nickel, nitrate, potassium, oxidation-reduction potential, silica, sodium, strontium, sulfur, sulfate, titanium, vanadium, and zinc. These aquifers had a relatively high percentage of large-diameter wells. The effect of well diameter is discussed below.

Aquifer Group Effects

Results of hypothesis tests for age-based aquifer groups are illustrated in Table D.48. There were significant differences in ranked concentrations for most chemicals. The Cretaceous aquifer group showed greater concentrations of alkalinity, boron, calcium, chloride, copper, lithium, magnesium, phosphorus, potassium, sodium, specific conductivity, strontium, sulfur, sulfate, temperature, total dissolved solids, and vanadium compared to other groups. These results generally reflect the deposition history of Cretaceous deposits, which were laid down in a marine environment, and the greater residence times within Cretaceous aquifers compared to other aquifers, which leads to greater dissolution and increased concentrations of dissolved solids. For the Devonian group, elevated concentrations were observed for barium, beryllium, cadmium, copper, iron, phosphorus, and total organic carbon. Cambrian aquifers ranked low to moderate for most chemicals except for temperature and zinc, while cadmium, thallium, and zinc were elevated in Ordovician aquifers. The Precambrian group ranked high for aluminum, beryllium, lead, and pH. Quaternary aquifers ranked intermediate for most chemicals, although nitrate and chloride were elevated in surficial Quaternary aquifers. Elevated nitrate and chloride concentrations may reflect human influences, since the QWTA aquifers are considered to be relatively responsive to land use.

There were fewer significant differences between hydrology-based aquifer groups (Table D.49). Each of these aquifer groups consists of sedimentary deposits which were laid down sequentially over several million years. It makes some sense, therefore, that differences between these groups will be more related to hydrologic processes, such as changes in oxidation-reduction potential and recharge, than to geologic factors. Consequently, the Upper Carbonate group, which is the uppermost of these hydrologic groups, showed elevated concentrations of chemicals which may reflect recent recharge, including alkalinity, phosphorus, boron, sodium, and total organic carbon, while the deeper aquifers have greater concentrations of chemicals reflecting the geochemical environment within those aquifers, including chromium, iron, and manganese. Additional analysis and interpretations will be provided for these aquifers in a subsequent report.

Well Diameter Effects

Results of hypothesis tests for well diameter classes are illustrated in Table D.50 for all data, in Tables D.51 through D.57 for age-based groups, and D.58 through D.61 for hydrology-based groups. Overall, there were significant differences in ranked concentrations for most chemicals. Most chemicals for which there were significant differences between diameter classes showed greater concentrations in the larger diameter classes, particularly the 24, 30, and 36 inch wells. Large diameter wells are often dug wells and are subject to infiltration of water along the joints in the casing. Consequently, they may be impacted by processes occurring at the land surface or in the upper portions of an aquifer. These wells also tend to be shallower than drilled wells. Concentrations of nitrate, chloride, phosphorus, dissolved oxygen, sulfate, and oxidation-reduction potential were greater in the larger diameter wells.

In general, diameter class was not an important factor affecting chemical concentration among the hydrology-based aquifer groups. Within the age-based aquifer groups, there were some interesting results attributable to well diameter. There were few significant differences between diameter classes within the Cretaceous group. This is largely due to the high concentrations of dissolved solids within this aquifer, regardless of well diameter or other well or geographic factors. These high natural concentrations mask the effect of well diameter. Close examination of the data reveals that trends within the Cretaceous group are similar to overall trends, with a tendency for greater concentrations of nitrate and lower concentrations of iron, phosphorus, silver, and chromium in larger diameter wells. For aquifer groups where there were no large diameter wells (Precambrian and Devonian groups), there were few significant differences for any chemical parameter between the smaller diameter classes. There were a large number of significant differences among the Cambrian and Ordovician groups. However, the results are inconsistent in many cases with the overall trends associated with well diameter. Approximately half of the large diameter wells (greater than six inches) in these two groups were used for irrigation, commercial, or public supply. Consequently, they probably have a large screened or open hole interval and withdraw large quantities of water.

Chemicals such as nitrate, chloride, and dissolved oxygen and oxidation-reduction potential showed little effect of well diameter, while many major cations and anions (sodium, calcium, alkalinity, and potassium) show mixed results between different well diameters. This contrasts sharply with the Quaternary wells. All but one large-diameter buried Quaternary well and all large-diameter surficial Quaternary wells were used for domestic supply. Nearly all chemical parameters differed among well diameter classes for these two aquifer groups. Nitrate was much greater in wells exceeding 16 inches in diameter, and dissolved oxygen, chloride, and oxidation-reduction potential were generally greater in these larger diameter wells. Results for other chemicals were mixed, but total dissolved solids were greater in the larger diameter wells. These wells, which are probably mostly dug wells, are susceptible to seepage of water into the well along casing joints. The relationships involving major cations and anions were most evident for the surficial Quaternary group. The results indicate that water quality is generally of poorer quality in larger diameter wells and that statistical analysis of data from these two aquifer groups should be separated based on well diameter. There were many fewer significant differences by diameter class for the hydrology-based aquifer groups. This is partly due to the lack of wells greater than 16 inches in diameter.

VOCs and Tritium as Indicators of Water Quality

Results of hypothesis tests for wells with and without a detected VOC are illustrated in Table D.62. Concentrations of aluminum, chloride, cesium, copper, dissolved oxygen, nitrate, and lead, and oxidation-reduction potential, were greater in wells containing a detectable VOC than in wells without a detectable VOC. The relationship between presence of a VOC and chloride, nitrate, dissolved oxygen, oxidation-reduction potential, and possibly cesium, may reflect an increased likelihood of detecting VOCs in shallow aquifers. This may also explain why there were lower concentrations of alkalinity and barium and lower values for specific conductivity in aquifers with a detectable VOC, since these parameters would be expected to increase in older waters containing greater concentrations of total dissolved solids. Nevertheless, the results are not clear cut, possibly for the following reasons:

- some VOCs, such as nonhalogenated aromatic compounds, are not persistent in oxygenated environments but may be persistent in deeper, anaerobic aquifers;
- most detections were near the reporting limit, suggesting there may be many wells which were sampled that had VOCs present below the reporting limit; and
- results for individual aquifers are masked by considering all data together.

Tests for individual aquifers were conducted to determine if there were some aquifer-specific patterns to VOC detections, but the number of detections was insufficient to complete a meaningful analysis. Significant results from hypothesis testing for aquifer groups are summarized qualitatively in Table D.63. The results are mixed, with redox-sensitive relationships being opposite in some aquifers. This may reflect the impact of different groups of VOC compounds which are sensitive to different redox conditions. These are discussed in greater detail in Section 3.3.

Results of hypothesis tests for wells with and without detectable tritium are illustrated in Table D.64. The presence of tritium reflects post-1953 water. Nitrate, chloride, and dissolved oxygen were greater in wells with detectable tritium, while iron, alkalinity, magnesium, manganese, potassium, and total dissolved solids were greater in wells without detectable tritium. These results were expected, since recent waters should show some effect of land use, while deeper wells show evidence of dissolution and ion exchange reactions and depletion of oxidized species (oxygen, nitrate). Significant results from hypothesis testing for aquifer groups are summarized qualitatively in Table D.65. The patterns for aquifer groups are similar to those for all data combined. Nitrate, chloride, sulfate, and dissolved oxygen are elevated in many aquifer groups where tritium was detected, compared to wells within the same group in which tritium was not detected. Conversely, potassium, manganese, alkalinity, magnesium, sodium, molybdenum, and iron are greater in wells with no detectable tritium. Aquifers which show a large range of hydrogeologic sensitivity showed the greatest response to the presence or absence of tritium. These include the Prairie du Chien (OPDC), Jordan (CJDN), St. Peter (OSTP), and buried Quaternary aquifers (QBAA, QBUA, QBUU). In these aquifers, there were several parameters which showed a response to the presence of tritium. This is in contrast to aquifers which are generally considered to be hydrogeologically sensitive (Upper Carbonate, Devonian, surficial Quaternary) or insensitive (Cretaceous, most Precambrian, Mount Simon-Hinckley). There were very few responses of chemical parameters to the presence of tritium in these aquifers. Tritium may have great utility in identifying sensitive portions of an aquifer, but may be less effective in defining the overall sensitivity of an aquifer. Additional analysis is warranted before these conclusions can be confirmed.

Effect of Sampling Year

Results of hypothesis tests, with year of sampling as the treatment, are illustrated in Tables D.66 through D.76. Differences in chemical concentrations between years are not desired because it may confound the analysis by masking true differences based on hydrology or geology. Differences in concentrations of a chemical between sampling years may be due to:

- climate;
- a large influence of certain aquifers constituting an aquifer group (for example, among the Cambrian group, sampling mostly Jordan wells one year and then Mt. Simon wells the next year);
- different times of sampling (for example, spring in one year and summer in another);
- systematic sampling error;
- differences due to geographical location; and
- true geologic or hydrologic differences between chemical concentrations.

Determining which of these factors accounted for yearly differences within an aquifer group is beyond the scope of this paper, but it is apparent from the results that there were many differences by year. The results are very complicated and no obvious patterns for indicator chemicals such as nitrate, dissolved oxygen, and chloride are apparent. The results indicate that additional data analysis in subsequent reports must include an assessment of the effect of sampling year. One additional analysis which is warranted is to determine if there was an effect of sampling year for individual aquifers, as opposed to the analysis for aquifer groups conducted here. This means, for example, aquifers in which sampling size was adequate to evaluate yearly differences should be tested independent of aquifer group. In terms of this dataset, this is an important consideration. For individual aquifers in which there were significant differences in water quality between sampling years, the differences may reflect a response of the aquifer to some physical factor such as precipitation or recharge.

Effect of Sampling Month

Similarly, month of sampling was considered as an independent factor. Results are illustrated in Tables D.77 through D.87. There were many differences by month, although fewer than with year of sampling. Again, the analysis is complicated and no clear pattern is evident. Additional analysis must consider month of sampling as a potential factor affecting chemical concentrations. As with sampling year, the effect of sampling month should be investigated for individual aquifers rather than aquifer groups.

Effects of Well Depth, Static Water Elevation, and UTM Coordinate

Correlation analysis between chemical parameters and well depth, static water level, UTM-east coordinate, and UTM-north coordinate are summarized by aquifer group in Tables D.88 through D.98. Correlations with well depth were not particularly strong or consistent across age-based aquifer groups. Increasing well depth may reflect increasing residence time in an aquifer. Major cations and anions increased with well depth, as would be expected with increasing residence time in ground water. Increased residence times results in greater dissolution and exchange. Among redox-sensitive parameters, iron, manganese, and sulfate increased with well depth, redox potential and nitrate decreased, and dissolved oxygen was unaffected. Other parameters which correlated positively with well depth in more than one aquifer group included phosphorus, zinc, cadmium, boron, fluoride, lithium, strontium, and vanadium. Tritium decreased in concentration with increasing well depth.

There were many fewer significant correlations for static water elevation. This makes physical sense since the static water elevation represents a potentiometric surface in a confined aquifer and has no relationship to where the sample is being collected within the aquifer. In unconfined aquifers, static water elevation would potentially be a very useful factor, but as discussed earlier, some wells designated as surficial Quaternary wells are in fact confined. In summary, static water elevation was not a useful indicator of water quality in the sampled aquifers.

UTM-east coordinate showed very strong correlations with chemical concentrations. Most chemicals showed a negative correlation, meaning concentrations increased from east to west. This observation is consistent with previous investigations of Minnesota's principal aquifers (Adolphson et al., 1981). The strongest correlations were noted for the major cations and anions (calcium, alkalinity or bicarbonate, potassium, magnesium, sodium, and sulfate), all of which increased from east to west in five or more of the aquifer groups. Arsenic, boron, lithium, phosphorus, silica, strontium, and molybdenum all increased from east to west in at least four aquifer groups. Oxidation-reduction potential, pH, and aluminum decreased from east to west in at least three aquifer groups. Aquifers generally become more protected by overlying clay-rich tills from east to west and recharge diminishes from east to west. Topography also tends to become flatter. Ground water flow path lengths and travel times, on average, increase from east to west, resulting in greater residence times. This increases the extent of dissolution and ion-exchange reactions. Two additional factors are likely to affect ground water chemistry from east to west. First, the impact of Cretaceous aquifers on water chemistry increases to the west. Cretaceous aquifers often have upward flow gradients and have a very strong chemical signature, as indicated in the analysis results. Buried Quaternary aquifers often show evidence of this signature in areas where they are underlain by Cretaceous aquifers (Trojan, 1998). Second, the chemistry of glacial deposits and soils changes from east to west as a result of different till types and different soils.

There were also many significant correlations for UTM-north coordinate. Most chemicals increased in concentration from north to south. The same factors related to UTM-east coordinate account for patterns with UTM-north coordinate. Consequently, the relationships nearly mirrored those for UTM-east, with major cations and anions and most trace inorganics increasing in concentration from north to south, while pH and aluminum decreased to the south. The number of significant correlations was less than for UTM-east coordinate, but for most major cations and anions there were at least three aquifer groups in which significant correlations were observed. The correlation coefficients were typically less than 0.500. The greatest correlation coefficients were for aquifer groups which were relatively homogenous, such as the Devonian, Cretaceous, and Cambrian groups. The lowest coefficients were observed for heterogeneous groups such as the Quaternary aquifers.

Within the hydrology-based aquifer groups, the results were somewhat different. For the CFIG-CFRN-CIGL (Franconia-Ironton-Galesville aquifer) group, there were few correlations between chemical concentration and either well depth or static water elevation. There were many significant correlations with UTM-east coordinate, most of which were negative, indicating increasing concentrations of chemicals from east to west. This follows the pattern for age-based groups and reflects increased aquifer protection, residence times, and lower recharge to the west. Exceptions were for nitrate, dissolved oxygen, lead, oxidation-reduction potential, and pH. Increasing nitrate concentration, more oxidizing conditions, and greater pH to the east are possibly related to increased recharge in the eastern portion of this aquifer group. The effect of UTM-north coordinate is much weaker than for east-west coordinate. For the OSTP-OPDC-CJDN group, most major cations and anions, including nitrate, decrease with well depth and static water elevation. This may indicate a strong relationship between the aquifer and processes occurring at the land surface. Nitrate, sodium, phosphorus, and chloride, in particular, provide evidence that portions of this aquifer in direct contact with vertical recharge from the vadose zone have a large effect on the distribution of chemicals. Additional evidence to support this is provided by the results for UTM-east coordinate. The redox-sensitive parameters follow a clear east-west pattern, with nitrate, dissolved oxygen, and oxidation-reduction potential increasing to the east and iron, manganese, and sulfate increasing to the west. The eastern portions of this aquifer are more likely to have little surficial cover and increased recharge than the western portions. More detailed analysis of these data are needed to determine the impact of confinement on water chemistry within this aquifer.

The CMSH-CMTS-PMHN aquifer, which is generally well protected, shows relationships more typical of vertical effects within an aquifer. Most chemicals which are significantly correlated with well depth or static water elevation increase in concentration with depth. This is what would be expected in an aquifer which is less sensitive to surficial processes such as recharge and land use and more sensitive to residence-related processes such as dissolution and ion exchange. Geographical effects are similar to other groups, with most chemical concentrations increasing to the west and south. Parameters which may indicate impacts from surficial processes, including nitrate, chloride, phosphorus, oxidation-reduction potential, and dissolved oxygen, are largely unaffected by geographic location.

The Upper Carbonate aquifer shows very few significant correlations with well depth, static water elevation, or UTM-north coordinate. This may be partly due to this aquifer system often occurring in karstic settings, which are highly dynamic and not well represented by one-time sampling. UTM-east coordinate again shows the greatest effect on chemical concentrations. The Upper Carbonate is more likely to be affected by surficial processes in the eastern portion of this aquifer. This is reflected by increased nitrate, dissolved oxygen, chloride, and phosphorus concentrations to the east.

Relationships With Oxidation-Reduction Parameters

Correlation analysis between chemical parameters and dissolved oxygen, total iron, total manganese, and oxidation-reduction potential are summarized by aquifer group in Tables D.99 through D.109. Ground water is assumed to originate as recharge at the surface of an aquifer. Recharge water is typically oxygenated. Ground water therefore goes through a series of reduction reactions. Electron acceptors, sequentially from greatest to lowest potential, are dissolved oxygen, nitrate, manganese (+4), iron (+3), sulfate, and carbon dioxide. Additional redox couples exist in ground water, such as the nitrate-ammonia couple, but these are not important in "typical" ground water. For example, the nitrate-ammonia couple will be important only in reduced environments with nitrate inputs or oxidized environments with ammonia inputs, such as might occur beneath a feedlot or septic drainfield. Nitrate was not considered in this analysis of redox parameters because concentrations in ground water are often the result of human activity, which confounds correlations with other chemical parameters. Sulfate was not considered because most redox values were greater than the value at which the sulfate-sulfide couple would be important. Another factor is that many chemicals have "redox windows." These are ranges of redox potential in which chemical concentrations are likely to be greater. Consequently, a linear relationship (i.e., correlation analysis) does not properly describe these windows. However, use of nonparametric correlation analysis and imprecision in the redox measurements allow identification of significant correlations, although the correlation coefficients will be low. Garrels and Christ (1965) provide an excellent discussion of the limitations of field redox measurements.

Interpreting these results is somewhat subjective. Assessing redox conditions within an aquifer should consider a variety of redox-sensitive measurements because of the uncertainty associated with any single measurement of redox status. As stated, four redox indicators are used in this analysis - total iron concentration, total manganese concentration, dissolved oxygen concentration, and oxidation-reduction potential. For the correlation analyses summarized in Tables D.99 through D.105, a qualitative scoring procedure was used to summarize the relationships between chemical parameters and the four selected redox parameters. For each age-based aquifer group in which a significant (p less than 0.05) correlation was observed between a chemical parameter and a redox parameter, a score of 1 or -1 was assigned to the parameter depending on the sign of the correlation. Thus, there was a potential score of ± 7 (seven age-based groups) for each chemical parameter. A final average score was computed as the average score for the four redox parameters. However, in computing the average score, the sign for dissolved oxygen and redox potential needs to be changed (conversely, the signs could be changed for iron and manganese) to represent the effect on concentration as ground water becomes more reducing (i.e., redox potential and dissolved oxygen concentrations decrease as ground water becomes more reducing, while iron and manganese concentrations increase). Thus, high positive average scores represent increasing concentrations of a chemical with more reducing conditions.

For example, arsenic had significant negative correlations with dissolved oxygen for five of the aquifer groups, positive correlations with both iron and manganese for four groups, and significant negative correlations with redox potential for four aquifer groups. The overall average score for arsenic was $(score_{Fe} + score_{Mn} - score_{DO} - score_{redox})/4$ or $[(4 + 4 - (-5) - (-4)]/4$ or 4.25. Chemicals with scores of 4.00 or greater were considered to have concentrations which were strongly positively correlated with reducing conditions. These included arsenic, barium, iron, manganese, phosphorus, and total suspended solids. Chemicals with values between two and four included alkalinity, beryllium, boron, cobalt, lithium, potassium, silicate, strontium, total organic carbon, total phosphate, and sodium. Lithium, potassium, barium, and sodium may be related to increased concentrations of dissolved solids in older, more reduced waters. Strong negative correlations (average score less than -4.00) were observed for dissolved oxygen, nitrate, and redox. Chloride and lead had scores of less than -2.00. The relationship for chloride may be due to increased loading of chloride in surficial aquifers as a result of human activity, such as road de-icing. Average scores for each chemical parameter are illustrated in Table D.110.

The above qualitative discussion does not explain the response of all chemicals to these four redox parameters. For example, total organic carbon had an average score of 2.50, but was most strongly correlated with iron and manganese. These results suggest a tendency for iron and manganese concentrations to increase with increasing concentrations of total organic matter as a result of adsorption. Some observations from Table D.110 are summarized below.

- Calcium, magnesium, cobalt, lithium, phosphate, and potassium were strongly correlated with iron and manganese and not well correlated with oxygen or redox. Cobalt and phosphate may be related to redox processes, while the remaining chemicals probably reflect increased dissolution in older, more reduced waters.
- Beryllium was strongly correlated with oxygen and iron concentrations and not correlated with redox or manganese. This may reflect redox windows for beryllium.
- Sulfate showed positive correlations with both redox and dissolved oxygen. This trend may be partially attributable to anthropogenic sources of sulfur, including percolation of rain water containing sulfate.
- Silicate was most strongly correlated with iron, manganese, and redox, and not well correlated with dissolved oxygen. This may reflect the slow weathering rates for silicate minerals.

More detailed discussion for individual chemicals is provided in section 3.2.4.

3.2.3. Health and Risk

Risk criteria are summarized in Table D.111. A summary of water quality exceedances is provided in Table D.112 for aquifers and aquifer groups. The highest percent exceedance occurred for iron. Exceedances of the secondary water quality criteria for iron (SMCL) was greater than thirty percent for most aquifer groups. The presence of iron at high concentrations in sampled wells may be due to samples not being filtered. The percent of samples exceeding water quality criteria was more than one percent for aluminum, beryllium, boron, manganese, nitrate, and sulfate. Percent exceedances for aluminum, boron, and beryllium were greatest in Precambrian aquifers, particularly the Duluth Complex (PMDC), Precambrian crystalline (PCCR), and Sioux Quartzite (PMSX) aquifers. Nitrate exceedances were greatest for the surficial Quaternary group (QWTA and QUUU aquifers). Except for nitrate, these exceedances are most likely associated with natural concentrations of these chemicals.

Background hazard indices (HI) help identify aquifers in which background concentrations of chemicals exceed the long-term exposure level considered unlikely to result in deleterious effects to humans. Hazard indices are calculated for target endpoints, such as cancer or the cardiovascular-blood system, and consider the cumulative effects of all chemicals which affect a particular target endpoint. Only HRLs, HBVs, and in the case of arsenic, the MCL were used in calculating the values for HI. Median hazard indices are provided in Table D.113. The values illustrated in these tables include the effects of VOCs. Endpoints for which the HI exceeded 1.0 represent a condition where further investigation is recommended to determine if the exposure assumptions are met and to identify factors which may be contributing to the observed chemical concentrations. The exposure assumption pertaining to daily ingestion is considered to be applicable to baseline data, since sampled wells are used for domestic supply. Median hazard indices were less than 1.0 for all endpoints.

The percentages of wells in which the hazard index would be expected to exceed a value of 1.0 are illustrated by aquifer or aquifer group in Table D.114 for nine target endpoints. For example, the percentage of wells expected to exceed a hazard index of 1.0 for the cardiovascular/blood, cancer, reproductive, kidney, gastrointestinal/liver, nervous system, whole body, skin, and bone endpoints in Cretaceous aquifers was 12, 4 to 5, 35, 3 to 4, 4 to 5, 7, less than one, less than one, and less than one, respectively.

NOTE: These percentages are a nonparametric measure of the distribution of HI in an aquifer for a target endpoint. Parametric calculations of the probability of exceeding a HI of 1.0 can also be made. Parametric calculations consider the variability in observed concentrations rather than the distribution of HI for a target endpoint in an aquifer. Individual probabilities were not calculated because the procedure is somewhat time intensive, but these values can be generated. Generally, for low percentages of HI exceeding 1.0 (less than about five percent), the probability of exceeding a HI of 1.0 is about 1.5 to two times greater than the percentile illustrated in Table D.114. The reason for this is that the distribution of chemicals is typically skewed to the right, reflecting a few high concentrations. When the percentage illustrated in Table D.114 is very low (less than one) or high (greater than ten), calculated probabilities are very close to the percentile. If the sample size is greater than about 40, the expected percentages probably provide adequate information about the potential for exceeding a HI of 1.0.

Water resource managers conducting risk assessments at individual sites should utilize concentration information provided in Tables D.6 through D.44 when comparing ground water concentrations at a contaminated site to background concentrations. Hazard indices calculated for the baseline data are not intended for comparison with site-specific hazard indices. Hazard indices provide an indication of the relative suitability of an aquifer for drinking supply and may be used to identify potential areas or aquifers of concern.

3.2.4. Geochemical Interpretations for Individual Parameters

Chemical-specific interpretations are provided in this section. The discussion is general. The primary purpose is to relate distribution of chemicals, particularly those which may potentially represent a health risk, with physical controls over their concentration in ground water. Assumptions used in identifying physical controls were presented in section 2.2.4. The effect of variability in factors such as pH, Eh, bicarbonate, sulfate, and silica concentrations on calculated values is qualitatively described in the following discussion.

The following information is provided for each element or parameter:

- natural occurrence in rocks and soils;
- the most important anthropogenic sources;
- solubility controls and theoretical concentrations when source material is not limiting;
- comparison of theoretical and observed concentrations;
- an overview of aquifers where concentrations are greatest or least;
- an overview of some factors which may affect distribution, including factors utilized in the solubility calculations; and
- estimates of aquifer chemical sensitivity to contamination.

Background concentrations used in solubility calculations are provided in Table D.115. Concentrations of elements in source rocks and soil are provided in Table D.116. Soil refers to the uppermost portion of the unsaturated zone, hence the most highly weathered zone and the plant root zone. Governing equations and references for geochemical information utilized in calculations are provided in Section 2.2.4. Individual references are not provided throughout this discussion. The primary references used in preparing this discussion include Alloway (1995), Appelo and Postma (1993), Bohn et al. (1979), Dragun (1988), Fetter (1993), Garrels and Christ (1965), Hem (1992), Hounslow (1995), Eary et al. (1990), and Neve et al. (1996).

Aluminum (Al)

Aluminum is an abundant element in minerals, particularly in igneous rocks and shales. During the weathering of igneous rocks, aluminum is retained primarily in the solid phase. Aluminum oxides and hydroxides are thus very common. In soils, clay minerals have a layered structure in which aluminum is coordinated with oxide or hydroxide ions. Aluminum is an important metal in industrial applications, where it is used in alloys, paints, as a protective coating, in the electrical industry, and in building and construction machinery and equipment.

The solubility of aluminum is controlled by the many oxide and hydroxide species. In acidic waters, solubility may be estimated using gibbsite as the solubility control. In alkaline waters bayerite may be used. Hem (1992) estimates equilibrium concentrations ranging from about 0.5 to 20 ug/L at a pH between 6 and 7. The overall baseline median concentration was 1.12 ug/L, which is within the range of predicted concentrations. Concentrations were greatest in Precambrian aquifers. For example, concentrations in Crystalline bedrock (PCCR), North Shore Volcanics (PMNS), and Metasedimentary undifferentiated (PMUD) aquifers were 9.4, 37, and 3.9 ug/L, respectively, compared to concentrations of 1.0, 0.93, and 2.1 ug/L in the Jordan (CJDN), Prairie du Chien (OPDC), and St. Peter (OSTP) aquifers, respectively. Aluminum solubility in soil is similar to that in equilibrium with source rocks. The MCL for aluminum is 50 ug/L. This is greater than predicted concentrations in equilibrium with solid phases of aluminum.

Aluminum did not correlate well with most chemical parameters. It is insensitive to redox reactions and has limited solubility. Solubility controls on aluminum are sufficient to keep concentrations below concentrations of concern. Leaching of aluminum through the unsaturated zone and into ground water will not lead to concentrations exceeding drinking water criteria except in specific instances of contamination of acidic soils. Ground water, in general, appears to be in equilibrium with aluminum-bearing solids.

Antimony (Sb)

Natural sources of antimony primarily include sulfide minerals such as stibnite (Sb_2S_3). The oxidation state of antimony ranges from +3 to +5 and it is often associated with other metals such as copper, lead, silver, and iron in sulfides. Concentrations in minerals are generally less than 1 mg/kg. However, concentrations in soil are much greater, often exceeding 5 mg/kg. Anthropogenic sources of antimony include atmospheric deposition of coal combustion products, sewage sludges, mining wastes, and fertilizers. Antimony is also widely used in industrial products such as flame retardants, pigments, and explosives. It may occur as free metal under reducing conditions and as Sb_2O_3 at higher Eh values. However, the most mobile forms in soil may be associated with humic materials.

Little geochemical information is available for antimony. Antimony in equilibrium with sulfides would have a very low concentration, less than 0.001 ug/L. Antimony in equilibrium with senarmontite (Sb_4O_6) would have a theoretical concentration of 4.5 ug/L at pH 7.28. The overall median concentration of antimony was 0.015 ug/L, with only one sample exceeding the HRL of 6 ug/L. Concentration differences between individual aquifers, although significant, were not dramatic. Concentrations of antimony were greatest in Sioux Quartzite (PMSX), Quaternary buried unconfined (QBUU), and Quaternary unconfined undifferentiated (QUUU) aquifers. These are aquifers which had an increased frequency of large diameter wells and the elevated concentrations may reflect inputs from the unsaturated zone, where antimony concentrations in solution are likely to be much greater than in ground water in equilibrium with parent material.

Both sulfide and oxide forms of antimony-bearing minerals will hold concentrations of antimony below the HRL. Elevated concentrations in ground water may reflect impacts from the unsaturated zone.

Arsenic (As)

Sources of arsenic include arsenates, sulfides, and smaller quantities associated with arsenides, arsenites, oxides, and elemental arsenic. Average concentrations in minerals are about 1 mg/kg, with greater concentrations occurring in shales. Arsenic is often associated with many other metals, primarily iron (arsenopyrite) but also Cu, Pb, Au, and Ag. Concentrations in soil average about 10 mg/kg and arsenic is often associated with sulfur in soil. At Eh values greater than about -50 mV, arsenic in solution will primarily exist as arsenic acid (H_3AsO_4) with an oxidation state of +5. At lower redox values the +3 form of arsenic dominates and the primary soluble form is arsenous acid (H_3AsO_3). Arsenic was once used widely as a pesticide, but this use has declined considerably. Arsenic has many industrial applications, including use in dyestuff, medicines, and wood treating. Atmospheric deposition may be important due to the relatively high volatility of arsenic compounds. Atmospheric deposition results from natural sources such as volcanoes and low-temperature volatilization from source rock and soils, and anthropogenic sources such as smelting activity and fossil fuel combustion. Some sludges may also be enriched in arsenic.

Arsenic readily forms oxides with iron. The solubility of arsenic is therefore sensitive to redox conditions. At redox values exceeding approximately 0 mV, arsenic (+5) associated with iron oxides will have very low solubility, with calculated concentrations being less than 1 ug/L, perhaps as low as 0.001 ug/L. Calculated concentrations of arsenic (+5) in equilibrium with As_2O_5 would be about 55 ug/L. Other metals may also limit the solubility of arsenic under oxic conditions, including aluminum, barium, calcium, and lead. Arsenic (+3) in equilibrium with oxides such as claudetite (As_4O_6) and sulfides such as orpiment (As_2S_3) would have concentrations of greater than 1000 and about 210 ug/L, respectively. The MCL for arsenic is 50 ug/L. The median concentration of arsenic was 1.6 ug/L, with eight exceedances of the MCL. Arsenic occurrence in Minnesota is currently under review and a strictly health-based drinking water criteria for arsenic would probably be considerably lower than the current MCL. There were 593 and 339 samples exceeding 1.0 and 3.0 ug/L, respectively.

The mobility of arsenic in soil will be controlled by redox potential and the availability of sulfur and iron. Arsenic will have low mobility if present in the +5 oxidation state. When sufficient iron or sulfide is present, arsenic in the +3 state will also be relatively immobile as iron and sulfides control solubility. Eary et al. (1990), studying soils to which coal ash had been applied, observed arsenic concentrations in the soil solution exceeding 80 ug/L and often greater than 1000 ug/L. Without effective solubility controls or in acidic soils, leaching of arsenic represents a threat to shallow ground water if sufficient arsenic is present in soil.

Solubility data alone are insufficient to explain the distribution of arsenic in ground water. There is inadequate information in the literature to calculate concentrations of arsenic in equilibrium with the metal oxides likely to be found in ground water. Field measurement of redox and lack of filtering for iron hamper interpretation of the data. Despite these difficulties, arsenic correlated well with redox parameters, although there were numerous low concentrations of arsenic at low redox values, and numerous high concentrations at high redox values. In the first case, availability of arsenic-bearing minerals controls concentrations of arsenic in ground water. In the second case, there may be inadequate solubility controls to prevent arsenic concentrations from becoming elevated.

An additional factor with arsenic is toxicity. The +3 form is considered to be much more toxic than the +5 state. Neve et al. (1996) describes methods for evaluating the ratio of +3 to +5 arsenic in ground water. However, arsenic ingested with drinking water may be converted to the more toxic +3 form in the digestive tract. From a health perspective, this would render concerns over this ratio irrelevant, but the ratio of +3 to +5 may also be used to estimate redox conditions in ground water (Neve, et al., 1996; Cherry et al., 1979).

In summary, under reducing conditions, natural solubility controls on arsenic are not likely to keep the concentration of arsenic below 1 ug/L and possibly not below 50 ug/L. At greater redox values or in the presence of sufficient iron, arsenic concentrations will be well below 1 ug/L. Under very reducing conditions, sulfides will provide an effective control over arsenic concentrations. These same principles apply to both soil and ground water. The primary control on arsenic appears to be availability of arsenic-bearing minerals. Evaluation of aquifer sensitivity to contamination with arsenic should include rigorous establishment of redox conditions within an aquifer, including speciation of iron.

Barium (Ba), Beryllium (Be), Calcium (Ca), Magnesium (Mg), and Strontium (Sr)

The alkaline earth metals barium, beryllium, calcium, magnesium, and strontium are all divalent cations. Natural sources include carbonates ($MeCO_3$) and sulfates ($MeSO_4$), where Me is the metal, except for beryllium, which is primarily associated with silicates and hydroxy-silicates. Where carbonate and sulfate forms are limited, the metals may be associated with silicates, although these rocks tend to be resistant to weathering. Calcium and magnesium are abundant in rocks and soils, with concentrations exceeding 10000 mg/kg. Strontium and barium are relatively abundant in rocks and soil, with strontium occurring at somewhat greater concentrations than barium except in sandstones. Barium concentrations in limestones are lower than in other sedimentary rocks and greater in igneous rocks. Beryllium concentrations in rocks and soil are approximately 1 mg/kg. The primary aqueous form is free metal (Me^{2+}), except for beryllium, which will form hydroxides at pH values greater than about five. There are no major anthropogenic sources for these metals, but they have many industrial applications.

Sulfates are too soluble to form effective controls on solubility of calcium and magnesium. Calcite and dolomite may be effective in controlling solubility of calcium and magnesium. The median concentration of 76176 ug/L for calcium is relatively close to the calculated value of 65000 ug/L for ground water in equilibrium with calcite ($CaCO_3$). Calcium concentrations were lowest in several of the Precambrian aquifers, where solubility may be controlled by silicates. Calcium in equilibrium with silicates would be expected to have concentrations ranging from 30000 to 40000 ug/L. Median concentrations in the PCCR (Precambrian crystalline), PMNS (North Shore Volcanics), and PMUD (Precambrian Metasedimentary undifferentiated) aquifers were 38909, 26763, and 31704 ug/L, respectively. Median concentrations of calcium were much greater in Ordovician and Quaternary aquifer groups compared to other groups. Calcite and dolomite are likely to control calcium and magnesium concentrations in these two aquifer groups. Concentrations of magnesium and calcium were greatest in Cretaceous aquifers. Some ion exchange of sodium by calcium is indicated since the contribution of sodium to total cations increased more than the contribution of chloride to total anions. Ion exchange alone cannot account for the distribution of calcium and magnesium in Cretaceous aquifers, since this process should lead to a reduction in calcium concentration. Calcium, magnesium, and sulfate concentrations were greater in Cretaceous aquifers than in other aquifers, indicating the potential impact of sulfate deposits on water chemistry of Cretaceous aquifers. Since these are much more soluble than carbonates, they may explain concentrations of calcium and magnesium which exceed calculated concentrations for a system with carbonate controls on solubility. There are currently no health concerns with calcium and magnesium, but both contribute to hardness in water, which leads to scaling in pipes and plumbing fixtures. Ninety percent of all samples can be classified as hard or very hard (greater than 120000 and 180000 ug/L as $CaCO_3$, respectively).

Calculated theoretical concentrations of strontium in equilibrium with celestite ($SrSO_4$) or strontianite ($SrCO_3$) are approximately 100000 and 14600 ug/L, respectively. These are well above the observed median concentration of 190 ug/L and greater than the HRL (4000 ug/L). Strontium to calcium ratios in carbonate aquifers were approximately 0.0026, close to the value of 0.0022 reported in the literature for carbonate rocks. The strontium to calcium ratio in Precambrian aquifers was about 0.006, compared to a value of about 0.01 reported in the literature for igneous rocks. These data seem to indicate silicates may be controlling solubility in the Precambrian aquifers, while calcite and dolomite control solubility in the carbonate aquifers. A strong relationship was observed between strontium and sulfur concentrations ($p = 4.1 \times 10^{-200}$; $R^2 = 0.60$). Sulfur-bearing minerals such as celestite may be an important source of strontium in ground water, but ground water appears to be undersaturated with respect to strontium. Concentrations of strontium appear to be limited by the availability of strontium-bearing minerals.

Calculated theoretical concentrations of barium in equilibrium with barite ($BaSO_4$) and witherite ($BaCO_3$) are approximately 150 and 53000 ug/L, respectively. The observed median barium concentration was 60 ug/L. A negative correlation was observed between sulfur and barium concentrations. Barium was one of the mostly highly correlated parameters with redox parameters. Barium solubility may be controlled by iron and manganese oxides as indicated by the strong correlations between barium, iron, and manganese. Only one sample exceeded the HRL of 2000 ug/L and only one other exceeded 1000 ug/L.

Beryllium, although an alkaline earth metal, readily replaces silica in igneous rocks. Beryllium has an extremely low HRL of 0.08 ug/L. Equilibrium data for beryllium in equilibrium with silicates were not found. Hem (1992) estimated that beryllium in equilibrium with hydroxide would have a concentration of approximately 1 ug/L at pH values found in most samples. Calculated concentrations using thermodynamic data were much lower; however, typically being less than 0.0001 ug/L. Median concentrations for most aquifers were less than 0.01 ug/L, but upper 95th percent limit concentrations and 95th percentile concentrations exceeded the HRL for Precambrian crystalline (PCCR), North Shore Volcanics (PMNS), and Precambrian Metasedimentary (PMUD) aquifers. These results reflect the greater concentration of beryllium in igneous rocks. Twenty-two samples exceeded the HRL of 0.08 ug/L, but many of these were between 0.08 and 0.10 ug/L.

Estimating aquifer sensitivity to contamination with barium, strontium, and beryllium is difficult because it is difficult to determine which minerals are controlling solubility. Barium and beryllium solubility may be controlled by hydroxides, and these species are likely to hold concentrations below the drinking water standards. Strontium concentrations cannot be held below the HRL if sufficient source mineral is available, but these minerals are not present in sufficient quantity to be a concern for drinking water quality. Soil inputs of these metals are unimportant, except in specific cases of contamination.

Bicarbonate (HCO_3^-) (alkalinity)

The carbonate system is extensively discussed in many hydrogeologic and soil texts. The carbonate system provides the primary control on pH in most ground water in Minnesota. Between pH 6.5 and 10.0, bicarbonate (HCO_3^-) will be the primary dissolved carbonate species present in ground water. Alkalinity is a measure of the capacity of water to neutralize acids. Since the concentration of hydroxyl (OH^-) and carbonate (CO_3^{2-}) ions is small relative to the concentration of bicarbonate ion in most ground water, alkalinity is essentially a measure of bicarbonate. Salts of weak acids such as phosphates, borates, silicates, and some organic compounds may contribute to alkalinity, but these are usually negligible in natural waters.

Carbonates may be present in ground water from two reactions. The first involves equilibrium between carbon dioxide and water:

$$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-.$$

The second reaction involves dissolution of calcite or dolomite:

$$(Ca,Mg)CO_3 \rightarrow (Ca,Mg)^{2+} + CO_3^{2-} \xrightarrow{H^+} HCO_3^-.$$

These two reactions have the effect of lowering and raising the pH of ground water, respectively. The first reaction may be more prevalent in shallow aquifers receiving direct recharge, since the partial pressure of carbon dioxide in soil is approximately 0.01, which is much greater than that of the atmosphere (0.0003). The second reaction is dependent on the availability of carbonate-bearing rocks, including those in the unsaturated zone.

There were significant differences in alkalinity between aquifers, primarily attributable to two factors. First, concentrations were greater in Cretaceous aquifers and lower in surficial aquifers compared to other aquifer groups. This reflects residence time. As residence time increases, dissolution of parent material occurs and alkalinity increases if carbonates are present. Cretaceous ground water is likely to be very old and contain high concentrations of dissolved solids, whereas the opposite is true for surficial aquifers. The second factor is availability of source material, evident from lower concentrations of alkalinity in most Precambrian aquifers. An interesting calculation is the ratio of calcium to alkalinity concentrations (ug/L). Ratios for age-based aquifer groups ranged from 0.26 to 0.30 except for the Cretaceous and Precambrian groups, in which the ratios were 0.41 and 0.22, respectively. The lower ratio in the Precambrian aquifer indicates that other compounds may be contributing to alkalinity, such as boric and silicic acid. The result should be a slightly greater pH in Precambrian aquifers, which was observed. Using median concentrations of calcium and alkalinity for Cretaceous and Precambrian aquifers, predicted pH using solubility data would be 6.9 and 7.1 in the two aquifer groups, respectively. The observed pH was 7.0 and about 8.2, respectively. In a system where calcite is not controlling bicarbonate and using a partial pressure of 0.001 for carbon dioxide, the estimated pH in Precambrian aquifers would be 8.6. These calculations reflect the importance of carbonate minerals in controlling bicarbonate, thus buffering pH in ground water. Many of the Precambrian aquifers may have low buffering capacity and thus be sensitive to changes in pH.

Bismuth (Bi)

Little information is available on the occurrence of bismuth in the environment. Bismuth may occur as sulfides, chlorides, or oxides. The aqueous form of bismuth is as free metal (+3) below Eh values of about 0 mV and BiO+ at greater Eh values. Bismuth in equilibrium with Bi_2O_3 would have a theoretical concentration of approximately 15 ug/L at pH 7.28. Sulfides would hold concentrations much lower than this. Bismuth was undetected in most samples at a reporting limit of 0.03 ug/L. No sample exceeded 0.1 ug/L. There are no current health criteria for bismuth. The occurrence of bismuth in ground water appears to be limited by availability of bismuth-bearing minerals.

Boron (B)

Boron is present in the minerals kernite ($Na_2B_4O_7 \cdot 4H_2O$), sodium tetraborate, and tourmaline $[(Na,Ca)(Li,Mg,Al)(Al,Mn,Fe)]_6(BO_3)_3$. Information related to the natural occurrence and factors controlling dissolution of these minerals is limited, although tourmaline is considered to be resistant to dissolution. Soil concentrations of boron range from 2 to 100 mg/kg. Boron released from minerals exist in solution as the weak acid H_3BO_3. Boron solubility in soil and the vadose zone may be controlled by iron and aluminum hydroxides, which it interacts with. Maximum adsorption of these hydroxides occurs at a pH of approximately seven to nine. The primary anthropogenic sources of boron include atmospheric deposition of coal combustion products, coal ash, and animal wastes. Boron is used in some industrial processes and as a softener in water treatment systems.

Equilibrium information for boron is sparse. Calculated theoretical concentrations of boron in equilibrium with oxides exceed 10000 ug/L, well above the HRL of 600 ug/L. The solubility of aluminum and iron hydroxides would be much lower and these hydroxides probably form effective solubility controls for boron. The overall median concentration of boron was 46 ug/L. There were widely varying concentrations between aquifers. The greatest concentrations were detected in the Cretaceous (KRET), Duluth Complex (PMDC), North Shore Volcanics (PMNS), and some buried Quaternary aquifers. The lowest concentrations were observed in Quaternary water table wells (QWTA) and in the Hinckley (PMHN) aquifer. The strongest correlations with boron concentrations were with sodium, potassium, iron, calcium, strontium, and fluoride (all positive). Boron concentrations were greater in reducing environments. Since boron is not redox-sensitive in aqueous environments, the correlation with redox is due to the effect of iron hydroxides on solubility. The relationship with fluoride is due to replacement of hydroxyl groups in H_3BO_3 by fluoride. Correlations with sodium, potassium, calcium, and strontium may reflect increased residence time in ground water. As residence time increases, ground water tends to become more reducing. Thus, the relationship between boron concentrations and concentrations of sodium, potassium, calcium, and strontium may be due to the indirect relationship between redox potential and residence time.

Seventy samples exceeded the HRL for boron and another 25 had concentrations between 500 and 600 ug/L. The HRL exceedances were limited to the Precambrian, Cretaceous, buried Quaternary, and surficial Quaternary aquifers. Many aquifers had upper 95 percent confidence limits well above the HRL. The exceedances for Precambrian, Cretaceous, and buried Quaternary aquifers probably reflects a natural abundance of boron in aquifer materials. Exceedances of boron for the surficial Quaternary aquifer contrasts with the overall trend of increasing boron concentrations in older, more reducing waters and the low median concentrations of boron in this aquifer. The results suggest that surficial aquifers are sensitive to contamination with boron if there is a source of boron in the unsaturated zone. Boron is likely to be mobile in soils, particularly soils with low concentrations of iron and organic matter.

Bromide (Br), Chloride (Cl), Fluoride (F)

The halogens bromide, chloride, and fluoride occur as anions (charge of -1) in ground water. They are relatively unreactive, often being used as conservative tracers. Natural sources of chloride include halite (NaCl) and brines. Bromide contents of halite and natural brines are approximately 68000 and 100000 to 1000000 ug/L, respectively. There are no natural sinks for bromide and chloride. Fluoride is the most common halide in igneous rocks, being found both in fluorite (CaF_2) and apatite [$Ca_5(F,OH)(PO_4)_3$]. Unlike other halides, fluoride undergoes anion exchange, primarily with aluminum and iron hydroxides. Natural concentrations of bromide and fluoride in soil are generally low. Anthropogenic sources of chloride include fertilizer (KCl), sewage and animal wastes, industrial releases, and road salting. Bromide may also be used in fertilizers (KBr) and industrial processes, but much less commonly than chloride. Fluoride is used in industrial processes as a strong acid (HF). It is also a constituent of phosphate-bearing rocks used in the manufacture of phosphorus fertilizers.

Fluoride concentrations in ground water in equilibrium with calcium at a concentration of 76176 ug/L (the overall median) will be approximately 850 ug/L. The overall median fluoride concentration was 340 ug/L. For fluoride concentrations of 800 ug/L and greater, there was no correlation between calcium and fluoride concentration ($p = 0.17$). Below concentrations of 500 ug/L, fluoride concentration was strongly correlated with calcium ($p = 10^{-12}$). The slope of the molar concentrations was 1.41 ([F/Ca]), which, although slightly less than the theoretical ratio of two, reflects the importance of calcium in controlling fluoride concentrations. An important consideration of the calcium-fluoride relationship is for water supplies to which fluoride is added. Addition of fluoride to municipal water supplies containing high concentrations of calcium may be ineffective due to precipitation of the fluoride. Approximately 78 percent of the data was below 500 ug/L. Calcium does appear to exert a solubility control over fluoride for much of the data set. Concentrations were greatest in the Cretaceous (KRET), unconfined Quaternary (QUUU), Precambrian crystalline (PCCR), and Duluth Complex (PMDC) aquifers. Concentrations were lowest in the Hinckley (PMHN) and Sioux Quartzite (PMSX) aquifers. The variability in the Precambrian aquifers reflects the presence or absence of fluoride-bearing minerals.

There are no effective solubility controls on either bromide or chloride in ground water. Bromide was detected in only 21 samples (reporting limit = 0.100 ug/L). The overall median concentration was 2400 ug/L, but there was considerable variability among aquifers. The greatest concentrations were in the Cretaceous (KRET), Sioux Quartzite (PMSX), Platteville (OPVL), Duluth Complex (PMDC), and unconfined Quaternary (QUUU) aquifers. Concentrations in the Cretaceous aquifer are likely to reflect the presence of marine deposits, while concentrations in the remaining aquifers may reflect inputs from human activity. Within age-based aquifer groups, concentrations were greatest in the Cretaceous and surficial Quaternary aquifers. These reflect natural and anthropogenic sources for the two aquifers, respectively. Concentrations were lowest in the Cambrian aquifers.

Drinking water criteria exist for chloride (SMCL = 250000 ug/L) and fluoride (MCL = 4000 ug/L), but these criteria are not linked to specific health effects. Seven and two samples exceeded the drinking water criteria for chloride and fluoride, respectively. Halogenated aliphatic compounds represent a much more substantial health risk in ground water. Brominated compounds are the most toxic, with chlorinated compounds being slightly less toxic and fluorinated compounds being much less toxic. However, due to the abundance of chloride relative to bromide, trihalomethane (THM) compounds detected in ground water samples were primarily chlorinated. It is unclear what the contribution of chlorine from well disinfection is to the presence of THMs in ground water.

Cadmium (Cd)

Natural sources of cadmium include zinc-bearing minerals sphalerite and wurtzite (ZnS) and smithsonite ($ZnCO_3$), which typically contain 0.2 to 0.4 percent cadmium. Concentrations in igneous and metamorphic rocks are generally less than 1 mg/kg, with an average of approximately 0.20 mg/kg. Concentrations in sedimentary rocks are not necessarily greater on average, but concentrations are more variable and may exceed 100 mg/kg. Concentrations in soil range from 0.05 to about 1 mg/kg. The primary form of cadmium in soil is as free metal (Cd^{2+}) at pH values below about eight and as hydroxides at higher pH values, although cadmium may form complexes with chloride, sulfur, carbonates, and organic matter. Cadmium behavior in soil is highly variable, although generally it is controlled more by adsorption processes than by coprecipitation, mobility increases rapidly with decreasing pH, and mobility is highly affected by the presence of ligands, chloride, and competing ions. Anthropogenic sources of cadmium include small amounts associated with atmospheric deposition, land application of sludges, lead-zinc smelting and mining activity, and disposal of industrial wastes, including metal wastes.

Stability relationships indicate carbonates will control solubility down to Eh values of approximately -100 mV. Theoretical concentrations of cadmium in equilibrium with bicarbonate are approximately 135 ug/L. This is greater than the HRL (4 ug/L). Theoretical concentrations under reducing conditions in a system controlled by sulfides would be much less than 1 ug/L. The overall median concentration of less than 0.03 ug/L indicates cadmium concentrations may be limited by availability of cadmium-bearing minerals. There were five exceedances of the HRL, another five samples between 3 and 4 ug/L, and a total of 38 samples in which the concentration exceeded 1 ug/L. Concentrations in the Upper Carbonate group were much greater than in other aquifer groups. Concentrations decreased steadily from the Upper Carbonate to OSTP-OPDC-CJDN to CFIG-CFRN-CIGL to CMSH-CMTS-PMHN groups. Crystalline Precambrian aquifers had the lowest concentrations of cadmium in ground water.

Concentrations of cadmium cannot be held below the drinking water criteria of 4 ug/L if sufficient cadmium-bearing material is present in ground water, except in strongly reducing environments. Surficial aquifers are susceptible to leaching of cadmium if sufficient cadmium is present in soil. Natural concentrations are extremely low; however, and the primary concern with cadmium is proper management of soils to which cadmium-bearing wastes are applied.

Carbon (C)

Carbon exists in ground water in inorganic and organic forms. Most of the inorganic carbon occurs as bicarbonate. Organic carbon represents waste products of living matter. Although concentrations of organic carbon in ground water are low, organic carbon can have profound effects on ground water chemistry. The primary influences of organic carbon are on redox reactions and adsorption. Many metals, for example, form complexes with organic matter which greatly increases or decreases their mobility and toxicity in ground water.

Organic carbon in ground water is assumed to have properties similar to soil organic carbon. These are well described in numerous soil texts, but it is important to note that organic matter, which consists of approximately 60 percent carbon by weight, can be involved in both cation and anion adsorption, has a cation exchange capacity approximately an order of magnitude greater than that of iron and aluminum hydroxides, can be highly hydrated (adsorbs water readily), and is a food source for microbes.

The primary source of organic carbon in ground water is likely to be leaching from the soil zone. Consequently, concentrations were greatest in aquifers which occur in soils rich in organic material and which are likely to receive direct recharge. These included some aquifers of the Upper Carbonate group and buried Quaternary aquifers. Concentrations were lowest in most of the Precambrian aquifers, reflecting the low organic carbon content of soils overlying these aquifers. Concentrations in surficial Quaternary aquifers were not particularly high compared to other aquifers. Although these aquifers are hydrologically sensitive, soils overlying these aquifers are often sandy and have low organic carbon contents.

Total organic carbon showed significant but relatively weak correlations with many parameters. These results reflect the importance of carbon in influencing water chemistry, but the difficulty in identifying specific impacts because of the complex nature of the organic material. More specific fractionation of organic material would be required to attempt to correlate distributions of chemicals with organic carbon content. These types of studies are warranted only when attempting to quantify natural attenuation capacities of ground water, such as at contaminated sites.

Synthetic organic carbon in the form of VOCs occurred in 11 percent of sampled wells. In wells where VOCs were detected, concentrations of VOCs were generally less than ten percent of the total concentration of organic carbon. When synthetic carbon concentrations exceed about ten percent of the total organic carbon in an aquifer, their effect on water chemistry should be considered.

Cesium (Cs), Lithium (Li), Potassium (K), Rubidium (Rb), Sodium (Na)

The alkali metals cesium, lithium, potassium, rubidium, and sodium all form monovalent species in ground water and are not involved in redox processes. Similarities between these elements largely end there, however. Silicates are the primary mineral sources for the alkali metals, particularly the feldspars. Sodium and potassium are by far the most abundant of the alkali metals, with concentrations ranging from a few thousand mg/kg in sedimentary rocks to several thousand mg/kg in igneous rocks. Concentrations of rubidium, lithium, and cesium are typically a few hundred, ten to 50, and less than 10 mg/kg, respectively, with concentrations being greatest in igneous rocks and shales. Concentrations in soil are within similar ranges. The mobile form is free metal, but mobility varies widely. The order of mobility is Li > Na > K > Rb > Cs. Although the alkali metals are widely used in industrial applications, anthropogenic sources do not typically represent a major input of these elements into soil or ground water. Exceptions include sodium and potassium in fertilizers and animal wastes, including septic systems, and sodium in road salts.

The primary controls on solubility are likely to be silicates, although retention in clay lattices represents a significant sink for potassium. Weathering rates of silicates are slow. Sodium and potassium in equilibrium with feldspars would have concentrations of approximately 8000 and 2000 ug/L, respectively. Concentrations of sodium and potassium in equilibrium with chlorides and carbonates would be in excess of 1000000 ug/L. The overall median concentrations of sodium and potassium were 9302 and 2297 ug/L, close to the concentrations predicted from solubility calculations for silicates. The standard deviations were very large; however, particularly for sodium. Both sodium and potassium would be expected to increase with residence time in ground water as a result of increased dissolution and ion exchange reactions involving calcium and magnesium. However, concentrations in aquifers exposed to direct recharge may also show increased concentrations of sodium and potassium. Ratios of sodium to (sodium + chloride) provide insight into which of these two processes may be more important in an aquifer. Low ratios reflect potential inputs of chloride as well as sodium, as might occur with leaching through the unsaturated zone. Higher ratios reflect increasing sodium but not chloride, as would occur from dissolution and ion exchange. The lowest ratios were observed for the Quaternary water table (QWTA), Platteville (OPVL), Prairie du Chien (OPDC), Quaternary unconfined and undifferentiated (QUUU), and St. Lawrence-Hinckley (CSLH) aquifers. Except for the CSLH aquifer, these are all aquifers which are likely to be impacted by direct recharge.

Equilibrium information was limited for rubidium, cesium, and lithium. If the dissolution rates of minerals containing these elements were similar to sodium, and using concentrations of these elements in source minerals, calculated concentrations would be 10.5, 55, and 1.4 ug/L for lithium, rubidium, and cesium, respectively. Observed median concentrations were nine, less than 555, and less than 0.009 ug/L, respectively. Lithium concentrations appear to be somewhat predictable based on solubility calculations, while concentrations of cesium are not. This supports the conclusion that lithium mobility within ground water will be much greater than cesium. Lithium, potassium, and sodium were correlated with redox parameters, with concentrations being greater under increasingly reducing conditions. These correlations reflect increased residence time, which also results in ground water becoming more reducing.

There are no health-based criteria for the alkali metals, although sodium has a MCL of 250000 ug/L and lithium toxicity in plants has been observed at concentrations greater than 1000 ug/L. Ingestion of sodium at very high concentrations may increase the risk of hypertension. Fourteen samples exceeded 250000 ug/L, with an additional 11 samples exceeding 200000 ug/L. All of these samples were from Cretaceous or buried Quaternary aquifers and chloride concentrations in these wells were very high, typically being in excess of 100000 ug/L compared to an overall mean of 2400 ug/L. In aquifers where silicates control solubility, concentrations of the alkali metals will be relatively low. Concentrations of sodium may be very high in aquifers susceptible to direct recharge or in which sodium-bearing carbonates or chlorides are present.

Chromium (Cr)

Chromium readily substitutes for iron and is therefore a common constituent of mafic and ultramafic rocks. Concentrations in igneous rocks exceed 100 mg/kg, but concentrations in sandstones and limestones are less. Average concentrations in soil are about 100 mg/kg. The most common oxidation states of chromium are +3 and +6, with the trivalent form being prevalent under redox and pH conditions typically encountered in soil and ground water. Anthropogenic sources include atmospheric deposition resulting from release of chromium-bearing particles associated with ferrochrome, brick, and coal production. Chromium is widely used in industrial applications, including the plating, wood treating, and tanning industries. Chromium is enriched in sewage sludges and coal fly ash. The hexavalent form of chromium is much more mobile than the trivalent form and is considered to be more toxic.

Trivalent chromium in equilibrium with either chromite ($FeCr_2O_4$) or Cr_2O_3 would have concentrations less than 0.001 ug/L. Hexavalent chromium in equilibrium with oxides would have concentrations well in excess of 1000 ug/L. Additional controlling minerals may include $Cr(OH)_3$ under oxic conditions and $(Fe, Ba, Pb)CrO_4$ under anoxic conditions. The overall median concentration was 0.36 ug/L. Hem (1992) estimated that concentrations in equilibrium with hydroxides would have concentrations ranging from 1 to 5 ug/L. Although there were significant differences between aquifers, the spread in median concentrations between aquifers was not large. Chromium showed many significant correlations with other parameters, but none of these was particularly strong (all R^2 Spearmann rho coefficients were less than ± 0.350). Chromium concentrations were positively correlated with dissolved oxygen. This may reflect contributions of more mobile forms of chromium, which are stable only under oxidizing conditions. However, the maximum concentration of chromium was 93 ug/L, well below the HRLs of 600 and 20000 ug/L for hexavalent and trivalent chromium.

Even when chromium-bearing minerals are not limiting, concentrations of trivalent chromium in equilibrium with oxides and hydroxides are well below health-based drinking water criteria. Oxygenated ground water is somewhat more susceptible to elevated chromium concentrations, but only under highly oxidized conditions would ground water be susceptible to contamination through leaching of chromium.

Cobalt (Co)

Cobalt is most commonly found in ferromagnesian minerals such as olivine, pyroxenes, amphibole, and biotite, where it substitutes for iron and manganese in the crystal structure. Concentrations in igneous rocks and shale typically range from 3 to about 25 mg/kg, although concentrations may exceed 100 mg/kg in mafic and ultramafic rocks. Concentrations in sandstones and limestones are less than 1 mg/kg. Concentrations in soil vary with parent material, but are typically less than 5 mg/kg. Cobalt is widely used in industrial applications, including as a pigment in paint and printing.

Solubility controls on cobalt are likely to be primarily hydroxides, including those of iron and manganese. Hem (1992) estimates the concentration of cobalt in equilibrium with $Co(OH)_2$ at pH 8 to be about 6 ug/L. The calculated theoretical solubility of cobalt in equilibrium with carbonate is about 10 ug/L. Iron and manganese hydroxides and sulfides would be expected to provide solubility controls resulting in much lower concentrations of cobalt. The median concentration of cobalt was 0.47 ug/L. The HBV for cobalt is 30 ug/L. There was one exceedance of the HBV (49 ug/L), but all other concentrations were below 5.2 ug/L. The strongest correlations between cobalt and other parameters were with, in order, calcium, magnesium, manganese (all positive correlations), and pH (negative correlation).

The solubility controls discussed above will effectively prevent cobalt concentrations from reaching levels of health concern. Observed concentrations were approximately an order of magnitude below calculated concentrations, indicating cobalt concentrations in ground water are limited by the availability of cobalt-bearing minerals.

Copper (Cu)

Copper forms sulfides, sulfates, carbonates, and some less significant compounds. It is typically found at concentrations ranging from 10 to 100 mg/kg. Concentrations are lower in carbonates. In soil, copper is found in oxides of iron and manganese, in organic matter, and in silicate clays. Soil concentrations are on average about 20 mg/kg. Copper is one of the most important metals in industrial applications, being used in alloys, paints, electrical wiring, electroplating, piping, and in construction materials. It has been used as a pesticide and in fertilizers and may be enriched in sewage sludges and animal wastes. Atmospheric depositions can be important in the vicinity of zinc smelting operations.

The primary aqueous forms of copper are Cu^{+2} in oxidizing and acidic environments and as $Cu(OH)_2$ in reducing and alkaline environments. Copper in equilibrium with sulfides (covellite, CuS) would occur at very low concentrations, less than 0.001 ug/L, while concentrations in equilibrium with sulfates (chalcanthite, $CuSO_4 \cdot 5H_2O$) would be very high, greater than 10000 ug/L. Concentrations in equilibrium with carbonates would be about 3500 ug/L, but hydroxy-carbonate species would have much lower solubility, probably closer to 10 ug/L. Copper in equilibrium with oxides would be at a concentration of about 8 ug/L. The HBV for copper is 1000 ug/L. The overall median concentration was 6.15 ug/L. Nearly half the samples were below the reporting limit of 5.5 ug/L and the maximum concentration was 530 ug/L.

Although copper can occur in the +2 or +1 form in aqueous systems, the +2 form dominates and no correlation between copper concentration and redox parameters was observed. Differences in concentrations between aquifers probably reflect differences in the copper concentration of source minerals. For example, copper concentrations were relatively high in the St. Lawrence formations and low in the Quaternary aquifers. Despite these differences, the range in concentrations was not great, with median concentrations for individual aquifers being between about 4 and 20 ug/L. The strongest correlations of copper were metals with which it may be found in association in minerals. These included Ti, Ni, V, and Zn.

Solubility controls on copper will maintain concentrations below the HBV of 1000 ug/L. Ground water concentrations are in the range of 4 to 20 ug/L, which is within predicted solubility limits of copper oxides and hydroxides.

Dissolved and Suspended Solids, Conductivity

The total dissolved solid content (TDS) is equal to the sum of the mass of ions plus silica. The conductivity is the reciprocal of the resistance in ohms between the opposite facies of a 1-cm cube of an aqueous solution at 25 degrees Celsius. The ratio of the conductivity to TDS ranges from 0.55 to 0.76 for most samples. Total suspended solids (TSS) represent the solid content of water retained by a filter, generally a 0.45 um filter.

Each of these parameters is useful as an indicator of the water chemistry of a sample or an aquifer. TDS and conductivity can be used to predict concentrations of major cations and anions for individual aquifers. For example, the concentration of calcium (ug/L) in buried Quaternary aquifers is given by the equation:

$$Ca = 16498 + 99.97SC$$

where *SC* is the specific conductivity in umhos. Regressions of concentrations of major cations and anions on TDS and specific conductivity were highly significant (p less than 0.001) for nearly all aquifer groups and individual aquifers with sample sizes greater than 20. Consequently, for aquifers in which the appropriate regression coefficients have been determined, concentrations of major cations and anions can be predicted.

These relationships did not hold for TSS. TSS concentrations were most highly correlated with iron. When samples are acidified in the field, metal in the sample will be converted to dissolved forms. Consequently, samples with high concentrations of suspended solids may reflect samples in which much of the measured metal was not dissolved prior to acidification. This explains why iron and TSS are correlated, since iron forms numerous complexes in ground water.

Concentrations of TDS were greatest in Cretaceous (KRET), Sioux Quartzite (PMSX), and undifferentiated Quaternary (QBUU and QUUU) aquifers, and lowest in some of the Precambrian aquifers. Generally, these results reflect the slower rate of weathering in Precambrian aquifers, except for the Sioux Quartzite. Because conductivity and TDS are related, the primary utility of conductivity is that it can be measured in situ with a field instrument and thus has utility as a screening tool. TSS may be used to assess the importance of filtering samples, particularly when attempting to establish redox conditions within an aquifer.

Dissolved Oxygen

Dissolved oxygen is necessary for aerobic microorganisms and is a useful hydrologic indicator. Presence of oxygen at concentrations greater than about 1000 ug/L indicates aerobic environments. Theoretical concentrations of dissolved oxygen at temperatures found in ground water are approximately 10000 ug/L, but concentrations greater than 5000 ug/L are rarely achieved. Sources of oxygenated water to aquifers include percolation of water through the vadose zone and direct interaction with surface water. Immediately after oxygenated water is introduced into ground water, reduction reactions continually consume oxygen.

Stability of many chemicals is directly impacted by the presence of oxygen. Nitrate and halogenated VOCs in particular will not be degraded under aerobic conditions. Redox reactions affecting the concentrations of many other chemicals such as arsenic cannot proceed until oxygen is consumed.

Although there were significant differences in dissolved oxygen concentrations between aquifers, the differences in median concentrations were not very large. This reflects the sample design for the baseline study, in that most wells sampled are screened near the middle or bottom of an aquifer. Oxygen is consumed relatively quickly in the upper 20 feet of an aquifer provided there are microbes and a food source present. Sixty percent of samples contained dissolved oxygen at a concentration less than 500 ug/L. For samples with concentrations greater than 500 ug/L, almost 80 percent of these samples had concentrations between 1000 and 5000 ug/L. Dissolved oxygen is a useful indicator but, in general, provides little additional understanding of geochemical conditions within ground water unless a vertical dissolved oxygen profile can be established.

Iron (Fe)

Iron is a common metal found in minerals such as the pyroxenes, the amphiboles, biotite, magnetite, and olivine. Concentrations range from about 8000 to 40000 mg/kg, being less in carbonates and greater in igneous rocks. Concentrations in soil are about 40000 mg/kg. Iron is widely used in machinery and structural materials, but it has many other industrial applications.

The predominant form of iron in solution is the ferrous ion (+2). Various hydroxides and organic complexes may also occur. Ferric iron (+3) may also occur, but in neutral solutions the concentration will be less than 10 ug/L. Numerous authors have developed Eh-pH stability diagrams for iron in systems with various concentrations of sulfate and bicarbonate. Between a pH of five to nine and Eh of -200 to 200 mV, ferrous iron concentrations can exceed 1000 ug/L and may approach about 60000 ug/L. Above pH 8.5, siderite ($FeCO_3$) begins to control solubility and equilibrium concentrations will decrease to about 250 ug/L. At lower redox values, sulfides control solubility and concentrations will again decrease to sub-ppm concentrations. Under oxidizing conditions iron may occur as a dissolved species in the ferric state, but concentrations will be less than 10 ug/L. The overall median concentration was 948 ug/L. The maximum concentration was 123000 ug/L, but the next highest concentration was 63000 ug/L. The MCL for iron is 300 ug/L, which was exceeded by about 70 percent of the samples. However, particulate forms of iron may be substantial in ground water. Fractionation of iron was not possible because samples were not filtered and were preserved in the field. The primary concerns with iron are discoloration of water and pipes and possibly poor taste if the iron is associated with organic matter or sulfides. More than 90 percent of the exceedances of the MCL were at redox values between 100 and -200 mV (Eh approximately of 0 to 300 mV).

Although there were significant differences in iron concentrations between aquifers, the differences were not particularly strong. Some aquifers, such as the St. Lawrence formation (CSLF and CSTL), showed elevated concentrations, while others such as the Sioux Quartzite (PMSX) and St. Peter (OSTP) had low concentrations. Differences appeared to be related to the availability of iron-bearing minerals in the parent material. Iron was most strongly correlated with redox-sensitive parameters, such as nitrate, redox potential, dissolved oxygen (negative correlations) and manganese (positive correlations). Iron occurred at greater concentrations in the absence of tritium and in deeper wells, both of which are likely to reflect aquifers which will be more reducing.

Iron is a valuable indicator of water chemistry. The baseline dataset is confounded by the lack of filtering for iron samples, since the important parameter in water quality analysis is the concentration of ferrous iron. Samples with redox values between 100 and -200 mV have iron concentrations which are reflective of solubility controls imposed by hydroxide and oxide species. Within these redox limits, iron concentrations cannot be held below the MCL of 300 ug/L if there are sufficient concentrations of iron in source minerals. There were many samples with relatively low concentrations of iron within these redox limits, suggesting that in many aquifers, availability of iron may limit concentrations, or dissolution rates are sufficiently slow to maintain concentrations below the MCL. Data outside these redox limits could not be evaluated to determine if iron was in equilibrium with parent minerals, since the samples were not filtered and much of the iron may be associated with colloidal material.

Lead (Pb)

Natural sources of lead include the minerals cerrusite ($PbCO_3$), anglesite ($PbSO_4$), and galena (PbS). Lead contents of rocks range from about 2 mg/kg in gabbro to over 20 mg/kg in granite. Anthropogenic sources include automobile emissions, mining and smelting activities, sewage sludge, lead-containing alloys and pipes, and batteries. Lead in soil will primarily be controlled by $Pb(OH)_2$ in noncalcareous soils and aquifers and by $PbCO_3$ in calcareous soils and aquifers, although sulfates are a common form for automobile emissions and metallic lead is a common form from salvaging and munitions operations. Lead has a very low mobility in soil and ground water.

Stability diagrams indicate that lead will most often be in equilibrium with carbonate or mixed hydroxy-carbonate minerals. If pH decreases below about six, sulfates may control lead solubility, while sulfides are important at redox values less than approximately -150 mV. Lead in equilibrium with carbonates will have a concentration of approximately 5 ug/L. This is below the ground water action level for lead (15 ug/L), although there is no level of lead that is considered to be safe for ingestion. Lead has no known beneficial health effects. Lead in equilibrium with $Pb(OH)_2$ at a pH of 7.28 would have a solubility limit of 1249 ug/L.

The overall median concentration of lead was 0.22 ug/L. Medians for most aquifers and aquifer groups were between 0.20 and 0.50 ug/L, indicating concentrations of lead in ground water may be limited by availability of lead-bearing minerals. Sixteen samples exceeded 10 ug/L, with three samples exceeding 50 ug/L. These greater concentrations may reflect soil inputs, although these wells were not resampled for verification.

There were nine exceedances of the drinking water criteria (15 ug/L). There was no apparent pattern to the occurrence of these exceedances and they were distributed among several aquifers. Lead concentrations were greatest in the St. Lawrence (CSTL), Duluth Complex (PMDC), and Fond du Lac (PMFL) aquifers. Among aquifer groups, concentrations of lead were greatest in Precambrian aquifers, although the median concentration was still less than 0.50 ug/L. Lead concentrations were lowest in Quaternary aquifers (buried and surficial).

Lead concentrations in ground water will be held below concentrations of 5 ug/L even when lead-bearing minerals are not limiting. Shallow aquifers, particularly non-carbonate aquifers, may be susceptible to lead contamination in areas where greatly elevated soil lead concentrations exist (probably greater than 10000 mg/kg, less in acidic soils), such as might occur adjacent to smelting, mining, and munitions operations, in soil where sludges are being applied, or near some waste disposal facilities.

Manganese (Mn)

Sources of manganese include the minerals rhodochrosite ($MnCO_3$), manganite (Mn_2O_3), pyrolusite (MnO_2), and alabandite (MnS). Concentrations range from 200 to 1000 mg/kg in igneous and metamorphic rocks to 20 to 600 mg/kg in sedimentary rocks, with lower concentrations in sandstones. The primary anthropogenic source is addition as an amendment to deficient crops, although manganese is present in alloys. Manganese most commonly occurs as oxides in soil, with oxidized forms (+4) prevailing in aerated soils and reduced forms (+2) present in reducing environments. Generally, more reduced forms of manganese are the most mobile in soil.

Stability diagrams indicate that most sampled wells fall within the carbonate stability field. The calculated solubility for manganese in equilibrium with rhodochrosite is approximately 1200 ug/L, which is greater than the HRL (100 ug/L). **However, calculations made for this report consider a drinking**

criteria of 1000 ug/L, as outlined in the Minnesota Department of Health memo (MDH, 1997). The calculated solubility of 1200 ug/L is close to this value of 1000 ug/L. Neve et al. (1996) demonstrated that less than five percent of sampled wells exceeded theoretical concentrations calculated for individual wells. He also demonstrated that manganese concentrations increase as pH decreases. Although correlation coefficients are very low for this relationship, the pH-manganese relationship was highly significant (p less than 10^{-10}), with a slope of approximately -150 ug/L per unit increase in pH.

The overall median concentration was 110 ug/L. Twenty-six values exceeded 1200 ug/L. Concentrations were greatest in Quaternary and Cretaceous aquifers and in the Mount Simon-Hinckley aquifer and somewhat lower in Ordovician aquifers. These trends coincide with lower redox values in the Quaternary and Cretaceous aquifers and greater redox values in the Ordovician aquifers.

Natural manganese concentrations will be held close to the drinking water criteria unless manganese-bearing minerals are limiting. Elevated manganese concentrations will occur in reducing and low pH environments. Minimizing manganese concentrations in a well can be accomplished only through proper well location based on good geochemical interpretation.

Mercury (Hg)

Mercury concentrations in minerals and soil are very low, generally between 0.05 and 0.5 mg/kg. Mercury occurs primarily in nature as a sulfide and less frequently as a chloride. As a sulfide it may occur with Zn, Fe, and other metals. Mercury sulfides are resistant to weathering and are relatively insoluble. Volatilization of elemental mercury and volcanic emissions represent the two most significant natural inputs of mercury into the environment. In soil, mercury occurs primarily as free metal. Oxidation states include +2 (oxidizing conditions) and zero (reducing conditions). Mercury forms strong complexes with sulfides, chlorides, and organic matter in soil. Mercury has had a wide variety of uses throughout history. Some uses, such as in pesticides and metal separating processes, have been dramatically reduced. The primary anthropogenic inputs of mercury are through atmospheric deposition. Smelting and mining, burning of fossil fuels, waste incineration, and land disposal of wastes containing mercury are the primary sources of mercury today. Mercury may also occur in elevated concentrations in sewage sludges, industrial wastes, pharmaceuticals, and electrical products.

Mercury in equilibrium with free metal (Hg^0) would have a solubility of approximately 25 ug/L in a closed system. When exposed to the atmosphere mercury would be expected to have a lower concentration due to volatilization. A concentration of 25 ug/L is much greater than predicted if mercury were in equilibrium with sulfide minerals. Mercury released to ground water or soil solutions appears to associate with organic matter and iron hydroxides, which may then control solubility. Mercury leaching in soil will be minimal if there is sufficient organic matter and iron present, except in acidic soils (pH less than about five).

The MCL for mercury is 2 ug/L. The median concentration was less than the reporting limit of 0.10 ug/L. There were no exceedances of the MCL and the greatest observed concentration was 0.38 ug/L. Mercury was detected in only 11 percent of the samples collected and was discontinued as a sampling parameter after 1994 (MPCA, 1995). Although there were significant differences in concentration between aquifers, there were no striking relationships. Mercury concentrations appeared to be elevated in samples collected from the Cedar Valley aquifer, but the median concentration was still below the reporting limit for this aquifer. Correlations between mercury and other sampled parameters were weak.

Mercury solubility in ground water is likely to be controlled by dissolved organic matter and iron hydroxides, but the availability of mercury appears to be limited. Under natural conditions, ground water is not sensitive to contamination with mercury. There is evidence in the literature that ground water may be sensitive to mercury contamination at concentrations greater than the MCL if there is a source of mercury in soil. Assessing the mobility of mercury requires fractionation of mercury species, which was not done for the baseline samples.

Molybdenum (Mo)

Molybdenum concentrations in minerals are low, generally in the 0.1 to 1.0 mg/kg range. Molybdenum may occur as a sulfide, but more commonly is associated with metal ores, including those of tungsten, iron, tin, titanium, calcium, and lead. Concentrations of molybdenum in soil have an average concentration of about 8 mg/kg. Anthropogenic sources of molybdenum include atmospheric disposition resulting from mining and smelting activity and combustion of fossil fuels, and land application of molybdenum fertilizers, coal ash, and sewage sludges. Molybdenum is also widely used in steel manufacturing and in alloys for providing strength.

Although solubility of native minerals containing molybdenum is low, molybdenum exists as an anion and may therefore be relatively mobile, particularly as pH increases. Molybdenum exists as hydroxides of iron and aluminum, as organic complexes, and as oxides. Molybdenum in equilibrium with MoO_4 would have a concentration well in excess of 1000 ug/L, much greater than the HBV of 30 ug/L. However, hydroxides of Ca and Fe would have equilibrium concentrations of 50 to 100 ug/L, and polymers of Mo have equilibrium concentrations of 10 ug/L or less. The overall median concentration was below the reporting limit of 4.2 ug/L. Estimated mean concentrations were between 2 and 4 ug/L for most aquifers and aquifer groups. There was one exceedance of the HBV at a concentration of 32.9 ug/L.

Concentrations of molybdenum were greatest in Cretaceous, buried Quaternary, and the Precambrian aquifers PMSX (Sioux Quartzite) and PMDC (Duluth Complex), and lowest in some of the Cambrian aquifers. Correlations of molybdenum with other selected parameters were greatest with metals such as nickel, titanium, and sodium. Correlations with other parameters, including redox parameters, well depth, and pH, were poor.

Factors affecting molybdenum distribution are not completely understood. If concentrations are in equilibrium with organic-molybdenum complexes, the observed concentrations correlate well with predicted concentrations. Other solubility controls such as iron and calcium hydroxides cannot hold molybdenum concentrations below the HBV of 30 ug/L. Observed concentrations were an order of magnitude below the HBV and if these hydroxide species are controlling molybdenum solubility, concentrations of molybdenum are being limited by availability of molybdenum-bearing minerals. In this case, aquifers would be sensitive to contamination with molybdenum, since molybdenum can be mobile in soil.

Nickel (Ni)

Natural sources of nickel include sulfides such as millerite (NiS) and pentlandite $(Ni,Fe)_9S_8$ and silicates such as garnierite $[(Ni,Mg)_6Si_4O_{10}](OH)_8$. Concentrations range from 2000 mg/kg in ultramafic igneous rocks, to about 100 mg/kg in basalts, to 50 mg/kg or less in sedimentary rocks and granites. Concentrations in soil are approximately 50 mg/kg, but may be as high as 7000 mg/kg in soils formed on serpentine. The primary form of nickel in soil is as free metal or a hydroxy-compound at pH values greater than eight, and as free metal, sulfates, or phosphates at lower pH values. Nickel mobility increases with decreasing pH and it readily forms complexes with iron. Anthropogenic sources of nickel include fertilizers (primarily phosphates), atmospheric deposition of fossil fuel combustion products, diesel exhaust, and sewage sludges, although the concentration of nickel in sludge is highly variable and may not be much greater than background soil concentrations. Nickel is also a widely used alloy and may be associated with metal waste.

Nickel in equilibrium with silicates will have a theoretical concentration of approximately 0.036 ug/L. The overall median concentration in ground water was less than the reporting limit of 6.0 ug/L. The theoretical concentration of nickel in equilibrium with $Ni(OH)_2$ is approximately 10000 ug/L, although Baes and Mesmer (1976) report $Ni(OH)_2$ may control concentrations at about 100 ug/L. The results suggest nickel solubility is being controlled by something other than silicates or that ground water is not in equilibrium with respect to nickel. Potential controls on nickel concentration are formation of iron and manganese co-precipitates and sulfide compounds, both of which will hold nickel concentrations well below the HRL. Sulfides would exert a solubility control only in reducing environments.

The overall median concentration is well below the HRL of 100 ug/L. Only one sample exceeded the HRL and the next greatest concentration was only half of the HRL. There appear to be sufficient geochemical controls on nickel solubility to minimize pollution susceptibility of ground water, except in cases where soils are not properly managed (e.g., low pH, low iron content) and a source of nickel is added to the soil.

Nitrogen (N)

Nitrogen concentrations in shales and igneous rocks are about 500 and 50 mg/kg, respectively. Concentrations in soil are generally greater than 1000 mg/kg. The main source of nitrogen in soil is through interaction with the atmosphere, which is about 78 percent nitrogen by volume. Nitrogen is retained in soil due to the intensity with which it is utilized by living organisms. Consequently available nitrogen is rapidly assimilated into plant and animal tissue and is concentrated in the organic fraction of soil. Human activity in the past century has dramatically altered the nitrogen cycle by increasing the quantities of nitrogen input into soil and by accelerating the release of nitrogen from organic fractions. Anthropogenic sources of nitrogen include atmospheric deposition of nitrous oxides and ammonia associated with combustion of fossil fuels, land application of animal wastes, and application of fertilizers to agricultural crops. Much smaller but locally significant release of nitrogen-containing compounds may occur through mining, energy production, and industrial activities. Examples include soil contamination with trinitrotoluene (TNT) associated with manufacture of munitions and cyanide contamination of soils beneath coal gasification facilities.

Although nitrogen may occur in any redox state from -3 to +5, the three most important states with respect to ground water are -3, 0, and +5. Other oxidation states may occur but they are transitory and reflect systems which are not in equilibrium. The oxidation state which occurs is a function of the redox potential of the system. In natural ground water systems, the Eh boundary between nitrate and nitrogen gas is approximately 50 mV. Above this value, nitrate will be stable in ground water. Because it is poorly adsorbed and mobile, nitrate can accumulate to levels of concern. Below Eh values of about 50 mV, nitrate will undergo a series of reduction reactions called denitrification, which results in transformation of nitrate to nitrogen gas, which then volatilizes. In reducing ground water, ammonia can be a concern if there are direct sources of ammonia to the aquifer. High concentrations of nitrate and ammonia can occur simultaneously in reducing waters when nitrogen inputs are significant, as might occur beneath landfills, waste lagoons, feedlots, or failed septic systems. A less significant form of nitrogen in unimpacted ground water will be organic nitrogen. Nitrogen makes up about five percent of organic matter, by mass. Typical concentrations of organic nitrogen in ground water should therefore be approximately 100 ug/L.

Organic nitrogen and ammonia nitrogen were not measured during the baseline study. For much of the baseline dataset, a reporting limit of 500 ug/L was used for nitrate. These factors prevented a rigorous understanding of nitrogen in ground water. Not considering point sources of nitrogen, the primary source of nitrogen into ground water will be through leaching of nitrate from the unsaturated zone. There has been considerable debate regarding natural concentrations of nitrate in the soil solution and ground water. Unless conditions in ground water are sufficient for denitrification to occur, nitrate will be conservative. Consequently, in aerobic aquifers, baseline concentrations reflect concentrations likely to be found in leachate. Unfortunately, the baseline data is not ideally suited to separating data into nitrate-stable and nitrate-unstable conditions in ground water. Utilizing a procedure described by Neve et al. (1996), median nitrate concentrations were calculated for each aquifer and overall for samples in which nitrate would be expected to be thermodynamically stable. The overall median in these "nitrate stable" waters was 510 ug/L, with a 95th percentile of 18063 ug/L. The median for the Quaternary water table aquifer (QWTA) was 1750 ug/L. The median in some aquifers, such as the Cretaceous, was greater than 5000 ug/L, while in others, such as the buried Quaternary aquifers, the median was less than 500 ug/L. The overall mean for all samples, not considering nitrate stability, was less than 100 ug/L. Consequently, background concentrations of nitrate in aerobic aquifers varies, but appear to range from less than 500 to about 1500 ug/L for most aquifers. In anaerobic aquifers, background nitrate concentrations are less than 100 ug/L.

Concentrations of nitrate cannot be held below the HRL of 10000 ug/L through solubility controls. Nitrate is also poorly adsorbed and is mobile. Consequently, the primary attenuation mechanism for nitrate will be denitrification.

Nitrate concentrations were greatest in the QWTA aquifer and lowest in the Devonian aquifer. Concentrations were greater in large diameter wells, in wells containing VOCs, and in wells containing tritium. Nitrate concentrations also varied by year and by season, although the seasonal pattern varied between aquifers. Nitrate was highly correlated with the redox parameters. The overall median was well below the HRL of 10000 ug/L, but 3.25 percent of all samples exceeded the HRL, including 7.7 percent of Cretaceous samples and 5.7 percent of surficial Quaternary samples.

Nitrate cannot be held below the HRL in aerobic aquifers if a source of nitrogen exists. The primary source of nitrate will be percolation through the unsaturated zone. Nitrate is highly affected by many physical, chemical, and human factors and deserves much greater consideration than provided in this short summary. Nitrate results will be studied extensively in subsequent reports.

Oxidation-reduction potential

The oxidation-reduction (redox) potential of a system, usually expressed as the Eh (mV), is a numerical index of the intensity of oxidizing or reducing conditions within a system. This nomenclature can be somewhat confusing, since the reported values of Eh are relative to the standard hydrogen half-cell. Unlike concentrations, which represent mass per unit volume, Eh values are a relative measurement which reflects the redox status of an aqueous system. Physically, the value of Eh has little meaning, but rather expresses the tendency of a system to accept or donate electrons. For example, reducing environments would have a tendency to donate electrons.

Redox reactions are extremely important in aqueous systems. From an environmental perspective, the most important application is for chemicals which may have toxic effects in ground water. Most metal and organic contaminants of ground water are sensitive to redox reactions, and many have redox “windows” in which they will undergo transformation. This transformation may increase or reduce chemical mobility, or it may increase or decrease the toxicity of a chemical. One example is degradation of most halogenated VOCs, which generally proceeds under strongly reducing conditions. Another example is arsenic, in which the more toxic form (+3) is more prevalent under reducing conditions.

Most redox reactions are biologically mediated. Microorganisms utilize various electron acceptors in the production of food. Consequently, ground water proceeds through a series of reduction reactions. The primary electron acceptors, from most oxidized to most reduced conditions, are oxygen, nitrate, manganese (+4), iron (+3), sulfate, carbon dioxide, and finally hydrogen. Other redox couples are present but they are generally not as important as the sequence described above. Lower boundaries of these redox couples, expressed as Eh in mV, are approximately 200, 50, 25, -500, -700, -725, and -800, although these vary with pH, temperature, and water chemistry.

Despite the potential utility of measuring Eh, accurate measurement is difficult. Eh is likely to vary widely within ground water even over short distances and the Eh electrode itself is subject to a variety of processes which reduce its accuracy. These are described in numerous texts.

Despite these difficulties, general patterns of chemical behavior associated with redox values were evident from the baseline dataset. There were significant differences between aquifers, but the results are mixed. Aside from the difficulties inherent in measuring Eh, an important factor is that many sampled wells are screened near the bottom of an aquifer. Oxygen and nitrate will probably decrease rapidly in the upper ten to twenty feet of an aquifer. The redox window for manganese is relatively small, while that for iron is large. Consequently, most data fall within either the oxygen or iron windows. The most important utility of redox is in correlations with other parameters. Some of these were investigated in Section 3.2.2.

pH

The negative log of the hydrogen ion activity represents the pH. The overall median pH was 7.24. If pH is adjusted for temperatures occurring within ground water, a neutral pH would be about 7.3. The overall median pH of 7.24 was therefore close to neutral.

The pH of ground water has important effects on biogeochemical processes. Solubility of many metals and metalloids are pH sensitive. Microorganisms prefer a pH in the range of six to eight. In addition, pH can be an indicator of geochemical processes, particularly of which species may be controlling solubility.

Ninety-eight percent of the samples had pH values between 6.0 and 8.6. Acidic ground water will be more likely in aquifers overlain by acidic parent material, under forested vegetation (especially oak and coniferous species), under land receiving inorganic nitrogen fertilizers, or under land receiving direct recharge water enriched in carbon dioxide. Alkaline ground water will be more likely under silicate parent material, in sodium-enriched ground water, and under certain types of vegetation (native grass and some broadleaf species).

The pH values were greatest in some of the Precambrian aquifers, reflecting the impact of low-carbonate and silica-rich parent material. pH values were lowest in the Cretaceous and Sioux Quartzite aquifers, both of which had high concentrations of total dissolved solids, and in the undifferentiated Quaternary (QBUU and QUUU) aquifers. These aquifers have a high percentage of large diameter wells. These wells may be dug wells and the low pH may reflect direct seepage from the unsaturated zone. pH was negatively correlated with dissolved oxygen, probably because carbon dioxide concentrations will be greater in oxygenated water. More detailed information concerning land use, soil types, and geology would be needed to use pH information for interpreting ground water geochemistry data.

Phosphorus (P)

The primary phosphate-bearing mineral is apatite, which is a calcium-phosphate mineral containing variable amounts of OH^-, F^-, and Cl^-. Concentrations in rocks and soil range between 100 and

1000 mg/kg. Phosphorus is used widely in fertilizers and detergents and is enriched in sewage sludges. It is also used in some pesticides.

The predominant form of phosphorus in the environment is the oxidized form (+5), phosphate. Reduced forms, which are often associated with organic matter, are quickly oxidized except under reducing conditions. In aqueous systems, the primary form of phosphorus will be $H_2PO_4^-$ or HPO_4^{2-}. The equilibrium constant for these two species is about 7.2, which means that in most ground water samples, the two forms will be nearly equal in concentration. Phosphorus is strongly adsorbed in aqueous systems, forming complexes with metals, particularly iron and manganese. These will limit solubility of phosphorus to 10 to 100 ug/L in most ground water. The overall median concentration of phosphorus was 70.6 ug/L. The median concentrations for total phosphate and orthophosphate were 50 and 10 ug/L, respectively. At pH values observed in most samples, the orthophosphate species (OPO_4^{3-}) would be relatively unimportant.

Concentrations of phosphorus varied widely between aquifers. Concentrations were higher in some surficial aquifers (e.g., Upper Carbonate aquifers) and also in some buried aquifers (buried Quaternary aquifers). These may reflect inputs from the unsaturated zone and from weathering, respectively. Lower concentrations were observed in some Precambrian and Cambrian aquifers, probably as a result of low concentrations of phosphorus in parent materials. Phosphorus was strongly correlated with redox parameters, increasing in concentration as ground water became more reducing. This correlation reflects the association between phosphorus and various metals which become more available under reducing conditions, particularly iron and manganese.

A potentially important application of phosphorus in ground water occurs in surficial systems where ground water may be discharging to surface water. Phosphorus is an important contaminant in surface water, resulting in excess microbiological growth, oxygen depletion, and eutrophication when concentrations exceed 1000 ug/L. Surface waters have phosphorus concentrations in excess of 100 ug/L and typically in excess of 500 ug/L when there are inputs related to human activity. Ground water having concentrations of phosphorus between 50 and 100 ug/L will dilute surface water concentrations of phosphorus. The dynamics of these relationships require further investigation.

There are currently no health concerns associated with phosphorus in ground water. Phosphorus concentrations in ground water will be controlled by metal hydroxides, particularly those of iron and manganese. Hydroxides of phosphorus readily precipitate and equilibrium concentrations of phosphorus in the presence of iron and manganese will be less than 100 ug/L. Although enrichment of surficial aquifers may occur if there are phosphorus inputs into soils, concentrations should remain less than 100 ug/L because of the strong tendency to associate with hydroxides in ground water.

Selenium (Se)

Selenium is typically associated with sulfide ore deposits. Relatively high concentrations, up to 675 mg/kg, may be found in black shales and organic-rich sandstones. More typical concentrations; however, are in the 0.01 to 0.5 mg/kg range. Elevated concentrations in soil may result from atmospheric deposition of volcanic emissions. The primary forms of selenium in soil include elemental selenium at Eh values below about 40 mV, selenite ($HSeO_3^-$ or SeO_3^{2-}) at redox values up to about 440 mV, and selenate (SeO_4^{2-}) under more oxidizing conditions. The anionic forms are relatively mobile in soil, although anion exchange may occur with iron and aluminum hydroxides and organic matter. Selenium mobility increases with pH and it is thus more leachable in arid climates. Selenium has been used in the production of pigments, steel, and rubber, it is contained in phosphate fertilizers, and it is present in sewage sludges, though at concentrations less than 10 mg/kg. The primary anthropogenic source of selenium appears to be atmospheric deposition resulting from coal combustion.

Sulfides have low solubility in ground water and selenium concentrations in ground water will be very low. The primary contribution of selenium to ground water will be percolation through the unsaturated zone. Since selenium mobility will be greatest at higher pH and redox values, ground water occurring under these conditions may be susceptible to elevated concentrations. Significant correlations were observed between selenium and geographic location for surficial Quaternary aquifers, with concentrations increasing to the west and south.

Selenium toxicity in plants is well documented. Despite this, it is often deficient in soils. The overall median concentration in ground water was 1.9 ug/L, well below the HRL of 30 ug/L. There were seven exceedances of the HRL (30 ug/L). Concentrations appeared to be elevated in Quaternary aquifers and lower in the Cambrian, Devonian, and Ordovician aquifers. The primary controls on selenium in ground water appear to be related to availability of selenium in the unsaturated zone and subsequent leaching to ground water. Shallow, oxygenated aquifers will be susceptible if a source of selenium exists in the unsaturated zone.

Silica (Si)

Silica is the second most abundant element in the earth's crust. It comprises 20 to 40 percent of minerals, by weight, except for the carbonates. The chemical bond between silica and oxygen is very strong and silica therefore occurs as various oxides, generally in a hydrated state. In oxygen-rich environments, silica will occur as dissolved H_4SiO_4 or in association with some divalent metal such as magnesium in the mineral forsterite (Mg_2SiO_4). Other silica-oxygen configurations exist, including sheetlike structures such as kaolinite ($Al_2Si_2O_5(OH)_4$) and silicates with the general formula $(SiO_2)_n$.

In general, resistance to weathering for a silicate varies directly with the proportion of bonds occurring between oxygen and silica, as opposed to bonds involving other metals such as calcium, magnesium, and iron. The primary dissolved form of silica will be silicic acid (H_4SiO_4), which will dissociate at a pH of approximately 9.4. The lower solubility control on silica will be quartz, which would yield a dissolved concentration of approximately 5000 ug/L silica at neutral pH and about ten degrees Celsius. The upper end of solubility limits would be for amorphous silica, which is reported by Hem to yield silica concentrations in natural waters of 350000 to 400000 ug/L. The baseline median concentration was 10766 ug/L. Hem proposed that various amorphous forms of silica control solubility.

Silica concentrations were greatest in the Quaternary aquifers, particularly the buried aquifers. Concentrations were lowest in Cambrian and Precambrian aquifers. For the Cambrian aquifers, the low concentrations may be due to reduced concentrations of silica in carbonate aquifers, although concentrations of silica in the Jordan sandstone were similar to other Cambrian aquifers. For Precambrian aquifers, the lower concentrations may be the result of resistant parent material. Despite these differences in silica concentration between aquifers, the range in silica concentrations was relatively narrow. Most aquifers had concentrations from about 6500 to 12000 ug/L. There are currently no health concerns with silica in ground water.

Despite the natural abundance of silica, silica has a relatively minor role in ground water chemistry. In some aquifers, particularly low carbonate aquifers, silicate minerals may control solubility of some metals.

Silver (Ag)

Silver occurs primarily in metal sulfides, associated with lead, antimony, arsenic, tellurium, and selenium. It also occurs less frequently in halide minerals. Natural concentrations are low, less than 0.5 mg/kg on average. Concentrations in soil are even lower, being about 0.01 mg/kg on average. Silver has a wide variety of uses, including photography, alloys, mirrors, electronics, and pharmaceuticals. It has also been used as a microbial poison, since the soluble forms of silver, particularly the +1 form, are extremely toxic to lower life forms.

Silver has a very low solubility. The most soluble forms of silver are the chlorides, which would be expected to result in silver concentrations of approximately 0.03 ug/L. Concentrations of silver in equilibrium with sulfides and oxides would be much lower. The median concentration for silver was less than the reporting limit of 0.009 ug/L. The HRL for silver is 30 ug/L. The maximum concentration detected was 0.967 ug/L. About 65 percent of the samples were below the reporting limit. Despite significant differences in concentrations by aquifers, there was no clear pattern to the distribution of silver. Larger diameter wells showed lower concentrations of silver. If these large diameter wells were primarily dug wells, these results may reflect the low concentrations of silver likely to occur in the unsaturated zone.

Natural controls on silver solubility will maintain silver concentrations well below the HRL. Soil concentrations are likely to be even lower than those in ground water. Ground water is generally not susceptible to contamination with silver.

Sulfur (S)

Sulfur is widely distributed in rocks as metallic sulfides and sulfates, many of which are of economic importance. Sulfides have very low solubility. Upon release, sulfides may be oxidized to sulfate. Sulfate-bearing minerals are relatively common and most are highly soluble. Sulfur is important in many biogeochemical reactions and processes and is readily taken up by plants. Sulfur is recycled rather quickly in soil. Sulfur will occur in oxidized soil waters as the sulfate ion and under reducing conditions as hydrogen sulfide. Large quantities of sulfate may be released with volcanic emissions. Although sulfates are widely used in many industrial processes and in fertilizers and pesticides, the primary anthropogenic sources of sulfur are associated with burning of fossil fuels and with mining and smelting operations.

The MCL for sulfate is 500000 ug/L. The primary solubility control on sulfate will be gypsum ($CaSO_4$) in most systems. The concentration of sulfate in equilibrium with gypsum will be about 107.18 x 10^7 ug/L. Barium and strontium can form effective solubility controls in systems where their concentration is about 1000 and 10000 ug/L, respectively, but these were not encountered. The greatest control on solubility is likely to be imposed by bacterial reduction of sulfate. The minimum concentration of sulfate in ground water in equilibrium with modern day rainfall should have a concentration between 1000 and 10000 ug/L. Below Eh values of about -200 mV, sulfate will be reduced to hydrogen sulfide. Few wells have Eh values this low. Hydrogen sulfide was not analyzed.

Although sulfur concentrations in ground water are reflective of geochemical processes in an aquifer, some of these processes act to cancel each other, making interpretations of sulfur distribution difficult. Sulfur will increase in concentration as residence time increases due to increasing dissolution. This was validated by increasing concentrations of sulfate and sulfur with increasing well depth, greater concentrations of sulfur and sulfate in Cretaceous aquifers, and increasing concentrations of sulfur and sulfate from east to west. However, two factors tended to counteract these patterns. First is the increase in atmospheric sulfur concentrations during this century, which has resulted in percolation of water containing concentrations of sulfate greater than those in older ground water. For example, QWTA wells and wells containing detectable concentrations of tritium might be expected to have low concentrations of sulfate because of the influence of recharge water, which should be high in oxygen and low in dissolved solid concentrations. This was not observed; however, probably because concentrations of sulfate in percolating water reflect atmospheric inputs. The second factor is the continuous recycling of sulfur by microorganisms, which will consume sulfur and diminish the effect of dissolution reactions.

Sulfate was highly correlated ($R^2 > 0.60$) with calcium, magnesium, strontium, total dissolved solids, and specific conductivity. The correlation between total sulfur and sulfate was 0.98, reflecting the dominance of sulfate in most ground water. There was a tendency for lower Eh values and lower ratios of sulfate to total sulfur when sulfate concentrations were low (less than 250 ug/L).

Naturally-occurring sulfates cannot effectively keep the concentration of sulfate below the MCL of 500000. Concentrations rarely exceed 100000 ug/L, however. Concentrations of sulfate are probably controlled by biological processes or by the availability of sulfate-bearing minerals. Waters with high concentrations of sulfate may have poor taste and a laxative effect.

Thallium (Tl)

Generally, thallium concentrations in minerals are relatively low, but the element is widely dispersed. Some igneous rocks and shales may contain sulfides which are somewhat enriched in thallium. Thallium may also substitute for potassium in micas, feldspars, and clays. Soil concentrations are likely to vary widely because of the uneven distribution in parent rock. Most soils would be expected to have concentrations below 1 mg/kg. Thallium was once used widely as a pesticide, but has now been banned in many countries. Its use in glass, electrical engineering, and semiconductor industries is expanding. Thallium is relatively volatile and the primary anthropogenic sources of thallium are from flue dusts associated with smelting of lead and zinc sulfides and high temperature production of metals.

Geochemical information on thallium was not found. The +1 form is likely to occur in solution. Under oxidizing conditions the +3 form will precipitate as iron or manganese oxides. The HRL for thallium is very low at 0.6 ug/L. There were two exceedances of the HRL, with one sample having a concentration of 42.70 ug/L. Sixty percent of the samples were below the reporting limit of 0.005 ug/L. Thallium concentrations tended to be greatest in the Cambrian aquifers and least in the Precambrian aquifers. Correlations between thallium and potassium would be expected because thallium readily substitutes for potassium in mineral structures. No correlation was observed; however, suggesting concentrations of thallium in ground water may be limited by the availability of thallium-bearing minerals.

Temperature

Temperature is a critical factor controlling microbiological activity and solubility reactions in ground water. The primary controls on temperature in ground water were well depth and UTM-north coordinate. Temperature increased with well depth and decreased to the north. Other relationships involving temperature were relatively weak and the temperature range found in ground water is insignificant with respect to potential impacts on microbiology or geochemistry.

Tin (Sn)

The primary natural source of tin is the mineral cassiterite (SnO_2). Tin also commonly occurs in sulfide ores. Concentrations in igneous rocks and shales are a few mg/kg and much less in sandstones and limestones. Concentrations in soil range from 1 to 10 mg/kg. Tin is widely used in heavy industrial applications, including as a protective coating, in solders, and in the manufacture of bronze.

Tin, in equilibrium with cassiterite, would have a concentration of approximately 21 ug/L at pH 7.28. The median concentration was less than the reporting limit of 0.06 ug/L. The HRL is 4000 ug/L. The maximum concentration was 2.6 ug/L. Tin was the only sampled parameter in which concentrations did not differ between aquifers. Tin in ground water appears to be controlled by the availability of tin-bearing minerals, but even if these minerals were abundant, solubility controls will effectively keep the concentration of tin well below levels of concern.

Titanium (Ti)

Titanium is a common element in crustal rocks such as rutile (TiO_2) and ilmenite ($FeTiO_3$). It is also common in soils, with an average concentration of about 5000 mg/kg. Titanium is widely used in alloys, paints, ceramics, and structural materials.

Titanium oxides are extremely resistant to weathering. Little is known about solubility controls in natural waters, but Hem (1992) estimates that concentrations in equilibrium with source minerals will be less than 1000 ug/L, perhaps less than 100 ug/L. The highest concentration from the baseline data was 0.23 ug/L and over half of the samples were below the reporting limit of 0.0034 ug/L. There are currently no available health criteria for titanium. Concentrations of titanium in ground water appear to be controlled by the availability of titanium-bearing minerals.

Tritium (^3H)

Tritium represents a heavy isotope of hydrogen in which there are two neutrons and one proton, yielding an atomic mass of 3 g/mole. Tritium is a natural isotope of hydrogen, but since atomic testing began in the 1950's, concentrations of tritium in the atmosphere have been much greater than the natural background concentrations. Consequently, tritium provides a useful indicator of the relative age of ground water (pre- or post-1950's). The concentration of tritium in the atmosphere has not been stable over time, fluctuating with the level of nuclear testing. Unless a profile of tritium concentrations in rain water can be established locally, tritium concentrations in ground water cannot be used to estimate the age of ground water. Ground water containing tritium at concentrations greater than about ten tritium units (TUs) is assumed to reflect "young" water (post-1950's), samples with tritium concentrations less than 0.8 TUs (non-detect) reflects "old" water (pre-1950's), and water with tritium concentrations between 0.8 and ten TUs is considered to be "mixed."

Tritium correlated well with many parameters considered to reflect the relative age of ground water. Concentrations of chloride, nitrate, and dissolved oxygen were greater in wells containing detectable tritium, while concentrations of boron, iron, bicarbonate, magnesium, and manganese were greater in wells not containing detectable tritium. Tritium was less effective as an indicator of age in aquifers which are highly responsive or not responsive to recharge, such as the Quaternary water table (QWTA) and Cretaceous aquifers, compared to aquifers with variable hydrologic sensitivity, such as some of the Ordovician and Cambrian aquifers. Sampling was biased in that tritium was only sampled in wells considered to be potentially hydrologically sensitive. The primary utility of tritium appears to be for aquifers with variable hydrologic sensitivity or for highly sensitive aquifers in which nitrates are not detected. Absence of nitrate and presence of tritium is an indication that nitrate inputs into an aquifer are low or that nitrate is being reduced within the aquifer.

Vanadium (V)

Vanadium is primarily associated with nickel and iron sulfides. It is relatively common in igneous rocks and shales. Concentrations are lower in sandstones and limestones. Average concentrations in soil are approximately 100 mg/kg. The major anthropogenic sources of vanadium are related to fossil fuel combustion, both through atmospheric deposition and land application of fly ash. Vanadium is widely used in industry but generally in small quantities.

The chemical behavior of vanadium is complex. Three oxidation states, +3, +4, and +5, can be present in solution, but the +5 form is considered to be most important. Hem (1992) estimated a vanadium solubility of about 10 ug/L in a system in equilibrium with 10000 ug/L sulfate and 61000 ug/L bicarbonate. Vanadium will interact with iron and organic matter, but there is insufficient information to establish solubility relationships for these compounds. Vanadium is readily reduced, particularly by organic matter.

The overall median concentration of vanadium was 4.9 ug/L, but 480 samples were below the reporting limit of 4.6 ug/L. The HRL is 50 ug/L. Two samples exceeded the HRL and another 181 samples exceeded 10 ug/L. The strongest correlations for vanadium were with copper, nickel, and titanium. Well diameter had a large impact on vanadium concentrations, with concentrations being greater in large diameter, dug wells.

Solubility controls on vanadium should keep concentrations in ground water below the HRL. However, the predicted concentrations are sufficiently close to the HRL, vanadium is relatively abundant in rocks and soil, vanadium can be mobile in soil in the absence of organic matter and iron, and there is enough uncertainty about the behavior of vanadium in the environment to warrant some concern for this element in ground water.

Zinc (Zn)

Natural sources of zinc include the minerals smithsonite ($ZnCO_3$), sphalerite and wurtzite (ZnS), willemite (Zn_2SiO_4), zincite (ZnO), and zinkosite ($ZnSO_4$). Concentrations range from 10 to 30 mg/kg in sedimentary rocks to 40 mg/kg in granites to 100 mg/kg in basalts. Anthropogenic sources include atmospheric deposition resulting from combustion of fossil fuels, sewage sludges, and to a lesser extent, crop amendments. Atmospheric deposition also occurs as the result of volcanic eruptions. Zinc occurs in soil in a variety of forms, including free zinc (+2), as hydroxides ($Zn(OH)_2$), including association with iron and aluminum hydroxides, and fractions associated with organic ligands. Zinc is somewhat immobile in soil due to precipitation, but its mobility increases rapidly as pH decreases.

Stability diagrams indicate zinc solubility may be controlled by carbonates or silicates, although Neve (1996) points out that precipitation of zinc silicates is very slow in ground water. Below redox values of approximately -100 to -150 mV, sulfides will control solubility. Zinc sulfides and silicates are both relatively insoluble and will hold the concentration of zinc well below 1 ug/L. The theoretical concentration of zinc in equilibrium with carbonate is approximately 2300 ug/L. The HRL for zinc is 2000 ug/L. The theoretical value is close enough to the HRL to warrant geochemical analysis in individual wells. Neve (1996) computed theoretical concentrations in individual wells and observed that 73 percent of sampled wells had theoretical concentrations less than the HRL, although the majority of these were in the 1000 to 2000 ug/L range.

The overall median concentration for zinc was 15.7 ug/L, well below the theoretical concentration. Ten samples had zinc concentrations of 996 ug/L or greater, with one exceedance of the HRL (3224 ug/L). Alkalinity was greater in these ten wells (351000 ug/L) than overall (294000 ug/L). In general; however, zinc concentrations in ground water appear to be limited by availability of zinc-bearing minerals, since concentrations are above the theoretical values calculated for silicate- or sulfide-controlled systems, but well below the theoretical concentration for a carbonate-controlled system.

Ground water in which carbonates control zinc solubility is moderately susceptible to contamination with zinc. Concentrations may be held near the HRL. Soil concentrations of zinc in equilibrium with $Zn(OH)_2$ range from approximately 15 ug/L at pH 6 to less than 1 ug/L at pH 7.

Zirconium (Zr)

Little information is available on the occurrence of zirconium in the environment. Zirconium may occur as oxides or hydroxides, both in soil and parent rock. Concentrations in rocks and soil can be relatively high, exceeding 100 mg/kg. The aqueous form of zirconium is as a hydroxide. Zirconium in equilibrium with ZrO_2 would have a theoretical concentration exceeding 1000 ug/L at pH 7.28. Zirconium mobility in soil is extremely low and presence of zirconium is often used as an indicator of weathering. Zirconium was undetected in most samples at a reporting limit of 0.02 ug/L. Eleven samples exceeded 1 ug/L, with a maximum of 5.8 ug/L. There are no current health criteria for zirconium. The occurrence of zirconium in ground water appears to be limited by availability or weathering rates of zirconium-bearing minerals.

3.3. Organics - Volatile Organic Compounds

Organics in sampled wells were treated as a binomial population in which a VOC was either detected or not detected in individual wells. Non-detections were treated as zeroes.

3.3.1. Descriptive Summaries

Results for VOCs are summarized in Tables D.117 and D.118 by aquifer and chemical class, respectively. There were a total of 162 VOC detections in 109 wells. Twenty wells (2.1 percent) had more than one chemical class detected and two wells (0.2 percent) had three chemical classes detected. Twenty-five wells (2.6 percent) had more than one compound detected. Many of the greater detection frequencies were for aquifers with small sample sizes. However, the overall frequency of detection was relatively high for the Cretaceous (24 percent) and Precambrian (21 percent) aquifers. The distribution of chemical classes within the Cretaceous was relatively uniform, but there was a greater incidence of detection of chlorofluorocarbons (CFCs) in the Precambrian group. This may reflect atmospheric inputs of CFCs. Travel times may be reduced in these aquifers because of fracturing within the bedrock. Detection frequencies in the buried and surficial Quaternary aquifer groups were 11 and 13 percent, respectively. Distribution of chemical classes within the Quaternary aquifers followed the overall trend of detection for VOCs, with trihalomethanes (THMs) being the most commonly detected chemical class, followed by nonhalogenated and then halogenated compounds. The overall frequency of VOC detection was 11 percent.

The occurrence of THMs in a domestic well is often attributed to well disinfection with chlorine. However, THMs may form naturally within ground water if there is sufficient chlorine and organic carbon present. THMs have been reported in shallow monitoring wells which had not been disinfected and to which no apparent source of the VOCs could be identified (MPCA, 1998b).

3.3.2. Factor Analysis

The non-halogenated aromatic compounds were strongly positively correlated with well diameter and tritium, which may suggest relatively young water (Table D.119). However, the presence of these VOCs was also positively correlated with calcium, alkalinity, sodium, and potassium. Increased concentrations of these chemicals often reflects older water which has undergone dissolution and ion exchange. Nonhalogenated aromatic compounds will occur in sensitive hydrologic settings, such as shallow surficial aquifers. However, some nonhalogenated VOCs will also be recalcitrant in anaerobic ground water and this persistence may account for the correlations with inorganic chemicals which indicate older ground water.

The halogenated aliphatic compounds, including THMs and CFCs, were strongly negatively correlated with apparent age of ground water (positive correlations with factors indicating recent water, such as tritium, nitrate, and chloride and negative correlations with factors suggesting older waters, such as calcium, alkalinity, magnesium, and sodium) and positively correlated with oxidation-reduction potential (positive correlation with redox and dissolved oxygen, negative correlation with sulfate and manganese) (Tables D.120 through D.122). These compounds should be more prevalent in sensitive hydrologic settings and under oxidizing conditions. It may be that redox conditions and hydrologic sensitivity are correlated, which masks the importance of either of these two factors. However, it is apparent that aquifers sensitive to contamination with inorganic chemicals resulting from activities at the land surface are also sensitive to halogenated aliphatic VOCs.

The ketones (Class 3) showed no strong relationship with any factor (Table D.123). This may be partly due to the small number of wells in which these compounds were detected. Ketones, particularly acetone, which accounted for two of the three detections, are common laboratory contaminants and laboratory contamination of these samples cannot be dismissed.

The ether compounds, which include tetrahydrofuran, showed strong positive correlations with many chemicals, including manganese, calcium, potassium, sodium, and magnesium (Table D.124). These may reflect older, reducing waters. However, the correlations with redox parameters were not particularly strong. The mixed results for these compounds may reflect their relatively recalcitrant nature and high mobility.

Well diameter was positively correlated with presence of VOCs, both overall ($p = 0.0076$) and for many chemical classes. It is unclear if this is due to increased pumping in large capacity wells, which may pull shallow ground water deeper into the aquifer, or poor well construction associated with dug wells, or both. Additional analysis of these will be conducted in a follow-up report.

3.3.3. Health and Risk

Drinking water criteria (HRLs) for VOCs were exceeded in four wells. A summary of the VOC exceedances is provided in Table D.125. VOCs are included in the analysis and discussion presented in Section 3.2.3. Individual VOC contributions to hazard indices are not discussed in this report. The effect of VOCs on overall median and 95th percentile hazard indices was negligible, although a few individual wells had elevated hazard indices attributable to the presence of VOCs.

3.3.4. Geochemical Interpretations for Individual Parameters

Correlating the presence of individual VOCs with geochemical conditions in ground water is a very difficult task. In addition to understanding the chemical data, detailed geologic interpretations may be required. These are beyond the scope of this paper and consequently, no additional discussion is presented. However, a follow-up report is planned to summarize additional analysis relating presence of VOCs in sampled wells to aquifer geochemistry.

Summary/
Examples

Part IV: Summary and Examples

This chapter presents a summary and examples of analysis results. The objectives are to provide the reader with general information and recommendations for how to use the baseline information. Limitations are discussed and should be considered when applying the baseline information. Examples are provided concurrently with the summary. Three comprehensive problems are presented at the end of the chapter.

4.1. Inorganics

Inorganic chemicals occur naturally in ground water. With adequate sampling, the natural distribution of inorganic chemicals in different aquifers can be determined. Detailed information regarding analysis methods and analysis results is presented in Parts II and III, respectively. Geographic Information System (GIS) coverages and data are available upon request.

4.1.1. Chemical Distributions

A rigorous statistical analysis was conducted to determine the distribution of 52 inorganic chemical and water quality parameters sampled from Minnesota's principal aquifers and aquifer groups. Concentration distributions have been established for selected parameters from these aquifers. The types of distribution (normal or log-normal) and descriptive statistics were determined for sampled parameters. A description of the principal aquifers and aquifer groups is provided in Table 1.

Assumptions and Considerations

The primary assumptions applied during this analysis are summarized below. A number of points are included which the reader should consider. Assumptions pertaining to statistical analysis are discussed in greater detail in MPCA, 1998a.

- For aquifers and aquifer groups, data were assumed to come from a single population.
- Analysis for outliers was not conducted.
- Non-detections were censored at the highest reporting limit and treated as missing data in the analyses.
- No data were eliminated based on QA/QC criteria.
- All samples were collected from wells with permanent pumps (primarily domestic wells).
- Samples were not filtered.

- Sampled wells were selected based on aquifer designation. Factors such as screened interval, presence of confining layers, or other hydrologic or geologic factors were not extensively examined.
- Information on land use was not considered in this analysis.
- Data near the minimum and maximum concentrations may appear inconsistent with other summary information. This is due to large variability in the distribution of some chemicals.
- Censored data were analyzed with curve-fitting methods. These are described in Newmann et al., 1995. This methodology assumed a log-normal distribution for the parameter of interest.
- Spatial analysis could not be conducted with the sampling design employed during this study. Nevertheless, qualitative and semi-quantitative evaluation of data may suggest spatial patterns to the data. Users are encouraged to utilize GIS coverages of the data.

GWMAP results correlated well with other monitoring studies conducted in Minnesota. Additional monitoring information may be found in various United States Geological Survey (USGS) hydrologic reports, Minnesota Geological Survey (MGS) and Minnesota Department of Natural Resources (DNR) Atlas and regional assessments, and Minnesota Pollution Control Agency and Minnesota Department of Agriculture, 1991. An extensive and formal literature search of existing data from Minnesota's principal aquifers was not conducted as part of this study.

Application of Results - Chemical Distributions

1. **Chemical distributions can be described for the principal aquifers in Minnesota.** Summary statistics are provided in Tables D.6 through D.44. Summary statistics include the number of samples and censored values, type of distribution, mean, median, minimum, maximum, 95th percentile, and 95th percent upper confidence limit concentrations (ug/L).

Example 1 - What are the mean, median, 95th percentile, and 95th percent upper confidence limit concentrations of lead, cadmium, nitrate, and iron in the Prairie du Chien (OPDC), Jordan (CJDN), and Quaternary water table (QWTA) aquifers?

Solution - Statistical summaries are illustrated in Tables D.9, D.18, and D.35 for the CJDN, OPDC, and QWTA aquifers, respectively. The values are read directly from these tables and are shown in Table 7 below.

Table 7: Summary statistics for Example 1.

Parameter	Mean (ug/L)	Median (ug/L)	95th UCL (ug/L)	95th Percentile (ug/L)
Lead				
CJDN	0.46	0.40	4.6	6.4
OPDC	0.44	0.50	4.8	4.4
QWTA	0.19	0.18	2.4	3.6
Cadmium				
CJDN	0.048	0.060	1.0	3.5
OPDC	0.074	0.075	1.4	2.9
QWTA	0.029	< 0.020	0.15	0.16
Nitrate				
CJDN	45	< 500	3646	5324
OPDC	649	< 500	9042	10864
QWTA	310	< 500	8348	10400
Iron				
CJDN	133	246	8977	4750
OPDC	225	487	458	4028
QWTA	492	811	16899	9884

Interpretation - Mean and median concentrations for a particular parameter within an individual aquifer should be relatively close. The same should be true for 95th percentile and 95th percent upper confidence limit (UCL) concentrations. These comparisons appear reasonable for lead. UCL concentrations for cadmium are about half or less of the 95th percentile concentrations for the CJDN and OPDC aquifers. This indicates there are a few relatively large values in the data. Mean and median concentrations cannot be compared for nitrate because of the high degree of censoring (non-detections). The 95th UCL and 95th percentile concentrations for nitrate are reasonably close to each other. The differences between mean and median iron concentrations suggest the log-transformation did not adequately describe the distribution of iron. UCL and 95th percentile concentrations also differ widely for iron. In the case of the CJDN and QWTA aquifers, the UCL concentration is greater than the 95th percentile concentration, suggesting large variability in the data. For the OPDC aquifer, the UCL concentration is less than the 95th percentile concentration, reflecting the effect of a few high concentrations in individual wells.

Comments - The data for lead, cadmium, and nitrate appear reasonable. Large variability within individual aquifers for iron suggest that more detailed analysis of the data may be warranted. When 95th percentile and UCL concentrations vary widely, as with some of the data in this example, the UCL concentration is probably more useful for smaller sample sizes (less than about 40). As sample size increases, the UCL and 95th percentile concentrations should become more similar. If they are not similar for large sample sizes, the data distribution should be reassessed.

---

2. **Chemicals with the greatest likelihood of exceeding drinking water criteria have been identified for the principal aquifers in Minnesota.** A qualitative summary of parameters, by aquifer and aquifer group, is provided in Table 8. Three categories were established using Tables D.6 through D.44 and assuming that five percent of samples exceeding the drinking criteria represents a moderate probability of exceedance.
   - Category 1: The upper 95th percent confidence limit and the 95th percentile concentrations were both less than 25 percent of the drinking water criteria. These are considered to be chemicals in which the probability of exceeding the drinking criteria is very low.
   - Category 2: The greater of the upper 95th percent confidence limit or the 95th percentile concentration was between 25 and 100 percent of the drinking water criteria. These are considered to be chemicals in which the probability of exceeding the drinking criteria is low to moderate.
   - Category 3: The upper 95th percent confidence limit or the 95th percentile exceeded the drinking water criteria. These are considered to be chemicals in which the probability of exceeding the drinking criteria is moderate to high.

The following drinking water criteria were used, in order of priority: Health Risk Limit (HRL), Health Based Value (HBV), Maximum Contaminant Level (MCL) and Secondary Maximum Contaminant Level (SMCL). **NOTE: The HRL and HBV are health-based criteria, while the MCL and SMCL, are not strictly health-based. The HRL represents a promulgated value, while MCLs are enforceable for public drinking supplies. Drinking water criteria are summarized for individual chemicals in Table D.111.** The following chemicals or chemical parameters had no drinking water criteria at the time of this report: alkalinity (bicarbonate), bismuth, bromide, calcium, cesium, potassium, lithium, magnesium, sodium, phosphate, orthophosphate, total phosphorus, specific conductance, pH, rubidium, oxidation-reduction potential, total sulfur, silicate, temperature, total dissolved solids, total organic carbon, total suspended solids, titanium, and zirconium. There was insufficient sample size to calculate summary statistics for many aquifers. Summary statistics could not be calculated for many parameters within aquifer groups because mean concentrations of these parameters differed between the aquifers comprising the group (see Section 2.2.1).

Table 8: Summary of chemicals which fall into one of three analysis categories: the greater of the 95th percentile or 95 percent upper confidence limit is 1) less than 25 percent of the drinking water criteria; 2) 25 to 100 percent of the drinking water criteria; and 3) exceeds the drinking water criteria.

Aquifer or Aquifer Group	No. of samples	Category 1	Category 2	Category 3	No calculation
Franconia-Ironton-Galesville (CFIG)	5	As, Ba, Cr, Cl, Sr, SO_4, Zn	B, Mn	Fe	Al, Sb, Be, Cd, Co, Cu, F, Pb, Hg, Mo, Ni, NO_3, Se, Ag, Sn, Tl, V
Franconia (CFRN)	27	Al, Sb, Ba, Cd, Cr, Cl, Co, Cu, F, Ni, Mo, SO_4, Sr, Ag, Se, Sn, Zn	B, As, Be, Pb, Mn, NO_3, Tl, V	Fe	Hg
Ironton-Galesville (CIGL)	8	Al, Sb, As, Ba, Cd, Cr, Cl, Co, Cu, F, Pb, Ni, Sr, Ag, Se, Sn, V, Zn	Be, B, Mn, SO_4, Tl	Fe	Hg, Mo, NO_3
Jordan (CJDN)	31	Al, Sb, As, Ba, Cr, Cl, Co, Cu, Mo, Ni, Se, Ag, Sr, SO_4, Sn, V, Zn	Be, B, Cd, Pb, Mn, NO_3, Tl	Fe	F, Hg
Mount Simon-Hinckley (CMSH)	10	Al, Sb, As, Ba, Cd, Cr, Cl, Co, Cu, F, Pb, Ni, Se, Ag, Sr, SO_4, Sn, Zn	B, Mn, Mo, NO_3, V	Be, Fe	Hg, Tl
Mount Simon (CMTS)	13	Sb, As, Ba, B, Cd, Cr, Co, Cu, F, Pb, Mn, Se, Ag, Sr, SO_4, Tl, Sn, V, Zn	Be, NO_3	Al, Fe	Cl, Hg, Mo, Ni
St. Lawrence-Franconia (CSLF)	4	insufficient sample size	-	-	-
St. Lawrence (CSTL)	4	insufficient sample size	-	-	-
Cedar Valley (DCVA)	10	Al, Sb, Ba, Cr, Cl, Co, Cu, F, Pb, Hg, Mo, Ni, Se, Ag, Na, Sr, SO_4, Tl, V, Zn	As, Be, B, Mn,	Cd, Fe	Sn, NO_3
Cretaceous (KRET)	39	Sb, As, Ba, Cd, Cr, Co, Cu, Hg, Ag	Cl, Pb, Be, Mn, Mo, Ni, Se, Sr, Tl, V, Zn	F, Fe, B, Al, NO_3, SO_4,	Sn
Galena (OGAL)	22	Al, Sb, Ba, Cr, Co, Cu, F, Mo, Ni, Se, Ag, Sr, Tl, Zn	As, B, Be, Cd, Cl, Pb, Mn, SO_4, V	Fe, NO_3	Sn, Hg
Maquoketa (OMAQ)	1	insufficient sample size	-	-	-

Aquifer or Aquifer Group	No. of samples	Category 1	Category 2	Category 3	No calculation
Prairie du Chien (OPDC)	36	Sb, As, Ba, Cr, Co, Cu, Hg, Mo, Ni, Se, Ag, Sr, SO_4, Sn, V	Al, Be, B, Cd, Cl, F, Pb, Mn, Tl, Zn	Fe, NO_3	-
Platteville (OPVL)	3	insufficient sample size	-	-	-
St. Peter-Prairie du Chien (OSPC)	2	insufficient sample size	-	-	-
St. Peter (OSTP)	23	Al, Sb, As, Ba, Cr, Cl, Co, Cu, F, Pb, Ni, Se, Ag, Sr, SO_4, Tl, Zn	Be, B, Mn, Mo, NO_3, V	Cd, Fe	Hg, Sn
Precambrian crystalline formations (PCCR)	26	Sb, Cd, Cl, Cr, Co, Cu, Ni, Ag, Tl, Sn	Ba, Pb, Mn, Se, Sr, V, Zn	Al, As, Be, B, F, Fe, Mo, NO_3, SO_4	Hg
Undifferentiated Precambrian formations (PCUU)	3	insufficient sample size	-	-	-
Biwabik Iron Formation (PEBI)	1	insufficient sample size	-	-	-
Duluth Complex (PMDC)	1	insufficient sample size	-	-	-
Mount Simon-Fond du Lac(PMFL)	2	insufficient sample size	-	-	-
Mount Simon-Hinckley (PMHN)	3	insufficient sample size	-	-	-
North Shore Volcanics (PMNS)	17	Sb, As, Ba, Cd, Cr, Cl, Co, Cu, Mn, NO_3, Ag, Sr, SO_4, Tl, Sn, Zn	F, Mo, Ni, Se, V	Al, Be, B, Fe	Hg, Pb
Sioux Quartzite (PMSX)	4	insufficient sample size	-	-	-
Undifferentiated Proterozoic Metasedimentary Units (PMUD)	23	Sb, As, Ba, Cd, Cr, Co, Cu, Ni, Ag, Sr, SO_4, Tl, Sn, Zn	B, F, Pb, Mn, Mo, NO_3, V	Al, Be, Cl, Fe, Se	Hg
Quaternary buried artesian (QBAA)	387	Ba, Cd, Cl, Cr, Co, Cu, Pb, Hg, Ni, NO_3, Ag, Tl, Sn, Zn	Al, Be, F, Mn, Mo, Se, Sr, V	Sb, As, B, Fe, SO_4	-
Quaternary undifferentiated artesian (QBUA)	104	Sb, Ba, Cd, Cr, Cl, Co, Cu, Pb, Hg, Ni, Ag, Sr, Tl, Sn, Zn	Al, As, Be, B, F, Mn, Mo, Se, SO_4, V	Fe, NO_3	-

Aquifer or Aquifer Group	No. of samples	Category 1	Category 2	Category 3	No calculation
Quaternary buried undifferentiated (QBUU)	22	Sb, Ba, Cd, Co, Cr, Cu, F, Ni, Ag, Tl, Zn	Cl, Pb, Mn, NO_3, Mo, Se, Sr, V	Al, As, Be, B, Fe, SO_4	Sn, Hg
Quaternary unconfined undifferentiated (QUUU)	4	insufficient sample size	-	-	-
Quaternary water table (QWTA)	119	Sb, As, Ba, B, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Ag, Sr, SO_4, Tl, Sn, Zn	Be, Cl, F, Mn, Se, V	Al, Fe, NO_3	-
Cambrian (Cxxx)	102	Sb, As, Ba, Cd, Cr, Cl, Co, Cu, Hg, Mo, Ni, Se, Ag, Sn, V	Al, Be, B, F, NO_3, SO_4	Fe	Pb, Mn, Sr, Tl, Zn
Ordovician (Oxxx)	87	Al, Cl, Co, Cu, Mo, Ni, Se, Sr, SO_4, Sn, Zn	Be, B, F, Pb, Mn, NO_3, Tl, V		Sb, As, Ba, Cd, Cr, Fe, Hg, Ag
Precambrian (Pxxx)	80	Sb, As, Cd, Cr, Co, Cu, Ag, Tl, Sn, Zn	F, Pb, Mn, Mo, Ni, NO_3, Se, V	Be, Fe	Al, Ba, B, Cl, Hg Sr, SO_4
buried Quaternary (QBxx)	513	Ba, Cu, Pb, Hg, Sn	Al, Mn, V		Sb, As, Be, B, Cd, Cr, Cl, Co, F, Fe, Mo, Ni, NO_3, Ag, Se, Sr, SO_4, Tl, Zn
surficial Quaternary (QUUU and QWTA)	123	As, B, Cr, Co, Cu, Pb, Hg, Ag, Tl, Sn, Zn	Be, Cl, Mn, Se	Al, Fe	Sb, Ba, Cd, F, Mo, Ni, NO_3, Sr, SO_4, V
St. Peter-Prairie du Chien-Jordan (CJDN, OSTP, OSPC, OPDC)	90	Al, As, Cu, Hg, Mo, Ni, Se, Ag, Sn, V	Be, Mn, Pb, NO_3, Tl, Zn	Cd, Fe	Sb, Ba, B, Cr, Cl, Co, F, Sr, SO_4
Franconia-Ironton-Galesville (CFIG, CFRN, CIGL)	40	Sb, As, Ba, Cr, Cl, Co, Cu, Pb, Mo, Ni, Ag, Sr, SO_4, Sn, V	Al, Be, B, Cd, F, Mn, NO_3, Se, Tl, Zn	Fe	Hg
Mount Simon-Hinckley (CMTS, CMSH, PMHN)	26	Sb, As, Ba, Cd, Cr, Co, Cu, Pb, Mo, Ni, Se, Ag, Sr, SO_4, Tl, Sn, Zn	Al, Be, B, Cl, F, Mn, NO_3, V	Fe	Hg
Upper Carbonate (OGAL, OMAQ, OPVL, DCVA)	36	Al, Sb, Ba, Cr, Cu, Pb, Mo, Ni, Se, Sr, Tl, Zn	As, B, SO_4, V	-	Be, Cd, Cl, Co, Fe, F, Hg, Mn, NO_3, Ag, Sn

----

Example 2 - In which aquifers is there a five percent or greater chance that the drinking water criteria will be exceeded for nitrate? for cadmium?

Solution - Reading directly from Table 8, five percent or more wells, randomly selected, would exceed the HRL for nitrate in the Quaternary water table, Quaternary buried unconfined, Precambrian crystalline, Prairie du Chien, Galena, and Cretaceous aquifers. Five percent or more of randomly selected wells would exceed the HRL for cadmium in the Cedar Valley, St. Peter, and St. Peter-Prairie du Chien-Jordan aquifers.

Interpretation - If 100 wells were randomly sampled in the Prairie du Chien aquifer, five or more percent of these wells would exceed the HRL for nitrate. Exact probabilities can be calculated using the baseline data and a statistical software package.

Comments - All drinking water criteria are used and no distinction is made among health-based criteria, MCLs (which are enforceable for public drinking supplies), and non-enforceable criteria (see Table D.111 for individual drinking water criteria).

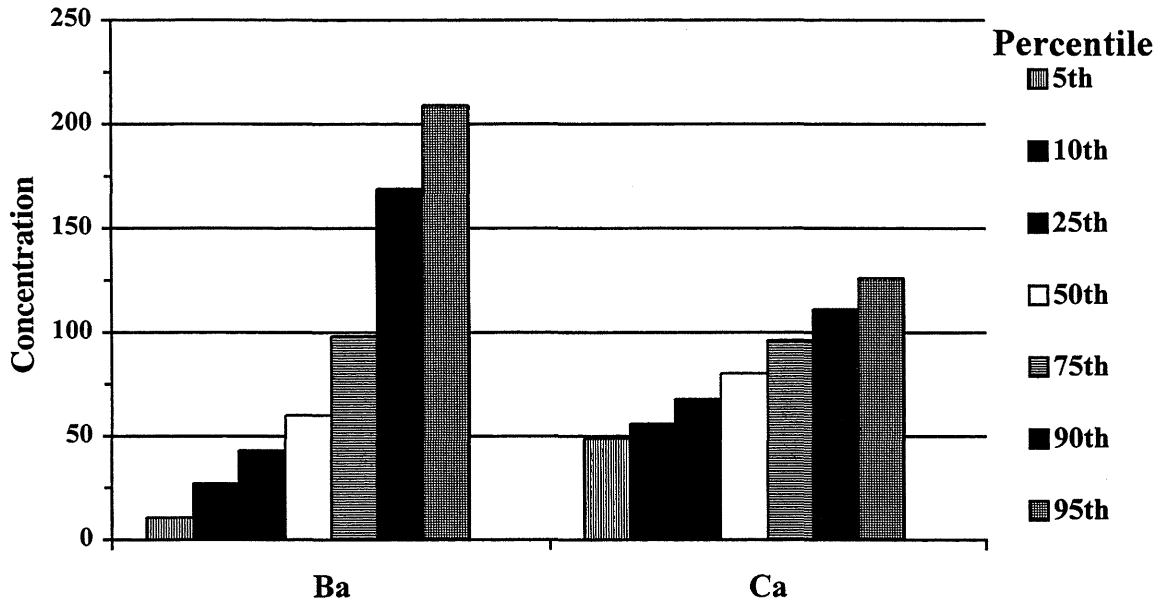
---

3. **Percentile concentrations can be determined for chemicals in Minnesota's principal aquifers.** Percentiles are nonparametric descriptive statistics for an aquifer. They provide an indication of the data spread based strictly on the sampled wells. They do not allow for predicting probabilities. If the true distribution is well described by the sampled wells, use of percentiles is a quick way of describing the distribution of a population.

Example 3. What are 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentile concentrations of barium and calcium in the Prairie du Chien aquifer?

Solution. To make these calculations, the baseline data were used in a statistical software package. The percentiles were specified and the resulting output is summarized graphically in Figure 2 below. **The baseline data are available on request. The data can be delivered in either spreadsheet or database format.**

Figure 2: Distribution of barium and calcium in the Prairie du Chien aquifer (OPDC). Barium concentrations are in ug/L and calcium in mg/L.



Interpretation. An illustration such as Figure 2 can be used to represent the distribution of data at certain percentiles. For example, concentrations of 100 and 96000 ug/L lie at the 75th percentile for barium and calcium, respectively, in the Prairie du Chien aquifer. If 100 wells were randomly selected from the Prairie du Chien aquifer, 25 percent of these sampled wells would be expected to exceed concentrations of 100 and 96000 ug/L for barium and calcium, respectively, assuming the distributions shown in Figure 2 are an accurate estimator of the true distribution. The log-normal and normal distributions are apparent for Ba and Ca, respectively.

Comments. Use of percentiles gives concentrations at user-specified percentiles. Interpolating concentrations between these percentiles is inexact and may lead to significant errors if the underlying distribution of data is not well understood. It is best not to interpolate between percentiles but rather make the desired calculation in a statistical software package.

---

4. **The probability of having a particular chemical concentration in a well can be determined for Minnesota's principal aquifers.** If data can be fit to a normal or log-normal distribution, the probability of having a particular concentration can be quantified. Two equations can be utilized to

estimate the probability of having a particular concentration or to determine the concentration at a particular probability, α:

$$C = \mu \pm t_{\alpha}\sigma/\sqrt{n} \qquad [17]$$

$$C = \exp(a + bz_{\alpha}) \qquad [18]$$

where C is the concentration (ug/L), μ is the mean concentration (ug/L), σ is the standard deviation, n is the sample size, a and b are regression coefficients (see Part III, Section 3.2.1), and t and z are coefficients associated with a particular probability α. Equation 17 is applied for normal and log-normal distributions and Equation 18 is applied to log-censored data. Log-censored data are data which could be fit to a log-normal distribution but in which there were values below the reporting limit. Means (μ) and types of distribution are illustrated in Tables D.6 through D.44, values for n and σ are contained in Table D.45, values for a and b are shown in Table D.46, and values for t and z are illustrated in Tables 3 and 5 or can be found in standard statistical texts. **NOTE: Calculating distributions, percentiles, or probabilities makes no distinction between natural and anthropogenic sources for a chemical in ground water. Because of the nature of the sample design, most of the samples collected will represent natural conditions. Consequently, statistical parameters which represent central tendencies, such as the mean, median, and quartiles, are likely to represent natural concentrations, while statistical parameters which represent variability and extremes in the data, such as the standard deviation and upper confidence limits, may reflect either natural variability or human effects.**

In many cases, it will be more desirable to apply data which were collected for a particular location, such as a county, region, or watershed. The baseline data can be queried to achieve the subset of data desired for a particular application. This can be accomplished by requesting GWMAP to do the querying and associated analysis or by requesting the baseline data.

Example 4. Calculate the upper bound concentrations of nitrate and chloride which will occur in 90, 95, and 99 percent of a randomly selected set of wells completed in the Quaternary water table aquifer (QWTA).

Solution. We are interested in the upper bounds of these data. The probabilities (α) for 90, 95, and 99 percent of the data correspond with probabilities of 0.10, 0.05, and 0.01, respectively. However, these probabilities include data above and below a certain confidence level. For example, at a probability of 0.10 or ten percent, five percent of the data will be below some value and five percent will be above some value, with the 90 percent occurring between these two points. When we want the upper bound we are interested in a probability of $\alpha/2$. We therefore want t values for ($\alpha/2$) which corresponds with the t values at 0.10/2, 0.05/2, and 0.01/2 or 0.05, 0.025, and 0.005, respectively. From Table 3 (Section 2.2.1), the t values are 1.67, 2.00, and 2.66, respectively. Table D.35 indicates that the distribution for chloride was log-normal and the mean was 5102 ug/L or 3.708 ug/L after transformation. From Table D.45 the standard deviation (σ) and sample size (n) were 0.71 and 119, respectively. These values are inserted into Equation 17 for each different value of t. The results are then transformed back. The resulting concentrations are 6561, 6887, and 7586 ug/L at the 90, 95, and 99 percent probability levels, respectively. Nitrate followed a log-censored distribution (see Table D.35) and Equation 18 is used. Values for a and b are taken from Table D.46 for QWTA aquifers and are 5.737 and 2.058, respectively. Values for z from Table 5 are 1.65, 1.95, and 2.6 for the 90, 95, and 99 percent levels, respectively. Inserting these values into Equation 18 gives concentrations of 11304, 17262, and 45842 ug/L at the 90, 95, and 99 percent probability levels, respectively.

Interpretation. If 200 wells were randomly sampled from the QWTA aquifer, 199 wells (99.5 percent) would be expected to have chloride concentrations less than 7311 ug/L. To reiterate, we were looking at just an upper bound, so a 99 percent confidence interval and an upper bound of the 99 percent distribution are not the same. In this data, there would be one well (0.5 percent) which would have a low concentration which is equally as far from the mean concentration as 7311 ug/L was above the mean value. The standard deviation for chloride was relatively small compared to the mean and there is not much spread to the data, even at the 99 percent level. For nitrate, 99.5 percent of randomly sampled wells would be expected to have nitrate concentrations less than 45842 ug/L. This is well above the HRL of 10000 ug/L and the large spread in the nitrate concentrations is evident. This is not surprising, considering the sensitivity of QWTA aquifers to nitrate contamination and the likelihood that many wells completed in these aquifers will have elevated nitrate concentrations.

Comment - Note the values for t and z were essentially equal. This is true for larger sample sizes. Equation 17 indicates that the concentration at a particular probability may change considerably as sample size changes. When designing a monitoring program in which these types of statistical analysis will be used, the effects of sample size should be considered.

Example 5 - The concentration of chloride and nitrate in a well were 4792 and 891 ug/L, respectively. What percent of randomly selected wells from this aquifer will have concentrations greater than the concentrations observed in this well?

Solution - Equations 17 and 18 need to be rearranged to solve for t and z, since these values are associated with probabilities:

$$t_\alpha = (C - \mu)\sqrt{n}/\sigma \qquad [19]$$

$$z_\alpha = (\ln(C) - a)/b \qquad [20].$$

Equations 19 and 20 are solved for t and z. All other values remain the same as in Example 3, except for C. C is log transformed for chloride, and the calculated value of t is -0.422. The corresponding probability is $\alpha/2 = 0.33/2 = 0.165$. However, the concentration of 4792 ug/L is below the mean, as indicated by the negative value for t. We therefore need to add 0.50 to it to account for the 50 percent of the wells that will exceed the mean. The resulting probability of exceeding a concentration of 4792 ug/L chloride in a randomly selected well is therefore (0.50 + 0.165) or 66.5 percent. This means if 100 wells were randomly sampled from this aquifer, 66.5 would have a concentration greater than 4792 ug/L. Considering the nitrate concentration, inserting values for C, a, and b for nitrate, z is equal to 0.512. The corresponding probability, from Table 3, is $\alpha/2$ or about 0.30/2 or 0.15. If 100 wells were randomly sampled from this aquifer, about 15 percent of the wells would be expected to have concentrations greater than 891 ug/L.

Comments - Another way of looking at probabilities is to consider a probability as representing the likelihood that the observed concentration equals the mean concentration. Consequently, a probability of 0.10 means there is a ten percent chance that the concentration in a well equals the overall mean concentration for that aquifer. This concept primarily applies to a population of wells, however. For example, in the above problem, if 100 wells were sampled and the mean concentration of nitrate was 891 ug/L, then there is a ten percent chance that the mean for this population equals the mean from the baseline data. For an individual well which we are comparing to the baseline data, a probability of 0.10 means we would expect 90 percent of other sampled wells to have concentrations less than the concentration in this well. If we want the percentage of wells which are a certain distance from the mean, then we would consider a two-tailed analysis because we would also want the low values.

4.1.2. Factor Analysis

A rigorous statistical analysis was conducted for several factors which may potentially affect the concentrations and distribution of chemicals in ground water. Hypothesis tests and correlation tests were conducted using nonparametric procedures. Hypothesis tests were conducted for each of the following factors:

- aquifer;
- age-based aquifer group;
- hydrology-based aquifer group;
- well diameter;
- presence or absence of VOCs;
- presence or absence of tritium;
- sampling year; and
- sampling month.

In all cases the null hypothesis was that concentrations did not differ between the treatments or groups within each factor. Examples of treatments or groups are the individual years within the factor "sampling year." The null hypothesis, in this case, states that concentrations did not differ between different sampling years. Output from hypothesis tests include the probability that the null hypothesis is true and information on the variability in the data, which can then be used to determine which treatments within a factor differ. Examples are provided below.

Correlation analysis was conducted between chemical concentration and the following factors:

- well depth;
- static water elevation;
- UTM-east coordinate;
- UTM-north coordinate;
- dissolved oxygen concentration;
- total iron concentration;
- total manganese concentration; and
- redox potential.

Correlations were conducted for all chemical parameters. The null hypothesis in all cases was that values for the factor were not correlated with chemical concentration. Output data for correlation analysis includes the probability that the null hypothesis is true and the correlation coefficient, which quantifies the amount of variability accounted for by the correlation. Examples are provided below.

Assumptions and Considerations

The primary assumptions applied during this analysis are summarized below. In addition, there are a number of points the reader should consider.

- Any assumption in Section 4.1.1 (*Chemical Distributions*) which applies to factor analysis is valid for factor analysis.
- Many aquifers had very small sample sizes. Sample size does not hamper the applicability of the various tests, but additional tests comparing individual treatments are strongly influenced by sample size, in particular the Least Significant Difference test. Aquifers with small sizes which appear to have very low or high concentrations for a particular chemical should be viewed with caution.
- The correlation analysis conducted for this study utilizes a nonparametric procedure, which involves comparison of ranks instead of concentrations. Consequently, the results can be used to predict the tendency for lower or higher concentrations of a chemical in response to the factor being considered. The results cannot be used to predict a concentration as the factor changes.
- Presence or absence of a VOC was used in a hypothesis test. The absence (non-detection) of a VOC in a well does not mean VOC(s) were not present, since the VOC(s) may be present at a concentration below the reporting limit or may be a VOC not included in the MDH 465 list.

Application of Results - Factor Tests

1. **There were significant differences between individual aquifers in concentrations of all sampled parameters except tin.** The p-values of most hypothesis tests were less than 0.01. This means the probability that the null hypothesis was true is less than 0.01, significantly less in most cases. Most statistical procedures utilize a value of 0.05 to identify factors where there are significant differences between treatments. P-values for all chemicals are illustrated in Table D.47. Included in Table D.47 are ranks and the Least Significant Difference (LSD). Application of the LSD is illustrated in examples 15 and 16.

Example 6 - What are the probabilities that median concentrations of tin, vanadium, nickel, and cadmium are equal in all aquifers? For which chemicals would you assume the concentrations differ between aquifers?

Solution. The probabilities that median concentrations of tin, vanadium, nickel, and cadmium are equal in all aquifers are taken directly from Table D.47. and are 0.569, 0.049, 0.001, and less than 0.001, respectively.

Interpretation. We conclude that median concentrations of tin are equal in all aquifers and that median concentrations of nickel and cadmium are different. The value of 0.049 for vanadium may be sufficiently low to establish significant differences for some ground water managers or programs but not for others.

Comment. The level at which significant differences are considered to occur is subjective. Most people use a value of 0.05, but when a high degree of assurance is desired, a value of 0.01 may be used. Similarly, if less assurance is required, a value of 0.10 may be used. In some cases, the goal may simply be to quantify the probability without using this value for making decisions.

---

2. **There were significant differences between age-based aquifer groups in concentrations of all sampled parameters except dissolved oxygen and tin.** P-values for all chemicals are illustrated in Table D.48. Included in Table D.48 are ranks and the Least Significant Difference (LSD). Application of the LSD is illustrated in examples 15 and 16.

Example 7 - What are the probabilities that median concentrations of tin, vanadium, nickel, and cadmium are equal in all age-based aquifer groups? For which chemicals would you assume the concentrations differ between aquifers?

Solution. The probabilities that median concentrations of tin, vanadium, nickel, and cadmium are equal in all aquifer groups are taken directly from Table D.48 and are 0.171, 0.043, 0.010, and less than 0.001, respectively.

Interpretation. We conclude that median concentrations of tin are equal in all aquifer groups and that median concentrations of nickel and cadmium are different. The value of 0.043 for vanadium may be sufficiently low to establish significant differences for some ground water managers or programs but not for others.

Comment. See comment in example 6.

---

3. **There were significant differences between hydrology-based aquifer groups in concentrations of many sampled parameters.** The number of significant differences in chemical concentrations were fewer and p-values were greater than for age-based aquifer groups. P-values for all chemicals are illustrated in Table D.49 for hydrology-based aquifer groups Included in Table D.49 are ranks and the Least Significant Difference (LSD). Application of the LSD is illustrated in examples 15 and 16.

Example 8 - What are the probabilities that median concentrations of tin, vanadium, nickel, and cadmium are equal in all hydrology-based aquifer groups? For which chemicals would you assume the concentrations differ between aquifers?

Solution. The probabilities that median concentrations of tin, vanadium, nickel, and cadmium are equal in all aquifers are taken directly from Table D.49. and are 0.147, 0.648, 0.015, and less than 0.001, respectively.

Interpretation. We conclude that median concentrations of tin and vanadium are equal in all aquifers and that median concentrations of nickel and cadmium are different.

Comment. Chemical concentrations, in general, are more similar within the hydrology-based groups than within age-based groups. One reason for this is that the geology within the hydrology-based groups is more uniform than within the age-based groups. Comparing ground water in equilibrium with different geologic materials will reflect the differences in these parent materials.

---

4. **Median concentrations of most chemical parameters differed between wells with different diameters.** Results for all wells combined are illustrated in Table D.50, for age-based aquifer groups in Tables D.51 through D.57, and for hydrology-based aquifer groups in Tables D.58 through D.61. In general, the number of significant differences were fewer for aquifer groups than for all groups combined. Part of this is due to smaller sample sizes within the aquifer groups. Large diameter wells (greater then eight inches in diameter) may impact water chemistry in two ways. First, municipal wells are typically large diameter wells which pump large quantities of water across a large screened interval. This mixes water from different vertical positions in an aquifer. Second, large diameter domestic wells are often dug wells. Water from the unsaturated zone and upper portions of an aquifer may contribute to the water pumped from these wells, since these wells often leak along joints in the casing. This may account for the greater concentrations of chemicals which are likely to be greater in concentration in the soil solution than in ground water, including vanadium, antimony, molybdenum, nitrate, nickel, dissolved oxygen, and chloride.

Example 9 - What are the probabilities that median concentrations of tin, vanadium, nickel, and cadmium are equal in wells with different well diameters? For which chemicals would you assume the concentrations differ between diameter classes?

Solution. The probabilities that median concentrations of tin, vanadium, nickel, and cadmium are equal in all wells, regardless of well diameter, are taken directly from Table D.50. and are 0.372, 0.003, 0.001, and less than 0.001, respectively.

Interpretation. We conclude that median concentrations of tin are probably equal in all wells, regardless of well diameter, and that median concentrations of vanadium, nickel, and cadmium are probably different. Chemicals which are more prevalent in the unsaturated zone or in near-surface ground water are more likely to be affected by larger well diameters. Tin does not appear to show vertical variability in ground water or between the unsaturated zone and ground water. Nickel and vanadium are potentially mobile in the unsaturated zone and their concentrations appear to be elevated in larger diameter wells, perhaps reflecting inputs from the unsaturated zone. Cadmium is relatively immobile in soil and concentrations appear to be lower in larger diameter wells compared to smaller diameter wells.

Comment. Actual differences between individual well diameter groups were not calculated in this example and the above interpretations are subjective. Identifying actual differences between treatments will be illustrated in Examples 15 and 16.

---

5. **Median concentrations of some chemical parameters differed between wells containing a detected VOC and wells with no detected VOCs.** Aluminum, cesium, chloride, copper, dissolved oxygen, lead, nitrate, and redox potential were greater in wells containing a detected VOC. Alkalinity and barium concentrations were greater in wells not containing a detected VOC. Results are illustrated in Table D.62. A summary of significant differences by aquifer group is illustrated in Table D.63. The presence of VOCs may reflect relatively recent water. This may account for the results for cesium, chloride, dissolved oxygen, nitrate, and redox potential. Reasons for the association with aluminum, copper, and lead are not clear, unless the presence of these chemicals is directly related to the presence of the VOC(s).

6. **Median concentrations of some chemical parameters differed between wells containing detectable tritium and wells with no detectable tritium.** Aluminum, chloride, chromium, dissolved oxygen, nitrate, silicate, and thallium concentrations were greater in wells containing detectable tritium. Alkalinity, boron, iron, magnesium, manganese, molybdenum, potassium, strontium, phosphate, and total suspended solid concentrations were less in wells which did not contain detectable tritium. Presence of tritium reflects water which is post-1953 in age. Tritium is therefore a useful indicator of recent water. However, tritium was only sampled in wells which were considered to potentially be hydrologically sensitive. The most interesting results are for nitrate, dissolved oxygen, chromium, iron, and manganese. These parameters are all strongly related to redox potential and indicate that tritium may be a useful indicator of redox conditions within ground water. This has implications for the mobility, persistence, and toxicity of many chemicals. Results are illustrated in Table D.64 for all wells combined. Significant results (p less than 0.05) are illustrated in Table D.65 for aquifer groups.

7. **Median concentrations of some chemical parameters within the same aquifer group differed between wells sampled in different years.** In a true random design, differences in concentration would not be expected between different sampling years. The observed differences may be due to several factors:

- effects of weather, primarily as it relates to recharge;
- differences in sampling methods;
- differences in laboratory analysis methods;
- physical factors such as geology; and
- random chance.

The effect of these factors was not explored in this analysis. Differences in concentration between sampling years are undesirable because they add variability to the data which was not accounted for in the hypothesis tests and correlation analysis. Reasons for the yearly differences will be addressed in subsequent analyses. Differences in physical factors, such as geology, are an important consideration when comparing aquifer groups. For example, if we are comparing concentrations of a chemical in Cambrian wells between different years, but most of the samples were from the Jordan aquifer in one year and from the Mt. Simon in another year, apparent differences in concentration may be due to differences between these two aquifers rather than differences attributable to sampling year. Ideally, the effect of sampling year would be conducted for individual aquifers, because differences in geology can be eliminated as a confounding factor. Applications to individual aquifers are illustrated in Examples 10 and 11.

Example 10 - What are the probabilities that median concentrations of tin, vanadium, nickel, and cadmium were equal in wells sampled from the Jordan aquifer in different years? For which chemicals would you assume the concentrations differ between months?

Solution. The Jordan is a Cambrian aquifer. The probabilities that median concentrations of tin, vanadium, nickel, and cadmium are equal in all wells, regardless of sampling year, are taken directly from Table D.66 and are 0.616, 0.002, 0.009, and 0.005, respectively.

Interpretation. We conclude that median concentrations of tin are equal in all wells, regardless of sampling year, and that median concentrations of vanadium, nickel, and cadmium are different.

Comment. Since the number of samples collected from the Jordan aquifer was relatively large (31 samples), we could conduct year-to-year comparisons for just the Jordan aquifer. This analysis was conducted and the resulting probabilities for vanadium, nickel, and cadmium were 0.283, 0.445, and 0.979, respectively. Tin was only sampled in 1996. These results indicate that differences in concentrations of these parameters by sampling year are related to differences in concentrations of these chemicals between the individual aquifers comprising the Cambrian group. This is a desirable result because the confounding effects of sampling year are eliminated when looking only at the Jordan aquifer.

---

8. **Median concentrations of some chemical parameters within the same aquifer group differed between wells sampled in different months.** In a true random design, differences in concentration would not be expected between different sampling months. The observed differences may be due to the same factors which led to yearly differences. Differences in concentration between sampling months are undesirable because they add variability to the data which was not accounted for in the hypothesis tests and correlation analysis. Reasons for the monthly differences will be addressed in subsequent analyses.

Example 11 - What are the probabilities that median concentrations of tin, vanadium, nickel, and cadmium were equal in wells sampled from the Jordan aquifer in different months? For which chemicals would you assume the concentrations differ between months?

Solution. The Jordan is a Cambrian aquifer. The probabilities that median concentrations of tin, vanadium, nickel, and cadmium are equal in all wells, regardless of sampling month, are taken directly from Table D.77 and are 0.026, 0.017, 0.218, and 0.002, respectively.

Interpretation. We conclude that median concentrations of nickel are equal in all wells, regardless of sampling month, and that median concentrations of tin, vanadium, and cadmium are different.

Comment. Since the number of samples collected from the Jordan aquifer was relatively large (31 samples), we could conduct month-to-month comparisons for just the Jordan aquifer. This analysis was conducted and the resulting probabilities for tin, vanadium, nickel, and cadmium were 0.613, 0.035, 0.330, and 0.609, respectively. These results indicate that differences in concentrations of tin, nickel, and cadmium by sampling month are related to differences in concentrations of these chemicals between the individual aquifers comprising the Cambrian group. Vanadium concentrations; however, did differ by month. This result is interesting, since vanadium is a relatively mobile chemical in soil. An interesting test at this point would be to determine which months or seasons had the greatest concentrations of vanadium and then attempt to correlate this with ground water recharge.

---

9. **Concentrations of many chemical parameters were correlated with well depth and static water level.** Results for correlation tests are summarized in Tables D.88 through D.94 for age-based aquifer groups and Tables D.95 through D.98 for hydrology-based aquifer groups. Negative correlations indicate the concentration for a chemical parameter decreases with depth or with static water level, while positive correlations reflect an increase in concentration with depth. The results vary widely between aquifer groups, both in the number of significant correlations, the parameters for which there are significant correlations, and in some cases the sign (+ or -) of the correlation. The most consistent correlations were with nitrate (-), dissolved oxygen (-), tritium (-), iron (+), and boron (+). When these chemicals are present in sufficient amounts to be quantified, they are good indicators of depth-related processes within an aquifer.

Example 12. What are the probabilities that concentrations of tin, vanadium, nickel, and cadmium were correlated with well depth in the Jordan aquifer? For those chemicals in which significant correlations were observed, what percentage of the variability in the concentration is **not** accounted for by the correlation?

Solution. The Jordan is a Cambrian aquifer. The probabilities that concentrations of tin, vanadium, nickel, and cadmium are correlated with well depth are taken directly from Table D.88 and are 0.021, 0.423, 0.753, and 0.139, respectively.

Interpretation. We conclude that concentrations of vanadium, nickel, and cadmium are not correlated with well depth, whereas concentrations of tin are correlated with well depth. The correlation coefficient for tin is -0.347. This means concentrations of tin decrease with increasing well depth and that 34.7 percent of the variability in tin concentration is explained by the relationship with well depth. This means 65.3 percent of the variability in tin concentrations is due to some other factor(s).

Comment. Since the number of samples collected from the Jordan aquifer was relatively large (31 samples), we could conduct this analysis for just the Jordan aquifer. This analysis was conducted and the resulting p-values for tin, vanadium, nickel, and cadmium were 0.904, 0.865, 0.170, and 0.241, respectively. We would conclude that none of these parameters is correlated with well depth.

---

10. **Concentrations of most chemical parameters were correlated with UTM-east and UTM-north location within age-based aquifer groups, and concentrations of many parameters were correlated with UTM coordinates within hydrology-based groups.** UTM coordinates increase from west to east and from south to north. Negative correlations reflect an increase in concentration from east to west or an increase in concentration from north to south. Most of the significant correlations were negative. There were more significant correlations and stronger correlations for UTM-east coordinate compared to UTM-north coordinate. The following general factors may contribute to the results:
    - glacial tills change in chemistry, primarily from east to west;
    - thickness of glacial cover increases from east to west and north to south;
    - recharge decreases from east to west and from north to south; and
    - temperature of ground water decreases from south to north.

    Because of these factors, there is a tendency for increased residence time, greater dissolution and ion exchange, reduced rates of weathering, and less dilution of ground water from east to west and from north to south. Effects of human activity, particularly in the Twin Cities Metro area and from agriculture, cannot be discounted but were not considered in this analysis. The major cations and anions and boron were the most highly correlated parameters with UTM-east and always increased in concentration from east to west. The correlations differed somewhat for UTM-north, reflecting the effect of source material to a greater extent than UTM-east coordinate. For some aquifers, trace metals such as silver, cobalt, titanium, and cadmium had the highest correlation coefficients with UTM-north coordinate. Another example is orthophosphate, which was the most highly correlated parameter for the surficial Quaternary group, probably reflecting the impact of increasing agriculture to the south.

Example 13. What are the probabilities that concentrations of tin, vanadium, nickel, and cadmium were correlated with UTM-east and UTM-north coordinate in the Jordan aquifer? For those chemicals in which significant correlations were observed, what percentage of the variability in the concentration is **not** accounted for by the correlation?

Solution. The Jordan is a Cambrian aquifer. The probabilities that concentrations of tin, vanadium, nickel, and cadmium are correlated with well depth are taken directly from Table D.88 and are 0.343, 0.981, less than 0.001, and 0.165 for UTM-east coordinate, respectively, and 0.012, 0.159, 0.274, and 0.002 for UTM-north coordinate, respectively.

Interpretation. We conclude that concentrations of tin, vanadium, and cadmium are not correlated with UTM-east coordinate, concentrations of nickel are correlated with UTM-east coordinate, concentrations of vanadium and nickel are not correlated with UTM-north coordinate, and concentrations of tin and cadmium are correlated with UTM-north coordinate. The correlation coefficients for the significant relationships with nickel, tin, and cadmium are 0.385, 0.377, and -0.302, respectively. This means concentrations of nickel increase from west to east, concentrations of tin increase from south to north, and concentrations of cadmium increase from north to south. The percentage of variability in nickel, tin, and cadmium concentration due to some factor other than UTM coordinate is [(1-probability)*100] or 61.5, 62.3, and 69.7, respectively.

Comment. Since the number of samples collected from the Jordan aquifer was relatively large (31 samples), we could conduct this analysis for just the Jordan aquifer. This analysis was conducted and the resulting p-values for tin, vanadium, nickel, and cadmium were 0.565, 0.731, 0.023 ($R^2 = 0.406$), and 0.246 for UTM-east coordinate and 0.694, 0.988, 0.184, and 0.972 for UTM-north coordinate, respectively. We conclude that only nickel was correlated with UTM-east coordinate, with concentrations increasing from west to east. This example illustrates that whenever possible, the most detailed level of analysis possible is desired. In this example, using data from just the Cambrian group would have been misleading if we were strictly interested in the Jordan aquifer.

---

11. **Concentrations of many chemicals were correlated with redox parameters.** Redox potential, and dissolved oxygen, iron, and manganese concentrations were used as indicators of redox conditions within ground water. Redox potential and dissolved oxygen concentration increase with increasingly oxidizing conditions, while iron and manganese concentrations increase with increasingly reducing conditions. The strongest correlations were for concentrations of arsenic, barium, iron, manganese, phosphorus, and total suspended solids, which increased with increasingly reducing conditions, and for concentrations of nitrate, dissolved oxygen, and redox potential, which increased with increasingly oxidizing conditions. Many other chemicals, such as boron and phosphate, showed a

moderate response to the redox parameters, while some chemicals such as nickel and molybdenum showed little or no response. The correlations seemed to reflect two independent processes. First, there are parameters which are redox sensitive. Examples include arsenic, oxygen, nitrate, iron, sulfate, and manganese. Second, ground water typically becomes more reducing as residence time increases. The extent of dissolution and ion exchange reactions typically also increase with residence time. Consequently, many parameters which increase in concentration as a result of dissolution and ion exchange reactions, such as potassium, sodium, and chloride, also increased in concentration as ground water became more reducing, although these chemicals are not redox-sensitive.

Example 14. Which chemical parameters appear to be the most highly correlated with redox parameters for the surficial Quaternary aquifer group?

Solution. We could arbitrarily select the three most highly correlated chemical parameters for each of the four redox parameters. The strength of a correlation which is considered to be significant (p less than 0.05) is indicated by the absolute value of the correlation coefficient (R^2). Using Table D.105, the three strongest correlations with dissolved oxygen were for tin (+0.414), nitrate (+0.397), and beryllium (-0.323). The three strongest correlations with iron were for orthophosphate (-0.899), total suspended solids (+0.818), and nitrate (-0.654). The three strongest correlations with manganese were for orthophosphate (-0.899), iron (+0.563), and total suspended solids (+0.511). The three strongest correlations with redox potential were for iron (-0.549), nitrate (+0.544), and total suspended solids (-0.438).

Interpretation. Nitrate, orthophosphate, iron, and total suspended solids appear more than once in these results. Iron, orthophosphate, and total suspended solids show consistently increasing concentrations with more reducing conditions, while nitrate shows consistently increasing concentrations with more oxidizing conditions. The correlations are strongest for iron and manganese.

---

12. **The occurrence of VOCs in wells coincided with parameters which reflect recent water.** VOCs were more likely to be found in wells with high nitrate, dissolved oxygen, copper, lead, aluminum, and tritium concentrations, in wells with lower pH and barium concentrations, and in large diameter wells. The relationships with nitrate, dissolved oxygen, well diameter, and tritium all reflect recent

water. The relationship with dissolved oxygen was not significant for nonhalogenated aromatic compounds, as would be expected, since these compounds will be degraded in the presence of oxygen. The pH effect may be related to activity of the hydroxyl ion, which is involved in hydrolysis reactions with halogenated compounds. The relationships with lead, copper, and barium are interesting, but cannot be explained with existing information. The results for individual chemical classes are illustrated in Tables D.119 through D.124.

13. **For hypothesis tests involving more than two treatments, it can be determined which treatments differ in concentration for a particular chemical.** Several statistical procedures are available. The Least Significant Difference (LSD) method was utilized in this report. The LSD is given by:

$$\text{LSD} = t_{\alpha/2,N-y}\sqrt{MS_E(1/n_i + 1/_{nj} + \ldots + 1/n_z)} \qquad [21]$$

where MS_E is the expected mean square for error, N is the total number of samples, y is the number of treatments (i.e., aquifers in Example 1), n is the number of samples in treatments i through z, α is the probability. In the tables where LSD is provided, a value of 0.05 was chosen for α. However, the probability, α, of two treatments being equal in concentration can also be determined by rearranging the above equation to solve for MS_E at the 0.05 level:

$$MS_E = (1/(1/n_i + 1/_{nj} + \ldots + 1/n_z))(\text{LSD}/t)^2 \qquad [22];$$

then solving for t at different values for LSD:

$$t = \text{LSD}/\sqrt{MS_E(1/n_i + 1/_{nj} + \ldots + 1/n_z)} \qquad [23].$$

This procedure seems complicated but it is potentially very useful. The following two examples illustrate the use of these calculations.

Example 15. Which aquifers have significantly different concentrations of nitrate and manganese than the Quaternary water table aquifer (QWTA)? What is the probability associated with these calculations?

Solution. Table D.47 indicates that the probability of nitrate and manganese concentrations being equal in all aquifers is less than 0.0001 for both chemicals. We conclude that concentrations do differ between some aquifers. The LSD provides the difference in ranks (remember nonparametric methods were used), at the 0.05 level, at which we conclude concentrations differ between aquifers. The probability associated with calculations involving the LSD values illustrated in Table D.47 is therefore 0.05. The interpretation of LSD is that any two aquifers which differ in mean rank by more than the LSD are considered to differ in concentration at a probability of 0.05. The mean rank nitrate value for the QWTA is 543 and the LSD is 275. Any aquifer with a mean rank less than 268 (543 - 275) has lower concentrations of nitrate than the QWTA aquifer, while any aquifer with a mean rank greater than 818 (543 + 275) has greater concentrations. The only aquifer qualifying for either of these criteria is the Maquoketa (OMAQ), with a rank of 901, which reflects concentrations greater than those in the QWTA aquifer. For manganese, the mean rank in the QWTA aquifer was 556 and the LSD was 242. Aquifers with mean ranks less than 314 (556 - 242) had lower manganese concentrations than the QWTA aquifer and aquifers with mean ranks greater than 798 (556 + 242) had greater concentrations. The St. Peter-Prairie du Chien (OSPC) aquifer had greater concentrations (mean rank = 829) and the Jordan (CJDN, mean rank = 277) and OMAQ (mean rank = 160) had lower concentrations.

Comments. Two important points should be noted. First, some aquifers had a very small sample size. The OMAQ aquifer, for example, had one sample. Aquifers with small sample sizes are more influenced by small or large mean ranks, thus limiting the utility of comparisons in Table D.47. Second, the LSDs are very large in Table D.47, since looking at all aquifers individually greatly increases the variability in the data. In particular, small sample sizes will have a dramatic effect on the LSD as shown in Equation 21. Two alternatives are recommended to comparing individual aquifers. The first is to compare aquifer groups. Close examination of Table D.48., in which aquifer groups are compared, reveals that LSD values are much smaller than in Table D.47. Comparing surficial Quaternary aquifer manganese concentrations with other aquifer groups indicates that manganese concentrations are greater in the surficial Quaternary group than in Cambrian, Devonian, Ordovician, and Precambrian aquifer groups. The second alternative is to conduct a nonparametric two-sample test (Mann-Whitney) between individual aquifers. If the desired comparisons are known, these can be conducted quickly within a statistical software package. For example, suppose a user wants to compare nitrate concentrations between Quaternary water table (QWTA), Quaternary buried artesian (QBAA), and Cretaceous (KRET) aquifers. This is a comparison of some importance in southwestern Minnesota, for example. Using the baseline data, the user would simply run three separate Mann-Whitney tests comparing QWTA with

QBAA, QWTA with KRET, and QBAA with KRET aquifers. These analyses were conducted and showed that concentrations did not differ between the QWTA and KRET aquifers ($p = 0.26$), did not differ between the QBAA and KRET groups ($p = 0.22$), but were significantly greater in the QWTA aquifer than in the QBAA aquifer (p less than 0.0001). This is potentially very useful information, since it indicates surficial aquifers are more sensitive to nitrate contamination than deeper aquifers, but that there are some potentially confounding effects in areas where Cretaceous aquifers interact with Quaternary aquifers. It would be even more useful to conduct these tests using data only from the geographic areas of concern, provided sample sizes were sufficiently large. It is evident that as the number of aquifers being compared increases, the number of potential comparisons increases very quickly.

Example 16. What is the probability that nitrate concentrations in surficial Quaternary and buried Quaternary aquifers are equal?

Solution. This is a difficult problem but is potentially very important. Examination of Table D.48 shows that the LSD for nitrate is 77 and that mean ranks for surficial and buried Quaternary groups differ by 75. These are very close and we would conclude that concentrations do not differ at the 0.05 level. We can calculate the exact probability rather than rely on the uncertainty of the results shown in Table D.48. The first step is to set up Equation 22:

$$MS_E = (1/(1/n_i + 1/_{nj} + ... + 1/n_z))(\text{LSD}/t)^2$$

and retrace some procedures made in the initial calculation of LSD. First, we assumed α was equal to 0.05. Another assumption was that t at this probability was equal to 2.0. This is reasonable for general analysis, but for this example we want an exact value for t. Table 3 (Section 2.2.1) shows that t is equal to 2.000 for a sample size of 60, but the sample size in this example is much larger. The t value for a sample size of 120, for example, is actually 1.98, and that is the value we will use in this example. Next, we know the LSD is 77. We get the sample sizes from Tables D.31 and D.35 for the QBAA and QWTA aquifers, respectively, and find them to be 386 and 119. We used QWTA and QBAA because these are representative of the surficial and buried Quaternary systems. We can now calculate the mean square for error (MS_E) and calculate it as:

$$MS_E = 1/(1/386 + 1/119)(77/1.98)^2 = 1/(0.0026 + 0.0084)(38.89)^2$$

$$= (1/(0.0110))(1512.2) = 137486.$$

Next we solve for t using Equation 23 and the observed difference of 75 in place of the LSD:

$$t = \text{LSD}/\sqrt{MS_E}(1/n_i + 1/_{nj} + \ldots + 1/n_z) = 75/\sqrt{137486(0.0110)} = 75/38.89 = 1.93.$$

Now we look up this value of t in a statistics book and find the corresponding value of α. We find the α value to be about 0.0578. The probability of nitrate concentrations being equal in the surficial and buried Quaternary aquifer groups is about 0.06.

Comments. Users unfamiliar with the statistical procedures described above should be aware of a few issues. First, many tables containing t-values show what is called a "two-tailed" value. The example above was only concerned with one-tail. Thus, the t-table from which the calculations were made in this example used the α value of 0.025 because it was a two-tailed table. Second, the importance of sample size should be evident from Equations 21, 22, and 23. The effect of sample size on the above calculations becomes very important as sample size decreases. For example, if the sample sizes were reduced to 25, t values were adjusted accordingly, and the other values remained the same, the calculated value for α would be 0.0542, which upon rounding becomes 0.05. The final consideration is more general in nature. The LSD is a parametric procedure, using the mean square for error, which is a measure of the variability in the population. However, remember that the hypothesis test was nonparametric. The calculation of LSD is done on the ranks rather than the concentrations. As in example 15, it would be best to use the baseline data directly in a statistical software package and make the desired calculations.

4.1.3. Health and Risk

The percentage of wells exceeding drinking water criteria was calculated for each chemical having a Health Risk Limit (HRL), Health-Based Value (HBV), Maximum Contaminant Level (MCL), or Secondary Maximum Contaminent Level (SMCL). These calculations were made for each aquifer, for each age-based aquifer group, and for each hydrology-based aquifer group.

A risk analysis was performed in which the hazard index was calculated for nine different target endpoints. These calculations were made for each aquifer, for each age-based aquifer group, and for each hydrology-based aquifer group. The hazard index considers all chemicals with the same target endpoint. An example is the kidney endpoint, which includes the chemicals molybdenum, tin, and cadmium. A hazard index gives the approximate ratio of observed concentration to the health-based drinking water criteria.

Assumptions and Considerations

Risk analysis provides potentially useful information regarding the suitability of an aquifer for drinking supply. However, it is important to understand limitations of the risk analysis.

- Only health-based drinking water criteria, the HRLs and HBVs, were used in the calculations, except for the MCL in the case of arsenic.
- The effects of chemicals with the same endpoint are additive.
- The exposure assumptions are for lifetime ingestion of two liters of water per day and a body weight of 75 kg.
- A hazard index of 1.0 or less indicates water which is considered to have no adverse health effects for the endpoint being considered. A value greater than 1.0 reflects a condition in which additional analysis is required to determine if the exposure assumptions are applicable and to better quantify the distribution of chemicals affecting the target endpoint.
- The risk analysis was based on information available at the time of this report. Health information is frequently updated, including derivation of HRLs for chemicals which formerly lacked them, upgrading a HBV to a HRL, changing a HRL, or changes in target endpoints. The simplest way of assessing the impact of changes is to compare the information in table D.111 with updates to drinking water criteria.

Application of Results: Health and Risk

1. **Frequencies for exceeding drinking water criteria were calculated for all chemicals.** The percentage of wells exceeding the drinking water criteria were, from greatest to least, iron (67.9), boron (8.7), aluminum (6.5), manganese (4.1) sulfate (3.7), nitrate (3.3), beryllium (2.3), fluoride (1.3), and several others which had less than 1.0 percent frequency of exceedance. Manganese, boron, nitrate, and beryllium have health-based drinking water criteria, **although the drinking criteria for manganese used in this report is modified from the HRL (MDH, 1997).** Exceedances of boron were greatest in Cretaceous (33.3 percent), surficial Quaternary (16.3 percent), and Precambrian (12.5 percent) aquifer groups. Exceedances of manganese were greatest in the Precambrian (6.25 percent) and surficial Quaternary (5.7 percent) aquifer groups. Exceedances of

nitrate were greatest in Cretaceous (7.7 percent) and surficial Quaternary (5.7 percent) groups. Exceedances of beryllium were greatest in Precambrian (5.0 percent) groups, particularly the crystalline and North Shore Volcanic aquifers. Exceedances of fluoride were relatively high in the Cretaceous aquifer group (7.7 percent).

Example 17. What were the percentage of wells exceeding the drinking water criteria for boron, manganese, beryllium, and arsenic in Precambrian wells? Which individual aquifers had the greatest rates of exceedance? Which of these criteria are health-based?

Solution. The percentage of wells exceeding drinking water criteria are read directly from the Precambrian column in Table D.112. The percentage of wells exceeding the drinking water criteria for boron, manganese, beryllium, and arsenic in Precambrian wells was 12.5, 6.25, 5.0, and 0.0, respectively. There were four exceedances for boron in the North Shore Volcanic aquifer (PMNS) and three exceedances for the crystalline aquifers (PCCR and PCCU). The exceedances for manganese were spread among several aquifers, although two of the four Sioux Quartzite (PMSX) samples exceeded 1000 ug/L. Exceedances for beryllium were greatest for the Duluth Complex (100 percent but just one sample), North Shore Volcanics (29.4 percent), and the Sioux Quartzite aquifer (PMSX, 25 percent but just four samples). The MCL for arsenic was exceeded in one well (a PCCR well). The HRL and HBV are health-based criteria and thus boron, manganese, and beryllium drinking water criteria are health-based (see Table D.111), **although the value of 1000 ug/L used for manganese is modified from the HRL (100 ug/L), as outlined in the MDH memo of (MDH, 1997)**. The drinking water criteria for arsenic is the MCL, which is not strictly health based since it considers factors such as treatability.

Comments. Sample size must be considered when looking at these data. When sample sizes are small, as they are for many of the Precambrian aquifers, a single exceedance can greatly affect the results.

---

2. **There were only four exceedances of the HRL for VOCs.** Although the frequency of detection for VOCs was about ten percent, the only exceedances of the HRL were for tetrachloroethene (8.6 ug/L), benzene (22 ug/L), 1,1-dichloroethene (12 ug/L), and tetrahydrofuran (480 ug/L) in four different wells.

3. **Risk analysis was performed, including calculation of median hazard indices and probability of exceeding health-based drinking water criteria for nine target endpoints.** Risk analysis focuses on target endpoints, such as cancer, and therefore includes the additive effect of all chemicals which impact the same endpoint. There was a greater than ten percent chance of exceeding a hazard index of 1.0 for the cancer and reproductive endpoints in Precambrian wells, the cardiovascular/blood and reproductive endpoints in Cretaceous wells, the kidney endpoint in Cedar Valley wells, the kidney endpoint in St. Peter wells, the cancer and reproductive endpoints in crystalline bedrock wells, and the cancer, nervous, and reproductive endpoints in QBUU (Quaternary buried unconfined undifferentiated) wells. Chemicals which contribute to each endpoint are illustrated in Table D.111.

Example 18. What are the percentages of wells that would be expected to exceed a hazard index of 1.0 in Cretaceous wells for the cardiovascular/blood, cancer, reproductive, and kidney endpoints? Which chemicals are the most important contributors for each endpoint?

Solution and Interpretation. The percentages may be read directly from the row with data for the Cretaceous aquifer group in Table D.114. Percentages were 12, 4 to 5, 35, and 3 to 4 for the cardiovascular/blood, cancer, reproductive, and kidney endpoints, respectively. Determining which chemicals are the most important contributors for each endpoint must be done indirectly by comparing concentrations in Table B.15 with the HRLs in Table D.111 for the respective chemicals. For the cardiovascular/blood endpoint, nitrate and barium are the contributing chemicals. The 95th percentile concentrations for barium and nitrate in the Cretaceous aquifer were 268 and 16450 ug/L respectively. The HRLs for barium and nitrate are 2000 and 10000 ug/L, respectively. Comparing these concentrations to the HRLs indicates nitrate is by far the primary contributor to high values for the hazard index. Beryllium, arsenic, and some VOCs are the contributing chemicals for the cancer endpoint. VOCs had a minimal impact on the calculated hazard indices. The 95th percentile concentrations for arsenic and beryllium were 8.6 and 0.06 ug/L and the MCL and HRL are 50 and 0.08 ug/L, respectively. Comparing the concentrations with the drinking water criteria indicates that beryllium is the primary contributor to this endpoint, but that arsenic did have a significant contribution. Boron and some pesticides contribute to the reproductive endpoint. Contributions from pesticides were insignificant. Boron will therefore be the primary contributor to this endpoint. Comparison of the 95th percentile concentration for boron (3104 ug/L) with the HRL (600 ug/L) indicates that a Hazard Index of 1.0 will be exceeded relatively frequently for this endpoint as a result of boron concentrations.

Cadmium, molybdenum, and tin are the contributing chemicals for the kidney endpoint. The 95th percentile concentrations for these chemicals were 0.82, and 25 ug/L for cadmium and molybdenum, respectively, while tin was not sampled. Tin was therefore not utilized in the analysis shown in Table D.114. The HRL and HBV for cadmium and molybdenum are 4.0 and 30 ug/L, respectively. Molybdenum is therefore the most important contributor to this endpoint, but cadmium does contribute about 20 percent to the overall hazard index.

Comments. For some endpoints, such as the nervous system and reproductive system, one chemical accounts for most of the value calculated for a hazard index. For other endpoints, such as cancer and kidney, there may be contributions from more than one chemical and the effect of additivity is important. Note that if the calculations for the kidney endpoint were being made for some of the Cambrian and the Devonian aquifers, cadmium would be more important than molybdenum, while molybdenum was more important in the example above and would be more important in most Precambrian aquifers. Exact contributions from different chemicals, including VOCs, can be made using the baseline data. It will generally be adequate to approximate the contributions of different chemicals, as was done in the example above. Finally, it is important to remember that risk analysis is intended as a screening tool to identify aquifers in which a chemical(s) may occur at concentrations which warrant additional analysis.

4.1.4. Geochemical Interpretations for Individual Parameters

Aquifers or portions of aquifers may be susceptible to contamination because, under equilibrium conditions, they have the potential to support concentrations of chemicals in excess of drinking water criteria. If there is sufficient source chemical available, either in parent rock or from anthropogenic sources, to reach these equilibrium concentrations, then chemical concentrations not only may exceed the drinking water criteria, but there may be low natural attenuation capacity in these aquifers. Chemical concentrations may exceed drinking water criteria when an aquifer is not in equilibrium, as in the case of a contaminant point source, but these aquifers may have natural attenuation capacities which allow for a decrease in chemical concentration as the system tends toward equilibrium.

An analysis was completed to determine the susceptibility of ground water to contamination by each of the sampled parameters. Only equilibrium conditions were considered. The analysis included an examination of natural concentrations in rocks and soil, anthropogenic sources, solubility calculations, observed concentrations, factors considered to affect the distribution of chemicals in ground water, and an assessment of ground water susceptibility to contamination. Methods for conducting the solubility calculations are described in Section 2.2.4.

Assumptions and Considerations

The primary assumptions made in the solubility calculations are described below.

- Solubility calculations were made using median concentrations for all wells rather than calculations for individual wells or groups of wells. Median concentrations of sulfate, bicarbonate, iron, silica, and hydrogen (or hydroxyl) ion were used.
- Ionic strength effects were not considered. This assumption would alter the resulting calculated concentrations by factors of approximately 1.5 and 2 for divalent and trivalent species, respectively.
- Complexation was ignored in the calculations.
- Ammonia and carbonate concentrations were assumed to be zero and the concentration of hydrogen sulfide was assumed to be equal to 10^{-4} M. The assumption for carbonate is based on the relative importance of carbonate to bicarbonate at the pH values observed in the samples.

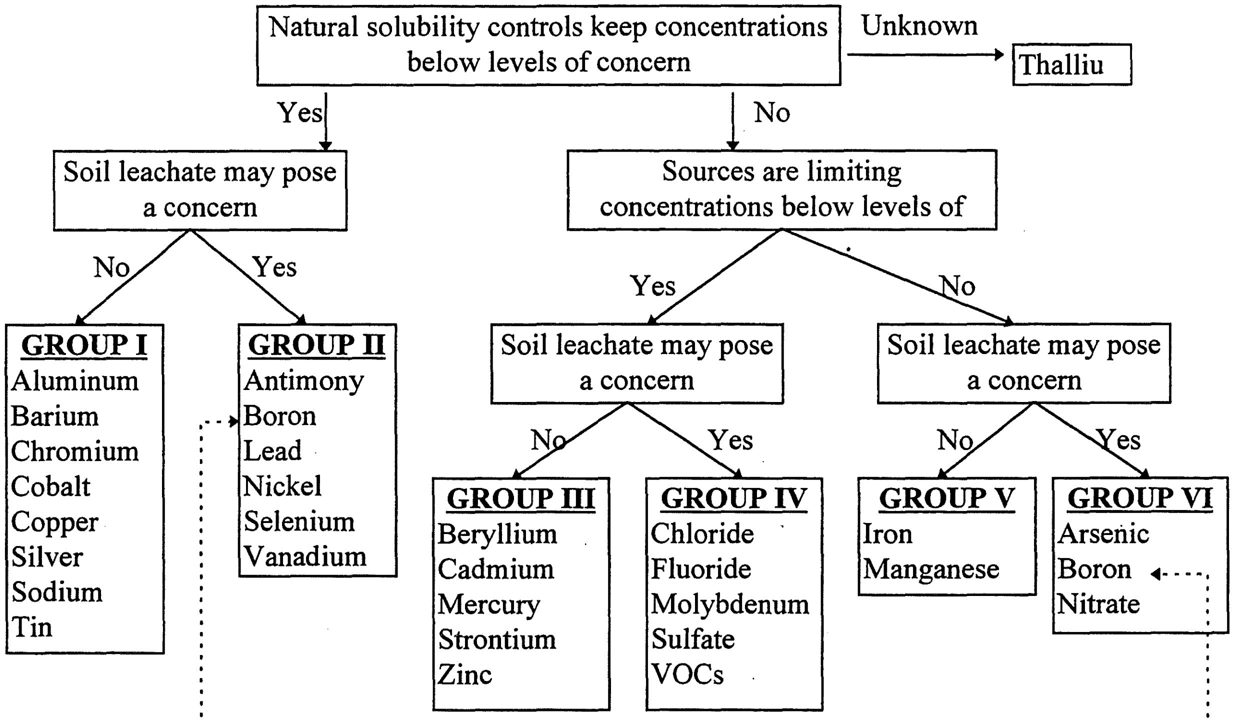
Application of Results: Geochemical Interpretations

The flow chart in Figure 3 (below) summarizes the assessment of susceptibility for individual chemicals which have drinking water criteria. Additional information regarding estimated equilibrium concentrations or controlling minerals is provided in Section 2.2.4.

Chemicals in Group I will not pose a concern in most ground water unless there is a point source of contamination. Ground water which does become contaminated with these chemicals would be expected to have a high potential for natural attenuation. No additional analysis of baseline data is recommended for these chemicals.

Chemicals in Group II are relatively mobile in the soil (antimony, boron, selenium, nickel, and vanadium) or may be elevated in soils due to anthropogenic sources (lead). The largest concern with these chemicals is by leaching through the unsaturated zone and into ground water. Boron concentrations may also be elevated in some rocks (boron was also placed in Group VI). Proper management of these chemicals in soil is important. Although under most conditions these chemicals would naturally attenuate in ground water due to solubility controls, they may be mobile because other natural attenuation mechanisms (e.g., adsorption, ion exchange) are less important. Additional analysis of the distribution of these chemicals in shallow, surficial aquifers is warranted.

Figure 3: Flowchart illustrating groups of chemicals based on geochemical analysis.



NO DRINKING WATER CRITERIA
Bicarbonate, Bismuth, Bromide, Calcium, Carbon, Cesium, Dissolved oxygen, Lithium, Magnesium, pH, Phosphorus, Potassium, Rubidium, Silica, Sulfur, Titanium, Total dissolved or suspended solids, Zirconium

Chemicals in Group III have the potential to exceed drinking water criteria when there is sufficient source material available. However, their occurrence in ground water is limited by the availability of the chemical in source minerals. They are generally not mobile in the unsaturated zone and should be attenuated in ground water. Consequently, ground water may locally be susceptible to contamination from these chemicals, but contamination is likely to remain isolated. No further analysis of baseline data is recommended for these chemicals.

Chemicals in Group IV have the potential to exceed drinking water criteria when there is sufficient source material available. They are also mobile in the unsaturated zone and will only slowly be attenuated in ground water. Additional analysis of the distribution of these chemicals is warranted. Chlorides and sulfate can provide valuable information about the water chemistry of ground water systems. Distribution of chlorides and sulfate in individual aquifers should be assessed. Fluoride and molybdenum distribution should be investigated in those aquifers where their concentrations were elevated. A separate analysis of VOCs is recommended for the Twin Cities Metro Counties. A mini-grid was employed in this area in which the sampling density was approximately tripled compared to the baseline sampling density. These additional data were not analyzed as part of the baseline data and they will be useful in understanding the distribution of VOCs in the Metro Area.

Chemicals in Group V are present at concentrations exceeding drinking water criteria in most wells and aquifers. **If the HRL for manganese is increased by an order of magnitude or more, it will probably be placed in Group III. Until a new HRL is established, it is difficult to determine which category is most appropriate for manganese; however, and it is thus retained in Group V for this report.** Limited additional analysis of these chemicals is warranted, but because of their potential importance to ground water receptors and in understanding geochemical processes in ground water, adjustments in sampling are recommended for these parameters. In particular, all future samples should include both filtered and non-filtered samples. Field kits for analyzing dissolved iron and manganese may also be recommended for local studies of shallow ground water.

Placing arsenic, boron, and nitrate into a Group VI is highly subjective. Nitrate is by far the most widely distributed chemical associated with human activity. The baseline data indicate background nitrate concentrations are likely to be well below the reporting limit of 500 ug/L, possibly even in environments where it will be stable but there are no human inputs. The nitrate data set must be further analyzed to understand the various subpopulations that appear to exist among the data. A comprehensive analysis is therefore warranted, not only for aquifers of concern but possibly for many factors which appear to control the distribution of nitrate in ground water. Arsenic was generally well below the MCL of 50 ug/L, but this concentration is not health-based. A large percentage of the sampled wells exceeded 1 and even 3 ug/L. Arsenic should be treated as an important chemical of concern. Unlike nitrate, the primary source of arsenic in ground water is natural and this will allow the additional analysis to be restricted to understanding those factors which control the behavior of arsenic in ground water. Boron concentrations are at levels of concern in certain aquifers, particularly the Cretaceous and some of the Precambrian aquifers. The primary source of boron in ground water is natural, but boron is mobile enough to warrant being included in Class VI (note that boron was also included in Class II, since its concentration is low in many aquifers).

No geochemical information was found for thallium and it could not be placed into one of the six groups. It is probably not mobile in soil and is not very abundant in rocks. It would therefore be placed either into Group I or Group III depending on the solubility calculations.

Many chemicals did not have drinking water criteria. This does not mean they should be ignored in further analysis, however. Dissolved oxygen, pH, alkalinity (bicarbonate), and total dissolved solids, in particular, are important indicators of biogeochemical processes and should be treated as such in additional analyses.

4.2. Organics - Volatile Organic Compounds

The discussion of organic compounds was limited to Volatile Organic Compounds (VOCs). Pesticides were sampled in wells considered to be potentially sensitive to contamination, but only two wells showed detections of atrazine, both at concentrations well below the drinking water criteria. Results are summarized below.

- VOCs were detected in 109 wells, or 11 percent of the total wells sampled.
- A total of 162 compounds were detected, with 25 wells having two or more compounds detected.
- The most common VOCs detected were the trihalomethane (THM) compounds, most of which was chloroform. The THMs have traditionally been assumed to be a result of well disinfection, but natural formation of THMs can occur if there are sufficient quantities of chloride and organic carbon in ground water.
- There were 33 detections of nonhalogenated aromatic compounds. These are primarily associated with fuel oils and gasoline. Toluene and xylene were the most common VOCs detected from this group of compounds.
- There were 23 detections of halogenated aliphatic compounds (other than trihalomethanes and chlorofluorocarbons). These chemicals are primarily used as solvents in industrial applications, although at one time they were commonly used in many household applications (e.g., strippers, degreasers, lubricants). Di- and trichloro- ethenes and ethanes made up the majority of these detections.
- The remaining detections were divided among chlorofluorocarbons (CFCs), ketones, tetrahydrofuran, and naphthalene. CFCs may be associated with atmospheric deposition, but they are used in industrial applications. Ketones are used as solvents but may also represent degradation products of other VOCs. Tetrahydrofuran and naphthalene were probably associated with fuel oil or gasoline.
- There were four exceedances of the HRL. These included detections of benzene (22 ug/L), tetrachloroethene (8.6 ug/L), tetrahydrofuran (480 ug/L), and 1,1-dichloroethene (12 ug/L). In general, the VOC contribution to overall hazard indices was insignificant except in a few individual wells where they were detected.
- The distribution of VOCs in samples was a function of chemical class. Nonhalogenated aromatic compounds were more prevalent in reducing environments, as would be expected since these chemicals are degraded in the presence of oxygen. Halogenated aliphatic

compounds were more prevalent in oxygenated environments, where they would be expected to be more persistent since they are degraded under reducing conditions. The halogenated chemicals also showed lower concentrations as pH increased, probably due to increasing rates of hydrolysis reactions at greater pH. Overall, VOCs tended to be more prevalent in large diameter wells, perhaps reflecting inputs from the unsaturated zone or the upper portions of aquifers.

4.3. Problems

The following problems are comprehensive and are intended to utilize concepts and information from the entire baseline report.

Problem 1. Water resource managers working in Isanti, Sherburne, Benton, Anoka, and Stearns counties are concerned about the impacts of increased irrigation on water quality in the Anoka Sand Plain aquifer. In a one-time sampling of fifty irrigation wells, the results shown in Table 9 (below) were obtained.

Table 9: Summary of information collected by county water managers.

Aquifer	Sample size	Censored values	Mean (ug/L)	Median (ug/L)	Standard deviation
surficial Quaternary	32	9	21252	12121	45894
buried Quaternary	18	12	991	665	889

The water resource managers would like to know if there are water quality concerns associated with increased irrigation and what recommendations can be made with respect to either management or additional data collection and analysis.

Solution. There is no clear cut solution to this problem. It would be useful to conduct the following analyses:

a) examine the above data and provide limited interpretation of it;
b) compare the water quality information for the surficial and buried aquifers with data statewide and from these five counties;
c) draw conclusions from the above analyses; and
d) suggest additional studies which would provide information needed to make management decisions.

We treat a) through d) as separate parts of the problem.

a) The first step is to look at the data in Table 9. There were a large number of censored values for both the surficial and buried Quaternary aquifers. The mean concentration and standard deviation therefore have little meaning. The data could be analyzed in a rigorous manner, but this is not necessary to answer the question. We will use nonparametric methods in the subsequent steps.

b) The second step is defining the aquifers with which to compare the county data. Although surficial Quaternary aquifers encompass both QWTA (water table) and QUUU (undifferentiated) designations, we choose to use just the QWTA designation for this problem. This designation is appropriate for the Anoka Sand Plain aquifer. Similarly, the QBAA and QBUA designations are used for buried Quaternary wells. We can now compare data. As stated above, parametric descriptive statistics (mean and standard deviation) have no value and they are not included in the table. We can get the statewide QWTA, QBAA, and QBUA data directly from Tables D.31, D.32, and D.35. Baseline data can be queried from the baseline database for the five counties of interest. We will call this data "County Baseline." Notice that no distinction is made between QBUA and QBAA for the regional data, since we have inadequate information to make this distinction. The three data sets are summarized in Table 10. Additional data have been added for the samples collected by the regional water managers.

Table 10: Comparison of all nitrate data for Problem 1.

	No. of samples	No. of censored	Median	Minimum	Maximum
QWTA					
Statewide	119	87	< 500	< 500	22300
County Baseline	15	11	< 500	< 500	9300
Regional[1]	32	9	12121	399	35681
QBUA					
Statewide	104	76	< 500	< 500	98020
County Baseline	13	10	< 500	< 500	12000
Regional	18	12	665	127	7994
QBAA					
Statewide	386	342	< 500	< 500	33240
County Baseline	24	19	< 500	< 500	16800
Regional	18	12	665	127	7994

[1] Log-transformed data

We can now look at the data more rigorously. Helsel's method was used to calculate mean and 95 percent UCL concentrations for the county data. The results are illustrated in Table 11. We applied Equation 2 to calculate the mean and 95 percent UCL:

$C = \exp(a + bz_{\alpha}).$

The values for z at the mean and 95 percent UCL are 0 and 2.0, respectively (see Table 5).

Table 11: Summary of analysis for county baseline data using Helsel's method.

Aquifer	Intercept (a)	Slope (b)	Mean	95% UCL
County baseline				
QBAA	4.158	2.85	64	19230
QBUA	5.624	2.447	277	37110
QWTA	7.46	1.014	1745	13280
Statewide				
QBAA	-	-	9.0	1465
QBUA	-	-	76	10949
QWTA	-	-	310	8348

The data show that concentrations of nitrate appear to be greater in all three aquifers within these five counties compared to the remainder of the state. It is therefore appropriate to use the county baseline data for comparison with the data collected by the regional water managers.

To compare the data collected at the regional level with the county baseline data, we take the median concentrations and insert these in as C, then solve for z.

$$z_{\alpha} = (\ln(C) - a)/b$$

We use the values for a and b shown in Table 11. The calculated values for z are 1.92, 0.36, and 0.82 for the QWTA, QBUA, and QBAA aquifers, respectively. We then look up the probability associated with these calculated values for z. The probabilities for the QWTA, QBUA, and QBAA aquifers are about 0.029, 0.38, and 0.21, respectively.

c) If we use a decision level of 0.05, we conclude that the water table aquifer (QWTA) is being impacted by irrigation, while buried portions of the Anoka Sand Plain aquifer are not.
It is useful at this point to identify factors which may be important in controlling nitrate distribution in the surficial aquifer. A second objective of additional analysis would be to attempt to understand why nitrate concentrations are not elevated in the lower aquifer and whether they are likely to increase with time. Figure 3 indicated that nitrate is primarily a concern as a result of soil leaching. Once in ground water, geologic controls cannot keep concentrations below the HRL (10000 ug/L). In reviewing the discussion for nitrate in 3.2.4, oxidation-reduction conditions were the primary control on the distribution of nitrate in ground water. Table D.57 indicates well diameter is an important factor, but within the Anoka Sand Plain no large diameter wells were identified. Nitrate

was highly correlated with tritium (p less than 0.001), indicating it was more likely to be found in "young" ground water. Table D.83 indicates that nitrate concentrations were greatest in June and lowest in April, probably in response to both application of nitrogen fertilizer and aquifer recharge.

d) The following are recommendations for the study area.

- A tritium sample should be collected in all wells with nitrate concentrations less than 500 ug/L. Tritium confirms the presence of relatively recent water. Recent water with low nitrate concentrations suggests nitrate is being denitrified within the aquifer.
- Sample each well for dissolved iron and manganese, hydrogen sulfide, methane, dissolved oxygen, oxidation-reduction potential, temperature, sulfate, nitrate, conductivity, pH, dissolved and total organic carbon, and alkalinity (bicarbonate). This information provides an indication of the redox status within each well and the likelihood for natural attenuation of nitrate within the aquifer. The data can be used to estimate the sensitivity of the aquifer to contamination by nitrate, regardless of nitrate inputs associated with land use.
- Establish a long-term monitoring network in the aquifer to evaluate seasonal variability and long-term trends in the nitrate concentrations. The network should consist of wells from the shallow and deep aquifers, covering a range of nitrate concentrations. In addition to nitrate, the parameters outlined in the second recommendation should be sampled. Sampling should be quarterly for at least four years.

Problem 2. A prospective property owner in Hennepin County wants to develop a parcel of land which had contaminated soil. The soil has been cleaned up to meet industrial land use criteria. Three wells have been installed at the site and the information shown in Table 12 has been collected from them.

Well 1 represents background conditions, Well 2 represents ground water directly beneath the impacted soil, and Well 3 represents ground water at the down-gradient edge of the property. Monitoring Wells 2 (MW-2) and 3 (MW-3) are 500 feet apart. The cleanup goals for ground water at the property boundary are one-half of the drinking water criteria. The aquifer underlying the site is a surficial outwash sand, approximately 20 feet to water, and 30 feet thick. What information from the baseline network can be used in interpreting data for this site?

Table 12: Summary data for Problem 2.

Parameter	MW-1	MW-2	MW-3
Lead (ug/L)			
June, 1996	1.20	19.3	4.1
October, 1996	1.01	21.5	3.5
June, 1997	0.97	16.9	2.9
October, 1997	1.04	20.4	2.8
Cadmium			
June, 1996	0.056	13.9	1.9
October, 1996	0.051	12.2	1.5
June, 1997	0.042	10.6	1.3
October, 1997	0.049	11.1	1.4
Nickel			
June, 1996	3.9	119	45
October, 1996	3.1	141	41
June, 1997	3.5	151	38
October, 1997	3.7	137	36

Solution. The following analyses are conducted:

a) conduct analysis of the site data;

b) compare MW-1 to statewide data;

c) conduct intrawell comparisons;

d) provide general information about the factors affecting chemical fate in ground water; and

e) provide recommendations.

Points a) through e) are treated as separate parts of this problem.

a) Descriptive statistical analysis is performed on the site data. The data from each individual well should not vary, although analysis of seasonal effects could be made if samples were collected for an additional year or more. Means and medians are illustrated in Table 13. As expected, the means and medians are very close.

Table 13: Descriptive statistics for monitoring wells 1 through 3.

Parameter	MW-1		MW-2		MW-3	
	Mean	Median	Mean	Median	Mean	Median
Lead	1.06	1.03	19.5	19.9	3.3	3.2
Cadmium	0.050	0.050	12.0	11.7	1.53	1.45
Nickel	3.6	3.6	137	139	40	39.5

b) The aquifer we use will be the Quaternary water table aquifer (QWTA). The statewide mean concentrations for lead, cadmium, and nickel are 0.19, 0.029, and 4.9 ug/L, respectively (see Table D.35). We need to establish a probability on which to base our decisions. A probability value of 0.05 is chosen. We can simply compare the site concentrations with the 95 percent upper confidence limits (UCLs) to determine if the concentrations in the individual wells represent background. The baseline UCLs for lead, cadmium, and nickel were 2.4, 0.15, and 13 ug/L, respectively. We conclude that Monitoring Well 1 does represent a background concentration. Monitoring wells 2 and 3 both exceed background and are therefore considered to be impacted.

c) Intrawell comparisons can be conducted to determine if the concentrations in the three wells are different. This is a hypothesis test, with the null hypothesis being that concentrations in the three wells are not different. Although we could probably do an Analysis of Variance (ANOVA) analysis of the data (parametric method of hypothesis testing), the nonparametric method is quicker to run and may be sufficient. The resulting p-value was 0.0000392, which provides strong evidence to reject the null hypothesis. Concentrations do differ between wells. The mean ranks for all chemicals were 2.5, 10.5, and 6.5 for MW-1, MW-2, and MW-3, respectively. Since the difference between MW-1 and MW-3 (6.5 - 2.5 = 4.5) is the same as the difference between MW-2 and MW-3 (10.5 - 6.5 = 4.5), we know that the concentrations follow the order MW-2 > MW-3 > MW-1. This is an important conclusion, because it not only tells us that MW-2 and MW-3 are impacted, but it also tells us that MW-3 and MW-2 are significantly different. The key question now is whether MW-3 is at equilibrium, since this is the compliance well. If concentrations in this well are not changing with time, we can make a decision based on the existing data. Let us assume for now that concentrations are at equilibrium and they will not change with time. The compliance concentrations for lead, cadmium, and nickel are half of the drinking water criteria. A drinking water criterion of 15 ug/L is used for lead, while the HRLs for cadmium and nickel are 4 and 100 ug/L, respectively. Half of these values are 7.5, 2, and 50 ug/L, respectively. The mean concentrations of lead, cadmium, and nickel in MW-3 were 3.3, 1.53, and 40 ug/L, respectively. But we want a 95 percent confidence level, so we use the equation (see Section 2.2.1):

$$C = \mu \pm t_{\alpha}\sigma/\sqrt{n}.$$

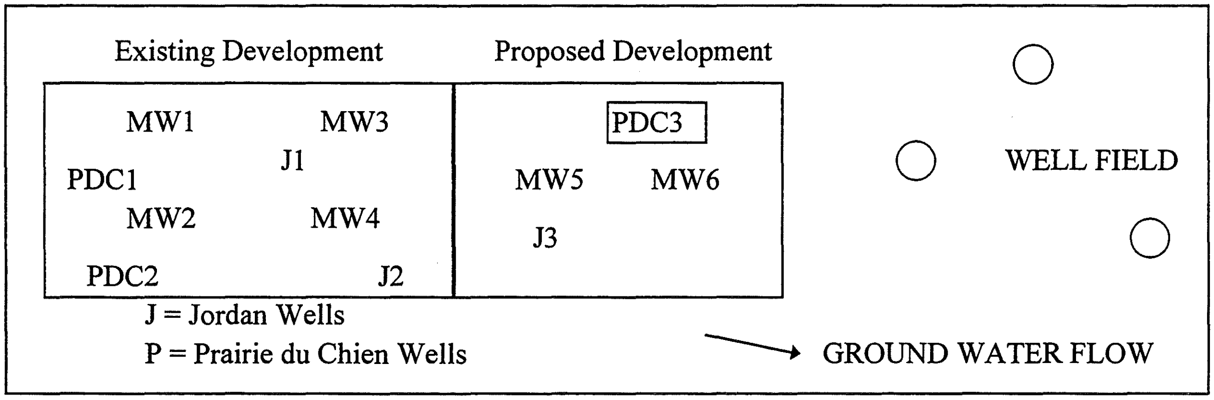
The standard deviations (σ) for these data are 0.602, 0.263, and 3.92 for lead, cadmium, and nickel, respectively. The means were 3.3, 1.53, and 40 ug/L, with a sample size (n) of 4. The t-value for three degrees of freedom (n-1) at a probability of 0.05 (remember we are interested in just the upper tail of the distribution) is 3.182. The resulting values for *C* are 4.26, 1.95, and 46.2 ug/L for lead, cadmium, and nickel, respectively. These are below the target values and if we assume the concentration in the wells will not increase with time, there will be no need for cleanup or long-term monitoring of ground water.

d) The upper confidence limits are close to the target values, particularly for cadmium. If we are unsure about the assumption that the plume is stable (i.e., concentrations will not increase with time), we may wish to assess the natural attenuation capability of the aquifer. Since the soil has been cleaned up to levels which should be protective of ground water, we can eliminate the soil leaching pathway. Lead and nickel were both placed into Group II in Figure 3. Concentrations of these chemicals in equilibrium with ground water will be below levels of concern unless the pH of ground water is less than about six. Cadmium was placed into Group III in Figure 3. Cadmium in equilibrium with minerals at Eh values greater than about -100 mV will exceed the drinking water criteria. Attenuation of cadmium will be greatest in low ionic strength ground water with high organic matter or iron concentrations and pH greater than about seven. Under these conditions, cadmium will be strongly sorbed to organic matter.

e) If there is uncertainty about the stability of the plume, either long-term monitoring can be conducted at MW-3 or a natural attenuation study can be conducted. A long-term monitoring program would include quarterly sampling for a period of at least four years. If no upward trend in concentration is demonstrated, the plume can be considered stable. A natural attenuation study would include sampling for total and dissolved organic matter content, pH, total iron, and redox potential. Speciation of cadmium would be beneficial to demonstrate adsorption of cadmium to specific minerals or organic matter.

Problem 3. A County Water Planning organization wants to know if increased unsewered development with one-half acre lots is going to impact drinking water quality for the town of X whose well field is nearby. Town X has three wells completed in the Jordan aquifer at depths of 150 to 200 feet. The Prairie du Chien aquifer overlies the Jordan aquifer and extends from twenty feet below the land surface to a depth of about 100 feet. The county has secured funding to conduct a study to assess the impacts from unsewered areas. They are in the planning stages of this study. Figure 4 illustrates the location of the well field, an existing unsewered development, the proposed development, and some existing Prairie du Chien and Jordan aquifer wells.

Figure 4: Schematic representation of Problem 3.



Solution. The initial goal should be to determine the hydrogeology of the study area and collect ground water data from unsewered residential areas within the study area. Water quality from unsewered areas can be compared with statewide information from the Prairie du Chien and Jordan aquifers.

Existing hydrogeologic information can be used to determine the likely depth to water, ground water flow direction and gradient, and vertical connectivity of the Prairie du Chien and Jordan aquifers. USGS studies, MGS-DNR Atlas information, and County Well Index can be used to establish a schematic flow model of the area. Water levels can be measured in wells with known depths to further calibrate the flow model. Assume that ground water flows in the direction indicated in Figure 4, that the depth to water is about 30 feet, and that the water elevations in the Prairie du Chien and Jordan aquifers are about equal. We could then consider the Prairie du Chien and Jordan to be a single aquifer which is unconfined.

A monitoring well network needs to be established to collect the appropriate water quality information. Each of the wells indicated in Figure 4 can be incorporated into the network. The wells from the well field would be included in the network. All these wells are likely to be screened deeper in the aquifer. A shallow monitoring network must be established to determine water quality impacts directly beneath the unsewered area. Monitoring wells 1 through 4 are completed in the existing unsewered area and are screened at the water table. Monitoring wells 5 and 6 are completed in the proposed unsewered area. Locations of the monitoring wells are illustrated in Figure 4.

All wells would be sampled quarterly for a minimum of four years. Wells 1 through 6 would be sampled for nitrate, major cations and anions, trace inorganics, VOCs, and redox parameters. Redox parameters include dissolved oxygen, temperature, redox potential, pH, conductivity, dissolved iron and manganese, hydrogen sulfide, and methane. The existing wells would be sampled for major anions and cations and for redox parameters. The list is reduced for these deeper wells because of cost considerations. If parameters in monitoring wells are at concentrations greater than statewide background, the deeper wells could be sampled for these additional parameters.

The amount of data collected during the initial four years would be quite large and cannot be fully discussed in this problem. Assume the most relevant data after four years of sampling are shown in Table 14. Assume there was no seasonal or long-term trend in the concentrations. The data in Table 14 illustrate mean concentrations of the parameters, in ug/L. Even this condensed data represent a considerable challenge to analyze. A first step might be to visually examine the distribution of concentrations for each parameter, breaking the data into Monitoring wells 1 through 4, Monitoring wells 5 and 6, Prairie du Chien (PDC) wells 1 through 3, Jordan (J) wells 1 through 3, and the well field wells. These plots are illustrated for each parameter in Figures 5 through 7. The data appear to indicate greater concentrations of nitrate, chloride, total dissolved solids, dissolved oxygen, greater redox, and lower concentrations of iron in the monitoring wells compared to the remaining wells. The well field appears to be intermediate between the deeper wells and the monitoring wells. The next step would be to test these hypotheses.

Table 14: Mean concentrations, in ug/L, of select parameters after four years of quarterly sampling. MW= monitoring well; PDC = Prairie du Chien well; J = Jordan well; OPDC = Prairie du Chien aquifer; CJDN = Jordan aquifer.

Well	Nitrate	Iron	Chloride	TDS	Eh	Dissolved Oxygen
MW1	23015	31	10012	519586	415	2159
MW2	21056	39	12519	589741	426	2425
MW3	16954	27	11497	596415	457	2674
MW4	18174	26	13917	574251	419	2185
MW5	3689	28	10986	531486	399	2041
MW6	3741	39	11364	528475	405	2514
PDC1	1294	198	4586	419523	258	991
PDC2	989	211	5164	409562	264	946
PDC3	1104	213	5027	413427	251	923
J1	789	158	1423	301548	204	967
J2	561	169	1512	308624	201	928
J3	774	187	1097	299854	195	1012
Well Field 1	1529	99	8914	489452	309	1512
Well Field 2	1756	85	9614	497458	315	1421
Well Field 3	1924	109	9147	485765	322	1601
Statewide mean OPDC	649	225	3448	410472	258	934
Statewide UCL OPDC	9042	458	6150	457447	300	-
Statewide mean CJDN	45	133	1153	299916	195	1072
Statewide UCL CJDN	3646	8977	1616	346577	276	-
Statewide OPDC-CJDN	418	770	2073	-	-	219
MW1 - MW4	19800	31	11986	569998	429	2361
MW5 - MW6	3715	34	11175	529981	402	2278
PDC1 - PDC3	1129	207	4926	414171	258	953
J1 - J3	708	171	1344	303342	200	969
Well Field	1736	98	9225	490892	315	1511

Figure 5: Comparison of nitrate and chloride concentrations (ug/L) between different well groups

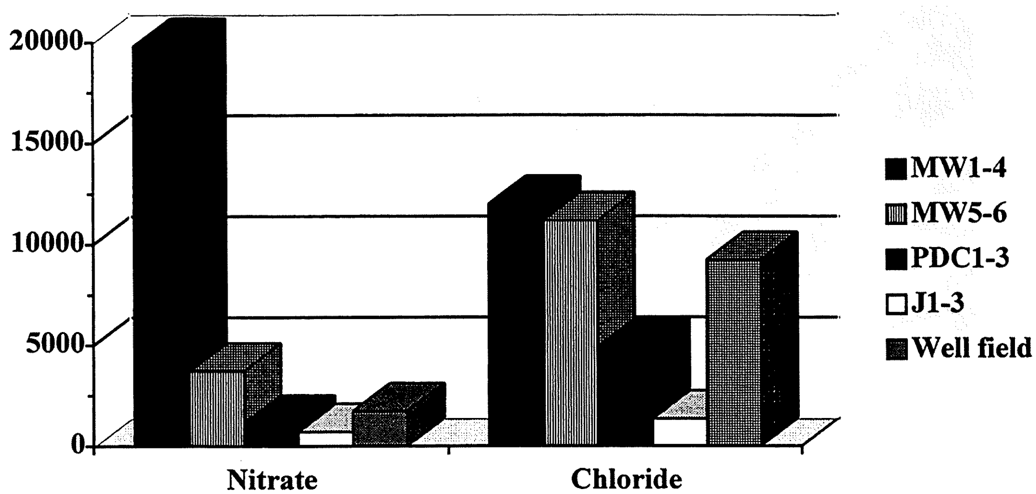


Figure 6: Comparison of iron (ug/L), Eh (mV), and dissolved oxygen (ug/L) between different well groups.

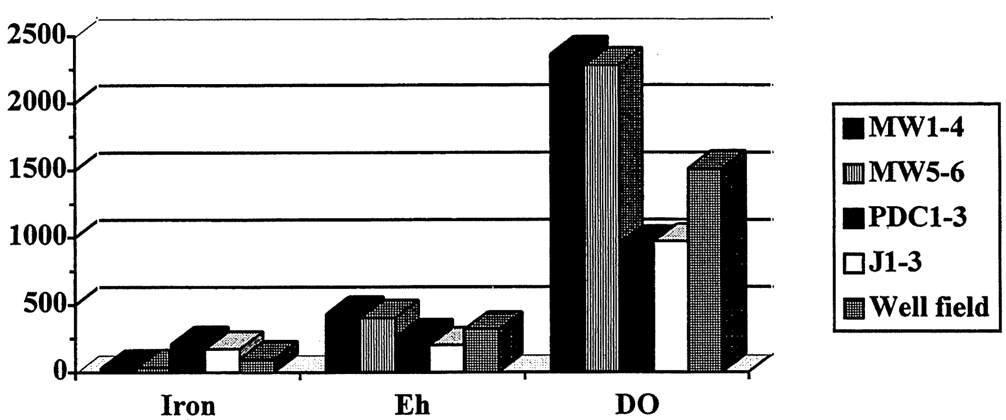
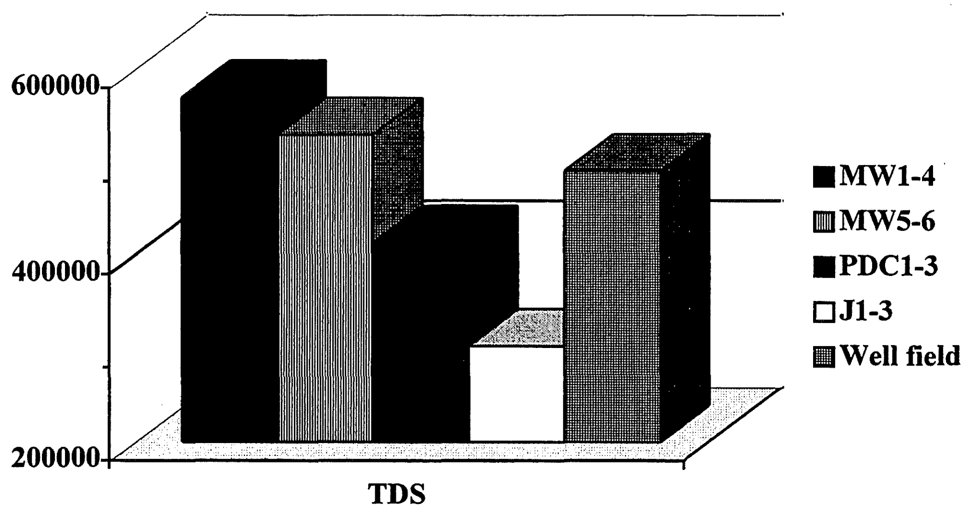


Figure 7: Comparison of total dissolved solid (ug/L) concentrations between different well groups.



Results from the hypothesis tests are illustrated in Table 15. The results confirm that nitrate concentrations are greatest in Monitoring wells 1 through 4 and are significantly greater in these wells than in any of the deeper well groups (PDC, J, or well field wells). Nitrate concentrations in monitoring wells 5 and 6 are greater than concentrations in the PDC and J wells. The well field wells are intermediate in concentration. The patterns of concentration for all parameters are similar. Chlorides are greater in the monitoring wells than in the deeper wells, with the well field wells being intermediate in concentration. Dissolved oxygen, Eh, and total dissolved solids are greater and iron is lower in the monitoring wells than in the deeper wells, with the well field wells again being intermediate. We can conclude that the shallow portion of the Prairie du Chien aquifer differs from the deeper portion of this aquifer and differs from the Jordan aquifer. The municipal wells (well field) have concentrations which appear to reflect the shallow and deeper systems, which is not surprising since these are probably high capacity wells which pump water from different vertical positions in the Prairie du Chien-Jordan aquifer.

Table 15: Results of hypothesis tests comparing different well groups. Mean ranks and p-values from the hypothesis test are illustrated. LSD represents the least significant difference at which mean ranks differ, at a probability of 0.05.

Well group	Nitrate	Iron	Chloride	Eh	TDS	Dissolved Oxygen
MW1-4	2.5	12.9	3	2	3	3
MW5-6	5.5	11.8	4.5	5	4.5	4
PDC wells	11	2	11	10.5	11	12.8
J wells	14	5	14	13.5	14	12
Well field	8	8	8	8	8	8
LSD	3.9	5.3	5.2	3.9	5.2	6.8
p-value	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

The next step is to compare the different well groups to the statewide data to determine if the shallow system is impacted. Examination of Table 14 reveals that monitoring wells 1 through 4 have concentrations of nitrate, chloride, and total dissolved solids greater than the statewide upper 95 percent confidence level for the Prairie du Chien aquifer. Eh is also greater than the statewide UCL. The data indicate that the upper portion of the aquifer is impacted beneath the existing development and that the potential for nitrate to be degraded within this portion of the aquifer is very low, since nitrate will only be degraded once oxygen is nearly depleted. The stability field for nitrate occurs at Eh values greater than about 50 mV, which is exceeded in the upper portion of the Prairie du Chien aquifer. Nitrate does not exceed the statewide UCL in either the well field or monitoring wells 5 and 6, but there is evidence of impacts because chloride and total dissolved solid concentrations are greater in the well field and monitoring wells 5 and 6 compared to the statewide UCL. Eh is also greater in the well field and monitoring wells 5 and 6, indicating lower potential for nitrate degradation in these wells.

We conclude that unsewered development with 0.5 acre lots impacts shallow ground water and may be impacting the well field of city X. Nitrate has not reached levels of concern in the well field, but there is sufficient evidence to suggest that expansion of unsewered development in the direction of the well field may further degrade water quality in the well field. The data indicate that the nitrate attenuation capacity of the well field is impaired, probably because the municipal wells draw water from the upper portions of the aquifer. Nitrate is much more stable in the upper portions of the aquifer compared to deeper portions.

Several recommendations can be made. These are described below.

1. Investigate the potential effects of increasing lot size (for example, to one-acre lots).
2. Characterize the vertical nitrate attenuation characteristics of the aquifer and make recommendations regarding pumping schedules. The objective would be to minimize the amount of draw down from the upper portions of the aquifer into the municipal wells.
3. Limit or alter expansion plans for the unsewered development.
4. Modify the well field by drilling additional wells or adjusting pumping schedules.
5. Continue to monitor water quality in the well field.
6. If the expansion occurs, establish a monitoring network within the newly developed area and include down-gradient monitoring in the well field and between the well field and new development.

Program
Direction

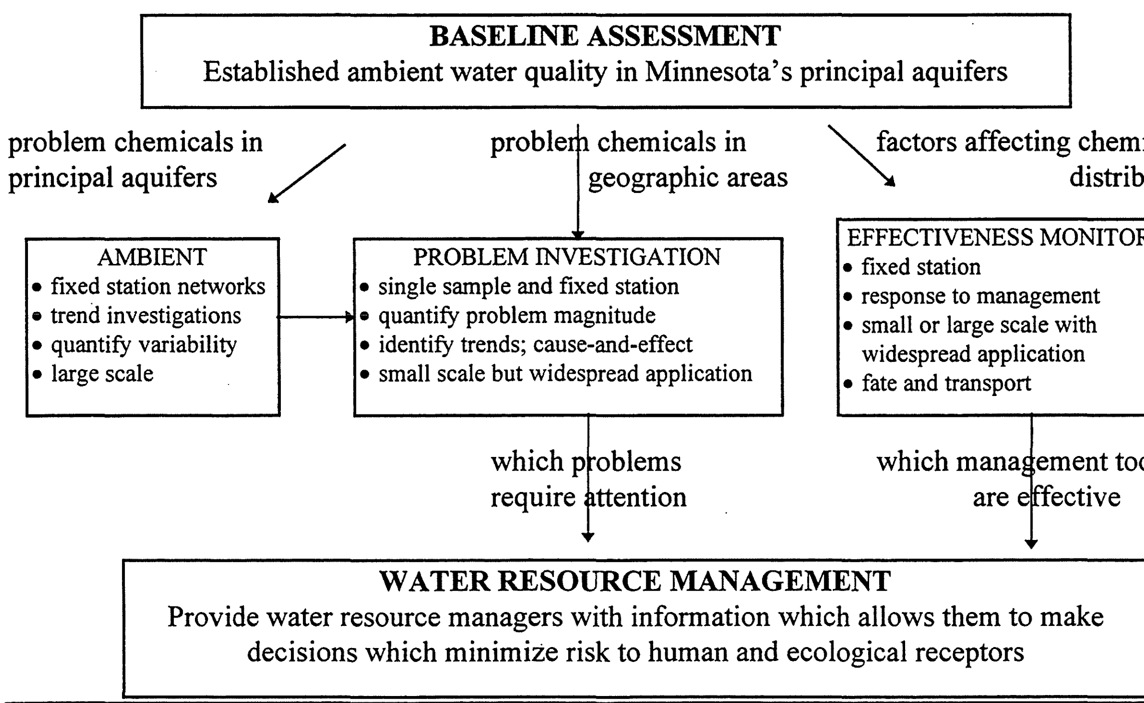
Part V: Additional Products and Future of the Program

Implementation of the baseline was a comprehensive and energy-intensive endeavor for GWMAP. From 1991 through 1995 it consumed nearly all of GWMAP resources and staff time. However, as staff gained experience implementing the program, many parts were streamlined. Also, over time, new positions were added, budgets improved, and the program shifted its focus towards becoming a more comprehensive program that includes more than the baseline work. Thus, GWMAP began assessing how to address local ground water information needs which were not yet being met.

5.1 Development of Special Studies/Program Design

Since 1996, when the last baseline samples were collected, the program has begun to branch out into other types of monitoring work. Ambient monitoring will continue, but smaller scale assessments of regional or local ground water quality will be the main focus of the program and will assess how well Minnesota's ground water resources are being protected. These studies are either designed to address problems that we know exist in certain regions, or designed to assess the effectiveness of certain management practices. The information that results from these studies will be directed towards planners and water resource managers who can best use the information to make decisions to protect ground water supplies. The flowchart in Figure 8 illustrates the relationships between these different components.

Figure 8: Flowchart illustrating the different components of GWMAP.



At the time this report goes to press, two studies are being implemented by GWMAP to address gaps in ground water information. The larger of these studies, called "Understanding the Effects of Land Use on Ground Water Quality in Surficial Sand and Gravel Aquifers," was initiated in 1996 to evaluate the unknown impacts of dramatic growth in some Minnesota communities on ground water quality. The study location is the St. Cloud area of Stearns County. This area was chosen because it contained sandy soils, a shallow water table, and rapid, variable development patterns. This combination of factors is not unique to the St. Cloud area; thus the information should be useful to other similar communities across the state. The main objectives of this study are to determine if and why water quality differs beneath different land uses and to evaluate if impacts reach human or ecological receptors. This study fits the criteria for a problem investigation study as illustrated in Figure 8, and has also relied on previously collected ground water quality information on the Anoka Sand Plain aquifer, as well as the baseline database. The baseline data has been used together with more local data to establish geochemical "norms" for this aquifer to which the data from the land-use study can be compared to help assess the magnitude of human impacts on the ground water quality.

Also underway is a smaller scale study to monitor the effectiveness of a permitted manure management facility. The farm being studied has recently improved its animal confinement and manure containment systems. These are being monitored to see if the new system is adequate to protect shallow ground water. This work is in the central sand plain of Minnesota where sandy soils and a shallow water table make impacts to ground water a potential concern. Here, as in the land use study, the baseline data is used as one gauge by which to measure any variances in the quality of the water at the top of a surficial aquifer as compared to the aquifer as a whole.

GWMAP hopes to begin new studies each year to continue to address the needs for localized ground water information. Ideally, new studies need to be problem investigation or effectiveness monitoring projects with regional applicability. They need to have application to decisions that the MPCA is facing, and they need to address relevant concerns of members of the community.

5.2 Additional GWMAP Services

GWMAP has been available to provide technical assistance on ground water issues to all levels of government and the consulting community, and this continues. Moreover, new efforts are being made to be more customer-friendly and provide more comprehensive information with responses to requests. Some of the examples in Part IV reflect our expectation that the interpreted information provided by this report will aid in better answering many questions where ambient ground water quality information can be a problem-solving tool. Not all users will become intimately familiar with all aspects of our program, so we would like to encourage others to talk with GWMAP staff individually so we can assist in your use of this data set. The program is committed to providing this kind of support. Recently we have provided information to a variety of colleagues and programs with local, state or nationwide perspectives. For examples see the table below.

Table 16: GWMAP Data Usage by Other Programs

Program	Project	GWMAP Data Used
USGS/ NAQWA	VOC Retrospective	VOC Data for Metro Area
MGS/MDH	Occurrence of Arsenic in MN Ground Water	Statewide Arsenic Data
MDH	Statewide	Nitrate
DNR Atlas Program	Various Regional Assessments	General Chemistry, Tritium
Individual counties	County Assessments	Nutrients

5.3 Data and Interpretation

In addition to providing baseline data and technical guidance, GWMAP is producing information on how to apply the data to actual problems involving natural resource management. Interpretive reports are peer reviewed and once comments are addressed, the report is finalized. One of the MPCA's key strategies is to use measured environmental outcomes to inform and drive land management decision-making, and GWMAP will be part of that effort.

Other interpretive tools that GWMAP can make accessible are GIS-generated maps of relevant data. Visually displayed data in a map is often an excellent tool because it allows users to process information quickly. Additional services include reports that further assess results from the baseline assessment or from our localized special studies.

GWMAP also has the capability to develop ground water models or simulations to predict possible scenarios. These capabilities would utilize baseline information in addition to other relevant datasets. These simulations can use what is known about the hydrologic system and can predict the potential impacts of development scenarios or other factors. Risk assessments can also be developed as a tool to aid in decision making through better understanding of how measured impacts to an aquifer might be relevant to human or ecological receptors using that aquifer.

5.4 Program Improvements

As the focus of GWMAP's work shifts, some changes will be necessary in study design, collection and analysis of data, and products delivered to the ground water community. Some of these changes include the following, many of which are pertinent to monitoring and assessment by others.

1. Rigorous geologic screening of wells will be conducted prior to well selection because development of conceptual geologic and hydrologic models will be essential to studies involving problem investigation and effectiveness monitoring. The objective of well screening is not only to ensure accurate interpretation of the well log but selection of wells which will help better understand local geology and hydrology.
2. The following factors can be characterized and included as fields in the database:
   - dominant land use within a one mile radius of the well;
   - predominant regional flow direction, in degrees;
   - location (in degrees) of and distance of wellhead from visible point and non-point sources of contaminants;
   - cumulative thickness of confining units;
   - surface watershed the well is located in; and
   - water elevation.
3. Quality assurance analysis will be conducted within two weeks of receiving laboratory results for each sample batch. Many GWMAP studies will now utilize quarterly sampling and it is important to quickly identify the need for re-sampling a well or flagging data.
4. Sampling more than once from fixed-station networks requires consideration of serial effects. For baseline networks in Minnesota, sampling should be conducted between June 1 and June 30 for spring and November 1 and November 30 for autumn. For fixed-station networks, sampling events should be conducted two weeks either side of the following dates:
   - Winter - March 15;
   - Spring - May 15;
   - Summer - August 31; and
   - Autumn - November 1.
5. Annual summary reports will be prepared during the course of a study.
6. Oxidation-reduction conditions will be characterized for each well when the chemical parameters of concern are redox-sensitive. Parameters which will be sampled to characterize redox conditions include:

- field measurement of dissolved oxygen, alkalinity, oxidation-reduction potential, temperature, and pH;
- laboratory analysis of dissolved iron and manganese, nitrate, sulfate, bicarbonate, and chloride;
- in environments suspected to be strongly reducing, field or laboratory analysis of hydrogen sulfide, methane, nitrite, and possibly dissolved hydrogen;
- laboratory analysis of total and dissolved organic carbon; and
- field notes if there is a strong hydrogen sulfide odor to the water, discoloration due to iron or manganese, or excessive bubbling in the flow through cell, since these are conditions which are likely to occur in many of the studies GWMAP is now undertaking.

7. Special studies conducted by GWMAP will require additional sampling of parameters. Examples are presented below.
   - For nitrogen studies, ammonia and total Kjeldahl nitrogen should be included in laboratory analysis.
   - For land use studies, pesticide lists will vary. Base-neutral pesticides should be sampled in agricultural areas and in locations where weed control is practiced in right-of-ways. In established urban areas (greater than ten years age), acid pesticides should be sampled. In newly established urban areas, both pesticide groups should be sampled.
8. GWMAP will need to make greater efforts to work with other ground water groups. Communication with these and other groups may be achieved through the following:
   - establish cooperative studies (for example, the Isanti County feedlot study involves GWMAP, MPCA's feedlot program, and the Isanti County area Soil and Water Conservation groups);
   - co-authoring papers with other ground water groups;
   - improving access to data;
   - producing reports in a more timely manner; and
   - improving outreach efforts, including distributing fact sheets or newsletters, providing demonstrations, conducting seminars or community meetings, and sharing technical expertise.

References

Adkins, N. C. 1993. *A Framework for Development of Data Analysis Protocols for Ground Water Quality Monitoring*. Colorado Water Resources Research Institute. Colorado State University.

Adolphson, D. G., J. F. Ruhl, and R. J. Wolf. 1981. *Designation of Principal Water Supply Aquifers in Minnesota.* U. S. Geological Survey Report of Investigations 81-51. St. Paul, MN. 19 p.

Alloway, B.J. ed. 1995. *Heavy Metals In Soil.* Blackie Academic and Professional. Glasgow, UK. 368 p.

Appelo, C.A.J., and D. Postma. 1993. *Geochemistry, Groundwater And Pollution.* A.A. Balkema. Rotterdam, Netherlands. 536 p.

Bohn, H., B. McNeal, and G. O'Connor. 1979. *Soil Chemistry.* John Wiley and Sons. New York, NY. 329 p.

Cherry, J.A., A.U. Shaikh, D.E. Tallman, and R.V. Nicholson. 1979. *Arsenic Species as an Indicator of Redox Conditions in Ground Water.* Journal of Hydrogeology 43:373-392.

Dragun, James. 1988. *The Soil Chemistry of Hazardous Materials.* Hazardous Materials Control Research Institute. Silver Spring, MD. 458 p.

Eary, L.E., Rai Dhanpat, S.V. Mattigod, and C.C. Ainsworth. 1990. *Geochemical Factors Controlling The Mobilization of Inorganic Constituents from Fossil Fuel Combustion Residues: II. Review of the Minor Elements.* Journal of Environmental Quality 19:202-214.

Environmental Systems Research Institute, Inc. (ESRI). 1993. *ARC/INFO Version 6.1, ARCPLOT Command References.* ESRI, Inc. Redlands, CA.

Fetter, C.W. 1993. *Contaminant Hydrogeology.* Macmillan Publishing Company. New York, NY. 458 p.

Garrels, R. M., and C. L. Christ. 1965. *Solutions, Minerals And Equilibria.* Freeman, Cooper, and Company. San Francisco, CA 449 p.

Hem, J. D. 1992. *Study And Interpretation of the Chemical Characteristics of Natural Water.* U.S. Geological Survey Water-Supply Paper 2254. 263 p.

Hounslow, A. W. 1995. *Water Quality Data - Analysis and Interpretation.* Lewis Publishers. 397 p.

Hsu, Y. M., G. Myers, T. Clark, D. Jakes, and J. Schlotthauer. 1993. *Integrating GIS/GPS into Minnesota's Ground Water Monitoring and Assessment Program.* Proceedings of the GIS/LIS Annual Conference and Exposition. Minneapolis, MN. p 323-330.

Hsu, Y. M., J. Schlotthauer, and T. Clark. 1996. *Operation of Minnesota's Statewide Baseline Ground Water Monitoring Program Using a GIS/GPS Database.* Proceedings of the

Air and Waste Management Association Conference on Geographic Information Systems in Environmental Resources Management. Reno, NV. p. 215-227.

Hult, M. F. 1979. *Design of a Network for Monitoring Ground Water Quality in Minnesota.* U. S. Geological Survey Open File Report 79-1164. St. Paul, MN. 44 p.

Minnesota Department of Health. 1997. *Health Based Value for Manganese.* Office Memorandum by Larry Gust, Supervisor, Health Risk Assessment Unit. St. Paul, MN. 1 p.

Minnesota Pollution Control Agency and Minnesota Department of Agriculture. 1991. *Nitrogen in Minnesota Ground Water*. St. Paul, MN.

Minnesota Pollution Control Agency. 1994. *Ground Water Monitoring and Assessment Program (GWMAP) Annual Report.* St. Paul, MN. 182 p.

Minnesota Pollution Control Agency. 1995. *Ground Water Monitoring and Assessment Program (GWMAP) Annual Report.* St. Paul, MN. 116 p.

Minnesota Pollution Control Agency. 1996. *GWMAP Field Guidance Manual.* St. Paul, MN 42 p.

Minnesota Pollution Control Agency. 1997. *Field Data Entry System (FDES) Operating Manual.* St. Paul, MN.

Minnesota Pollution Control Agency. 1998a. *Data Analysis Protocol for the Ground Water Monitoring and Assessment Program (GWMAP)*. Draft in review.

Minnesota Pollution Control Agency. 1998b. *Effects of Land Use on Ground Water Quality, St. Cloud Area, Minnesota. First Annual Monitoring Report*. Draft in review.

Montgomery, D.C. 1984. *Design and Analysis of Experiments*. John Wiley and Sons. New York, NY 538 p.

Myers, Georgianna, S. Magdalene, D. Jakes, E. Porcher. 1992. *The Redesign of the Ambient Ground Water Monitoring Program.* Minnesota Pollution Control Agency. St. Paul, MN. 151 p.

Neve, H., T. Clark, J. Schlotthauer, Y. Hsu., and J. Stockinger. 1996. *Ground Water Monitoring and Assessment Program: Interpretations of Selected Parameters*. Minnesota Pollution Control Agency. St. Paul, MN.

Newman, M.C., K.D. Greene, and P.M. Dixon. 1995. *Uncensor v4.0*. Savannah River Ecology Laboratory. 91 p.

Research Analytical Laboratory. 1997. *Quality Assurance/Quality Control Policy.* University of Minnesota, Department of Soil Water and Climate. St. Paul, MN. 28 p. and appendices.

Statistical Package for the Social Sciences, Inc. 1996. *SPSS Base 7.0 for Windows - User's Guide.* Prentice Hall. Chicago, IL. 564 p.

Tipping, R. G. 1994. *Southeast Minnesota Regional Ground Water Monitoring Study.* Report to the Zumbro-Root River Joint Powers Board. Minnesota Geological Survey Open File Report 94-1. Minneapolis, MN. 117p.

Trojan, M.D. 1998. *Surficial Hydrogeology, Plate 3.* In: Falteisek, J.D., ed., Regional Hydrogeologic Assessment, Southern Red River Valley, Minnesota: Minnesota Department Natural Resources Regional Hydrogeologic Assessment Series RHA-3. Part B. Scale 1:200,000. St. Paul, MN. In press.

United States Environmental Protection Agency. 1989. *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities: Interim Final Guidance.* Office of Solid Waste, Waste Management Division, United States Environmental Agency, Washington, D.C.

United States Geological Survey. 1996. *Few Volatile Organic Compounds Detected in Rivers and Ground Water In The Upper Mississippi River Basin, Minnesota And Wisconsin.* Fact Sheet FS-095-96. Mounds View, MN. 2 p.

Wahl, T. E., and R. G. Tipping. 1991. *Ground-water Data Management - The County Well Index.* Minnesota Geological Survey. Minneapolis, MN. 38 p.

Appendices

APPENDIX A

Technical Specifications for the Handheld Global Positioning System (GPS)

Manufacturer: Trimble Navigation, Ltd.
645 North Mary Avenue
PO Box 3642
Sunnyvale, California 94088
1-800-827-8000

Model: GPS Pathfinder (™) Basic Plus

Receiver: 6-channel parallel/sequential; tracks up to 8 satellites, L1/CA code

Size: 6.5" x 7.0" x 2.0"

Weight: 4.2 lbs., with rechargable battery

Power: 8.4V rechargable NiCad battery; vehicle cigarette lighter adapter

Operating temperature: -20 to 140 degrees F

Software: PFINDER (™) differential correction post-processing software (5 meter accuracy)

APPENDIX B

Sample Bottle Descriptions

General Chemistry

500 ml HDPE Level II cleaned bottle
no preservative, refrigerate
analyses: solids-suspended and dissolved, specific conductance, sulfate

Anions

250 ml Clear HDPE Level II cleaned bottle with blue cap
preservative: sulfuric acid 5 mls or 2 full droppers, refrigerate
analyses: nitrate, phosphate, fluoride, bromide

Cations

250 ml Clear HDPE Level II cleaned bottle with white cap
preservative: nitric acid, 5 mls or 2 full droppers, refrigerate
analyses: metals

TOC (Total Organic Carbon)

20 ml glass vial
preservative: phosphoric acid, 8 drops, refrigerate

VOC (Volatile Organic Compounds)

three glass vials per sample
preservative: hydrochloric acid, 2 drops, refrigerate
analyses: VOCs, MDH code 465
Note: Keep sets together and deliver to lab within 2 weeks of date on trip blank

Tritium

500 ml HDPE Level II cleaned bottle with blue cap
no preservative
analyses: tritium, age dating (selected samples)

Pesticides

1000 ml Amber glass bottle
preservative: refrigerate
analyses: pesticide - Dept. Of Agriculture (selected samples)
Note: Seven day shelf life. Deliver weekly

All plastic bottles are purchased pre-cleaned at EPA Level II standards. VOC vials come pre-cleaned from the Department of Health Lab.

APPENDIX C

Table C.1 : Inorganic Chemistry Measured at the University of Minnesota Research Analytical Laboratory and Years Analyzed.

Alkalinity (field and lab)	92-96	Nitrate	92-96
Aluminum	92-96	Orthophosphate	92-96
Antimony	92-96	Oxidation-reduction potential (field)	92-96
Arsenic	92-96	pH (field)	92-96
Barium	92-96	Phosphorus	92-96
Beryllium	92-96	Phosphate	92-96
Bismuth	95-96	Potassium	92-96
Boron	92-96	Rubidium	92-96
Bromide	92-96	Selenium	92-96
Cadmium	92-96	Silica	92-96
Calcium	92-96	Silver	92-96
Cesium	95-96	Sodium	92-96
Chloride	92-96	Specific conductivity (field and lab)	92-96
Chromium	92-96	Strontium	92-96
Cobalt	92-96	Sulfate	92-96
Copper	92-96	Sulfur	92-96
Dissolved Oxygen (field)	92-96	Temperature (field)	92-96
Fluoride	92-96	Thallium	92-96
Iron	92-96	Tin	95-96
Lead	92-96	Titanium	92-96
Lithium	92-96	Total dissolved solids	92-96
Magnesium	92-96	Total organic carbon	92-96
Manganese	92-96	Total suspended solids	92-96
Mercury	92-94	Vanadium	92-96
Molybdenum	92-96	Zinc	92-96
Nickel	92-96	Zirconium	95-96

All metals reported as total, unfiltered.

[1]Tritium was analyzed on selected samples at the University of Waterloo, Canada, laboratory.

Table C.2 : Volatile Organic Compounds Measured at the Minnesota Department of Health Laboratory.

Dichlorodifluoromethane	Dichlorofluoromethane
Vinyl Chloride	Trichlorotrifluoroethane
Chloroethane	Allyl Chloride
Trichlorofluoromethane	T-1,2-dichloroethene
1,1-dichloroethane	2,2-dichloropropane
1,1-dichloroethene	Chloroform
C-1,2 dichloroethene	1,1,1-trichloroethane
Bromochloromethane	Carbon Tetrachloride
1,2-dichloropropane	Trichloroethene
1,1-dichloropropene	Bromodichloromethane
1,2-dichloroethane	C-1,3-dichloropropene
Dibromomethane	1,1,2-trichloroethane
T-1,2-dichloropropene	tetrachloroethene
1,3-dichloropropane	1,2-dibromoethane
Chlorodibromomethane	1,1,1,2-tetrachloroethane
Chlorobenzene	1,1,2,2-tetrachloroethane
Bromoform	Bromobenzene
1,2,3-trichloropropane	4-chlorotoluene
2-chlorotoluene	1,4-dichlorobenzene
1,3-dichlorobenzene	1,2-dibromo-3-chloropropane
1,2-dichlorobenzene	Hexachlorobutadiene
1,2,4-trichlorobenzene	Ethyl Ether
1,2,3-trichlorobenzene	Methyl tertiary-butyl ether
Acetone	Tetrahydrofuran
Methyl ethyl ketone	Methyl isobutyl ketone
Benzene	Ethyl Benzene
Toluene	O-xylene
M+P-xylene	Isopropyl Benzene
Styrene	1,3,5-trimethylbenzene
N-propyl Benzene	1,2,4-trimethylbenzene
Tert-butyl Benzene	Sec-butylbenzene
Chloromethane	N-butylbenzene
Bromomethane	P-isopropyltoluene
Methylene chloride	
Naphthalene	

APPENDIX D

List of Tables

D.1. QA/QC summary for charge balance, TDS, and SC relationships.
D.2. Ratios illustrating distribution of major ions.
D.3. Comparison of laboratory duplicates with field samples. Values are relative percent difference.
D.4. Comparison of field primary and duplicate samples. Values are relative percent difference.
D.5. Summary information for all chemical parameters. Censoring values were established just below the maximum reporting limit.
D.6. Descriptive statistics for the Franconia-Ironton-Galesville Formation (CFIG).
D.7. Descriptive statistics for the Franconia Formation (CFRN).
D.8. Descriptive statistics for the Ironton-Galesville Formation (CIGL).
D.9. Descriptive statistics for the Jordan Sandstone (CJDN).
D.10. Descriptive statistics for the Mount Simon-Hinckley Formation (CMSH)
D.11. Descriptive statistics for the Mount Simon Formation (CMTS)
D.12. Descriptive statistics for the St. Lawrence-Franconia Formation (CSLF).
D.13. Descriptive statistics for the St. Lawrence Formation (CSTL).
D.14. Descriptive statistics for the Cedar Valley Formation (DCVA).
D.15. Descriptive statistics for Cretaceous Sandstones (KRET).
D.16. Descriptive statistics for the Galena Formation (OGAL).
D.17. Descriptive statistics for the Maquoketa Formation (OMAQ).
D.18. Descriptive statistics for the Prairie du Chien Group (OPDC).
D.19. Descriptive statistics for the Plateville Limestone (OPVL).
D.20. Descriptive statistics for the St. Peter-Prairie du Chien Formation (OSPC).
D.21. Descriptive statistics for the St. Peter Sandstone (OSTP).
D.22. Descriptive statistics for undifferentiated Precambrian formations (PCCR).
D.23. Descriptive statistics for undifferentiated Precambrian crystalline formations (PCUU).
D.24. Descriptive statistics for the Biwabik Iron Formation (PEBI).
D.25. Descriptive statistics for Duluth Complex (PMDC).
D.26. Descriptive statistics for the Mount Simon-Fon du Lac Formation (PMFL).
D.27. Descriptive statistics for the Mount Simon-Hinckley Formation (PMHN).
D.28. Descriptive statistics for the North Shore Volcanics group (PMNS).
D.29. Descriptive statistics for the Sioux Quartzite (PMSX).
D.30. Descriptive statistics for undifferentiated Proterozoic Metasedimentary units (PMUD).
D.31. Descriptive statistics for buried Quaternary artesian aquifers (QBAA).
D.32. Descriptive statistics for unconfined buried Quaternary aquifers (QBUA).
D.33. Descriptive statistics for buried undifferentiated Quaternary aquifers (QBUU).
D.34. Descriptive statistics for unconfined, undifferentiated Quaternary aquifers (QUUU).
D.35. Descriptive statistics for Quaternary water table aquifers (QWTA).
D.36. Descriptive statistics for Cambrian aquifer group.
D.37. Descriptive statistics for Ordovician aquifer group.
D.38. Descriptive statistics for Precambrian aquifer group.
D.39. Descriptive statistics for buried Quaternary aquifer group.
D.40. Descriptive statistics for surficial Quaternary aquifer group.
D.41. Descriptive statistics for CFIG-CFRN-CIGL aquifers.
D.42. Descriptive statistics for OSTP-OPDC-CJDN aquifers.
D.43. Descriptive statistics for CMSH-CMTS-PMHN aquifers.
D.44. Descriptive statistics for Upper Carbonate aquifers.
D.45. Standard deviations and sample size for parameters which had a normal or log-normal b distribution.

D.46. Slopes and intercepts from Helsel's robust method. All regression coefficients are applied to concentrations of ug/L.

D.47. Mean ranks using Kruskal-Wallis test, by chemical and aquifer subgroup. The null hypothesis was concentrations of individual chemicals did not differ by aquifer group. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.48. Mean ranks using Kruskal-Wallis test, by chemical and aquifer age group. The null hypothesis was concentrations of individual chemicals did not differ by aquifer group. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.49. Mean ranks using Kruskal-Wallis test, by chemical and aquifer hydrologic group. The null hypothesis was concentrations of individual chemicals did not differ by aquifer group. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.50. Mean ranks using Kruskal-Wallis test, by chemical and well diameter. The null hypothesis was concentrations of individual chemicals did not differ by well diameter. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.51. Mean ranks using Kruskal-Wallis test, by chemical and well diameter for the Cambrian group. The null hypothesis was concentrations of individual chemicals did not differ by well diameter. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.52. Mean ranks using Kruskal-Wallis test, by chemical and well diameter for the Devonian group. The null hypothesis was concentrations of individual chemicals did not differ by well diameter. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.53. Mean ranks using Kruskal-Wallis test, by chemical and well diameter for the Cretaceous group. The null hypothesis was concentrations of individual chemicals did not differ by well diameter. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.54. Mean ranks using Kruskal-Wallis test, by chemical and well diameter for the Ordovician group. The null hypothesis was concentrations of individual chemicals did not differ by well diameter. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.55. Mean ranks using Kruskal-Wallis test, by chemical and well diameter for the Precambrian group. The null hypothesis was concentrations of individual chemicals did not differ by well diameter. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.56. Mean ranks using Kruskal-Wallis test, by chemical and well diameter for the buried Quaternary group. The null hypothesis was concentrations of individual chemicals did not differ by well diameter. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.57. Mean ranks using Kruskal-Wallis test, by chemical and well diameter for the surficial Quaternary group. The null hypothesis was concentrations of individual chemicals did not differ by well diameter. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.58. Mean ranks using Kruskal-Wallis test, by chemical and well diameter for the CFIG-CFRN-CIGL group. The null hypothesis was concentrations of individual chemicals did not differ by well diameter. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.59. Mean ranks using Kruskal-Wallis test, by chemical and well diameter for the OSTP-OPDC-CJDN group. The null hypothesis was concentrations of individual chemicals did not differ by well diameter. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.60. Mean ranks using Kruskal-Wallis test, by chemical and well diameter for the CMSH-CMTS-PMHN group. The null hypothesis was concentrations of individual chemicals did not differ by well diameter. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.61. Mean ranks using Kruskal-Wallis test, by chemical and well diameter for the Upper Carbonate group. The null hypothesis was concentrations of individual chemicals did not differ by well diameter. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.62. Mean ranks using Mann-Whitney test comparing concentrations of individual chemicals in wells containing a detectable volatile organic compound (VOC) and those without a detected VOC. The null hypothesis was concentrations of individual chemicals did not differ between wells with and without a VOC detected. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.63. Summary of significant results comparing water quality parameter concentrations in wells with and without a VOC detection.

D.64. Mean ranks using Mann-Whitney test comparing concentrations of individual chemicals in wells containing detectable tritium and those with no tritium detected. The null hypothesis was concentrations of individual chemicals did not differ between wells with or without detectable tritium. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.65. Summary of significant results comparing water quality parameter concentrations in wells with and without detectable tritium.

D.66. Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in Cambrian wells for different sampling years. The null hypothesis was concentrations of individual chemicals did not differ by sampling year. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.67. Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in Devonian wells for different sampling years. The null hypothesis was concentrations of individual chemicals did not differ by sampling year. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.68. Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in Cretaceous wells for different sampling years. The null hypothesis was concentrations of individual chemicals did not differ by sampling year. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.69. Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in Ordovician wells for different sampling years. The null hypothesis was concentrations of individual chemicals did not differ by sampling year. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.70. Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in Precambrian wells for different sampling years. The null hypothesis was concentrations of individual chemicals did not differ by sampling year. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.71. Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in buried Quaternary wells for different sampling years. The null hypothesis was concentrations of individual chemicals did not differ by sampling year. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.72. Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in surficial Quaternary wells for different sampling years. The null hypothesis was concentrations of individual chemicals did not differ by sampling year. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.73. Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in CFIG-CFRN-CIGL wells for different sampling years. The null hypothesis was concentrations of individual chemicals did not differ by sampling year. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.74. Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in OSTP-OPDC-OSTP wells for different sampling years. The null hypothesis was concentrations of individual chemicals did not differ by sampling year. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.75. Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in CMSH-CMTS-PMHN wells for different sampling years. The null hypothesis was concentrations of individual chemicals did not differ by sampling year. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.76. Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in Upper Carbonate wells for different sampling years. The null hypothesis was concentrations of individual chemicals did not differ by sampling year. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.77. Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in Cambrian wells for different sampling months. The null hypothesis was concentrations of individual chemicals did not differ by sampling month. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.78. Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in Devonian wells for different sampling months. The null hypothesis was concentrations of individual chemicals did not differ by sampling month. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.79. Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in Cretaceous wells for different sampling months. The null hypothesis was concentrations of individual chemicals did not differ by sampling month. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.80. Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in Ordovician wells for different sampling months. The null hypothesis was concentrations of individual chemicals did not differ by sampling month. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.81. Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in Precambrian wells for different sampling months. The null hypothesis was concentrations of individual chemicals did not differ by sampling month. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.82. Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in buried Quaternary wells for different sampling months. The null hypothesis was concentrations of individual chemicals did not differ by sampling month. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.83. Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in surficial Quaternary wells for different sampling months. The null hypothesis was concentrations of individual chemicals did not differ by sampling month. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.84. Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in CFIG-CFRN-CIGL wells for different sampling months. The null hypothesis was concentrations of individual chemicals did not differ by sampling month. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.85. Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in OSTP-OPDC-CJDN wells for different sampling months. The null hypothesis was concentrations of individual chemicals did not differ by sampling month. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.86. Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in CMSH-CMTS-PMHN wells for different sampling months. The null hypothesis was concentrations of individual chemicals did not differ by sampling month. The null hypothesis is generally rejected if the p-value is less than 0.05.

D.87. Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in Upper Carbonate wells for different sampling months. The null hypothesis was concentrations of individual chemicals did not differ by sampling month. The null hypothesis is generally rejected if the p-value is less than 0.05.
D.88. Correlation coefficients between chemical parameters and well depth, static water level, and UTM coordinates, for the Cambrian aquifer group.
D.89. Correlation coefficients between chemical parameters and well depth, static water level, and UTM coordinates, for the Devonian aquifer group.
D.90. Correlation coefficients between chemical parameters and well depth, static water level, and UTM coordinates, for the Cretaceous aquifer group.
D.91. Correlation coefficients between chemical parameters and well depth, static water level, and UTM coordinates, for the Ordovician aquifer group.
D.92. Correlation coefficients between chemical parameters and well depth, static water level, and UTM coordinates, for the Precambrian aquifer group.
D.93. Correlation coefficients between chemical parameters and well depth, static water level, and UTM coordinates, for the buried Quaternary aquifer group.
D.94. Correlation coefficients between chemical parameters and well depth, static water level, and UTM coordinates, for the surficial Quaternary aquifer group.
D.95. Correlation coefficients between chemical parameters and well depth, static water level, and UTM coordinates, for the CFIG-CFRN-CIGL aquifer group.
D.96. Correlation coefficients between chemical parameters and well depth, static water level, and UTM coordinates, for the OSTP-OPDC-CJDN aquifer group.
D.97. Correlation coefficients between chemical parameters and well depth, static water level, and UTM coordinates, for the CMSH-CMTS-PMHN aquifer group.
D.98. Correlation coefficients between chemical parameters and well depth, static water level, and UTM coordinates, for the Upper Carbonate aquifer group.
D.99. Correlation coefficients between chemical parameters and dissolved oxygen, iron, manganese, and oxidation-reduction potential for the Cambrian aquifer group.
D.100. Correlation coefficients between chemical parameters and dissolved oxygen, iron, manganese, and oxidation-reduction potential for the Devonian aquifer group.
D.101. Correlation coefficients between chemical parameters dissolved oxygen, iron, manganese, and oxidation-reduction potential, for the Cretaceous aquifer group.
D.102. Correlation coefficients between chemical parameters dissolved oxygen, iron, manganese, and oxidation-reduction potential, for the Ordovician aquifer group.
D.103. Correlation coefficients between chemical parameters dissolved oxygen, iron, manganese, and oxidation-reduction potential, for the Precambrian aquifer group.
D.104. Correlation coefficients between chemical parameters dissolved oxygen, iron, manganese, and oxidation-reduction potential, for the buried Quaternary aquifer group.
D.105. Correlation coefficients between chemical parameters dissolved oxygen, iron, manganese, and oxidation-reduction potential, for the surficial Quaternary aquifer group.
D.106. Correlation coefficients between chemical parameters dissolved oxygen, iron, manganese, and oxidation-reduction potential, for the CFIG-CFRN-CIGL aquifer group.
D.107. Correlation coefficients between chemical parameters dissolved oxygen, iron, manganese, and oxidation-reduction potential, for the OSTP-OPDC-CJDN aquifer group.
D.108. Correlation coefficients between chemical parameters dissolved oxygen, iron, manganese, and oxidation-reduction potential, for the CMSH-CMTS-PMHN aquifer group.
D.109. Correlation coefficients between chemical parameters dissolved oxygen, iron, manganese, and oxidation-reduction potential, for the Upper Carbonate aquifer group.

D.110. Summary of the number and sign of significant correlations, by chemical parameter, for age-based aquifer groups, for dissolved oxygen, iron, manganese, and redox potential. The average score is equal to (iron + manganese - dissolved oxygen - redox)/n.
D.111. Summary of water quality criteria, basis of criteria, and endpoints, by chemical parameter.
D.112. Summary of water quality exceedances for each chemical parameter, by aquifer and aquifer group.
D.113. Median background hazard indices for target endpoints, by aquifer group.
D.114. Estimate of percent of samples exceeding a hazard index of 1.0.
D.115. Assumed concentrations for solubility calculations. Concentrations represent the median concentration for all data. Standard deviations are for the entire data set.
D.116. Concentrations of chemicals in igneous rocks, various sedimentary rocks, soil, and air. Concentrations are in mg/kg (ppm) except for air.
D.117. Summary of VOC detections by aquifer and aquifer group.
D.118. Summary of VOC detections by chemical class.
D.119. Summary of chemical parameters and other factors which differed significantly between wells containing a detectable non-halogenated aromatic compound compared to wells with no detectable VOC. "-" represents a concentration or value for the parameter was lower in wells with the detectable VOC; "+" represents a concentration or value for the parameter was greater in wells with the detectable VOC.
D.120. Summary of chemical parameters and other factors which differed significantly between wells containing a detectable halogenated aliphatic compound compared to wells with no detectable VOC. "-" represents a concentration or value for the parameter was lower in wells with the detectable VOC; "+" represents a concentration or value for the parameter was greater in wells with the detectable VOC.
D.121. Summary of chemical parameters and other factors which differed significantly between wells containing a detectable trihalomethane compound compared to wells with no detectable VOC. "-" represents a concentration or value for the parameter was lower in wells with the detectable VOC; "+" represents a concentration or value for the parameter was greater in wells with the detectable VOC.
D.122. Summary of chemical parameters and other factors which differed significantly between wells containing a detectable chlorofluorocarbon compound compared to wells with no detectable VOC. "-" represents a concentration or value for the parameter was lower in wells with the detectable VOC; "+" represents a concentration or value for the parameter was greater in wells with the detectable VOC.
D.123. Summary of chemical parameters and other factors which differed significantly between wells containing a detectable ketone or aldehyde compound compared to wells with no detectable VOC. "-" represents a concentration or value for the parameter was lower in wells with the detectable VOC; "+" represents a concentration or value for the parameter was greater in wells with the detectable VOC.
D.124. Summary of chemical parameters and other factors which differed significantly between wells containing a detectable ether compound compared to wells with no detectable VOC. "-" represents a concentration or value for the parameter was lower in wells with the detectable VOC; "+" represents a concentration or value for the parameter was greater in wells with the detectable VOC.
D.125. Summary of VOC exceedances of the HRL.

Table D.1.: QA/QC summary for charge balance, TDS, and SC relationships.

Aquifer or Aquifer Group	Samples exceeding 10% charge balance (%)	Mean charge balance (%)	TDS/SC	Out of range[1]	SC/(sum meq cations)	Out of range[2]
CFIG	20.0	8.9	0.61	0	82.3	0
CFRN	3.7	2.5	0.61	5	90.3	2
CIGL	25.0	4.4	0.62	1	86.9	0
CJDN	12.9	3.7	0.61	7	89.7	2
CMSH	30.0	7.5	0.72	8	90.9	2
CMTS	0.0	3.2	0.59	2	90.8	0
CSLH	50.0	6.9	0.66	0	90.5	0
CSTL	0.0	4.7	0.64	1	81.2	0
DCVA	0.0	0.2	0.59	1	92.0	0
KRET	74.4	19.5	0.76	22	83.9	2
OGAL	18.2	4.0	0.58	9	92.1	0
OMAQ	0.0	5.7	ins[3]	0	ins	0
OPDC	11.1	4.6	0.61	5	91.3	1
OPVL	0.0	4.0	0.57	0	86.4	0
OSPC	0.0	4.0	0.72	0	90.4	0
OSTP	13.0	5.8	0.59	2	90.9	0
PCCR	11.5	5.0	0.67	6	91.1	4
PCUU	66.7	14.8	0.84	2	85.8	1
PEBI	100.0	16.2	ins	0	ins	0
PMDC	0.0	-2.6	ins	0	ins	0
PMFL	0.0	3.4	0.63	0	91.3	0
PMHN	0.0	1.1	0.61	0	101.8	0
PMNS	18.8	6.3	0.65	4	92.0	0
PMSX	50.0	24.3	0.79	2	86.4	0
PMUD	4.8	3.6	0.63	7	92.6	2
QBAA	30.6	8.2	0.69	150	85.4	35
QBUA	23.1	5.1	0.66	33	89.5	4
QBUU	40.9	12.3	0.70	8	85.2	2
QUUU	75.0	22.7	0.80	2	84.9	0
QWTA	9.3	4.4	0.67	36	89.4	10
Cambrian	13.7	4.2	0.61	24	87.6	6
Ordovician	12.6	4.8	0.61	16	89.6	1
Precambrian	16.7	6.1	0.66	21	91.5	7
Buried Quaternary	29.2	7.8	0.71	191	84.3	41
Surficial Quaternary	11.5	5.0	0.69	34	88.1	10
CFIG-CFRN-CIGL	10.0	3.7	0.61	6	87.5	2
OSTP-OPDC-CJDN	12.2	4.6	0.61	14	90.7	3
CMSH-CMTS-PMHN	11.5	4.6	0.61	10	91.2	2
Upper Carbonate	11.1	2.9	0.58	4	92.0	0
All wells	23.8	6.9	0.68	290	86.4	67
Year of Sampling						
1992	7.7	1.9	0.55	13	85.8	4
1993	45.0	12.5	0.69	80	83.4	13
1994	28.5	7.2	0.69	44	89.8	3
1995	14.9	4.4	0.70	148	77.3	47
1996	9.2	5.0	0.63	5	90.9	0

[1] Number of samples exceeding 0.75 or less than 0.55 for the ratio of TDS to SC
[2] Number of samples exceeding 50 or less than 150 for the ratio of SC to the sum of meq of cations
[3] ins = insufficient sample size

Table D.2.: Ratios illustrating distribution of major ions.

Aquifer or Aquifer Group	Mg/(Mg + Ca)		Na/(Na + Cl)		Ca/(Ca + SO_4)		K/(K + Na)	
	Median	% > 0.40	Median	% < 0.50	Median	% < 0.50	Median	% > 0.20
CFIG	0.28	0.0	0.89	0.0	0.80	0.0	0.27	80.0
CFRN	0.30	0.0	0.84	18.5	0.91	0.0	0.29	59.3
CIGL	0.26	0.0	0.84	0.0	0.90	0.0	0.20	50.0
CJDN	0.28	0.0	0.78	16.1	0.93	0.0	0.23	61.3
CMSH	0.25	0.0	0.64	10.0	0.94	0.0	0.22	90.0
CMTS	0.26	0.0	0.89	23.1	0.95	0.0	0.16	38.5
CSLH	0.24	0.0	0.48	50.0	0.82	0.0	0.24	75.0
CSTL	0.28	0.0	0.95	0.0	0.88	0.0	0.15	50.0
DCVA	0.23	0.0	0.94	0.0	0.97	0.0	0.15	20.0
KRET	0.25	0.0	0.91	10.3	0.56	30.8	0.08	10.3
OGAL	0.24	0.0	0.96	18.2	0.90	4.5	0.10	13.6
OMAQ	ins[1]	0.0	ins	100.0	ins	0.0	ins	100.0
OPDC	0.26	2.8	0.48	52.8	0.91	0.0	0.23	58.3
OPVL	0.32	33.3	0.34	66.7	0.95	0.0	0.28	100.0
OSPC	0.26	0.0	0.48	50.0	0.91	0.0	0.33	100.0
OSTP	0.25	0.0	0.77	26.1	0.91	0.0	0.30	87.0
PCCR	0.26	11.5	0.86	11.5	0.92	7.7	0.13	30.8
PCUU	0.26	0.0	0.93	0.0	0.64	33.3	0.09	0.0
PEBI	ins	0.0	ins	0.0	ins	0.0	ins	100.0
PMDC	ins	0.0	ins	0.0	ins	0.0	ins	0.0
PMFL	0.25	0.0	0.82	0.0	0.93	0.0	0.19	0.0
PMHN	0.26	0.0	0.71	0.0	0.92	0.0	0.13	0.0
PMNS	0.30	11.8	0.84	11.8	0.89	17.6	0.05	5.9
PMSX	0.25	0.0	0.92	25.0	0.65	25.0	0.06	0.0
PMUD	0.27	0.0	0.80	8.7	0.94	8.7	0.13	21.7
QBAA	0.27	5.7	0.89	12.4	0.90	11.6	0.14	35.1
QBUA	0.25	1.9	0.59	42.3	0.92	2.9	0.24	61.5
QBUU	0.26	0.0	0.98	9.1	0.69	9.1	0.14	18.2
QUUU	0.21	0.0	0.48	50.0	0.57	0.0	0.15	0.0
QWTA	0.23	4.2	0.49	50.4	0.93	2.5	0.24	61.3
Cambrian	0.27	0.0	0.82	15.7	0.92	0.0	0.22	60.8
Ordovician	0.25	2.3	0.72	37.9	0.91	1.1	0.23	57.5
Precambrian	0.27	6.3	0.85	10.0	0.91	11.3	0.11	18.8
Buried Quaternary	0.26	4.7	0.87	18.3	0.90	9.7	0.16	39.8
Surficial Quaternary	0.23	4.1	0.49	50.4	0.92	2.4	0.23	59.3
CFIG-CFRN-CIGL	0.28	0.0	0.85	12.5	0.91	0.0	0.26	60.0
OSTP-OPDC-CJDN	0.26	1.1	0.75	33.3	0.91	0.0	0.26	66.7
CMSH-CMTS-PMHN	0.25	0.0	0.76	15.4	0.95	0.0	0.21	53.8
Upper Carbonate	0.24	2.8	0.94	19.4	0.93	2.8	0.14	25.0
All wells	0.26	3.8	0.83	22.7	0.91	7.9	0.17	93.0

[1] ins = insufficient sample size

Table D.3: Comparison of laboratory duplicates with field samples. Values are relative percent difference.

Parameter	Count	No. of common non-detects	Mean	Median	Minmum	Maximum	Standard deviation
Alkalinity	34	-	0.03	0.31	-3.86	4.68	2.33
Aluminum (Al)	123	17	5.07	1.70	-88.0	77.5	24.1
Antimony (Sb)	123	24	1.70	0.00	-99.3	66.7	25.7
Arsenic (As)	123	3	3.27	0.21	-47.2	64.5	15.6
Barium (Ba)	133	1	1.01	0.06	-5.08	19.7	3.43
Beryllium (Be)	123	86	4.19	0.00	-50.0	90.0	17.3
Bismuth (Bi)	46	45	-	-	-	-	-
Boron (B)	133	10	-0.56	0.00	-37.2	38.2	8.74
Bromide (Br)	112	112	-	-	-	-	-
Cadmium (Cd)	123	47	-6.95	-6.67	-70.2	62.5	27.2
Calcium (Ca)	133	-	0.06	-0.07	-2.55	3.67	0.97
Cesium (Cs)	46	29	4.78	0.00	-6.02	20.0	7.41
Chloride (Cl)	114	1	-0.25	0.00	-11.6	8.15	2.55
Chromium (Cr)	123	26	-2.35	-0.68	-58.0	44.4	13.2
Cobalt (Co)	123	-	-0.02	0.46	-73.5	25.9	10.4
Copper (Cu)	133	45	2.23	1.74	-98.6	76.1	24.3
Dissolved Oxygen	-	-	-	-	-	-	-
Eh	-	-	-	-	-	-	-
Fluoride (F)	112		0.16	0.00	-98.0	29.0	10.6
Iron (Fe)	133	52	-1.10	-0.10	-86.5	821.9	13.8
Lead (Pb)	123	15	1.02	0.00	-94.3	57.1	17.4
Lithium (Li)	133	-	-2.28	0.00	-93.4	35.4	15.6
Magnesium (Mg)	133	-	0.02	-0.10	-2.70	3.50	1.03
Manganese (Mn)	133	5	-0.69	0.00	-99.3	30.0	10.1
Mercury (Hg)	65	0	1.99	0.99	-16.7	16.1	11.3
Molybdenum (Mo)	133	36	-0.02	0.00	-99.2	55.6	15.9
Nickel (Ni)	133	30	-0.78	0.00	-98.7	37.7	18.4
Nitrate (NO_3)	97	79	0.09	0.00	-7.69	8.00	2.74
Ortho-phosphate	-	-	-	-	-	-	-
pH	-	-	-	-	-	-	-
$Phosphorus_{total}$	133	-	-0.30	0.00	-92.6	38.3	11.5
Potassium (K)	133	17	0.20	-0.05	-14.9	29.9	4.77
Redox	-	-	-	-	-	-	-
Rubidium (Rb)	133	112	9.91	9.65	2.19	18.2	6.62
Selenium (Se)	110	12	0.18	0.00	-20.0	33.3	5.43
Silcate (Si)	133	-	0.05	-0.05	-3.70	3.38	0.86
Silver (Ag)	-	-	-	-	-	-	-
Sodium (Na)	133	-	0.06	0.03	-4.39	4.90	1.06
Specific Conductivity	96	-	-0.09	0.00	-17.9	6.40	2.17
Strontium (Sr)	133	-	0.14	0.00	-2.46	5.62	0.95
Sulfate (SO_4)	114	13	-0.41	0.04	-48.4	4.34	5.09
Sulfur (S)	133	-	0.26	0.04	-17.3	28.4	3.45
Temperature	-	-	-	-	-	-	-
Thallium (Tl)	123	61	4.39	0.00	-33.3	77.8	19.2
Tin (Sn)	46	4	1.54	0.00	-84.0	69.2	34.6
Titanium (Ti)	-	-	-	-	-	-	-
Total dissolved solids	156	-	0.84	0.70	-13.9	12.1	3.31
Total organic carbon	122	6	-0.16	0.00	-18.2	12.5	4.28
Total phosphate	116	39	-1.40	0.00	-27.3	15.4	7.53
Total suspended solids	162	-	1.29	0.00	-33.3	50.0	14.6
Vanadium (V)	133	49	0.24	0.66	-99.1	44.0	22.5
Zinc (Zn)	133	8	0.85	0.32	-80.5	40.2	13.3
Zirconium (Zr)	46	20	3.22	0.00	-28.6	70.4	19.4

Table D.4: Comparison of field primary and duplicate samples. Values are relative percent difference.

Parameter	Count	No. of common nondetects	Mean	Median	Minimum	Maximum	Standard deviation
Alkalinity	19	0	-0.26	-0.25	-3.29	2.52	1.40
Aluminum (Al)	82	6	-2.67	0.00	-45.83	46.20	16.71
Antimony (Sb)	82	27	0.38	0.00	-40.21	38.57	16.68
Arsenic (As)	82	1	-0.01	-0.34	-41.01	47.39	13.14
Barium (Ba)	83	3	0.08	0.00	-6.57	10.00	2.20
Beryllium (Be)	82	54	-0.24	0.00	-35.71	30.00	11.35
Bismuth (Bi)	33	30	0.10	0.00	-3.33	20.00	7.48
Boron (B)	83	3	0.20	0.35	-18.25	11.17	3.87
Bromide (Br)	82	81	-0.02	0.00	-1.79	0.00	0.20
Cadmium (Cd)	82	36	-0.77	0.00	-38.24	42.59	15.31
Calcium (Ca)	83	0	0.10	0.08	-1.84	1.89	0.51
Cesium (Cs)	33	26	0.16	0.00	-16.67	25.00	7.05
Chloride (Cl)	82	0	0.34	0.00	-7.86	5.60	2.01
Chromium (Cr)	82	23	4.57	0.00	-28.38	45.10	13.66
Cobalt (Co)	82	0	0.18	-0.18	-17.24	15.85	4.08
Copper (Cu)	83	27	-1.22	0.00	-41.50	21.43	10.74
Dissolved Oxygen	-	-	-	-	-	-	-
Eh	-	-	-	-	-	-	-
Fluoride (F)	78	35	0.92	0.00	-13.16	8.33	2.53
Iron (Fe)	83	0	-0.17	-0.01	-32.11	14.41	4.63
Lead (Pb)	82	5	0.40	0.00	-31.82	22.97	8.21
Lithium (Li)	83	16	-0.72	0.00	-18.53	16.92	6.28
Magnesium (Mg)	83	0	0.02	0.05	-4.67	1.78	0.70
Manganese (Mn)	83	2	-0.26	0.05	-15.12	1.84	2.03
Mercury (Hg)	32	27	0.13	0.00	-16.67	10.00	3.69
Molybdenum (Mo)	83	50	0.43	0.00	-18.25	30.30	6.50
Nickel (Ni)	83	49	0.50	0.00	-23.21	23.79	7.28
Nitrate (NO_3)	81	63	-0.45	0.00	-42.97	10.00	5.42
Ortho-phosphate	6	4	-1.11	0.00	-16.67	10.00	8.61
pH	-	-	-	-	-	-	-
$Phosphorus_{total}$	83	5	0.39	0.00	-10.69	14.47	4.43
Potassium (K)	83	1	-0.47	0.02	-13.68	4.45	2.66
Redox	-	-	-	-	-	-	-
Rubidium (Rb)	83	54	-0.58	0.00	-15.64	15.99	4.70
Selenium (Se)	80	19	3.42	0.00	-38.89	47.96	20.44
Silcate (Si)	83	0	0.04	0.01	-1.14	1.62	0.51
Silver (Ag)	82	44	-1.93	0.00	-48.08	46.67	16.34
Sodium (Na)	83	0	0.14	0.07	-0.91	4.62	0.68
Specific Conductivity	83	0	-0.09	0.00	-2.16	2.36	0.72
Strontium (Sr)	83	0	0.11	0.05	-0.89	1.57	0.36
Sulfate (SO_4)	82	8	0.37	0.00	-1.83	17.74	2.13
Sulfur (S)	83	0	0.12	-0.07	-10.27	14.77	2.40
Temperature	-	-	-	-	-	-	-
Thallium (Tl)	82	49	1.76	0.00	-36.59	39.13	14.25
Tin (Sn)	33	8	-2.26	0.00	-41.49	40.00	18.51
Titanium (Ti)	83	50	-0.05	0.00	-22.90	29.62	7.91
Total dissolved solids	82	0	-0.02	0.03	-6.62	9.33	2.90
Total organic carbon	82	1	-0.23	0.00	-46.81	23.91	9.48
Total phosphate	75	21	1.76	0.00	-10.00	40.70	6.46
Total suspended solids	82	0	0.72	0.00	-30.00	47.17	11.73
Vanadium (V)	83	25	-0.22	0.00	-29.57	20.34	9.12
Zinc (Zn)	83	5	-0.02	0.00	-38.69	14.49	6.94
Zirconium (Zr)	33	14	-0.38	0.00	-40.00	32.35	10.85

Table D.5.: Summary information for all chemical parameters. Censoring values were established just below the maximum reporting limit.

Parameter	No. of samples	No. of missing	Maximum reporting limit (ug/L)	No. detections above censoring value	No. censored values
Alkalinity	949	5	nnd[1]	949	0
Aluminum (Al)	944	10	0.060	760	184
Antimony (Sb)	944	10	0.008	595	349
Arsenic (As)	944	10	0.060	873	71
Barium (Ba)	954	0	1.4	946	8
Beryllium (Be)	944	10	0.010	289	655
Bismuth (Bi)	300	654	0.040	5	295
Boron (B)	954	0	13	847	107
Bromide (Br)	947	7	0.20	21	926
Cadmium (Cd)	944	10	0.020	498	446
Calcium (Ca)	954	0	nnd	954	0
Cesium (Cs)	300	654	0.010	95	205
Chloride (Cl)	953	1	200	951	2
Chromium (Cr)	944	10	0.050	727	217
Cobalt (Co)	944	10	0.0020	942	2
Copper (Cu)	954	0	5.5	487	467
Dissolved Oxygen	954	0	nnd	954	0
Eh	952	2	nnd	952	0
Fluoride (F)	686	268	[2]	686	0
Iron (Fe)	954	0	3.2	940	14
Lead (Pb)	943	11	0.03	866	77
Lithium (Li)	954	0	4.5	680	274
Magnesium (Mg)	954	0	nnd	954	0
Manganese (Mn)	954	0	0.90	888	66
Mercury (Hg)	451	504	0.10	46	405
Molybdenum (Mo)	954	0	4.2	274	680
Nickel (Ni)	954	0	6.0	280	674
Nitrate (NO_3)	953	1	500	176	777
Ortho-phosphate	135	819	5.0	94	41
pH	952	2	nnd	952	0
$Phosphorus_{total}$	954	0	14.9	868	86
Potassium (K)	954	0	118.5	949	5
Redox	952	2	nnd	952	0
Rubidium (Rb)	954	0	555	104	850
Selenium (Se)	910	44	1.0	706	204
Silcate (Si)	954	0	nnd	954	0
Silver (Ag)	944	10	0.0090	322	622
Sodium (Na)	954	0	nnd	954	0
Specific Conductivity	951	3	nnd	951	0
Strontium (Sr)	954	0	0.60	951	3
Sulfate (SO_4)	953	1	100	885	68
Sulfur (S)	954	0	21.8	952	2
Temperature	952	2	nnd	952	0
Thallium (Tl)	944	10	0.0050	371	573
Tin (Sn)	300	654	0.040	188	112
Titanium (Ti)	954	0	0.0035	231	723
Total dissolved solids	951	3	nnd	951	0
Total organic carbon	951	3	500	929	22
Total phosphate	819	135	20	646	173
Total suspended solids	951	3	nnd	951	0
Vanadium (V)	954	0	4.7	491	463
Zinc (Zn)	954	0	2.7	871	83
Zirconium (Zr)	300	654	0.030	145	155

[1] nnd = no samples were below the maximum reporting limit

[2] Fluoride was censored at several detection limits. Censoring at the highest detection limit would result in only six values above the censoring limit. Consequently, all non-detections were treated as missing data and removed from the data set.

Table D.6: Descriptive statistics for the Franconia-Ironton-Galesville Formation (CFIG).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
		ug/L							
Alkalinity	5	0	normal	330200	446109	330000	ins[1]	244000	467000
Aluminum (Al)	5	2	ins	ins	ins	2.9	ins	< 0.060	105
Antimony (Sb)	5	1	ins	ins	ins	0.017	ins	< 0.0080	0.030
Arsenic (As)	5	0	normal	0.93	1.9	0.99	ins	< 0.060	1.9
Barium (Ba)	5	0	normal	38	54	35	ins	24	58
Beryllium (Be)	5	4	ins	ins	ins	< 0.010	ins	< 0.010	0.020
Bismuth (Bi)	3	3	ins	ins	ins	< 0.040	ins	< 0.040	< 0.040
Boron (B)	5	0	normal	112	235	113	ins	17	250
Bromide (Br)	5	5	ins	ins	ins	< 0.20	ins	< 0.20	< 0.20
Cadmium (Cd)	5	1	ins	ins	ins	0.040	ins	< 0.020	0.090
Calcium (Ca)	5	0	normal	96364	127895	99107	ins	60161	130435
Cesium (Cs)	3	1	ins	ins	ins	0.040	ins	< 0.010	0.040
Chloride (Cl)	5	0	normal	1296	2058	1310	ins	350	2060
Chromium (Cr)	5	0	normal	0.73	1.8	0.27	ins	0.080	2.0
Cobalt (Co)	5	0	[2]	-	-	0.55	ins	0.49	1.4
Copper (Cu)	5	5	ins	ins	ins	< 5.5	ins	< 5.5	< 5.5
Dissolved Oxygen	5	3	ins	ins	ins	< 300	ins	< 300	18000
Eh	5	0	normal	143	244	140	ins	20	234
Fluoride (F)[4]	5	1	log-normal	377	ins	325	ins	250	770
Iron (Fe)	5	0	normal	1157	2261	876	ins	221	2550
Lead (Pb)	5	2	ins	ins	ins	0.20	ins	< 0.030	0.33
Lithium (Li)	5	2	ins	ins	ins	6.2	ins	< 4.5	12
Magnesium (Mg)	5	0	normal	36518	501198	36044	ins	24077	52959
Manganese (Mn)	5	0	log-normal	56	698	53	ins	4.7	1022
Mercury (Hg)	2	2	ins	ins	ins	< 0.10	ins	< 0.10	< 0.10
Molybdenum (Mo)	5	5	ins	ins	ins	< 4.2	ins	< 4.2	< 4.2
Nickel (Ni)	5	5	ins	ins	ins	< 6.0	ins	< 6.0	< 6.0
Nitrate (NO_3)	5	5	ins	ins	ins	< 500	ins	< 500	< 500
Ortho-phosphate	0	ns[3]	ns	ns	ns	ns	ns	ns	ns
pH	5	0	normal	7.11	7.33	7.20	ins	6.92	7.28
$Phosphorus_{total}$	5	0	normal	50	99	33	ins	26	119
Potassium (K)	5	0	normal	3866	7032	4099	ins	1280	7318
Redox	5	0	normal	-69	32	-74	ins	-193	23
Rubidium (Rb)	5	5	ins	ins	ins	< 555	ins	< 555	< 555
Selenium (Se)	5	2	ins	ins	ins	2.9	ins	< 1.0	8.1
Silcate (Si)	5	0	normal	7870	12608	6233	ins	4447	13957
Silver (Ag)	5	3	ins	ins	ins	< 0.0090	ins	< 0.0090	0.077
Sodium (Na)	5	0	normal	15617	35358	10760	ins	3387	42265
Specific Conductivity	5	0	normal	707	973	700	ins	404	980
Strontium (Sr)	5	0	normal	377	763	363	ins	93	870
Sulfate (SO_4)	5	0	normal	22530	49184	24330	ins	1730	54030
Sulfur (S)	5	0	normal	23089	50561	23426	ins	2037	56024
Temperature	5	0	normal	10.2	11.6	9.7	ins	9.0	11.8
Thallium (Tl)	5	4	ins	ins	ins	< 0.0050	ins	< 0.0050	0.16
Tin (Sn)	3	1	ins	ins	ins	0.14	ins	< 0.040	0.16
Titanium (Ti)	5	4	ins	ins	ins	< 0.0035	ins	< 0.0035	0.0052
Total dissolved solids	5	0	normal	457200	674371	428000	ins	270000	732000
Total organic carbon	5	1	ins	ins	ins	1000	ins	< 500	7500
Total phosphate	5	3	ins	ins	ins	< 20	ins	< 20	90
Total suspended solids	5	0	normal	6000	9926	6000	ins	2000	10000
Vanadium (V)	5	2	ins	ins	ins	4.9	ins	< 4.7	5.6
Zinc (Zn)	5	0	normal	62	126	39	ins	9.7	134
Zirconium (Zr)	3	1	ins	ins	ins	0.050	ins	< 0.030	0.050

[1] ins = insufficient number of detections to calculate statistics
[2] Data did not fit a normal or log-normal distribution
[3] ns=not sampled
[4] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.7: Descriptive statistics for the Franconia Formation (CFRN).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
						ug/L			
Alkalinity	27	0	normal	302077	341959	270000	503600	148000	538000
Aluminum (Al)	26	3	log-censored	1.1	10	1.5	7.3	< 0.060	7.9
Antimony (Sb)	26	10	log-censored	0.014	0.097	0.012	0.12	< 0.0080	0.13
Arsenic (As)	26	4	log-censored	0.67	14	0.68	14	< 0.060	16
Barium (Ba)	27	0	log-normal	48	77	48	242	2.1	263
Beryllium (Be)	26	20	log-censored	0.0025	0.034	< 0.010	0.059	< 0.010	0.080
Bismuth (Bi)	9	9	ins	ins	ins	< 0.040	ins	< 0.040	< 0.040
Boron (B)	27	5	log-censored	35	301	28	288	< 13	299
Bromide (Br)	27	27	ins	ins	ins	< 0.20	ins	< 0.20	< 0.20
Cadmium (Cd)	26	11	log-censored	0.044	0.98	0.055	1.9	< 0.020	2.2
Calcium (Ca)	27	0	normal	74463	84554	69745	122698	28627	126770
Cesium (Cs)	9	4	log-censored	0.0096	0.050	0.010	ins	< 0.010	0.040
Chloride (Cl)	27	0	[2]	-	-	1030	90866	200	127350
Chromium (Cr)	26	5	log-censored	0.33	4.8	0.29	4.7	< 0.050	5.3
Cobalt (Co)	26	0	log-normal	0.62	0.74	0.58	1.2	0.21	1.2
Copper (Cu)	27	16	log-censored	5.2	21	< 5.5	26	< 5.5	32
Dissolved Oxygen	27	15	log-censored	536	39379	< 300	89140	< 300	105300
Eh	27	0	normal	193	237	213	399	-36	451
Fluoride (F)[3]	27	8	log-normal	291	316	280	ins	210	400
Iron (Fe)	27	0	log-normal	527	1127	856	4462	13	4669
Lead (Pb)	26	2	log-censored	0.30	3.9	0.23	19	< 0.030	28
Lithium (Li)	27	10	log-censored	5.5	38	5.1	49	< 4.5	55
Magnesium (Mg)	27	0	normal	30997	35005	30514	48955	15915	51185
Manganese (Mn)	27	3	log-censored	28	467	47	348	< 0.90	372
Mercury (Hg)	17	15	log-censored	ins	ins	< 0.10	ins	< 0.10	0.10
Molybdenum (Mo)	27	21	log-censored	2.3	7.2	< 4.2	8.4	< 4.2	9.6
Nickel (Ni)	27	21	log-censored	3.9	11	< 6.0	13	< 6.0	14
Nitrate (NO_3)	27	20	log-censored	137	4679	< 500	7470	< 500	7850
Ortho-phosphate	10	9	ins	ins	ins	< 5.0	ins	< 5.0	10
pH	27	0	normal	7.30	7.40	7.34	7.91	6.90	7.96
$Phosphorus_{total}$	27	7	log-censored	29	255	29	535	< 15	696
Potassium (K)	27	0	log-normal	1798	2503	1691	7683	153	9321
Redox	27	0	normal	5.3	56	0	186	-249	239
Rubidium (Rb)	27	25	log-censored	193	658	< 555	791	< 555	893
Selenium (Se)	22	5	log-censored	1.1	4.7	1.0	7.6	< 1.0	7.7
Silcate (Si)	27	0	log-normal	8318	9750	8291	15054	3601	15184
Silver (Ag)	26	14	log-censored	0.011	0.40	< 0.0090	0.61	< 0.0090	0.78
Sodium (Na)	27	0	[2]	-	-	4997	46775	1627	51287
Specific Conductivity	27	0	normal	569	671	510	0.93	3	951
Strontium (Sr)	27	0	log-normal	143	214	110	1146	37	1412
Sulfate (SO_4)	27	1	log-censored	5580	27906	6330	33528	< 100	40940
Sulfur (S)	27	0	log-normal	5690	9827	6948	36414	51	41634
Temperature	27	0	normal	10.0	10.3	9.8	11.4	8.9	11.5
Thallium (Tl)	26	15	log-censored	0.0015	0.22	< 0.0050	1.6	< 0.0050	2.4
Tin (Sn)	9	5	log-censored	0.058	0.25	< 0.040	ins	< 0.040	0.20
Titanium (Ti)	27	21	log-censored	0.0024	0.0070	< 0.0035	0.0080	< 0.0035	0.0087
Total dissolved solids	26	0	normal	379808	437359	339000	670600	150000	700000
Total organic carbon	27	2	log-censored	2497	13902	2900	16220	< 500	16700
Total phosphate	17	5	log-censored	27	526	20	ins	< 20	640
Total suspended solids	26	0	log-normal	3264	4789	3500	16	1000	16000
Vanadium (V)	27	15	log-censored	5.2	17	< 4.7	12	< 4.7	12
Zinc (Zn)	27	0	log-normal	64	124	88	1349	4.9	1760
Zirconium (Zr)	9	6	log-censored	0.024	0.040	< 0.030	ins	< 0.030	0.040

[1] ins = insufficient number of detections to calculate statistics
[2] Data did not fit a normal or log-normal distribution
[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.8: Descriptive statistics for the Ironton-Galesville Formation (CIGL).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
		ug/L							
Alkalinity	8	0	normal	352333	421104	353500	ins[1]	136000	405000
Aluminum (Al)	8	0	normal	3.1	7.0	2.1	ins	0.16	29
Antimony (Sb)	8	2	log-censored	0.021	0.084	0.019	ins	< 0.0080	0.062
Arsenic (As)	8	0	log-normal	0.72	1.4	0.65	ins	0.34	3.8
Barium (Ba)	8	0	normal	82	152	47	ins	5.6	205
Beryllium (Be)	8	3	log-censored	0.011	0.042	0.010	ins	< 0.010	0.030
Bismuth (Bi)	5	4	ins	ins	ins	< 0.040	ins	< 0.040	0.040
Boron (B)	8	2	log-censored	51	210	59	ins	< 13	152
Bromide (Br)	8	8	ins	ins	ins	< 0.20	ins	< 0.20	< 0.20
Cadmium (Cd)	8	1	log-censored	0.095	0.32	0.090	ins	< 0.020	0.27
Calcium (Ca)	8	0	normal	95863	135415	89046	ins	41057	154746
Cesium (Cs)	5	2	log-censored	0.018	0.048	0.020	ins	< 0.010	0.040
Chloride (Cl)	8	0	normal	1585	2529	1310	ins	570	2660
Chromium (Cr)	8	1	log-censored	0.28	9.3	0.27	ins	< 0.050	28
Cobalt (Co)	8	0	log-normal	0.93	1.9	0.72	ins	0.36	4.9
Copper (Cu)	8	3	log-censored	8.8	126	10	ins	< 5.5	117.8
Dissolved Oxygen	8	7	ins	ins	ins	< 300	ins	< 300	1990
Eh	8	0	normal	197	284	207	ins	27	343
Fluoride (F)[2]	8	2	log-censored	255	315	245	ins	200	350
Iron (Fe)	8	0	normal	1865	3597	1005	ins	31	4427
Lead (Pb)	8	0	normal	0.71	1.5	0.88	ins	0.050	2.1
Lithium (Li)	8	2	log-censored	8.7	19	10	ins	< 4.5	16
Magnesium (Mg)	8	0	normal	25594	44265	32668	ins	11370	45702
Manganese (Mn)	8	0	normal	199	431	136	ins	11	717
Mercury (Hg)	3	3	ins	ins	ins	< 0.10	ins	< 0.10	< 0.10
Molybdenum (Mo)	8	8	ins	ins	ins	< 4.2	ins	< 4.2	< 4.2
Nickel (Ni)	8	6	log-censored	3.1	12	< 6.0	ins	< 6.0	11
Nitrate (NO_3)	8	8	ins	ins	ins	< 500	ins	< 500	< 500
Ortho-phosphate	1	1	ins	ins	ins	< 5.0	ins	< 5.0	< 5.0
pH	8	0	normal	7.15	7.55	7.27	ins	7.01	7.95
$Phosphorus_{total}$	8	0	normal	48	70	57	ins	15	147
Potassium (K)	8	0	normal	3186	5032	2564	ins	837	6130
Redox	8	0	normal	-5	66	-5	ins	-187	131
Rubidium (Rb)	8	7	ins	ins	ins	< 555	ins	< 555	631
Selenium (Se)	8	5	log-censored	0.73	4.1	< 1.0	ins	< 1.0	3.0
Silcate (Si)	8	0	normal	7188	9144	7059	ins	5439	14437
Silver (Ag)	8	3	log-censored	0.017	0.28	0.025	ins	< 0.0090	0.26
Sodium (Na)	8	0	normal	28572	55747	9965	ins	1790	68775
Specific Conductivity	8	0	normal	769	1078	651	ins	298	1217
Strontium (Sr)	8	0	normal	281	594	224	ins	47	798
Sulfate (SO_4)	8	0	normal	34837	77866	8155	ins	580	108920
Sulfur (S)	8	0	normal	36474	81386	8333	ins	567	112855
Temperature	8	0	normal	10.7	12.0	10.3	ins	8.9	13.0
Thallium (Tl)	8	3	log-censored	0.025	0.21	0.027	ins	< 0.0050	0.18
Tin (Sn)	5	1	log-censored	0.090	0.44	0.090	ins	< 0.040	0.25
Titanium (Ti)	8	7	ins	ins	ins	< 0.0035	ins	< 0.0035	0.0041
Total dissolved solids	8	0	normal	528000	830532	373000	ins	194000	1012000
Total organic carbon	8	0	normal	2550	4185	1650	ins	1000	5300
Total phosphate	7	3	log-censored	30	223	30	ins	< 20	150
Total suspended solids	8	0	normal	6000	9982	5000	ins	1000	11000
Vanadium (V)	8	4	log-censored	8.9	12	6.7	ins	< 4.7	11
Zinc (Zn)	8	0	log-normal	86	266	56	ins	22	1132
Zirconium (Zr)	5	3	log-censored	0.022	0.15	< 0.030	ins	< 0.030	0.090

[1] ins = insufficient number of detections to calculate statistics

[2] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.9: Descriptive statistics for the Jordan Sandstone (CJDN).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
						ug/L			
Alkalinity	31	0	normal	256733	286457	250000	426800	126000	467000
Aluminum (Al)	30	7	log-censored	1.1	9.7	1.0	12	< 0.060	14
Antimony (Sb)	30	14	log-censored	0.012	0.060	0.0090	0.057	< 0.0080	0.059
Arsenic (As)	30	1	log-censored	0.64	5.6	0.58	14	< 0.060	18
Barium (Ba)	31	0	log-normal	30	46	23	389	1.8	664
Beryllium (Be)	30	25	log-censored	0.0011	0.022	< 0.010	0.038	< 0.010	0.060
Bismuth (Bi)	8	7	ins[1]	ins	ins	< 0.040	ins	< 0.040	0.080
Boron (B)	31	12	log-censored	18	193	19	244	< 13	297
Bromide (Br)	31	31	ins	ins	ins	< 0.20	ins	< 0.20	< 0.20
Cadmium (Cd)	30	9	log-censored	0.048	1.0	0.060	3.5	< 0.020	4.6
Calcium (Ca)	31	0	normal	67964	77455	63229	126477	14031	137412
Cesium (Cs)	8	3	log-censored	0.0094	0.032	0.010	ins	< 0.010	0.030
Chloride (Cl)	31	0	log-normal	1153	1616	950	9430	310	11020
Chromium (Cr)	30	6	log-censored	0.46	2.7	0.59	2.2	< 0.050	2.9
Cobalt (Co)	30	0	log-normal	0.41	0.58	0.41	1.2	0.14	1.5
Copper (Cu)	31	14	log-censored	7.2	36	8.1	50	< 5.5	68
Dissolved Oxygen	31	14	log-censored	1072	36732	500	52500	< 300	94500
Eh	31	0	log-normal	217	228	199	452	-7.0	457
Fluoride (F)[3]	31	12	[2]	-	-	290	ins	150	2510
Iron (Fe)	31	4	log-censored	133	8977	246	4750	< 3.2	5777
Lead (Pb)	30	2	log-censored	0.46	4.6	0.40	6.4	< 0.030	11
Lithium (Li)	31	16	log-censored	4.4	28	< 4.5	36	< 4.5	43
Magnesium (Mg)	31	0	log-normal	23610	27810	23845	45660	3954	47548
Manganese (Mn)	31	11	log-censored	22	377	27	385	< 0.90	419
Mercury (Hg)	21	20	ins	ins	ins	< 0.10	0.16	< 0.10	0.17
Molybdenum (Mo)	31	26	log-censored	1.6	7.0	< 4.2	9.2	< 4.2	10
Nickel (Ni)	31	21	log-censored	5.3	8.6	< 6.0	9.2	< 6.0	9.2
Nitrate (NO_3)	31	20	log-censored	45	3646	< 500	5324	< 500	9200
Ortho-phosphate	16	8	log-censored	5.1	45	5.0	ins	< 5.0	40
pH	31	0	log-normal	6.98	7.79	7.34	8.36	1.50	8.69
$Phosphorus_{total}$	31	11	log-censored	25	181	25	229	< 15	242
Potassium (K)	31	0	log-normal	1155	1574	990	5028	120	5656
Redox	31	0	log-normal	-24	57	-12	239	-219	244
Rubidium (Rb)	31	29	log-censored	238	576	< 555	646	< 555	740
Selenium (Se)	20	6	log-censored	1.1	4.3	1.0	5.6	< 1.0	5.7
Silcate (Si)	31	0	log-normal	8065	8876	7971	13492	5880	15231
Silver (Ag)	30	19	log-censored	0.0050	0.12	< 0.0090	0.19	< 0.0090	0.25
Sodium (Na)	31	0	log-normal	4612	6979	2497	55311	1790	61464
Specific Conductivity	31	0	log-normal	360	600	492	1100	3	1205
Strontium (Sr)	31	0	log-normal	95	131	69	637	27	765
Sulfate (SO_4)	31	0	log-normal	5580	27906	6160	75646	420	93790
Sulfur (S)	31	0	log-normal	6030	9185	6607	79752	947	96320
Temperature	31	0	normal	9.9	10.1	9.8	11.4	8.3	11.5
Thallium (Tl)	30	10	log-censored	0.018	0.19	0.018	0.24	< 0.0050	0.30
Tin (Sn)	8	4	log-censored	0.052	0.15	0.045	ins	< 0.040	0.14
Titanium (Ti)	31	26	log-censored	0.0031	0.0055	< 0.0035	0.0060	< 0.0035	0.0070
Total dissolved solids	30	0	log-normal	299916	346577	288000	745500	148000	828000
Total organic carbon	31	3	log-censored	1735	11193	1500	12720	< 500	17400
Total phosphate	15	6	log-censored	49	203	20	ins	< 20	210
Total suspended solids	30	0	log-normal	2615	3642	3000	13800	1000	16000
Vanadium (V)	31	18	log-censored	4.9	11	< 4.7	11	< 4.7	12
Zinc (Zn)	31	1	log-censored	49	474	51	922	< 2.7	1858
Zirconium (Zr)	8	6	log-censored	0.024	0.040	< 0.030	ins	< 0.030	0.070

[1] ins = insufficient number of detections to calculate statistics
[2] Data did not fit a normal or log-normal distribution
[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.10: Descriptive statistics for the Mount Simon-Hinckley Formation (CMSH)

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
		ug/L							
Alkalinity	10	0	normal	160500	236344	132500	ins[1]	13000	399000
Aluminum (Al)	10	1	log-censored	1.5	8.5	1.2	ins	< 0.060	23
Antimony (Sb)	10	4	log-censored	0.013	0.12	0.010	ins	< 0.0080	0.090
Arsenic (As)	10	3	log-censored	0.53	5.0	0.86	ins	< 0.060	4.1
Barium (Ba)	10	0	normal	67	107	57	ins	7.6	200
Beryllium (Be)	10	8	log-censored	0.00028	0.085	< 0.010	ins	< 0.010	0.070
Bismuth (Bi)	8	8	ins	ins	ins	< 0.040	ins	< 0.040	< 0.040
Boron (B)	10	3	log-censored	24	253	23	ins	< 13	300
Bromide (Br)	10	10	ins	ins	ins	< 0.20	ins	< 0.20	< 0.20
Cadmium (Cd)	10	6	log-censored	0.023	0.32	< 0.020	ins	< 0.020	0.22
Calcium (Ca)	10	0	log-normal	34080	66605	43648	ins	5032	157955
Cesium (Cs)	8	7	ins	ins	ins	< 0.010	ins	< 0.010	0.020
Chloride (Cl)	10	0	log-normal	2206	5920	2135	ins	370	36070
Chromium (Cr)	10	4	log-censored	0.21	8.3	0.25	ins	< 0.050	4.2
Cobalt (Co)	10	0	normal	0.46	0.72	0.41	ins	0.090	1.1
Copper (Cu)	10	5	log-censored	6.1	19	5.7	ins	< 5.5	16
Dissolved Oxygen	10	4	log-censored	657	16445	630	ins	< 300	10910
Eh	10	0	normal	192	237	212	ins	69	254
Fluoride (F)[3]	10	0	log-normal	254	323	225	ins	200	580
Iron (Fe)	10	0	log-normal	772	3798	387	ins	20	62577
Lead (Pb)	10	0	log-normal	0.19	0.43	0.17	ins	0.050	1.8
Lithium (Li)	10	3	log-censored	6.8	33	7.0	ins	< 4.5	48
Magnesium (Mg)	10	0	log-normal	11466	21434	13269	ins	1889	49440
Manganese (Mn)	10	1	log-censored	46	3977	44	ins	< 0.90	1856
Mercury (Hg)	1	1	ins	ins	ins	< 0.10	ins	< 0.10	< 0.10
Molybdenum (Mo)	10	7	log-censored	4.3	7.8	< 4.2	ins	< 4.2	7.5
Nickel (Ni)	10	6	log-censored	5.1	16	< 6.0	ins	< 6.0	14
Nitrate (NO_3)	10	7	log-censored	126	4865	< 500	ins	< 500	4000
Ortho-phosphate	0	ns[2]	ns	ns	ns	ns	ns	ns	ns
pH	10	0	normal	7.17	7.74	7.30	ins	5.30	8.10
$Phosphorus_{total}$	10	0	log-normal	43	393	34	ins	15	721
Potassium (K)	10	0	normal	1621	2321	1292	ins	525	3799
Redox	10	0	normal	-22	23	-3	ins	-145	40
Rubidium (Rb)	10	8	log-censored	567	716	< 555	ins	< 555	710
Selenium (Se)	10	3	log-censored	1.6	7.2	1.6	ins	< 1.0	5.9
Silcate (Si)	10	0	log-normal	9993	14444	10894	ins	4313	29313
Silver (Ag)	10	7	log-censored	0.0084	0.049	< 0.0090	ins	< 0.0090	0.051
Sodium (Na)	10	0	log-normal	5138	10508	3823	ins	1870	66103
Specific Conductivity	10	0	normal	367	587	304	ins	60	1093
Strontium (Sr)	10	0	log-normal	91	188	109	ins	20	510
Sulfate (SO_4)	10	3	log-censored	1268	44152	1735	ins	< 100	72260
Sulfur (S)	10	0	log-normal	1550	6174	1948	ins	176	76310
Temperature	10	0	normal	8.8	9.2	8.7	ins	8.0	9.5
Thallium (Tl)	10	9	ins	ins	ins	< 0.0050	ins	< 0.0050	0.010
Tin (Sn)	8	1	log-censored	0.11	0.47	0.11	ins	< 0.040	0.70
Titanium (Ti)	10	6	log-censored	0.0037	0.0091	< 0.0035	ins	< 0.0035	0.0082
Total dissolved solids	10	0	log-normal	199159	336512	218000	ins	60000	874000
Total organic carbon	10	1	log-censored	1781	10792	1850	ins	< 500	18500
Total phosphate	10	4	log-censored	15	545	20	ins	< 20	720
Total suspended solids	10	0	log-normal	6917	19249	5000	ins	2000	206000
Vanadium (V)	10	5	log-censored	5.4	23	4.9	ins	< 4.7	20
Zinc (Zn)	10	1	log-censored	12	91	12	ins	< 2.7	127
Zirconium (Zr)	8	6	log-censored	0.00015	5.4	< 0.030	ins	< 0.030	1.8

[1] ins= insufficient number of detections to calculate statistics
[2] ns=not sampled
[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.11: Descriptive statistics for the Mount Simon Formation (CMTS)

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
		ug/L							
Alkalinity	13	0	normal	305111	401950	257000	ins[1]	143000	488000
Aluminum (Al)	13	3	log-censored	0.39	54	0.53	ins	< 0.060	44
Antimony (Sb)	13	4	log-censored	0.018	0.10	0.016	ins	< 0.0080	0.084
Arsenic (As)	13	1	log-censored	0.79	11	1.6	ins	< 0.060	7.4
Barium (Ba)	13	0	log-normal	57	98	57	ins	13	276
Beryllium (Be)	13	7	log-censored	0.0080	0.048	< 0.010	ins	< 0.010	0.050
Bismuth (Bi)	6	6	ins	ins	ins	< 0.040	ins	< 0.040	< 0.040
Boron (B)	13	0	log-normal	40	71	33	ins	14	150
Bromide (Br)	13	12	ins	ins	ins	< 0.20	ins	< 0.20	0.55
Cadmium (Cd)	13	9	log-censored	0.018	0.14	< 0.020	ins	< 0.020	0.19
Calcium (Ca)	13	0	normal	74239	93140	76615.2	ins	37694	102162
Cesium (Cs)	6	2	log-censored	0.025	0.052	0.025	ins	< 0.010	0.040
Chloride (Cl)	13	0	[2]	-	-	1010	ins	310	98370
Chromium (Cr)	13	2	log-censored	0.38	4.6	0.31	ins	< 0.050	2.8
Cobalt (Co)	13	0	normal	0.65	0.95	0.60	ins	0.30	1.5
Copper (Cu)	13	9	log-censored	2.1	32	< 5.5	ins	< 5.5	30
Dissolved Oxygen	13	10	log-censored	53	8189	< 300	ins	< 300	9410
Eh	13	0	normal	119	181	79	ins	-4.1	269
Fluoride (F)[4]	9	0	normal	284	333	280	ins	220	370
Iron (Fe)	13	1	log-censored	722	13646	1259	ins	< 3.2	5569
Lead (Pb)	13	0	log-normal	0.28	0.61	0.20	ins	0.080	3.36
Lithium (Li)	13	9	log-censored	3.1	25	< 4.5	ins	< 4.5	33
Magnesium (Mg)	13	0	normal	27537	36477	26883	ins	9553	41173
Manganese (Mn)	13	1	log-censored	1.9	7.3	100	ins	< 0.90	531
Mercury (Hg)	7	7	ins	ins	ins	< 0.10	ins	< 0.10	< 0.10
Molybdenum (Mo)	13	13	ins	ins	ins	< 4.2	ins	< 4.2	< 4.2
Nickel (Ni)	13	13	ins	ins	ins	< 6.0	ins	< 6.0	< 6.0
Nitrate (NO_3)	13	11	log-censored	53	8189	< 500	ins	< 500	1300
Ortho-phosphate	0	ns[3]	ns	ns	ns	ns	ns	ns	ns
pH	13	0	normal	7.29	7.40	7.30	ins	7.11	7.59
$Phosphorus_{total}$	13	0	[2]	-	-	64	ins	35	558
Potassium (K)	13	0	normal	2731	4035	1700	ins	799	5960
Redox	13	0	normal	-69	6	-132	ins	-217	59
Rubidium (Rb)	13	13	ins	ins	ins	< 555	ins	< 555	< 555
Selenium (Se)	13	4	log-censored	2.0	6.4	2.4	ins	< 1.0	5.6
Silcate (Si)	13	0	normal	8372	10378	8567	ins	5135	13086
Silver (Ag)	13	9	log-censored	0.0017	0.52	< 0.0090	ins	< 0.0090	0.41
Sodium (Na)	13	0	log-normal	11776	23961	8085	ins	3007	97890
Specific Conductivity	13	0	normal	648	866	661	ins	269	1055
Strontium (Sr)	13	0	normal	314	504	159	ins	63	800
Sulfate (SO_4)	13	1	log-censored	2602	62318	2450	ins	< 100	39850
Sulfur (S)	13	0	log-normal	3378	9211	2732	ins	352	40991
Temperature	13	0	normal	10.0	10.8	9.6	ins	8.6	12.1
Thallium (Tl)	13	5	log-censored	0.0054	0.047	0.0060	ins	< 0.0050	0.046
Tin (Sn)	6	3	log-censored	0.14	1.8	0.10	ins	< 0.040	0.97
Titanium (Ti)	13	12	ins	ins	ins	< 0.0035	ins	< 0.0035	0.0064
Total dissolved solids	13	0	normal	405111	547759	374000	ins	130000	678000
Total organic carbon	13	0	normal	2067	2805	2000	ins	700	3700
Total phosphate	13	3	log-censored	49	833	40	ins	< 20	710
Total suspended solids	13	0	normal	5778	9253	5000	ins	2000	15000
Vanadium (V)	13	10	log-censored	2.9	7.9	< 4.7	ins	< 4.7	8.6
Zinc (Zn)	13	0	normal	80	159	14	ins	3.1	266
Zirconium (Zr)	6	4	log-censored	0.030	0.24	< 0.030	ins	< 0.030	0.16

[1] ins = insufficient number of detections to calculate statistics
[2] Data did not fit a normal or log-normal distribution
[3] ns=not sampled
[4] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.12: Descriptive statistics for the St. Lawrence-Franconia Formation (CSLF).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
						ug/L			
Alkalinity	4	0	ins[1]	ins	ins	257500	ins	181000	416000
Aluminum (Al)	4	1	ins	ins	ins	1.2	ins	< 0.060	4.2
Antimony (Sb)	4	2	ins	ins	ins	0.0120	ins	< 0.0080	0.026
Arsenic (As)	4	0	ins	ins	ins	3.9	ins	0.84	14.1
Barium (Ba)	4	0	ins	ins	ins	115	ins	20	212
Beryllium (Be)	4	4	ins	ins	ins	< 0.010	ins	< 0.010	< 0.010
Bismuth (Bi)	3	3	ins	ins	ins	< 0.040	ins	< 0.040	0.030
Boron (B)	4	2	ins	ins	ins	25	ins	< 13	279
Bromide (Br)	4	4	ins	ins	ins	< 0.20	ins	< 0.20	0.10
Cadmium (Cd)	4	1	ins	ins	ins	0.045	ins	< 0.020	0.110
Calcium (Ca)	4	0	ins	ins	ins	83603	ins	53769	111650
Cesium (Cs)	3	2	ins	ins	ins	< 0.010	ins	< 0.010	0.020
Chloride (Cl)	4	0	ins	ins	ins	6580	ins	740	18340
Chromium (Cr)	4	0	ins	ins	ins	0.15	ins	0.070	2.25
Cobalt (Co)	4	0	ins	ins	ins	0.67	ins	0.32	1.34
Copper (Cu)	4	1	ins	ins	ins	17	ins	< 5.5	40.4
Dissolved Oxygen	4	4	ins	ins	ins	< 300	ins	< 300	250
Eh	4	0	ins	ins	ins	53	ins	-201	249
Fluoride (F)[3]	4	3	ins	ins	ins	380	ins	380	380
Iron (Fe)	4	0	ins	ins	ins	1863	ins	865	5114
Lead (Pb)	4	0	ins	ins	ins	0.22	ins	0.19	0.55
Lithium (Li)	4	1	ins	ins	ins	11	ins	< 4.5	14
Magnesium (Mg)	4	0	ins	ins	ins	28739	ins	13069	44450
Manganese (Mn)	4	0	ins	ins	ins	282	ins	80	938
Mercury (Hg)	1	1	ins	ins	ins	< 0.10	ins	< 0.10	< 0.10
Molybdenum (Mo)	4	4	ins	ins	ins	< 4.2	ins	< 4.2	4.1
Nickel (Ni)	4	4	ins	ins	ins	< 6.0	ins	< 6.0	< 6.0
Nitrate (NO_3)	4	4	ins	ins	ins	< 500	ins	< 500	< 500
Ortho-phosphate	0	ns[2]	ns	ns	ns	ns	ns	ns	ns
pH	4	0	ins	ins	ins	7.45	ins	7.26	7.66
$Phosphorus_{total}$	4	0	ins	ins	ins	117	ins	35	254
Potassium (K)	4	0	ins	ins	ins	1935	ins	900	3604
Redox	4	0	ins	ins	ins	-160	ins	-412	37
Rubidium (Rb)	4	4	ins	ins	ins	< 555	ins	< 555	< 555
Selenium (Se)	4	1	ins	ins	ins	1.0	ins	< 1.0	8.1
Silcate (Si)	4	0	ins	ins	ins	12104	ins	7018	15416
Silver (Ag)	4	2	ins	ins	ins	0.010	ins	< 0.0090	0.013
Sodium (Na)	4	0	ins	ins	ins	5258	ins	3232	79743
Specific Conductivity	4	0	ins	ins	ins	611	ins	384	1063
Strontium (Sr)	4	0	ins	ins	ins	165	ins	63	420
Sulfate (SO_4)	4	0	ins	ins	ins	22850	ins	2270	61440
Sulfur (S)	4	0	ins	ins	ins	23610	ins	2630	63876
Temperature	4	0	ins	ins	ins	10.5	ins	9.5	11.4
Thallium (Tl)	4	0	ins	ins	ins	0.015	ins	0.0060	0.022
Tin (Sn)	3	0	ins	ins	ins	0.070	ins	0.040	0.11
Titanium (Ti)	4	3	ins	ins	ins	< 0.0035	ins	< 0.0035	0.0045
Total dissolved solids	4	0	ins	ins	ins	384000	ins	248000	708000
Total organic carbon	4	0	ins	ins	ins	2000	ins	1400	2700
Total phosphate	4	1	ins	ins	ins	90	ins	< 20	210
Total suspended solids	4	0	ins	ins	ins	4500	ins	3000	13000
Vanadium (V)	4	2	ins	ins	ins	5.3	ins	< 4.7	9.4
Zinc (Zn)	4	0	ins	ins	ins	27	ins	6.3	60
Zirconium (Zr)	3	3	ins	ins	ins	< 0.030	ins	< 0.030	< 0.030

[1] ins = insufficient number of detections to calculate statistics
[2] ns=not sampled
[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.13: Descriptive statistics for the St. Lawrence Formation (CSTL).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
						ug/L			
Alkalinity	4	0	ins[1]	ins	ins	450500	ins	181000	518000
Aluminum (Al)	4	0	ins	ins	ins	2.0	ins	0.81	7.9
Antimony (Sb)	4	1	ins	ins	ins	0.065	ins	< 0.0080	0.12
Arsenic (As)	4	0	ins	ins	ins	4.6	ins	0.12	14
Barium (Ba)	4	0	ins	ins	ins	37	ins	8.9	270
Beryllium (Be)	4	2	ins	ins	ins	< 0.010	ins	< 0.010	0.040
Bismuth (Bi)	2	2	ins	ins	ins	< 0.040	ins	< 0.040	< 0.040
Boron (B)	4	0	ins	ins	ins	142	ins	14	353
Bromide (Br)	4	4	ins	ins	ins	< 0.20	ins	< 0.20	< 0.20
Cadmium (Cd)	4	0	ins	ins	ins	0.085	ins	0.050	0.17
Calcium (Ca)	4	0	ins	ins	ins	97724	ins	48461	152865
Cesium (Cs)	3	1	ins	ins	ins	0.025	ins	< 0.010	0.040
Chloride (Cl)	4	0	ins	ins	ins	980	ins	580	1460
Chromium (Cr)	4	1	ins	ins	ins	0.13	ins	< 0.050	0.76
Cobalt (Co)	4	0	ins	ins	ins	0.77	ins	0.45	1.4
Copper (Cu)	4	1	ins	ins	ins	20.0	ins	< 5.5	94.3
Dissolved Oxygen	4	2	ins	ins	ins	375	ins	< 300	750
Eh	4	0	ins	ins	ins	208	ins	205	253
Fluoride (F)[3]	1	0	ins	ins	ins	305	ins	290	320
Iron (Fe)	4	0	ins	ins	ins	3385	ins	62	8880
Lead (Pb)	4	0	ins	ins	ins	2.7	ins	0.91	52
Lithium (Li)	4	0	ins	ins	ins	15	ins	7.0	28
Magnesium (Mg)	4	0	ins	ins	ins	39958	ins	18197	51315
Manganese (Mn)	4	0	ins	ins	ins	61	ins	19	139
Mercury (Hg)	1	1	ins	ins	ins	< 0.10	ins	< 0.10	< 0.10
Molybdenum (Mo)	4	2	ins	ins	ins	4.8	ins	< 4.2	8.2
Nickel (Ni)	4	2	ins	ins	ins	6.0	ins	< 6.0	7.3
Nitrate (NO_3)	4	3	ins	ins	ins	< 500	ins	< 500	1500
Ortho-phosphate	0	ns[2]	ns	ns	ns	ns	ns	ns	ns
pH	4	0	ins	ins	ins	7.21	ins	6.72	7.50
$Phosphorus_{total}$	4	0	ins	ins	ins	64	ins	15	306
Potassium (K)	4	0	ins	ins	ins	3367	ins	1123	3571
Redox	4	0	ins	ins	ins	-5	ins	-9	40
Rubidium (Rb)	4	4	ins	ins	ins	< 555	ins	< 555	< 555
Selenium (Se)	4	2	ins	ins	ins	1.0	ins	< 1.0	1.4
Silcate (Si)	4	0	ins	ins	ins	11639	ins	6858	13720
Silver (Ag)	4	1	ins	ins	ins	0.014	ins	< 0.0090	0.15
Sodium (Na)	4	0	ins	ins	ins	26940	ins	2679	68771
Specific Conductivity	4	0	ins	ins	ins	0.81	ins	0.37	1.1
Strontium (Sr)	4	0	ins	ins	ins	381	ins	59	639
Sulfate (SO_4)	4	0	ins	ins	ins	12020	ins	2860	70530
Sulfur (S)	4	0	ins	ins	ins	15416	ins	3016	79617
Temperature	4	0	ins	ins	ins	9.7	ins	9.1	10.3
Thallium (Tl)	4	1	ins	ins	ins	0.018	ins	< 0.0050	0.060
Tin (Sn)	2	1	ins	ins	ins	0.48	ins	< 0.040	0.93
Titanium (Ti)	4	4	ins	ins	ins	< 0.0035	ins	< 0.0035	< 0.0035
Total dissolved solids	4	0	ins	ins	ins	518000	ins	208000	828000
Total organic carbon	4	1	ins	ins	ins	2650	ins	< 500	4200
Total phosphate	4	1	ins	ins	ins	35	ins	< 20	260
Total suspended solids	4	0	ins	ins	ins	8000	ins	1000	22000
Vanadium (V)	4	1	ins	ins	ins	7.2	ins	< 4.7	9.7
Zinc (Zn)	4	0	ins	ins	ins	245	ins	100	470
Zirconium (Zr)	2	1	ins	ins	ins	0.035	ins	< 0.030	0.050

[1] ins = insufficient number of detections to calculate statistics
[2] ns=not sampled
[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.14: Descriptive statistics for the Cedar Valley Formation (DCVA).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
		ug/L							
Alkalinity	10	0	normal	315778	351129	289500	421000	225000	421000
Aluminum (Al)	10	1	log-censored	1.8	5.5	1.79	6.4	< 0.060	6.4
Antimony (Sb)	10	3	log-censored	0.011	0.041	0.011	0.042	< 0.0080	0.042
Arsenic (As)	10	0	log-normal	2.8	5.1	2.6	13	0.44	13
Barium (Ba)	10	0	normal	190	226	168	331	66	331
Beryllium (Be)	10	5	log-censored	0.0092	0.052	0.0100	0.05	< 0.010	0.050
Bismuth (Bi)	0	ns[3]	ns	ns	ns	ns	ns	ns	ns
Boron (B)	10	1	log-censored	49	490	44	499	< 13	499
Bromide (Br)	9	9	ins	ins	ins[1]	< 0.20	ins	< 0.20	< 0.20
Cadmium (Cd)	10	0	log-normal	0.75	1.8	1.4	37	0.060	37
Calcium (Ca)	10	0	normal	76516	81296	75524	95426	61286	95426
Cesium (Cs)	0	ns	ns	ns	ns	ns	ns	ns	ns
Chloride (Cl)	9	0	[2]	-	-	600	ins	410	4720
Chromium (Cr)	10	6	log-censored	0.021	1.6	< 0.050	1.2	< 0.050	1.2
Cobalt (Co)	10	0	[2]	-	-	0.32	1.5	0.24	1.5
Copper (Cu)	10	1	log-censored	10	24	9.3	21	< 5.5	21
Dissolved Oxygen	10	4	log-censored	472	2338	450	1800	< 300	1800
Eh	10	0	[2]	-	-	99	272	57	272
Fluoride (F)[4]	9	0	normal	256	270	270	ins	210	300
Iron (Fe)	10	0	normal	1638	2117	1612	3561	7.0	3561
Lead (Pb)	10	0	log-normal	0.36	0.62	0.39	1.1	0.060	1.1
Lithium (Li)	10	1	log-censored	12	80	11	95	< 4.5	95
Magnesium (Mg)	10	0	normal	22489	24789	22465	29740	15711	29740
Manganese (Mn)	10	0	normal	88	111	90	156	9.1	156
Mercury (Hg)	10	5	log-censored	0.093	0.25	< 0.10	0.23	< 0.10	0.23
Molybdenum (Mo)	10	9	ins	ins	ins	< 4.2	4.9	< 4.2	4.9
Nickel (Ni)	10	6	log-censored	6.6	9.4	< 6.0	9.2	< 6.0	9.2
Nitrate (NO_3)	10	10	ins	ins	ins	< 500	ins	< 500	< 500
Ortho-phosphate	10	3	log-censored	16	197	15	170	< 5.0	170
pH	10	0	normal	7.12	7.17	7.12	ins	6.94	7.34
$Phosphorus_{total}$	10	0	log-normal	126	278	203	1120	16	1120
Potassium (K)	10	0	[2]	-	-	1318	5998	931	5998
Redox	10	0	[2]	-	-	-115	58	-156	58
Rubidium (Rb)	10	10	ins	ins	ins	< 555	ins	< 555	< 555
Selenium (Se)	8	0	[2]	-	-	1.0	ins	1.0	4.0
Silcate (Si)	10	0	normal	10904	11927	10666	13959	8544	13959
Silver (Ag)	10	8	log-censored	0.0080	0.015	< 0.0090	0.015	< 0.0090	0.015
Sodium (Na)	10	0	[2]	-	-	6764	60355	4808	60355
Specific Conductivity	10	0	log-normal	580	650	534	828	440	828
Strontium (Sr)	10	0	[2]	-	-	151	519	90	519
Sulfate (SO_4)	9	0	log-normal	2298	5691	2240	ins	97	13330
Sulfur (S)	10	0	log-normal	3219	6041	2779	13394	488	13394
Temperature	10	0	log-normal	9.1	9.4	9.3	9.7	8.7	9.7
Thallium (Tl)	10	5	log-censored	0.0058	0.068	0.0050	0.061	< 0.0050	0.061
Tin (Sn)	0	ns	ns	ns	ns	ns	ns	ns	ns
Titanium (Ti)	10	8	log-censored	0.0047	0.0050	< 0.0035	0.0050	< 0.0035	0.0050
Total dissolved solids	9	0	normal	348111	390988	320000	ins	250000	500000
Total organic carbon	10	0	log-normal	4536	7238	5250	11800	1500	11800
Total phosphate	0	ns	ns	ns	ns	ns	ns	ns	ns
Total suspended solids	9	0	log-normal	5441	7191	5000	ins	3000	14000
Vanadium (V)	10	5	log-censored	5.1	9.0	4.9	8.5	< 4.7	8.5
Zinc (Zn)	10	1	log-censored	12	67	12	72	< 2.7	72
Zirconium (Zr)	0	ns	ns	ns	ns	ns	ns	ns	ns

[1] ins = insufficient number of detections to calculate statistics
[2] Data did not fit a normal or log-normal distribution
[3] ns = not sampled
[4] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.15: Descriptive statistics for Cretaceous Sandstones (KRET).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
						ug/L			
Alkalinity	39	0	normal	369821	394901	356000	534000	204000	591000
Aluminum (Al)	39	5	log-censored	1.5	102	1.5	223	< 0.060	617
Antimony (Sb)	39	11	log-censored	0.022	0.13	0.025	0.15	< 0.0080	0.20
Arsenic (As)	39	3	log-censored	1.2	11	1.3	8.6	< 0.060	21
Barium (Ba)	39	0	log-normal	23	34	20	268	2.5	402
Beryllium (Be)	39	31	log-censored	0.0080	0.063	< 0.010	0.060	< 0.010	0.14
Bismuth (Bi)	0	ns	ns[2]	ns	ns	ns	ns	ns	ns
Boron (B)	39	1	log-censored	439	2906	410	3104	< 13	4659
Bromide (Br)	39	33	log-censored	0.036	0.71	< 0.20	ins[1]	< 0.20	2.0
Cadmium (Cd)	39	14	log-censored	0.055	0.76	0.050	0.82	< 0.020	0.95
Calcium (Ca)	39	0	normal	158086	192943	132699	391128	12750	474535
Cesium (Cs)	0	ns	ns	ns	ns	ns	ns	ns	ns
Chloride (Cl)	39	0	log-normal	8224	14508	5840	189280	480	447280
Chromium (Cr)	39	15	log-censored	0.18	4.9	0.14	5.8	< 0.050	6.5
Cobalt (Co)	39	1	log-censored	0.54	1.8	0.60	1.7	< 0.090	1.9
Copper (Cu)	39	9	log-censored	13	84	13	163	< 5.5	248
Dissolved Oxygen	39	22	log-censored	588	11726	< 300	10500	< 300	17460
Eh	39	0	normal	160	197	138	359	-129	450
Fluoride (F)[4]	39	13	[3]	-	-	430	5750	200	7500
Iron (Fe)	39	0	[3]	-	-	1514	7056	19	7630
Lead (Pb)	39	4	log-censored	0.40	6.5	0.45	6.6	< 0.030	8.7
Lithium (Li)	39	6	log-censored	30	202	35.2	160	< 4.5	161
Magnesium (Mg)	39	0	normal	52778	63541	51635	115738	4713	154091
Manganese (Mn)	39	1	log-censored	90	1798	112	1316	< 0.90	3213
Mercury (Hg)	35	34	ins	ins	ins	< 0.10	0.15	< 0.10	0.38
Molybdenum (Mo)	39	27	log-censored	3.7	21	< 4.2	25	< 4.2	33
Nickel (Ni)	39	24	log-censored	7.0	34	< 6.0	42	< 6.0	51.3
Nitrate (NO_3)	39	33	log-censored	16	6513	< 500	16450	< 500	23300
Ortho-phosphate	9	0	normal	54	78	40	ins[1]	30	130
pH	39	0	[3]	-	-	7.00	8.29	6.30	8.80
$Phosphorus_{total}$	39	0	log-normal	125	164	140	453	15	663
Potassium (K)	39	0	log-normal	5587	6610	5474	13471	1347	14702
Redox	39	0	normal	-53	-16	-75	146	-341	236
Rubidium (Rb)	39	29	log-censored	337	1718	< 555	2203	< 555	2637
Selenium (Se)	39	15	log-censored	1.7	9.5	1.5	8.4	< 1.0	11
Silcate (Si)	39	0	[3]	-	-	10955	15795	3136	22629
Silver (Ag)	39	27	log-censored	0.0067	0.16	< 0.0090	0.23	< 0.0090	0.34
Sodium (Na)	39	0	log-normal	75945	112357	76187	635166	4074	743427
Specific Conductivity	39	0	normal	1465	1712	1436	3290	10	3370
Strontium (Sr)	39	0	log-normal	809	1041	754	2712	72	2920
Sulfate (SO_4)	39	1	log-censored	152412	191576	140130	417630	< 100	531620
Sulfur (S)	39	0	[3]	-	-	162675	454466	356	613372
Temperature	39	0	normal	9.9	10.1	10.0	11.7	6.50	11.7
Thallium (Tl)	39	23	log-censored	0.0025	0.28	< 0.0050	0.062	< 0.0050	43
Tin (Sn)	0	ns	ns	ns	ns	ns	ns	ns	ns
Titanium (Ti)	39	29	log-censored	0.0019	0.018	< 0.0035	0.025	< 0.0035	0.031
Total dissolved solids	39	0	normal	1215436	1426278	1110000	2576000	268000	3158000
Total organic carbon	39	0	[3]	-	-	2800	8500	1300	10200
Total phosphate	30	7	log-censored	41	304	50	466	< 20	570
Total suspended solids	39	0	log-normal	6177	8892	8000	52000	1000	56000
Vanadium (V)	39	14	log-censored	8.0	39	7.2	50	< 4.7	56
Zinc (Zn)	39	1	log-censored	29	361	26	996	< 2.7	3224
Zirconium (Zr)	0	ns	ns	ns	ns	ns	ns	ns	ns

[1] ins = insufficient number of detections to calculate statistics
[2] ns = not sampled
[3] Data did not fit a normal or log-normal distribution
[4] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.16: Descriptive statistics for the Galena Formation (OGAL).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
		ug/L							
Alkalinity	22	0	normal	332227	358690	380000	428000	236000	435000
Aluminum (Al)	22	5	log-censored	0.78	7.8	1.1	9.8	< 0.060	12
Antimony (Sb)	22	9	log-censored	0.010	0.041	0.0090	0.04	< 0.0080	0.040
Arsenic (As)	22	1	log-censored	2.0	22	2.5	17	< 0.060	19
Barium (Ba)	22	0	normal	162	207	148	389	8.3	397
Beryllium (Be)	22	16	log-censored	0.0063	0.019	< 0.010	0.020	< 0.010	0.020
Bismuth (Bi)	0	ns[2]	ns	ns	ns	ns	ns	ns	ns
Boron (B)	22	0	[3]	-	-	43	522	16	567
Bromide (Br)	21	21	ins	ins	ins	< 0.20	ins[1]	< 0.20	< 0.20
Cadmium (Cd)	22	0	normal	0.16	0.28	0.63	3	0.040	3.1
Calcium (Ca)	22	0	[3]	-	-	79932	139422	55363	139890
Cesium (Cs)	0	ns	ns	ns	ns	ns	ns	ns	ns
Chloride (Cl)	22	0	log-normal	1814	3726	1340	80433	220	95070
Chromium (Cr)	22	12	log-censored	0.055	0.52	< 0.050	0.71	< 0.050	0.81
Cobalt (Co)	22	0	normal	0.60	0.90	0.33	0.88	0.17	0.95
Copper (Cu)	22	4	log-censored	11	34	11	40	< 5.5	43
Dissolved Oxygen	22	12	log-censored	459	7616	< 300	14443	< 300	17140
Eh	22	0	[3]	-	-	97	397	37	426
Fluoride (F)[4]	21	0	normal	427	481	460	477	220	480
Iron (Fe)	22	0	normal	1596	2008	1500	3439	23	3517
Lead (Pb)	22	0	normal	0.077	0.13	0.060	5.0	0.030	6.07
Lithium (Li)	22	2	log-censored	15	56	14	59	< 4.5	62
Magnesium (Mg)	22	0	log-normal	25954	29614	24237	55848	15357	60246
Manganese (Mn)	22	0	[3]	-	-	51	264	1.2	313
Mercury (Hg)	21	21	ins	ins	ins	< 0.10	ins	< 0.10	0.090
Molybdenum (Mo)	22	17	log-censored	3.9	6.6	< 4.2	6.8	< 4.2	6.8
Nickel (Ni)	22	11	log-censored	6.3	12	6.3	13	< 6.0	14
Nitrate (NO_3)	22	19	log-censored	31	10392	< 500	24610	< 500	30460
Ortho-phosphate	19	2	log-censored	23	273	30	200	< 5.0	200
pH	22	0	[3]	-	-	7.17	7.43	5.85	7.44
$Phosphorus_{total}$	22	0	[3]	-	-	108	453	34	474
Potassium (K)	22	0	[3]	-	-	1789	14992	751	18309
Redox	22	0	[3]	-	-	-116	184	-177	213
Rubidium (Rb)	22	20	ins	ins	ins	< 555	661	< 555	661
Selenium (Se)	17	0	normal	2.2	3.0	1.0	2.9	1.0	2.9
Silcate (Si)	22	0	log-normal	9484	10627	9780	13471	4491	13771
Silver (Ag)	22	21	ins	ins	ins	< 0.0090	0.012	< 0.0090	0.013
Sodium (Na)	22	0	log-normal	18205	32352	13465	145031	4310	145608
Specific Conductivity	22	0	log-normal	690	790	667	1400	425	1475
Strontium (Sr)	22	0	normal	243	296	231	514	94	554
Sulfate (SO_4)	22	2	log-censored	6292	139553	9776	125233	< 100	142430
Sulfur (S)	22	0	log-normal	5888	15097	10853	129440	50	148668
Temperature	22	0	[3]	-	-	9.1	10.7	8.6	11.1
Thallium (Tl)	22	9	log-censored	0.0062	0.036	0.0060	0.053	< 0.0050	0.062
Tin (Sn)	0	ns	ns	ns	ns	ns	ns	ns	ns
Titanium (Ti)	22	14	log-censored	0.0028	0.0069	< 0.0035	0.0070	< 0.0035	0.0077
Total dissolved solids	22	0	log-normal	434410	520355	385500	1144500	238000	1234000
Total organic carbon	22	0	log-normal	7335	11225	8900	69250	1500	77800
Total phosphate	3	0	log-normal	49	129	40	ins	20	150
Total suspended solids	22	0	log-normal	3872	5257	4000	12000	1000	12000
Vanadium (V)	22	9	log-censored	5.6	12	5.8	13	< 4.7	14
Zinc (Zn)	22	0	normal	11	15	24	413	6.0	429
Zirconium (Zr)	0	ns	ns	ns	ns	ns	ns	ns	ns

[1] ins = insufficient number of detections to calculate statistics
[2] ns = not sampled
[3] Data did not fit a normal or log-normal distribution
[4] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.17: Descriptive statistics for the Maquoketa Formation (OMAQ).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
		ug/L							
Alkalinity	1	0	ins[1]	ins	ins	212000	ins	ins	ins
Aluminum (Al)	1	0	ins	ins	ins	0.69	ins	ins	ins
Antimony (Sb)	1	1	ins	ins	ins	< 0.0080	ins	ins	ins
Arsenic (As)	1	0	ins	ins	ins	0.84	ins	ins	ins
Barium (Ba)	1	0	ins	ins	ins	90	ins	ins	ins
Beryllium (Be)	1	1	ins	ins	ins	< 0.01	ins	ins	ins
Bismuth (Bi)	0	ns[2]	ins	ins	ins	ns	ns	ns	ns
Boron (B)	1	1	ins	ins	ins	< 13	ins	ins	ins
Bromide (Br)	1	1	ins	ins	ins	< 0.20	ins	ins	ins
Cadmium (Cd)	1	1	ins	ins	ins	< 0.020	ins	ins	ins
Calcium (Ca)	1	0	ins	ins	ins	57522	ins	ins	ins
Cesium (Cs)	0	ns	ins	ins	ins	ns	ns	ns	ns
Chloride (Cl)	1	0	ins	ins	ins	3330	ins	ins	ins
Chromium (Cr)	1	0	ins	ins	ins	0.10	ins	ins	ins
Cobalt (Co)	1	0	ins	ins	ins	0.25	ins	ins	ins
Copper (Cu)	1	0	ins	ins	ins	26	ins	ins	ins
Dissolved Oxygen	1	0	ins	ins	ins	6940	ins	ins	ins
Eh	1	0	ins	ins	ins	266	ins	ins	ins
Fluoride (F)[3]	0	ns	ins	ins	ins	ns	ns	ns	ns
Iron (Fe)	1	0	ins	ins	ins	47	ins	ins	ins
Lead (Pb)	1	0	ins	ins	ins	0.32	ins	ins	ins
Lithium (Li)	1	0	ins	ins	ins	9.1	ins	ins	ins
Magnesium (Mg)	1	0	ins	ins	ins	24639	ins	ins	ins
Manganese (Mn)	1	0	ins	ins	ins	13	ins	ins	ins
Mercury (Hg)	1	0	ins	ins	ins	0.15	ins	ins	ins
Molybdenum (Mo)	1	1	ins	ins	ins	< 4.2	ins	ins	ins
Nickel (Ni)	1	0	ins	ins	ins	12	ins	ins	ins
Nitrate (NO_3)	1	0	ins	ins	ins	2030	ins	ins	ins
Ortho-phosphate	1	0	ns	ns	ns	10	ins	ins	ins
pH	1	0	ins	ins	ins	7.35	ins	ins	ins
$Phosphorus_{total}$	1	0	ins	ins	ins	31	ins	ins	ins
Potassium (K)	1	0	ins	ins	ins	734	ins	ins	ins
Redox	1	0	ins	ins	ins	53	ins	ins	ins
Rubidium (Rb)	1	0	ins	ins	ins	656	ins	ins	ins
Selenium (Se)	1	0	ins	ins	ins	2.0	ins	ins	ins
Silcate (Si)	1	0	ins	ins	ins	7655	ins	ins	ins
Silver (Ag)	1	1	ins	ins	ins	< 0.0090	ins	ins	ins
Sodium (Na)	1	0	ins	ins	ins	2177	ins	ins	ins
Specific Conductivity	1	0	ins	ins	ins	473	ins	ins	ins
Strontium (Sr)	1	0	ins	ins	ins	47	ins	ins	ins
Sulfate (SO_4)	1	0	ins	ins	ins	5160	ins	ins	ins
Sulfur (S)	1	0	ins	ins	ins	5239	ins	ins	ins
Temperature	1	0	ins	ins	ins	9.3	ins	ins	ins
Thallium (Tl)	1	0	ins	ins	ins	0.034	ins	ins	ins
Tin (Sn)	0	ns	ins	ins	ins	ns	ns	ns	ns
Titanium (Ti)	1	0	ins	ins	ins	0.0069	ins	ins	ins
Total dissolved solids	1	0	ins	ins	ins	289000	ins	ins	ins
Total organic carbon	1	0	ins	ins	ins	1100	ins	ins	ins
Total phosphate	0	ns	ins	ins	ins	ns	ns	ns	ns
Total suspended solids	1	0	ins	ins	ins	1000	ins	ins	ins
Vanadium (V)	1	0	ins	ins	ins	9.7	ins	ins	ins
Zinc (Zn)	1	0	ins	ins	ins	10	ins	ins	ins
Zirconium (Zr)	0	ns	ins	ins	ins	ns	ns	ns	ns

[1] ins = insufficient number of detections to calculate statistics
[2] ns=not sampled
[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.18: Descriptive statistics for the Prairie du Chien Group (OPDC).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
		ug/L							
Alkalinity	36	0	normal	293611	322434	272000	454550	111000	469000
Aluminum (Al)	34	6	log-censored	0.77	13	0.93	16	< 0.060	18
Antimony (Sb)	34	5	log-censored	0.024	0.18	0.023	0.23	< 0.0080	0.25
Arsenic (As)	34	1	log-censored	0.51	4.1	0.46	6.8	< 0.060	12
Barium (Ba)	36	0	log-normal	62	81	60	209	5.1	259
Beryllium (Be)	34	28	log-censored	0.0025	0.022	< 0.010	0.028	< 0.010	0.050
Bismuth (Bi)	9	9	ins[1]	ins	ins	< 0.040	ins	< 0.040	< 0.040
Boron (B)	36	6	log-censored	37	317	30	374	< 13	523
Bromide (Br)	36	36	ins	ins	ins	< 0.20	ins	< 0.20	< 0.20
Cadmium (Cd)	34	8	log-censored	0.074	1.4	0.075	2.9	< 0.020	5.7
Calcium (Ca)	36	0	normal	82180	893241	80176	123607	34318	144905
Cesium (Cs)	9	0	normal	0.026	0.032	0.030	ins	0.010	0.040
Chloride (Cl)	36	0	log-normal	3448	6150	2645	149660	320	242480
Chromium (Cr)	34	5	log-censored	0.25	2.1	0.26	2.5	< 0.050	3.6
Cobalt (Co)	34	0	log-normal	0.44	0.71	0.44	4.8	0.15	4.9
Copper (Cu)	36	17	log-censored	5.9	31	6.1	39	< 5.5	59
Dissolved Oxygen	36	11	log-censored	934	11059	920	9835	< 300	10200
Eh	36	0	normal	256	298	251	477	-36	696
Fluoride (F)[3]	24	0	log-normal	285	346	285	605	200	630
Iron (Fe)	36	0	log-normal	225	458	487	4028	4	6672
Lead (Pb)	34	2	log-censored	0.44	4.8	0.50	4.4	< 0.030	4.9
Lithium (Li)	36	10	log-censored	7.6	30	7.7	39	< 4.5	50
Magnesium (Mg)	36	0	log-normal	27599	30346	26492	48959	16033	57023
Manganese (Mn)	36	9	log-censored	15	673	23	368	< 0.90	451
Mercury (Hg)	25	24	ins	ins	ins	< 0.10	0.16	< 0.10	0.19
Molybdenum (Mo)	36	33	log-censored	1.6	4.7	< 4.2	5.1	< 4.2	6.7
Nickel (Ni)	36	26	log-censored	3.6	14	< 6.0	14	< 6.0	31
Nitrate (NO_3)	36	21	log-censored	649	9042	< 500	10864	< 500	15700
Ortho-phosphate	19	7	log-censored	9.2	64	10	ins	< 5.0	60
pH	36	0	normal	7.22	7.30	7.25	7.61	6.72	7.68
$Phosphorus_{total}$	36	0	log-normal	38	186	34	260	15	265
Potassium (K)	36	0	log-normal	1899	2370	1700	7494	551	8327
Redox	36	0	normal	39	81	39	263	-248	483
Rubidium (Rb)	36	33	log-censored	348	685	< 555	733	< 555	852
Selenium (Se)	26	6	log-censored	1.1	3.0	1.0	3.4	< 1.0	3.7
Silcate (Si)	36	0	log-normal	8017	9061	8419	14425	3387	15782
Silver (Ag)	34	22	log-censored	0.0032	0.16	< 0.0090	0.22	< 0.0090	0.48
Sodium (Na)	36	0	[2]	-	-	5763	93877	2013	96942
Specific Conductivity	36	0	normal	641	718	598	1100	2	1350
Strontium (Sr)	36	0	[2]	-	-	13	515	61	571
Sulfate (SO_4)	36	0	log-normal	9022	11452	8750	43601	2240	61850
Sulfur (S)	36	0	log-normal	10247	13056	9508	45927	2560	73010
Temperature	36	0	log-normal	9.5	9.8	9.5	10.8	6.4	10.9
Thallium (Tl)	34	13	log-censored	0.010	0.32	0.0095	0.36	< 0.0050	0.46
Tin (Sn)	9	4	log-censored	0.055	0.26	0.050	ins	< 0.040	0.19
Titanium (Ti)	36	29	log-censored	0.0014	0.0070	< 0.0035	0.0080	< 0.0035	0.011
Total dissolved solids	36	0	log-normal	410472	457447	370500	796450	264000	799000
Total organic carbon	36	1	log-censored	2714	15472	2400	27645	< 500	31300
Total phosphate	17	5	log-censored	26	178	20	ins	< 20	250
Total suspended solids	36	0	[2]	-	-	2000	15200	1000	22000
Vanadium (V)	36	15	log-censored	5.1	11	4.9	12	< 4.7	12
Zinc (Zn)	36	1	log-censored	69	675	79	731	< 2.7	1372
Zirconium (Zr)	9	8	ins	ins	ins	< 0.030	ins	< 0.030	0.040

[1] ins = insufficient number of detections to calculate statistics
[2] Data did not fit a normal or log-normal distribution
[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.19: Descriptive statistics for the Plateville Limestone (OPVL).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
		ug/L							
Alkalinity	3	0	ins[1]	ins	ins	329000	ins	283000	354000
Aluminum (Al)	3	0	ins	ins	ins	1.3	ins	0.32	5.3
Antimony (Sb)	3	1	ins	ins	ins	0.0400	ins	< 0.0080	0.044
Arsenic (As)	3	0	ins	ins	ins	4.2	ins	3.6	14
Barium (Ba)	3	0	ins	ins	ins	173	ins	138	228
Beryllium (Be)	3	3	ins	ins	ins	< 0.010	ins	< 0.010	< 0.010
Bismuth (Bi)	2	1	ins	ins	ins	0.050	ins	< 0.040	0.070
Boron (B)	3	0	ins	ins	ins	30	ins	30	85
Bromide (Br)	3	3	ins	ins	ins	< 0.20	ins	< 0.20	< 0.20
Cadmium (Cd)	3	1	ins	ins	ins	0.020	ins	< 0.020	0.050
Calcium (Ca)	3	0	ins	ins	ins	79425	ins	52628	93202
Cesium (Cs)	2	1	ins	ins	ins	0.015	ins	< 0.010	0.020
Chloride (Cl)	3	0	ins	ins	ins	12740	ins	4080	17510
Chromium (Cr)	3	2	ins	ins	ins	< 0.050	ins	< 0.050	0.10
Cobalt (Co)	3	0	ins	ins	ins	0.46	ins	0.41	1.2
Copper (Cu)	3	1	ins	ins	ins	17	ins	< 5.5	121.3
Dissolved Oxygen	3	2	ins	ins	ins	< 300	ins	< 300	130
Eh	3	0	ins	ins	ins	100	ins	50	240
Fluoride (F)[3]	3	0	ins	ins	ins	230	ins	210	270
Iron (Fe)	3	0	ins	ins	ins	733	ins	672	752
Lead (Pb)	3	0	ins	ins	ins	0.44	ins	0.070	0.96
Lithium (Li)	3	0	ins	ins	ins	6.8	ins	5.9	7
Magnesium (Mg)	3	0	ins	ins	ins	43458	ins	27311	52490
Manganese (Mn)	3	0	ins	ins	ins	186	ins	27	305
Mercury (Hg)	1	1	ins	ins	ins	< 0.10	ins	< 0.10	< 0.10
Molybdenum (Mo)	3	1	ins	ins	ins	4.7	ins	< 4.2	5.7
Nickel (Ni)	3	2	ins	ins	ins	< 6.0	ins	< 6.0	9.8
Nitrate (NO_3)	3	3	ins	ins	ins	< 500	ins	< 500	< 500
Ortho-phosphate	0	ns[2]	ns	ns	ns	ns	ns	ns	ns
pH	3	0	ins	ins	ins	7.30	ins	7.15	7.67
$Phosphorus_{total}$	3	0	ins	ins	ins	61	ins	38	76
Potassium (K)	3	0	ins	ins	ins	2156	ins	1925	3063
Redox	3	0	ins	ins	ins	-112	ins	-160	27
Rubidium (Rb)	3	3	ins	ins	ins	< 555	ins	< 555	< 555
Selenium (Se)	3	1	ins	ins	ins	1.0	ins	< 1.0	6.9
Silcate (Si)	3	0	ins	ins	ins	14233	ins	12594	14480
Silver (Ag)	3	1	ins	ins	ins	0.051	ins	< 0.0090	0.15
Sodium (Na)	3	0	ins	ins	ins	6690	ins	5931	7010
Specific Conductivity	3	0	ins	ins	ins	631	ins	568	738
Strontium (Sr)	3	0	ins	ins	ins	239	ins	219	394
Sulfate (SO_4)	3	0	ins	ins	ins	5440	ins	1940	8460
Sulfur (S)	3	0	ins	ins	ins	6221	ins	2184	9637
Temperature	3	0	ins	ins	ins	10.4	ins	10.0	11.6
Thallium (Tl)	3	1	ins	ins	ins	0.0170	ins	< 0.0050	0.059
Tin (Sn)	2	1	ins	ins	ins	0.12	ins	< 0.040	0.20
Titanium (Ti)	3	2	ins	ins	ins	< 0.0035	ins	< 0.0035	0.0052
Total dissolved solids	3	0	ins	ins	ins	352000	ins	325000	442000
Total organic carbon	3	0	ins	ins	ins	1900	ins	1200	3200
Total phosphate	3	0	ins	ins	ins	50	ins	30	50
Total suspended solids	3	0	ins	ins	ins	2000	ins	2000	4000
Vanadium (V)	3	2	ins	ins	ins	< 4.7	ins	< 4.7	13
Zinc (Zn)	3	0	ins	ins	ins	29	ins	20	43
Zirconium (Zr)	2	1	ins	ins	ins	0.060	ins	< 0.030	0.10

[1] ins = insufficient number of detections to calculate statistics
[2] ns=not sampled
[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.20: Descriptive statistics for the St. Peter-Prairie du Chien Formation (OSPC).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
		ug/L							
Alkalinity	2	0	ins[1]	ins	ins	ins	ins	166000	348000
Aluminum (Al)	0	ns[2]	ins	ins	ins	ns	ns	ns	ns
Antimony (Sb)	0	ns	ins	ins	ins	ns	ns	ns	ns
Arsenic (As)	0	ns	ins	ins	ins	ns	ns	ns	ns
Barium (Ba)	2	0	ins	ins	ins	ins	ins	69	76
Beryllium (Be)	0	ns	ins	ins	ins	ns	ns	ns	ns
Bismuth (Bi)	0	ns	ins	ins	ins	ns	ns	ns	ns
Boron (B)	2	1	ins	ins	ins	ins	ins	< 13	38
Bromide (Br)	2	2	ins	ins	ins	ins	ins	< 0.20	< 0.20
Cadmium (Cd)	0	ns	ins	ins	ins	ns	ns	ns	ns
Calcium (Ca)	2	0	ins	ins	ins	ins	ins	52226	91875
Cesium (Cs)	0	ns	ins	ins	ins	ns	ns	ns	ns
Chloride (Cl)	2	0	ins	ins	ins	ins	ins	1720	14800
Chromium (Cr)	0	ns	ins	ins	ins	ns	ns	ns	ns
Cobalt (Co)	0	ns	ins	ins	ins	ns	ns	ns	ns
Copper (Cu)	2	1	ins	ins	ins	ins	ins	< 5.5	6.8
Dissolved Oxygen	2	1	ins	ins	ins	ins	ins	< 300	530
Eh	2	0	ins	ins	ins	ins	ins	75	251
Fluoride (F)[3]	1	1	ins	ins	ins	ins	ins	270	270
Iron (Fe)	2	0	ins	ins	ins	ins	ins	171	732
Lead (Pb)	0	ns	ins	ins	ins	ns	ns	ns	ns
Lithium (Li)	2	1	ins	ins	ins	ins	ins	< 4.5	12
Magnesium (Mg)	2	0	ins	ins	ins	ins	ins	15933	36858
Manganese (Mn)	2	0	ins	ins	ins	ins	ins	365	398
Mercury (Hg)	0	ns	ins	ins	ins	ns	ns	ns	ns
Molybdenum (Mo)	2	2	ins	ins	ins	ins	ins	< 4.2	< 4.2
Nickel (Ni)	2	2	ins	ins	ins	ins	ins	< 6.0	< 6.0
Nitrate (NO_3)	2	2	ins	ins	ins	ins	ins	< 500	< 500
Ortho-phosphate	0	ns	ns	ns	ns	ns	ns	ns	ns
pH	2	0	ins	ins	ins	ins	ins	7.28	7.52
$Phosphorus_{total}$	2	0	ins	ins	ins	ins	ins	35	76
Potassium (K)	2	0	ins	ins	ins	ins	ins	1663	2809
Redox	2	0	ins	ins	ins	ins	ins	-136	38
Rubidium (Rb)	2	2	ins	ins	ins	ins	ins	< 555	< 555
Selenium (Se)	0	ns	ins	ins	ins	ns	ns	ns	ns
Silcate (Si)	2	0	ins	ins	ins	ins	ins	6839	11788
Silver (Ag)	0	ns	ins	ins	ins	ns	ns	ns	ns
Sodium (Na)	2	0	ins	ins	ins	ins	ins	3478	5424
Specific Conductivity	2	0	ins	ins	ins	ins	ins	400	662
Strontium (Sr)	2	0	ins	ins	ins	ins	ins	68	260
Sulfate (SO_4)	2	0	ins	ins	ins	ins	ins	4000	11320
Sulfur (S)	2	0	ins	ins	ins	ins	ins	4310	11205
Temperature	2	0	ins	ins	ins	ins	ins	10.0	11.0
Thallium (Tl)	0	ns	ins	ins	ins	ns	ns	ns	ns
Tin (Sn)	0	ns	ins	ins	ins	ns	ns	ns	ns
Titanium (Ti)	2	2	ins	ins	ins	ins	ins	< 0.0035	< 0.0035
Total dissolved solids	2	0	ins	ins	ins	ins	ins	288000	474000
Total organic carbon	2	0	ins	ins	ins	ins	ins	1000	2400
Total phosphate	2	0	ins	ins	ins	ins	ins	40	70
Total suspended solids	2	0	ins	ins	ins	ins	ins	2000	3000
Vanadium (V)	2	2	ins	ins	ins	ins	ins	< 4.7	< 4.7
Zinc (Zn)	2	0	ins	ins	ins	ins	ins	11	73
Zirconium (Zr)	0	ns	ins	ins	ins	ns	ns	ns	ns

[1] ins = insufficient number of detections to calculate statistics
[2] ns = not sampled
[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.21: Descriptive statistics for the St. Peter Sandstone (OSTP).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
						ug/L			
Alkalinity	23	0	normal	263546	296027	242000	398800	164000	399000
Aluminum (Al)	23	4	log-censored	1.0	11	2.1	5.7	< 0.060	5.7
Antimony (Sb)	23	10	log-censored	0.010	0.071	0.0080	0.078	< 0.0080	0.083
Arsenic (As)	23	1	log-censored	0.52	3.8	0.53	4.2	< 0.060	4.3
Barium (Ba)	23	0	normal	72	92	52	161	5.4	165
Beryllium (Be)	23	18	log-censored	0.0033	0.020	< 0.010	0.028	< 0.010	0.030
Bismuth (Bi)	9	9	ins[1]	ins	ins	< 0.040	ins	< 0.040	< 0.040
Boron (B)	23	3	log-censored	45	249	42	265	< 13	266
Bromide (Br)	23	23	ins	ins	ins	< 0.20	ins	< 0.20	< 0.20
Cadmium (Cd)	23	4	log-censored	0.11	5.3	0.080	12	< 0.020	13
Calcium (Ca)	23	0	log-normal	73097	80390	72852	122275	52866	123474
Cesium (Cs)	9	5	log-censored	0.019	0.034	< 0.010	ins	< 0.010	0.030
Chloride (Cl)	23	0	log-normal	1988	3589	1230	41520	310	48030
Chromium (Cr)	23	7	log-censored	0.15	1.2	0.15	1.7	< 0.050	1.8
Cobalt (Co)	23	0	log-normal	0.53	0.84	0.48	3.0	0.19	3.3
Copper (Cu)	23	10	log-censored	10	49	10	69	< 5.5	71
Dissolved Oxygen	23	11	log-censored	533	10150	470	10302	< 300	10830
Eh	23	0	normal	196	249	249	316	-53	322
Fluoride (F)[3]	14	0	normal	260	414	310	ins	210	630
Iron (Fe)	23	0	log-normal	269	652	384	3409	5.0	3531
Lead (Pb)	23	0	log-normal	0.26	0.47	0.25	1.2	0.040	1.2
Lithium (Li)	23	7	log-censored	7.9	24	7.9	27	< 4.5	27
Magnesium (Mg)	23	0	log-normal	25264	28662	23382	44442	18272	44471
Manganese (Mn)	23	2	log-censored	38	1219	31	992	< 0.90	1019
Mercury (Hg)	14	14	ins	ins	ins	< 0.10	ins	< 0.10	< 0.10
Molybdenum (Mo)	23	3	log-censored	1.5	7.0	4.1	8.7	< 4.2	9.0
Nickel (Ni)	23	12	log-censored	8.2	12	< 6.0	12	< 6.0	12
Nitrate (NO_3)	23	19	log-censored	146	3906	< 500	6516	< 500	7320
Ortho-phosphate	10	5	log-censored	3.7	28	5.0	ins	< 5.0	30
pH	23	0	[2]	-	-	7.25	7.63	4.38	7.64
$Phosphorus_{total}$	23	0	log-normal	38	186	40	222	16	235
Potassium (K)	23	0	log-normal	22	2730	1881	5154	1178	5214
Redox	23	0	normal	37	69	36	102	-264	107
Rubidium (Rb)	23	21	log-censored	566	617	< 555	624	< 555	627
Selenium (Se)	17	7	log-censored	0.87	4.4	1.0	ins	< 1.0	5.4
Silcate (Si)	23	0	log-normal	7150	8923	8458	13718	3121	13970
Silver (Ag)	23	14	log-censored	0.0065	0.064	< 0.0090	0.093	< 0.0090	0.11
Sodium (Na)	23	0	[2]	-	-	4207	66058	2296	73885
Specific Conductivity	23	0	log-normal	550	610	526	930	380	939
Strontium (Sr)	23	0	log-normal	147	188	143	476	60	500
Sulfate (SO_4)	23	0	log-normal	6822	9899	8130	51332	1230	53690
Sulfur (S)	23	0	log-normal	7802	11384	8558	55349	1542	58839
Temperature	23	0	normal	6.7	10.1	9.8	11.9	6.6	12.1
Thallium (Tl)	23	11	log-censored	0.0089	0.062	0.0080	0.094	< 0.0050	0.11
Tin (Sn)	9	7	ins	ins	ins	< 0.040	ins	< 0.040	0.17
Titanium (Ti)	23	15	log-censored	0.0039	0.0060	< 0.0035	0.0070	< 0.0035	0.0068
Total dissolved solids	23	0	[2]	-	-	312000	648000	252000	657000
Total organic carbon	23	0	log-normal	2714	15472	1900	18460	600	20000
Total phosphate	13	2	log-censored	48	169	50	ins	< 20	190
Total suspended solids	23	0	log-normal	2493	3295	3000	8000	1000	8000
Vanadium (V)	23	9	log-censored	5.4	15	4.9	15	< 4.7	16
Zinc (Zn)	23	0	log-normal	46	79	47	399	7.8	402
Zirconium (Zr)	9	7	ins	ins	ins	< 0.030	ins	< 0.030	0.21

[1] ins = insufficient number of detections to calculate statistics
[2] Data did not fit a normal or log-normal distribution
[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.22: Descriptive statistics for undifferentiated Precambrian formations (PCCR).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
		ug/L							
Alkalinity	26	0	normal	229154	286006	211000	515450	33000	541000
Aluminum (Al)	26	1	log-censored	8.2	428	9.4	1071	< 0.060	1396.4
Antimony (Sb)	26	7	log-censored	0.017	0.088	0.014	0.083	< 0.0080	0.090
Arsenic (As)	26	5	log-censored	0.62	8.8	0.64	103	< 0.060	157
Barium (Ba)	26	0	[2]	-	-	39	567	10	780
Beryllium (Be)	26	11	log-censored	0.016	0.14	0.020	0.37	< 0.010	0.51
Bismuth (Bi)	11	11	ins[1]	ins	ins	< 0.040	ins	< 0.040	< 0.040
Boron (B)	26	1	log-censored	71	788	55	1574	< 13	2013
Bromide (Br)	26	26	ins	ins	ins	< 0.20	ins	< 0.20	< 0.20
Cadmium (Cd)	26	13	log-censored	0.032	0.31	0.020	0.41	< 0.020	0.47
Calcium (Ca)	26	0	log-normal	41390	55259	38909	249881	11585	309399
Cesium (Cs)	11	4	log-censored	0.015	0.64	0.010	ins	< 0.010	0.75
Chloride (Cl)	26	0	log-normal	3205	5391	2680	26615	360	28830
Chromium (Cr)	26	5	log-censored	0.61	4.5	0.61	15	< 0.050	20
Cobalt (Co)	26	0	log-normal	0.44	0.68	0.37	2.2	0.12	2.3
Copper (Cu)	26	11	log-censored	7.4	38	7.3	36	< 5.5	37
Dissolved Oxygen	26	12	log-censored	761	29296	735	52395	< 300	56000
Eh	26	0	normal	208	247	217	337	-24	348
Fluoride (F)[3]	23	0	log-normal	490	787	490	3674	220	4090
Iron (Fe)	26	0	log-normal	433	1024	205	30235	20	39594
Lead (Pb)	26	0	log-normal	0.49	1.1	0.50	8.2	0.090	11
Lithium (Li)	26	8	log-censored	5.6	37	6.5	147	< 4.5	215
Magnesium (Mg)	26	0	log-normal	15635	21667	13501	112569	4206	147192
Manganese (Mn)	26	0	log-normal	6.9	224	102	1639	2.8	2087
Mercury (Hg)	6	5	ins	ins	ins	< 0.10	ins	< 0.10	0.10
Molybdenum (Mo)	26	18	log-censored	38	292	< 4.2	26	< 4.2	29
Nickel (Ni)	26	17	log-censored	4.5	15	< 6.0	19	< 6.0	23
Nitrate (NO_3)	26	24	log-censored	3.4	1998	< 500	11030	< 500	16700
Ortho-phosphate	0	ns[3]	ns	ns	ns	ns	ns	ns	ns
pH	26	0	normal	7.4	7.7	7.38	8.81	6.30	9.00
$Phosphorus_{total}$	26	0	log-normal	32	239	31	298	15	326
Potassium (K)	26	0	log-normal	2043	2792	2007	8620	360	9766
Redox	26	0	normal	2	32	3	120	-237	131
Rubidium (Rb)	26	25	ins	ins	ins	< 555	670	< 555	732
Selenium (Se)	26	6	log-censored	1.7	25	2.0	2.3	< 1.0	308
Silcate (Si)	26	0	normal	9278	10320	8567	15458	5083	16249
Silver (Ag)	26	13	log-censored	0.0076	0.13	0.0090	0.45	< 0.0090	0.66
Sodium (Na)	26	0	[2]	-	-	9821	155344	3338	160995
Specific Conductivity	26	0	normal	382	495	300	1100	5	1111
Strontium (Sr)	26	0	log-normal	228	313	197	1638	59	2077
Sulfate (SO_4)	26	0	[2]	-	-	3410	282984	130	402460
Sulfur (S)	26	0	[2]	-	-	3721	303757	586	429506
Temperature	26	0	normal	8.4	8.8	8.5	10.6	6.2	10.8
Thallium (Tl)	26	17	log-censored	0.0056	0.014	< 0.0050	0.020	< 0.0050	0.025
Tin (Sn)	11	2	log-censored	0.075	0.51	0.070	ins	< 0.040	0.52
Titanium (Ti)	26	10	log-censored	0.0019	0.020	< 0.0035	0.037	< 0.0035	0.049
Total dissolved solids	26	0	log-normal	282618	381066	257000	1941600	64000	2594000
Total organic carbon	26	1	log-censored	2409	10119	2100	12175	< 500	14100
Total phosphate	26	15	log-censored	17	218	< 20	242	< 20	270
Total suspended solids	26	0	[2]	-	-	4000	83500	1000	108000
Vanadium (V)	26	12	log-censored	4.6	19	5.1	29	< 4.7	35
Zinc (Zn)	26	1	log-censored	18	258	15	658	< 2.7	734
Zirconium (Zr)	11	1	log-censored	0.21	3.1	0.29	ins	< 0.030	4.1

[1] ins = insufficient number of detections to calculate statistics
[2] Data did not fit a normal or log-normal distribution
[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.23: Descriptive statistics for undifferentiated Precambrian crystalline formations (PCUU).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
						ug/L			
Alkalinity	3	0	ins[1]	ins	ins	333000	ins	72000	390000
Aluminum (Al)	3	2	ins	ins	ins	< 0.060	ins	< 0.060	1.5
Antimony (Sb)	3	2	ins	ins	ins	< 0.0080	ins	< 0.0080	0.015
Arsenic (As)	3	0	ins	ins	ins	1.4	ins	0.19	2.8
Barium (Ba)	3	0	ins	ins	ins	12	ins	1.7	59
Beryllium (Be)	3	2	ins	ins	ins	< 0.010	ins	< 0.010	0.080
Bismuth (Bi)	1	1	ins	ins	ins	< 0.040	ins	ins	ins
Boron (B)	3	1	ins	ins	ins	271	ins	< 13	806
Bromide (Br)	3	3	ins	ins	ins	< 0.20	ins	< 0.20	< 0.20
Cadmium (Cd)	3	2	ins	ins	ins	< 0.020	ins	< 0.020	0.060
Calcium (Ca)	3	0	ins	ins	ins	102262	ins	22568	160720
Cesium (Cs)	1	1	ins	ins	ins	< 0.010	ins	ins	ins
Chloride (Cl)	3	0	ins	ins	ins	2120	ins	420	9680
Chromium (Cr)	3	1	ins	ins	ins	1.1	ins	< 0.050	1.5
Cobalt (Co)	3	0	ins	ins	ins	0.54	ins	0.14	1.0
Copper (Cu)	3	0	ins	ins	ins	5.9	ins	5.5	52
Dissolved Oxygen	3	1	ins	ins	ins	1640	ins	< 300	9110
Eh	3	0	ins	ins	ins	159	ins	22	219
Fluoride (F)[2]	3	0	ins	ins	ins	410	ins	200	800
Iron (Fe)	3	0	ins	ins	ins	1650	ins	16	1941
Lead (Pb)	3	0	ins	ins	ins	0.11	ins	0.050	0.25
Lithium (Li)	3	0	ins	ins	ins	20	ins	4.7	41
Magnesium (Mg)	3	0	ins	ins	ins	46382	ins	5178	55448
Manganese (Mn)	3	1	ins	ins	ins	241	ins	< 0.90	390
Mercury (Hg)	2	2	ins	ins	ins	ins	ins	< 0.10	< 0.10
Molybdenum (Mo)	3	2	ins	ins	ins	< 4.2	ins	< 4.2	16
Nickel (Ni)	3	2	ins	ins	ins	< 6.0	ins	< 6.0	16
Nitrate (NO_3)	3	3	ins	ins	ins	< 500	ins	< 500	< 500
Ortho-phosphate	1	0	ns	ns	ns	20	ins	ins	ins
pH	3	0	ins	ins	ins	7.20	ins	7.11	7.22
$Phosphorus_{total}$	3	0	ins	ins	ins	70	ins	15	71
Potassium (K)	3	0	ins	ins	ins	5629	ins	400	6551
Redox	3	0	ins	ins	ins	-53	ins	-191	2
Rubidium (Rb)	3	2	ins	ins	ins	< 555	ins	< 555	885
Selenium (Se)	3	1	ins	ins	ins	2.0	ins	< 1.0	8.1
Silcate (Si)	3	0	ins	ins	ins	8621	ins	6227	8975
Silver (Ag)	3	3	ins	ins	ins	< 0.0090	ins	< 0.0090	< 0.0090
Sodium (Na)	3	0	ins	ins	ins	63903	ins	2961	125967
Specific Conductivity	3	0	ins	ins	ins	162	ins	14	1018
Strontium (Sr)	3	0	ins	ins	ins	743	ins	30	1682
Sulfate (SO_4)	3	0	ins	ins	ins	58010	ins	1970	182410
Sulfur (S)	3	0	ins	ins	ins	60092	ins	2200	182680
Temperature	3	0	ins	ins	ins	9.6	ins	6.8	10.1
Thallium (Tl)	3	2	ins	ins	ins	< 0.0050	ins	< 0.0050	0.014
Tin (Sn)	1	0	ins	ins	ins	0.070	ins	ins	ins
Titanium (Ti)	3	2	ins	ins	ins	< 0.0035	ins	< 0.0035	0.011
Total dissolved solids	3	0	ins	ins	ins	666000	ins	136000	1230000
Total organic carbon	3	0	ins	ins	ins	3000	ins	700	3400
Total phosphate	2	1	ins	ins	ins	ins	ins	< 20	40
Total suspended solids	3	0	ins	ins	ins	4000	ins	2000	6000
Vanadium (V)	3	0	ins	ins	ins	5.5	ins	4.8	19
Zinc (Zn)	3	0	ins	ins	ins	8.0	ins	5.1	48
Zirconium (Zr)	1	1	ins	ins	ins	< 0.030	ins	ins	ins

[1] Insufficient number of detections to calculate parametric statistics

[2] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.24: Descriptive statistics for the Biwabik Iron Formation (PEBI).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
		ug/L							
Alkalinity	1	0	ins[1]	ins	ins	78000	ins	ins	ins
Aluminum (Al)	1	0	ins	ins	ins	0.89	ins	ins	ins
Antimony (Sb)	1	0	ins	ins	ins	0.14	ins	ins	ins
Arsenic (As)	1	0	ins	ins	ins	5.0	ins	ins	ins
Barium (Ba)	1	0	ins	ins	ins	34	ins	ins	ins
Beryllium (Be)	1	0	ins	ins	ins	0.010	ins	ins	ins
Bismuth (Bi)	1	1	ins	ins	ins	< 0.040	ins	ins	ins
Boron (B)	1	0	ins	ins	ins	46	ins	ins	ins
Bromide (Br)	1	1	ins	ins	ins	< 0.20	ins	ins	ins
Cadmium (Cd)	1	1	ins	ins	ins	< 0.020	ins	ins	ins
Calcium (Ca)	1	0	ins	ins	ins	30801	ins	ins	ins
Cesium (Cs)	1	0	ins	ins	ins	0.11	ins	ins	ins
Chloride (Cl)	1	0	ins	ins	ins	1270	ins	ins	ins
Chromium (Cr)	1	1	ins	ins	ins	< 0.050	ins	ins	ins
Cobalt (Co)	1	0	ins	ins	ins	0.17	ins	ins	ins
Copper (Cu)	1	1	ins	ins	ins	< 5.5	ins	ins	ins
Dissolved Oxygen	1	1	ins	ins	ins	< 300	ins	ins	ins
Eh	1	0	ins	ins	ins	178	ins	ins	ins
Fluoride (F)[3]	1	0	ins	ins	ins	300	ins	ins	ins
Iron (Fe)	1	0	ins	ins	ins	155	ins	ins	ins
Lead (Pb)	1	0	ins	ins	ins	0.17	ins	ins	ins
Lithium (Li)	1	0	ins	ins	ins	7.0	ins	ins	ins
Magnesium (Mg)	1	0	ins	ins	ins	13310	ins	ins	ins
Manganese (Mn)	1	0	ins	ins	ins	290	ins	ins	ins
Mercury (Hg)	0	ns[2]	ins	ins	ins	ns	ns	ns	ns
Molybdenum (Mo)	1	1	ins	ins	ins	< 4.2	ins	ins	ins
Nickel (Ni)	1	1	ins	ins	ins	< 6.0	ins	ins	ins
Nitrate (NO_3)	1	1	ins	ins	ins	< 500	ins	ins	ins
Ortho-phosphate	0	ns	ns	ns	ns	ns	ns	ns	ns
pH	1	0	ins	ins	ins	7.80	ins	ins	ins
$Phosphorus_{total}$	1	0	ins	ins	ins	17	ins	ins	ins
Potassium (K)	1	0	ins	ins	ins	1727	ins	ins	ins
Redox	1	0	ins	ins	ins	-36	ins	ins	ins
Rubidium (Rb)	1	1	ins	ins	ins	< 555	ins	ins	ins
Selenium (Se)	1	0	ins	ins	ins	4.5	ins	ins	ins
Silcate (Si)	1	0	ins	ins	ins	7921	ins	ins	ins
Silver (Ag)	1	1	ins	ins	ins	< 0.0090	ins	ins	ins
Sodium (Na)	1	0	ins	ins	ins	4671	ins	ins	ins
Specific Conductivity	1	0	ins	ins	ins	285	ins	ins	ins
Strontium (Sr)	1	0	ins	ins	ins	96	ins	ins	ins
Sulfate (SO_4)	1	0	ins	ins	ins	21980	ins	ins	ins
Sulfur (S)	1	0	ins	ins	ins	21499	ins	ins	ins
Temperature	1	0	ins	ins	ins	9.0	ins	ins	ins
Thallium (Tl)	1	1	ins	ins	ins	< 0.0050	ins	ins	ins
Tin (Sn)	1	0	ins	ins	ins	0.27	ins	ins	ins
Titanium (Ti)	1	1	ins	ins	ins	< 0.0035	ins	ins	ins
Total dissolved solids	1	0	ins	ins	ins	202000	ins	ins	ins
Total organic carbon	1	1	ins	ins	ins	< 500	ins	ins	ins
Total phosphate	1	1	ins	ins	ins	< 20	ins	ins	ins
Total suspended solids	1	0	ins	ins	ins	2000	ins	ins	ins
Vanadium (V)	1	1	ins	ins	ins	< 4.7	ins	ins	ins
Zinc (Zn)	1	0	ins	ins	ins	151	ins	ins	ins
Zirconium (Zr)	1	1	ins	ins	ins	< 0.030	ins	ins	ins

[1] ins = insufficient number of detections to calculate statistics
[2] ns=not sampled
[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.25: Descriptive statistics for Duluth Complex (PMDC).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
		ug/L							
Alkalinity	1	0	ins[1]	ins	ins	177000	ins	ins	ins
Aluminum (Al)	1	0	ins	ins	ins	771	ins	ins	ins
Antimony (Sb)	1	0	ins	ins	ins	0.11	ins	ins	ins
Arsenic (As)	1	0	ins	ins	ins	1.2	ins	ins	ins
Barium (Ba)	1	0	ins	ins	ins	2.0	ins	ins	ins
Beryllium (Be)	1	0	ins	ins	ins	0.39	ins	ins	ins
Bismuth (Bi)	1	0	ins	ins	ins	0.060	ins	ins	ins
Boron (B)	1	0	ins	ins	ins	748	ins	ins	ins
Bromide (Br)	1	1	ins	ins	ins	< 0.20	ins	ins	ins
Cadmium (Cd)	1	1	ins	ins	ins	< 0.020	ins	ins	ins
Calcium (Ca)	1	0	ins	ins	ins	4781	ins	ins	ins
Cesium (Cs)	1	0	ins	ins	ins	0.10	ins	ins	ins
Chloride (Cl)	1	0	ins	ins	ins	5900	ins	ins	ins
Chromium (Cr)	1	0	ins	ins	ins	2.1	ins	ins	ins
Cobalt (Co)	1	0	ins	ins	ins	0.83	ins	ins	ins
Copper (Cu)	1	0	ins	ins	ins	79	ins	ins	ins
Dissolved Oxygen	1	0	ins	ins	ins	9100	ins	ins	ins
Eh	1	0	ins	ins	ins	169	ins	ins	ins
Fluoride (F)[3]	1	0	ins	ins	ins	1210	ins	ins	ins
Iron (Fe)	1	0	ins	ins	ins	1953	ins	ins	ins
Lead (Pb)	1	0	ins	ins	ins	26	ins	ins	ins
Lithium (Li)	1	1	ins	ins	ins	< 4.5	ins	ins	ins
Magnesium (Mg)	1	0	ins	ins	ins	1807	ins	ins	ins
Manganese (Mn)	1	0	ins	ins	ins	120	ins	ins	ins
Mercury (Hg)	0	ns[2]	ins	ins	ins	ns	ns	ns	ns
Molybdenum (Mo)	1	0	ins	ins	ins	8.1	ins	ins	ins
Nickel (Ni)	1	1	ins	ins	ins	< 6.0	ins	ins	ins
Nitrate (NO_3)	1	1	ins	ins	ins	< 500	ins	ins	ins
Ortho-phosphate	0	ns	ns	ns	ns	ns	ns	ns	ns
pH	1	0	ins	ins	ins	9.00	ins	ins	ins
$\text{Phosphorus}_{total}$	1	0	ins	ins	ins	66	ins	ins	ins
Potassium (K)	1	0	ins	ins	ins	749	ins	ins	ins
Redox	1	0	ins	ins	ins	-46	ins	ins	ins
Rubidium (Rb)	1	1	ins	ins	ins	< 555	ins	ins	ins
Selenium (Se)	1	0	ins	ins	ins	14	ins	ins	ins
Silcate (Si)	1	0	ins	ins	ins	8442	ins	ins	ins
Silver (Ag)	1	0	ins	ins	ins	0.050	ins	ins	ins
Sodium (Na)	1	0	ins	ins	ins	74622	ins	ins	ins
Specific Conductivity	1	0	ins	ins	ins	322	ins	ins	ins
Strontium (Sr)	1	0	ins	ins	ins	20	ins	ins	ins
Sulfate (SO_4)	1	0	ins	ins	ins	3240	ins	ins	ins
Sulfur (S)	1	0	ins	ins	ins	3468	ins	ins	ins
Temperature	1	0	ins	ins	ins	8.1	ins	ins	ins
Thallium (Tl)	1	1	ins	ins	ins	< 0.0050	ins	ins	ins
Tin (Sn)	1	0	ins	ins	ins	2.6	ins	ins	ins
Titanium (Ti)	1	0	ins	ins	ins	0.064	ins	ins	ins
Total dissolved solids	1	0	ins	ins	ins	186000	ins	ins	ins
Total organic carbon	1	0	ins	ins	ins	900	ins	ins	ins
Total phosphate	1	0	ins	ins	ins	60	ins	ins	ins
Total suspended solids	1	0	ins	ins	ins	86000	ins	ins	ins
Vanadium (V)	1	1	ins	ins	ins	< 4.7	ins	ins	ins
Zinc (Zn)	1	0	ins	ins	ins	168	ins	ins	ins
Zirconium (Zr)	1	0	ins	ins	ins	1.4	ins	ins	ins

[1] ins = insufficient number of detections to calculate statistics
[3] ns=not sampled
[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.26: Descriptive statistics for the Mount Simon-Fon du Lac Formation (PMFL).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
		ug/L							
Alkalinity	2	0	ins[1]	ins	ins	ins	ins	133000	223000
Aluminum (Al)	2	0	ins	ins	ins	ins	ins	6.8	174
Antimony (Sb)	2	0	ins	ins	ins	ins	ins	0.019	0.050
Arsenic (As)	2	0	ins	ins	ins	ins	ins	0.26	1.1
Barium (Ba)	2	0	ins	ins	ins	ins	ins	29	104
Beryllium (Be)	2	1	ins	ins	ins	ins	ins	< 0.010	0.020
Bismuth (Bi)	1	1	ins	ins	ins	< 0.040	ins	ins	ins
Boron (B)	2	0	ins	ins	ins	ins	ins	14	30
Bromide (Br)	2	2	ins	ins	ins	ins	ins	< 0.20	< 0.20
Cadmium (Cd)	2	1	ins	ins	ins	ins	ins	< 0.020	0.41
Calcium (Ca)	2	0	ins	ins	ins	ins	ins	37244	58420
Cesium (Cs)	1	1	ins	ins	ins	< 0.010	ins	ins	ins
Chloride (Cl)	2	0	ins	ins	ins	ins	ins	850	1020
Chromium (Cr)	2	0	ins	ins	ins	ins	ins	0.87	5.0
Cobalt (Co)	2	0	ins	ins	ins	ins	ins	0.31	0.68
Copper (Cu)	2	1	ins	ins	ins	ins	ins	< 5.5	48
Dissolved Oxygen	2	1	ins	ins	ins	ins	ins	< 300	800
Eh	2	0	ins	ins	ins	ins	ins	216	288
Fluoride (F)[3]	1	0	ins	ins	ins	300	ins	ins	ins
Iron (Fe)	2	0	ins	ins	ins	ins	ins	219	631
Lead (Pb)	2	0	ins	ins	ins	ins	ins	0.40	15
Lithium (Li)	2	1	ins	ins	ins	ins	ins	< 4.5	6.0
Magnesium (Mg)	2	0	ins	ins	ins	ins	ins	11902	19695
Manganese (Mn)	2	0	ins	ins	ins	ins	ins	4.5	243
Mercury (Hg)	0	ns[2]	ins	ins	ins	ns	ns	ns	ns
Molybdenum (Mo)	2	2	ins	ins	ins	ins	ins	< 4.2	< 4.2
Nickel (Ni)	2	2	ins	ins	ins	ins	ins	< 6.0	< 6.0
Nitrate (NO_3)	2	2	ins	ins	ins	ins	ins	< 500	< 500
Ortho-phosphate	0	ns	ns	ns	ns	ns	ns	ns	ns
pH	2	0	ins	ins	ins	ins	ins	7.38	7.50
$Phosphorus_{total}$	2	1	ins	ins	ins	ins	ins	< 14.9	16
Potassium (K)	2	0	ins	ins	ins	ins	ins	723	1390
Redox	2	0	ins	ins	ins	ins	ins	0	72
Rubidium (Rb)	2	2	ins	ins	ins	ins	ins	< 555	< 555
Selenium (Se)	2	1	ins	ins	ins	ins	ins	< 1.0	5.9
Silcate (Si)	2	0	ins	ins	ins	ins	ins	11069	11938
Silver (Ag)	2	0	ins	ins	ins	ins	ins	0.0090	0.12
Sodium (Na)	2	0	ins	ins	ins	ins	ins	3250	5884
Specific Conductivity	2	0	ins	ins	ins	ins	ins	282.0000	427
Strontium (Sr)	2	0	ins	ins	ins	ins	ins	41	60
Sulfate (SO_4)	2	0	ins	ins	ins	ins	ins	2550	4900
Sulfur (S)	2	0	ins	ins	ins	ins	ins	2803	5232
Temperature	2	0	ins	ins	ins	ins	ins	7.5	7.6
Thallium (Tl)	2	0	ins	ins	ins	ins	ins	0.0070	0.010
Tin (Sn)	1	0	ins	ins	ins	0.13	ins	ins	ins
Titanium (Ti)	2	1	ins	ins	ins	ins	ins	< 0.0035	0.014
Total dissolved solids	2	0	ins	ins	ins	ins	ins	186000	254000
Total organic carbon	2	0	ins	ins	ins	ins	ins	900	1600
Total phosphate	2	1	ins	ins	ins	ins	ins	< 20	30
Total suspended solids	2	0	ins	ins	ins	ins	ins	2000	12000
Vanadium (V)	2	0	ins	ins	ins	ins	ins	5.1	6.2
Zinc (Zn)	2	0	ins	ins	ins	ins	ins	3.3	196
Zirconium (Zr)	1	0	ins	ins	ins	0.060	ins	ins	ins

[1] ins = insufficient number of detections to calculate statistics
[2] ns=not sampled
[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.27: Descriptive statistics for the Mount Simon-Hinckley Formation (PMHN).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
						ug/L			
Alkalinity	3	0	ins[1]	ins	ins	110000	ins	91000	127000
Aluminum (Al)	3	0	ins	ins	ins	3.2	ins	0.74	7.0
Antimony (Sb)	3	1	ins	ins	ins	0.030	ins	< 0.0080	0.13
Arsenic (As)	3	0	ins	ins	ins	2.7	ins	1.1	3.3
Barium (Ba)	3	0	ins	ins	ins	33	ins	32	111
Beryllium (Be)	3	2	ins	ins	ins	< 0.010	ins	< 0.010	0.030
Bismuth (Bi)	3	3	ins	ins	ins	< 0.040	ins	< 0.040	< 0.040
Boron (B)	3	2	ins	ins	ins	< 13	ins	< 13	51
Bromide (Br)	3	3	ins	ins	ins	< 0.20	ins	< 0.20	< 0.20
Cadmium (Cd)	3	3	ins	ins	ins	< 0.020	ins	< 0.020	< 0.020
Calcium (Ca)	3	0	ins	ins	ins	26173	ins	21864	32651
Cesium (Cs)	3	2	ins	ins	ins	< 0.010	ins	< 0.010	0.020
Chloride (Cl)	3	0	ins	ins	ins	1660	ins	490	2690
Chromium (Cr)	3	1	ins	ins	ins	0.15	ins	< 0.050	2.3
Cobalt (Co)	3	0	ins	ins	ins	0.99	ins	0.41	3.8
Copper (Cu)	3	2	ins	ins	ins	< 5.5	ins	< 5.5	13
Dissolved Oxygen	3	3	ins	ins	ins	< 300	ins	< 300	< 300
Eh	3	0	ins	ins	ins	160	ins	158	242
Fluoride (F)[3]	3	1	ins	ins	ins	200	ins	200	200
Iron (Fe)	3	0	ins	ins	ins	1634	ins	121	15511
Lead (Pb)	3	0	ins	ins	ins	0.45	ins	0.060	1.3
Lithium (Li)	3	2	ins	ins	ins	< 4.5	ins	< 4.5	12
Magnesium (Mg)	3	0	ins	ins	ins	8925	ins	8202	9220
Manganese (Mn)	3	0	ins	ins	ins	139	ins	42	505
Mercury (Hg)	0	ns[2]	ins	ins	ins	ns	ns	ns	ns
Molybdenum (Mo)	3	2	ins	ins	ins	< 4.2	ins	< 4.2	4.4
Nickel (Ni)	3	2	ins	ins	ins	< 6.0	ins	< 6.0	9.2
Nitrate (NO_3)	3	3	ins	ins	ins	< 500	ins	< 500	< 500
Ortho-phosphate	0	ns	ns	ns	ns	ns	ns	ns	ns
pH	3	0	ins	ins	ins	6.80	ins	6.20	8.19
$Phosphorus_{total}$	3	0	ins	ins	ins	43	ins	19	160
Potassium (K)	3	0	ins	ins	ins	677	ins	525	1436
Redox	3	0	ins	ins	ins	-55	ins	-57	28
Rubidium (Rb)	3	2	ins	ins	ins	< 555	ins	< 555	713
Selenium (Se)	3	2	ins	ins	ins	< 1.0	ins	< 1.0	6.5
Silcate (Si)	3	0	ins	ins	ins	11996	ins	5742	15026
Silver (Ag)	3	2	ins	ins	ins	< 0.0090	ins	< 0.0090	0.020
Sodium (Na)	3	0	ins	ins	ins	4096	ins	3718	9340
Specific Conductivity	3	0	ins	ins	ins	248.000	ins	228	250
Strontium (Sr)	3	0	ins	ins	ins	45	ins	35	186
Sulfate (SO_4)	3	0	ins	ins	ins	2040	ins	310	2510
Sulfur (S)	3	0	ins	ins	ins	2200	ins	390	2695
Temperature	3	0	ins	ins	ins	7.8	ins	7.8	8.5
Thallium (Tl)	3	2	ins	ins	ins	< 0.0050	ins	< 0.0050	0.040
Tin (Sn)	3	1	ins	ins	ins	0.040	ins	< 0.040	0.18
Titanium (Ti)	3	2	ins	ins	ins	< 0.0035	ins	< 0.0035	0.0054
Total dissolved solids	3	0	ins	ins	ins	150000	ins	142000	152000
Total organic carbon	3	0	ins	ins	ins	2700	ins	1500	7200
Total phosphate	3	1	ins	ins	ins	20	ins	< 20	120
Total suspended solids	3	0	ins	ins	ins	4000	ins	3000	8000
Vanadium (V)	3	1	ins	ins	ins	6.1	ins	< 4.7	12
Zinc (Zn)	3	0	ins	ins	ins	16	ins	2.8	23
Zirconium (Zr)	3	2	ins	ins	ins	< 0.030	ins	< 0.030	0.52

[1] ins = insufficient number of detections to calculate statistics
[2] ns=not sampled
[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.28: Descriptive statistics for the North Shore Volcanics group (PMNS).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
		ug/L							
Alkalinity	16	0	normal	139500	168275	125500	ins[1]	66000	217000
Aluminum (Al)	17	0	log-normal	48	163	37	ins	1.1	2179
Antimony (Sb)	17	2	log-censored	0.031	0.20	0.040	ins	< 0.0080	0.26
Arsenic (As)	17	1	log-censored	0.9	7.9	0.98	ins	< 0.060	14.8
Barium (Ba)	17	3	log-censored	8.3	103	7.0	ins	< 1.4	153
Beryllium (Be)	17	6	log-censored	0.017	0.92	0.020	ins	< 0.010	2.5
Bismuth (Bi)	13	13	ins	ins	ins	< 0.040	ins	< 0.040	0.030
Boron (B)	17	1	log-censored	204	3156	129	ins	< 13	3524
Bromide (Br)	17	15	log-censored	0.074	1.1	< 0.20	ins	< 0.20	1.50
Cadmium (Cd)	17	8	log-censored	0.036	0.45	0.030	ins	< 0.020	1.0
Calcium (Ca)	17	0	normal	26867	35145	26763	ins	1298	55204
Cesium (Cs)	13	3	log-censored	0.032	1.5	0.030	ins	< 0.010	1.6
Chloride (Cl)	17	0	log-normal	3222	8995	1880	ins	280	231230
Chromium (Cr)	17	3	log-censored	0.60	20	0.66	ins	< 0.050	92
Cobalt (Co)	17	1	log-censored	0.38	5.2	0.29	ins	< 0.09	49
Copper (Cu)	17	5	log-censored	10	165	12	ins	< 5.5	450
Dissolved Oxygen	17	9	log-censored	1146	14919	< 300	ins	< 300	10690
Eh	17	0	normal	162	205	173	ins	7.3	263
Fluoride (F)[4]	17	2	normal	669	951	430	ins	230	1600
Iron (Fe)	17	0	log-normal	391	1514	238	ins	9.6	123730
Lead (Pb)	17	0	[2]	-	-	0.38	ins	0.060	16
Lithium (Li)	17	5	log-censored	8.0	43	11	ins	< 4.5	75
Magnesium (Mg)	17	0	normal	11626	15990	11528	ins	409	76379
Manganese (Mn)	17	0	log-normal	27	62	28	ins	1.5	1116
Mercury (Hg)	0	ns[3]	ns	ns	ns	ns	ns	ns	ns
Molybdenum (Mo)	17	9	log-censored	6.0	15	< 4.2	ins	< 4.2	15
Nickel (Ni)	17	9	log-censored	3.9	73	< 6.0	ins	< 6.0	234
Nitrate (NO_3)	17	15	log-censored	1.8	1686	< 500	ins	< 500	3900
Ortho-phosphate	0	ns	ns	ns	ns	ns	ns	ns	ns
pH	17	0	normal	8.20	8.60	8.00	ins	6.90	9.43
$Phosphorus_{total}$	17	5	log-censored	24	564	23	ins	< 15	1566
Potassium (K)	17	1	log-censored	908	4218	776	ins	< 119	6408
Redox	17	0	normal	-51	-4	-42	ins	-209	46
Rubidium (Rb)	17	15	log-censored	532	582	< 555	ins	< 555	589
Selenium (Se)	17	7	log-censored	1.4	9.4	1.7	ins	< 1.0	11
Silcate (Si)	17	0	normal	8956	11194	9039	ins	4637	53216
Silver (Ag)	17	5	log-censored	0.014	0.13	0.013	ins	< 0.0090	0.24
Sodium (Na)	17	0	log-normal	22454	39747	17890	ins	4187	177736
Specific Conductivity	17	0	log-normal	325	431	339.000	ins	163	1029
Strontium (Sr)	17	0	log-normal	113	189	121	ins	11	611
Sulfate (SO_4)	17	0	log-normal	3578	6677	2930	ins	580	82430
Sulfur (S)	17	0	log-normal	3965	7213	3390	ins	698	88252
Temperature	17	0	normal	7.8	8.7	7.8	ins	6.0	11.6
Thallium (Tl)	17	11	log-censored	0.0011	0.11	< 0.0050	ins	< 0.0050	0.42
Tin (Sn)	13	2	log-censored	0.087	0.28	0.080	ins	< 0.040	0.37
Titanium (Ti)	17	5	log-censored	0.0054	0.069	0.0050	ins	< 0.0035	0.23
Total dissolved solids	17	0	log-normal	217020	283204	238000	ins	108000	614000
Total organic carbon	17	0	log-normal	1631	2271	1300	ins	900	5700
Total phosphate	17	9	log-censored	8.2	792	< 20	ins	< 20	1660
Total suspended solids	17	0	[2]	-	-	4000	ins	2000	1732000
Vanadium (V)	17	5	log-censored	6.7	43	6.5	ins	< 4.7	112
Zinc (Zn)	17	2	log-censored	14	371	13	ins	< 2.7	1078
Zirconium (Zr)	13	2	log-censored	0.14	2.9	0.10	ins	< 0.030	5.8

[1] ins = insufficient number of detections to calculate statistics
[2] Data did not fit a normal or log-normal distribution
[3] ns=not sampled
[4] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.29: Descriptive statistics for the Sioux Quartzite (PMSX).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
		ug/L							
Alkalinity	4	0	ins[1]	ins	ins	244000	ins	161000	427000
Aluminum (Al)	4	1	ins	ins	ins	0.11	ins	< 0.060	3.1
Antimony (Sb)	4	0	ins	ins	ins	0.054	ins	0.025	0.20
Arsenic (As)	4	0	ins	ins	ins	3.2	ins	1.1	4.3
Barium (Ba)	4	0	ins	ins	ins	40	ins	9.9	470
Beryllium (Be)	4	3	ins	ins	ins	< 0.010	ins	< 0.010	0.080
Bismuth (Bi)	0	ns[2]	ins	ins	ins	ns	ns	ns	ns
Boron (B)	4	0	ins	ins	ins	315	ins	14	763
Bromide (Br)	4	4	ins	ins	ins	< 0.20	ins	< 0.20	< 0.20
Cadmium (Cd)	4	1	ins	ins	ins	0.040	ins	< 0.020	0.35
Calcium (Ca)	4	0	ins	ins	ins	215512	ins	61694	420429
Cesium (Cs)	0	ns	ins	ins	ins	ns	ns	ns	ns
Chloride (Cl)	4	0	ins	ins	ins	3780	ins	2010	42070
Chromium (Cr)	4	1	ins	ins	ins	0.15	ins	< 0.050	0.17
Cobalt (Co)	4	0	ins	ins	ins	1.1	ins	0.24	3.4
Copper (Cu)	4	0	ins	ins	ins	28	ins	5.4	39
Dissolved Oxygen	4	1	ins	ins	ins	3305	ins	< 300	11330
Eh	4	0	ins	ins	ins	401	ins	223	531
Fluoride (F)[3]	4	3	ins	ins	ins	200	ins	200	200
Iron (Fe)	4	1	ins	ins	ins	67	ins	< 3.2	782
Lead (Pb)	4	0	ins	ins	ins	0.62	ins	0.31	0.71
Lithium (Li)	4	1	ins	ins	ins	71	ins	< 4.5	125
Magnesium (Mg)	4	0	ins	ins	ins	68360	ins	18758	150542
Manganese (Mn)	4	1	ins	ins	ins	1062	ins	< 0.90	2364
Mercury (Hg)	4	4	ins	ins	ins	< 0.10	ins	< 0.10	< 0.10
Molybdenum (Mo)	4	1	ins	ins	ins	6.2	ins	< 4.2	11
Nickel (Ni)	4	1	ins	ins	ins	16	ins	< 6.0	25
Nitrate (NO_3)	4	1	ins	ins	ins	1030	ins	< 500	12220
Ortho-phosphate	1	0	ns	ns	ns	20	ins	ins	ins
pH	4	0	ins	ins	ins	6.63	ins	6.10	6.91
$Phosphorus_{total}$	4	0	ins	ins	ins	124	ins	45	247
Potassium (K)	4	0	ins	ins	ins	3846	ins	758	9560
Redox	4	0	ins	ins	ins	188	ins	13	318
Rubidium (Rb)	4	2	ins	ins	ins	663	ins	< 555	1009
Selenium (Se)	4	2	ins	ins	ins	1.0	ins	< 1.0	2.6
Silcate (Si)	4	0	ins	ins	ins	12707	ins	7706	14527
Silver (Ag)	4	4	ins	ins	ins	< 0.0090	ins	< 0.0090	< 0.0090
Sodium (Na)	4	0	ins	ins	ins	73459	ins	13522	134398
Specific Conductivity	4	0	ins	ins	ins	1414.000	ins	552	2550.000
Strontium (Sr)	4	0	ins	ins	ins	741	ins	234	2214
Sulfate (SO_4)	4	0	ins	ins	ins	197480	ins	8650	433230
Sulfur (S)	4	0	ins	ins	ins	235986	ins	8695	522112
Temperature	4	0	ins	ins	ins	9.9	ins	9.1	11.8
Thallium (Tl)	4	1	ins	ins	ins	0.014	ins	< 0.0050	0.37
Tin (Sn)	0	ns	ins	ins	ins	ns	ns	ns	ns
Titanium (Ti)	4	1	ins	ins	ins	0.0055	ins	< 0.0035	0.0099
Total dissolved solids	4	0	ins	ins	ins	1368500	ins	364000	2577000
Total organic carbon	4	0	ins	ins	ins	2050	ins	700	3300
Total phosphate	3	0	ins	ins	ins	40	ins	30	50
Total suspended solids	4	0	ins	ins	ins	1500	ins	1000	2000
Vanadium (V)	4	1	ins	ins	ins	19	ins	< 4.7	29
Zinc (Zn)	4	0	ins	ins	ins	8.0	ins	3.3	29
Zirconium (Zr)	0	ns	ins	ins	ins	ns	ns	ns	ns

[1] ins = insufficient number of detections to calculate statistics
[2] ns=not sampled
[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.30: Descriptive statistics for undifferentiated Proterozoic Metasedimentary units (PMUD).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
						ug/L			
Alkalinity	22	0	normal	170091	205509	159500	327600	47000	330000
Aluminum (Al)	23	2	log-censored	5.2	96	3.9	1876	< 0.060	2330
Antimony (Sb)	23	9	log-censored	0.016	0.097	0.010	0.090	< 0.0080	0.090
Arsenic (As)	23	9	log-censored	0.95	8.6	1.1	8.1	< 0.060	8.3
Barium (Ba)	23	2	log-censored	35	244	42	209	< 1.4	209
Beryllium (Be)	23	13	log-censored	0.0045	0.082	< 0.010	0.30	< 0.010	0.37
Bismuth (Bi)	15	15	ins	ins	ins[1]	< 0.040	ins	< 0.040	< 0.040
Boron (B)	23	3	log-censored	39	357	36	596	< 13	635
Bromide (Br)	23	23	ins	ins	ins	< 0.20	ins	< 0.20	< 0.20
Cadmium (Cd)	23	14	log-censored	0.020	0.19	< 0.020	0.25	< 0.020	0.25
Calcium (Ca)	23	0	normal	38707	49886	31704	86057	539	86947
Cesium (Cs)	15	7	log-censored	0.080	0.97	0.070	ins	< 0.010	0.83
Chloride (Cl)	23	0	[2]	-	-	1850	4049620	320	5029000
Chromium (Cr)	23	9	log-censored	0.26	2.8	0.28	4.6	< 0.050	5.4
Cobalt (Co)	23	1	log-censored	0.32	2.3	0.22	4.8	< 0.090	5.1
Copper (Cu)	23	11	log-censored	8.2	41	6.8	38	< 5.5	39
Dissolved Oxygen	23	17	log-censored	99	8111	< 300	27962	< 300	34100
Eh	22	0	normal	187	236	216	327	-63	327
Fluoride (F)[4]	20	0	normal	390	538	350	888	200	890
Iron (Fe)	23	0	log-normal	225	504	209	10337	12	11763
Lead (Pb)	23	0	log-normal	0.47	0.71	0.47	7.7	0.050	8.7
Lithium (Li)	23	10	log-censored	4.8	34	5.0	45	< 4.5	50
Magnesium (Mg)	23	0	log-normal	8268	15406	13317	31407	201	31558
Manganese (Mn)	23	1	log-censored	39	1358	65	2130	< 0.90	2508
Mercury (Hg)	2	1	ins	ins	ins	ins	ins	< 0.10	0.17
Molybdenum (Mo)	23	7	log-censored	4.0	8.9	< 4.2	9.7	< 4.2	10
Nickel (Ni)	23	16	log-censored	4.5	15	< 6.0	16	< 6.0	16
Nitrate (NO_3)	23	21	log-censored	30	3001	< 500	6880	< 500	8100
Ortho-phosphate	0	ns[3]	ns	ns	ns	ns	ns	ns	ns
pH	22	0	normal	7.64	7.95	7.60	9.00	6.10	9.10
Phosphorus$_{total}$	23	0	log-normal	35	147	35	269	15	292
Potassium (K)	23	0	normal	1804	2411	1540	5371	146	5761
Redox	22	0	normal	-3	10	-1	113	-279	113
Rubidium (Rb)	23	23	ins	ins	ins	< 555	ins	< 555	< 555
Selenium (Se)	23	4	log-censored	2.2	18	2.1	77	< 1.0	93
Silcate (Si)	23	0	normal	8498	9623	8688	13592	2921	13669
Silver (Ag)	23	12	log-censored	0.0085	0.083	< 0.0090	0.11	< 0.0090	0.12
Sodium (Na)	23	0	log-normal	12601	19638	10241	103693	3305	108875
Specific Conductivity	22	0	normal	357	441	330	765	56	778
Strontium (Sr)	23	0	log-normal	119	220	125	786	1	872
Sulfate (SO_4)	23	2	log-censored	1778	14458	1950	16714	< 100	16740
Sulfur (S)	23	1	log-censored	2088	20026	2374	16766	< 21.8	16781
Temperature	22	0	normal	7.8	8.2	7.7	9.7	6.7	9.8
Thallium (Tl)	23	17	log-censored	0.0049	0.031	< 0.0050	0.034	< 0.0050	0.035
Tin (Sn)	15	5	log-censored	0.095	0.23	0.10	ins	< 0.040	0.23
Titanium (Ti)	23	17	log-censored	0.00056	0.016	< 0.0035	0.055	< 0.0035	0.067
Total dissolved solids	23	0	log-normal	221871	272082	222000	618800	90000	664000
Total organic carbon	23	3	log-censored	1835	5562	1700	5420	< 500	5500
Total phosphate	23	11	log-censored	19	152	20	242	< 20	270
Total suspended solids	23	0	[2]	-	-	4000	120800	1000	148000
Vanadium (V)	23	16	log-censored	3.4	15	< 4.7	18	< 4.7	20
Zinc (Zn)	23	1	log-censored	12	102	11	249	< 2.7	278
Zirconium (Zr)	15	4	log-censored	0.049	0.19	0.050	ins	< 0.030	0.18

[1] ins = insufficient number of detections to calculate statistics
[2] Data did not fit a normal or log-normal distribution
[3] ns=not sampled
[4] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.31: Descriptive statistics for buried Quaternary artesian aquifers (QBAA).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
		ug/L							
Alkalinity	385	0	[2]	-	-	328000	466900	49000	565000
Aluminum (Al)	385	87	log-censored	0.78	26	0.88	48	< 0.060	870
Antimony (Sb)	385	159	log-censored	3.3	22	0.011	0.070	< 0.0080	6.8
Arsenic (As)	385	26	log-censored	5.7	90	2.6	35	< 0.060	91
Barium (Ba)	387	2	log-censored	59	345	61	332	< 1.4	1391
Beryllium (Be)	385	272	log-censored	0.0049	0.029	< 0.010	0.030	< 0.010	0.19
Bismuth (Bi)	117	ins[1]	ins	ins	ins	< 0.040	< 0.040	< 0.040	0.50
Boron (B)	387	25	log-censored	90	1022	98	924	< 13	4763
Bromide (Br)	386	375	log-censored	0.0024	0.10	< 0.20	ins	< 0.20	2.5
Cadmium (Cd)	385	202	log-censored	0.021	0.37	< 0.020	0.51	< 0.020	2.4
Calcium (Ca)	387	0	[2]	-	-	79537	279572	30	476013
Cesium (Cs)	117	99	log-censored	0.00090	0.041	< 0.010	0.071	< 0.010	0.36
Chloride (Cl)	387	2	log-censored	2788	30049	2320	39284	< 100	860510
Chromium (Cr)	385	88	log-censored	0.41	3.1	0.49	2.6	< 0.050	8.3
Cobalt (Co)	385	0	[2]	-	-	0.46	1.7	0.090	5.1
Copper (Cu)	387	215	log-censored	4.6	33	< 5.5	31	< 5.5	530
Dissolved Oxygen	387	254	log-censored	198	4410	< 300	5374	< 300	28300
Eh	386	0	normal	165	175	158	298	-82	576
Fluoride (F)[3]	387	95	[2]	-	-	380	964	200	3960
Iron (Fe)	387	3	log-censored	767	11612	1179	6706	< 3.2	20207
Lead (Pb)	385	47	log-censored	0.19	2.0	0.18	2.1	< 0.030	210
Lithium (Li)	387	91	log-censored	14	121	14	117	< 4.5	447
Magnesium (Mg)	387	0	[2]	-	-	30515	87088	59	206048
Manganese (Mn)	387	16	log-censored	119	1042	131	993	< 0.90	2939
Mercury (Hg)	173	152	log-censored	0.050	0.13	< 0.10	0.15	< 0.10	0.24
Molybdenum (Mo)	387	233	log-censored	4.0	12	< 4.2	13	< 4.2	21
Nickel (Ni)	387	176	log-censored	4.2	16	< 6.0	17	< 6.0	40
Nitrate (NO_3)	386	342	log-censored	9.0	1465	< 500	1800	< 500	33240
Ortho-phosphate	29	4	log-censored	48	313	50	335	< 5.0	410
pH	386	0	[2]	-	-	7.29	8.10	6.20	8.50
$Phosphorus_{total}$	387	19	log-censored	98	399	102	427	< 15	1514
Potassium (K)	387	1	log-censored	2981	10252	3068	10106	< 119	128473
Redox	386	0	normal	-48	-38	-56	86	-295	365
Rubidium (Rb)	387	340	log-censored	275	743	< 555	789	< 555	1581
Selenium (Se)	386	77	log-censored	2.3	12	2.4	11	< 1.0	31
Silcate (Si)	387	0	[2]	-	-	11914	15091	3490	17430
Silver (Ag)	385	274	log-censored	0.0037	0.10	< 0.0090	0.11	< 0.0090	0.97
Sodium (Na)	387	0	[2]	-	-	18812	174140	1597	1095280
Specific Conductivity	386	0	[2]	-	-	619	2126	2	6860
Strontium (Sr)	387	2	[2]	-	-	304	1630	< 0.60	3255
Sulfate (SO_4)	387	34	[2]	-	-	7300	307468	< 100	630080
Sulfur (S)	387	1	[2]	-	-	8110	339908	< 22	1451700
Temperature	386	0	[2]	-	-	8.9	10.6	6.4	13.0
Thallium (Tl)	385	269	log-censored	0.0031	0.036	< 0.0050	0.044	< 0.0050	0.15
Tin (Sn)	117	46	log-censored	0.058	0.45	0.060	0.48	< 0.040	1.5
Titanium (Ti)	387	303	log-censored	0.0016	0.0090	< 0.0035	0.010	< 0.0035	0.046
Total dissolved solids	387	0	[2]	-	-	430000	1875600	96000	3394000
Total organic carbon	385	4	log-censored	2633	7705	2600	7300	< 500	25600
Total phosphate	358	6	log-censored	48	313	60	411	< 20	1440
Total suspended solids	387	0	[2]	-	-	5000	22000	1000	516000
Vanadium (V)	387	194	log-censored	5.1	18	< 4.7	20	< 4.7	36
Zinc (Zn)	387	52	log-censored	13	124	13	152	< 2.7	1911
Zirconium (Zr)	117	59	log-censored	0.029	0.57	< 0.030	0.65	< 0.030	3.6

[1] ins = insufficient number of detections to calculate statistics
[2] Data did not fit a normal or log-normal distribution.
[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.32: Descriptive statistics for unconfined buried Quaternary aquifers (QBUA).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
		ug/L							
Alkalinity	104	0	normal	272524	292779	281000	441750	30000	515000
Aluminum (Al)	103	24	log-censored	0.72	12	0.91	20	< 0.060	65
Antimony (Sb)	103	43	log-censored	0.015	0.10	0.016	0.11	< 0.0080	0.20
Arsenic (As)	103	5	log-censored	1.7	16	1.9	17	< 0.060	40
Barium (Ba)	104	0	[2]	-	-	71	413	1.6	657
Beryllium (Be)	103	85	log-censored	0.0010	0.032	< 0.010	0.030	< 0.010	0.41
Bismuth (Bi)	30	30	ins	ins[1]	ins	< 0.040	ins	< 0.040	< 0.040
Boron (B)	104	17	log-censored	26	178	23	364	< 13	993
Bromide (Br)	102	102	ins	ins	ins	< 0.20	< 0.20	< 0.20	< 0.20
Cadmium (Cd)	103	64	log-censored	0.017	0.15	< 0.020	0.13	< 0.020	1.4
Calcium (Ca)	104	0	[2]	-	-	78821	174622	42	436238
Cesium (Cs)	30	27	log-censored	0.0021	0.012	< 0.010	0.014	< 0.010	0.020
Chloride (Cl)	104	0	log-normal	4404	6087	3625	57295	280	296800
Chromium (Cr)	103	13	log-censored	0.47	3.9	0.69	2.8	< 0.050	4.7
Cobalt (Co)	103	3	log-censored	0.43	1.3	0.46	1.3	< 0.090	2.4
Copper (Cu)	104	54	log-censored	5.7	32	< 5.5	36	< 5.5	65
Dissolved Oxygen	104	67	log-censored	725	12308	< 500	12910	< 500	23000
Eh	104	0	normal	210	226	220	351	-16	448
Fluoride (F)[3]	104	36	[2]	-	-	305	813	200	1500
Iron (Fe)	104	3	log-censored	250	9744	367	6307	< 3.2	22451
Lead (Pb)	103	6	log-censored	0.22	2.1	0.19	3.1	< 0.030	18
Lithium (Li)	104	36	log-censored	6.6	56	7.1	84	< 4.5	115
Magnesium (Mg)	104	0	[2]	-	-	26539	71524	70	139936
Manganese (Mn)	104	9	log-censored	87	1322	152	661	< 0.90	1311
Mercury (Hg)	40	37	log-censored	0.034	0.11	< 0.10	0.13	< 0.10	0.18
Molybdenum (Mo)	104	82	log-censored	1.7	9.3	< 4.2	11	< 4.2	21
Nickel (Ni)	104	82	log-censored	3.9	14	< 6.0	13	< 6.0	28
Nitrate (NO_3)	104	76	log-censored	76	10949	< 500	13650	< 500	98020
Ortho-phosphate	3	1	ins	ins	ins	10	ins	< 5.0	60
pH	104	0	[2]	-	-	7.20	7.99	6.00	8.40
$Phosphorus_{total}$	104	15	log-censored	54	247	57	269	< 14.9	508
Potassium (K)	104	0	[2]	-	-	1796	7188	313	94813
Redox	104	0	normal	-4.3	12	5	139	-230	234
Rubidium (Rb)	104	94	log-censored	305	702	< 555	764	< 555	1140
Selenium (Se)	103	11	log-censored	3.2	20	3.2	17	< 1.0	613
Silcate (Si)	104	0	[2]	-	-	10867	14427	3331	20396
Silver (Ag)	103	64	log-censored	0.0050	0.14	< 0.0090	0.22	< 0.0090	0.80
Sodium (Na)	104	0	log-normal	7259	9030	5906	102219	1438	239924
Specific Conductivity	104	0	[2]	-	-	533	1475	38	3160
Strontium (Sr)	104	0	[2]	-	-	112	967	0.70	2543
Sulfate (SO_4)	104	7	log-censored	5156	7394	5280	133763	< 100	328130
Sulfur (S)	104	0	log-normal	5843	8188	5406	133952	40	366990
Temperature	104	0	normal	8.9	9.0	8.8	11	7.0	12
Thallium (Tl)	103	64	log-censored	0.0029	0.027	< 0.0050	0.031	< 0.0050	0.15
Tin (Sn)	30	13	log-censored	0.060	0.65	0.060	0.92	< 0.040	1.2
Titanium (Ti)	104	87	log-censored	0.0024	0.0070	< 0.0035	0.0070	< 0.0035	0.011
Total dissolved solids	104	0	[2]	-	-	350000	1176500	28000	2737000
Total organic carbon	104	3	log-censored	2004	6591	1900	8575	< 500	21700
Total phosphate	101	23	log-censored	39	244	40	240	< 20	470
Total suspended solids	104	0	[2]	-	-	2000	16750	1000	44000
Vanadium (V)	104	53	log-censored	4.8	15	< 4.7	14	< 4.7	29
Zinc (Zn)	104	10	log-censored	13	97	12	144	< 2.7	420
Zirconium (Zr)	30	18	log-censored	0.011	0.29	< 0.030	0.78	< 0.030	1.4

[1] ins = insufficient number of detections to calculate statistics
[2] Data did not fit a normal or log-normal distribution
[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.33: Descriptive statistics for buried undifferentiated Quaternary aquifers (QBUU).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
						ug/L			
Alkalinity	22	0	normal	381143	406062	385000	476250	275000	477000
Aluminum (Al)	22	3	log-censored	0.50	29	0.36	983	< 0.060	1151
Antimony (Sb)	22	1	log-censored	0.052	0.14	0.056	0.13	< 0.0080	0.13
Arsenic (As)	22	1	log-censored	3.6	67	2.8	49	< 0.060	49
Barium (Ba)	22	1	log-censored	51	199	52	195	< 1.4	200
Beryllium (Be)	22	12	log-censored	0.0068	0.090	< 0.010	0.15	< 0.010	0.16
Bismuth (Bi)	0	ns[2]	ns	ns	ns	ns	ns	ns	ns
Boron (B)	22	0	log-censored	293	392	279	802	23	807
Bromide (Br)	22	22	ins[1]	ins	ins	< 0.20	ins	< 0.20	0.10
Cadmium (Cd)	22	3	log-censored	0.12	0.80	0.13	0.95	< 0.020	1.0
Calcium (Ca)	22	0	[3]	-	-	114917	322669	371	330219
Cesium (Cs)	0	ns	log-censored	0.0021	0.012	ns	ns	ns	ns
Chloride (Cl)	22	0	log-normal	2119	4310	2185	92968	200	105610
Chromium (Cr)	22	11	log-censored	0.066	2.1	0.060	7.1	< 0.050	8.0
Cobalt (Co)	22	0	log-normal	0.72	1.4	0.99	4.5	0.31	4.7
Copper (Cu)	22	12	log-censored	4.4	50	< 5.5	93	< 5.5	98
Dissolved Oxygen	22	15	log-censored	79	7135	< 500	16197	< 500	18400
Eh	22	0	[3]	-	-	261	494	86	526
Fluoride (F)[4]	22	17	log-censored	330	371	330	ins	200	520
Iron (Fe)	22	0	log-normal	250	9744	2080	9440	6.6	9966
Lead (Pb)	22	1	log-censored	0.30	3.8	0.27	8.4	< 0.030	9.5
Lithium (Li)	22	2	log-censored	33	156	36	171	< 4.5	182
Magnesium (Mg)	22	0	[3]	-	-	42087	106915	160	107828
Manganese (Mn)	22	0	log-normal	160	349	205	12	1.8	1239
Mercury (Hg)	22	22	ins	ins	ins	< 0.10	ins	< 0.10	< 0.10
Molybdenum (Mo)	22	16	log-censored	4.6	12	< 4.2	13	< 4.2	13
Nickel (Ni)	22	21	ins	ins	ins	< 6.0	7.5	< 6.0	7.8
Nitrate (NO_3)	22	20	log-censored	0.18	1815	< 500	9357	< 500	10870
Ortho-phosphate	0	ns	ins	ins	ins	ns	ns	ns	ns
pH	22	0	normal	7.0	7.01	7.10	7.28	6.59	7.29
$Phosphorus_{total}$	22	0	log-normal	74	320	80	615	15	677
Potassium (K)	22	0	normal	5116	6438	4960	13420	467	14311
Redox	22	0	[3]	-	-	49	280	-126	312
Rubidium (Rb)	22	19	log-censored	465	639	< 555	672	< 555	681
Selenium (Se)	22	6	log-censored	1.5	6.5	1.8	10	< 1.0	11
Silcate (Si)	22	0	log-normal	12788	14171	13548	15600	5859	15622
Silver (Ag)	22	20	log-censored	0.015	0.082	< 0.0090	0.11	< 0.0090	0.11
Sodium (Na)	22	0	normal	63364	91530	47568	217771	3267	218891
Specific Conductivity	22	0	[3]	-	-	955.000	1950	1.0000	1980
Strontium (Sr)	22	1	log-censored	507	1482	561	1903	< 0.60	2052
Sulfate (SO_4)	22	0	normal	75797	112129	42390	273149	5100	283800
Sulfur (S)	22	0	log-normal	47282	80427	43256	336056	5494	352026
Temperature	22	0	normal	10.2	10.5	10.1	11.8	8.7	11.8
Thallium (Tl)	22	8	log-censored	0.012	0.089	0.011	0.11	< 0.0050	0.12
Tin (Sn)	0	ns	ns	ns	ns	ns	ns	ns	ns
Titanium (Ti)	22	20	ins	ins	ins	< 0.0035	0.049	< 0.0035	0.057
Total dissolved solids	22	0	log-normal	713674	885523	608000	1856100	322000	1920000
Total organic carbon	21	0	log-normal	3463	4527	3400	10900	1000	11200
Total phosphate	22	3	log-censored	41	239	50	539	< 20	600
Total suspended solids	22	0	log-normal	5894	11814	7000	771400	1000	904000
Vanadium (V)	22	11	log-censored	5.5	16	5.1	18	< 4.7	18
Zinc (Zn)	22	1	log-censored	36	348	25	460	< 2.7	485
Zirconium (Zr)	0	ns	ns	ns	ns	ns	ns	ns	ns

[1] ins = insufficient number of detections to conduct statistical analysis
[2] ns=not sampled
[3] Data did not fit a normal or log-normal distribution
[4] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.34: Descriptive statistics for unconfined, undifferentiated Quaternary aquifers (QUUU).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
		ug/L							
Alkalinity	4	0	ins[1]	ins	ins	326000	ins	297000	342000
Aluminum (Al)	4	1	ins	ins	ins	0.74	ins	< 0.060	43
Antimony (Sb)	4	0	ins	ins	ins	0.049	ins	0.030	0.16
Arsenic (As)	4	0	ins	ins	ins	1.2	ins	0.35	2.8
Barium (Ba)	4	0	ins	ins	ins	15	ins	11	48
Beryllium (Be)	4	4	ins	ins	ins	< 0.010	ins	< 0.010	< 0.010
Bismuth (Bi)	0	ns[2]	ns	ns	ns	ns	ns	ns	ns
Boron (B)	4	1	ins	ins	ins	165	ins	< 13	682
Bromide (Br)	4	4	ins	ins	ins	< 0.20	ins	< 0.20	< 0.20
Cadmium (Cd)	4	1	ins	ins	ins	0.050	ins	< 0.020	0.15
Calcium (Ca)	4	0	ins	ins	ins	265785	ins	88108	404766
Cesium (Cs)	0	ns	ns	ns	ns	ns	ns	ns	ns
Chloride (Cl)	4	0	ins	ins	ins	15715.0	ins	3840	44620
Chromium (Cr)	4	1	ins	ins	ins	0.17	ins	< 0.050	0.56
Cobalt (Co)	4	0	ins	ins	ins	0.84	ins	0.18	1.4
Copper (Cu)	4	1	ins	ins	ins	27	ins	< 5.5	41
Dissolved Oxygen	4	0	ins	ins	ins	11305	ins	1000	17300
Eh	4	0	ins	ins	ins	463	ins	294	519
Fluoride (F)[3]	4	2	ins	ins	ins	1375	ins	510	2240
Iron (Fe)	4	1	ins	ins	ins	50	ins	< 3.2	3943
Lead (Pb)	4	0	ins	ins	ins	0.40	ins	0.13	0.76
Lithium (Li)	4	1	ins	ins	ins	86	ins	< 4.5	133
Magnesium (Mg)	4	0	ins	ins	ins	73278	ins	28445	86159
Manganese (Mn)	4	0	ins	ins	ins	143	ins	3.8	1039
Mercury (Hg)	4	3	ins	ins	ins	< 0.10	ins	< 0.10	0.11
Molybdenum (Mo)	4	1	ins	ins	ins	8.5	ins	< 4.2	14
Nickel (Ni)	4	1	ins	ins	ins	19	ins	< 6.0	27
Nitrate (NO_3)	4	1	ins	ins	ins	5080	ins	< 500	10550
Ortho-phosphate	3	1	ins	ins	ins	5.0	ins	< 5.0	10
pH	4	0	ins	ins	ins	6.83	ins	6.60	7.14
$Phosphorus_{total}$	4	1	ins	ins	ins	55	ins	< 15	157
Potassium (K)	4	1	ins	ins	ins	6757	ins	< 118.5	10582
Redox	4	0	ins	ins	ins	249	ins	80	306
Rubidium (Rb)	4	2	ins	ins	ins	779	ins	< 555	1459
Selenium (Se)	4	1	ins	ins	ins	2.2	ins	< 1.0	6.0
Silcate (Si)	4	0	ins	ins	ins	12463	ins	11894	15930
Silver (Ag)	4	4	ins	ins	ins	< 0.0090	ins	< 0.0090	< 0.0090
Sodium (Na)	4	0	ins	ins	ins	29180	ins	4185	75062
Specific Conductivity	4	0	ins	ins	ins	1817.000	ins	666	2230
Strontium (Sr)	4	0	ins	ins	ins	1005	ins	135	1415
Sulfate (SO_4)	4	0	ins	ins	ins	227065	ins	6070	307770
Sulfur (S)	4	0	ins	ins	ins	232842	ins	6051	334352
Temperature	4	0	ins	ins	ins	9.3	ins	8.9	9.4
Thallium (Tl)	4	2	ins	ins	ins	0.0065	ins	< 0.0050	0.026
Tin (Sn)	0	ns	ns	ns	ns	ns	ns	ns	ns
Titanium (Ti)	4	1	ins	ins	ins	0.0090	ins	< 0.0035	0.016
Total dissolved solids	4	0	ins	ins	ins	1466000	ins	383000	1971000
Total organic carbon	4	0	ins	ins	ins	3200	ins	2100	6500
Total phosphate	1	1	ins	ins	ins	< 20	ins	ins	ins
Total suspended solids	4	0	ins	ins	ins	4000	ins	1000	10000
Vanadium (V)	4	1	ins	ins	ins	20	ins	< 4.7	33
Zinc (Zn)	4	0	ins	ins	ins	30	ins	21	329
Zirconium (Zr)	0	ns	ns	ns	ns	ns	ns	ns	ns

[1] ins = insufficient number of detections to conduct statistics

[2] ns = not sampled

[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.35: Descriptive statistics for Quaternary water table aquifers (QWTA).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
		ug/L							
Alkalinity	118	0	normal	246155	264411	237500	415900	31000	528000
Aluminum (Al)	118	25	log-censored	0.99	46	1.2	83	< 0.060	756
Antimony (Sb)	118	44	log-censored	0.014	0.11	0.017	0.11	< 0.0080	0.41
Arsenic (As)	118	11	log-censored	1.0	10	1.3	10	< 0.060	22
Barium (Ba)	119	0	log-normal	78	94	85	349	2.9	2392
Beryllium (Be)	118	71	log-censored	0.0057	0.048	< 0.010	0.060	< 0.010	0.14
Bismuth (Bi)	43	43	ins[1]	ins	ins	< 0.040	ins	< 0.040	< 0.040
Boron (B)	119	19	log-censored	25	95	24	83	< 13	747
Bromide (Br)	117	117	ins	ins	ins	< 0.20	ins	< 0.20	< 0.20
Cadmium (Cd)	118	65	log-censored	0.029	0.15	< 0.020	0.16	< 0.020	0.29
Calcium (Ca)	119	0	[2]	-	-	74237	148883	99	278470
Cesium (Cs)	43	33	log-censored	0.0018	0.07	< 0.010	0.084	< 0.010	0.27
Chloride (Cl)	119	0	log-normal	5102	6917	5810	97250	260	357830
Chromium (Cr)	118	16	log-censored	0.44	3.4	0.55	3.0	< 0.050	5.7
Cobalt (Co)	118	0	[2]	-	-	0.48	1.5	0.020	2.5
Copper (Cu)	119	57	log-censored	5.9	28	6.3	25	< 5.5	140
Dissolved Oxygen	119	71	log-censored	497	9834	< 500	10140	< 500	17000
Eh	119	0	normal	188	203	187	311	-62	479
Fluoride (F)[3]	72	47	log-normal	324	355	300	676	200	1020
Iron (Fe)	119	1	log-censored	492	16899	811	9884	< 3.2	15824
Lead (Pb)	117	10	log-censored	0.19	2.4	0.18	3.6	< 0.030	162
Lithium (Li)	119	45	log-censored	5.6	30	5.7	35	< 4.5	72
Magnesium (Mg)	119	0	[2]	-	-	22224	59156	121	104892
Manganese (Mn)	119	10	log-censored	109	1417	176	1011	< 0.90	2474
Mercury (Hg)	37	29	log-censored	0.082	0.14	< 0.10	0.15	< 0.10	0.16
Molybdenum (Mo)	119	101	log-censored	2.0	6.6	< 4.2	6.6	< 4.2	12
Nickel (Ni)	119	82	log-censored	4.9	13	< 6.0	14	< 6.0	26
Nitrate (NO_3)	119	87	log-censored	310	8348	< 500	10400	< 500	22300
Ortho-phosphate	3	0	ins	ins	ins	20.0	ins	10	40
pH	119	0	[2]	-	-	7.21	8.08	5.70	8.40
$Phosphorus_{total}$	119	11	log-censored	57	253	56	310	< 15	488
Potassium (K)	119	1	log-censored	1783	5267	1766	5321	< 119	10434
Redox	119	0	normal	-24	2.9	-24	96	-274	264
Rubidium (Rb)	119	109	log-censored	343	644	< 555	667	< 555	868
Selenium (Se)	118	28	log-censored	2.2	15	2.1	10	< 1.0	214
Silcate (Si)	119	0	normal	10964	11515	10819	15847	5480	23012
Silver (Ag)	118	68	log-censored	0.0067	0.12	< 0.0090	0.15	< 0.0090	0.65
Sodium (Na)	119	0	[2]	-	-	4986	83019	1746	190579
Specific Conductivity	119	0	log-normal	415	480	465	1200	2	2160
Strontium (Sr)	119	0	[2]	-	-	105	484	1.3	1157
Sulfate (SO_4)	119	19	log-censored	3707	47877	4250	54680	< 100	297300
Sulfur (S)	119	0	[2]	-	-	4603	51980	100	320531
Temperature	119	0	[2]	-	-	8.8	11.1	5.8	13.2
Thallium (Tl)	118	70	log-censored	0.0042	0.030	< 0.0050	0.040	< 0.0050	0.076
Tin (Sn)	43	15	log-censored	0.059	0.20	0.060	0.19	< 0.040	0.31
Titanium (Ti)	119	87	log-censored	0.0015	0.010	< 0.0035	0.010	< 0.0035	0.047
Total dissolved solids	119	0	[2]	-	-	340000	964000	68000	1978000
Total organic carbon	119	1	log-censored	2446	8895	2400	10700	< 500	17600
Total phosphate	116	24	log-censored	44	343	40	376	< 20	1020
Total suspended solids	119	0	[2]	-	-	4000	25000	1000	42000
Vanadium (V)	119	54	log-censored	5.8	14	5.4	14	< 4.7	18
Zinc (Zn)	119	10	log-censored	13	108	12	109	< 2.7	1250
Zirconium (Zr)	43	21	log-censored	0.054	1.0	0.030	1.4	< 0.030	2.1

[1] ins = insufficient number of detections to conduct statistics

[2] Data did not fit a normal or log-normal distribution

[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.36: Descriptive statistics for Cambrian aquifer group.

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
		ug/L							
Alkalinity	102	0	[4]	-	-	-	-	-	-
Aluminum (Al)	100	17	log-censored	1.1	16	1.4	23	< 0.060	105
Antimony (Sb)	100	38	log-censored	0.015	0.082	0.013	0.090	< 0.0080	0.13
Arsenic (As)	100	9	log-censored	0.71	9.0	0.70	11	< 0.060	18
Barium (Ba)	102	0	log-normal	45	197	42	212	2.0	664
Beryllium (Be)	100	73	log-censored	0.0072	0.027	< 0.010	0.040	< 0.010	0.040
Bismuth (Bi)	44	42	ins[1]	ins	ins	< 0.040	ins	< 0.040	0.080
Boron (B)	102	24	log-censored	31	260	26	278	< 13	353
Bromide (Br)	102	101	ins	ins	ins	< 0.20	ins	< 0.20	0.49
Cadmium (Cd)	100	38	log-censored	0.039	0.55	0.050	0.46	< 0.020	4.6
Calcium (Ca)	102	0	[4]	-	-	-	-	-	-
Cesium (Cs)	45	22	log-censored	0.012	0.043	< 0.010	0.040	< 0.010	0.040
Chromium (Cr)	100	17	log-censored	0.32	4.2	0.31	2.9	< 0.050	28
Chloride (Cl)	102	2	log-censored	1389	10309	1090	34074	< 200	127
Cobalt (Co)	100	0	log-normal	0.51	0.61	0.53	1.5	0.090	4.9
Copper (Cu)	102	54	log-censored	5.4	38	< 5.5	38	< 5.5	118
Dissolved Oxygen	102	49	log-censored	454	20471	< 300	17496	< 300	105300
Eh	102	0	normal	184	207	202	418	-201	457
Fluoride (F)[3]	95	26	[2]	-	-	280	553	150	2510
Iron (Fe)	102	5	log-censored	440	12594	830	5746	< 3.2	62577
Lead (Pb)	100	6	[4]	-	-	-	-	-	-
Lithium (Li)	102	43	log-censored	0.0057	0.029	6.0	32	< 4.5	55
Magnesium (Mg)	102	0	[4]	-	-	-	-	-	-
Manganese (Mn)	102	16	[4]	-	-	-	-	-	-
Mercury (Hg)	53	50	log-censored	0.020	0.087	< 0.10	0.10	< 0.10	0.17
Molybdenum (Mo)	102	86	log-censored	2.4	6.6	< 4.2	7.4	< 4.2	10
Nickel (Ni)	102	78	log-censored	4.1	10	< 6.0	10	< 6.0	14
Nitrate (NO_3)	102	78	log-censored	205	2776	< 500	2686	< 500	9200
Ortho-phosphate	27	18	log-censored	2.9	31	< 5.0	36	< 5.0	40
pH	102	0	[2]	-	-	7.32	7.93	1.50	8.69
$Phosphorus_{total}$	102	18	[4]	-	-	-	-	-	-
Potassium (K)	102	0	[4]	-	-	-	-	-	-
Redox	102	0	normal	-17	9	-11	206	-412	244
Rubidium (Rb)	102	95	log-censored	324	613	< 555	637	< 555	893
Selenium (Se)	86	28	log-censored	1.2	5.9	< 1.0	6.4	< 1.0	8.1
Silcate (Si)	102	0	log-normal	7375	9169	8275	14797	3601	29313
Silver (Ag)	100	58	log-censored	0.0061	0.19	< 0.0090	0.26	< 0.0090	0.78
Sodium (Na)	102	0	[4]	-	-	-	-	-	-
Specific Conductivity	102	0	normal	579	654	498	1100	3	1217
Strontium (Sr)	102	0	[4]	-	-	-	-	-	-
Sulfate (SO_4)	102	5	log-censored	4923	51070	5785	63234	< 100	108920
Sulfur (S)	102	0	log-normal	6153	9320	6175	67981	51	112855
Temperature	102	0	[4]	-	-	-	-	-	-
Thallium (Tl)	100	47	[4]	-	-	-	-	-	-
Tin (Sn)	44	16	log-censored	0.067	0.50	0.070	0.87	< 0.040	0.97
Titanium (Ti)	102	83	log-censored	0.0028	0.0060	< 0.0035	0.0060	< 0.0035	0.0090
Total dissolved solids	100	0	[4]	-	-	-	-	-	-
Total organic carbon	102	8	log-censored	1895	9149	2000	13835	< 500	18500
Total phosphate	75	26	log-censored	27	398	20	648	< 20	720
Total suspended solids	100	0	log-normal	4147	5298	4000	16000	1000	206000
Vanadium (V)	102	57	log-censored	5.6	12	< 4.7	12	< 4.7	20
Zinc (Zn)	102	2	[4]	-	-	-	-	-	-
Zirconium (Zr)	44	30	log-censored	0.0088	0.18	< 0.030	0.14	< 0.030	1.8

[1] ins = insufficient number of detections to calculate statistics
[2] Data did not fit a normal or log-normal distribution
[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.
[4] Significant differences in concentrations between aquifer precluded statistical analysis for this parameter

Table D.37: Descriptive statistics for Ordovician aquifer group.

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
						ug/L			
Alkalinity	87	0	normal	319145	338045	284000	414200	111000	469000
Aluminum (Al)	83	15	log-censored	0.081	11	1.1	6.5	< 0.060	18
Antimony (Sb)	83	26	4	-	-	-	-	-	-
Arsenic (As)	83	3	4	-	-	-	-	-	-
Barium (Ba)	87	0	4	-	-	-	-	-	-
Beryllium (Be)	83	66	log-censored	0.0027	0.056	< 0.010	0.020	< 0.010	0.37
Bismuth (Bi)	20	19	4	-	-	-	-	-	-
Boron (B)	87	11	log-censored	43	333	37	374	< 13	567
Bromide (Br)	86	86	ins[1]	ins	ins	< 0.20	ins	< 0.20	0.67
Cadmium (Cd)	83	14	4	-	-	-	-	-	-
Calcium (Ca)	87	0	log-normal	80223	85585	78558	122024	34318	144905
Cesium (Cs)	20	6	log-censored	0.019	0.039	0.020	0.039	< 0.010	0.040
Chromium (Cr)	83	26	4	-	-	-	-	-	-
Chloride (Cl)	87	0	2	-	-	2170	46854	220	242480
Cobalt (Co)	83	0	2	-	-	0.41	3.1	0.15	4.9
Copper (Cu)	87	33	log-censored	8.2	42	9.0	53	< 5.5	121
Dissolved Oxygen	87	37	log-censored	680	8900	520	9138	< 300	17140
Eh	87	0	4	-	-	-	-	-	-
Fluoride (F)[3]	63	1	log-normal	304	328	290	586	200	630
Iron (Fe)	87	0	4	-	-	-	-	-	-
Lead (Pb)	83	2	log-censored	0.31	2.7	0.29	3.8	< 0.030	6.1
Lithium (Li)	87	20	log-censored	0.0090	0.034	9.0	44	< 4.5	62
Magnesium (Mg)	87	0	2	-	-	25408	46619	15357	60246
Manganese (Mn)	87	11	log-censored	32	610	36	430	< 0.90	1019
Mercury (Hg)	62	60	4	-	-	-	-	-	-
Molybdenum (Mo)	87	57	log-censored	2.8	6.3	< 4.2	6.7	< 4.2	9.0
Nickel (Ni)	87	53	log-censored	5.8	13	< 6.0	12	< 6.0	31
Nitrate (NO_3)	87	64	log-censored	29	6700	< 500	7668	< 500	30460
Ortho-phosphate	49	14	4	-	-	-	-	-	-
pH	87	0	2	-	-	7.20	7.60	4.38	7.68
$Phosphorus_{total}$	87	0	4	-	-	-	-	-	-
Potassium (K)	87	0	log-normal	1636	1908	1814	5314	551	18309
Redox	87	0	4	-	-	-	-	-	-
Rubidium (Rb)	87	61	log-censored	420	647	< 555	658	< 555	852
Selenium (Se)	64	14	log-censored	0.87	3.8	1.0	3.9	< 1.0	6.9
Silcate (Si)	87	0	4	-	-	-	-	-	-
Silver (Ag)	83	59	4	-	-	-	-	-	-
Sodium (Na)	87	0	4	-	-	-	-	-	-
Specific Conductivity	87	0	4	-	-	-	-	-	-
Strontium (Sr)	87	0	log-normal	167	439	162	497	47	571
Sulfate (SO_4)	87	2	log-censored	7700	44380	8130	58586	< 100	142430
Sulfur (S)	87	0	2	-	-	8935	65712	50	148668
Temperature	87	0	4	-	-	-	-	-	-
Thallium (Tl)	83	34	log-censored	0.0076	0.13	0.0080	0.17	< 0.0050	0.46
Tin (Sn)	20	12	log-censored	0.045	0.22	< 0.040	0.20	< 0.040	0.20
Titanium (Ti)	87	62	log-censored	0.0028	0.0068	< 0.0035	0.0070	< 0.0035	0.011
Total dissolved solids	87	0	2	-	-	352000	774400	238000	1234000
Total organic carbon	87	1	4	-	-	-	-	-	-
Total phosphate	38	7	log-censored	38	159	55	193	< 20	250
Total suspended solids	87	0	2	-	-	3000	11200	1000	22000
Vanadium (V)	87	37	log-censored	5.7	12	5.0	13	< 4.7	16
Zinc (Zn)	87	1	log-censored	47	400	52	418	< 2.7	1372
Zirconium (Zr)	20	16	ins	ins	ins	< 0.030	0.20	< 0.030	0.21

[1] ins = insufficient number of detections to calculate statistics
[2] Data did not fit a normal or log-normal distribution
[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.
[4] Significant differences in concentrations between aquifer precluded statistical analysis for this parameter

Table D.38: Descriptive statistics for Precambrian aquifer group.

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
		ug/L							
Alkalinity	78	0	log-normal	158489	181217	159500	427350	33000	541000
Aluminum (Al)	80	6	[4]	-	-	-	-	-	-
Antimony (Sb)	80	21	log-censored	0.021	0.14	0.021	0.14	< 0.0080	0.26
Arsenic (As)	80	15	log-censored	0.88	8.7	1.0	7.5	< 0.060	157
Barium (Ba)	80	5	[4]	-	-	-	-	-	-
Beryllium (Be)	80	38	log-censored	0.0016	0.086	0.010	0.37	< 0.010	2.5
Bismuth (Bi)	46	45	[4]	-	-	-	-	-	-
Boron (B)	80	8	[4]	-	-	-	-	-	-
Bromide (Br)	80	78	ins[1]	ins	ins	< 0.20	< 0.20	< 0.20	2510
Cadmium (Cd)	80	44	log-censored	0.025	0.29	< 0.020	0.35	< 0.020	1.0
Calcium (Ca)	80	0	[4]	-	-	-	-	-	-
Cesium (Cs)	46	18	log-censored	0.024	0.86	0.020	0.83	< 0.010	1.6
Chromium (Cr)	80	21	log-censored	0.41	6.0	0.54	5.4	< 0.050	92
Chloride (Cl)	80	0	[4]	-	-	2255	94577	280	5029000
Cobalt (Co)	80	2	log-censored	0.40	2.8	0.31	3.8	< 0.0020	49
Copper (Cu)	80	31	log-censored	8.0	68	8.0	59	< 5.5	450
Dissolved Oxygen	80	43	log-censored	613	16013	< 300	11298	< 300	56000
Eh	79	0	normal	198		215	348	-63	531
Fluoride (F)[4]	73	6	log-normal	462	545	410	1584	200	4090
Iron (Fe)	80	1	log-censored	330	11336	228	15378	< 3.2	123730
Lead (Pb)	80	0	log-normal	0.54	5.3	0.46	14	0.050	26
Lithium (Li)	80	28	log-censored	0.0059	0.050	6.0	74	< 4.5	215
Magnesium (Mg)	80	0	[2]	-	-	13313	75333	201	150542
Manganese (Mn)	80	3	log-censored	52	1458	64	2038	< 0.90	2508
Mercury (Hg)	14	12	ins	ins	ins	< 0.10	ins	< 0.10	0.17
Molybdenum (Mo)	80	42	log-censored	3.8	14	< 4.2	15	< 4.2	29
Nickel (Ni)	80	51	log-censored	3.8	25	< 6.0	23	< 6.0	234
Nitrate (NO_3)	80	71	log-censored	17	2211	< 500	3805	< 500	16700
Ortho-phosphate	2	0	ins	ins	ins	20	ins	20	20
pH	79	0	[4]	-	-	-	-	-	-
$Phosphorus_{total}$	80	6	log-censored	33	250	35	290	< 15	1566
Potassium (K)	80	1	log-censored	1464	6577	1515	6489	< 119	9766
Redox	79	0	normal	-26	-1	0	131	-279	318
Rubidium (Rb)	80	73	[4]	-	-	-	-	-	-
Selenium (Se)	80	23	log-censored	1.6	18	1.9	12	< 1.0	93
Silcate (Si)	80	0	[2]	-	-	8757	15018	2921	53216
Silver (Ag)	80	40	log-censored	0.0080	0.10	0.0090	0.12	< 0.0090	0.66
Sodium (Na)	80	0	log-normal	17555	23475	12775	144326	2961	177736
Specific Conductivity	79	0	[2]	-	-	308	1000	5.0	2550
Strontium (Sr)	80	0	[4]	-	-	-	-	-	-
Sulfate (SO_4)	80	2	[4]	-	-	-	-	-	-
Sulfur (S)	80	1	[4]	-	-	-	-	-	-
Temperature	79	0	normal	8.4	8.4	7.9	10.2	6.0	12
Thallium (Tl)	80	52	log-censored	0.0024	0.045	< 0.0050	0.035	< 0.0050	0.42
Tin (Sn)	46	10	log-censored	0.083	0.45	90	0.47	< 0.040	2.6
Titanium (Ti)	80	39	[4]	-	-	-	-	-	-
Total dissolved solids	80	0	[2]	-	-	231000	1205000	64000	2594000
Total organic carbon	80	5	log-censored	1882	6823	1750	7135	< 500	14100
Total phosphate	78	39	log-censored	16	220	35	270	< 20	1660
Total suspended solids	80	0	[2]	-	-	4000	146000	1000	1732000
Vanadium (V)	80	37	log-censored	4.5	25	5.3	25	< 4.7	112
Zinc (Zn)	80	4	log-censored	16	160	13	368	< 2.7	1078
Zirconium (Zr)	46	11	log-censored	0.082	1.6	0.075	3.1	< 0.030	5.8

[1] ins = insufficient number of detections to calculate statistics
[2] Data did not fit a normal or log-normal distribution
[3] ns=not sampled
[4] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.
[5] Significant differences in concentrations between aquifer precluded statistical analysis for this parameter

Table D.39: Descriptive statistics for buried Quaternary aquifer group.

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
		ug/L							
Alkalinity	511	0	[4]	-	-	-	-	-	-
Aluminum (Al)	510	114	log-censored	0.74	23	0.86	30	< 0.060	1151
Antimony (Sb)	510	203	[4]	-	-	-	-	-	-
Arsenic (As)	510	32	[4]	-	-	-	-	-	-
Barium (Ba)	513	3	log-censored	62	323	61	339	< 1.4	1391
Beryllium (Be)	510	369	[4]	-	-	-	-	-	-
Bismuth (Bi)	147	117	ins[1]	ins	ins	< 0.040	ins	< 0.040	0.50
Boron (B)	513	42	[4]	-	-	-	-	-	-
Bromide (Br)	510	499	ins	ins	ins	< 0.20	0.10	< 0.20	1.5
Cadmium (Cd)	510	269	[4]	-	-	-	-	-	-
Calcium (Ca)	513	0	[4]	-	-	-	-	-	-
Cesium (Cs)	147	126	log-censored	0.00071	0.032	< 0.010	0.030	< 0.010	0.36
Chromium (Cr)	510	112	[4]	-	-	-	-	-	-
Chloride (Cl)	513	0	[4]	-	-	-	-	-	-
Cobalt (Co)	510	3	[4]	-	-	-	-	-	-
Copper (Cu)	513	281	log-censored	4.8	33	< 5.5	34	< 5.5	530
Dissolved Oxygen	513	336	[4]	-	-	-	-	-	-
Eh	512	0	[4]	-	-	-	-	-	-
Fluoride (F)[3]	513	148	[4]	-	-	-	-	-	-
Iron (Fe)	513	6	[4]	-	-	-	-	-	-
Lead (Pb)	510	54	log-censored	0.20	2.4	0.19	2.2	< 0.030	210
Lithium (Li)	513	129	[4]	-	-	-	-	-	-
Magnesium (Mg)	513	0	[4]	-	-	-	-	-	-
Manganese (Mn)	513	25	log-censored	117	1075	136	974	< 0.90	2939
Mercury (Hg)	235	211	log-censored	0.048	0.13	< 0.10	0.13	< 0.10	0.24
Molybdenum (Mo)	513	331	[4]	-	-	-	-	-	-
Nickel (Ni)	513	279	[4]	-	-	-	-	-	-
Nitrate (NO_3)	512	438	[4]	-	-	-	-	-	-
Ortho-phosphate	32	5	log-censored	50	256	50	313	< 5.0	410
pH	512	0	[4]	-	-	-	-	-	-
$\text{Phosphorus}_{total}$	513	34	[4]	-	-	-	-	-	-
Potassium (K)	513	1	[4]	-	-	-	-	-	-
Redox	512	0	[4]	-	-	-	-	-	-
Rubidium (Rb)	513	453	log-censored	281	727	< 555	764	< 555	1581
Selenium (Se)	511	94	[4]	-	-	-	-	-	-
Silcate (Si)	513	0	[4]	-	-	-	-	-	-
Silver (Ag)	510	358	[4]	-	-	-	-	-	-
Sodium (Na)	513	0	[4]	-	-	-	-	-	-
Specific Conductivity	512	0	[4]	-	-	-	-	-	-
Strontium (Sr)	513	3	[4]	-	-	-	-	-	-
Sulfate (SO_4)	513	41	[4]	-	-	-	-	-	-
Sulfur (S)	513	1	[4]	-	-	-	-	-	-
Temperature	512	0	[4]	-	-	-	-	-	-
Thallium (Tl)	510	341	[4]	-	-	-	-	-	-
Tin (Sn)	147	59	log-censored	0.058	0.48	60	0.51	< 0.040	1.5
Titanium (Ti)	513	410	log-censored	0.0015	0.0088	< 0.0035	0.0090	< 0.0035	0.057
Total dissolved solids	513	0	[4]	-	-	-	-	-	-
Total organic carbon	510	7	[4]	-	-	-	-	-	-
Total phosphate	481	32	[4]	-	-	-	-	-	-
Total suspended solids	513	0	[4]	-	-	-	-	-	-
Vanadium (V)	513	258	log-censored	5.9	17	< 4.7	18	< 4.7	36
Zinc (Zn)	513	63	[4]	-	-	-	-	-	-
Zirconium (Zr)	147	77	log-censored	0.024	0.51	< 0.030	0.57	< 0.030	3.6

[1] ins = insufficient number of detections to calculate statistics
[2] Data did not fit a normal or log-normal distribution
[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.
[4] Significant differences in concentrations between aquifer precluded statistical analysis for this parameter

Table D.40: Descriptive statistics for surficial Quaternary aquifer group.

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
		ug/L							
Alkalinity	122	0	[4]	-	-	-	-	-	-
Aluminum (Al)	122	26	log-censored	0.96	48	1.2	81	< 0.060	756
Antimony (Sb)	122	44	[4]	-	-	-	-	-	-
Arsenic (As)	122	11	log-censored	1.0	9.9	1.3	10	< 0.060	22
Barium (Ba)	123	0	[4]	-	-	-	-	-	-
Beryllium (Be)	122	75	log-censored	0.0062	0.037	< 0.010	0.058	< 0.010	0.080
Bismuth (Bi)	43	43	ins[1]	ins	ins	< 0.040	< 0.040	< 0.040	< 0.040
Boron (B)	123	20	log-censored	26	114	25	110	< 13	747
Bromide (Br)	121	121	ins	ins	ins	< 0.20	< 0.20	< 0.20	2.0
Cadmium (Cd)	122	66	[4]	-	-	-	-	-	-
Calcium (Ca)	123	0	[4]	-	-	-	-	-	-
Cesium (Cs)	43	33	log-censored	0.0018	0.070	< 0.010	0.084	< 0.010	0.27
Chromium (Cr)	122	17	log-censored	0.43	3.3	0.50	2.9	< 0.050	5.7
Chloride (Cl)	123	0	log-normal	5291	6397	5900	95328	220	357830
Cobalt (Co)	122	0	[2]	-	-	0.48	1.5	0.168	2.5
Copper (Cu)	123	58	log-censored	6.0	30	< 5.5	32	< 5.5	140
Dissolved Oxygen	123	71	[4]	-	-	-	-	-	-
Eh	123	0	[4]	-	-	-	-	-	-
Fluoride (F)[3]	76	49	[4]	-	-	-	-	-	-
Iron (Fe)	123	2	log-censored	462	16912	797	9770	< 3.2	15824
Lead (Pb)	121	10	log-censored	0.20	2.4	0.18	3.3	< 0.030	11
Lithium (Li)	123	46	[4]	-	-	-	-	-	-
Magnesium (Mg)	123	0	[4]	-	-	-	-	-	-
Manganese (Mn)	123	10	log-censored	109	1418	176	1034	< 0.90	2474
Mercury (Hg)	41	32	log-censored	0.082	0.13	< 0.10	0.15	< 0.10	0.16
Molybdenum (Mo)	123	102	[4]	-	-	-	-	-	-
Nickel (Ni)	123	83	[4]	-	-	-	-	-	-
Nitrate (NO_3)	123	88	[4]	-	-	-	-	-	-
Ortho-phosphate	6	1	log-censored	40	330	10		< 5.0	40
pH	123	0	[4]	-	-	-	-	-	-
$Phosphorus_{total}$	123	12	log-censored	57	250	56	309	< 14.9	488
Potassium (K)	123	2	log-censored	1824	5792	1768	6399	< 118.5	10582
Redox	123	0	[4]	-	-	-	-	-	-
Rubidium (Rb)	123	111	[4]	-	-	-	-	-	-
Selenium (Se)	122	29	log-censored	2.2	14	2.1	10	< 1.0	214
Silcate (Si)	123	0	normal	11021	11554	10896	15914	5480	23012
Silver (Ag)	122	72	log-censored	0.0063	0.11	< 0.0090	0.14	< 0.0090	0.65
Sodium (Na)	123	0	[4]	-	-	-	-	-	-
Specific Conductivity	123	0	[4]	-	-	-	-	-	-
Strontium (Sr)	123	0	[4]	-	-	-	-	-	-
Sulfate (SO_4)	123	19	[4]	-	-	-	-	-	-
Sulfur (S)	123	0	[4]	-	-	-	-	-	-
Temperature	123	0	normal	9.0	9.2	8.8	11.1	5.8	13.2
Thallium (Tl)	122	72	log-censored	0.0043	0.030	< 0.0050	0.040	< 0.0050	0.076
Tin (Sn)	43	15	log-censored	0.059	0.20	60	0.19	< 0.040	0.31
Titanium (Ti)	123	88	[4]	-	-	-	-	-	-
Total dissolved solids	123	0	[4]	-	-	-	-	-	-
Total organic carbon	123	1	log-censored	2473	8879	2400	10500	< 500	17600
Total phosphate	117	25	log-censored	43	342	40	374	< 20	1020
Total suspended solids	123	0	[2]	-	-	4000	24800	1000	42000
Vanadium (V)	123	55	[4]	-	-	-	-	-	-
Zinc (Zn)	123	10	log-censored	14	117	12	134	< 2.7	1250
Zirconium (Zr)	43	21	log-censored	0.054	1.0	< 0.030	1.4	< 0.030	2.1

[1] ins = insufficient number of detections to calculate statistics
[2] Data did not fit a normal or log-normal distribution
[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.
[4] Significant differences in concentrations between aquifer precluded statistical analysis for this parameter

Table D.41: Descriptive statistics for CFIG-CFRN-CIGL aquifers.

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
		ug/L							
Alkalinity	40	0	normal	311079	342751	292500	466250	136000	538000
Aluminum (Al)	39	5	log-censored	1.2	20	1.7	29	< 0.060	105
Antimony (Sb)	39	13	log-censored	0.016	0.083	0.015	0.090	< 0.008	0.13
Arsenic (As)	39	4	log-censored	0.68	8.6	0.72	11	< 0.060	16
Barium (Ba)	40	0	log-normal	45	64	46	209	2.1	263
Beryllium (Be)	39	27	log-censored	0.0051	0.034	< 0.010	0.030	< 0.010	0.080
Bismuth (Bi)	17	16	ins[1]	ins	ins	< 0.040	ins	< 0.040	0.040
Boron (B)	40	7	log-censored	40	300	35	271	< 13	299
Bromide (Br)	40	40	ins	ins	ins	< 0.20	ins	< 0.20	< 0.20
Cadmium (Cd)	39	13	log-censored	0.052	0.63	0.070	1.3	< 0.02	2.2
Calcium (Ca)	40	0	normal	80893	90148	79439	130252	28627	154746
Cesium (Cs)	17	7	log-censored	0.015	0.051	0.010	ins	< 0.010	0.040
Chloride (Cl)	40	0	log-normal	1107	1595	1225	35471	200	127350
Chromium (Cr)	39	5	log-censored	0.32	5.4	0.27	5.3	< 0.050	28
Cobalt (Co)	39	0	log-normal	0.63	0.77	0.60	1.8	0.21	4.9
Copper (Cu)	40	24	log-censored	4.:0	34	< 5.5	35	< 5.5	118
Dissolved Oxygen	40	25	log-censored	346	27108	< 300	62555	< 300	105300
Eh	40	0	normal	188	221	198	342	-36	451
Fluoride (F)[3]	40	11	log-censored	289	320	280	585	200	770
Iron (Fe)	40	0	log-normal	577	1010	882	4413	13	4669
Lead (Pb)	39	4	log-censored	0.29	3.5	0.23	2.2	< 0.030	28
Lithium (Li)	40	14	log-censored	6.1	30	6.2	41	< 4.5	55
Magnesium (Mg)	40	0	normal	32041	35392	31171	509111	11370	52959
Manganese (Mn)	40	3	log-censored	41	759	52	709	< 0.90	1022
Mercury (Hg)	22	20	ins	ins	ins	< 0.10	0.10	< 0.10	0.10
Molybdenum (Mo)	40	34	log-censored	1.8	6.2	< 4.2	6.5	< 4.2	9.6
Nickel (Ni)	40	32	log-censored	3.7	10	< 6.0	12	< 6.0	14
Nitrate (NO_3)	40	33	log-censored	1.8	1686	< 500	6670	< 500	7850
Ortho-phosphate	11	10	ins	ins	ins	< 5.0	ins	< 5.0	10
pH	40	0	normal	7.30	7.39	7.3	7.94	6.9	8.0
$Phosphorus_{total}$	40	7	log-censored	37	219	33	288	< 15	696
Potassium (K)	40	0	log-normal	2038	2650	2007	7259	153	9321
Redox	40	0	normal	-31	3	-15	130	-249	239
Rubidium (Rb)	40	37	log-censored	254	632	< 555	637	< 555	893
Selenium (Se)	35	12	log-censored	1.0	5.9	1.0	7.8	< 1.0	8.1
Silcate (Si)	40	0	log-normal	7147	9192	7464	14839	3601	15184
Silver (Ag)	39	20	log-censored	0.011	0.29	< 0.0090	0.30	< 0.0090	0.78
Sodium (Na)	40	0	log-normal	8222	12106	6965	50957	1627	68775
Specific Conductivity	40	0	normal	619	704	630	982	3	1217
Strontium (Sr)	40	0	log-normal	172	236	129	861	37	1412
Sulfate (SO_4)	40	1	log-censored	6674	51907	6380	53923	< 100	108920
Sulfur (S)	40	0	log-normal	7026	11355	6973	56778	51	112855
Temperature	40	0	normal	10.1	10.4	9.9	11.8	8.9	13
Thallium (Tl)	39	22	log-censored	0.0030	0.25	< 0.0050	0.18	< 0.0050	2.4
Tin (Sn)	17	7	log-censored	0.077	0.27	0.070	ins	< 0.040	0.25
Titanium (Ti)	40	32	log-censored	0.0024	0.0059	< 0.0035	0.0060	< 0.0035	0.0087
Total dissolved solids	39	0	log-normal	379228	433810	360000	732000	150000	1012000
Total organic carbon	40	3	log-censored	2154	11032	2050	15440	< 500	16700
Total phosphate	29	11	log-censored	23	355	20	635	< 20	640
Total suspended solids	39	0	[2]	-		4000	16000	1000	16000
Vanadium (V)	40	21	log-censored	5.1	12	< 4.7	12	< 4.7	12
Zinc (Zn)	40	0	log-normal	67	108	79	1112	4.9	1760
Zirconium (Zr)	17	10	log-censored	0.024	0.072	< 0.030	ins	< 0.030	0.090

[1] ins = insufficient number of detections to conduct statistics

[2] Data did not fit a normal or log-normal distribution

[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.

Table D.42: Descriptive statistics for OSTP-OPDC-CJDN aquifers.

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
						ug/L			
Alkalinity	90	0	normal	294518	316767	263000	413900	111000	469000
Aluminum (Al)	87	17	log-censored	0.91	11	0.99	8.4	< 0.060	18
Antimony (Sb)	87	29	[4]	-	-	-	-	-	-
Arsenic (As)	87	3	log-censored	0.55	4.4	0.49	5.1	< 0.060	18
Barium (Ba)	90	0	[4]	-	-	-	-	-	-
Beryllium (Be)	87	71	log-censored	0.0025	0.020	< 0.010	0.020	< 0.010	0.060
Bismuth (Bi)	26	25	ins	ins	ins	< 0.040	0.062	< 0.040	0.080
Boron (B)	90	21	[4]	-	-	-	-	-	-
Bromide (Br)	90	90	ins	ins	ins	< 0.20	ins	< 0.20	< 0.20
Cadmium (Cd)	87	21	log-censored	0.068	1.8	0.070	4.0	< 0.020	13
Calcium (Ca)	90	0	[4]	-	-	-	-	-	-
Cesium (Cs)	26	8	[4]	-	-	-	-	-	-
Chloride (Cl)	90	0	[4]	-	-	-	-	-	-
Chromium (Cr)	87	18	[4]	-	-	-	-	-	-
Cobalt (Co)	87	0	[2]	-	-	-	-	-	-
Copper (Cu)	90	41	log-censored	7.2	37	7.6	48	< 5.5	71
Dissolved Oxygen	90	36	log-censored	798	17004	550	12748	< 300	94500
Eh	90	0	normal	227	255	246	436	-53	696
Fluoride (F)[3]	69	12	[2]	-	-	-	-	-	-
Iron (Fe)	90	4	log-censored	195	6767	3645	3565	< 3.2	6672
Lead (Pb)	87	4	log-censored	0.37	3.5	0.36	3.8	< 0.030	11
Lithium (Li)	90	33	log-censored	6.6	27	6.6	29	< 4.5	49.7
Magnesium (Mg)	90	0	[2]	-	-	-	-	-	-
Manganese (Mn)	90	22	log-censored	20	658	28	433	< 0.90	1019
Mercury (Hg)	60	58	log-censored	0.097	0.15	< 0.10	0.090	< 0.10	0.19
Molybdenum (Mo)	90	62	log-censored	1.6	5.8	< 4.2	7.2	< 4.2	10
Nickel (Ni)	90	59	log-censored	5.0	12	< 6.0	11	< 6.0	31
Nitrate (NO_3)	90	60	log-censored	418	5474	< 500	7581	< 500	15700
Ortho-phosphate	45	20	log-censored	6.2	47	5.0	47	< 5.0	60
pH	90	0	[4]	-	-	7.28	7.66	1.5	8.69
$Phosphorus_{total}$	90	11	[2]	-	-	-	-	-	-
Potassium (K)	90	0	[4]	-	-	-	-	-	-
Redox	90	0	normal	23	50	33	223	-264	483
Rubidium (Rb)	90	83	log-censored	344	621	< 555	636	< 555	852
Selenium (Se)	63	19	log-censored	1.1	3.6	1.0	3.9	< 1.0	5.7
Silcate (Si)	90	0	normal	7995	8793	8223	13277	3121	15782
Silver (Ag)	87	55	log-censored	0.0046	0.11	< 0.0090	0.12	< 0.0090	0.48
Sodium (Na)	90	0	[4]	-	-	-	-	-	-
Specific Conductivity	90	0	[4]	-	-	-	-	-	-
Strontium (Sr)	90	0	[4]	-	-	-	-	-	-
Sulfate (SO_4)	90	0	[4]	-	-	-	-	-	-
Sulfur (S)	90	0	[4]	-	-	-	-	-	-
Temperature	90	0	normal	9.54	9.75	9.7	10.8	6.4	12.1
Thallium (Tl)	87	34	log-censored	0.011	0.18	0.011	0.24	< 0.0050	0.46
Tin (Sn)	26	15	log-censored	0.043	0.18	< 0.040	0.19	< 0.040	0.19
Titanium (Ti)	90	70	log-censored	0.0025	0.0063	< 0.0035	0.0070	< 0.0035	0.011
Total dissolved solids	89	0	[4]	-	-	-	-	-	-
Total organic carbon	90	4	log-censored	2147	12108	2150	17345	< 500	31300
Total phosphate	45	13	log-censored	32	189	30	204	< 20	250
Total suspended solids	89	0	[2]	-	-	-	-	-	-
Vanadium (V)	90	42	log-censored	5.0	12	4.7	12	< 4.7	16
Zinc (Zn)	90	2	log-censored	55	502	57.4	475	< 2.7	1858
Zirconium (Zr)	26	21	log-censored	0.0081	0.10	< 0.030	0.16	< 0.030	0.21

[1] ins = insufficient number of detections to conduct statistics
[2] Data did not fit a normal or log-normal distribution
[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.
[4] Significant differences in concentrations between aquifer precluded statistical analysis for this parameter

Table D.43: Descriptive statistics for CMSH-CMTS-PMHN aquifers.

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
		ug/L							
Alkalinity	26	0	[4]	-	-	-	-	-	-
Aluminum (Al)	26	4	log-censored	0.98	22	1.2	37	< 0.060	44
Antimony (Sb)	26	9	log-censored	0.017	0.11	0.015	0.12	< 0.0080	0.13
Arsenic (As)	26	4	log-censored	0.75	8.1	1.1	6.4	< 0.060	7.4
Barium (Ba)	26	0	log-normal	50	77	54	250	7.6	276
Beryllium (Be)	26	17	log-censored	0.0053	0.049	< 0.010	0.063	< 0.010	0.070
Bismuth (Bi)	17	17	ins	ins	ins	< 0.040	ins	< 0.040	< 0.040
Boron (B)	26	5	log-censored	29	197	26	247	< 13	300
Bromide (Br)	26	25	ins	ins	ins	< 0.20	0.39	< 0.20	0.55
Cadmium (Cd)	26	18	log-censored	0.016	0.17	< 0.020	0.21	< 0.020	0.22
Calcium (Ca)	26	0	[4]	-	-	-	-	-	-
Cesium (Cs)	17	11	log-censored	0.014	0.039	< 0.010	ins	< 0.010	0.040
Chloride (Cl)	26	0	log-normal	2073	4014	1190	83800	310	98370
Chromium (Cr)	26	7	log-censored	0.29	5.1	0.31	3.7	< 0.05	4.2
Cobalt (Co)	26	0	log-normal	0.48	0.74	0.54	3.0	0.090	3.8
Copper (Cu)	26	16	log-censored	3.9	24	< 5.5	29	< 5.5	30
Dissolved Oxygen	26	7	log-censored	219	8385	290	10385	< 300	10910
Eh	26	0	[2]	-	-	190	266	-4.1	269
Fluoride (F)[3]	22	1	[2]	-	-	230	559	200	580
Iron (Fe)	26	1	log-censored	770	23737	1254	46104	< 3.2	62577
Lead (Pb)	26	0	log-normal	0.24		0.19	3.1	0.050	3.4
Lithium (Li)	26	14	log-censored	4.6	26	< 4.5	42	< 4.5	48
Magnesium (Mg)	26	0	[4]	-	-	-	-	-	-
Manganese (Mn)	26	2	log-censored	76	1306	95	1413	< 0.90	1856
Mercury (Hg)	8	8	ins	ins	ins	< 0.10	ins	< 0.10	< 0.10
Molybdenum (Mo)	26	22	log-censored	2.5	6.3	< 4.2	7.2	< 4.2	7.5
Nickel (Ni)	26	21	log-censored	3.3	11	< 6.0	13	< 6.0	14
Nitrate (NO_3)	26	21	log-censored	127	2010	< 500	3125	< 500	4000
Ortho-phosphate	0	0	ns	ns	ns	ns	ns	ns	ns
pH	26	0	[4]	-	-	7.30	8.16	5.30	8.19
$Phosphorus_{total}$	26	0	[2]	-	-	48	664	15	721
Potassium (K)	26	0	log-normal	1589	2183	1543	5520	525	5960
Redox	26	0	[2]	-	-	-25	54	-217	59
Rubidium (Rb)	26	23	log-censored	583	692	< 555	712	< 555	713
Selenium (Se)	26	9	log-censored	1.7	7.2	1.6	6.3	< 1.0	6.5
Silcate (Si)	26	0	log-normal	9358	11374	9314	24313	4313	29313
Silver (Ag)	26	18	log-censored	0.0023	0.17	< 0.0090	0.38	< 0.0090	0.41
Sodium (Na)	26	0	[2]	-	-	5029	86764	1870	97890
Specific Conductivity	26	0	[4]	-	-	-	-	-	-
Strontium (Sr)	26	0	log-normal	123	201	120	698	20	800
Sulfate (SO_4)	26	4	log-censored	1744	42787	2245	60917	< 100	72260
Sulfur (S)	26	0	log-normal	2567	5920	2437	63949	176	76310
Temperature	26	0	[4]	-	-	-	-	-	-
Thallium (Tl)	26	16	log-censored	0.0028	0.036	< 0.0050	0.046	< 0.0050	0.046
Tin (Sn)	17	5	log-censored	0.088	0.82	0.10	ins	< 0.050	0.97
Titanium (Ti)	26	20	log-censored	0.0030	0.0072	< 0.0035	0.0080	< 0.0035	0.0082
Total dissolved solids	26	0	[4]	-	-	-	-	-	-
Total organic carbon	26	1	log-censored	1824	6499	2000	14545	< 500	18500
Total phosphate	26	8	log-censored	30	585	25	717	< 20	720
Total suspended solids	26	0	log-normal	5573	9249	4500	141600	2000	206000
Vanadium (V)	26	16	log-censored	3.7	15	< 4.7	18	< 4.7	20
Zinc (Zn)	26	1	log-censored	14	183	14	257	< 2.7	266
Zirconium (Zr)	17	12	log-censored	0.0052	1.1	< 0.030	ins	< 0.030	1.8

[1] ins = insufficient number of detections to conduct statistics
[2] Data did not fit a normal or log-normal distribution
[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.
[4] Significant differences in concentrations between aquifer precluded statistical analysis for this parameter

Table D.44: Descriptive statistics for Upper Carbonate aquifers.

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Minimum	Maximum
						ug/L			
Alkalinity	36	0	normal	324853	340585	314000	423100	212000	435000
Aluminum (Al)	36	6	log-censored	1.0	7.2	1.3	7.2	< 0.060	12
Antimony (Sb)	36	14	log-censored	0.011	0.044	0.010	0.042	< 0.0080	0.041
Arsenic (As)	36	1	log-censored	2.3	20	2.7	15	< 0.060	19
Barium (Ba)	36	0	normal	146	380	161	369	8.3	397
Beryllium (Be)	36	25	[4]	-	-	-	-	-	-
Bismuth (Bi)	2	1	ins	ins[1]	ins	ins	ins	< 0.040	0.070
Boron (B)	36	2	log-censored	56	451	41	509	< 13	567
Bromide (Br)	34	34	ins	ins	ins	< 0.20	ins	< 0.20	< 0.20
Cadmium (Cd)	36	2	[4]	-	-	-	-	-	-
Calcium (Ca)	36	0	[2]	-	-	79500	138299	52628	140000
Cesium (Cs)	2	1	ins	ins	ins	ins	ins	< 0.010	0.020
Chloride (Cl)	36	0	[4]	-	-	-	-	-	-
Chromium (Cr)	35	20	log-censored	0.042	0.60	< 0.050	0.76	< 0.050	1.22
Cobalt (Co)	36	0	[4]	-	-	-	-	-	-
Copper (Cu)	36	6	log-censored	0.011	0.041	11	55	< 5.5	121
Dissolved Oxygen	36	20	log-censored	402	6056	< 300	8470	< 300	17140
Eh	36	0	[2]	-	-	100	327	37	426
Fluoride (F)[3]	33	0	[4]	-	-	-	-	-	-
Iron (Fe)	36	0	[4]	-	-	-	-	-	-
Lead (Pb)	36	0	log-normal	0.27	1.9	0.27	2.4	0.030	6.1
Lithium (Li)	36	3	[4]	-	-	-	-	-	-
Magnesium (Mg)	36	0	[4]	-	-	-	-	-	-
Manganese (Mn)	36	0	[4]	-	-	-	-	-	-
Mercury (Hg)	33	27	[4]	-	-	-	-	-	-
Molybdenum (Mo)	36	28	log-censored	3.8	6.4	< 4.2	6.7	< 4.2	7.0
Nickel (Ni)	36	19	log-censored	6.3	12	< 6.0	13	< 6.0	14
Nitrate (NO_3)	36	32	[4]	-	-	-	-	-	-
Ortho-phosphate	30	5	log-censored	25	195	20	195	< 5.0	200
pH	36	0	[4]	-	-	-	-	-	-
$Phosphorus_{total}$	36	0	[4]	-	-	-	-	-	-
Potassium (K)	36	0	log-normal	2025	2452	1828	7845	734	18309
Redox	36	0	[4]	-	-	-113	114	-177	213
Rubidium (Rb)	36	15	[4]	-	-	-	-	-	-
Selenium (Se)	29	1	log-censored	0.57	4.1	1.0	5.5	< 1.0	6.9
Silcate (Si)	36	0	[4]	-	-	-	-	-	-
Silver (Ag)	36	31	[4]	-	-	-	-	-	-
Sodium (Na)	36	0	[2]	-	-	7133	143645	2177	145608
Specific Conductivity	36	0	[4]	-	-	-	-	-	-
Strontium (Sr)	36	0	normal	202	497	221	524	47	554
Sulfate (SO_4)	35	2	log-censored	4595	71222	5300	87398	< 100	142430
Sulfur (S)	36	0	[2]	-	-	5853	83292	50	148668
Temperature	36	0	[4]	-	-	-	-	-	-
Thallium (Tl)	36	15	log-censored	0.0071	0.050	0.0070	0.061	< 0.0050	0.062
Tin (Sn)	2	1	ins	ins	ins	ins	ins	< 0.040	0.20
Titanium (Ti)	36	24	log-censored	0.0031	0.0067	< 0.0035	0.0070	< 0.0035	0.0080
Total dissolved solids	35	0	[2]	-	-	369	947600	238000	1234000
Total organic carbon	36	0	[4]	-	-	-	-	-	-
Total phosphate	6	0	log-normal	28	183	45	95	20	150
Total suspended solids	35	0	[4]	-	-	-	-	-	-
Vanadium (V)	36	16	log-censored	5.6	12	5.5	13	< 4.7	14
Zinc (Zn)	36	1	log-censored	23	161	16	375	< 2.7	429
Zirconium (Zr)	2	1	ins	ins	ins	ins	ins	< 0.030	0.10

[1] ins = insufficient number of detections to conduct statistics
[2] Data did not fit a normal or log-normal distribution
[3] Fluoride was censored at several detection limits. All non-detections were treated as missing data and removed from the data set.
[4] Significant differences in concentrations between aquifer precluded statistical analysis for this parameter

Table D.45: Standard deviations and sample size for parameters which had a normal or log-normal distribution.

Parameter	CFIG		CFRN		CIGL		CJDN	
	Std. Dev.	n	Std. Dev.	n	Std. Dev.	n	Std. Dev.	n
Alkalinity	93350	5	97282	27	93903	8	78266	31
Aluminum (Al)	-[1]	-	-	-	9.84	8	-	-
Antimony (Sb)	-	-	-	-	-	-	-	-
Arsenic (As)	0.76	5	-	-	0.33	8	-	-
Barium (Ba)	-	-	0.50	27	64.0	8	0.49	31
Beryllium (Be)	-	-	-	-	-	-	-	-
Bismuth (Bi)	-	-	-	-	-	-	-	-
Boron (B)	99	5	-	-	-	-	-	-
Bromide (Br)	-	-	-	-	-	-	-	-
Cadmium (Cd)	-	-	-	-	-	-	-	-
Calcium (Ca)	25394	5	24650	27	37186	8	25020	31
Cesium (Cs)	-	-	-	-	-	-	-	-
Chloride (Cl)	614	5	-	-	773	8	0.39	31
Chromium (Cr)	-	-	-	-	-	-	-	-
Cobalt (Co)	-	-	0.23	26	0.38	8	0.24	30
Copper (Cu)	-	-	-	-	-	-	-	-
Dissolved Oxygen	-	-	-	-	-	-	-	-
Fluoride (F)[4]	0.22	4	0.08	19	-	-	-	-
Iron (Fe)	890	5	0.80	27	1547	8	-	-
Lead (Pb)	-	-	-	-	0.78	8	-	-
Lithium (Li)	-	-	-	-	-	-	-	-
Magnesium (Mg)	10954	5	9733	27	11171	8	0.19	31
Manganese (Mn)	0.88	5	-	-	263	8	-	-
Mercury (Hg)	-	-	-	-	-	-	-	-
Molybdenum (Mo)	-	-	-	-	-	-	-	-
Nickel (Ni)	-	-	-	-	-	-	-	-
Nitrate (NO_3)	-	-	-	-	-	-	-	-
Ortho-phosphate	-	-	-	-	-	-	-	-
pH	0.18	5	0.27	27	0.34	8	0.13	31
$Phosphorus_{total}$	2550	5	0.35	27	1730	8	-	-
Potassium (K)	39.2	5	-	-	47.4	8	-	-
Redox	81.7	5	112	27	105	8	142	31
Rubidium (Rb)	-	-	-	-	-	-	-	-
Selenium (Se)	-	-	-	-	-	-	-	-
Silcate (Si)	3816	5	0.17	27	3014	8	0.11	31
Silver (Ag)	-	-	-	-	-	-	-	-
Sodium (Na)	15899	5	-	-	24700	8	0.48	31
Specific Conductivity	0.21	5	0.25	27	0.30	8	0.58	31
Strontium (Sr)	311	5	0.43	27	237	8	0.37	31
Sulfate (SO_4)	21475	5	-	-	37642	8	0.51	31
Sulfur (S)	22126	5	0.58	27	39268	8	0.49	31
Temperature	1.14	5	0.71	27	1.24	8	0.64	31
Thallium (Tl)	-	-	-	-	-	-	-	-
Tin (Sn)	-	-	-	-	-	-	-	-
Titanium (Ti)	-	-	-	-	-	-	-	-
Total dissolved solids	174903	5	142487	26	273774	8	0.17	30
Total organic carbon	-	-	-	-	1450	8	-	-
Total phosphate	-	-	-	-	-	-	-	-
Total suspended solids	3162	5	0.41	26	3882	8	0.39	30
Vanadium (V)	-	-	-	-	-	-	-	-
Zinc (Zn)	51.1	5	0.71	27	0.59	8	-	-
Zirconium (Zr)	-	-	-	-	-	-	-	-

Table D.45 continued

Parameter	CMSH		CMTS		DCVA		KRET	
	Std. Dev.	n	Std. Dev.	n	Std. Dev.	n	Std. Dev.	n
Alkalinity	106022	10	112821	13	67949	20	77369	39
Aluminum (Al)	-	-	-	-	-	-	-	-
Antimony (Sb)	-	-	-	-	-	-	-	-
Arsenic (As)	-	-	-	-	0.49	20	-	-
Barium (Ba)	56.4	10	-	-	78.3	20	0.51	39
Beryllium (Be)	-	-	-	-	-	-	-	-
Bismuth (Bi)	-	-	-	-	-	-	-	-
Boron (B)	-	-	-	-	-	-	-	-
Bromide (Br)	-	-	-	-	-	-	-	-
Cadmium (Cd)	-	-	-	-	0.74	20	-	-
Calcium (Ca)	0.41	10	22179	13	9483	20	107532	39
Cesium (Cs)	-	-	-	-	-	-	-	-
Chloride (Cl)	0.60	10	-	-	-	-	0.76	39
Chromium (Cr)	-	-	-	-	-	-	-	-
Cobalt (Co)	0.37	10	0.36	13	-	-	-	-
Copper (Cu)	-	-	-	-	-	-	-	-
Dissolved Oxygen	-	-	-	-	-	-	-	-
Fluoride (F)	0.15	10	63.1	9	29.2	18	-	-
Iron (Fe)	0.97	10	-	-	976	20	-	-
Lead (Pb)	0.49	10	-	-	0.47	20	-	-
Lithium (Li)	-	-	-	-	-	-	-	-
Magnesium (Mg)	0.38	10	10635	13	4393	20	33203	39
Manganese (Mn)	-	-	-	-	46.5	20	-	-
Mercury (Hg)	-	-	-	-	-	-	-	-
Molybdenum (Mo)	-	-	-	-	-	-	-	-
Nickel (Ni)	-	-	-	-	-	-	-	-
Nitrate (NO3)	-	-	-	-	-	-	-	-
Ortho-phosphate	-	-	-	-	-	-	31.3	9
pH	0.81	10	0.15	13	0.10	20	-	-
$\text{Phosphorus}_{total}$	979	10	1521	13	-	-	0.23	39
Potassium (K)	0.50	10	-	-	0.52	20	0.36	39
Redox	62.5	10	105	13	-	-	-	-
Rubidium (Rb)	-	-	-	-	-	-	-	-
Selenium (Se)	-	-	-	-	-	-	-	-
Silicate (Si)	0.22	10	2309	13	1659	20	-	-
Silver (Ag)	-	-	-	-	-	-	-	-
Sodium (Na)	0.43	10	-	-	-	-	0.52	3\9
Specific Conductivity	0.31	10	0.25	13	0.09	20	0.76	39
Strontium (Sr)	0.44	10	224	13	-	-	0.34	39
Sulfate (SO4)	-	-	-	-	0.61	18	-	-
Sulfur (S)	0.84	10	-	-	0.44	20	-	-
Temperature	0.53	10	0.97	13	0.01	20	1.01	39
Thllium (Tl)	-	-	-	-	-	-	-	-
Tin (Sn)	-	-	-	-	-	-	-	-
Titanium (Ti)	-	-	-	-	-	-	-	-
Total dissolved solids	0.32	10	164155	13	86221	18	650420	39
Total organic carbon	-	-	903	13	0.31	20	-	-
Total phosphate	-	-	-	-	-	-	-	-
Ttotal suspended solids	0.62	10	4811	13	0.19	18	0.49	39
Vanadium (V)	-	-	-	-	-	-	-	-
Zinc (Zn)	-	-	90.5	13	-	-	-	-
Zirconium (Zr)	-	-	-	-	-	-	-	-

Table D.45 continued

Parameter	CMSH		CMTS		DCVA		KRET	
	Std. Dev.	n	Std. Dev.	n	Std. Dev.	n	Std. Dev.	n
Alkalinity	58987	44	85187	36	76720	23	140755	26
Aluminum (Al)	-	-	-	-	-	-	-	-
Antimony (Sb)	-	-	-	-	-	-	-	-
Arsenic (As)	-	-	-	-	-	-	-	-
Barium (Ba)	101	44	0.34	36	43.0	23	-	-
Beryllium (Be)	-	-	-	-	-	-	-	-
Bismuth (Bi)	-	-	-	-	-	-	-	-
Boron (B)	-	-	-	-	-	-	-	-
Bromide (Br)	-	-	-	-	-	-	-	-
Cadmium (Cd)	1.01	44	-	-	-	-	-	-
Calcium (Ca)	-	-	21114	36	0.10	23	0.31	26
Cesium (Cs)	-	-	0.01	9	-	-	-	-
Chloride (Cl)	0.70	44	0.74	36	0.57	23	0.56	26
Chromium (Cr)	-	-	-	-	-	-	-	-
Cobalt (Co)	0.17	44	0.40	34	0.32	23	0.38	26
Copper (Cu)	-	-	-	-	-	-	-	-
Dissolved Oxygen	-	-	-	-	-	-	-	-
Fluoride (F)	85.8	42	0.14	24	134	14	0.31	23
Iron (Fe)	917	44	0.91	36	0.84	23	0.92	26
Lead (Pb)	1.28	44	-	-	0.42	23	0.45	26
Lithium (Li)	-	-	-	-	-	-	-	-
Magnesium (Mg)	0.13	44	0.12	36	0.12	23	0.35	26
Manganese (Mn)	-	-	-	-	-	-	0.76	26
Mercury (Hg)	-	-	-	-	-	-	-	-
Molybdenum (Mo)	-	-	-	-	-	-	-	-
Nickel (Ni)	-	-	-	-	-	-	-	-
Nitrate (NO3)	-	-	-	-	-	-	-	-
Ortho-phosphate	-	-	-	-	-	-		-
pH	-	-	0.24	36	-	-	0.70	26
$Phosphorus_{total}$	-	-	0.28	36	0.20	23	0.34	26
Potassium (K)	-	-	0.37	36	0.34	23	0.42	26
Redox	-	-	122	36	121	23	96.4	26
Rubidium (Rb)	-	-	-	-	-	-	-	-
Selenium (Se)	0.59	44	-	-	-	-	-	-
Silicate (Si)	0.11	44	0.16	36	0.21	23	2479	26
Silver (Ag)	-	-	-	-	-	-	-	-
Sodium (Na)	0.56	44	-	-	-	-	-	-
Specific Conductivity	0.13	44	0.23	36	0.10	22	0.28	26
Strontium (Sr)	120	44	-	-	0.24	23	0.34	26
Sulfate (SO4)	-	-	0.31	36	0.40	23	-	-
Sulfur (S)	0.91	44	0.31	36	0.41	23	-	-
Temperature	-	-	0.04	36	1.05	23	1.19	26
Thllium (Tl)	-	-	-	-	-	-	-	-
Tin (Sn)	-	-	-	-	-	-	-	-
Titanium (Ti)	-	-	-	-	-	-	-	-
Total dissolved solids	0.17	44	0.13	36	-	-	0.32	26
Total organic carbon	0.41	44	-	-	0.40	23	-	-
Total phosphate	0.40	44	-	-	-	-	-	-
Ttotal suspended solids	0.30	44	-	-	0.27	23	-	-
Vanadium (V)	-	-	-	-	-	-	-	-
Zinc (Zn)	111	44	-	-	0.53	23	-	-
Zirconium (Zr)	-	-	-	-	-	-	-	-

Table D.45 continued

Parameter	PMNS		PMUD		QBAA		QBUA	
	Std. Dev.	n	Std. Dev.	n	Std. Dev.	n	Std. Dev.	n
Alkalinity	50389	16	79883	22	-	-	103171	104
Aluminum (Al)	1.04	17	-	-	-	-	-	-
Antimony (Sb)	-	-	-	-	-	-	-	-
Arsenic (As)	-	-	-	-	-	-	-	-
Barium (Ba)	-	-	-	-	-	-	-	-
Beryllium (Be)	-	-	-	-	-	-	-	-
Bismuth (Bi)	-	-	-	-	-	-	-	-
Boron (B)	-	-	-	-	-	-	-	-
Bromide (Br)	-	-	-	-	-	-	-	-
Cadmium (Cd)	-	-	-	-	-	-	-	-
Calcium (Ca)	13892		24678	23	-	-	-	-
Cesium (Cs)	-	-	-	-	-	-	-	-
Chloride (Cl)	0.87	17	-	-	-	-	0.72	104
Chromium (Cr)	-	-	-	-	-	-	-	-
Cobalt (Co)	-	-	-	-	-	-	-	-
Copper (Cu)	-	-	-	-	-	-	-	-
Dissolved Oxygen	-	-	-	-	-	-	-	-
Fluoride (F)	477	15	230	20	-	-	-	-
Iron (Fe)	1.14	17	0.79	23	-	-	-	-
Lead (Pb)	-	-	0.60	23	-	-	-	-
Lithium (Li)	-	-	-	-	-	-	-	-
Magnesium (Mg)	17371	17	0.60	23	-	-	-	-
Manganese (Mn)	0.72	17	-	-	-	-	-	-
Mercury (Hg)	-	-	-	-	-	-	-	-
Molybdenum (Mo)	-	-	-	-	-	-	-	-
Nickel (Ni)	-	-	-	-	-	-	-	-
Nitrate (NO3)	-	-	-	-	-	-	-	-
Ortho-phosphate	-	-	-	-	-	-	-	-
pH	0.72	17	0.70	22	-	-	-	-
$Phosphorus_{total}$	-	-	1399	23	-	-	-	-
Potassium (K)	-	-	0.34	23	-	-	-	-
Redox	84.2	17	111	22	95.1	386	81.4	104
Rubidium (Rb)	-	-	-	-	-	-	-	-
Selenium (Se)	-	-	-	-	-	-	-	-
Silicate (Si)	011269	17	2537	23	-	-	-	-
Silver (Ag)	-	-	-	-	-	-	-	-
Sodium (Na)	0.48	17	0.43	23	-	-	0.49	104
Specific Conductivity	0.24	17	0.19	22	-	-	-	-
Strontium (Sr)	0.44	17	0.59	23	-	-	-	-
Sulfate (SO4)	0.53	17	-	-	-	-	-	-
Sulfur (S)	0.51	17	-	-	-	-	0.75	104
Temperature	1.36	17	0.81	22	-	-	0.91	104
Thllium (Tl)	-	-	-	-	-	-	-	-
Tin (Sn)	-	-	-	-	-	-	-	-
Titanium (Ti)	-	-	-	-	-	-	-	-
Total dissolved solids	0.22	17	0.20	23	-	-	-	-
Total organic carbon	0.28	17	-	-	-	-	-	-
Total phosphate	-	-	-	-	-	-	-	-
Ttotal suspended solids	-	-	-	-	-	-	-	-
Vanadium (V)	-	-	-	-	-	-	-	-
Zinc (Zn)	-	-	-	-	-	-	-	-
Zirconium (Zr)	-	-	-	-	-	-	-	-

Table D.45 continued

Parameter	QBUU		QWTA		Cambrian		Ordovician	
	Std. Dev.	n	Std. Dev.	n	Std. Dev.	n	Std. Dev.	n
Alkalinity	55293	22	98749	118	-	-	78875	87
Aluminum (Al)	-	-	-	-	-	-	-	-
Antimony (Sb)	-	-	-	-	-	-	-	-
Arsenic (As)	-	-	-	-	-	-	-	-
Barium (Ba)	-	-	0.44	119	0.47	102	-	-
Beryllium (Be)	-	-	-	-	-	-	-	-
Bismuth (Bi)	-	-	-	-	-	-	-	-
Boron (B)	-	-	-	-	-	-	-	-
Bromide (Br)	-	-	-	-	-	-	-	-
Cadmium (Cd)	-	-	-	-	-	-	-	-
Calcium (Ca)	-	-	-	-	-	-	0.11	87
Cesium (Cs)	-	-	-	-	-	-	-	-
Chloride (Cl)	0.68	22	0.71	119	-	-	-	-
Chromium (Cr)	-	-	-	-	-	-	-	-
Cobalt (Co)	0.35	22	-	-	0.29	100	-	-
Copper (Cu)	-	-	-	-	-	-	-	-
Dissolved Oxygen	-	-	-	-	-	-	-	-
Fluoride (F)	-	-	0.17	72	-	-	0.13	63
Iron (Fe)	0.73	22	-	-	-	-	-	-
Lead (Pb)	-	-	-	-	-	-	-	-
Lithium (Li)	-	-	-	-	-	-	-	-
Magnesium (Mg)	-	-	-	-	-	-	-	-
Manganese (Mn)	0.73	22	-	-	-	-	-	-
Mercury (Hg)	-	-	-	-	-	-	-	-
Molybdenum (Mo)	-	-	-	-	-	-	-	-
Nickel (Ni)	-	-	-	-	-	-	-	-
Nitrate (NO3)	-	-	-	-	-	-	-	-
Ortho-phosphate	-	-	-	-	-	-	-	-
pH	0.17	22	-	-	-	-	-	-
$Phosphorus_{total}$	2834	22	-	-	-	-	-	-
Potassium (K)	0.40	22	-	-	-	-	0.28	87
Redox	-	-	87.5	119	121.7	102	-	-
Rubidium (Rb)	-	-	-	-	-	-	-	-
Selenium (Se)	-	-	-	-	-	-	-	-
Silicate (Si)	0.10	22	2970	119	0.15	102	-	-
Silver (Ag)	-	-	-	-	-	-	-	-
Sodium (Na)	60700	22	-	-	-	-	-	-
Specific Conductivity	-	-	-	-	0.27	102	-	-
Strontium (Sr)	-	-	-	-	-	-	0.26	87
Sulfate (SO4)	78342	22	-	-	-	-	-	-
Sulfur (S)	0.50	22	-	-	0.65	102	-	-
Temperature	0.76	22	-	-	-	-	-	-
Thllium (Tl)	-	-	-	-	-	-	-	-
Tin (Sn)	-	-	-	-	-	-	-	-
Titanium (Ti)	-	-	-	-	-	-	-	-
Total dissolved solids	0.20	22	-	-	-	-	-	-
Total organic carbon	0.26	21	-	-	-	-	-	-
Total phosphate	-	-	-	-	-	-	-	-
Ttotal suspended solids	0.65	22	-	-	0.43	100	-	-
Vanadium (V)	-	-	-	-	-	-	-	-
Zinc (Zn)	-	-	-	-	-	-	-	-
Zirconium (Zr)	-	-	-	-	-	-	-	-

Table D.45 continued

Parameter	Precambrian		Buried Quaternary		Surficial Quaternary		CFIG-CFRN-CIGL	
	Std. Dev.	n	Std. Dev.	n	Std. Dev.	n	Std. Dev.	n
Alkalinity	0.26	79	-	-	-	-	94531	40
Aluminum (Al)	-	-	-	-	-	-	-	-
Antimony (Sb)	-	-	-	-	-	-	-	-
Arsenic (As)	-	-	-	-	-	-	-	-
Barium (Ba)	-	-	-	-	-	-	0.46	40
Beryllium (Be)	-	-	-	-	-	-	-	-
Bismuth (Bi)	-	-	-	-	-	-	-	-
Boron (B)	-	-	-	-	-	-	-	-
Bromide (Br)	-	-	-	-	-	-	-	-
Cadmium (Cd)	-	-	-	-	-	-	-	-
Calcium (Ca)	-	-	-	-	-	-	28133	40
Cesium (Cs)	-	-	-	-	-	-	-	-
Chloride (Cl)	-	-	-	-	0.71	123	0.57	40
Chromium (Cr)	-	-	-	-	-	-	-	-
Cobalt (Co)	-	-	-	-	-	-	0.27	39
Copper (Cu)	-	-	-	-	-	-	-	-
Dissolved Oxygen	-	-	-	-	-	-	-	-
Fluoride (F)	0.29	67	-	-	-	-	-	-
Iron (Fe)	-	-	-	-	-	-	0.73	40
Lead (Pb)	0.63	80	-	-	-	-	-	-
Lithium (Li)	-	-	-	-	-	-	-	-
Magnesium (Mg)	-	-	-	-	-	-	10061	40
Manganese (Mn)	-	-	-	-	-	-	-	-
Mercury (Hg)	-	-	-	-	-	-	-	-
Molybdenum (Mo)	-	-	-	-	-	-	-	-
Nickel (Ni)	-	-	-	-	-	-	-	-
Nitrate (NO3)	-	-	-	-	-	-	-	-
Ortho-phosphate	-	-	-	-	-	-	-	-
pH	-	-	-	-	-	-	0.28	40
Phosphorus$_{total}$	-	-	-	-	-	-	0.34	40
Potassium (K)	-	-	-	-	-	-	-	-
Redox	106	79	-	-	-	-	106	40
Rubidium (Rb)	-	-	-	-	-	-	-	-
Selenium (Se)	-	-	-	-	-	-	-	-
Silicate (Si)	-	-	-	-	2962	123	0.17	40
Silver (Ag)	-	-	-	-	-	-	-	-
Sodium (Na)	0.52	80	-	-	-	-	0.51	40
Specific Conductivity	-	-	-	-	-	-	0.26	40
Strontium (Sr)	-	-	-	-	-	-	0.42	40
Sulfate (SO4)	-	-	-	-	-	-	-	-
Sulfur (S)	-	-	-	-	-	-	0.62	40
Temperature	1.21	79	-	-	1.23	123	0.88	40
Thllium (Tl)	-	-	-	-	-	-	-	-
Tin (Sn)	-	-	-	-	-	-	-	-
Titanium (Ti)	-	-	-	-	-	-	-	-
Total dissolved solids	-	-	-	-	-	-	0.18	39
Total organic carbon	-	-	-	-	-	-	-	-
Total phosphate	-	-	-	-	-	-	-	-
Ttotal suspended solids	-	-	-	-	-	-	-	-
Vanadium (V)	-	-	-	-	-	-	-	-
Zinc (Zn)	-	-	-	-	-	-	0.65	40
Zirconium (Zr)	-	-	-	-	-	-	-	-

Table D.45 continued

Parameter	OSTP-OPDC-CJDN		CMSH-CMTS-PMHN		Upper Carbonate	
	Std. dev.	n	Std. dev.	n	Std. dev.	n
Alkalinity	81464	90	-	-	62458	36
Aluminum (Al)	-	-	-	-	-	-
Antimony (Sb)	-	-	-	-	-	-
Arsenic (As)	-	-	-	-	-	-
Barium (Ba)	-	-	0.39	26	91.7	36
Beryllium (Be)	-	-	-	-	-	-
Bismuth (Bi)	-	-	-	-	-	-
Boron (B)	-	-	-	-	-	-
Bromide (Br)	-	-	-	-	-	-
Cadmium (Cd)	-	-	-	-	-	-
Calcium (Ca)	-	-	-	-	-	-
Cesium (Cs)	-	-	-	-	-	-
Chloride (Cl)	-	-	0.68	26	-	-
Chromium (Cr)	-	-	-	-	-	-
Cobalt (Co)	-	-	0.37	26	-	-
Copper (Cu)	-	-	-	-	-	-
Dissolved Oxygen	-	-	-	-	-	-
Fluoride (F)	-	-	-	-	-	-
Iron (Fe)	-	-	-	-	-	-
Lead (Pb)	-	-	0.53	26	0.53	36
Lithium (Li)	-	-	-	-	-	-
Magnesium (Mg)	-	-	-	-	-	-
Manganese (Mn)	-	-	-	-	-	-
Mercury (Hg)	-	-	-	-	-	-
Molybdenum (Mo)	-	-	-	-	-	-
Nickel (Ni)	-	-	-	-	-	-
Nitrate (NO3)	-	-	-	-	-	-
Ortho-phosphate	-	-	-	-	-	-
pH	-	-	-	-	-	-
$Phosphorus_{total}$	-	-	0.27	26	0.32	36
Potassium (K)	-	-	-	-	-	-
Redox	130	90	-	-	-	-
Rubidium (Rb)	-	-	-	-	-	-
Selenium (Se)	-	-	-	-	-	-
Silicate (Si)	2859	90	0.17	26	-	-
Silver (Ag)	-	-	-	-	-	-
Sodium (Na)	-	-	-	-	-	-
Specific Conductivity	-	-	-	-	-	-
Strontium (Sr)	-	-	0.43	26	123	36
Sulfate (SO4)	-	-	-	-	-	-
Sulfur (S)	-	-	0.74	26	-	-
Temperature	0.86	90	-	-	-	-
Thllium (Tl)	-	-	-	-	-	-
Tin (Sn)	-	-	-	-	-	-
Titanium (Ti)	-	-	-	-	-	-
Total dissolved solids	-	-	-	-	-	-
Total organic carbon	-	-	-	-	-	-
Total phosphate	-	-	-	-	0.29	6
Ttotal suspended solids	-	-	0.46	26	-	-
Vanadium (V)	-	-	-	-	-	-
Zinc (Zn)	-	-	-	-	-	-
Zirconium (Zr)	-	-	-	-	-	-

[1] Analysis could not be performed because distribution was not normal or log-normal or sample size was insufficient.

Table D.46: Slopes and intercepts from Helsel's robust method. All regression coefficients are applied to concentrations of ug/L.

Parameter	CFIG		CFRN		CIGL		CJDN	
	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope
Alkalinity	-[1]	-	-	-	-	-	-	
Aluminum (Al)	-	-	0.071	1.42	-	-	0.091	1.362
Antimony (Sb)	-	-	-4.243	1.195	-3.869	0.866	-4.388	0.989
Arsenic (As)	-	-	-0.397	1.888	-	-	-0.44	1.355
Barium (Ba)	-	-	-	-	-	-	-	-
Beryllium (Be)	-	-	-5.974	1.625	-4.476	0.813	-6.792	1.86
Bismuth (Bi)	-	-	-	-	-	-	-	-
Boron (B)	-	-	3.562	1.34	3.931	0.884	2.898	1.478
Bromide (Br)	-	-	-	-	-	-	-	-
Cadmium (Cd)	-	-	-3.127	1.943	-2.355	0.766	-3.028	1.897
Calcium (Ca)	-	-	-	-	-	-	-	-
Cesium (Cs)	-	-	-4.648	1.036			-4.671	0.769
Chloride (Cl)	-	-	-	-	-	-	-	-
Chromium (Cr)	-	-	-1.12	1.684	-1.258	2.18	-0.766	1.093
Cobalt (Co)	-	-	-	-	-	-	-	-
Copper (Cu)	-	-	1.653	0.867	2.179	1.661	1.973	1.002
Dissolved Oxygen	-	-	6.285	2.685	-	-	6.977	2.209
Fluoride (F)	-	-	-	-	-	-	-	-
Iron (Fe)	-	-	-	-	-	-	4.888	2.634
Lead (Pb)	-	-	-1.201	1.602	-	-	-0.767	1.438
Lithium (Li)	-	-	1.707	1.213	2.159	0.498	1.478	1.154
Magnesium (Mg)	-	-	-	-	-	-	-	
Manganese (Mn)	-	-	3.32	1.767	-	-	3.093	1.774
Mercury (Hg)	-	-	-	-	-	-	-	-
Molybdenum (Mo)	-	-	0.853	0.7	-	-	0.457	0.929
Nickel (Ni)	-	-	1.368	0.656	1.142	0.856	1.67	0.3
Nitrate (NO3)	-	-	4.918	2.208	-	-	6.115	1.304
Ortho-phosphate	-	-	-	-	-	-	1.633	1.358
pH	-	-	-	-	-	-	-	-
$Phosphorus_{total}$	-	-	-	-	-	-	-	-
Potassium (K)	-	-	3.372	1.356	-	-	3.234	1.227
Redox	-	-	-	-	-	-	-	-
Rubidium (Rb)	-	-	5.264	0.766	-	-	5.471	0.553
Selenium (Se)	-	-	0.129	0.892	-0.315	1.073	0.111	0.835
Silicate (Si)	-	-	-	-	-	-	-	-
Silver (Ag)	-	-	-4.55	2.276	-4.053	1.741	-5.303	2
Sodium (Na)	-	-	-	-	-	-	-	-
Specific Conductivity	-	-	-	-	-	-	-	-
Strontium (Sr)	-	-	-	-	-	-		-
Sulfate (SO4)	-	-	8.627	1.006	-	-	8.627	1.006
Sulfur (S)	-	-	-	-	-	-	-	-
Temperature	-	-	-	-	-	-	-	-
Thllium (Tl)	-	-	-6.495	3.117	-3.698	1.324	-4.047	1.499
Tin (Sn)	-	-	-2.845	0.914	-2.404	0.989	-2.966	0.653
Titanium (Ti)	-	-	-6.034	0.625	-	-	-5.791	0.37
Total dissolved solids	-	-	-	-	-	-	-	-
Total organic carbon	-	-	7.823	1.073	-	-	7.459	1.165
Total phosphate	-	-	3.286	1.862	3.4	1.254	3.9	0.882
Ttotal suspended solids	-	-	-	-	-	-	-	-
Vanadium (V)	-	-	1.644	0.509	2.189	0.171	1.587	0.504
Zinc (Zn)	-	-	-	-	-	-	3.9	1.413
Zirconium (Zr)	-	-	-	-	-	-	-	-

Table D.46continued

Parameter	CMSH		CMTS		DCVA		KRET	
	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope
Alkalinity	-	-	-	-	-	-	-	-
Aluminum (Al)	0.396	1.09	-0.929	3.069	0.582	0.699	0.425	2.625
Antimony (Sb)	-4.379	1.386	-4.047	1.101	-4.503	0.816	-3.809	1.126
Arsenic (As)	-0.626	1.398	-0.23	1.662	-	-	0.161	1.38
Barium (Ba)	-	-	-	-	-	-	-	-
Beryllium (Be)	-8.168	3.561	-4.832	1.121	-4.684	1.083	-4.823	1.288
Bismuth (Bi)	-	-	-	-	-	-		
Boron (B)	3.175	1.473	-	-	3.892	1.439	6.085	1.181
Bromide (Br)	-	-	-	-	-	-	-3.312	1.856
Cadmium (Cd)	-3.778	1.651	-4.005	1.254	-	-	-2.902	1.641
Calcium (Ca)	-	-	-	-	-	-		
Cesium (Cs)			-3.684	0.457	-	-	-	-
Chloride (Cl)	-	-	-	-	-	-		
Chromium (Cr)	-1.576	2.31	-0.963	1.551	-3.88	2.714	-1.69	2.051
Cobalt (Co)	-	-	-	-	-	-	-0.624	0.765
Copper (Cu)	1.802	0.704	0.731	1.717	2.303	0.542	2.557	1.171
Dissolved Oxygen	6.487	2.013	-	-	6.157	1	6.376	1.871
Fluoride (F)	-	-	-	-	-	-	-	-
Iron (Fe)	-	-	6.582	1.837	-	-	-	-
Lead (Pb)	-	-	-	-	-	-	-0.922	1.745
Lithium (Li)	1.919	0.992	1.13	1.308	2.469	1.193	3.392	1.198
Magnesium (Mg)	-	-	-	-	-	-	-	-
Manganese (Mn)	3.834	2.784	0.637	0.844	-	-	4.501	1.871
Mercury (Hg)	-	-	-	-	-2.38	0.617	-	-
Molybdenum (Mo)	1.448	0.378	-	-	-	-	1.305	1.087
Nickel (Ni)	1.621	0.7			1.882	0.222	1.952	0.99
Nitrate (NO3)	4.837	2.283	3.969	3.151	-	-	2.788	3.746
Ortho-phosphate	-	-	-	-	2.782	1.564	-	-
pH	-	-	-	-	-	-	-	-
$Phosphorus_{total}$	-	-	-	-	-	-	-	-
Potassium (K)	3.75	1.39	-	-	-	-	3.234	1.227
Redox	-	-	-	-	-	-	-	-
Rubidium (Rb)	6.341	0.145	-	-	-	-	5.82	1.018
Selenium (Se)	0.491	0.926	-	-	-	-	0.525	1.079
Silicate (Si)	-	-	-	-	-	-	-	-
Silver (Ag)	-4.785	1.11	-6.363	3.563	-4.831	0.408	-5.008	1.982
Sodium (Na)	-	-	-	-	-	-	-	-
Specific Conductivity	-	-	-	-	-		-	
Strontium (Sr)	-	-	-	-	-	-	-	-
Sulfate (SO4)	7.145	2.219	7.864	1.985	-	-	11.32	1.379
Sulfur (S)	-	-	-	-	-	-	-	-
Temperature	-	-	-	-	-	-	-	-
Thllium (Tl)	-	-	-5.225	1.351	-5.152	1.541	-6.006	2.966
Tin (Sn)	-2.191	0.904	-1.946	1.571	-	-	-	-
Titanium (Ti)	-	-	-	-	-5.356	0.037	-6.267	1.408
Total dissolved solids	-	-	-	-	-	-	-	-
Total organic carbon	7.485	1.126	-	-	-	-	-	-
Total phosphate	2.703	2.249	3.887	1.774	-	-	3.711	1.253
Ttotal suspended solids	-	-	-	-	-	-	-	-
Vanadium (V)	1.683	0.903	1.066	0.622	1.621	0.36	2.074	0.988
Zinc (Zn)	2.449	1.292	-	-	2.517	1.054	3.366	1.576
Zirconium (Zr)	-8.809	6.558	-3.492	1.294	-	-	-	-

Table D.46 continued

Parameter	OGAL		OPDC		OSTP		PCCR	
	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope
Alkalinity	-	-	-	-	-	-	-	-
Aluminum (Al)	-0.244	1.436	-0.265	1.787	-0.004	1.493	2.1	2.475
Antimony (Sb)	-4.562	0.857	-3.718	1.261	-4.604	1.223	-4.096	1.044
Arsenic (As)	0.702	1.491	-	-	-0.663	1.244	-0.472	1.657
Barium (Ba)	-	-	-	-	-	-	-	-
Beryllium (Be)	-5.067	0.692	-5.997	1.357	-5.717	1.135	-4.132	1.34
Bismuth (Bi)	-	-	-	-	-	-	-	-
Boron (B)	-	-	3.598	1.35	3.809	1.068	4.261	1.505
Bromide (Br)	-	-	-	-	-	-	-	-
Cadmium (Cd)	-	-	-2.598	1.851	-	-	-3.447	1.42
Calcium (Ca)	-	-	-	-	-	-	-	-
Cesium (Cs)	-	-	-	-	-	-	-4.224	2.357
Chloride (Cl)	-	-	-	-	-	-	3.5058	3.7317
Chromium (Cr)	-2.896	1.398	-1.367	1.309	-1.871	1.289	-0.487	1.239
Cobalt (Co)	-	-	-	-	-	-		-
Copper (Cu)	2.384	0.708	1.778	1.039	2.334	0.974	2.001	1.021
Dissolved Oxygen	6.13	1.755	6.839	1.545	6.278	1.842	6.634	2.282
Fluoride (F)	-	-	-	-	-	-	-	-
Iron (Fe)	-	-	-	-	-	-	-	-
Lead (Pb)	-	-	-0.829	1.497	-	-	-	-
Lithium (Li)	2.699	0.824	2.027	0.855	2.064	0.689	1.726	1.183
Magnesium (Mg)	-	-	-	-	-	-	-	-
Manganese (Mn)	-	-	2.737	2.359	3.632	2.171	1.936	2.171
Mercury (Hg)	-	-	-	-	-	-	-	-
Molybdenum (Mo)	1.361	0.328	0.494	0.658	0.375	0.985	3.632	1.279
Nickel (Ni)	1.843	0.376	1.279	0.851	2.103	0.262	1.512	0.735
Nitrate (NO3)	3.428	3.638	6.476	1.646	4.987	2.052	1.211	3.993
Ortho-phosphate	3.122	1.555	2.217	1.211	1.31	1.263	-	-
pH	-	-	-	-	-	-	-	-
$Phosphorus_{total}$	-	-	-	-	-	-	-	-
Potassium (K)	-	-	3.634	0.996	3.634	0.996	3.452	1.265
Redox	-	-	-	-	-	-	-	-
Rubidium (Rb)	-	-	5.853	0.423	6.338	0.054	-	-
Selenium (Se)	-	-	0.13	0.608	-0.134	1.012	0.545	1.673
Silicate (Si)	-	-	-	-	-	-	-	-
Silver (Ag)	-	-	-5.75	2.439	-5.032	1.424	-4.879	1.774
Sodium (Na)	-	-	-	-	-	-	-	-
Specific Conductivity	-	-	-	-	-	-	-	-
Strontium (Sr)	-	-	-	-	-	-	-	-
Sulfate (SO4)	8.747	1.937	-	-	-	-	-	-
Sulfur (S)	-	-	-	-	-	-	-	-
Temperature	-	-	-	-	-	-	-	-
Thllium (Tl)	-5.085	1.108	-4.588	2.153	-4.724	1.213	-5.19	0.594
Tin (Sn)	-	-	-2.902	0.98	-	-	-2.595	1.198
Titanium (Ti)	-5.861	0.553	-6.55	0.991	-5.558	0.273	-6.275	1.466
Total dissolved solids	-	-	-	-	-	-	-	-
Total organic carbon	-	-	7.906	1.088	7.906	1.088	7.787	0.897
Total phosphate	-	-	3.275	1.192	3.867	0.789	2.821	1.602
Ttotal suspended solids	-	-	-	-	-	-	-	-
Vanadium (V)	1.727	0.463	1.635	0.487	1.685	0.645	1.529	0.872
Zinc (Zn)	-	-	4.241	1.421	-	-	2.912	1.65
Zirconium (Zr)	-	-	-	-	-	-	-1.54	1.667

Table D.46 continued

Parameter	PMNS		PMUD		QBAA		QBUA	
	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope
Alkalinity	-	-	-	-	-	-	-	-
Aluminum (Al)	-	-	1.651	1.821	-	-	-0.329	1.739
Antimony (Sb)	-3.482	1.159	-4.165	1.143	-	-	-4.175	1.168
Arsenic (As)	-0.141	1.381	-0.048	1.376	-	-	0.52	1.419
Barium (Ba)	2.118	1.575	-	-	4.073	1.106	-	-
Beryllium (Be)	-4.084	2.501	-5.401	1.814	-	-	-6.89	2.152
Bismuth (Bi)	-	-	-	-	-	-	-	-
Boron (B)	5.318	1.712	3.667	1.381	4.502	1.517	3.243	1.213
Bromide (Br)	-2.604	1.675	-	-	-6.014	2.31	-	-
Cadmium (Cd)	-3.318	1.577	-3.913	1.405	-		-4.046	1.33
Calcium (Ca)	-	-	-	-	4.8799	4.9197	-	-
Cesium (Cs)	-3.429	2.375	-2.527	1.558	-	-	-6.187	1.085
Chloride (Cl)	-	-	-	-	7.933	1.486	-	-
Chromium (Cr)	-0.509	2.175	-1.332	1.475	-	-	-0.756	1.319
Cobalt (Co)	-0.981	1.639	-1.141	1.234	-	-	-0.842	0.6933
Copper (Cu)	2.345	1.724	2.103	1.003	-	-	1.737	1.09
Dissolved Oxygen	7.044	1.604	4.593	2.755	5.286	1.941	6.586	1.77
Fluoride (F)	-	-	-	-	-	-	-	-
Iron (Fe)	-	-	-	-	-	-	5.522	2.289
Lead (Pb)	-	-	-	-	-	-	-1.512	1.413
Lithium (Li)	2.078	1.059	1.559	1.228	-	-	1.892	1.332
Magnesium (Mg)	-	-	-	-	-	-	-	-
Manganese (Mn)	-	-	3.652	2.226	-	-	4.464	1.702
Mercury (Hg)	-	-	-	-	-	-	-3.374	0.768
Molybdenum (Mo)	1.785	0.563	1.383	0.5	-	-	0.526	1.062
Nickel (Ni)	1.369	1.829	1.512	0.735	-	-	1.359	0.78
Nitrate (NO3)	0.598	4.27	3.389	2.886	-	-	4.325	3.11
Ortho-phosphate	-	-	-	-	3.864	1.177	-	-
pH	-	-	-	-	-	-	-	-
Phosphorus$_{total}$	6.811	0.96	-	-	-	-	-	-
Potassium (K)	3.195	1.962	3.559	0.894	-	-	3.991	0.95
Redox	-	-	-	-	-	-	-	-
Rubidium (Rb)	6.276	0.057	-	-	-	-	5.719	0.522
Selenium (Se)	0.32	1.2	0.768	1.334	-	-	1.164	1.13
Silicate (Si)	-	-	-	-	-	-	-	-
Silver (Ag)	-4.277	1.41	-4.768	1.424	-	-	-5.295	2.094
Sodium (Na)	-	-	-	-	-	-	-	-
Specific Conductivity	-	-	-	-	-	-	-	-
Strontium (Sr)	-	-	-	-	-	-	-	-
Sulfate (SO4)	-	-	7.483	1.31	-	-	-	-
Sulfur (S)	-	-	7.644	1.413	-	-	-	-
Temperature	-	-	-	-	-	-	-	-
Thllium (Tl)	-6.808	2.871	-5.323	1.156	-	-	-5.861	1.408
Tin (Sn)	-2.438	0.722	-2.354	0.55	-	-	-2.813	1.492
Titanium (Ti)	-5.22	1.595	-7.485	2.109	-	-	-6.02	0.659
Total dissolved solids	-	-	-	-	-	-	-	-
Total organic carbon	-	-	7.515	0.693	-	-	7.603	0.744
Total phosphate	2.098	2.86	2.948	1.297	-	-	3.675	1.139
Ttotal suspended solids	-	-	-	-	-	-	-	-
Vanadium (V)	1.907	1.158	1.22	0.909	-	-	1.566	0.707
Zinc (Zn)	2.635	2.051	2.512	1.32	-	-	2.554	1.265
Zirconium (Zr)	-1.989	1.899	-3.012	0.851	-3.539	1.86	-4.499	2.046

Table D.46 continued

Parameter	QBUU		QWTA		Cambrian		Ordovician	
	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope
Alkalinity	-	-	-	-	-	-	-	-
Aluminum (Al)	-0.697	2.537	-0.01	2.397	0.067	1.695	-0.209	1.617
Antimony (Sb)	-2.965	0.616	-4.241	1.273	-4.205	1.066	-4.258	1.264
Arsenic (As)	1.271	1.837	0.019	1.437	-0.337	1.582	-0.233	1.52
Barium (Ba)	3.932	0.852	-	-	-3.101	0.924	-2.535	0.734
Beryllium (Be)	-4.997	1.62	-5.173	1.335	-4.932	0.826	-5.906	1.886
Bismuth (Bi)	-	-	-	-	-	-	-	-
Boron (B)	-	-	-	-	-3.473	1.329	-3.141	1.276
Bromide (Br)	-	-	-	-	-	-	-	-
Cadmium (Cd)	-2.092	1.165	-3.529	1.019	-3.232	1.65	-2.062	2.056
Calcium (Ca)	-	-	-	-	-	-	-	-
Cesium (Cs)	-6.187	1.085	-6.296	2.275	-	-	-	-
Chloride (Cl)	-	-	-	-	-	-	-	-
Chromium (Cr)	-2.713	2.161	-0.816	1.279	-1.154	1.622	-1.979	1.419
Cobalt (Co)	-	-	-	-	-	-	-	-
Copper (Cu)	1.484	1.518	1.767	0.971	-5.217	1.209	-4.807	1.018
Dissolved Oxygen	4.364	2.818	6.208	1.866	-0.789	2.38	-0.393	1.615
Fluoride (F)	-	-	-	-	-	-	-	-
Iron (Fe)	5.522	2.289	6.199	2.21	-0.822	2.097	-1.029	1.846
Lead (Pb)	-1.218	1.588	-1.638	1.583	-1.069	1.555	-1.178	1.35
Lithium (Li)	3.493	0.973	1.731	1.038	-5.161	1.002	-4.714	0.834
Magnesium (Mg)	-	-	-	-	-	-	-	-
Manganese (Mn)	-	-	4.687	1.606	-3.351	2.02	-3.428	1.836
Mercury (Hg)	-	-	-2.505	0.315	-3.916	0.923	-	-
Molybdenum (Mo)	1.524	0.62	0.715	0.73	-6.055	0.649	-5.863	0.496
Nickel (Ni)	-	-	1.583	0.621	-5.486	0.531	-5.146	0.505
Nitrate (NO3)	-1.736	5.775	5.737	2.058	-1.587	1.63	-1.232	1.96
Ortho-phosphate	-	-	-	-	-	-	-	-
pH	-	-	-		-	-	-	-
$Phosphorus_{total}$	-	-	-	-	-	-	-	-
Potassium (K)	4.3	0.918	4.038	0.935	-3.1	0.946	-2.883	0.996
Redox	-	-	-	-	-	-	-	-
Rubidium (Rb)	6.142	0.199	5.837	0.394	-	-	-	-
Selenium (Se)	0.436	0.899	0.773	1.194	0.162	1.009	-0.142	0.922
Silicate (Si)	-	-	-	-	-	-	-	-
Silver (Ag)	-4.213	1.069	-5.008	1.781	-5.095	2.131	-5.915	2.162
Sodium (Na)	-	-	-	-	-	-	-	-
Specific Conductivity	-	-	-	-	-	-	-	-
Strontium (Sr)	6.229	0.67	-	-	-2.001	0.952	-1.79	0.604
Sulfate (SO4)	-	-	-	-	1.594	1.462	2.044	1.093
Sulfur (S)	-	-	-	-	-	-	-	-
Temperature	-	-	-	-	-	-	-	-
Thllium (Tl)	-4.425	1.253	-5.464	1.23	-5.085	1.994	-4.876	1.773
Tin (Sn)	-	-	-2.838	0.76	-	-	-	-
Titanium (Ti)	-	-	-6.497	1.18	-5.886	0.479	-5.873	0.549
Total dissolved solids	-	-	-	-	-	-	-	-
Total organic carbon	-	-	7.802	0.807	-	-	-	-
Total phosphate	3.719	1.099	3.778	1.288	-3.601	1.675	-3.735	1.11
Ttotal suspended solids	-	-	-	-	-	-	-	-
Vanadium (V)	1.708	0.667	1.762	0.541	-5.193	0.465	-5.163	0.48
Zinc (Zn)	3.583	1.419	2.589	1.306	-3.106	1.54	-3.049	1.329
Zirconium (Zr)	-	-	-2.926	1.826	-	-	-	-

Table D.46 continued

Parameter	Precambrian		Buried Quaternary		Surficial Quaternary		CFIG-CFRN-CIGL	
	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope
Alkalinity	-	-	-	-	-	-	-	-
Aluminum (Al)	1.975	2.714	-0.306	2.152	-0.038	2.438	0.193	1.748
Antimony (Sb)	-3.876	1.176	-4.284	1.189	-4.183	1.267	-4.113	1.013
Arsenic (As)	-0.127	1.432	0.842	1.69	0.022	1.417	-0.38	1.579
Barium (Ba)	-3.521	0.195	-2.788	1.037	-2.601	0.973	-	-
Beryllium (Be)	-6.429	2.484	-5.743	1.622	-5.083	1.111	-5.283	1.189
Bismuth (Bi)	-	-	-	-	-	-	-	-
Boron (B)	-2.66	1.737	-2.631	1.553	-3.644	0.922	3.686	1.261
Bromide (Br)	-	-	-	-	-	-	-	-
Cadmium (Cd)	-3.688	1.534	-3.833	1.731	-3.503	1.008	-2.965	1.568
Calcium (Ca)	-	-	-	-	-	-	-	-
Cesium (Cs)	-	-	-	-	-	-	-4.225	0.780
Chloride (Cl)	-	-	-	-	-	-	-	-
Chromium (Cr)	-0.903	1.683	-0.933	1.319	-0.852	1.288	-1.165	1.780
Cobalt (Co)	-	-	-	-	-	-	-	-
Copper (Cu)	-4.831	1.336	-5.333	1.203	-5.116	1.01	1.395	1.332
Dissolved Oxygen	-0.489	2.039	-1.255	1.894	-0.357	1.711	5.846	2.726
Fluoride (F)	-	-	-	-	-	-	-	-
Iron (Fe)	-1.108	2.21	-0.468	1.854	-0.772	2.25	-	-
Lead (Pb)	-0.617	1.432	-1.631	1.485	-1.617	1.558	-1.247	1.568
Lithium (Li)	-5.133	1.331	-4.389	1.371	-5.165	1.194	1.814	1.002
Magnesium (Mg)	-	-	-	-	-	-	-	-
Manganese (Mn)	-2.956	2.083	-2.144	1.385	-2.217	1.604	3.725	1.817
Mercury (Hg)	-	-	-3.045	0.615	-2.499	0.302	-	-
Molybdenum (Mo)	-5.586	0.824	-5.589	0.716	-6.145	0.775	0.602	0.766
Nickel (Ni)	-5.576	1.181	-5.538	0.834	-5.367	0.728	1.305	0.652
Nitrate (NO3)	-4.093	3.054	-4.242	3.257	-1.06	2.032	0.598	4.270
Ortho-phosphate	-	-	-	-	-	-	-	-
pH	-	-	-	-	-	-	-	-
$Phosphorus_{total}$	-	-	-	-	-	-	-	-
Potassium (K)	-3.42	1.273	-2.459	0.925	-2.873	0.933	3.6	1.118
Redox	-	-	-	-	-	-	-	-
Rubidium (Rb)	-	-	-	-	-	-	5.536	0.571
Selenium (Se)	0.479	1.492	0.886	1.061	0.778	1.176	0.037	1.082
Silicate (Si)	-	-	-	-	-	-	-	-
Silver (Ag)	-4.824	1.594	-5.575	2.091	-5.07	1.801	-4.531	2.052
Sodium (Na)	-	-	-	-	-	-	-	-
Specific Conductivity	-	-	-	-	-	-	-	-
Strontium (Sr)	-1.843	1.099	-1.395	1.032	-2.075	0.765	-	-
Sulfate (SO4)	1.27	1.642	2.073	2.209	1.362	1.78	8.806	1.282
Sulfur (S)	-	-	-	-	-	-	-	-
Temperature	-	-	-	-	-	-	-	-
Thllium (Tl)	-6.043	1.845	-5.785	1.544	-5.443	1.219	-5.813	2.757
Tin (Sn)	-	-	-	-	-	-	-2.562	0.790
Titanium (Ti)	-6.174	1.684	-6.492	1.097	-6.382	1.171	-6.045	0.572
Total dissolved solids	-	-	-	-	-	-	-	-
Total organic carbon	-	-	-	-	-	-	7.675	1.021
Total phosphate	-4.152	1.645	-2.861	1.143	-3.217	1.321	3.129	1.714
Ttotal suspended solids	-	-	-	-	-	-	-	-
Vanadium (V)	-5.411	1.065	-5.239	0.727	-5.126	0.61	1.636	0.519
Zinc (Zn)	-4.105	1.428	-4.29	1.386	-4.287	1.34	-	-
Zirconium (Zr)	-	-	-	-	-	-	-3.75	0.698

Table D.46 continued

Parameter	OSTP-OPDC-CJDN		CMSH-CMTS-PMHN		Upper Carbonate	
	Intercept	Slope	Intercept	Slope	Intercept	Slope
Alkalinity	-	-	-	-	-4.508	0.866
Aluminum (Al)	-0.095	1.569	-0.021	1.947	0.04	1.207
Antimony (Sb)	-	-	-4.104	1.208	-	-
Arsenic (As)	-0.6	1.305	-0.29	1.488	0.825	1.343
Barium (Ba)	-	-	-	-	-5.462	1.272
Beryllium (Be)	-5.983	1.296	-5.239	1.385	-	-
Bismuth (Bi)	-	-	-	-	-2.888	1.307
Boron (B)	-	-	3.369	1.195	-1.926	0.598
Bromide (Br)	-	-	-	-	-	-
Cadmium (Cd)	-2.682	2.029	-4.118	1.482	-	-
Calcium (Ca)	-	-	-	-	-0.785	1.853
Cesium (Cs)	-	-	-4.252	0.637	-	-
Chloride (Cl)	-	-	-	-	-	-
Chromium (Cr)	-	-	-1.224	1.788	-3.168	1.66
Cobalt (Co)	-	-	-	-	-	-
Copper (Cu)	1.97	1.022	1.364	1.121	-4.502	0.816
Dissolved Oxygen	6.682	1.912	5.391	2.277	-0.911	1.6095
Fluoride (F)	-	-	-	-	-	-
Iron (Fe)	5.271	2.218	6.646	2.143	-0.074	1.269
Lead (Pb)	-0.992	1.41	-	-	-2.129	0.994
Lithium (Li)	1.891	0.877	1.53	1.082	-	-
Magnesium (Mg)	-	-	-	-	-3.071	1.148
Manganese (Mn)	3.014	2.172	4.335	1.775	-2.486	0.475
Mercury (Hg)	-2.328	0.289	-	-	-1.326	1.237
Molybdenum (Mo)	0.475	0.806	0.897	0.585	-5.587	0.336
Nickel (Ni)	1.611	0.557	1.2	0.763	-4.002	3.484
Nitrate (NO3)	6.035	1.608	4.841	1.728	-	-
Ortho-phosphate	1.818	1.262	-	-	-	-
pH	-	-	-	-	-	-
$Phosphorus_{total}$	-	-	-	-	-4.362	0.914
Potassium (K)	-	-	-	-	-	-
Redox	-	-	-	-	-	-
Rubidium (Rb)	5.841	0.369	6.369	0.107	-0.556	1.231
Selenium (Se)	0.068	0.758	0.553	0.888	-1.601	0.564
Silicate (Si)	-	-	-	-	1.525	1.713
Silver (Ag)	-5.391	1.973	-6.067	2.677	-	-
Sodium (Na)	-	-	-	-	-5.068	0.377
Specific Conductivity	-	-	-	-	-	-
Strontium (Sr)	-	-	-	-	-	-
Sulfate (SO4)	-	-	7.464	2	-4.953	1.218
Sulfur (S)	-	-	-	-	-7.856	2.787
Temperature	-	-	-	-	-	-
Thllium (Tl)	-4.482	1.743	-5.863	1.593	-	-
Tin (Sn)	-3.153	0.896	-2.436	1.395	-	-
Titanium (Ti)	-5.998	0.577	-5.808	0.547	-	-
Total dissolved solids	-	-	-	-	-5.767	0.474
Total organic carbon	7.672	1.081	7.509	0.794	-3.573	1.171
Total phosphate	3.48	1.101	3.388	1.865	-	-
Ttotal suspended solids	-	-	-	-	-	-
Vanadium (V)	1.613	0.543	1.301	0.883	-5.184	0.462
Zinc (Zn)	4.016	1.377	2.673	1.585	-3.77	1.215
Zirconium (Zr)	-4.812	1.575	-5.251	3.323	-	-

[1] Analysis could not be performed because distribution was not log-censored or sample size was insufficient.

Table D.47: Mean ranks using Kruskal-Wallis test, by chemical and aquifer subgroup. The null hypothesis was concentrations of individual chemicals did not differ by aquifer group. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD[1]	CFIG[2]	CFRN	CIGL	CJDN	CMSH	CMTS	CSLF	CSTL
Alkalinity	< 0.0001	166	593	503	598	384	183	479	452	749
Aluminum (Al)	< 0.0001	281	516	510	590	477	519	423	448	625
Antimony (Sb)	< 0.0001	307	514	489	556	432	481	526	381	676
Arsenic (As)	< 0.0001	205	316	378	328	329	299	395	657	504
Barium (Ba)	< 0.0001	190	319	453	419	315	443	482	587	399
Beryllium (Be)	< 0.0001	289	439	451	641	416	441	566	340	587
Bismuth (Bi)	0.0039	82	149	149	178	168	149	149	149	149
Boron (B)	< 0.0001	170	508	403	437	294	341	418	337	581
Bromide (Br)	< 0.0001	335	481	481	481	481	481	518	481	481
Cadmium (Cd)	< 0.0001	169	456	535	672	566	421	354	523	688
Calcium (Ca)	< 0.0001	191	663	461	557	392	219	470	540	619
Cesium (Cs)	< 0.0001	105	214	179	190	181	120	206	148	186
Chloride (Cl)	< 0.0001	248	318	322	359	309	447	385	564	277
Chromium (Cr)	< 0.0001	221	543	515	449	537	459	536	461	351
Cobalt (Co)	< 0.0001	313	652	579	723	451	408	577	590	733
Copper (Cu)	< 0.0001	315	237	424	585	522	450	380	696	681
Dissolved Oxygen	0.0001	341	617	542	410	563	599	485	335	394
Fluoride (F)	< 0.0001	193	377	257	169	299	170	240	442	297
Iron (Fe)	< 0.0001	269	514	485	526	349	496	531	688	611
Lead (Pb)	< 0.0001	328	367	526	602	608	428	506	527	906
Lithium (Li)	< 0.0001	202	353	385	441	331	410	272	453	580
Magnesium (Mg)	< 0.0001	195	664	558	571	440	208	460	496	644
Manganese (Mn)	< 0.0001	242	420	329	576	277	456	484	707	365
Mercury (Hg)	< 0.0001	150	217	243	217	229	217	217	217	217
Molybdenum (Mo)	< 0.0001	258	355	452	355	427	495	355	355	592
Nickel (Ni)	0.001	341	347	451	458	476	537	347	347	534
Nitrate (NO3)	< 0.0001	275	405	531	405	576	546	476	405	524
Ortho-phosphate	< 0.0001	48	-[3]	28	24	53	-	-	-	-
pH	< 0.0001	275	354	546	545	563	528	593	694	428
Phosphorus$_{total}$	< 0.0001	160	319	292	436	263	353	506	598	480
Potassium (K)	< 0.0001	162	599	416	481	252	300	427	408	536
Redox/Eh	< 0.0001	272	386	537	557	553	521	330	227	606
Rubidium (Rb)	0.0007	339	442	479	501	473	539	442	442	442
Selenium (Se)	< 0.0001	222	466	335	243	327	414	432	371	216
Silicate (Si)	< 0.0001	188	273	345	261	277	450	313	600	536
Silver (Ag)	< 0.0001	306	517	573	648	507	468	488	517	668
Sodium (Na)	< 0.0001	160	457	335	467	228	274	480	405	553
Specific Conductivity	< 0.0001	183	598	464	552	387	242	490	526	625
Strontium (Sr)	< 0.0001	154	592	384	498	253	295	458	408	586
Sulfate (SO4)	< 0.0001	222	571	466	535	436	267	371	592	569
Sulfur (S)	< 0.0001	218	568	470	528	448	261	373	592	575
Temperature	< 0.0001	195	744	737	789	722	394	659	845	685
Thallium (Tl)	< 0.0001	280	429	503	678	691	336	559	747	680
Tin (Sn)	0.569	213	176	128	180	119	193	168	163	178
Titanium (Ti)	< 0.0001	331	469	478	425	450	572	414	483	374
Total dissolved solids	< 0.0001	164	552	437	490	325	187	434	477	588
Total organic carbon	< 0.0001	199	258	496	377	391	372	321	383	452
Total phosphate	< 0.0001	209	240	342	316	325	290	417	451	372
Total suspended solids	0.0001	298	575	426	515	362	574	507	563	496
Vanadium (V)	0.049	399	407	448	526	431	516	323	458	584
Zinc (Zn)	< 0.0001	251	695	711	785	690	402	512	499	923
Zirconium (Zr)	0.0005	117	153	108	127	112	118	129	79	135

Table D.47 continued

Parameter	p-value	LSD	DCVA	CRET	OGAL	OMAQ	OPDC	OPVL	OSPC	OSTP
Alkalinity	< 0.0001	166	552	705	614	232	493	585	405	420
Aluminum (Al)	< 0.0001	281	565	541	445	374	463	540	-	501
Antimony (Sb)	< 0.0001	307	425	572	399	182	606	592	-	427
Arsenic (As)	< 0.0001	205	574	444	550	354	298	758	-	298
Barium (Ba)	< 0.0001	190	815	268	719	637	516	835	559	491
Beryllium (Be)	< 0.0001	289	624	460	461	340	433	340	-	437
Bismuth (Bi)	0.0039	82	-	-	-	-	149	224	-	149
Boron (B)	< 0.0001	170	470	827	529	55	413	466	254	453
Bromide (Br)	< 0.0001	335	481	556	481	481	481	481	481	481
Cadmium (Cd)	< 0.0001	169	904	555	857	225	619	422	657	461
Calcium (Ca)	< 0.0001	191	488	693	558	281	543	488	458	477
Cesium (Cs)	< 0.0001	105	-	-	-	-	247	170	-	167
Chloride (Cl)	< 0.0001	248	248	660	398	566	514	756	629	421
Chromium (Cr)	< 0.0001	221	254	434	241	287	452	175	-	360
Cobalt (Co)	< 0.0001	313	411	571	374	173	490	604	-	528
Copper (Cu)	< 0.0001	315	632	666	641	892	484	678	384	565
Dissolved Oxygen	0.0001	341	507	487	482	906	610	270	549	524
Fluoride (F)	< 0.0001	193	180	497	304	-	277	132	221	304
Iron (Fe)	< 0.0001	269	605	587	586	159	369	439	351	370
Lead (Pb)	< 0.0001	328	530	575	486	584	599	550	-	494
Lithium (Li)	< 0.0001	202	543	686	602	497	431	396	366	423
Magnesium (Mg)	< 0.0001	195	371	698	474	447	514	723	455	465
Manganese (Mn)	< 0.0001	242	405	516	323	160	310	550	829	399
Mercury (Hg)	< 0.0001	150	338	224	217	462	227	217	-	217
Molybdenum (Mo)	< 0.0001	258	395	529	457	355	389	631	355	416
Nickel (Ni)	0.001	341	518	572	568	910	477	511	347	587
Nitrate (NO3)	< 0.0001	275	405	495	478	901	615	405	405	492
Ortho-phosphate	< 0.0001	48	84	122	98	73	66	-	-	47
pH	< 0.0001	275	367	353	389	626	463	598	653	485
$Phosphorus_{total}$	< 0.0001	160	706	666	649	209	331	413	389	391
Potassium (K)	< 0.0001	162	348	809	445	71	410	501	465	474
Redox/Eh	< 0.0001	272	371	433	380	812	695	331	447	598
Rubidium (Rb)	0.0007	339	442	577	486	919	483	442	442	482
Selenium (Se)	< 0.0001	222	317	417	320	487	317	393	-	289
Silicate (Si)	< 0.0001	188	519	463	412	189	306	838	370	307
Silver (Ag)	< 0.0001	306	403	493	344	327	499	717	-	505
Sodium (Na)	< 0.0001	160	470	815	574	33	381	389	243	289
Specific Conductivity	< 0.0001	183	479	805	606	340	540	582	418	434
Strontium (Sr)	< 0.0001	154	481	846	526	52	411	604	356	410
Sulfate (SO4)	< 0.0001	222	337	810	508	447	560	419	503	522
Sulfur (S)	< 0.0001	218	323	813	494	432	568	424	490	527
Temperature	< 0.0001	195	517	723	512	556	614	882	872	666
Thallium (Tl)	< 0.0001	280	545	520	562	886	632	677	-	570
Tin (Sn)	0.569	213	-	-	-	-	136	159	-	88
Titanium (Ti)	< 0.0001	331	465	526	539	904	466	532	374	553
Total dissolved solids	< 0.0001	164	403	831	537	282	492	472	462	395
Total organic carbon	< 0.0001	199	729	567	795	142	508	383	297	393
Total phosphate	< 0.0001	209		386	423	314	384	442	408	263
Total suspended solids	0.0001	298	579	596	478	73	356	328	317	333
Vanadium (V)	0.049	399	433	625	501	797	482	461	240	521
Zinc (Zn)	< 0.0001	251	419	577	601	373	743	647	604	686
Zirconium (Zr)	0.0005	117	-	-	-	-	89	156		109

Table D.47 continued

Parameter	p-value	LSD	PCCR	PCUU	PEBI	PMDC	PMFL	PMHN	PMNS	PMSX
Alkalinity	< 0.0001	166	347	479	23	160	178	56	97	420
Aluminum (Al)	< 0.0001	281	725	281	434	972	902	655	863	309
Antimony (Sb)	< 0.0001	307	520	284	959	945	685	610	663	820
Arsenic (As)	< 0.0001	205	322	403	740	429	289	566	387	608
Barium (Ba)	< 0.0001	190	377	196	281	16	468	413	153	416
Beryllium (Be)	< 0.0001	289	660	547	734	977	587	527	703	495
Bismuth (Bi)	0.0039	82	149	149	149	298	149	149	149	-
Boron (B)	< 0.0001	170	530	598	497	943	258	209	702	637
Bromide (Br)	< 0.0001	335	481	481	481	481	481	481	539	481
Cadmium (Cd)	< 0.0001	169	357	225	225	558	225	487	544	394
Calcium (Ca)	< 0.0001	191	251	570	95	15	215	78	89	678
Cesium (Cs)	< 0.0001	105	204	104	288	285	104	148	229	-
Chloride (Cl)	< 0.0001	248	527	434	349	675	273	352	486	640
Chromium (Cr)	< 0.0001	221	567	559	119	897	822	458	586	289
Cobalt (Co)	< 0.0001	313	440	497	74	792	497	745	338	571
Copper (Cu)	< 0.0001	315	526	642	237	975	597	402	627	748
Dissolved Oxygen	0.0001	341	569	571	379	931	386	237	555	684
Fluoride (F)	< 0.0001	193	514	393	287	699	287	24	471	24
Iron (Fe)	< 0.0001	269	444	474	249	694	344	617	418	186
Lead (Pb)	< 0.0001	328	700	307	404	975	800	559	628	703
Lithium (Li)	< 0.0001	202	385	607	413	139	258	284	450	708
Magnesium (Mg)	< 0.0001	195	299	576	152	15	205	77	185	633
Manganese (Mn)	< 0.0001	242	499	525	758	520	412	579	302	522
Mercury (Hg)	< 0.0001	150	253	217	217	344	246	235	217	274
Molybdenum (Mo)	< 0.0001	258	518	561	355	873	355	477	610	718
Nickel (Ni)	0.001	341	511	547	347	347	347	503	602	771
Nitrate (NO3)	< 0.0001	275	475	405	405	405	405	405	460	771
Ortho-phosphate	< 0.0001	48	-	91	-	-	-	-	-	91
pH	< 0.0001	275	540	433	883	978	698	345	813	57
$Phosphorus_{total}$	< 0.0001	160	313	342	102	469	67	401	298	603
Potassium (K)	< 0.0001	162	459	590	375	73	165	124	212	542
Redox/Eh	< 0.0001	272	592	359	473	442	730	509	441	885
Rubidium (Rb)	0.0007	339	461	616	442	442	442	606	495	703
Selenium (Se)	< 0.0001	222	459	480	710	921	437	333	384	260
Silicate (Si)	< 0.0001	188	359	236	209	259	584	547	391	635
Silver (Ag)	< 0.0001	306	558	327	327	875	792	469	649	327
Sodium (Na)	< 0.0001	160	548	618	273	850	245	302	630	767
Specific Conductivity	< 0.0001	183	266	299	143	166	205	107	242	739
Strontium (Sr)	< 0.0001	154	531	621	250	12	59	185	351	765
Sulfate (SO4)	< 0.0001	222	377	654	734	337	358	202	371	813
Sulfur (S)	< 0.0001	218	377	653	717	323	351	188	365	810
Temperature	< 0.0001	195	321	507	453	196	81	181	190	752
Thallium (Tl)	< 0.0001	280	437	457	295	295	673	497	459	687
Tin (Sn)	0.569	213	170	166	275	302	224	142	177	
Titanium (Ti)	< 0.0001	331	566	567	374	988	670	534	745	757
Total dissolved solids	< 0.0001	164	335	574	112	89	142	46	205	728
Total organic carbon	< 0.0001	199	483	432	12	88	190	560	318	357
Total phosphate	< 0.0001	209	224	87	482	195	316	273	363	262
Total suspended solids	0.0001	298	445	454	253	977	543	529	567	163
Vanadium (V)	0.049	399	492	663	240	240	558	566	605	767
Zinc (Zn)	< 0.0001	251	478	399	900	910	512	399	434	326
Zirconium (Zr)	0.0005	117	238	79	79	296	202	146	220	-

Table D.47 continued

Parameter	p-value	LSD	PMUD	QBAA	QBUA	QBUU	QUUU	QWTA
Alkalinity	< 0.0001	166	186	557	444	764	586	370
Aluminum (Al)	< 0.0001	281	710	459	434	389	444	499
Antimony (Sb)	< 0.0001	307	496	456	483	797	821	489
Arsenic (As)	< 0.0001	205	391	572	509	619	410	424
Barium (Ba)	< 0.0001	190	386	497	544	452	182	568
Beryllium (Be)	< 0.0001	289	549	480	426	573	340	533
Bismuth (Bi)	0.0039	82	149	150	149	-	-	149
Boron (B)	< 0.0001	170	425	576	341	738	597	329
Bromide (Br)	< 0.0001	335	481	494	485	481	481	481
Cadmium (Cd)	< 0.0001	169	444	379	701	548	419	-
Calcium (Ca)	< 0.0001	191	184	527	504	741	881	465
Cesium (Cs)	< 0.0001	105	204	126	115	-	-	138
Chloride (Cl)	< 0.0001	248	499	488	564	423	790	592
Chromium (Cr)	< 0.0001	221	422	517	572	307	349	551
Cobalt (Co)	< 0.0001	313	317	490	470	725	638	496
Copper (Cu)	< 0.0001	315	521	451	473	463	745	476
Dissolved Oxygen	0.0001	341	395	451	577	355	896	519
Fluoride (F)	< 0.0001	193	348	414	311	339	644	313
Iron (Fe)	< 0.0001	269	349	540	401	629	298	493
Lead (Pb)	< 0.0001	328	576	440	469	535	580	443
Lithium (Li)	< 0.0001	202	358	564	428	740	743	378
Magnesium (Mg)	< 0.0001	195	207	551	477	725	841	400
Manganese (Mn)	< 0.0001	242	412	545	532	626	494	556
Mercury (Hg)	< 0.0001	150	268	-	-	-	-	-
Molybdenum (Mo)	< 0.0001	258	502	554	455	503	764	424
Nickel (Ni)	0.001	341	504	492	455	366	789	497
Nitrate (NO3)	< 0.0001	275	488	460	540	450	792	543
Ortho-phosphate	< 0.0001	48		115	77		50	93
pH	< 0.0001	275	678	517	480	252	181	471
$Phosphorus_{total}$	< 0.0001	160	297	589	422	506	399	434
Potassium (K)	< 0.0001	162	342	584	427	732	692	394
Redox/Eh	< 0.0001	272	531	441	579	661	958	516
Rubidium (Rb)	0.0007	339	442	502	490	506	711	483
Selenium (Se)	< 0.0001	222	495	511	586	405	470	492
Silicate (Si)	< 0.0001	188	294	572	521	744	743	514
Silver (Ag)	< 0.0001	306	548	471	513	381	327	529
Sodium (Na)	< 0.0001	160	510	582	362	724	622	340
Specific Conductivity	< 0.0001	183	242	534	459	737	862	390
Strontium (Sr)	< 0.0001	154	392	586	364	745	789	330
Sulfate (SO4)	< 0.0001	222	278	518	465	766	830	399
Sulfur (S)	< 0.0001	218	291	522	460	778	821	399
Temperature	< 0.0001	195	170	446	429	784	522	452
Thallium (Tl)	< 0.0001	280	428	443	456	633	528	480
Tin (Sn)	0.569	213	165	150	152	-	-	141
Titanium (Ti)	< 0.0001	331	495	483	457	421	792	504
Total dissolved solids	< 0.0001	164	204	556	455	764	825	402
Total organic carbon	< 0.0001	199	378	515	406	624	626	478
Total phosphate	< 0.0001	209	480	382	392	87	404	-
Total suspended solids	0.0001	298	433	534	428	562	405	513
Vanadium (V)	0.049	399	395	495	474	497	778	510
Zinc (Zn)	< 0.0001	251	408	437	429	630	705	436
Zirconium (Zr)	0.0005	117	174	154	129	-	-	166

[1] LSD = Least Significant Difference. For an individual chemical, mean ranks between aquifers which differ by more than the LSD have significantly different mean ranks at the 0.05 significance level.
[2] see Table 1 for minor aquifer group descriptions
[3] Insufficient sample size or not sampled

Table D.48: Mean ranks using Kruskal-Wallis test, by chemical and aquifer age group. The null hypothesis was concentrations of individual chemicals did not differ by aquifer group. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD[1]	Ca[2]	D	Cr	O	P	BQ	SQ
Alkalinity	< 0.0001	40	452	552	705	503	237	543	377
Aluminum (Al)	< 0.0001	60	498	565	540	470	714	450	497
Antimony (Sb)	0.044	120	486	425	572	596	568	476	500
Arsenic (As)	< 0.0001	45	367	574	444	382	388	561	423
Barium (Ba)	< 0.0001	46	408	815	268	574	325	505	555
Beryllium (Be)	< 0.0001	71	470	624	460	437	623	473	527
Bismuth (Bi)	< 0.0001	84	155	-	-	156	152	150	149
Boron (B)	< 0.0001	42	378	470	827	447	530	535	337
Bromide (Br)	< 0.0001	72	485	481	556	481	493	492	481
Cadmium (Cd)	< 0.0001	39	522	904	555	681	435	442	423
Calcium (Ca)	< 0.0001	40	444	488	693	522	218	432	479
Cesium (Cs)	< 0.0001	61	274	-[3]	-	204	206	124	138
Chromium (Cr)	< 0.0001	43	506	254	434	359	516	519	544
Chloride (Cl)	< 0.0001	58	349	248	660	482	499	500	599
Cobalt (Co)	0.0062	111	545	411	571	470	404	496	500
Copper (Cu)	< 0.0001	69	475	632	666	554	560	456	485
Dissolved Oxygen	0.224	-	526	507	487	545	507	472	531
Fluoride (F)	< 0.0001	49	257	180	497	284	423	392	322
Iron (Fe)	0.0008	82	468	605	587	424	404	515	486
Lead (Pb)	< 0.0001	69	552	530	575	538	631	450	447
Lithium (Li)	< 0.0001	49	370	543	686	470	406	544	390
Magnesium (Mg)	< 0.0001	42	483	371	698	496	259	543	415
Manganese (Mn)	< 0.0001	48	385	405	516	355	438	546	554
Mercury (Hg)	0.0001	55	229	338	224	225	250	241	268
Molybdenum (Mo)	< 0.0001	60	425	395	529	420	541	532	435
Nickel (Ni)	0.010	106	448	518	572	533	534	479	506
Nitrate (NO_3)	0.0007	77	518	405	495	539	482	476	551
Ortho-phosphate	< 0.0001	91	43	84	122	75	91	111	71
pH	< 0.0001	70	547	367	353	461	615	498	462
$Phosphorus_{total}$	< 0.0001	43	349	706	666	430	317	552	433
Potassium (K)	< 0.0001	39	374	348	809	436	356	558	404
Redox/Eh	0.003	90	498	371	433	573	545	479	530
Rubidium (Rb)	0.031	111	475	442	577	486	485	500	490
Selenium (Se)	< 0.0001	50	352	317	417	317	448	522	492
Silicate (Si)	< 0.0001	35	338	519	463	351	366	569	522
Silver (Ag)	0.0018	90	536	403	493	465	558	476	523
Sodium (Na)	< 0.0001	40	343	470	815	399	551	544	349
Specific Conductivity	< 0.0001	40	444	479	805	525	269	527	406
Strontium (Sr)	< 0.0001	38	373	481	746	441	433	548	345
Sulfate (SO_4)	< 0.0001	51	445	337	810	529	376	518	413
Sulfur (S)	< 0.0001	50	449	323	813	530	378	520	413
Temperature	< 0.0001	36	695	517	723	516	268	457	454
Thallium (Tl)	< 0.0001	70	577	545	520	601	457	454	481
Tin (Sn)	0.171	131	157	-	-	117	175	150	141
Titanium (Ti)	0.0002	90	462	465	526	513	597	475	513
Total dissolved solids	< 0.0001	47	396	403	831	474	277	545	516
Total organic carbon	< 0.0001	58	402	729	567	536	394	497	483
Total phosphate	< 0.0001	59	343	ns	386	367	269	456	402
Total suspended solids	0.0003	85	455	579	596	376	464	514	509
Vanadium (V)	0.043	123	443	433	625	494	506	491	518
Zinc (Zn)	< 0.0001	42	654	419	577	681	447	444	445
Zirconium (Zr)	< 0.0001	40	118	-	-	105	200	149	166

[1] LSD = Least Significant Difference. For an individual chemical, mean ranks between aquifers which differ by more than the LSD have significantly different mean ranks at the 0.05 significance level.
[2] Ca=Cambrian; D=Devonian; Cr=Cretaceous; O=Ordovician; P=Precambrian; BQ=buried Quaternary; SQ=surficial Quaternary; UC=upper carbonate
[3] Insufficient sample size or not sampled

Table D.49: Mean ranks using Kruskal-Wallis test, by chemical and aquifer hydrologic group. The null hypothesis was concentrations of individual chemicals did not differ by aquifer group. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD[1]	CFIG-CFRN-CIGL[2]	OSTP-OPDC-CJDN	CMSH-CMTS-PMHN	Upper Carbonate
Alkalinity	< 0.0001	12	122	98	67	137
Aluminum (Al)	0.709	56	118	106	107	103
Antimony (Sb)	0.193	30	114	112	116	94
Arsenic (As)	< 0.0001	12	98	87	102	145
Barium (Ba)	< 0.0001	9	88	89	93	160
Beryllium (Be)	0.216	32	113	100	119	110
Bismuth (Bi)	0.003	12	32	32	31	47
Boron (B)	0.039	23	110	100	96	128
Bromide (Br)	0.064	24	108	108	112	108
Cadmium (Cd)	< 0.0001	9	89	102	54	149
Calcium (Ca)	0.002	16	116	108	69	125
Cesium (Cs)	0.413	24	34	36	27	28
Chloride (Cl)	0.443	40	94	113	110	112
Chromium (Cr)	< 0.0001	11	130	121	125	67
Cobalt (Co)	0.001	17	137	106	117	87
Copper (Cu)	0.000	14	88	108	83	137
Dissolved Oxygen	0.196	30	109	119	103	98
Fluoride (F)	0.116	23	83	89	60	84
Iron (Fe)	< 0.0001	14	117	86	123	134
Lead (Pb)	0.295	33	105	117	97	100
Lithium (Li)	< 0.0001	12	98	99	81	144
Magnesium (Mg)	0.000	14	138	109	66	110
Manganese (Mn)	0.021	23	116	96	136	114
Mercury (Hg)	0.253	33	74	71	68	77
Molybdenum (Mo)	0.267	32	108	105	108	118
Nickel (Ni)	0.015	20	94	110	94	125
Nitrate (NO3)	0.027	21	103	121	104	100
Ortho-phosphate	< 0.0001	7	23	45	-[2]	68
pH	0.019	22	119	115	124	89
Phosphorustotal	< 0.0001	10	88	87	117	153
Potassium (K)	0.254	33	123	103	98	115
Redox/Eh	0.000	14	110	130	88	88
Rubidium (Rb)	0.901	87	108	108	113	111
Selenium (Se)	0.333	31	83	82	101	91
Silicate (Si)	0.000	16	96	95	117	137
Silver (Ag)	0.001	16	129	112	107	88
Sodium (Na)	< 0.0001	14	104	90	110	141
Specific Conductivity	0.000	15	113	101	75	134
Strontium (Sr)	0.001	16	113	94	95	135
Sulfate (SO4)	0.005	18	114	117	68	111
Sulfur (S)	0.003	17	115	120	69	108
Temperature	< 0.0001	11	144	122	76	83
Thallium (Tl)	0.015	19	98	121	82	105
Tin (Sn)	0.147	19	34	27	39	37
Titanium (Ti)	0.297	34	103	106	108	119
Total dissolved solids	0.001	15	116	102	69	128
Total organic carbon	< 0.0001	11	96	95	84	150
Total phosphate	0.504	32	52	56	57	68
Total suspended solids	0.002	18	117	90	133	118
Vanadium (V)	0.648	51	106	110	98	115
Zinc (Zn)	< 0.0001	13	131	125	71	89
Zirconium (Zr)	0.379	25	35	29	34	41

[1] LSD = Least Significant Difference. For an individual chemical, mean ranks between aquifers which differ by more than the LSD have significantly different mean ranks at the 0.05 significance level.
[2] Insufficient sample size or not sampled

Table D.50: Mean ranks using Kruskal-Wallis test, by chemical and well diameter. The null hypothesis was concentrations of individual chemicals did not differ by well diameter. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	4 inch	5 inch	6 inch	7 inch	8 inch	12 to 16 inch	24 inch	30 inch	36 inch
Alkalinity	<0.0001	107	435	700	383	588	435	520	555	539	765
Aluminum (Al)	0.0001	205	498	429	627	137	270	561	501	554	565
Antimony (Sb)	<0.0001	113	424	719	434	763	645	555	767	799	661
Arsenic (As)	<0.0001	170	473	584	381	262	209	501	537	488	424
Barium (Ba)	0.065	252	511	476	428	210	394	409	211	399	500
Beryllium (Be)	0.024	259	500	455	540	668	340	340	340	418	415
Bismuth (Bi)	0.769	422	152	-[1]	149	-	-	149	-	-	-
Boron (B)	<0.0001	113	432	707	452	701	535	521	786	518	601
Bromide (Br)	0.978	789	491	492	480	480	480	480	480	480	480
Cadmium (Cd)	<0.0001	150	443	603	629	552	618	622	590	384	480
Calcium (Ca)	<0.0001	119	426	708	434	720	607	537	879	834	839
Cesium (Cs)	0.405	273	150	-	166	-	-	215	-	-	-
Chloride (Cl)	0.0009	297	492	464	523	399	727	531	815	867	766
Chromium (Cr)	<0.0001	110	537	381	412	371	443	323	284	273	297
Cobalt (Co)	<0.0001	194	456	599	445	447	633	643	666	648	588
Copper (Cu)	<0.0001	231	464	558	580	472	638	470	681	725	713
Dissolved Oxygen	0.021	353	483	500	526	482	896	659	580	741	692
Fluoride (F)	0.227	369	362	331	369	367	495	446	412	513	507
Iron (Fe)	<0.0001	113	472	622	423	494	110	414	367	192	192
Lead (Pb)	0.061	310	479	488	611	484	342	448	395	619	598
Lithium (Li)	<0.0001	126	435	687	438	742	560	502	850	686	747
Magnesium (Mg)	<0.0001	130	437	681	418	607	620	533	814	784	836
Manganese (Mn)	<0.0001	135	485	587	375	255	68	399	658	346	202
Mercury (Hg)	0.834	277	246	240	238	217	217	217	274	263	217
Molybdenum (Mo)	0.018	296	482	531	504	473	355	406	631	743	582
Nickel (Ni)	0.001	281	477	539	484	495	718	601	758	722	534
Nitrate (NO3)	<0.0001	166	488	457	552	564	749	606	914	939	895
Ortho-phosphate	0.005	67	63	100	86	91	53	78	72	83	103
pH	<0.0001	63	565	296	470	101	408	405	105	215	230
Phosphorus$_{total}$	<0.0001	111	460	661	367	452	516	272	455	525	351
Potassium (K)	<0.0001	120	442	687	403	508	518	528	769	666	566
Redox/Eh	<0.0001	131	425	689	511	841	678	623	906	780	760
Rubidium (Rb)	0.0003	252	494	448	518	499	784	596	922	932	850
Selenium (Se)	<0.0001	165	473	605	359	402	428	360	530	703	580
Silicate (Si)	<0.0001	179	153	-	137	-	-	57	-	-	-
Silver (Ag)	<0.0001	173	517	415	472	327	450	476	327	431	406
Sodium (Na)	<0.0001	127	434	684	491	813	571	490	754	557	624
Specific Conductivity	<0.0001	189	486	462	265	432	518	297	519	660	478
Strontium (Sr)	<0.0001	107	421	731	444	657	593	521	853	684	764
Sulfate (SO4)	<0.0001	114	422	718	429	757	598	539	873	759	800
Sulfur (S)	<0.0001	204	457	572	454	650	727	624	765	900	849
Temperature	<0.0001	152	446	648	462	893	552	639	753	463	555
Thallium (Tl)	<0.0001	152	447	635	497	462	350	614	658	613	678
Tin (Sn)	0.372	126	422	698	512	840	689	610	905	788	770
Titanium (Ti)	0.014	189	453	573	591	793	744	578	444	652	509
Total dissolved solids	<0.0001	313	489	484	559	535	527	503	666	789	567
Total organic carbon	<0.0001	179	415	460	275	362	87	241	87	440	159
Total phosphate	0.0001	239	481	522	530	442	442	506	694	648	565
Total suspended solids	<0.0001	152	480	583	429	508	193	313	381	301	267
Vanadium (V)	0.003	293	474	536	527	454	622	501	729	792	690
Zinc (Zn)	0.149	329	484	533	499	214	398	411	382	627	635
Zirconium (Zr)	0.229	168	150	-	176	-	-	79	-	-	-

[1] Insufficient sample size or no samples collected

Table D.51: Mean ranks using Kruskal-Wallis test, by chemical and well diameter for the Cambrian group. The null hypothesis was concentrations of individual chemicals did not differ by well diameter. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	4 inch	5 inch	6 inch	8 inch	12 to 16 inch	36 inch
Alkalinity	0.023	58.5	47.7	79.3	51.6	51.0	43.8	100.0
Aluminum (Al)	0.027	40.5	53.1	26.0	61.9	9.5	64.5	19.0
Antimony (Sb)	0.001	50.7	46.6	81.2	32.3	90.0	58.5	95.0
Arsenic (As)	0.126	51.0	49.1	72.4	42.9	13.0	49.2	27.5
Barium (Ba)	0.314	84.7	49.5	67.4	42.0	78.0	54.0	83.0
Beryllium (Be)	0.300	75.1	50.6	53.2	45.6	37.0	37.0	97.0
Bismuth (Bi)	0.928	139.5	22.6	-[1]	21.5	-	21.5	-
Boron (B)	0.001	43.5	47.3	88.5	51.1	25.0	38.5	87.0
Bromide (Br)	0.998	313.6	51.6	51.0	51.0	51.0	51.0	51.0
Cadmium (Cd)	0.716	79.5	51.4	54.3	45.5	20.0	45.3	20.0
Calcium (Ca)	0.046	61.5	47.9	78.8	47.6	69.0	48.7	83.0
Cesium (Cs)	0.147	37.0	21.7	-	38.5	-	25.0	-
Chloride (Cl)	0.298	80.7	51.1	46.4	53.8	100.0	71.7	13.5
Chromium (Cr)	0.013	47.5	53.8	21.8	46.2	93.0	61.5	26.0
Cobalt (Co)	0.494	80.9	49.3	66.9	41.0	43.0	44.3	64.0
Copper (Cu)	0.304	59.0	53.5	49.1	33.1	27.0	65.7	27.0
Dissolved Oxygen	0.004	51.3	52.6	20.5	62.1	92.0	82.5	64.5
Fluoride (F)	0.998	285.9	35.1	36.1	37.9	-	35.5	35.5
Iron (Fe)	0.008	45.9	51.1	73.4	40.3	3.0	16.3	97.0
Lead (Pb)	0.378	65.8	51.9	37.5	51.3	20.5	71.7	31.0
Lithium (Li)	0.000	32.7	48.2	93.0	38.9	22.0	50.8	22.0
Magnesium (Mg)	0.393	84.8	48.9	68.1	56.0	53.0	43.7	82.0
Manganese (Mn)	0.049	41.2	53.4	64.9	26.9	8.5	29.3	47.0
Mercury (Hg)	0.906	71.7	28.3	26.0	26.0	26.0	26.0	26.0
Molybdenum (Mo)	0.794	103.4	51.7	54.8	43.5	43.5	58.5	43.5
Nickel (Ni)	0.009	44.0	52.9	39.5	39.5	39.5	90.3	39.5
Nitrate (NO3)	0.091	63.3	51.6	39.5	54.2	88.0	74.8	39.5
Ortho-phosphate	0.069	14.8	12.7	-	18.2	-	22.5	-
pH	0.002	39.1	54.3	17.4	59.2	37.5	83.3	35.5
$Phosphorus_{total}$	0.070	54.5	49.8	77.5	38.3	55.0	37.3	56.0
Potassium (K)	0.001	41.7	47.0	90.1	55.1	35.0	28.7	83.0
Redox/Eh	0.853	124.4	50.6	52.9	55.6	66.5	65.0	24.0
Rubidium (Rb)	0.516	80.8	51.9	48.0	48.0	48.0	64.0	48.0
Selenium (Se)	0.528	91.2	42.9	43.5	48.5	77.0	26.8	69.5
Silicate (Si)	0.131	57.8	50.9	72.3	32.4	64.0	41.7	42.0
Silver (Ag)	0.291	82.9	50.4	49.0	37.2	65.0	64.8	98.0
Sodium (Na)	0.002	50.5	47.7	85.1	45.9	82.0	31.7	91.0
Specific Conductivity	0.011	54.1	48.0	81.8	47.9	74.0	32.7	85.0
Strontium (Sr)	0.002	47.1	47.2	87.4	51.3	57.0	34.7	83.0
Sulfate (SO4)	0.086	60.9	48.0	77.3	56.1	50.0	42.0	71.0
Sulfur (S)	0.077	60.3	47.5	76.9	61.1	50.0	45.7	67.0
Temperature	0.130	70.2	47.7	70.8	63.2	46.0	51.0	91.0
Thallium (Tl)	0.593	101.4	49.9	43.6	54.9	52.0	69.8	83.0
Tin (Sn)	0.134	18.8	23.5	-	8.5	-	4.0	-
Titanium (Ti)	0.116	55.1	52.9	42.0	42.0	42.0	75.3	42.0
Total dissolved solids	0.018	54.1	46.7	80.4	48.7	68.5	39.3	76.0
Total organic carbon	0.040	53.0	48.5	79.7	47.9	20.0	49.3	71.5
Total phosphate	0.475	54.4	38.0	46.1	31.5	13.5	32.5	13.5
Total suspended solids	0.030	51.0	49.3	70.2	49.9	31.0	12.0	88.0
Vanadium (V)	0.448	72.1	51.4	58.8	40.4	29.0	70.0	29.0
Zinc (Zn)	0.308	74.0	51.8	45.5	61.2	4.0	42.8	93.0
Zirconium (Zr)	0.795	-	22.6	-	23.5	-	-	15.5

[1] Insufficient sample size or no samples collected

Table D.52: Mean ranks using Kruskal-Wallis test, by chemical and well diameter for the Devonian group. The null hypothesis was concentrations of individual chemicals did not differ by well diameter. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	4 inch	5 inch
Alkalinity	0.383	3.0	5.8
Aluminum (Al)	0.223	2.0	5.9
Antimony (Sb)	1.000	5.5	5.5
Arsenic (As)	0.862	5.0	5.6
Barium (Ba)	0.602	7.0	5.3
Beryllium (Be)	0.856	6.0	5.4
Bismuth (Bi)	-[1]	-	-
Boron (B)	0.384	3.0	5.8
Bromide (Br)	1.000	5.0	5.0
Cadmium (Cd)	0.384	3.0	5.8
Calcium (Ca)	0.862	5.0	5.6
Cesium (Cs)	-	-	-
Chloride (Cl)	0.699	6.0	4.9
Chromium (Cr)	0.431	7.5	5.3
Cobalt (Co)	0.862	5.0	5.6
Copper (Cu)	0.384	8.0	5.2
Dissolved Oxygen	0.117	10.0	5.0
Fluoride (F)	0.115	9.0	4.5
Iron (Fe)	0.862	5.0	5.6
Lead (Pb)	0.384	8.0	5.2
Lithium (Li)	0.862	5.0	5.6
Magnesium (Mg)	0.384	5.8	3.0
Manganese (Mn)	0.862	6.0	5.4
Mercury (Hg)	0.350	3.0	5.8
Molybdenum (Mo)	0.739	5.0	5.6
Nickel (Ni)	0.433	3.5	5.7
Nitrate (NO3)	1.000	5.5	5.5
Ortho-phosphate	0.724	4.5	5.6
pH	0.861	6.0	5.4
$Phosphorus_{total}$	0.384	3.0	5.8
Potassium (K)	0.384	3.0	5.8
Redox/Eh	0.384	8.0	5.2
Rubidium (Rb)	1.000	5.5	5.5
Selenium (Se)	0.706	4.0	4.6
Silicate (Si)	0.602	4.0	5.7
Silver (Ag)	0.619	4.5	5.6
Sodium (Na)	0.117	1.0	6.0
Specific Conductivity	0.862	5.0	5.6
Strontium (Sr)	0.223	2.0	5.9
Sulfate (SO4)	0.439	3.0	5.3
Sulfur (S)	0.602	4.0	5.7
Temperature	0.287	2.5	5.8
Thallium (Tl)	0.353	3.0	5.8
Tin (Sn)	-	-	-
Titanium (Ti)	0.619	4.5	5.6
Total dissolved solids	0.245	2.0	5.4
Total organic carbon	0.117	10.0	5.0
Total phosphate	-	-	-
Total suspended solids	1.000	5.0	5.0
Vanadium (V)	0.853	6.0	5.4
Zinc (Zn)	0.384	3.0	5.8
Zirconium (Zr)	-	-	-

[1] Insufficient sample size or no samples collected

Table D.53: Mean ranks using Kruskal-Wallis test, by chemical and well diameter for the Cretaceous group. The null hypothesis was concentrations of individual chemicals did not differ by well diameter. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	4 inch	5 inch	6 inch	8 inch	12 to 16 inch	36 inch
Alkalinity	0.535	47.5	15.6	20.8	30.0	23.0	12.0	33.0
Aluminum (Al)	0.621	46.8	19.0	20.4	32.0	3.0	21.0	23.0
Antimony (Sb)	0.131	34.1	23.7	18.6	6.0	37.0	6.0	35.0
Arsenic (As)	0.357	31.7	23.1	20.0	2.0	16.0	5.0	28.0
Barium (Ba)	0.764	54.2	21.9	19.3	21.0	19.0	8.0	32.0
Beryllium (Be)	0.895	56.6	22.2	19.9	16.0	16.0	16.0	16.0
Bismuth (Bi)	-[1]	-	-	-	-	-	-	-
Boron (B)	0.717	37.2	19.7	21.4	16.0	13.0	12.0	6.0
Bromide (Br)	0.762	46.9	23.1	19.4	17.0	17.0	17.0	17.0
Cadmium (Cd)	0.827	58.0	21.9	19.4	7.5	24.5	27.0	19.5
Calcium (Ca)	0.094	37.0	11.9	21.0	33.0	36.0	32.0	26.0
Cesium (Cs)	-	-	-	-	-	-	-	-
Chloride (Cl)	0.192	36.6	25.1	17.8	4.0	35.0	21.0	31.0
Chromium (Cr)	0.008	24.8	30.7	16.2	39.0	19.0	8.0	18.0
Cobalt (Co)	0.462	42.0	13.8	21.7	31.0	27.0	18.0	17.0
Copper (Cu)	0.790	65.2	19.2	19.2	30.0	31.0	18.0	28.0
Dissolved Oxygen	0.221	41.0	14.8	20.5	38.0	35.0	13.0	28.0
Fluoride (F)	0.231	24.4	16.8	11.1	-	21.0	-	18.0
Iron (Fe)	0.035	27.9	14.1	22.1	39.0	4.0	34.0	2.0
Lead (Pb)	0.464	38.2	18.6	21.0	34.0	11.5	3.0	19.0
Lithium (Li)	0.325	40.9	23.9	18.2	27.0	32.0	4.0	29.0
Magnesium (Mg)	0.114	38.3	12.2	20.9	30.0	35.0	32.0	31.0
Manganese (Mn)	0.058	23.2	12.7	23.4	29.0	1.0	22.0	7.0
Mercury (Hg)	0.997	123.3	17.5	18.2	17.5	17.5	17.5	17.5
Molybdenum (Mo)	0.695	51.8	20.7	19.5	30.0	14.0	14.0	29.0
Nickel (Ni)	0.405	47.9	16.5	19.7	32.0	31.0	27.0	29.0
Nitrate (NO3)	0.002	25.1	25.0	17.2	16.5	37.0	16.5	39.0
Ortho-phosphate	0.280	11.5	-	4.6	9.0	-	-	4.0
pH	0.329	28.6	24.8	19.7	6.0	22.0	3.0	13.0
$Phosphorus_{total}$	0.026	19.1	10.9	24.2	27.0	9.0	11.0	6.0
Potassium (K)	0.908	66.9	21.2	19.7	25.0	8.0	24.0	20.0
Redox/Eh	0.301	45.4	21.3	18.2	20.0	39.0	19.0	38.0
Rubidium (Rb)	0.518	45.8	19.1	19.8	32.0	15.0	15.0	31.0
Selenium (Se)	0.106	27.2	29.0	17.4	8.0	26.0	16.0	17.0
Silicate (Si)	0.268	43.6	16.8	19.8	37.0	35.0	11.0	32.0
Silver (Ag)	0.002	17.2	31.9	16.8	14.0	14.0	14.0	14.0
Sodium (Na)	0.820	47.7	19.0	21.2	13.0	23.0	16.0	7.0
Specific Conductivity	0.254	36.6	15.0	21.4	26.0	33.0	27.0	2.0
Strontium (Sr)	0.068	31.2	11.0	22.2	25.0	32.0	35.0	11.0
Sulfate (SO4)	0.207	36.1	12.1	21.9	26.0	30.0	31.0	15.0
Sulfur (S)	0.236	36.6	12.3	21.9	24.0	30.0	31.0	15.0
Temperature	0.094	20.5	13.0	23.7	10.5	3.0	20.0	13.5
Thallium (Tl)	0.344	35.3	14.9	21.8	12.0	25.0	12.0	30.5
Tin (Sn)	-	-	-	-	-	-	-	-
Titanium (Ti)	0.190	36.4	16.8	20.4	36.0	14.5	14.5	34.0
Total dissolved solids	0.365	42.7	13.4	21.2	27.0	34.0	26.0	20.0
Total organic carbon	0.244	34.3	12.4	22.3	28.5	30.0	15.5	15.5
Total phosphate	0.223	17.1	12.5	17.8	-	4.5	10.0	-
Total suspended solids	0.090	26.9	14.3	22.5	31.5	3.0	27.5	3.0
Vanadium (V)	0.262	44.3	14.6	20.1	34.0	31.0	29.0	32.0
Zinc (Zn)	0.774	51.3	22.3	19.6	28.0	11.0	9.0	23.0
Zirconium (Zr)	-	-	-	-	-	-	-	-

[1] Insufficient sample size or no samples collected

Table D.54: Mean ranks using Kruskal-Wallis test, by chemical and well diameter for the Ordovician group. The null hypothesis was concentrations of individual chemicals did not differ by well diameter. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	4 inch	5 inch	6 inch	7 inch	8 inch	12 to 16 inch
Alkalinity	0.011	49.2	37.5	58.9	45.2	70.0	10.5	71.0
Aluminum (Al)	0.179	48.9	46.4	33.0	43.7	7.5	54.0	22.5
Antimony (Sb)	0.928	142.8	41.7	41.7	41.7	56.5	30.0	62.0
Arsenic (As)	0.007	41.4	36.2	56.8	41.1	2.0	27.0	78.0
Barium (Ba)	0.118	48.2	40.4	50.2	56.8	3.0	16.0	45.0
Beryllium (Be)	0.222	65.0	39.6	45.6	44.3	78.5	33.0	33.0
Bismuth (Bi)	0.819	-[1]	10.5	-	10.0	-	-	-
Boron (B)	0.011	57.8	37.9	57.7	38.0	77.5	64.0	85.0
Bromide (Br)	1.000	-	43.5	43.5	43.5	43.5	43.5	43.5
Cadmium (Cd)	0.335	74.1	37.7	48.0	47.9	27.0	72.0	54.0
Calcium (Ca)	0.025	51.2	38.4	52.4	57.0	86.0	6.0	32.0
Cesium (Cs)	0.278	-	10.2	-	16.5	-	-	-
Chloride (Cl)	0.028	40.5	47.2	30.0	60.6	38.0	27.0	28.0
Chromium (Cr)	0.328	54.3	45.2	35.1	45.9	48.0	14.0	14.0
Cobalt (Co)	0.588	95.6	42.7	42.0	33.0	54.0	57.0	73.0
Copper (Cu)	0.463	71.7	43.1	43.3	53.4	17.0	64.0	17.0
Dissolved Oxygen	0.857	119.2	44.0	43.0	45.9	25.0	72.0	37.5
Fluoride (F)	0.500	72.8	32.0	28.5	34.6	55.5	39.5	55.5
Iron (Fe)	0.089	56.4	39.3	56.9	40.7	73.0	22.0	46.0
Lead (Pb)	0.403	57.8	43.0	37.3	52.4	26.0	36.5	9.0
Lithium (Li)	0.003	52.9	36.5	59.5	42.0	77.0	58.5	87.0
Magnesium (Mg)	0.505	82.3	41.7	50.3	42.6	78.0	30.0	28.0
Manganese (Mn)	0.416	69.8	42.7	52.5	33.5	53.0	25.0	49.0
Mercury (Hg)	0.989	145.6	31.6	32.0	30.5	30.5	30.5	30.5
Molybdenum (Mo)	0.979	168.1	44.0	43.8	46.5	37.5	37.5	37.5
Nickel (Ni)	0.613	88.8	43.7	45.0	43.3	27.0	78.0	27.0
Nitrate (NO3)	0.357	61.1	44.4	39.4	55.3	32.5	32.5	32.5
Ortho-phosphate	0.003	15.7	18.7	35.6	28.7	-	17.5	-
pH	0.028	35.7	50.5	31.6	42.3	4.0	45.0	14.0
$Phosphorus_{total}$	0.017	50.5	36.8	59.1	47.5	53.0	74.0	34.5
Potassium (K)	0.193	76.7	42.2	50.2	32.2	65.0	67.0	81.0
Redox/Eh	0.372	74.4	45.6	35.4	52.6	25.0	52.5	68.0
Rubidium (Rb)	0.660	84.9	42.5	46.1	49.1	40.0	40.0	40.0
Selenium (Se)	0.140	50.4	28.4	39.8	29.3	59.5	29.5	46.5
Silicate (Si)	0.357	69.8	41.7	50.1	45.3	42.0	1.0	68.0
Silver (Ag)	0.154	44.2	46.9	34.9	36.5	30.0	30.0	30.0
Sodium (Na)	0.001	46.7	35.6	60.5	48.4	85.0	21.0	80.0
Specific Conductivity	0.056	62.3	38.8	51.5	51.7	87.0	12.0	73.0
Strontium (Sr)	0.009	54.3	37.8	59.0	37.5	80.0	48.0	81.0
Sulfate (SO4)	0.216	82.9	39.9	49.0	46.4	87.0	66.0	70.0
Sulfur (S)	0.268	85.6	40.1	48.4	46.9	87.0	59.0	71.0
Temperature	0.023	50.4	50.2	34.0	28.1	84.0	51.0	40.0
Thallium (Tl)	0.576	90.0	42.0	42.1	39.0	65.0	71.0	17.5
Tin (Sn)	0.433	-	10.7	-	6.5	-	-	-
Titanium (Ti)	0.630	90.4	43.3	43.4	48.8	31.0	73.0	31.0
Total dissolved solids	0.019	55.3	37.4	54.6	52.6	87.0	16.0	68.0
Total organic carbon	0.100	58.9	39.0	56.0	43.8	52.0	19.5	74.0
Total phosphate	0.893	67.1	19.4	20.3	26.5	19.5		10.5
Total suspended solids	0.012	46.8	37.4	59.4	45.9	79.5	29.5	29.5
Vanadium (V)	0.552	76.5	44.7	40.6	50.3	19.0	64.5	19.0
Zinc (Zn)	0.435	57.0	46.6	42.8	39.9	5.0	41.0	12.5
Zirconium (Zr)	0.620	-	10.6	-	8.5	-	-	-

[1] Insufficient sample size or no samples collected

Table D.55: Mean ranks using Kruskal-Wallis test, by chemical and well diameter for the Precambrian group. The null hypothesis was concentrations of individual chemicals did not differ by well diameter. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	4 inch	5 inch	6 inch	7 inch
Alkalinity	0.458	77.7	38.3	62.0	40.6	54.0
Aluminum (Al)	0.306	41.8	42.6	29.5	34.9	9.0
Antimony (Sb)	0.957	174.1	40.9	32.0	39.7	42.5
Arsenic (As)	0.520	86.5	40.2	47.5	38.4	73.0
Barium (Ba)	0.814	116.5	40.5	34.0	39.8	61.0
Beryllium (Be)	0.613	67.9	39.9	35.0	45.5	19.5
Bismuth (Bi)	0.672	-[1]	23.6	-	23.0	-
Boron (B)	0.534	80.4	39.9	64.5	39.8	40.0
Bromide (Br)	0.909	135.7	40.8	39.5	39.5	39.5
Cadmium (Cd)	0.139	44.2	38.6	22.5	51.1	46.5
Calcium (Ca)	0.186	62.5	37.9	61.5	47.3	66.0
Cesium (Cs)	0.403	-	24.2	-	19.7	-
Chloride (Cl)	0.864	113.9	39.9	33.0	44.7	37.0
Chromium (Cr)	0.799	87.8	41.7	32.8	37.4	26.5
Cobalt (Co)	0.890	135.5	39.6	49.5	43.4	37.0
Copper (Cu)	0.171	64.2	39.2	66.0	40.3	74.0
Dissolved Oxygen	0.258	60.1	38.4	32.3	49.5	65.0
Fluoride (F)	0.496	54.7	34.3	29.0	36.0	5.0
Iron (Fe)	0.185	43.6	42.2	53.5	33.6	3.0
Lead (Pb)	0.662	94.9	40.1	60.0	39.0	48.0
Lithium (Li)	0.201	64.0	40.5	62.5	34.9	72.0
Magnesium (Mg)	0.183	60.7	38.3	71.0	45.3	52.0
Manganese (Mn)	0.242	45.6	42.1	50.0	34.9	2.0
Mercury (Hg)	0.541	13.2	6.5	6.5	8.5	6.5
Molybdenum (Mo)	0.911	154.9	40.3	46.5	39.8	52.0
Nickel (Ni)	0.089	51.5	41.0	67.5	33.1	59.5
Nitrate (NO3)	0.034	43.8	38.9	34.0	46.4	75.0
Ortho-phosphate	1.000	-	-	-	1.5	1.5
pH	0.080	28.8	43.4	21.5	29.1	18.0
$Phosphorus_{total}$	0.735	103.3	40.8	52.5	36.5	53.0
Potassium (K)	0.196	58.6	39.2	75.0	41.7	35.0
Redox/Eh	0.309	68.0	39.1	29.5	42.7	79.0
Rubidium (Rb)	0.099	45.5	39.4	58.5	42.9	37.0
Selenium (Se)	0.145	39.4	43.0	48.5	30.1	12.5
Silicate (Si)	0.528	86.6	40.1	56.5	38.1	65.0
Silver (Ag)	0.612	72.5	41.4	50.3	36.6	20.5
Sodium (Na)	0.747	103.7	39.5	57.0	42.5	41.0
Specific Conductivity	0.162	60.4	37.4	64.5	46.1	64.0
Strontium (Sr)	0.116	57.5	38.7	77.5	42.2	55.0
Sulfate (SO4)	0.372	76.9	39.0	56.0	42.8	72.0
Sulfur (S)	0.364	76.7	39.1	56.5	42.1	73.0
Temperature	0.004	41.1	35.3	71.3	54.1	71.5
Thallium (Tl)	0.000	27.8	36.3	26.5	60.2	58.5
Tin (Sn)	0.854	-	23.7	-	22.6	-
Titanium (Ti)	0.602	87.1	41.0	44.8	36.0	62.5
Total dissolved solids	0.165	58.5	37.6	58.5	49.6	61.0
Total organic carbon	0.377	50.0	40.0	32.8	46.3	8.0
Total phosphate	0.990	422.5	39.7	39.8	38.7	-
Total suspended solids	0.163	35.3	43.1	33.0	32.4	6.0
Vanadium (V)	0.150	60.3	40.3	66.5	35.4	70.0
Zinc (Zn)	0.094	33.1	43.7	38.8	28.3	14.0
Zirconium (Zr)	0.782	-	23.3	-	24.8	-

[1] Insufficient sample size or no samples collected

Table D.56: Mean ranks using Kruskal-Wallis test, by chemical and well diameter for the buried Quaternary group. The null hypothesis was concentrations of individual chemicals did not differ by well diameter. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	4 inch	5 inch	6 inch	12 to 16 inch	24 inch	30 inch	36 inch
Alkalinity	0.000	92.0	227.3	364.3	190.3	179.5	258.5	201.5	330.5
Aluminum (Al)	0.001	226.7	252.8	234.3	401.8	455.0	457.0	298.5	308.8
Antimony (Sb)	0.000	165.5	230.6	327.4	260.5	495.0	438.0	497.0	365.2
Arsenic (As)	0.042	234.5	244.3	297.8	217.0	363.0	273.5	280.0	203.2
Barium (Ba)	0.000	68.7	278.0	200.4	153.6	136.0	60.5	117.5	301.0
Beryllium (Be)	0.071	202.0	262.2	229.0	295.2	184.5	184.5	184.5	184.5
Bismuth (Bi)	0.798	-[1]	74.0	-	73.5	-	-	-	-
Boron (B)	0.000	28.8	222.0	376.7	248.2	174.0	481.0	318.0	245.3
Bromide (Br)	0.992	864.8	255.7	253.7	249.0	249.0	249.0	249.0	249.0
Cadmium (Cd)	0.000	163.8	234.9	309.2	349.5	322.0	381.3	270.0	278.0
Calcium (Ca)	0.000	89.2	216.4	391.0	228.6	366.0	448.0	456.5	401.3
Cesium (Cs)	0.395	-	73.5	-	81.1	-	-	-	-
Chloride (Cl)	0.025	314.7	252.1	255.6	271.4	476.0	442.0	473.0	433.5
Chromium (Cr)	0.000	106.8	272.5	214.9	167.7	56.5	167.8	99.5	142.8
Cobalt (Co)	0.000	133.6	224.5	351.3	286.0	355.0	377.3	471.5	264.3
Copper (Cu)	0.000	211.7	242.4	287.6	324.7	141.0	427.5	470.5	379.7
Dissolved Oxygen	0.008	261.7	249.5	278.9	191.2	440.0	437.3	279.5	476.3
Fluoride (F)	0.487	408.9	189.5	175.9	229.3	206.5	279.0	367.0	234.5
Iron (Fe)	0.000	132.9	240.7	320.9	259.8	385.0	237.0	83.8	35.3
Lead (Pb)	0.641	422.1	249.4	263.8	318.2	288.0	259.0	263.3	314.8
Lithium (Li)	0.000	115.9	224.1	363.5	249.9	248.5	414.5	430.5	377.0
Magnesium (Mg)	0.000	110.7	221.7	375.3	218.3	378.0	391.0	435.5	398.7
Manganese (Mn)	0.000	146.4	236.1	329.1	277.6	492.0	268.5	235.0	88.8
Mercury (Hg)	0.202	122.0	124.0	111.1	125.0	106.0	106.0	106.0	106.0
Molybdenum (Mo)	0.006	224.8	245.0	289.2	278.2	166.0	299.8	473.8	309.5
Nickel (Ni)	0.001	214.7	247.0	280.4	271.5	189.5	449.8	508.0	260.5
Nitrate (NO3)	0.000	165.7	252.0	249.1	281.0	457.0	491.0	501.0	503.3
Ortho-phosphate	0.695	29.1	18.9	13.4	15.8	-	9.0	15.0	18.8
pH	0.000	49.2	293.8	134.9	257.4	7.0	90.8	29.5	113.3
Phosphorus$_{total}$	0.003	173.8	243.9	308.8	215.2	74.0	301.0	328.8	189.5
Potassium (K)	0.000	102.2	222.5	377.7	218.3	316.0	499.0	361.5	197.7
Redox/Eh	0.001	244.8	252.3	258.9	224.9	97.5	498.5	507.0	506.7
Rubidium (Rb)	0.000	176.2	248.9	272.7	297.7	226.5	350.3	495.5	226.5
Selenium (Se)	0.002	176.7	259.0	263.7	97.4	202.0	200.8	400.3	269.2
Silicate (Si)	0.000	127.2	237.3	333.8	196.5	232.0	172.5	311.0	267.7
Silver (Ag)	0.025	176.0	265.0	222.4	276.1	179.0	179.0	179.0	179.0
Sodium (Na)	0.000	121.2	226.8	353.9	280.5	251.0	467.5	334.0	251.3
Specific Conductivity	0.000	101.5	217.2	388.9	215.0	376.5	486.8	439.5	325.8
Strontium (Sr)	0.000	99.9	217.2	388.2	249.7	325.0	488.5	390.0	325.3
Sulfate (SO4)	0.000	101.9	214.0	391.9	286.9	388.0	482.5	441.0	370.0
Sulfur (S)	0.000	104.0	215.2	388.4	282.6	386.0	482.5	436.5	363.7
Temperature	0.000	102.6	227.5	361.0	223.3	197.0	414.3	239.3	220.7
Thallium (Tl)	0.000	155.4	235.4	313.6	296.1	468.0	324.3	468.0	170.5
Tin (Sn)	0.234	-	75.0	-	58.2	-	-	-	-
Titanium (Ti)	0.002	218.0	253.0	252.0	331.1	205.0	351.5	494.3	288.8
Total dissolved solids	0.000	102.9	217.0	389.3	229.3	369.0	478.0	437.3	384.0
Total organic carbon	0.000	176.3	234.3	320.7	267.3	379.0	324.3	355.5	335.3
Total phosphate	0.124	204.6	241.4	253.9	176.0		140.5	34.5	34.5
Total suspended solids	0.026	205.2	247.5	291.7	275.8	303.5	309.3	160.5	62.5
Vanadium (V)	0.000	214.8	243.1	283.7	341.0	129.5	437.3	496.5	328.2
Zinc (Zn)	0.032	233.2	245.5	289.8	285.7	31.5	193.8	408.5	335.3
Zirconium (Zr)	0.397	-	73.3	-	84.8	-	-	-	-

[1] Insufficient sample size or no samples collected

Table D.57: Mean ranks using Kruskal-Wallis test, by chemical and well diameter for the surficial Quaternary group. The null hypothesis was concentrations of individual chemicals did not differ by well diameter. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	4 inch	5 inch	6 inch	24 inch	30 inch	36 inch
Alkalinity	0.001	42.0	58.3	86.3	10.3	89.0	92.0	105.5
Aluminum (Al)	0.003	40.5	62.4	31.9	108.3	22.3	71.5	84.7
Antimony (Sb)	0.000	42.2	56.5	88.2	31.4	82.5	107.8	118.0
Arsenic (As)	0.904	111.7	62.9	58.8	42.3	62.8	57.0	54.2
Barium (Ba)	0.176	44.0	64.4	68.4	29.3	28.5	52.3	36.5
Beryllium (Be)	0.229	49.7	64.2	45.3	69.5	38.0	53.5	38.0
Bismuth (Bi)	1.000	-[1]	22.0	-	22.0	-	-	-
Boron (B)	0.007	52.2	58.3	78.2	38.5	109.0	79.3	115.3
Bromide (Br)	1.000	-	61.0	61.0	61.0	61.0	61.0	61.0
Cadmium (Cd)	0.121	61.4	58.7	70.4	100.0	73.5	48.0	78.3
Calcium (Ca)	0.000	39.4	57.1	94.0	12.8	110.5	103.0	112.3
Cesium (Cs)	0.259	-	22.5	-	17.0	-	-	-
Chloride (Cl)	0.012	51.8	58.5	81.6	32.1	86.0	96.0	104.0
Chromium (Cr)	0.021	32.0	63.8	78.1	34.8	17.5	29.3	27.8
Cobalt (Co)	0.809	111.0	59.6	73.5	63.3	73.5	57.7	77.0
Copper (Cu)	0.053	60.2	57.7	76.6	83.1	73.3	80.8	104.0
Dissolved Oxygen	0.014	46.4	58.9	92.8	46.0	42.3	105.8	55.7
Fluoride (F)	0.132	52.6	34.6	53.5	51.0	32.0	48.5	62.5
Iron (Fe)	0.063	36.7	64.6	70.4	48.8	37.0	27.5	15.8
Lead (Pb)	0.148	64.6	59.1	54.4	80.4	46.5	98.7	92.8
Lithium (Li)	0.000	46.4	56.1	90.1	57.3	116.5	81.2	116.7
Magnesium (Mg)	0.000	40.9	56.8	93.8	20.5	112.5	100.7	113.3
Manganese (Mn)	0.048	43.1	63.0	77.9	40.8	86.5	26.7	22.0
Mercury (Hg)	0.836	40.8	21.1	20.8	-	25.5	22.5	16.5
Molybdenum (Mo)	0.102	60.6	59.4	71.0	65.4	86.3	88.2	71.7
Nickel (Ni)	0.298	71.3	59.2	80.4	70.5	82.0	68.0	64.0
Nitrate (NO3)	0.000	42.1	58.6	65.5	44.5	103.5	109.7	114.7
Ortho-phosphate	0.803	11.9	-	3.5	-	2.0	3.5	4.3
pH	0.001	24.8	67.9	27.8	67.6	6.0	45.0	25.3
$Phosphorus_{total}$	0.111	42.9	64.0	70.9	16.4	39.3	55.2	47.0
Potassium (K)	0.292	72.1	59.6	77.4	43.0	77.0	79.8	88.0
Redox/Eh	0.002	50.9	58.7	62.6	42.0	112.5	111.2	115.7
Rubidium (Rb)	0.118	57.4	60.8	69.1	56.0	89.0	56.0	76.0
Selenium (Se)	0.116	51.4	61.3	79.0	19.5	71.3	70.0	50.3
Silicate (Si)	0.026	51.7	58.7	90.6	33.8	83.5	89.3	75.0
Silver (Ag)	0.515	68.8	62.3	59.8	77.1	36.5	60.2	36.5
Sodium (Na)	0.019	55.4	58.3	78.9	42.3	100.5	84.7	109.7
Specific Conductivity	0.000	40.2	57.1	96.1	21.8	80.0	104.7	113.7
Strontium (Sr)	0.000	43.0	56.2	93.4	35.8	113.5	100.0	117.0
Sulfate (SO4)	0.000	47.1	55.5	87.5	63.5	117.5	103.7	115.0
Sulfur (S)	0.000	47.2	55.6	88.0	60.5	118.5	102.0	114.0
Temperature	0.117	58.3	61.3	72.9	21.0	97.0	67.0	77.2
Thallium (Tl)	0.128	55.0	59.0	86.2	72.8	36.5	64.3	61.5
Tin (Sn)	0.231	-	21.3	-	29.0	-	-	-
Titanium (Ti)	0.703	99.7	61.2	58.9	62.4	81.8	83.7	65.7
Total dissolved solids	0.000	39.4	57.2	94.3	12.5	112.0	98.3	113.3
Total organic carbon	0.378	81.5	59.6	66.9	60.8	87.3	74.0	99.5
Total phosphate	0.139	56.5	61.1	59.8	18.1	13.0	63.0	45.5
Total suspended solids	0.162	42.1	64.4	68.9	42.8	22.8	36.0	34.8
Vanadium (V)	0.179	67.9	59.3	71.9	51.0	75.0	85.0	101.7
Zinc (Zn)	0.438	73.9	61.8	65.1	30.5	62.8	80.5	80.5
Zirconium (Zr)	0.911	-	21.9	-	22.6	-	-	-

[1] Insufficient sample size or no samples collected

Table D.58: Mean ranks using Kruskal-Wallis test, by chemical and well diameter for the CFIG-CFRN-CIGL group. The null hypothesis was concentrations of individual chemicals did not differ by well diameter. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	4 inch	5 inch	6 inch
Alkalinity	0.343	25.7	19.3	27.5	24.5
Aluminum (Al)	0.240	16.5	21.2	11.0	19.3
Antimony (Sb)	0.029	14.3	18.6	34.0	16.2
Arsenic (As)	0.606	31.9	19.8	24.5	16.0
Barium (Ba)	0.506	31.0	19.6	26.5	22.7
Beryllium (Be)	0.169	14.0	21.3	14.0	14.0
Bismuth (Bi)	0.803	-[1]	9.0	-	8.5
Boron (B)	0.012	14.8	18.0	34.0	30.0
Bromide (Br)	1.000	-	20.5	20.5	20.5
Cadmium (Cd)	0.471	26.9	19.6	26.0	16.5
Calcium (Ca)	0.260	23.3	19.2	28.5	24.7
Cesium (Cs)	-	-	8.8	-	13.0
Chloride (Cl)	0.917	80.3	20.2	22.6	21.3
Chromium (Cr)	0.007	8.1	22.4	3.5	16.8
Cobalt (Co)	0.163	18.5	19.1	30.0	16.0
Copper (Cu)	0.378	20.9	21.2	20.8	12.5
Dissolved Oxygen	0.050	10.8	22.4	7.6	17.0
Fluoride (F)	0.592	25.9	14.1	17.8	18.0
Iron (Fe)	0.430	28.7	19.4	25.8	25.7
Lead (Pb)	0.137	13.7	21.4	9.4	19.2
Lithium (Li)	0.010	13.3	18.8	37.0	17.0
Magnesium (Mg)	0.627	37.0	19.8	22.0	26.3
Manganese (Mn)	0.702	37.7	20.6	23.5	16.0
Mercury (Hg)	0.675	22.3	11.9	10.5	10.5
Molybdenum (Mo)	0.596	31.5	20.5	23.1	17.5
Nickel (Ni)	0.362	20.1	21.4	16.5	16.5
Nitrate (NO3)	0.420	22.0	21.2	17.0	17.0
Ortho-phosphate	-	-	6.1	-	5.5
pH	0.012	8.6	22.8	4.9	16.0
$Phosphorus_{total}$	0.327	24.0	19.6	28.8	19.2
Potassium (K)	0.003	13.4	17.7	37.0	29.7
Redox/Eh	0.360	20.8	21.1	22.5	11.3
Rubidium (Rb)	0.716	37.6	20.8	19.0	19.0
Selenium (Se)	0.517	29.0	18.2	13.8	23.3
Silicate (Si)	0.468	23.3	21.3	19.8	12.7
Silver (Ag)	0.614	31.6	20.0	23.5	15.5
Sodium (Na)	0.106	18.0	19.2	32.3	19.3
Specific Conductivity	0.187	21.3	19.0	29.5	25.0
Strontium (Sr)	0.025	15.7	18.3	33.8	27.3
Sulfate (SO4)	0.301	24.7	19.2	27.0	26.3
Sulfur (S)	0.144	20.5	18.9	27.0	30.0
Temperature	0.239	22.9	19.1	28.1	26.0
Thallium (Tl)	0.139	13.2	21.5	11.5	15.5
Tin (Sn)	-	-	9.3	-	4.0
Titanium (Ti)	0.362	20.1	21.4	16.5	16.5
Total dissolved solids	0.184	20.4	18.6	29.5	22.3
Total organic carbon	0.161	20.2	19.1	30.8	22.5
Total phosphate	0.968	101.5	15.2	14.4	14.0
Total suspended solids	0.265	22.9	18.7	27.5	24.3
Vanadium (V)	0.274	21.5	19.9	28.3	16.3
Zinc (Zn)	0.255	21.3	20.3	15.0	29.7
Zirconium (Zr)	-	-	8.8	11.5	-

[1] Insufficient sample size or no samples collected

Table D.59: Mean ranks using Kruskal-Wallis test, by chemical and well diameter for the OSTP-OPDC-CJDN group. The null hypothesis was concentrations of individual chemicals did not differ by well diameter. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	4 inch	5 inch	6 inch	8 inch	12 to 16 inch
Alkalinity	0.034	34.1	42.5	66.0	42.9	16.5	37.7
Aluminum (Al)	0.009	32.8	47.0	21.0	53.8	52.0	56.8
Antimony (Sb)	0.095	42.1	40.4	61.0	43.8	33.5	50.8
Arsenic (As)	0.020	36.1	39.1	64.1	51.4	32.0	51.5
Barium (Ba)	0.447	57.8	44.4	57.2	36.4	37.0	44.0
Beryllium (Be)	0.287	47.8	42.8	53.3	42.2	35.5	35.5
Bismuth (Bi)	0.959	130.5	13.5	-	13.0	-	13.0
Boron (B)	0.000	29.5	42.2	72.8	28.4	73.0	31.3
Bromide (Br)	1.000	-[1]	45.5	45.5	45.5	45.5	45.5
Cadmium (Cd)	0.370	62.8	45.1	36.4	49.1	80.0	32.3
Calcium (Ca)	0.012	30.8	42.1	67.7	46.0	11.0	33.7
Cesium (Cs)	0.471	37.3	13.3	-	22.0	-	10.5
Chloride (Cl)	0.449	61.9	45.5	37.0	58.6	36.5	55.5
Chromium (Cr)	0.187	46.2	44.1	36.1	57.4	10.0	60.8
Cobalt (Co)	0.777	90.1	42.2	52.0	44.2	53.0	45.7
Copper (Cu)	0.353	61.3	47.2	34.6	41.9	71.0	54.8
Dissolved Oxygen	0.232	59.0	44.8	36.7	55.9	66.0	68.7
Fluoride (F)	0.528	44.8	31.4	22.0	28.9	34.0	29.0
Iron (Fe)	0.004	26.1	45.3	65.2	23.4	33.0	20.5
Lead (Pb)	0.071	40.5	45.0	28.9	59.9	32.0	60.3
Lithium (Li)	0.001	29.7	41.9	72.5	28.4	69.5	39.5
Magnesium (Mg)	0.330	51.6	43.6	59.4	42.7	34.0	37.0
Manganese (Mn)	0.002	26.1	43.7	69.9	25.1	33.0	30.3
Mercury (Hg)	0.895	76.5	31.0	29.5	29.5	29.5	29.5
Molybdenum (Mo)	0.361	53.4	46.9	40.0	40.0	40.0	53.7
Nickel (Ni)	0.083	51.1	45.7	37.0	43.8	84.0	68.7
Nitrate (NO3)	0.049	39.3	45.3	34.8	63.7	30.5	58.8
Ortho-phosphate	0.190	34.5	20.7	34.3	31.8	23.0	30.8
pH	0.002	31.1	47.9	21.4	55.8	37.0	75.2
$Phosphorus_{total}$	0.037	44.2	42.4	63.5	40.1	85.0	35.7
Potassium (K)	0.002	30.7	43.5	68.7	26.6	72.0	24.0
Redox/Eh	0.482	65.4	45.1	38.5	61.1	50.0	45.7
Rubidium (Rb)	0.556	68.7	44.8	45.3	48.6	42.0	56.0
Selenium (Se)	0.048	28.0	29.5	45.6	23.7	30.5	20.3
Silicate (Si)	0.076	37.2	43.3	61.6	45.3	1.0	40.3
Silver (Ag)	0.354	52.2	45.4	36.7	38.8	28.0	60.8
Sodium (Na)	0.002	28.1	41.7	72.6	39.3	40.0	27.0
Specific Conductivity	0.067	33.4	45.1	60.4	35.6	19.5	21.5
Strontium (Sr)	0.000	27.2	42.3	73.9	29.9	61.0	24.7
Sulfate (SO4)	0.006	34.3	43.0	67.3	34.8	75.0	21.7
Sulfur (S)	0.014	36.0	42.7	66.8	38.1	68.0	24.7
Temperature	0.999	352.6	45.5	46.4	43.8	40.5	47.7
Thallium (Tl)	0.550	76.7	42.4	42.6	55.9	67.0	53.3
Tin (Sn)	0.500	25.2	14.0	-	8.0	-	8.0
Titanium (Ti)	0.103	50.9	45.8	38.7	42.4	80.5	63.7
Total dissolved solids	0.025	32.5	42.3	65.9	41.8	28.0	27.3
Total organic carbon	0.310	48.9	44.6	58.1	34.7	29.0	41.3
Total phosphate	0.312	29.9	21.2	29.3	18.8	-	17.5
Total suspended solids	0.001	25.5	41.9	70.5	41.0	35.5	14.0
Vanadium (V)	0.474	69.1	46.6	37.8	40.4	67.5	60.2
Zinc (Zn)	0.453	52.8	48.2	35.1	46.2	38.0	32.0
Zirconium (Zr)	0.783	48.9	13.7	-	11.0	-	11.0

[1] Insufficient sample size or no samples collected

Table D.60: Mean ranks using Kruskal-Wallis test, by chemical and well diameter for the CMSH-CMTS-PMHN group. The null hypothesis was concentrations of individual chemicals did not differ by well diameter. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	4 inch	5 inch	8 inch	36 inch
Alkalinity	0.225	33.3	12.4	20.0	19.0	26.0
Aluminum (Al)	0.243	22.9	13.9	22.0	3.0	6.0
Antimony (Sb)	0.201	28.7	13.0	5.0	22.0	24.0
Arsenic (As)	0.533	23.3	14.3	10.0	5.0	8.0
Barium (Ba)	0.560	43.2	12.8	16.0	19.0	22.0
Beryllium (Be)	0.146	27.5	12.9	21.5	9.0	-
Bismuth (Bi)	1.000	-[1]	9.0	9.0	-	-
Boron (B)	0.240	30.2	13.0	22.0	6.0	24.0
Bromide (Br)	0.988	127.0	13.6	13.0	13.0	13.0
Cadmium (Cd)	0.708	32.0	14.0	9.5	9.5	9.5
Calcium (Ca)	0.321	36.0	12.5	19.0	20.0	24.0
Cesium (Cs)	0.072	-	8.5	16.5	-	-
Chloride (Cl)	0.184	28.1	13.1	21.0	25.0	4.0
Chromium (Cr)	0.319	26.5	13.7	4.0	23.0	9.0
Cobalt (Co)	0.949	79.5	13.5	11.0	12.0	17.0
Copper (Cu)	0.596	25.9	14.2	8.5	8.5	8.5
Dissolved Oxygen	0.392	36.7	12.8	13.5	25.0	19.0
Fluoride (F)	0.881	68.5	10.8	11.0	-	14.0
Iron (Fe)	0.234	24.8	13.7	12.0	1.0	23.0
Lead (Pb)	0.703	31.3	14.1	7.5	7.5	12.0
Lithium (Li)	0.505	30.2	13.7	20.0	7.5	7.5
Magnesium (Mg)	0.321	36.0	12.5	20.0	19.0	24.0
Manganese (Mn)	0.243	15.8	14.5	5.5	1.5	10.0
Mercury (Hg)	1.000	-	4.5	-	4.5	4.5
Molybdenum (Mo)	0.899	55.1	13.8	11.5	11.5	11.5
Nickel (Ni)	0.858	47.0	13.8	11.0	11.0	11.0
Nitrate (NO3)	0.214	26.0	13.3	11.0	24.0	11.0
Ortho-phosphate	-	-	-	-	-	-
pH	0.924	65.7	13.6	16.5	11.0	10.0
$Phosphorus_{total}$	0.934	68.3	13.7	16.0	10.0	11.0
Potassium (K)	0.226	31.3	12.8	25.0	9.0	23.0
Redox/Eh	0.717	40.6	13.6	10.0	19.5	8.0
Rubidium (Rb)	0.935	66.7	13.7	12.0	12.0	12.0
Selenium (Se)	0.585	41.2	13.1	10.0	22.0	18.0
Silicate (Si)	0.394	21.8	14.2	2.0	14.0	8.0
Silver (Ag)	0.190	28.2	12.9	9.5	19.0	25.0
Sodium (Na)	0.238	34.0	12.4	22.0	21.0	23.0
Specific Conductivity	0.303	35.7	12.5	20.0	21.0	23.0
Strontium (Sr)	0.386	37.1	12.7	23.0	14.0	22.0
Sulfate (SO4)	0.333	36.4	12.5	23.0	19.0	21.0
Sulfur (S)	0.334	36.5	12.5	23.0	19.0	21.0
Temperature	0.331	35.8	12.6	16.0	20.0	25.0
Thallium (Tl)	0.136	29.4	12.5	20.0	18.5	26.0
Tin (Sn)	0.215	-	9.4	3.0	-	-
Titanium (Ti)	0.812	40.8	13.9	10.5	10.5	10.5
Total dissolved solids	0.267	34.8	12.4	22.0	20.0	23.0
Total organic carbon	0.466	33.7	13.4	17.0	5.0	21.5
Total phosphate	0.370	21.6	14.2	15.5	4.5	4.5
Total suspended solids	0.444	32.9	13.4	17.0	5.0	21.5
Vanadium (V)	0.638	34.8	13.7	18.5	8.5	8.5
Zinc (Zn)	0.207	25.3	13.6	9.0	4.0	26.0
Zirconium (Zr)	0.527	-	9.2	6.5	-	-

[1] Insufficient sample size or no samples collected

Table D.61: Mean ranks using Kruskal-Wallis test, by chemical and well diameter for the Upper Carbonate group. The null hypothesis was concentrations of individual chemicals did not differ by well diameter. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	4 inch	5 inch	6 inch	7 inch	12 to 16 inch
Alkalinity	0.031	25.3	21.6	35.6	25.3	47.5	50.0
Aluminum (Al)	0.169	22.6	34.2	33.3	30.8	6.0	14.5
Antimony (Sb)	0.109	32.5	34.8	28.3	29.7	50.5	54.5
Arsenic (As)	0.003	18.3	33.8	35.6	19.2	1.5	52.5
Barium (Ba)	0.075	19.9	35.3	32.4	33.0	1.5	12.5
Beryllium (Be)	0.032	24.1	24.5	33.3	31.3	57.0	22.5
Bismuth (Bi)	-[1]	-	2.5	-	-	-	-
Boron (B)	0.050	28.5	24.4	33.6	26.3	47.5	58.5
Bromide (Br)	1.000	-	30.0	30.0	30.0	30.0	30.0
Cadmium (Cd)	0.050	18.5	26.1	37.7	25.0	11.5	23.5
Calcium (Ca)	0.112	29.8	29.2	30.6	34.2	61.5	16.5
Cesium (Cs)	-	-	2.5	-	-	-	-
Chloride (Cl)	0.003	18.0	42.5	23.2	41.0	30.5	21.5
Chromium (Cr)	0.100	27.4	27.6	30.0	38.8	51.5	17.5
Cobalt (Co)	0.003	22.7	40.7	29.9	18.7	48.5	58.5
Copper (Cu)	0.041	18.7	35.2	30.9	37.6	6.0	6.0
Dissolved Oxygen	0.756	48.9	30.0	30.6	37.1	22.0	32.5
Fluoride (F)	0.010	24.5	22.2	26.5	35.5	53.5	53.5
Iron (Fe)	0.181	27.4	26.2	35.1	28.2	45.5	12.5
Lead (Pb)	0.139	23.3	26.8	32.4	39.3	24.5	8.0
Lithium (Li)	0.023	26.6	21.9	33.6	28.6	48.5	60.5
Magnesium (Mg)	0.225	32.7	34.4	31.5	26.2	55.5	20.5
Manganese (Mn)	0.070	24.2	42.6	30.6	21.7	34.5	30.5
Mercury (Hg)	0.178	23.3	25.0	31.3	25.0	25.0	25.0
Molybdenum (Mo)	0.702	43.7	32.6	30.7	34.9	24.0	24.0
Nickel (Ni)	0.244	25.2	35.4	33.6	26.6	16.5	16.5
Nitrate (NO3)	0.145	25.5	27.5	31.3	37.8	27.5	27.5
Ortho-phosphate	0.055	9.7	16.1	29.2	21.6	-	-
pH	0.030	18.2	39.0	30.6	34.4	3.5	8.5
$Phosphorus_{total}$	0.002	13.5	25.2	39.9	20.3	23.5	8.5
Potassium (K)	0.216	35.5	27.3	32.0	28.5	43.5	56.5
Redox/Eh	0.050	27.7	29.1	27.1	41.5	35.5	55.5
Rubidium (Rb)	0.589	39.5	28.5	32.1	34.0	28.5	28.5
Selenium (Se)	0.042	23.3	22.0	24.4	25.4	46.5	38.5
Silicate (Si)	0.169	28.1	38.6	31.6	23.8	17.5	44.5
Silver (Ag)	0.002	16.5	42.1	29.3	27.5	27.5	27.5
Sodium (Na)	0.005	23.4	18.7	34.6	29.0	57.5	53.5
Specific Conductivity	0.041	29.4	25.2	29.9	34.5	61.5	50.5
Strontium (Sr)	0.014	25.4	27.9	34.0	20.7	54.5	56.5
Sulfate (SO4)	0.039	28.7	28.5	27.1	36.7	60.5	46.5
Sulfur (S)	0.030	28.7	29.7	27.2	37.2	61.5	49.5
Temperature	0.034	27.9	38.3	28.8	24.7	59.5	45.5
Thallium (Tl)	0.119	27.9	35.1	31.9	26.0	54.0	13.0
Tin (Sn)	-	-	2.5	-	-	-	-
Titanium (Ti)	0.593	37.2	31.0	31.7	35.3	20.5	20.5
Total dissolved solids	0.032	27.4	22.2	32.0	30.3	60.5	47.5
Total organic carbon	0.121	26.0	25.7	36.2	23.9	23.5	45.5
Total phosphate	0.040	6.5	6.8	11.5	-	5.5	1.5
Total suspended solids	0.064	24.5	27.3	34.6	24.8	53.5	12.5
Vanadium (V)	0.269	26.4	33.2	31.2	36.3	14.0	14.0
Zinc (Zn)	0.188	23.1	30.3	34.2	32.2	5.5	17.5
Zirconium (Zr)	0.291	82.9	2.5	-	-	-	-

[1] Insufficient sample size or no samples collected

Table D.62: Mean ranks using Mann-Whitney test comparing concentrations of individual chemicals in wells containing a detectable volatile organic compound and those without a detected VOC. The null hypothesis was concentrations of individual chemicals did not differ between wells with and without a VOC detected. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	Wells containing a detectable VOC	Wells not containing a detectable VOC
Alkalinity	0.045	442	499
Aluminum (Al)	0.004	563	481
Antimony (Sb)	0.827	485	491
Arsenic (As)	0.713	481	491
Barium (Ba)	0.003	419	505
Beryllium (Be)	0.908	488	491
Bismuth (Bi)	0.421	149	152
Boron (B)	0.064	448	502
Bromide (Br)	0.245	498	490
Cadmium (Cd)	0.156	457	495
Calcium (Ca)	0.973	496	495
Cesium (Cs)	0.005	187	148
Chloride (Cl)	0.019	554	487
Chromium (Cr)	0.825	485	491
Cobalt (Co)	0.790	497	490
Copper (Cu)	0.014	555	488
Dissolved Oxygen	0.007	564	487
Fluoride (F)	0.114	397	356
Iron (Fe)	0.840	490	496
Lead (Pb)	0.0002	586	478
Lithium (Li)	0.225	465	499
Magnesium (Mg)	0.435	476	498
Manganese (Mn)	0.683	506	494
Mercury (Hg)	0.181	255	241
Molybdenum (Mo)	0.180	468	499
Nickel (Ni)	0.792	490	496
Nitrate (NO3)	0.004	544	489
Ortho-phosphate	0.683	78	83
pH	0.093	452	500
$Phosphorus_{total}$	0.709	486	497
Potassium (K)	0.817	490	496
Redox/Eh	0.023	552	487
Rubidium (Rb)	0.094	518	493
Selenium (Se)	0.523	455	472
Silicate (Si)	0.478	477	498
Silver (Ag)	0.389	472	493
Sodium (Na)	0.909	498	495
Specific Conductivity	0.403	473	497
Strontium (Sr)	0.568	497	481
Sulfate (SO4)	0.331	519	491
Sulfur (S)	0.351	519	492
Temperature	0.571	509	493
Thallium (Tl)	0.066	532	485
Tin (Sn)	0.541	161	151
Titanium (Ti)	0.829	491	496
Total dissolved solids	0.591	480	495
Total organic carbon	0.786	487	495
Total phosphate	0.164	382	417
Total suspended solids	0.498	511	491
Vanadium (V)	0.632	507	494
Zinc (Zn)	0.295	469	499
Zirconium (Zr)	0.174	171	149

Table D.63: Summary of significant results comparing water quality parameter concentrations in wells with and without a VOC detection.

Aquifer Group	Parameters with greater concentrations in wells with a VOC detected	Parameters with lower concentrations in wells with a VOC detected
Cretaceous	Cu, Pb	-
Ordovician	Nitrate, pH	Fe, Mn, Sr, total organic carbon, total phosphate, total suspended solids
Precambrian	Al, Fe, Pb, total suspended solids	-
buried Quaternary	-	Cr, Cs, dissolved oxygen, nitrate, oxidation-reduction potential
surficial Quaternary	Ba, Zn	Hg, oxidation-reduction potential, Tl
Upper Carbonate	Alkalinity, Ca, K, specific conductivity, Sr, total dissolved solids, total organic carbon	-
OSTP-OPDC-CJDN	Cr, Si	-

Table D.64: Mean ranks using Mann-Whitney test comparing concentrations of individual chemicals in wells containing detectable tritium and those with no tritium detected. The null hypothesis was concentrations of individual chemicals did not differ between wells with or without detectable tritium. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	Wells containing detectable tritium	Wells not containing detectable tritium
Alkalinity	0.011	110	133
Aluminum (Al)	0.009	123	100
Antimony (Sb)	0.100	119	105
Arsenic (As)	0.968	114	114
Barium (Ba)	0.923	119	118
Beryllium (Be)	0.707	115	112
Bismuth (Bi)	0.205	59	57
Boron (B)	0.0002	106	140
Bromide (Br)	0.744	118	119
Cadmium (Cd)	0.985	114	114
Calcium (Ca)	0.543	117	122
Cesium (Cs)	0.958	58	59
Chloride (Cl)	< 0.001	147	74
Chromium (Cr)	0.003	124	98
Cobalt (Co)	0.795	115	113
Copper (Cu)	0.198	123	112
Dissolved Oxygen	0.008	128	104
Fluoride (F)	0.191	80	90
Iron (Fe)	0.011	110	133
Lead (Pb)	0.400	117	109
Lithium (Li)	0.284	115	125
Magnesium (Mg)	0.015	110	133
Manganese (Mn)	0.029	111	131
Mercury (Hg)	0.356	39	38
Molybdenum (Mo)	0.044	114	127
Nickel (Ni)	0.670	118	121
Nitrate (NO3)	< 0.001	134	95
Ortho-phosphate	0.175	35	29
pH	0.238	114	125
$\text{Phosphorus}_{\text{total}}$	0.089	113	129
Potassium (K)	0.005	109	135
Redox/Eh	0.094	124	109
Rubidium (Rb)	0.395	117	121
Selenium (Se)	0.884	99	98
Silicate (Si)	0.004	129	103
Silver (Ag)	0.059	120	104
Sodium (Na)	0.342	116	124
Specific Conductivity	0.227	114	125
Strontium (Sr)	0.002	108	137
Sulfate (SO4)	0.161	124	111
Sulfur (S)	0.275	123	113
Temperature	0.256	115	125
Thallium (Tl)	0.024	121	103
Tin (Sn)	0.350	56	62
Titanium (Ti)	0.583	121	116
Total dissolved solids	0.958	118	119
Total organic carbon	0.819	120	118
Total phosphate	0.013	80	99
Total suspended solids	0.032	111	131
Vanadium (V)	0.726	120	117
Zinc (Zn)	0.164	114	127
Zirconium (Zr)	0.139	62	53

Table D.65: Summary of significant results comparing water quality parameter concentrations in wells with and without detectable tritium.

Aquifer Group	Parameters with greater concentrations in wells with tritium detected	Parameters with lower concentrations in wells with no tritium detected
Cambrian	Cl, Cr, dissolved oxygen, nitrate, Si	Mn
Ordovician	Ag, As, Cl, Co, nitrate, Si, total dissolved solids, Tl	B, K, Li, Sr, Ti
Precambrian	S, sulfate	alkalinity, specific conductivity
buried Quaternary	Cl, nitrate, Tl	alkalinity, B, K, Mg, Mo, Na, N, phosphorus, Sr
CFIG-CFRN-CIGL	Cl, dissolved oxygen, nitrate	Be, Fe, Mn
OSTP-OPDC-CJDN	alkalinity, Ca, Cl, Cr, Mg, nitrate, Sb, Si, total dissolved solids	B, Mn, Mo, Ti
CMSH-CMTS-PMHN	Cr, dissolved oxygen, nitrate, sulfate	Al
Upper Carbonate	Cl	total suspended solids

Table D.66: Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in Cambrian wells for different sampling years. The null hypothesis was concentrations of individual chemicals did not differ by sampling year. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	1992	1993	1994	1995	1996
Alkalinity	0.000	9.8	45.8	67.3	74.8	15.6	51.3
Aluminum (Al)	0.000	8.3	57.0	31.4	17.0	56.1	69.3
Antimony (Sb)	0.040	17.4	44.3	65.6	56.8	44.9	44.1
Arsenic (As)	0.000	12.2	32.0	52.5	72.9	35.5	58.0
Barium (Ba)	0.013	16.0	34.6	58.5	69.5	47.0	52.4
Beryllium (Be)	0.378	25.8	42.5	54.2	48.3	48.1	54.5
Bismuth (Bi)	0.354	15.9	-[1]	-	-	21.5	22.9
Boron (B)	0.000	12.4	29.9	63.0	71.9	42.9	53.1
Bromide (Br)	0.457	28.5	51.0	53.3	51.0	51.0	51.0
Cadmium (Cd)	0.005	13.5	59.7	57.6	31.7	33.1	54.7
Calcium (Ca)	0.000	10.0	37.7	64.4	75.5	19.7	55.9
Cesium (Cs)	0.075	7.9	-	-	-	17.5	24.6
Chloride (Cl)	0.019	15.7	42.5	42.5	40.5	61.7	62.4
Chromium (Cr)	0.000	12.9	60.0	38.7	81.0	45.0	44.2
Cobalt (Co)	0.011	14.5	36.3	52.9	54.3	36.4	61.7
Copper (Cu)	0.055	17.3	53.7	52.4	29.6	51.8	57.2
Dissolved Oxygen	0.000	11.3	78.8	38.4	56.6	57.3	39.7
Fluoride (F)	0.044	14.6	39.3	37.4	48.9	24.9	28.6
Iron (Fe)	0.002	13.9	35.0	60.7	74.5	41.6	51.2
Lead (Pb)	0.001	12.2	72.3	50.3	27.1	43.2	49.7
Lithium (Li)	0.001	12.6	31.7	68.7	53.4	44.0	54.4
Magnesium (Mg)	0.000	10.4	49.6	62.5	74.3	15.5	52.3
Manganese (Mn)	0.000	11.1	23.8	51.4	58.4	53.9	64.5
Mercury (Hg)	0.284	23.3	26.0	27.3	30.4	-	26.0
Molybdenum (Mo)	0.535	31.0	48.3	48.6	51.0	58.5	52.5
Nickel (Ni)	0.009	15.1	64.2	49.4	39.5	58.8	46.7
Nitrate (NO3)	0.014	15.8	64.7	48.7	43.5	57.7	45.8
Ortho-phosphate	0.391	15.0	13.4	15.9	-	-	-
pH	0.000	10.2	66.5	24.9	44.0	50.3	63.0
Phosphorustotal	0.000	10.0	19.8	57.4	79.8	54.3	55.2
Potassium (K)	0.000	10.0	21.8	65.6	71.8	41.6	56.8
Redox/Eh	0.000	9.3	78.3	59.6	20.0	58.4	38.7
Rubidium (Rb)	0.656	35.0	50.7	52.6	48.0	55.4	50.9
Selenium (Se)	0.000	10.5	39.0	49.5	70.7	53.4	26.7
Silicate (Si)	0.041	17.6	33.1	55.0	54.6	59.7	55.7
Silver (Ag)	0.028	15.7	48.0	46.0	46.2	37.7	61.9
Sodium (Na)	0.000	9.4	18.0	62.0	77.9	45.8	57.5
Specific Conductivity	0.000	9.4	33.6	68.9	76.3	21.1	54.5
Strontium (Sr)	0.000	9.3	21.7	65.0	80.8	37.6	55.7
Sulfate (SO4)	0.000	12.3	46.4	67.8	63.6	24.6	50.7
Sulfur (S)	0.001	12.5	48.6	66.8	63.8	24.1	50.2
Temperature	0.011	14.6	49.6	55.2	48.8	27.8	60.9
Thallium (Tl)	0.000	8.9	65.7	42.3	30.3	26.1	65.0
Tin (Sn)	0.616	30.3	24.0	21.9	-	-	-
Titanium (Ti)	0.071	18.8	52.6	49.0	42.0	64.1	50.7
Total dissolved solids	0.000	9.9	34.6	66.3	73.0	21.7	52.6
Total organic carbon	0.010	15.6	63.7	61.5	57.3	38.0	41.4
Total phosphate	0.224	19.3	38.6	48.6	38.6	33.7	4.4
Total suspended solids	0.037	18.0	40.5	54.0	71.2	53.8	44.9
Vanadium (V)	0.002	12.9	42.4	52.6	29.0	55.9	62.3
Zinc (Zn)	0.000	11.9	75.3	56.0	47.6	31.2	44.4
Zirconium (Zr)	0.523	23.8	-	-	-	24.1	21.8

[1] Insufficient sample size or no samples collected

Table D.67: Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in Devonian wells for different sampling years. The null hypothesis was concentrations of individual chemicals did not differ by sampling year. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	1992	1993
Alkalinity	0.089	4.4	2.3	6.3
Aluminum (Al)	0.794	34.5	6.0	5.4
Antimony (Sb)	0.353	8.5	3.8	5.9
Arsenic (As)	0.296	7.4	3.5	6.0
Barium (Ba)	0.794	34.5	6.0	5.4
Beryllium (Be)	0.495	11.8	5.3	5.8
Bismuth (Bi)	-[1]	-	-	-
Boron (B)	0.068	4.1	2.0	6.4
Bromide (Br)	1.000	-	5.0	5.0
Cadmium (Cd)	0.602	17.9	6.5	5.3
Calcium (Ca)	0.296	7.4	3.5	6.0
Cesium (Cs)	-	-	-	-
Chloride (Cl)	0.143	6.7	7.5	4.3
Chromium (Cr)	0.104	6.6	8.3	4.8
Cobalt (Co)	0.192	5.8	3.0	6.1
Copper (Cu)	1.000	-	5.5	5.5
Dissolved Oxygen	0.117	6.9	8.5	4.8
Fluoride (F)	0.137	6.6	7.5	4.3
Iron (Fe)	0.433	10.2	4.0	5.9
Lead (Pb)	0.117	6.9	8.5	4.8
Lithium (Li)	0.192	5.8	3.0	6.1
Magnesium (Mg)	0.117	4.8	2.5	6.3
Manganese (Mn)	0.602	17.9	6.5	5.3
Mercury (Hg)	0.161	5.4	3.0	6.1
Molybdenum (Mo)	0.617	16.8	5.0	5.6
Nickel (Ni)	0.239	6.6	3.5	6.0
Nitrate (NO3)	1.000	-	5.5	5.5
Ortho-phosphate	0.895	64.4	5.3	5.6
pH	0.600	17.8	6.5	5.3
Phosphorustotal	0.794	32.2	5.0	5.6
Potassium (K)	0.117	4.8	2.5	6.3
Redox/Eh	0.117	6.9	8.5	4.8
Rubidium (Rb)	1.000	-	5.5	5.5
Selenium (Se)	0.706	24.3	4.0	4.6
Silicate (Si)	0.117	4.8	2.5	6.3
Silver (Ag)	0.352	10.2	6.8	5.2
Sodium (Na)	0.068	4.1	2.0	6.4
Specific Conductivity	0.296	7.4	3.5	6.0
Strontium (Sr)	0.036	3.6	1.5	6.5
Sulfate (SO4)	1.000	-	5.0	5.0
Sulfur (S)	1.000	-	5.5	5.5
Temperature	0.690	20.8	4.8	5.7
Thallium (Tl)	0.164	5.5	3.0	6.1
Tin (Sn)	-	-	-	-
Titanium (Ti)	0.456	11.0	4.5	5.8
Total dissolved solids	0.143	4.8	2.5	5.7
Total organic carbon	0.296	9.6	7.5	5.0
Total phosphate	-	-	-	-
Total suspended solids	0.550	12.6	4.0	5.3
Vanadium (V)	0.578	14.7	4.5	5.8
Zinc (Zn)	1.000	-	5.5	5.5
Zirconium (Zr)	-	-	-	-

[1] Insufficient sample size or no samples collected

Table D.68: Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in Cretaceous wells for different sampling years. The null hypothesis was concentrations of individual chemicals did not differ by sampling year. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	1993	1994	1995
Alkalinity	0.856	46.0	20.4	18.1	21.3
Aluminum (Al)	0.559	26.1	18.9	21.4	25.0
Antimony (Sb)	0.666	28.9	20.4	17.2	23.0
Arsenic (As)	0.872	51.1	19.6	20.1	22.8
Barium (Ba)	0.052	10.5	19.4	26.8	10.1
Beryllium (Be)	0.035	11.5	18.9	18.9	29.9
Bismuth (Bi)	-[1]	-	-	-	-
Boron (B)	0.049	12.4	19.3	16.1	32.8
Bromide (Br)	0.010	9.8	17.7	24.5	26.5
Cadmium (Cd)	0.068	12.4	20.3	14.1	29.8
Calcium (Ca)	0.001	5.6	24.6	8.4	12.3
Cesium (Cs)	-	-	-	-	-
Chloride (Cl)	0.035	12.4	17.3	23.0	32.3
Chromium (Cr)	0.000	8.0	14.7	30.6	34.3
Cobalt (Co)	0.020	7.7	23.4	13.4	10.5
Copper (Cu)	0.586	23.0	21.2	17.8	16.3
Dissolved Oxygen	0.012	7.7	21.8	22.0	3.9
Fluoride (F)	0.005	7.2	12.7	7.8	24.0
Iron (Fe)	0.089	10.6	22.5	12.5	18.3
Lead (Pb)	0.367	19.5	18.4	24.9	20.9
Lithium (Li)	0.001	8.8	20.2	11.1	36.5
Magnesium (Mg)	0.001	6.0	24.3	8.8	13.3
Manganese (Mn)	0.024	8.2	23.2	11.3	15.6
Mercury (Hg)	0.586	26.4	18.2	17.5	0.3
Molybdenum (Mo)	0.557	24.0	20.4	17.1	22.8
Nickel (Ni)	0.140	11.9	22.0	14.2	18.1
Nitrate (NO3)	0.836	44.2	19.5	20.9	21.4
Ortho-phosphate	-	-	-	-	-
pH	0.013	11.2	16.7	24.9	32.6
Phosphorustotal	0.167	12.0	21.7	19.1	10.3
Potassium (K)	0.001	8.8	20.0	11.4	37.3
Redox/Eh	0.640	25.8	21.1	16.9	18.6
Rubidium (Rb)	0.592	24.2	20.9	17.3	19.8
Selenium (Se)	0.001	8.6	15.4	31.1	28.9
Silicate (Si)	0.075	9.9	22.0	19.0	8.3
Silver (Ag)	0.000	7.2	15.2	28.8	34.5
Sodium (Na)	0.085	13.3	19.7	15.6	31.0
Specific Conductivity	0.201	14.2	21.4	13.6	23.0
Strontium (Sr)	0.011	7.8	23.3	9.5	19.0
Sulfate (SO4)	0.013	7.8	23.3	9.8	18.5
Sulfur (S)	0.005	7.3	23.4	8.6	19.5
Temperature	0.098	10.3	22.6	14.5	13.4
Thallium (Tl)	0.168	13.1	20.1	23.8	12.0
Tin (Sn)	-	-	-	-	-
Titanium (Ti)	0.142	12.3	21.7	14.5	19.6
Total dissolved solids	0.036	9.6	22.4	10.8	22.3
Total organic carbon	0.005	6.6	23.9	10.4	12.6
Total phosphate	0.440	15.5	15.3	18.1	11.4
Total suspended solids	0.388	17.8	21.4	15.1	20.3
Vanadium (V)	0.017	8.0	23.2	10.6	17.3
Zinc (Zn)	0.468	20.0	21.3	15.6	20.1
Zirconium (Zr)	-	-	-	-	-

[1] Insufficient sample size or no samples collected

Table D.69: Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in Ordovician wells for different sampling years. The null hypothesis was concentrations of individual chemicals did not differ by sampling year. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	1992	1993	1996
Alkalinity	0.014	9.7	36.4	52.4	36.7
Aluminum (Al)	0.000	6.0	38.4	31.5	67.6
Antimony (Sb)	0.506	24.9	37.1	43.1	45.1
Arsenic (As)	0.036	10.9	32.7	48.6	38.8
Barium (Ba)	0.741	37.5	41.4	46.2	42.8
Beryllium (Be)	0.475	23.5	38.6	44.2	41.3
Bismuth (Bi)	-[1]	-	-	-	-
Boron (B)	0.001	7.5	43.9	53.0	28.0
Bromide (Br)	1.000	2.8	43.5	43.5	43.5
Cadmium (Cd)	0.003	8.4	51.4	44.5	26.6
Calcium (Ca)	0.242	17.0	39.4	48.8	40.0
Cesium (Cs)	-	-	-	-	-
Chloride (Cl)	0.000	7.1	45.1	32.9	62.7
Chromium (Cr)	0.003	9.1	51.0	32.9	50.8
Cobalt (Co)	0.001	8.3	29.5	41.5	56.8
Copper (Cu)	0.548	27.0	48.7	43.0	41.2
Dissolved Oxygen	0.099	14.1	53.7	40.1	41.3
Fluoride (F)	0.001	7.6	43.8	28.6	15.6
Iron (Fe)	0.002	8.2	38.9	53.6	32.0
Lead (Pb)	0.193	16.1	48.5	42.0	35.0
Lithium (Li)	0.002	8.2	40.5	53.2	31.0
Magnesium (Mg)	0.177	16.0	38.7	42.5	52.0
Manganese (Mn)	0.118	14.1	34.7	47.3	47.5
Mercury (Hg)	0.290	15.7	30.5	32.1	1.1
Molybdenum (Mo)	0.689	34.2	46.4	43.0	43.5
Nickel (Ni)	0.424	22.6	48.7	43.4	40.3
Nitrate (NO3)	0.278	18.7	43.4	41.3	49.4
Ortho-phosphate	0.001	4.3	17.8	31.4	11.3
pH	0.000	6.9	47.1	31.9	62.5
Phosphorustotal	0.001	7.5	28.2	53.2	43.4
Potassium (K)	0.752	38.6	40.9	45.8	43.9
Redox/Eh	0.010	10.0	56.4	42.5	34.2
Rubidium (Rb)	0.124	14.4	47.6	44.2	40.0
Selenium (Se)	0.023	9.7	31.6	37.7	24.2
Silicate (Si)	0.000	6.3	24.7	45.5	60.7
Silver (Ag)	0.000	4.8	37.0	32.1	67.9
Sodium (Na)	0.004	8.5	37.1	53.5	34.0
Specific Conductivity	0.543	26.1	40.2	47.1	42.4
Strontium (Sr)	0.010	9.4	40.5	52.2	32.9
Sulfate (SO4)	0.026	10.8	49.5	47.8	31.8
Sulfur (S)	0.058	12.2	48.4	47.6	33.2
Temperature	0.000	5.5	28.4	38.1	70.0
Thallium (Tl)	0.135	15.1	39.6	38.9	51.1
Tin (Sn)	-	-	-	-	-
Titanium (Ti)	0.839	49.3	45.2	44.6	41.9
Total dissolved solids	0.026	10.6	32.1	49.7	45.7
Total organic carbon	0.000	5.6	59.2	48.6	20.5
Total phosphate	0.707	34.7	20.3	19.0	0.1
Total suspended solids	0.006	8.8	36.1	53.0	35.8
Vanadium (V)	0.449	23.7	46.6	40.5	47.6
Zinc (Zn)	0.003	8.8	55.3	45.4	30.3
Zirconium (Zr)	-	-	-	-	-

[1] Insufficient sample size or no samples collected

Table D.70: Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in Precambrian wells for different sampling years. The null hypothesis was concentrations of individual chemicals did not differ by sampling year. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	1993	1994	1995	1996
Alkalinity	0.046	19.1	59.8	51.7	36.4	35.2
Aluminum (Al)	0.002	11.1	11.7	25.9	43.3	51.7
Antimony (Sb)	0.230	23.3	54.8	29.2	41.5	38.3
Arsenic (As)	0.209	25.1	60.2	38.7	38.2	44.6
Barium (Ba)	0.303	26.6	39.8	53.8	38.0	42.4
Beryllium (Be)	0.580	33.2	39.9	32.9	40.6	46.7
Bismuth (Bi)	0.575	28.8	-[1]	-	23.7	23.0
Boron (B)	0.502	33.1	53.8	44.4	39.5	36.3
Bromide (Br)	0.481	29.9	39.5	39.5	40.2	43.2
Cadmium (Cd)	0.091	20.4	51.0	34.9	38.0	53.0
Calcium (Ca)	0.002	15.5	73.2	53.6	35.5	39.9
Cesium (Cs)	0.395	18.4	-	-	24.4	20.6
Chloride (Cl)	0.250	25.3	55.3	46.7	39.8	32.2
Chromium (Cr)	0.036	16.4	19.8	56.6	39.5	41.7
Cobalt (Co)	0.136	23.1	54.0	46.4	36.5	49.5
Copper (Cu)	0.231	25.1	59.3	35.4	39.1	43.1
Dissolved Oxygen	0.116	21.6	43.6	57.4	37.4	40.9
Fluoride (F)	0.977	82.8	29.5	34.3	34.3	31.3
Iron (Fe)	0.695	37.6	29.4	44.6	41.0	39.9
Lead (Pb)	0.660	38.5	36.7	47.3	38.8	45.0
Lithium (Li)	0.128	22.7	63.5	39.6	38.3	41.8
Magnesium (Mg)	0.012	17.4	68.4	51.6	37.3	34.6
Manganese (Mn)	0.839	52.8	45.4	37.4	39.7	44.9
Mercury (Hg)	0.274	7.5	6.5	8.1	-	-
Molybdenum (Mo)	0.196	24.0	59.2	40.0	39.3	38.4
Nickel (Ni)	0.048	18.4	62.9	32.8	40.4	37.2
Nitrate (NO3)	0.005	14.8	58.8	48.4	38.8	34.0
Ortho-phosphate	-	-	-	-	-	-
pH	0.015	12.2	12.1	31.0	44.1	40.0
$Phosphorus_{total}$	0.094	21.4	62.6	46.6	38.8	33.9
Potassium (K)	0.032	18.5	57.0	57.1	37.6	34.1
Redox/Eh	0.109	20.7	62.4	33.2	40.1	35.1
Rubidium (Rb)	0.000	11.9	62.2	37.0	39.1	40.6
Selenium (Se)	0.000	9.8	23.6	65.4	42.4	18.4
Silicate (Si)	0.355	27.4	55.2	31.9	40.7	39.9
Silver (Ag)	0.069	16.4	20.5	33.9	41.6	49.6
Sodium (Na)	0.037	18.8	63.4	50.2	38.7	31.4
Specific Conductivity	0.005	16.1	58.0	60.0	34.8	41.2
Strontium (Sr)	0.013	17.6	69.4	49.9	37.4	35.4
Sulfate (SO4)	0.006	16.5	74.0	46.9	37.6	34.7
Sulfur (S)	0.003	15.7	74.0	50.8	37.1	33.9
Temperature	0.000	12.2	72.3	65.5	32.1	43.2
Thallium (Tl)	0.000	10.9	52.3	49.7	32.9	65.5
Tin (Sn)	1.000	-	-	-	23.5	23.5
Titanium (Ti)	0.200	23.1	56.4	31.1	40.6	40.5
Total dissolved solids	0.001	15.1	71.6	56.9	35.8	36.5
Total organic carbon	0.613	35.7	40.6	36.3	39.5	48.8
Total phosphate	0.185	23.9	55.0	50.6	37.6	36.0
Total suspended solids	0.102	16.2	19.9	34.5	44.0	37.4
Vanadium (V)	0.041	18.7	63.6	30.9	38.8	46.3
Zinc (Zn)	0.138	19.3	30.8	50.8	42.0	29.1
Zirconium (Zr)	0.815	70.4	-	-	23.2	24.3

[1] Insufficient sample size or no samples collected

Table D.71: Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in buried Quaternary wells for different sampling years. The null hypothesis was concentrations of individual chemicals did not differ by sampling year. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	1993	1994	1995	1996
Alkalinity	0.000	11.1	361.6	288.0	207.1	180.4
Aluminum (Al)	0.000	8.8	255.5	196.9	266.8	397.9
Antimony (Sb)	0.000	7.2	328.0	265.9	225.2	221.3
Arsenic (As)	0.002	4.5	285.9	274.9	241.4	194.9
Barium (Ba)	0.000	6.7	179.7	283.9	272.6	261.4
Beryllium (Be)	0.000	9.5	238.3	193.9	293.6	281.3
Bismuth (Bi)	0.569	49.7	-[1]	-	74.2	73.5
Boron (B)	0.000	12.7	397.8	247.9	221.0	158.6
Bromide (Br)	0.201	2.5	249.5	257.0	258.2	249.5
Cadmium (Cd)	0.000	11.4	366.8	204.4	231.5	303.5
Calcium (Ca)	0.000	14.9	404.3	293.1	188.3	183.8
Cesium (Cs)	0.003	9.9	-	-	70.3	85.3
Chloride (Cl)	0.003	4.4	253.2	292.3	234.6	280.4
Chromium (Cr)	0.000	15.9	118.1	379.3	251.5	190.5
Cobalt (Co)	0.000	9.9	355.2	267.3	206.1	267.3
Copper (Cu)	0.000	8.5	340.1	237.8	227.4	295.4
Dissolved Oxygen	0.000	10.1	245.0	348.6	210.2	254.2
Fluoride (F)	0.000	4.9	176.1	149.8	207.5	150.4
Iron (Fe)	0.000	6.6	326.2	259.9	237.4	194.8
Lead (Pb)	0.002	4.5	285.4	273.3	228.8	283.7
Lithium (Li)	0.000	12.3	389.4	260.9	216.2	163.2
Magnesium (Mg)	0.000	12.7	385.2	283.0	201.0	189.3
Manganese (Mn)	0.000	7.8	330.2	265.0	215.5	298.5
Mercury (Hg)	0.677	260.5	115.8	119.7	-	106.0
Molybdenum (Mo)	0.000	5.4	306.2	256.9	243.7	216.2
Nickel (Ni)	0.000	5.5	304.2	238.4	252.5	231.4
Nitrate (NO3)	0.231	2.4	267.2	263.6	248.0	256.9
Ortho-phosphate	-	-	-	-	-	-
pH	0.000	13.2	132.9	216.0	315.5	345.9
Phosphorustotal	0.000	6.7	317.8	277.0	231.2	194.5
Potassium (K)	0.000	12.4	391.0	260.7	216.7	157.0
Redox/Eh	0.034	3.4	274.1	224.9	266.2	263.2
Rubidium (Rb)	0.000	5.6	288.2	264.0	243.0	240.6
Selenium (Se)	0.000	15.2	185.5	384.9	236.0	102.4
Silicate (Si)	0.000	9.2	352.2	273.3	213.8	226.8
Silver (Ag)	0.000	6.4	204.2	270.9	258.0	318.7
Sodium (Na)	0.000	11.4	378.5	256.3	225.1	152.6
Specific Conductivity	0.000	15.0	397.6	302.3	182.3	196.6
Strontium (Sr)	0.000	14.1	409.1	267.0	204.8	162.6
Sulfate (SO4)	0.000	15.0	409.3	286.9	189.1	187.6
Sulfur (S)	0.000	14.8	409.2	283.5	189.7	196.4
Temperature	0.000	12.8	368.0	291.6	184.3	293.7
Thallium (Tl)	0.000	9.7	285.8	293.1	208.6	340.2
Tin (Sn)	0.776	99.1	-	-	74.6	72.3
Titanium (Ti)	0.016	3.7	277.1	234.9	259.7	266.9
Total dissolved solids	0.000	14.6	405.5	284.9	196.0	162.8
Total organic carbon	0.000	7.6	338.9	241.5	241.3	185.4
Total phosphate	0.003	4.3	233.2	271.3	235.3	184.9
Total suspended solids	0.000	5.8	295.6	235.8	268.0	168.9
Vanadium (V)	0.000	7.2	326.6	215.3	248.1	281.5
Zinc (Zn)	0.000	8.0	330.2	275.7	213.1	276.3
Zirconium (Zr)	0.416	34.2	-	-	75.5	69.4

[1] Insufficient sample size or no samples collected

Table D.72: Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in surficial Quaternary wells for different sampling years. The null hypothesis was concentrations of individual chemicals did not differ by sampling year. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	1993	1994	1995	1996
Alkalinity	0.001	4.9	90.9	72.7	56.6	43.2
Aluminum (Al)	0.000	5.9	55.1	40.1	62.9	92.0
Antimony (Sb)	0.000	6.0	105.0	65.1	57.8	41.5
Arsenic (As)	0.535	1.7	65.6	64.9	62.5	51.2
Barium (Ba)	0.020	3.6	38.4	72.4	65.2	52.1
Beryllium (Be)	0.000	5.8	48.0	39.6	72.4	68.0
Bismuth (Bi)	1.000	-[1]	-	-	22.0	22.0
Boron (B)	0.000	5.0	102.9	51.2	60.9	56.8
Bromide (Br)	1.000	-	61.0	61.0	61.0	61.0
Cadmium (Cd)	0.006	4.1	74.7	47.8	60.0	77.9
Calcium (Ca)	0.000	6.5	107.7	75.1	51.3	49.0
Cesium (Cs)	0.576	24.1	-	-	21.3	22.9
Chloride (Cl)	0.000	6.1	85.5	81.3	45.6	69.5
Chromium (Cr)	0.000	6.3	33.7	89.5	58.9	45.6
Cobalt (Co)	0.358	2.1	72.9	63.8	56.3	67.3
Copper (Cu)	0.000	5.1	93.0	62.1	51.4	74.9
Dissolved Oxygen	0.000	5.6	81.3	83.8	48.4	60.2
Fluoride (F)	0.026	3.5	52.6	24.2	35.8	48.1
Iron (Fe)	0.021	3.6	38.3	61.5	70.0	52.9
Lead (Pb)	0.086	3.0	76.7	65.0	53.5	68.9
Lithium (Li)	0.000	5.8	107.3	61.6	58.8	45.9
Magnesium (Mg)	0.000	6.3	108.4	71.7	53.4	47.0
Manganese (Mn)	0.329	2.1	55.7	70.3	62.5	52.6
Mercury (Hg)	1.000	-	21.0	21.0	-	-
Molybdenum (Mo)	0.001	4.8	87.7	59.9	60.7	54.1
Nickel (Ni)	0.016	3.7	82.8	53.6	64.7	53.8
Nitrate (NO3)	0.000	5.4	94.6	66.0	53.5	62.6
Ortho-phosphate	-	-	-	-	-	-
pH	0.000	5.5	31.7	44.8	71.3	76.0
Phosphorustotal	0.961	0.6	59.8	60.2	63.8	60.6
Potassium (K)	0.090	2.9	80.4	67.6	59.8	50.1
Redox/Eh	0.000	5.7	108.1	49.2	59.6	60.4
Rubidium (Rb)	0.083	3.0	72.1	64.6	60.9	56.0
Selenium (Se)	0.000	7.4	56.7	94.1	56.8	31.4
Silicate (Si)	0.016	3.7	89.4	66.9	54.5	61.4
Silver (Ag)	0.175	2.6	46.4	63.8	60.2	71.3
Sodium (Na)	0.002	4.4	98.8	62.1	56.8	55.9
Specific Conductivity	0.000	6.8	105.2	78.6	47.4	56.9
Strontium (Sr)	0.000	6.4	111.1	68.5	55.3	44.6
Sulfate (SO4)	0.000	8.1	111.8	79.5	42.6	65.8
Sulfur (S)	0.000	8.0	110.8	80.1	42.5	65.8
Temperature	0.001	4.6	80.4	74.6	49.5	70.5
Thallium (Tl)	0.001	4.8	72.5	64.2	51.1	82.6
Tin (Sn)	0.155	9.6	-	-	19.5	24.9
Titanium (Ti)	0.003	4.3	77.8	46.7	66.6	60.8
Total dissolved solids	0.000	6.8	108.3	76.6	50.8	47.7
Total organic carbon	0.116	2.8	83.1	58.2	62.8	53.0
Total phosphate	0.583	1.6	44.6	60.5	61.4	54.0
Total suspended solids	0.004	4.2	42.5	54.6	73.3	50.5
Vanadium (V)	0.001	4.6	95.6	48.8	60.9	64.1
Zinc (Zn)	0.037	3.4	80.8	65.1	53.6	71.5
Zirconium (Zr)	0.170	9.8	-	-	24.3	19.4

[1] Insufficient sample size or no samples collected

Table D.73: Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in CFIG-CFRN-CIGL wells for different sampling years. The null hypothesis was concentrations of individual chemicals did not differ by sampling year. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	1992	1993	1994	1995	1996
Alkalinity	0.021	12.8	15.9	23.0	34.4	7.8	18.8
Aluminum (Al)	0.000	9.0	18.3	14.3	4.4	27.5	28.5
Antimony (Sb)	0.052	13.4	21.3	29.2	16.8	16.8	15.3
Arsenic (As)	0.014	11.7	9.5	18.9	30.0	15.5	23.5
Barium (Ba)	0.496	21.9	18.0	22.8	26.4	11.0	19.9
Beryllium (Be)	0.928	44.4	19.1	18.3	21.1	24.0	20.6
Bismuth (Bi)	0.715	36.2	-[1]	-	-	8.5	9.1
Boron (B)	0.008	11.9	11.8	24.2	34.4	13.8	19.8
Bromide (Br)	0.000	-	20.5	20.5	20.5	20.5	20.5
Cadmium (Cd)	0.078	12.9	25.3	23.4	11.1	7.5	19.7
Calcium (Ca)	0.024	12.8	12.2	21.4	32.8	12.5	21.9
Cesium (Cs)	0.815	60.0	-	-	-	9.8	8.9
Chloride (Cl)	0.031	13.7	16.7	16.6	12.2	34.0	26.1
Chromium (Cr)	0.087	15.9	23.0	15.3	31.3	22.8	17.1
Cobalt (Co)	0.090	13.0	12.8	22.8	15.4	12.5	24.7
Copper (Cu)	0.417	20.6	19.7	22.9	12.5	23.5	21.8
Dissolved Oxygen	0.013	13.1	30.4	13.5	23.3	28.8	16.7
Fluoride (F)	0.032	11.1	15.9	15.6	24.3	17.0	7.4
Iron (Fe)	0.038	13.6	15.7	24.2	33.0	10.5	18.3
Lead (Pb)	0.083	14.5	27.6	21.2	9.6	23.0	18.3
Lithium (Li)	0.026	12.2	11.6	29.0	21.1	14.8	21.3
Magnesium (Mg)	0.035	13.6	17.7	21.4	34.8	9.5	18.3
Manganese (Mn)	0.016	11.2	10.4	20.2	19.6	17.0	27.5
Mercury (Hg)	94.000	2.6	10.5	10.5	14.9	-	-
Molybdenum (Mo)	0.643	27.7	19.7	20.0	21.0	28.3	20.1
Nickel (Ni)	0.114	15.9	25.3	21.4	16.5	26.8	17.6
Nitrate (NO3)	0.313	19.8	23.8	19.1	17.0	27.5	19.6
Ortho-phosphate	0.637	19.3	6.1	5.5	-	-	-
pH	0.006	10.8	27.3	10.5	12.2	22.0	25.0
Phosphorustotal	0.003	11.6	8.6	20.8	32.8	24.5	22.9
Potassium (K)	0.007	11.6	9.4	25.9	30.6	15.5	21.2
Redox/Eh	0.005	10.9	29.2	23.4	4.8	21.0	18.7
Rubidium (Rb)	0.924	42.2	21.3	21.1	19.0	19.0	20.3
Selenium (Se)	0.001	11.2	18.0	19.8	31.3	28.0	11.1
Silicate (Si)	0.196	17.2	14.8	18.7	17.0	27.5	25.3
Silver (Ag)	0.217	15.6	22.1	19.4	10.5	16.0	22.9
Sodium (Na)	0.001	10.1	7.3	24.2	32.8	14.5	22.9
Specific Conductivity	0.005	11.2	11.3	23.5	34.0	9.0	21.3
Strontium (Sr)	0.000	9.9	7.0	24.3	34.8	16.5	22.1
Sulfate (SO4)	0.060	14.0	16.1	24.9	30.6	7.5	18.9
Sulfur (S)	0.097	14.9	17.4	24.4	30.2	8.0	18.4
Temperature	0.779	29.7	17.4	19.8	22.8	15.5	22.7
Thallium (Tl)	0.016	10.3	20.5	15.5	11.5	11.5	26.4
Tin (Sn)	0.589	23.1	-	-	-	7.3	9.2
Titanium (Ti)	0.063	15.8	21.3	20.8	16.5	36.0	19.1
Total dissolved solids	0.023	12.5	11.5	22.4	32.0	12.0	20.2
Total organic carbon	0.078	14.0	24.1	24.5	24.5	3.0	16.9
Total phosphate	0.173	14.6	-	13.8	21.9	18.3	12.8
Total suspended solids	0.074	15.2	16.5	20.8	33.1	19.0	17.1
Vanadium (V)	0.107	15.1	16.4	24.3	11.0	26.0	23.1
Zinc (Zn)	0.016	12.2	29.2	24.3	21.8	13.5	13.5
Zirconium (Zr)	0.066	9.7	-	-	-	14.5	8.3

[1] Insufficient sample size or no samples collected

Table D.74: Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in OSTP-OPDC-OSTP wells for different sampling years. The null hypothesis was concentrations of individual chemicals did not differ by sampling year. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	1992	1993	1994	1996
Alkalinity	0.025	39.0	39.5	55.4	82.0	39.7
Aluminum (Al)	0.000	15.8	44.7	25.5	35.0	64.9
Antimony (Sb)	0.193	50.9	36.9	48.2	73.0	45.5
Arsenic (As)	0.170	53.3	37.9	48.0	85.0	44.3
Barium (Ba)	0.265	43.8	38.7	50.6	24.0	47.6
Beryllium (Be)	0.483	56.6	40.1	45.5	35.5	46.7
Bismuth (Bi)	-[1]	-	-	-	-	-
Boron (B)	0.024	38.9	42.6	54.9	82.0	37.1
Bromide (Br)	0.000	-	45.5	45.5	45.5	45.5
Cadmium (Cd)	0.399	51.5	49.3	44.8	35.0	38.0
Calcium (Ca)	0.013	35.1	35.6	56.0	76.0	43.2
Cesium (Cs)	-	-	-	-	-	-
Chloride (Cl)	0.004	23.9	41.1	37.4	17.0	59.5
Chromium (Cr)	0.071	45.7	48.1	36.2	86.0	47.2
Cobalt (Co)	0.007	33.5	33.8	42.3	79.0	55.3
Copper (Cu)	0.476	54.6	50.4	43.1	20.5	44.0
Dissolved Oxygen	0.022	30.7	57.7	41.5	42.5	37.7
Fluoride (F)	0.024	21.4	36.0	23.7	35.5	18.9
Iron (Fe)	0.087	44.8	39.9	53.8	76.0	41.2
Lead (Pb)	0.021	26.5	53.9	44.2	10.5	34.7
Lithium (Li)	0.024	39.3	40.2	54.9	84.0	39.4
Magnesium (Mg)	0.318	63.8	40.6	46.0	83.0	48.6
Manganese (Mn)	0.070	40.4	35.3	51.2	65.0	48.9
Mercury (Hg)	0.593	62.6	29.5	31.4	29.5	29.5
Molybdenum (Mo)	0.007	34.6	47.5	40.0	83.0	48.1
Nickel (Ni)	0.263	44.7	52.0	42.6	30.0	42.6
Nitrate (NO3)	0.841	97.4	46.0	43.9	30.5	47.3
Ortho-phosphate	0.056	7.9	20.4	27.8		
pH	0.000	19.7	52.1	25.9	53.0	59.6
Phosphorustotal	0.001	26.0	30.1	55.6	57.0	49.8
Potassium (K)	0.080	46.4	36.9	51.0	84.0	46.8
Redox/Eh	0.000	20.4	57.2	49.9	13.0	30.2
Rubidium (Rb)	0.712	80.0	46.7	46.4	42.0	43.5
Selenium (Se)	0.003	24.2	30.5	39.9	63.0	23.7
Silicate (Si)	0.000	25.1	28.5	48.3	75.0	58.6
Silver (Ag)	0.000	16.7	35.5	31.8	64.0	66.1
Sodium (Na)	0.034	41.0	35.7	52.8	84.0	46.2
Specific Conductivity	0.108	48.9	37.8	51.1	84.0	45.9
Strontium (Sr)	0.025	39.4	39.6	55.2	84.0	39.7
Sulfate (SO4)	0.039	41.5	45.8	52.9	83.0	36.0
Sulfur (S)	0.055	43.8	44.9	52.7	84.0	37.1
Temperature	0.000	19.9	33.3	37.8	52.5	65.7
Thallium (Tl)	0.083	32.5	48.9	36.1	17.0	49.0
Tin (Sn)	-	-	-	-	-	-
Titanium (Ti)	0.954	157.4	46.1	45.5	35.0	45.2
Total dissolved solids	0.002	30.8	31.3	55.3	82.0	45.9
Total organic carbon	0.000	20.6	61.8	47.1	56.5	27.2
Total phosphate	0.066	18.7	28.7	7.0		20.6
Total suspended solids	0.020	37.9	42.4	54.2	82.5	36.4
Vanadium (V)	0.145	37.5	44.3	40.1	21.5	53.3
Zinc (Zn)	0.001	21.3	57.4	48.7	13.0	31.4
Zirconium (Zr)	-	-	-	-	-	-

[1] Insufficient sample size or no samples collected

Table D.75: Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in CMSH-CMTS-PMHN wells for different sampling years. The null hypothesis was concentrations of individual chemicals did not differ by sampling year. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	1992	1993	1994	1996
Alkalinity	0.002	9.4	23.5	19.8	8.4	17.0
Aluminum (Al)	0.004	8.1	11.5	5.2	14.8	22.5
Antimony (Sb)	0.168	14.4	23.5	15.5	11.9	11.1
Arsenic (As)	0.191	14.2	17.0	17.5	10.5	16.3
Barium (Ba)	0.232	14.4	14.8	18.0	10.8	15.8
Beryllium (Be)	0.027	11.2	24.3	10.7	12.0	17.8
Bismuth (Bi)	0.000	-[1]	-	-	9.0	9.0
Boron (B)	0.022	11.5	24.5	14.7	9.9	19.0
Bromide (Br)	0.007	8.5	19.5	13.0	13.0	13.0
Cadmium (Cd)	0.753	26.5	17.0	13.0	12.7	15.3
Calcium (Ca)	0.004	9.7	23.0	19.8	8.7	16.0
Cesium (Cs)	0.004	4.6	11.0	11.0	11.0	11.0
Chloride (Cl)	0.897	34.5	15.0	15.0	15.0	15.0
Chromium (Cr)	0.083	10.8	14.1	14.1	14.1	14.1
Cobalt (Co)	0.520	20.5	13.3	13.3	13.3	13.3
Copper (Cu)	0.202	12.3	20.0	14.5	11.9	14.5
Dissolved Oxygen	0.848	28.5	12.0	20.3	11.9	9.5
Fluoride (F)	0.159	15.7	16.0	15.6	9.0	11.0
Iron (Fe)	0.273	15.9	21.5	16.2	11.8	11.5
Lead (Pb)	0.677	23.6	16.5	11.7	12.9	16.9
Lithium (Li)	0.658	23.1	16.3	12.8	12.4	16.9
Magnesium (Mg)	0.008	10.2	23.0	19.3	9.0	15.8
Manganese (Mn)	0.973	57.9	15.5	14.1	13.1	12.9
Mercury (Hg)	0.000	-	4.5	4.5	-	-
Molybdenum (Mo)	0.572	18.3	11.5	11.5	14.4	14.4
Nickel (Ni)	0.452	15.8	11.0	11.0	14.7	14.3
Nitrate (NO3)	0.547	17.1	11.0	13.2	14.7	11.0
Ortho-phosphate	-	-	-	-	-	-
pH	0.181	12.9	8.0	14.3	12.0	20.4
Phosphorustotal	0.161	12.8	12.5	19.3	10.9	14.3
Potassium (K)	0.035	11.9	24.5	15.8	9.9	17.0
Redox/Eh	0.011	7.8	17.0	7.4	17.5	6.8
Rubidium (Rb)	0.583	19.1	12.0	12.0	13.8	15.5
Selenium (Se)	0.097	10.4	11.5	18.3	13.8	6.3
Silicate (Si)	0.265	12.0	5.5	15.0	15.1	9.8
Silver (Ag)	0.222	14.5	17.3	16.3	11.1	15.8
Sodium (Na)	0.014	10.8	24.5	18.3	9.4	15.0
Specific Conductivity	0.004	9.8	24.0	19.7	8.8	15.5
Strontium (Sr)	0.007	10.2	24.0	18.3	8.9	17.3
Sulfate (SO4)	0.236	15.6	23.0	15.3	11.8	12.0
Sulfur (S)	0.197	14.9	23.0	15.8	11.7	11.5
Temperature	0.028	11.3	25.5	17.7	11.0	9.9
Thallium (Tl)	0.000	8.7	25.5	13.3	9.4	22.1
Tin (Sn)	0.000	-	-	-	9.0	9.0
Titanium (Ti)	0.260	13.2	10.5	10.5	14.2	17.0
Total dissolved solids	0.006	10.1	24.0	19.0	8.9	16.0
Total organic carbon	0.590	22.1	20.3	13.3	12.4	14.4
Total phosphate	0.235	12.7	4.5	16.8	13.0	14.9
Total suspended solids	0.881	34.1	13.3	13.3	12.8	16.3
Vanadium (V)	0.029	9.2	8.5	8.5	14.4	20.5
Zinc (Zn)	0.230	15.5	23.5	14.8	12.0	11.8
Zirconium (Zr)	0.833	48.2	-	-	9.1	8.6

[1] Insufficient sample size or no samples collected

Table D.76: Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in Upper Carbonate wells for different sampling years. The null hypothesis was concentrations of individual chemicals did not differ by sampling year. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	1992	1993	1996
Alkalinity	0.068	12.7	20.0	17.5	26.5
Aluminum (Al)	0.464	28.8	20.0	17.5	26.5
Antimony (Sb)	0.611	31.4	15.3	19.1	21.8
Arsenic (As)	0.093	14.0	10.8	20.2	22.5
Barium (Ba)	0.990	214.9	18.0	18.6	18.5
Beryllium (Be)	0.223	15.2	14.6	19.9	12.5
Bismuth (Bi)	-[1]	-	-	-	-
Boron (B)	0.041	11.3	9.5	20.8	19.5
Bromide (Br)	1.000	-	17.5	17.5	17.5
Cadmium (Cd)	0.131	13.6	21.4	18.8	4.5
Calcium (Ca)	0.681	35.3	21.6	17.9	16.5
Cesium (Cs)	-	-	-	-	-
Chloride (Cl)	0.003	12.4	26.7	14.6	31.5
Chromium (Cr)	0.002	10.3	30.0	15.6	18.0
Cobalt (Co)	0.092	16.3	12.3	19.3	29.5
Copper (Cu)	0.169	20.6	20.4	17.1	31.0
Dissolved Oxygen	0.060	13.9	26.9	16.6	14.5
Fluoride (F)	0.268	18.1	22.5	16.0	12.5
Iron (Fe)	0.182	13.6	15.4	20.1	7.5
Lead (Pb)	0.076	16.7	25.1	16.2	26.3
Lithium (Li)	0.098	11.5	12.8	20.7	9.5
Magnesium (Mg)	0.042	15.7	13.3	18.7	34.5
Manganese (Mn)	0.794	47.2	16.9	18.6	22.5
Mercury (Hg)	0.169	9.9	14.0	17.8	-
Molybdenum (Mo)	0.706	37.9	16.9	18.7	21.8
Nickel (Ni)	0.854	56.3	17.2	18.6	21.5
Nitrate (NO3)	0.260	18.9	21.6	17.8	16.5
Ortho-phosphate	0.040	5.9	9.6	17.3	-
pH	0.516	30.4	17.5	18.2	26.8
Phosphorustotal	0.147	12.9	13.1	20.5	10.8
Potassium (K)	0.259	19.4	13.0	19.5	24.0
Redox/Eh	0.005	10.4	29.9	16.2	10.5
Rubidium (Rb)	0.732	38.3	19.7	18.3	17.0
Selenium (Se)	0.163	11.8	14.5	15.9	6.5
Silicate (Si)	0.009	13.0	10.6	19.3	35.5
Silver (Ag)	0.000	10.1	20.7	16.7	35.5
Sodium (Na)	0.023	9.4	9.3	21.2	14.0
Specific Conductivity	0.605	32.6	15.9	18.8	24.0
Strontium (Sr)	0.008	10.5	7.7	20.7	26.0
Sulfate (SO4)	0.754	37.2	19.1	18.1	13.0
Sulfur (S)	0.786	41.9	19.9	18.5	14.0
Temperature	0.024	14.5	12.2	18.9	35.0
Thallium (Tl)	0.161	19.7	15.9	18.2	31.3
Tin (Sn)	-	-	-	-	-
Titanium (Ti)	0.826	52.5	18.2	18.3	22.3
Total dissolved solids	0.342	20.3	13.0	19.1	21.0
Total organic carbon	0.068	12.3	23.5	18.3	4.0
Total phosphate	0.814	25.4	3.6	3.3	0.1
Total suspended solids	0.155	13.0	12.6	19.9	11.5
Vanadium (V)	0.895	68.3	18.2	18.3	21.8
Zinc (Zn)	0.170	19.2	24.3	16.6	24.0
Zirconium (Zr)	-	-	-	-	-

[1] Insufficient sample size or no samples collected

Table D.77: Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in Cambrian wells for different sampling months. The null hypothesis was concentrations of individual chemicals did not differ by sampling month. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	Jan.	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Alkalinity	0.038	27.7	40.9	62.5	36.0	41.7	74.5	46.4	51.3	46.5	54.3
Aluminum (Al)	0.535	43.7	60.6	40.9	47.8	62.8	45.1	56.0	47.2	65.2	44.5
Antimony (Sb)	0.858	56.0	43.3	52.7	40.9	55.0	60.3	48.8	49.9	52.6	53.7
Arsenic (As)	0.009	24.5	25.8	54.2	52.6	66.4	68.4	56.3	36.2	25.8	49.8
Barium (Ba)	0.205	32.9	43.0	53.2	53.8	47.9	62.9	61.7	41.9	29.6	50.7
Beryllium (Be)	0.991	85.5	47.5	53.9	49.8	44.0	52.9	50.6	51.6	44.9	51.0
Bismuth (Bi)	0.007	12.2	-[1]	21.5	21.5	21.5	30.3	21.5	21.5	-	-
Boron (B)	0.001	20.8	16.1	53.4	46.7	52.2	79.2	56.8	49.9	30.9	20.8
Bromide (Br)	0.758	49.6	51.0	51.0	51.0	51.0	51.0	51.0	54.0	51.0	51.0
Cadmium (Cd)	0.002	27.1	78.8	46.5	42.2	68.4	64.2	34.3	47.6	52.8	92.5
Calcium (Ca)	0.015	25.0	37.5	64.3	41.6	40.3	77.4	50.2	44.4	41.9	39.3
Cesium (Cs)	0.435	21.7	-	22.1	23.8	31.1	21.3	21.9	11.5	-	-
Chloride (Cl)	0.570	42.8	34.0	54.5	57.7	52.3	54.9	57.0	43.0	37.4	62.8
Chromium (Cr)	0.077	30.9	55.4	68.3	49.3	50.5	38.2	36.3	54.9	55.0	62.5
Cobalt (Co)	0.077	27.8	42.3	59.5	48.8	34.0	70.4	48.8	46.9	42.4	20.0
Copper (Cu)	0.022	27.8	70.5	51.0	65.3	27.0	52.3	39.9	59.4	42.4	66.8
Dissolved Oxygen	0.002	25.4	68.6	54.8	39.7	39.8	25.3	54.3	64.1	65.3	85.7
Fluoride (F)	0.199	28.3	39.2	52.9	30.1	33.1	39.0	25.8	41.8	31.1	29.0
Iron (Fe)	0.229	33.0	51.3	51.3	50.9	47.0	66.5	59.9	43.9	40.5	20.7
Lead (Pb)	0.053	31.8	63.6	48.0	40.1	40.6	44.5	42.7	61.5	68.9	85.3
Lithium (Li)	0.016	24.2	33.0	51.4	52.4	41.9	73.7	56.6	51.8	26.3	31.5
Magnesium (Mg)	0.087	30.6	50.8	59.9	31.8	51.1	70.9	48.1	51.5	48.6	52.3
Manganese (Mn)	0.001	21.0	41.3	59.1	54.2	44.6	76.3	57.8	39.9	25.6	14.7
Mercury (Hg)	0.386	30.7	26.0	28.8	34.8	26.0	26.0	31.3	26.0	26.0	26.0
Molybdenum (Mo)	0.287	34.7	43.5	46.4	60.1	50.9	51.8	49.2	58.4	43.5	43.5
Nickel (Ni)	0.218	34.7	54.6	45.7	52.3	39.5	43.4	50.8	60.9	63.5	56.7
Nitrate (NO3)	0.096	31.8	50.6	52.4	49.8	39.5	39.5	50.0	58.2	64.6	73.2
Ortho-phosphate	0.045	10.9	9.5	24.3	-	-	-	-	12.3	14.0	14.8
pH	0.005	26.4	31.6	48.5	68.1	70.7	36.4	37.2	54.0	60.8	83.2
Phosphorustotal	0.000	16.7	18.5	65.4	63.8	35.6	66.0	64.9	37.6	16.6	21.0
Potassium (K)	0.001	20.9	33.8	54.0	48.7	60.1	78.9	57.9	43.0	24.9	15.7
Redox/Eh	0.001	23.8	49.0	41.0	30.7	54.8	40.7	52.4	74.4	67.8	75.3
Rubidium (Rb)	0.814	51.7	48.0	51.3	54.5	48.0	48.0	53.4	54.1	48.0	48.0
Selenium (Se)	0.215	39.1	39.0	44.5	33.9	25.1	41.7	52.6	54.1	39.0	39.0
Silicate (Si)	0.006	22.2	35.5	60.5	49.6	31.0	61.9	66.3	49.8	23.6	27.7
Silver (Ag)	0.228	35.8	54.5	49.7	55.2	75.3	52.3	40.4	45.7	57.5	40.2
Sodium (Na)	0.000	18.1	18.0	56.9	54.1	54.7	76.5	59.5	46.4	13.3	19.0
Specific Conductivity	0.002	22.4	43.9	64.5	39.8	42.1	77.7	52.2	48.8	23.9	43.7
Strontium (Sr)	0.000	19.0	25.3	62.3	45.5	54.0	80.9	56.7	42.7	22.1	22.0
Sulfate (SO4)	0.246	36.5	65.0	46.8	37.0	61.4	69.0	50.9	49.6	50.5	49.7
Sulfur (S)	0.188	35.1	63.8	45.9	36.1	62.6	69.2	50.0	49.5	56.0	49.0
Temperature	0.014	26.7	27.0	36.6	63.8	75.6	66.6	45.2	46.2	48.1	59.2
Thallium (Tl)	0.003	24.1	34.6	47.1	59.8	39.9	59.0	30.8	54.3	77.5	60.0
Tin (Sn)	0.026	14.8	-	38.3	20.0	20.8	18.5	18.5	28.8	-	-
Titanium (Ti)	0.182	33.1	55.5	49.1	57.9	42.0	42.0	53.5	59.4	42.0	58.7
Total dissolved solids	0.009	23.8	36.3	61.6	37.2	42.4	76.9	50.0	46.5	35.9	43.0
Total organic carbon	0.052	30.6	68.9	41.2	40.4	29.9	63.3	54.4	52.3	71.0	63.5
Total phosphate	0.130	18.3	-	39.7	38.5	21.4	38.0	46.2	29.4	-	-
Total suspended solids	0.004	21.8	46.5	58.0	36.3	35.1	61.9	68.1	41.5	48.8	12.0
Vanadium (V)	0.017	25.1	44.3	46.0	74.0	33.6	54.5	54.9	48.7	34.2	47.3
Zinc (Zn)	0.004	26.2	60.5	37.9	40.1	49.6	48.9	41.7	69.9	76.6	75.2
Zirconium (Zr)	0.252	19.4	-	24.5	17.5	31.6	19.8	24.4	21.7	-	-

[1] Insufficient sample size or no samples collected

Table D.78: Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in Devonian wells for different sampling months. The null hypothesis was concentrations of individual chemicals did not differ by sampling month. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	Jan.	May	December
Alkalinity	0.168	6.3	4.0	6.6	2.3
Aluminum (Al)	0.293	8.1	1.0	6.0	6.0
Antimony (Sb)	0.240	6.8	2.0	6.5	3.8
Arsenic (As)	0.331	7.9	3.0	6.4	3.5
Barium (Ba)	0.680	14.8	3.0	5.7	6.0
Beryllium (Be)	0.397	12.3	9.0	5.4	4.3
Bismuth (Bi)	-[1]	-	-	-	-
Boron (B)	0.167	6.6	5.0	6.6	2.0
Bromide (Br)	1.000	-	5.0	5.0	5.0
Cadmium (Cd)	0.283	8.2	1.0	5.9	6.5
Calcium (Ca)	0.452	9.7	4.0	6.3	3.5
Cesium (Cs)	-	-	-	-	-
Chloride (Cl)	0.193	9.0	7.0	3.8	7.5
Chromium (Cr)	0.031	7.6	10.0	4.1	8.3
Cobalt (Co)	0.407	10.7	7.0	6.0	3.0
Copper (Cu)	0.869	28.9	7.0	5.3	5.5
Dissolved Oxygen	0.283	9.9	4.0	4.9	8.5
Fluoride (F)	0.261	9.5	6.0	4.0	7.5
Iron (Fe)	0.167	6.1	1.0	6.6	4.0
Lead (Pb)	0.283	9.9	4.0	4.9	8.5
Lithium (Li)	0.343	10.5	8.0	5.9	3.0
Magnesium (Mg)	0.214	6.8	4.0	6.6	2.5
Manganese (Mn)	0.452	10.4	2.0	5.7	6.5
Mercury (Hg)	0.185	6.3	3.0	6.6	3.0
Molybdenum (Mo)	0.807	20.5	5.0	5.7	5.0
Nickel (Ni)	0.365	10.9	8.0	5.7	3.5
Nitrate (NO3)	1.000	-	5.5	5.5	5.5
Ortho-phosphate	0.438	9.5	2.0	6.1	5.3
pH	0.450	10.4	2.0	5.7	6.5
Phosphorustotal	0.255	7.2	1.0	6.3	5.0
Potassium (K)	0.292	8.5	6.0	6.3	2.5
Redox/Eh	0.053	8.4	10.0	4.0	8.5
Rubidium (Rb)	1.000	-	5.5	5.5	5.5
Selenium (Se)	0.847	21.6	4.0	4.7	4.0
Silicate (Si)	0.183	8.9	9.0	5.9	2.5
Silver (Ag)	0.610	14.4	4.5	5.3	6.8
Sodium (Na)	0.132	5.9	4.0	6.7	2.0
Specific Conductivity	0.331	7.9	3.0	6.4	3.5
Strontium (Sr)	0.098	5.8	5.0	6.7	1.5
Sulfate (SO4)	0.925	34.7	6.0	4.8	5.0
Sulfur (S)	0.677	18.4	8.0	5.1	5.5
Temperature	0.223	6.8	1.0	6.4	4.8
Thallium (Tl)	0.359	10.0	7.0	6.0	3.0
Tin (Sn)	-	-	-	-	-
Titanium (Ti)	0.198	9.4	9.0	5.3	4.5
Total dissolved solids	0.273	7.1	4.0	6.0	2.5
Total organic carbon	0.545	13.3	4.0	5.1	7.5
Total phosphate	-	-	-	-	-
Total suspended solids	0.547	10.3	3.0	5.7	4.0
Vanadium (V)	0.405	12.5	9.0	5.3	4.5
Zinc (Zn)	0.283	7.7	1.0	6.1	5.5
Zirconium (Zr)	-	-	-	-	-

[1] Insufficient sample size or no samples collected

Table D.79: Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in Cretaceous wells for different sampling months. The null hypothesis was concentrations of individual chemicals did not differ by sampling month. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	Jan.	May	June	July	August
Alkalinity	0.014	12.2	3.0	19.5	17.1	16.1	28.0
Aluminum (Al)	0.432	22.8	24.0	15.5	22.2	11.8	20.3
Antimony (Sb)	0.170	18.2	28.0	6.0	19.1	15.7	23.8
Arsenic (As)	0.724	30.3	11.5	21.0	22.3	18.8	18.6
Barium (Ba)	0.008	16.5	33.5	37.0	14.3	16.3	24.2
Beryllium (Be)	0.271	18.8	16.0	16.0	19.3	16.0	23.7
Bismuth (Bi)	-[1]	-	-	-	-	-	-
Boron (B)	0.017	11.2	1.5	3.5	24.4	21.0	19.2
Bromide (Br)	0.684	28.6	17.0	17.0	20.4	17.0	21.6
Cadmium (Cd)	0.407	23.2	27.8	7.5	19.7	18.1	21.8
Calcium (Ca)	0.081	15.5	9.5	12.0	22.2	29.6	16.2
Cesium (Cs)	-	-	-	-	-	-	-
Chloride (Cl)	0.036	12.3	16.5	8.5	26.0	11.4	17.8
Chromium (Cr)	0.161	22.1	34.0	29.5	20.9	16.1	16.7
Cobalt (Co)	0.874	38.4	15.0	14.0	20.0	20.0	21.7
Copper (Cu)	0.351	21.3	23.5	13.5	23.9	17.4	16.4
Dissolved Oxygen	0.281	22.4	33.5	8.0	20.2	20.2	19.4
Fluoride (F)	0.012	9.1	2.0	3.5	19.1	12.7	10.5
Iron (Fe)	0.045	15.3	5.0	18.0	18.1	32.2	20.4
Lead (Pb)	0.038	14.1	25.5	14.0	22.0	5.8	22.9
Lithium (Li)	0.010	10.9	6.0	11.5	26.9	19.6	14.6
Magnesium (Mg)	0.091	15.0	7.5	9.0	22.8	27.2	17.2
Manganese (Mn)	0.032	14.8	3.5	18.5	18.8	32.6	19.5
Mercury (Hg)	0.792	31.8	17.5	17.5	18.9	17.5	17.5
Molybdenum (Mo)	0.109	15.4	14.0	14.0	24.1	21.4	15.9
Nickel (Ni)	0.035	14.1	12.5	19.3	24.4	24.4	13.9
Nitrate (NO3)	0.012	14.4	34.3	16.5	22.4	16.5	16.5
Ortho-phosphate	-	-	-	-	-	-	-
pH	0.006	11.8	5.5	28.5	24.4	5.9	20.6
Phosphorustotal	0.188	17.7	2.5	23.5	19.7	18.0	23.3
Potassium (K)	0.001	9.1	2.0	3.5	27.4	21.0	15.3
Redox/Eh	0.176	19.4	33.0	8.0	21.8	14.7	19.6
Rubidium (Rb)	0.092	16.7	15.0	24.0	23.0	23.2	15.0
Selenium (Se)	0.142	19.6	20.5	31.0	16.9	14.2	24.5
Silicate (Si)	0.881	45.8	18.5	27.5	19.1	22.0	19.5
Silver (Ag)	0.007	16.2	33.3	37.5	19.9	14.0	17.7
Sodium (Na)	0.013	10.9	2.0	5.0	25.4	20.2	18.0
Specific Conductivity	0.037	12.7	4.5	6.0	23.9	24.8	17.5
Strontium (Sr)	0.014	11.5	1.5	4.5	24.1	25.0	17.9
Sulfate (SO4)	0.002	10.2	4.5	1.5	25.4	27.0	15.5
Sulfur (S)	0.001	10.0	4.5	1.5	25.6	27.8	14.9
Temperature	0.036	12.9	1.5	5.3	21.0	25.6	21.7
Thallium (Tl)	0.010	11.6	12.0	12.0	16.2	18.5	28.1
Tin (Sn)	-	-	-	-	-	-	-
Titanium (Ti)	0.019	12.5	14.5	14.5	25.1	21.4	14.5
Total dissolved solids	0.003	10.1	3.0	2.5	25.8	24.4	16.0
Total organic carbon	0.030	12.2	1.5	10.3	19.1	18.6	26.1
Total phosphate	0.010	10.7	7.3	24.5	7.9	15.8	19.9
Total suspended solids	0.250	19.4	11.3	14.5	17.4	27.4	22.7
Vanadium (V)	0.066	14.9	11.3	16.3	24.3	25.5	14.2
Zinc (Zn)	0.066	16.2	32.0	4.0	23.4	16.0	17.7
Zirconium (Zr)	-	-	-	-	-	-	-

[1] Insufficient sample size or no samples collected

Table D.80: Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in Ordovician wells for different sampling months. The null hypothesis was concentrations of individual chemicals did not differ by sampling month. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	Jan.	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Alkalinity	0.003	27.4	34.7	47.4	18.7	37.4	68.0	52.9	67.1	33.0	37.0
Aluminum (Al)	0.002	18.5	36.8	38.0	59.7	56.3	60.9	16.8	23.8	-[1]	38.9
Antimony (Sb)	0.104	27.4	38.1	35.2	59.9	48.5	36.2	52.8	60.2	-	36.5
Arsenic (As)	0.016	20.5	22.5	53.6	32.7	36.5	57.8	49.0	42.7	-	33.0
Barium (Ba)	0.033	30.8	41.1	51.3	53.3	25.2	53.1	60.9	24.5	35.0	43.1
Beryllium (Be)	0.623	37.9	39.3	43.2	54.4	37.6	42.7	40.6	48.0	-	38.9
Bismuth (Bi)	0.311	9.4	-	-	10.0	10.0	11.7	-	-	-	-
Boron (B)	0.070	33.3	48.0	44.1	29.0	30.9	51.8	50.3	69.5	6.0	45.8
Bromide (Br)	1.000	-	43.5	43.5	43.5	43.5	43.5	43.5	43.5	43.5	43.5
Cadmium (Cd)	0.000	12.8	54.9	56.9	20.9	36.6	26.8	13.5	16.4	-	53.5
Calcium (Ca)	0.098	35.6	47.5	41.6	33.2	36.9	62.6	45.7	68.6	23.0	39.5
Cesium (Cs)	0.061	6.4	-	-	15.1	8.5	8.6	-	-	-	-
Chloride (Cl)	0.022	31.0	49.8	34.9	58.8	60.9	48.9	20.1	31.7	54.0	43.5
Chromium (Cr)	0.000	15.5	47.1	29.3	63.8	61.0	22.3	19.3	40.0	-	52.8
Cobalt (Co)	0.000	17.8	29.1	33.0	67.2	43.1	59.9	58.8	70.0	-	27.5
Copper (Cu)	0.001	21.9	47.9	57.8	57.8	31.9	34.8	17.0	21.4	17.0	51.7
Dissolved Oxygen	0.007	29.8	59.0	38.5	39.9	50.7	37.8	9.3	39.7	79.0	53.8
Fluoride (F)	0.005	18.6	42.6	27.1	5.5	30.1	24.8	13.3	28.0	-	43.7
Iron (Fe)	0.080	33.5	37.2	50.9	34.7	29.9	55.8	61.8	54.0	21.0	39.4
Lead (Pb)	0.110	23.7	54.8	48.1	27.3	34.7	37.6	22.9	38.9	-	48.3
Lithium (Li)	0.253	38.4	46.7	50.0	38.0	33.9	50.4	34.0	63.9	10.5	42.5
Magnesium (Mg)	0.015	32.2	35.8	36.2	45.0	42.9	71.9	42.3	65.2	57.0	37.1
Manganese (Mn)	0.000	25.2	31.2	37.6	49.3	34.6	71.9	67.0	71.8	19.0	34.1
Mercury (Hg)	0.596	35.0	30.5	33.8	-	30.5	30.5	30.5	30.5	-	30.5
Molybdenum (Mo)	0.773	53.8	37.5	44.2	37.5	47.9	42.9	44.8	37.5	37.5	47.2
Nickel (Ni)	0.023	28.0	50.3	53.7	55.9	34.3	31.2	27.0	34.0	27.0	49.1
Nitrate (NO3)	0.059	34.7	55.1	43.7	50.0	54.4	32.5	32.5	32.5	71.0	42.6
Ortho-phosphate	0.001	16.3	19.2	35.0	-	-	-	-	7.5	26.0	17.9
pH	0.058	29.8	30.5	41.7	56.6	58.1	47.1	27.3	25.4	9.5	47.2
Phosphorustotal	0.003	24.8	29.6	61.5	47.3	39.5	55.2	53.3	33.0	11.5	30.0
Potassium (K)	0.386	42.1	38.3	40.2	45.7	43.8	59.2	37.7	56.8	2.0	43.1
Redox/Eh	0.016	33.6	59.8	35.6	31.3	39.2	28.4	43.8	58.8	86.0	55.3
Rubidium (Rb)	0.474	43.5	46.7	46.7	40.0	40.0	40.0	40.0	40.0	40.0	48.3
Selenium (Se)	0.026	20.7	29.5	30.7	11.2	42.0	30.1	40.0	46.4	-	31.6
Silicate (Si)	0.000	22.9	26.2	43.4	44.0	62.1	70.2	56.2	43.8	32.0	24.4
Silver (Ag)	0.000	15.3	35.2	30.0	70.4	60.4	53.6	30.0	46.8	-	35.8
Sodium (Na)	0.085	33.5	33.3	48.3	27.8	39.2	56.1	54.8	64.8	9.0	39.0
Specific Conductivity	0.130	35.6	32.2	42.6	35.7	41.5	69.7	44.6	51.1	32.0	40.3
Strontium (Sr)	0.023	29.6	38.5	46.0	23.7	32.9	66.0	50.5	59.6	10.0	43.0
Sulfate (SO4)	0.384	42.8	54.2	38.0	32.7	37.9	50.1	38.3	60.2	27.0	49.8
Sulfur (S)	0.437	44.2	53.2	37.7	31.3	41.4	49.9	38.7	61.0	25.0	48.5
Temperature	0.000	19.3	12.3	33.5	62.2	71.4	66.3	56.8	51.2	15.5	27.4
Thallium (Tl)	0.345	31.7	36.5	39.3	59.5	53.2	39.0	36.1	47.3	-	37.6
Tin (Sn)	0.078	6.4	-	-	12.8	11.8	6.5	-	-	-	-
Titanium (Ti)	0.117	32.9	51.8	52.6	50.6	38.4	35.0	31.0	31.0	31.0	46.5
Total dissolved solids	0.034	31.7	39.9	43.8	39.3	46.3	68.0	41.0	62.7	21.0	32.5
Total organic carbon	0.002	26.0	58.1	47.5	17.3	24.4	38.2	45.8	41.4	60.0	58.2
Total phosphate	0.428	17.4	-	-	20.6	18.4	21.8	23.2	10.6	-	-
Total suspended solids	0.093	38.9	52.0	44.6	40.3	32.7	57.4	60.6	55.2	68.5	34.8
Vanadium (V)	0.002	25.3	53.8	50.7	73.2	32.4	36.7	19.0	33.3	19.0	47.7
Zinc (Zn)	0.056	32.9	54.5	44.1	32.7	25.9	35.4	53.5	47.4	50.0	55.2
Zirconium (Zr)	0.030	5.3	-	-	8.5	13.5	8.5	-	-	-	-

[1] Insufficient sample size or no samples collected

Table D.81: Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in Precambrian wells for different sampling months. The null hypothesis was concentrations of individual chemicals did not differ by sampling month. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	April	May	June	July	August	Sept.	Oct.
Alkalinity	0.101	44.2	49.0	39.8	51.6	27.9	36.1	35.0	57.0
Aluminum (Al)	0.004	31.6	51.0	59.8	27.9	44.0	52.6	33.6	11.0
Antimony (Sb)	0.451	48.0	11.5	37.3	44.0	49.7	37.9	38.8	11.5
Arsenic (As)	0.049	31.7	26.0	39.2	51.1	23.8	42.4	37.5	6.0
Barium (Ba)	0.234	49.4	52.0	41.0	52.0	37.6	34.0	37.0	48.0
Beryllium (Be)	0.136	44.2	50.5	56.8	40.5	48.4	44.0	29.0	19.5
Bismuth (Bi)	0.880	54.6	-[1]	23.0	23.0	-	24.1	23.0	23.0
Boron (B)	0.800	84.4	60.0	55.7	40.9	34.8	41.9	37.4	46.0
Bromide (Br)	0.038	36.8	39.5	53.0	39.5	39.5	41.0	39.5	39.5
Cadmium (Cd)	0.000	26.4	22.5	56.0	53.3	54.2	34.2	26.6	22.5
Calcium (Ca)	0.016	35.7	43.0	33.7	56.4	36.7	35.9	30.4	62.0
Cesium (Cs)	0.564	32.0	-	26.3	17.4	-	23.4	25.9	9.5
Chloride (Cl)	0.691	59.4	12.0	43.7	35.9	43.2	42.2	44.2	20.0
Chromium (Cr)	0.124	40.5	39.0	52.0	48.4	44.7	40.6	28.6	11.0
Cobalt (Co)	0.532	57.4	23.0	47.7	44.4	31.5	44.5	34.4	49.5
Copper (Cu)	0.895	94.0	65.0	37.7	44.4	38.0	39.4	38.2	38.0
Dissolved Oxygen	0.454	54.9	48.5	42.8	31.5	38.3	47.0	42.5	32.5
Fluoride (F)	0.233	39.5	29.0	36.0	32.7	32.7	42.2	24.8	33.5
Iron (Fe)	0.381	51.2	54.0	42.7	40.1	25.3	45.1	42.8	23.0
Lead (Pb)	0.648	69.2	68.0	48.3	43.8	42.2	39.2	36.3	14.0
Lithium (Li)	0.787	80.4	46.0	59.2	43.6	39.1	37.9	37.8	45.0
Magnesium (Mg)	0.231	52.3	62.0	38.7	51.0	34.5	34.8	38.0	57.0
Manganese (Mn)	0.332	51.9	21.0	50.3	46.1	28.4	42.8	35.8	60.0
Mercury (Hg)	0.703	17.8	6.5	-	7.4	6.5	6.5	9.8	-
Molybdenum (Mo)	0.417	57.3	26.0	42.7	41.0	30.5	43.9	39.4	70.0
Nickel (Ni)	0.358	59.2	57.0	44.0	37.9	29.9	41.6	44.8	67.0
Nitrate (NO3)	0.601	58.3	34.0	34.0	41.8	46.7	37.0	42.5	34.0
Ortho-phosphate	-	-	-	-	-	-	-	-	-
pH	0.492	56.0	32.0	57.3	37.5	28.5	43.7	41.8	36.5
Phosphorustotal	0.266	44.4	30.0	36.7	46.2	23.0	42.6	41.7	42.0
Potassium (K)	0.354	58.1	71.0	41.0	47.7	29.0	38.1	39.8	49.0
Redox/Eh	0.055	37.9	10.0	33.7	35.2	55.7	45.1	30.7	59.0
Rubidium (Rb)	0.896	84.1	37.0	37.0	42.8	40.7	38.5	41.5	37.0
Selenium (Se)	0.980	117.8	43.0	29.3	41.1	44.2	40.3	40.2	32.5
Silicate (Si)	0.860	80.2	38.0	51.7	39.9	42.0	37.1	44.6	21.0
Silver (Ag)	0.001	35.9	80.0	56.2	46.3	54.7	38.3	23.3	56.5
Sodium (Na)	0.774	70.3	40.0	50.0	43.5	30.9	42.7	38.4	27.0
Specific Conductivity	0.147	47.8	51.0	53.7	49.8	31.4	32.9	39.9	56.0
Strontium (Sr)	0.263	54.4	75.0	28.3	48.1	37.3	40.6	32.8	51.0
Sulfate (SO4)	0.962	102.6	34.0	44.7	39.6	40.5	43.9	36.8	29.0
Sulfur (S)	0.961	101.0	33.0	42.7	41.6	40.2	43.3	36.0	29.0
Temperature	0.011	36.8	63.5	44.3	53.5	28.4	29.9	42.8	54.0
Thallium (Tl)	0.000	25.1	26.5	69.0	51.9	54.7	33.3	26.5	26.5
Tin (Sn)	0.060	22.8	-	30.8	26.8	-	17.1	29.2	27.5
Titanium (Ti)	0.479	57.0	23.0	55.2	38.4	35.2	45.8	36.3	50.0
Total dissolved solids	0.343	52.9	38.0	48.8	50.0	31.2	36.2	38.9	52.5
Total organic carbon	0.936	92.0	10.0	43.2	41.2	40.4	40.3	41.2	42.5
Total phosphate	0.278	42.9	20.0	49.5	47.7	30.2	39.6	36.5	20.0
Total suspended solids	0.248	46.9	44.5	41.0	35.2	30.9	50.1	37.7	44.5
Vanadium (V)	0.560	66.6	55.0	49.3	44.6	30.7	41.6	36.4	57.0
Zinc (Zn)	0.959	106.6	38.0	31.2	42.5	44.5	37.5	41.6	48.0
Zirconium (Zr)	0.235	23.6	-	27.2	21.4	-	27.5	19.3	6.0

[1] Insufficient sample size or no samples collected

Table D.82: Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in buried Quaternary wells for different sampling months. The null hypothesis was concentrations of individual chemicals did not differ by sampling month. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	April	May	June	July	August	Sept.	Oct.
Alkalinity	0.006	97.3	192.5	303.9	233.6	240.1	251.0	317.0	259.2
Aluminum (Al)	0.354	151.2	205.0	226.9	248.8	261.9	256.2	289.9	210.4
Antimony (Sb)	0.000	95.8	460.0	274.9	295.5	236.0	225.4	273.1	289.5
Arsenic (As)	0.165	129.0	165.8	293.1	246.7	263.8	245.7	279.5	190.8
Barium (Ba)	0.000	84.6	313.8	329.3	207.6	272.1	255.1	285.2	233.1
Beryllium (Be)	0.000	73.8	185.0	197.5	273.1	245.7	276.7	216.4	264.1
Bismuth (Bi)	0.991	162.5	-[1]	73.5	73.5	73.5	74.3	73.5	73.5
Boron (B)	0.000	73.9	22.0	243.5	269.0	207.8	277.7	294.2	224.4
Bromide (Br)	0.027	106.8	249.5	249.5	251.7	249.5	264.4	254.1	249.5
Cadmium (Cd)	0.000	70.7	262.5	276.2	313.0	241.8	236.3	220.1	197.8
Calcium (Ca)	0.224	143.2	269.5	277.6	273.0	259.8	238.8	274.7	193.2
Cesium (Cs)	0.005	29.8	-	63.5	97.1	70.1	70.5	86.5	63.5
Chloride (Cl)	0.055	128.7	396.5	297.1	281.9	236.7	251.0	230.2	252.0
Chromium (Cr)	0.000	69.5	442.8	315.6	283.3	287.9	217.1	232.4	128.7
Cobalt (Co)	0.283	154.4	289.0	262.7	261.8	277.4	232.2	266.1	252.3
Copper (Cu)	0.001	87.4	252.0	316.3	291.1	243.0	236.8	242.1	216.3
Dissolved Oxygen	0.002	101.8	463.0	223.8	233.2	304.7	248.0	256.4	255.4
Fluoride (F)	0.011	37.6	-	141.6	202.3	179.0	203.8	181.1	119.6
Iron (Fe)	0.102	119.6	117.5	266.7	229.6	274.6	254.6	290.0	233.8
Lead (Pb)	0.004	90.9	225.3	278.2	286.5	264.3	222.7	276.8	185.8
Lithium (Li)	0.082	117.1	134.0	290.9	262.9	223.6	263.7	276.1	234.6
Magnesium (Mg)	0.223	136.3	178.5	278.5	269.5	243.7	250.3	282.6	187.8
Manganese (Mn)	0.347	157.7	185.0	259.2	252.5	278.7	239.3	268.9	295.3
Mercury (Hg)	0.212	69.5	106.0	125.1	125.6	118.5	109.8	115.3	106.0
Molybdenum (Mo)	0.270	147.4	166.0	254.6	268.5	239.8	251.7	278.7	300.0
Nickel (Ni)	0.133	128.7	190.0	268.2	278.9	239.3	254.7	241.4	283.0
Nitrate (NO3)	0.001	88.0	350.3	21.0	13.5	260.4	243.9	243.2	239.5
Ortho-phosphate	0.025	5.7	-	21.0	13.5	-	-	-	-
pH	0.497	161.1	103.8	261.9	256.7	256.4	267.0	235.8	212.2
Phosphorustotal	0.013	95.5	112.5	309.1	229.6	250.0	268.9	274.8	188.1
Potassium (K)	0.013	94.9	110.5	296.4	245.4	234.4	270.4	282.8	170.6
Redox/Eh	0.000	71.5	397.8	152.0	256.3	257.7	280.9	218.6	388.4
Rubidium (Rb)	0.000	65.2	227.0	305.1	284.0	250.2	236.6	240.4	263.1
Selenium (Se)	0.023	112.9	265.3	249.8	257.4	260.0	231.7	312.6	306.3
Silicate (Si)	0.088	125.3	195.0	302.9	240.5	249.4	248.2	297.6	273.9
Silver (Ag)	0.000	54.5	483.3	343.9	306.7	252.8	210.8	220.6	240.4
Sodium (Na)	0.005	94.7	210.0	257.2	275.0	205.6	269.2	283.4	271.4
Specific Conductivity	0.066	128.5	360.5	306.6	260.1	235.5	248.9	285.0	213.0
Strontium (Sr)	0.004	88.2	132.5	276.8	275.0	217.9	261.6	293.3	180.0
Sulfate (SO4)	0.012	101.4	251.5	267.4	291.7	222.7	245.9	288.0	228.1
Sulfur (S)	0.035	111.3	246.0	263.7	290.7	229.7	243.9	284.4	230.4
Temperature	0.000	77.3	174.5	264.2	278.7	226.8	231.3	335.6	302.6
Thallium (Tl)	0.075	122.2	261.8	228.8	268.0	247.1	245.0	298.0	259.1
Tin (Sn)	0.325	55.5	-	110.9	66.5	83.0	70.3	83.1	77.8
Titanium (Ti)	0.026	106.3	205.5	243.5	286.0	243.9	252.7	241.8	281.2
Total dissolved solids	0.281	145.9	212.3	278.9	273.1	234.6	253.9	275.6	208.3
Total organic carbon	0.001	75.9	23.3	181.4	249.9	255.0	272.0	294.0	208.7
Total phosphate	0.344	140.5	152.5	251.0	233.8	252.0	235.8	262.6	174.4
Total suspended solids	0.036	101.8	78.3	215.0	234.1	278.3	268.9	269.3	233.8
Vanadium (V)	0.011	95.6	199.0	277.1	291.4	240.8	257.4	213.4	215.5
Zinc (Zn)	0.000	77.9	342.0	340.9	271.0	264.5	211.1	268.1	337.3
Zirconium (Zr)	0.614	58.1	-	55.6	73.1	72.2	77.8	63.6	64.3

[1] Insufficient sample size or no samples collected

Table D.83: Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in surficial Quaternary wells for different sampling months. The null hypothesis was concentrations of individual chemicals did not differ by sampling month. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	April	May	June	July	August	Sept.
Alkalinity	0.566	59.3	52.0	71.3	54.0	61.0	63.0	77.3
Aluminum (Al)	0.127	39.2	41.5	61.8	57.6	51.1	66.6	87.3
Antimony (Sb)	0.018	32.7	81.8	58.9	78.8	50.8	54.1	64.4
Arsenic (As)	0.033	37.1	80.5	72.5	48.1	58.1	65.4	90.1
Barium (Ba)	0.001	31.5	100.0	92.3	43.7	67.9	61.2	82.2
Beryllium (Be)	0.743	66.2	38.0	56.3	62.2	64.6	59.4	71.6
Bismuth (Bi)	1.000	-[1]	-	22.0	22.0	22.0	22.0	22.0
Boron (B)	0.044	31.4	15.5	37.8	62.7	56.4	67.7	81.6
Bromide (Br)	1.000	-	61.0	61.0	61.0	61.0	61.0	61.0
Cadmium (Cd)	0.010	27.8	51.8	57.8	80.1	55.8	54.6	48.9
Calcium (Ca)	0.675	68.4	65.0	74.0	63.7	58.3	58.2	76.6
Cesium (Cs)	0.002	14.7	-	36.8	26.6	17.0	18.9	33.8
Chloride (Cl)	0.084	39.4	57.0	68.9	70.2	57.2	53.2	88.4
Chromium (Cr)	0.001	28.5	72.5	84.6	65.4	76.4	43.9	70.1
Cobalt (Co)	0.319	51.9	69.3	80.3	59.0	60.0	57.0	81.5
Copper (Cu)	0.030	33.9	63.3	69.3	75.5	47.7	57.2	74.1
Dissolved Oxygen	0.751	67.2	39.5	69.6	64.3	67.2	58.0	55.9
Fluoride (F)	0.149	30.2	3.0	-	31.5	35.0	43.4	40.6
Iron (Fe)	0.003	30.0	70.5	79.0	41.7	61.6	69.8	83.9
Lead (Pb)	0.113	37.4	55.0	54.9	75.9	58.3	52.6	64.9
Lithium (Li)	0.319	48.3	64.0	61.9	50.4	59.5	67.6	86.6
Magnesium (Mg)	0.736	70.3	60.5	58.9	60.8	56.7	63.5	79.8
Manganese (Mn)	0.319	49.0	76.5	72.6	52.7	58.4	69.6	55.4
Mercury (Hg)	0.073	15.1	16.5	16.5	23.4	29.1	16.5	21.0
Molybdenum (Mo)	0.359	46.5	51.5	51.5	63.2	56.2	66.2	66.3
Nickel (Ni)	0.174	42.8	70.5	62.6	67.1	48.8	63.7	72.9
Nitrate (NO3)	0.003	26.0	44.5	61.5	78.4	61.9	51.3	60.0
Ortho-phosphate	-	-	-	-	-	-	-	-
pH	0.376	45.0	17.0	55.0	57.1	68.4	65.1	61.6
Phosphorustotal	0.007	31.1	40.0	82.4	48.0	59.6	65.2	95.2
Potassium (K)	0.127	41.2	64.0	61.9	50.4	59.5	67.6	86.6
Redox/Eh	0.017	26.4	24.5	36.4	76.8	58.8	62.1	45.9
Rubidium (Rb)	0.088	37.2	56.0	79.4	63.5	58.3	61.4	56.0
Selenium (Se)	0.076	42.5	91.0	70.9	57.9	62.0	55.4	92.6
Silicate (Si)	0.013	32.3	41.0	89.8	47.2	61.6	65.3	83.3
Silver (Ag)	0.001	31.3	106.5	88.4	67.5	56.7	49.9	79.4
Sodium (Na)	0.077	33.4	33.5	28.3	63.6	63.8	64.6	75.4
Specific Conductivity	0.399	54.7	73.5	76.6	61.6	51.7	62.9	76.3
Strontium (Sr)	0.824	79.5	59.5	62.3	61.5	57.7	62.1	78.8
Sulfate (SO4)	0.039	38.2	99.5	51.5	72.2	51.0	57.6	83.3
Sulfur (S)	0.063	40.4	99.0	53.6	71.4	51.7	57.5	82.5
Temperature	0.175	43.7	53.3	75.7	69.2	56.6	54.5	81.5
Thallium (Tl)	0.160	38.1	36.5	56.0	72.4	63.7	54.3	61.8
Tin (Sn)	0.012	17.2	-	38.0	31.5	30.8	18.6	14.1
Titanium (Ti)	0.198	41.1	44.5	51.4	69.1	56.1	60.5	76.5
Total dissolved solids	0.828	80.8	63.0	67.8	63.4	55.9	61.2	75.0
Total organic carbon	0.488	50.9	13.8	70.4	59.6	62.4	64.2	62.1
Total phosphate	0.127	38.4	23.3	69.7	57.1	57.2	56.2	85.7
Total suspended solids	0.010	31.6	65.3	66.1	43.7	63.4	69.0	88.1
Vanadium (V)	0.214	44.6	61.3	76.7	68.8	49.0	61.1	68.7
Zinc (Zn)	0.035	38.7	105.0	77.1	68.6	68.6	49.6	57.0
Zirconium (Zr)	0.290	25.1	-	37.5	18.2	19.0	21.5	26.5

[1] Insufficient sample size or no samples collected

Table D.84: Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in CFIG-CFRN-CIGL wells for different sampling months. The null hypothesis was concentrations of individual chemicals did not differ by sampling month. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	Jan.	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Alkalinity	0.495	23.2	13.0	18.9	17.0	18.0	26.8	29.2	18.5	16.8	16.0
Aluminum (Al)	0.511	25.0	29.5	19.5	17.6	27.3	17.8	23.0	12.7	23.7	14.0
Antimony (Sb)	0.365	23.2	26.0	17.9	10.2	22.8	27.6	17.6	21.0	28.0	17.5
Arsenic (As)	0.011	14.2	9.5	20.3	20.1	26.6	22.8	31.9	12.4	4.0	15.8
Barium (Ba)	0.616	26.0	20.0	13.5	18.6	24.0	22.3	28.3	19.0	16.7	20.0
Beryllium (Be)	0.921	36.0	21.8	22.5	22.7	14.0	19.0	19.7	17.9	22.3	21.8
Bismuth (Bi)	0.007	9.1	-[1]	8.5	8.5	8.5	17.0	8.5	8.5	-	-
Boron (B)	0.064	17.0	6.0	19.8	20.4	21.8	35.0	24.6	17.4	19.3	4.0
Bromide (Br)	1.000	-	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5
Cadmium (Cd)	0.006	17.0	38.5	15.3	11.4	23.9	32.9	14.6	15.5	21.0	34.5
Calcium (Ca)	0.084	16.9	11.5	19.2	17.6	20.3	28.8	31.9	16.3	14.7	8.5
Cesium (Cs)	0.183	11.2	-	5.8	9.8	14.0	4.0	10.3	4.0	-	-
Chloride (Cl)	0.679	26.8	20.3	20.8	23.8	15.5	24.1	24.7	19.7	8.3	20.5
Chromium (Cr)	0.143	19.9	33.0	22.8	20.3	21.4	5.6	16.4	25.6	16.7	24.8
Cobalt (Co)	0.108	18.0	16.5	24.8	23.2	14.0	32.0	19.9	12.8	23.7	5.5
Copper (Cu)	0.119	19.4	32.5	21.5	27.1	12.5	20.8	14.3	24.7	12.5	23.5
Dissolved Oxygen	0.296	22.6	27.5	19.2	15.1	17.9	10.3	21.4	26.9	19.3	33.0
Fluoride (F)	0.079	15.8	11.5	26.5	8.7	7.7	18.6	15.6	18.8	15.8	2.8
Iron (Fe)	0.568	25.0	21.0	19.5	18.8	23.0	21.3	27.1	16.3	24.3	6.5
Lead (Pb)	0.056	19.4	35.5	20.8	10.9	20.0	11.6	16.1	23.8	25.2	36.0
Lithium (Li)	0.137	18.1	15.3	18.9	21.8	18.3	32.3	23.4	23.4	7.5	7.5
Magnesium (Mg)	0.223	20.0	19.5	17.2	12.0	24.5	22.3	31.3	16.9	20.7	16.0
Manganese (Mn)	0.186	18.9	13.0	28.3	23.0	22.8	24.8	24.0	13.1	15.3	6.5
Mercury (Hg)	0.102	15.0	10.5	10.5	21.5	10.5	10.5	14.2	10.5	10.5	10.5
Molybdenum (Mo)	0.533	24.2	17.5	17.5	24.7	22.6	23.1	17.5	23.4	17.5	17.5
Nickel (Ni)	0.031	16.5	27.8	16.5	19.8	16.5	16.5	16.5	28.5	28.8	16.5
Nitrate (NO3)	0.308	21.8	26.5	17.0	20.4	17.0	17.0	20.1	26.1	17.0	26.0
Ortho-phosphate	0.626	11.2	5.5	-	-	-	-	-	6.9	5.5	5.5
pH	0.035	17.2	10.8	22.7	28.9	25.5	6.5	12.8	24.5	21.5	32.3
Phosphorustotal	0.013	14.2	6.8	25.8	24.8	18.6	26.0	29.0	17.6	4.5	4.5
Potassium (K)	0.051	16.6	10.0	20.8	20.6	24.8	34.5	25.0	16.3	13.3	3.0
Redox/Eh	0.153	20.4	22.5	13.3	15.9	27.1	17.8	14.9	29.3	21.3	31.5
Rubidium (Rb)	0.467	23.0	19.0	19.0	23.0	19.0	19.0	19.0	24.7	19.0	19.0
Selenium (Se)	0.263	18.1	18.0	13.4	14.1	12.9	15.3	25.4	23.3	18.0	-
Silicate (Si)	0.249	19.1	16.0	20.5	24.0	17.0	14.3	29.4	23.0	10.3	11.0
Silver (Ag)	0.469	24.7	24.8	14.8	17.9	27.4	22.3	19.1	16.4	29.7	16.0
Sodium (Na)	0.005	13.9	7.0	21.3	22.8	20.5	35.3	27.9	17.6	5.0	4.0
Specific Conductivity	0.043	16.1	13.8	19.5	17.4	20.0	31.3	30.6	18.1	4.7	14.5
Strontium (Sr)	0.008	14.3	8.5	23.2	21.0	24.5	33.3	27.7	15.7	6.3	2.5
Sulfate (SO4)	0.198	20.2	22.5	17.2	9.8	26.8	29.0	27.0	17.6	19.3	15.0
Sulfur (S)	0.212	20.6	21.0	17.2	9.6	25.5	29.3	26.4	17.1	24.0	15.5
Temperature	0.288	21.7	12.5	18.4	21.1	32.3	28.4	21.4	13.9	16.2	20.3
Thallium (Tl)	0.279	21.6	20.3	24.3	26.8	11.5	18.1	17.8	14.6	24.3	28.3
Tin (Sn)	0.040	10.3	-	15.0	6.5	10.0	10.5	4.0	10.5	-	-
Titanium (Ti)	0.123	18.3	27.3	16.5	24.3	16.5	16.5	19.4	27.8	16.5	16.5
Total dissolved solids	0.052	15.8	10.0	17.5	15.8	19.4	30.3	30.9	17.6	12.3	9.5
Total organic carbon	0.108	20.5	26.3	16.3	19.1	12.0	28.9	21.4	14.1	34.7	29.0
Total phosphate	0.279	13.6	-	16.1	12.4	11.5	9.8	20.7	15.5	-	-
Total suspended solids	0.262	19.4	13.8	22.6	16.4	16.1	22.6	28.3	17.1	23.2	5.0
Vanadium (V)	0.201	19.4	23.0	17.0	29.6	14.3	24.8	20.3	24.4	11.0	11.0
Zinc (Zn)	0.022	17.6	32.5	14.9	11.4	20.9	10.0	18.0	29.7	29.7	31.0
Zirconium (Zr)	0.324	14.1	-	8.4	5.5	11.5	5.5	11.0	13.5	-	-

[1] Insufficient sample size or no samples collected

Table D.85: Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in OSTP-OPDC-CJDN wells for different sampling months. The null hypothesis was concentrations of individual chemicals did not differ by sampling month. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	Jan.	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Alkalinity	0.002	19.3	42.9	41.9	26.1	32.7	70.2	63.0	49.3	37.3	44.4
Aluminum (Al)	0.000	17.0	41.8	22.4	57.6	73.4	50.4	14.8	40.5	57.9	38.4
Antimony (Sb)	0.683	38.6	36.4	43.6	54.0	52.3	39.8	53.4	40.8	34.7	41.5
Arsenic (As)	0.041	22.9	26.8	41.1	38.6	40.4	65.5	57.1	43.9	38.0	38.8
Barium (Ba)	0.000	16.4	43.1	39.3	58.6	23.8	59.0	74.7	26.9	19.8	53.9
Beryllium (Be)	0.149	25.9	35.5	39.5	55.0	35.5	50.0	50.0	43.5	35.5	43.1
Bismuth (Bi)	0.257	9.9	-[1]	-	13.0	13.0	14.9	-	-	-	-
Boron (B)	0.000	16.7	46.6	35.8	42.7	20.5	61.0	62.1	52.7	13.5	56.7
Bromide (Br)	0.000	-	45.5	45.5	45.5	45.5	45.5	45.5	45.5	45.5	45.5
Cadmium (Cd)	0.000	16.6	63.7	59.8	31.8	50.8	33.6	18.7	28.8	34.3	60.0
Calcium (Ca)	0.090	24.8	51.1	43.9	39.0	36.5	66.2	51.7	43.4	27.7	43.2
Cesium (Cs)	0.216	9.1	-	-	16.5	11.6	11.0	-	-	-	-
Chloride (Cl)	0.014	21.0	45.1	49.4	56.0	66.1	46.6	16.4	30.4	41.1	44.3
Chromium (Cr)	0.007	20.7	36.4	53.2	52.4	61.4	31.2	13.8	44.0	60.2	43.8
Cobalt (Co)	0.001	18.8	33.7	29.1	61.2	42.1	55.1	57.3	59.3	31.2	28.4
Copper (Cu)	0.012	20.5	53.4	54.5	59.8	33.4	38.1	20.5	39.0	37.4	56.1
Dissolved Oxygen	0.001	18.4	58.5	49.9	37.3	51.4	28.6	8.3	54.8	66.4	52.7
Fluoride (F)	0.010	19.4	37.0	24.3	29.8	7.0	19.0	14.0	30.5	20.4	40.1
Iron (Fe)	0.001	18.6	43.4	33.1	43.6	25.2	68.5	70.3	49.0	30.3	43.9
Lead (Pb)	0.037	23.3	52.2	55.7	32.6	34.8	38.0	20.3	52.6	62.5	47.9
Lithium (Li)	0.091	24.5	46.1	42.6	50.6	28.0	55.5	50.0	48.8	21.9	51.2
Magnesium (Mg)	0.015	21.0	39.9	33.3	41.5	36.5	70.7	46.2	56.0	35.8	40.7
Manganese (Mn)	0.000	14.9	37.9	28.1	49.3	25.3	76.6	70.8	53.0	23.6	38.9
Mercury (Hg)	0.118	18.6	29.5	35.5	-	-	29.5	29.5	29.5	29.5	29.5
Molybdenum (Mo)	0.524	33.5	40.0	44.3	52.6	44.9	43.6	40.0	44.5	40.0	50.1
Nickel (Ni)	0.040	22.6	51.3	54.2	54.6	35.3	33.3	30.0	44.6	41.6	54.9
Nitrate (NO3)	0.002	19.6	51.7	57.2	46.3	61.8	30.5	30.5	37.0	64.3	41.1
Ortho-phosphate	0.025	11.2	19.6	34.2	-	-	-	-	13.8	22.6	21.9
pH	0.089	24.6	29.6	37.0	54.0	61.9	46.6	23.7	42.8	53.5	47.5
Phosphorustotal	0.000	17.8	35.1	50.8	57.7	35.3	66.2	67.7	30.1	19.8	39.3
Potassium (K)	0.004	19.1	45.1	37.4	47.6	40.0	63.8	50.2	37.6	9.3	54.1
Redox/Eh	0.000	17.5	50.2	62.4	26.5	43.2	20.4	40.1	65.9	61.7	50.7
Rubidium (Rb)	0.362	30.6	48.1	51.3	45.8	42.0	42.0	42.0	42.0	42.0	50.1
Selenium (Se)	0.039	25.8	30.5	39.2	13.7	35.2	35.1	36.4	42.4	30.5	30.5
Silicate (Si)	0.000	15.9	28.7	37.7	47.0	63.3	71.9	62.5	45.8	30.2	24.7
Silver (Ag)	0.000	15.2	36.4	31.6	71.7	68.2	45.4	28.0	40.0	39.6	33.4
Sodium (Na)	0.001	18.5	38.4	32.6	45.6	38.7	65.1	67.3	43.6	12.3	50.1
Specific Conductivity	0.021	21.5	41.6	41.6	42.4	36.1	69.2	56.0	38.1	25.1	46.7
Strontium (Sr)	0.000	15.2	42.9	37.5	35.3	25.1	72.5	64.0	38.3	15.8	57.5
Sulfate (SO4)	0.103	24.9	61.0	42.4	36.2	34.0	51.9	41.2	44.3	27.7	57.5
Sulfur (S)	0.263	28.6	59.4	43.4	33.8	40.1	51.4	40.7	44.4	29.8	55.1
Temperature	0.000	14.7	11.7	34.4	57.8	71.6	66.0	53.6	45.3	38.5	26.7
Thallium (Tl)	0.028	23.5	33.4	31.5	53.6	50.1	43.2	35.4	53.9	73.0	35.9
Tin (Sn)	0.218	9.1	-	-	15.9	13.1	10.1	-	-	-	-
Titanium (Ti)	0.057	23.2	48.9	57.9	53.8	40.1	37.9	35.0	39.6	35.0	51.3
Total dissolved solids	0.025	21.9	45.1	47.1	40.8	40.1	67.5	52.3	42.2	19.8	39.9
Total organic carbon	0.000	15.6	67.6	18.3	26.3	24.5	46.5	55.5	57.9	52.9	62.9
Total phosphate	0.057	17.1	-	7.0	22.7	15.8	29.4	29.6	15.5	-	-
Total suspended solids	0.000	17.9	56.6	27.3	34.7	25.5	64.7	68.6	55.9	51.7	37.3
Vanadium (V)	0.000	16.1	46.5	49.6	75.7	33.1	43.7	21.5	34.0	27.8	53.4
Zinc (Zn)	0.035	23.4	53.6	50.4	31.3	24.7	38.9	49.3	52.8	60.3	55.0
Zirconium (Zr)	0.035	6.4	-	-	12.2	17.4	11.0	-	-	-	-

[1] Insufficient sample size or no samples collected

Table D.86: Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in CMSH-CMTS-PMHN wells for different sampling months. The null hypothesis was concentrations of individual chemicals did not differ by sampling month. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	May	June	July	Sept.	Oct.
Alkalinity	0.010	10.9	21.8	12.0	9.0	8.8	17.5
Aluminum (Al)	0.355	15.2	11.7	9.7	3.0	16.1	14.0
Antimony (Sb)	0.735	25.9	16.3	11.5	11.0	12.0	15.8
Arsenic (As)	0.262	17.6	16.3	20.7	14.0	11.5	9.8
Barium (Ba)	0.397	20.1	18.0	15.7	17.0	10.9	12.1
Beryllium (Be)	0.492	21.6	14.4	9.0	19.0	12.7	16.6
Bismuth (Bi)	0.000	-[1]	9.0	9.0	-	9.0	9.0
Boron (B)	0.134	17.7	16.7	14.0	26.0	9.8	16.3
Bromide (Br)	0.240	15.8	13.0	13.0	13.0	13.0	16.3
Cadmium (Cd)	0.199	18.1	14.9	13.3	23.0	10.9	17.0
Calcium (Ca)	0.005	10.0	22.2	10.3	3.0	9.4	17.8
Cesium (Cs)	0.184	14.2	14.0	13.0	-	8.3	6.0
Chloride (Cl)	0.311	19.2	14.0	6.2	24.0	14.2	13.5
Chromium (Cr)	0.238	17.2	19.3	13.3	17.0	10.7	12.5
Cobalt (Co)	0.295	15.3	17.8	9.0	3.0	13.1	14.3
Copper (Cu)	0.940	39.3	14.4	13.0	8.5	13.3	14.5
Dissolved Oxygen	0.434	16.8	15.4	10.2	1.0	14.4	13.5
Fluoride (F)	0.113	17.3	17.2	11.0	21.0	8.7	10.9
Iron (Fe)	0.745	24.4	16.2	11.3	6.0	13.3	13.8
Lead (Pb)	0.744	24.2	15.0	13.3	3.5	13.7	13.4
Lithium (Li)	0.982	58.5	14.6	12.3	15.0	12.9	14.3
Magnesium (Mg)	0.006	9.9	22.0	9.0	2.0	9.9	17.8
Manganese (Mn)	0.799	26.6	15.6	12.3	5.5	13.2	14.1
Mercury (Hg)	0.000	-	4.5	4.5	-	-	4.5
Molybdenum (Mo)	0.749	26.2	11.5	15.3	11.5	13.8	14.6
Nickel (Ni)	0.367	16.9	11.0	15.3	11.0	15.3	11.0
Nitrate (NO3)	0.861	30.6	13.2	11.0	11.0	14.1	14.8
Ortho-phosphate	-	-	-	-	-	-	-
pH	0.068	16.3	13.6	23.0	25.0	10.7	11.9
Phosphorustotal	0.310	16.6	17.2	18.0	6.0	12.6	9.3
Potassium (K)	0.304	19.6	16.8	12.3	21.0	10.4	16.8
Redox/Eh	0.012	9.3	7.4	5.7	6.0	17.7	17.8
Rubidium (Rb)	0.514	20.2	12.0	16.7	12.0	14.1	12.0
Selenium (Se)	0.705	24.3	12.7	16.2	5.0	13.2	15.9
Silicate (Si)	0.114	11.6	17.2	8.0	1.0	15.4	9.5
Silver (Ag)	0.087	15.0	18.5	13.3	21.0	10.5	13.4
Sodium (Na)	0.073	16.3	16.5	16.3	25.0	9.1	17.3
Specific Conductivity	0.015	10.7	21.5	10.3	2.0	10.2	16.8
Strontium (Sr)	0.090	15.3	18.7	14.7	19.0	9.1	16.8
Sulfate (SO4)	0.535	23.0	15.1	8.7	20.0	12.3	16.6
Sulfur (S)	0.620	25.0	15.0	9.3	20.0	12.3	16.3
Temperature	0.533	21.8	14.2	14.8	11.0	11.3	18.8
Thallium (Tl)	0.052	14.5	17.8	13.7	21.5	9.5	17.0
Tin (Sn)	0.188	13.4	15.0	3.0	-	8.3	10.5
Titanium (Ti)	0.962	45.3	12.8	14.7	10.5	14.0	13.1
Total dissolved solids	0.018	11.8	21.2	9.7	14.0	9.2	17.8
Total organic carbon	0.992	66.7	13.8	12.3	10.5	13.9	13.4
Total phosphate	0.261	15.3	15.2	18.0	4.5	14.2	7.8
Total suspended solids	0.093	11.4	18.0	6.7	5.0	15.1	9.1
Vanadium (V)	0.784	25.5	12.4	13.3	8.5	15.1	11.6
Zinc (Zn)	0.376	17.7	13.3	15.5	1.5	12.6	18.0
Zirconium (Zr)	0.663	19.4	10.8	6.5	-	9.3	6.5

[1] Insufficient sample size or no samples collected

Table D.87: Mean ranks using Kruskal-Wallis test comparing concentrations of individual chemicals in Upper Carbonate wells for different sampling months. The null hypothesis was concentrations of individual chemicals did not differ by sampling month. The null hypothesis is generally rejected if the p-value is less than 0.05.

Parameter	p-value	LSD	January	May	July	August	Sept.	Oct.	Dec.
Alkalinity	0.003	17.3	10.3	35.0	44.5	43.8	19.5	18.0	17.5
Aluminum (Al)	0.013	16.5	6.0	35.6	15.8	36.5	16.5	34.6	14.0
Antimony (Sb)	0.002	21.5	13.0	29.3	37.0	58.0	57.5	26.6	15.8
Arsenic (As)	0.004	20.6	12.7	34.5	32.2	44.0	59.5	18.3	9.8
Barium (Ba)	0.098	25.3	36.7	34.2	13.2	25.5	47.5	30.8	12.1
Beryllium (Be)	0.031	22.2	53.0	33.1	34.0	22.5	22.5	24.7	16.6
Bismuth (Bi)	0.083	3.1	-[1]	-	1.5	3.5	-	-	9.0
Boron (B)	0.007	19.4	18.7	33.8	47.5	42.0	27.5	17.2	16.3
Bromide (Br)	1.000	-	30.0	30.0	30.0	30.0	30.0	30.0	16.3
Cadmium (Cd)	0.001	12.0	16.0	37.6	14.2	14.5	2.5	36.8	17.0
Calcium (Ca)	0.364	30.7	14.3	30.3	29.2	35.5	29.5	39.3	17.8
Cesium (Cs)	0.083	3.1	-	-	1.5	3.5	-	-	6.0
Chloride (Cl)	0.001	19.8	34.0	22.4	37.2	38.0	45.5	46.8	13.5
Chromium (Cr)	0.000	13.7	44.3	23.2	46.5	17.5	17.5	52.0	12.5
Cobalt (Co)	0.004	21.2	16.0	31.0	38.8	59.5	44.5	21.6	14.3
Copper (Cu)	0.119	21.8	26.0	34.1	18.5	33.8	6.0	35.2	14.5
Dissolved Oxygen	0.031	20.7	31.7	28.3	32.0	29.5	6.5	45.5	13.5
Fluoride (F)	0.012	19.7	32.7	24.4	37.3	40.3	2.0	38.6	10.9
Iron (Fe)	0.077	19.7	22.7	36.2	36.5	14.5	14.5	26.1	13.8
Lead (Pb)	0.076	20.4	17.0	32.3	21.2	30.3	12.5	41.6	13.4
Lithium (Li)	0.147	25.2	29.7	33.7	40.2	38.0	10.5	22.5	14.3
Magnesium (Mg)	0.084	25.3	12.3	32.2	44.5	39.0	39.5	24.0	17.8
Manganese (Mn)	0.170	32.6	36.3	30.2	28.2	45.0	57.5	27.0	14.1
Mercury (Hg)	0.364	29.1	25.0	30.9	25.0	25.0	25.0	25.0	4.5
Molybdenum (Mo)	0.014	22.5	24.0	30.5	44.0	24.0	55.5	28.7	14.6
Nickel (Ni)	0.228	23.7	25.7	35.1	29.5	16.5	16.5	30.9	11.0
Nitrate (NO3)	0.252	27.3	27.5	31.0	27.5	27.5	27.5	37.8	14.8
Ortho-phosphate	0.000	6.6	8.3	30.9	-	-	-	14.0	-
pH	0.384	33.3	24.7	33.1	30.8	18.0	50.5	30.1	11.9
Phosphorustotal	0.000	11.0	8.0	40.9	29.8	8.5	19.5	20.6	9.3
Potassium (K)	0.028	22.7	13.0	31.5	45.8	47.5	32.5	23.3	16.8
Redox/Eh	0.000	17.2	46.3	23.6	17.5	44.0	46.5	51.2	17.8
Rubidium (Rb)	0.772	44.1	28.5	31.9	28.5	28.5	28.5	34.0	12.0
Selenium (Se)	0.005	21.7	20.0	22.5	37.0	20.0	49.5	24.8	15.9
Silicate (Si)	0.004	22.2	27.3	31.1	41.2	53.0	54.5	18.0	9.5
Silver (Ag)	0.020	21.7	27.5	28.4	38.2	44.5	27.5	34.6	13.4
Sodium (Na)	0.002	17.3	12.3	34.9	48.5	36.5	30.5	16.3	17.3
Specific Conductivity	0.007	20.2	9.3	29.8	50.5	48.5	22.5	28.3	16.8
Strontium (Sr)	0.000	15.9	12.7	34.0	53.8	43.0	35.5	13.3	16.8
Sulfate (SO4)	0.360	34.6	27.7	27.3	43.5	37.5	36.5	33.1	16.6
Sulfur (S)	0.237	32.5	30.3	27.1	45.2	39.5	38.5	33.8	16.3
Temperature	0.000	17.5	6.7	29.8	55.5	51.5	55.5	20.1	18.8
Thallium (Tl)	0.065	23.3	22.0	30.7	49.8	35.8	13.0	28.8	17.0
Tin (Sn)	0.083	3.1	-	-	3.5	1.5	-	-	10.5
Titanium (Ti)	0.404	32.2	44.0	32.2	31.5	20.5	20.5	31.8	13.1
Total dissolved solids	0.012	20.0	11.0	31.3	47.8	45.5	20.5	23.7	17.8
Total organic carbon	0.042	18.4	11.7	34.0	17.5	28.0	18.5	39.6	13.4
Total phosphate	0.021	4.9	-	-	8.5	2.5	8.5	-	7.8
Total suspended solids	0.046	19.9	30.0	35.0	41.5	21.3	12.5	21.0	9.1
Vanadium (V)	0.128	23.9	44.7	33.7	29.2	14.0	14.0	31.8	11.6
Zinc (Zn)	0.013	18.4	2.7	31.5	22.5	30.0	33.5	43.5	18.0
Zirconium (Zr)	0.083	3.1	-	-	3.5	1.5	-	-	6.5

[1] Insufficient sample size or no samples collected

Table D.88: Correlation coefficients between chemical parameters and well depth, static water level, and UTM coordinates, for the Cambrian aquifer group.

Parameter	Well Depth (ft)		Static water level (ft)		UTM-east		UTM-north	
	R^2	p	R^2	p	R^2	p	R^2	p
Alkalinity	0.258	0.009	0.277	0.005	-0.557	0.000	-0.317	0.001
Aluminum (Al)	-0.097	0.336	-0.097	0.336	0.264	0.008	0.206	0.040
Antimony (Sb)	0.065	0.521	0.025	0.808	-0.324	0.001	-0.156	0.120
Arsenic (As)	-0.017	0.868	-0.028	0.782	-0.540	0.000	0.072	0.479
Barium (Ba)	-0.001	0.989	0.042	0.672	-0.458	0.000	0.035	0.725
Beryllium (Be)	0.145	0.151	-0.035	0.732	-0.127	0.208	0.103	0.310
Bismuth (Bi)	0.175	0.257	0.305	0.044	-0.299	0.049	-0.223	0.146
Boron (B)	0.079	0.432	-0.017	0.867	-0.707	0.000	0.034	0.733
Bromide (Br)	0.161	0.107	0.144	0.150	-0.103	0.303	-0.032	0.749
Cadmium (Cd)	0.149	0.139	0.172	0.087	0.140	0.165	-0.302	0.002
Calcium (Ca)	0.159	0.111	0.186	0.061	-0.633	0.000	-0.202	0.042
Cesium (Cs)	0.626	0.000	0.326	0.031	-0.282	0.064	-0.335	0.026
Chloride (Cl)	-0.145	0.147	-0.048	0.630	-0.037	0.710	0.244	0.013
Chromium (Cr)	0.075	0.460	0.171	0.089	0.129	0.200	-0.051	0.616
Cobalt (Co)	-0.042	0.680	-0.081	0.423	-0.477	0.000	0.105	0.300
Copper (Cu)	-0.083	0.408	0.019	0.850	0.200	0.044	0.003	0.979
Day	-0.249	0.012	-0.423	0.000	-0.414	0.000	0.668	0.000
Depth	-	-	0.642	0.000	0.106	0.288	-0.447	0.000
Diameter	0.149	0.136	0.172	0.084	-0.206	0.038	-0.340	0.000
Dissolved Oxygen	0.007	0.941	0.228	0.021	0.484	0.000	-0.102	0.308
Fluoride (F)	0.283	0.018	0.310	0.009	-0.095	0.436	-0.154	0.202
Iron (Fe)	0.114	0.254	-0.025	0.802	-0.542	0.000	0.024	0.807
Lead (Pb)	0.160	0.113	0.305	0.002	0.434	0.000	-0.271	0.006
Lithium (Li)	0.009	0.929	-0.010	0.921	-0.564	0.000	-0.049	0.624
Magnesium (Mg)	0.294	0.003	0.319	0.001	-0.452	0.000	-0.335	0.001
Manganese (Mn)	-0.144	0.150	-0.237	0.016	-0.549	0.000	0.366	0.000
Mercury (Hg)	-0.224	0.104	-0.276	0.043	-0.117	0.400	0.149	0.284
Molybdenum (Mo)	-0.100	0.318	-0.134	0.179	-0.064	0.522	0.110	0.270
Nickel (Ni)	0.032	0.753	0.084	0.400	0.385	0.000	-0.109	0.274
Nitrate (NO3)	-0.149	0.135	0.117	0.242	0.415	0.000	-0.132	0.185
Ortho-phosphate	-0.108	0.590	0.289	0.143	0.397	0.040	-0.396	0.041
pH	0.059	0.559	-0.085	0.396	0.351	0.000	0.157	0.115
Phosphorustotal	-0.107	0.286	-0.143	0.151	-0.639	0.000	0.283	0.004
Potassium (K)	0.119	0.235	0.018	0.860	-0.778	0.000	0.079	0.428
Redox/Eh	0.013	0.899	0.343	0.000	0.439	0.000	-0.337	0.001
Rubidium (Rb)	0.056	0.578	0.064	0.526	0.082	0.411	0.072	0.472
Selenium (Se)	0.003	0.980	0.127	0.246	-0.180	0.097	-0.039	0.725
Silicate (Si)	-0.395	0.000	-0.152	0.127	-0.341	0.000	0.258	0.009
Silver (Ag)	0.022	0.832	-0.059	0.562	-0.091	0.369	-0.005	0.962
Sodium (Na)	0.012	0.902	-0.050	0.621	-0.815	0.000	0.223	0.024
Specific Conductivity	0.177	0.075	0.249	0.011	-0.668	0.000	-0.189	0.058
Strontium (Sr)	0.116	0.246	0.037	0.712	-0.813	0.000	0.059	0.558
Sulfate (SO4)	0.338	0.001	0.286	0.004	-0.421	0.000	-0.369	0.000
Sulfur (S)	0.333	0.001	0.280	0.004	-0.401	0.000	-0.382	0.000
SWL	0.642	0.000	-	-	0.142	0.155	-0.559	0.000
Temperature	0.301	0.002	0.217	0.029	-0.232	0.019	-0.258	0.009
Thallium (Tl)	0.022	0.828	-0.024	0.816	0.111	0.274	-0.121	0.229
Tin (Sn)	-0.347	0.021	-0.271	0.075	0.146	0.343	0.377	0.012
Titanium (Ti)	-0.032	0.747	0.024	0.813	0.249	0.012	0.126	0.205
Total dissolved solids	0.191	0.056	0.237	0.017	-0.657	0.000	-0.231	0.021
Total organic carbon	0.056	0.578	0.069	0.490	-0.191	0.054	-0.274	0.005
Total phosphate	-0.123	0.294	-0.013	0.914	-0.210	0.070	0.014	0.905
Tritium	-0.289	0.026	0.021	0.875	-0.012	0.926	0.067	0.613
Total suspended solids	-0.002	0.982	-0.040	0.691	-0.413	0.000	0.087	0.388
Vanadium (V)	-0.080	0.423	-0.151	0.129	-0.002	0.981	0.140	0.159
Zinc (Zn)	0.412	0.000	0.454	0.000	0.160	0.108	-0.456	0.000
Zirconium (Zr)	0.188	0.222	0.194	0.206	0.169	0.273	-0.032	0.838

Table D.89: Correlation coefficients between chemical parameters and well depth, static water level, and UTM coordinates, for the Devonian aquifer group.

Parameter	Well Depth (ft)		Static water level (ft)		UTM-east		UTM-north	
	R^2	p	R^2	p	R^2	p	R^2	p
Alkalinity	0.626	0.053	0.116	0.751	-0.900	0.000	0.146	0.688
Aluminum (Al)	0.188	0.603	0.018	0.960	-0.139	0.701	0.164	0.651
Antimony (Sb)	0.332	0.348	0.548	0.101	-0.203	0.574	0.308	0.387
Arsenic (As)	0.612	0.060	0.067	0.855	-0.697	0.025	0.430	0.214
Barium (Ba)	0.261	0.467	-0.200	0.200	0.139	0.701	0.176	0.627
Beryllium (Be)	-0.108	0.767	-0.380	0.380	0.437	0.206	-0.127	0.727
Bismuth (Bi)	-[1]	-	-	-	-	-	-	-
Boron (B)	0.442	0.200	0.285	0.425	-0.733	0.016	0.067	0.855
Bromide (Br)	-	-	-	-	-	-	-	-
Cadmium (Cd)	0.127	0.726	0.212	0.556	-0.382	0.276	0.103	0.777
Calcium (Ca)	0.661	0.038	0.152	0.152	-0.746	0.013	0.067	0.855
Cesium (Cs)	-	-	-	-	-	-	-	-
Chloride (Cl)	-0.483	0.187	-0.183	0.637	0.567	0.112	-0.650	0.058
Chromium (Cr)	-0.432	0.213	-0.062	0.866	0.610	0.061	-0.185	0.609
Cobalt (Co)	0.139	0.701	0.382	0.276	-0.418	0.229	0.055	0.881
Copper (Cu)	-0.018	0.960	0.588	0.074	0.030	0.934	0.030	0.934
Day	0.514	0.128	0.050	0.890	-0.765	0.010	-0.075	0.836
Depth	-	-	0.309	0.385	-0.721	0.019	0.479	0.162
Diameter	-0.058	0.873	-0.406	0.244	-0.174	0.631	-0.290	0.416
Dissolved Oxygen	-0.006	0.987	0.236	0.511	0.249	0.489	0.152	0.676
Fluoride (F)	0.017	0.965	0.187	0.631	0.017	0.965	0.237	0.539
Iron (Fe)	0.770	0.009	0.079	0.829	-0.576	0.082	0.503	0.138
Lead (Pb)	-0.406	0.244	0.515	0.128	0.333	0.347	-0.200	0.580
Lithium (Li)	0.309	0.385	0.200	0.580	-0.539	0.108	-0.067	0.855
Magnesium (Mg)	0.685	0.029	-0.042	0.907	-0.794	0.006	0.115	0.751
Manganese (Mn)	-0.430	0.214	0.224	0.533	0.018	0.960	-0.285	0.425
Mercury (Hg)	0.664	0.036	-0.150	0.680	-0.840	0.002	0.475	0.165
Molybdenum (Mo)	0.406	0.244	0.174	0.631	-0.290	0.416	0.406	0.244
Nickel (Ni)	-0.068	0.851	0.157	0.665	-0.082	0.822	-0.253	0.481
Nitrate (NO3)	-	-	-	-	-	-	-	-
Ortho-phosphate	0.449	0.193	0.351	0.320	-0.400	0.252	-0.222	0.538
pH	-0.109	0.763	0.061	0.868	0.377	0.283	0.128	0.725
Phosphorustotal	0.285	0.425	0.055	0.881	-0.406	0.244	0.139	0.701
Potassium (K)	0.370	0.293	0.249	0.489	-0.673	0.033	-0.164	0.651
Redox/Eh	-0.576	0.082	-0.103	0.777	0.442	0.200	-0.527	0.117
Rubidium (Rb)	-	-	-	-	-	-	-	-
Selenium (Se)	0.412	0.310	0.083	0.846	-0.247	0.555	0.412	0.310
Silicate (Si)	0.188	0.603	-0.055	0.881	-0.297	0.405	-0.503	0.138
Silver (Ag)	-0.588	0.074	-0.069	0.849	0.510	0.132	-0.164	0.650
Sodium (Na)	0.297	0.405	0.273	0.446	-0.685	0.029	0.006	0.987
Specific Conductivity	0.600	0.067	0.285	0.425	-0.867	0.001	0.115	0.751
Strontium (Sr)	0.418	0.229	0.030	0.934	-0.721	0.019	-0.018	0.960
Sulfate (SO4)	-0.017	0.966	-0.150	0.700	-0.367	0.332	0.217	0.576
Sulfur (S)	-0.042	0.907	0.067	0.855	-0.309	0.385	-0.055	0.881
SWL	0.309	0.385			-0.224	0.533	0.103	0.777
Temperature	0.043	0.906	-0.154	0.670	-0.426	0.220	0.303	0.396
Thallium (Tl)	-0.136	0.708	0.032	0.929	-0.175	0.630	-0.226	0.530
Tin (Sn)	-	-	-	-	-	-	-	-
Titanium (Ti)	-0.320	0.367	0.043	0.906	0.398	0.255	-0.683	0.029
Total dissolved solids	0.517	0.154	-0.017	0.966	-0.833	0.005	0.133	0.732
Total organic carbon	0.236	0.511	0.042	0.907	0.055	0.881	0.055	0.881
Total phosphate	-	-	-	-	-	-	-	-
Tritium	-1.000	0.000	-0.500	0.667	0.500	0.667	-0.500	0.667
Total suspended solids	0.468	0.204	0.077	0.845	-0.536	0.137	0.255	0.507
Vanadium (V)	-0.149	0.682	0.239	0.506	0.058	0.873	-0.265	0.459
Zinc (Zn)	0.333	0.347	0.018	0.960	-0.382	0.276	-0.164	0.651
Zirconium (Zr)	-	-	-	-	-	-	-	-

[1] Insufficient sample size or no samples collected

Table D.90: Correlation coefficients between chemical parameters and well depth, static water level, and UTM coordinates, for the Cretaceous aquifer group.

Parameter	Well Depth (ft)		Static water level (ft)		UTM-east		UTM-north	
	R^2	p	R^2	p	R^2	p	R^2	p
Alkalinity	0.051	0.758	0.127	0.440	0.059	0.720	-0.109	0.510
Aluminum (Al)	0.028	0.867	-0.258	0.113	-0.114	0.489	0.022	0.894
Antimony (Sb)	-0.345	0.031	0.016	0.925	0.210	0.200	0.047	0.776
Arsenic (As)	0.036	0.828	0.029	0.862	-0.409	0.010	0.173	0.294
Barium (Ba)	-0.203	0.215	0.076	0.648	0.675	0.000	0.067	0.687
Beryllium (Be)	-0.150	0.362	-0.182	0.269	0.092	0.579	0.157	0.339
Bismuth (Bi)	-[1]	-	-	-	-	-	-	-
Boron (B)	0.261	0.109	-0.048	0.770	-0.686	0.000	0.112	0.496
Bromide (Br)	0.258	0.113	-0.210	0.201	-0.581	0.000	0.387	0.015
Cadmium (Cd)	0.055	0.738	-0.056	0.735	0.087	0.597	-0.045	0.786
Calcium (Ca)	0.180	0.273	0.279	0.085	0.053	0.750	-0.679	0.000
Cesium (Cs)	-	-	-	-	-	-	-	-
Chloride (Cl)	-0.074	0.657	-0.230	0.159	-0.690	0.000	0.562	0.000
Chromium (Cr)	-0.063	0.705	-0.266	0.102	-0.294	0.070	0.472	0.002
Cobalt (Co)	0.134	0.416	0.307	0.057	0.396	0.013	-0.574	0.000
Copper (Cu)	0.045	0.788	0.133	0.419	-0.253	0.120	-0.191	0.245
Day	-0.198	0.227	-0.365	0.023	-0.034	0.839	0.722	0.000
Depth	-	-	0.473	0.002	-0.221	0.176	-0.305	0.059
Diameter	0.043	0.794	0.234	0.153	0.143	0.385	-0.555	0.000
Dissolved Oxygen	-0.180	0.274	0.294	0.069	0.258	0.113	-0.191	0.244
Fluoride (F)	0.054	0.794	0.034	0.868	-0.844	0.000	0.412	0.037
Iron (Fe)	0.426	0.007	0.187	0.254	0.267	0.101	-0.482	0.002
Lead (Pb)	0.141	0.394	0.126	0.444	-0.054	0.742	-0.033	0.841
Lithium (Li)	0.387	0.015	0.312	0.053	-0.511	0.001	-0.124	0.453
Magnesium (Mg)	0.166	0.312	0.281	0.083	-0.001	0.996	-0.608	0.000
Manganese (Mn)	0.390	0.014	0.309	0.056	0.128	0.439	-0.684	0.000
Mercury (Hg)	0.272	0.114	0.289	0.092	-0.051	0.771	-0.153	0.381
Molybdenum (Mo)	0.272	0.094	0.333	0.039	-0.424	0.007	-0.184	0.261
Nickel (Ni)	0.144	0.382	0.196	0.231	-0.264	0.104	-0.364	0.023
Nitrate (NO3)	-0.433	0.006	-0.171	0.299	-0.058	0.727	0.301	0.062
Ortho-phosphate	-0.179	0.645	0.274	0.476	0.307	0.423	0.026	0.948
pH	0.117	0.479	-0.185	0.261	-0.419	0.008	0.490	0.002
Phosphorustotal	0.341	0.033	0.141	0.391	-0.185	0.259	-0.254	0.119
Potassium (K)	0.351	0.028	0.030	0.855	-0.749	0.000	-0.023	0.891
Redox/Eh	-0.460	0.003	-0.141	0.391	0.250	0.125	-0.217	0.184
Rubidium (Rb)	0.122	0.460	0.102	0.536	-0.266	0.102	-0.238	0.144
Selenium (Se)	-0.185	0.261	-0.244	0.134	-0.240	0.141	0.660	0.000
Silicate (Si)	0.049	0.769	0.545	0.000	0.229	0.161	-0.344	0.032
Silver (Ag)	-0.191	0.243	-0.393	0.013	-0.089	0.589	0.643	0.000
Sodium (Na)	0.303	0.061	-0.003	0.986	-0.748	0.000	0.090	0.587
Specific Conductivity	0.308	0.056	0.110	0.507	-0.535	0.000	-0.246	0.131
Strontium (Sr)	0.278	0.087	0.151	0.358	-0.314	0.052	-0.447	0.004
Sulfate (SO4)	0.270	0.097	0.085	0.606	-0.497	0.001	-0.435	0.006
Sulfur (S)	0.273	0.093	0.107	0.515	-0.470	0.003	-0.458	0.003
SWL	0.473	0.002	-	-	0.016	0.922	-0.296	0.067
Temperature	0.296	0.067	0.102	0.536	-0.268	0.099	-0.294	0.070
Thallium (Tl)	-0.157	0.340	-0.013	0.939	0.055	0.740	-0.148	0.370
Tin (Sn)	-	-	-	-	-	-	-	-
Titanium (Ti)	0.308	0.057	0.404	0.011	-0.270	0.097	-0.426	0.007
Total dissolved solids	0.212	0.194	0.068	0.679	-0.561	0.000	-0.319	0.047
Total organic carbon	0.166	0.313	0.258	0.112	0.058	0.725	-0.338	0.035
Total phosphate	0.311	0.094	0.171	0.365	0.052	0.786	-0.099	0.603
Tritium	-0.866	0.333	-0.866	0.333	0.866	0.333	0.866	0.333
Total suspended solids	0.427	0.007	0.112	0.497	0.289	0.074	-0.408	0.010
Vanadium (V)	0.236	0.148	0.341	0.034	-0.102	0.539	-0.505	0.001
Zinc (Zn)	0.212	0.194	0.131	0.428	0.141	0.391	-0.283	0.081
Zirconium (Zr)	-	-	-	-	-	-	-	-

[1] Insufficient sample size or no samples collected

Table D.91: Correlation coefficients between chemical parameters and well depth, static water level, and UTM coordinates, for the Ordovician aquifer group.

Parameter	Well Depth (ft)		Static water level (ft)		UTM-east		UTM-north	
	R^2	p	R^2	p	R^2	p	R^2	p
Alkalinity	-0.116	0.286	-0.254	0.018	-0.574	0.000	-0.029	0.793
Aluminum (Al)	-0.170	0.124	-0.083	0.456	-0.015	0.891	0.449	0.000
Antimony (Sb)	-0.039	0.725	0.074	0.508	-0.184	0.097	0.081	0.466
Arsenic (As)	-0.174	0.116	-0.380	0.000	-0.385	0.000	-0.115	0.299
Barium (Ba)	-0.151	-	-0.279	0.009	-0.115	0.290	0.028	0.801
Beryllium (Be)	-0.075	0.163	0.000	0.999	-0.174	0.116	-0.040	0.717
Bismuth (Bi)	-0.339	0.498	-0.120	0.615	-0.259	0.271	0.100	0.677
Boron (B)	0.210	0.051	0.036	0.741	-0.502	0.000	-0.248	0.021
Bromide (Br)	-[1]	0.144	-	-	-	-	-	-
Cadmium (Cd)	0.220	0.047	0.153	0.168	0.435	0.000	-0.549	0.000
Calcium (Ca)	-0.210	-	-0.296	0.005	-0.275	0.010	-0.024	0.823
Cesium (Cs)	0.117	0.510	-0.094	0.693	0.089	0.708	-0.272	0.246
Chloride (Cl)	-0.364	0.046	-0.181	0.093	0.286	0.007	0.293	0.006
Chromium (Cr)	-0.111	0.001	0.135	0.226	0.284	0.009	0.187	0.090
Cobalt (Co)	-0.073	0.979	-0.116	0.298	-0.458	0.000	0.329	0.002
Copper (Cu)	-0.061	0.575	0.020	0.857	0.292	0.006	-0.152	0.160
Day	-0.235	0.028	-0.198	0.066	-0.515	0.000	0.543	0.000
Depth	-	-	0.689	0.000	0.108	0.318	-0.323	0.002
Diameter	-0.053	0.629	-0.195	0.071	-0.075	0.492	-0.395	0.000
Dissolved Oxygen	-0.101	0.353	0.079	0.469	0.320	0.003	-0.048	0.656
Fluoride (F)	0.246	0.052	0.252	0.046	0.178	0.163	-0.225	0.076
Iron (Fe)	0.086	0.427	-0.204	0.059	-0.414	0.000	-0.239	0.026
Lead (Pb)	-0.033	0.770	0.211	0.056	0.404	0.000	-0.039	0.724
Lithium (Li)	0.087	0.421	-0.081	0.459	-0.406	0.000	-0.302	0.005
Magnesium (Mg)	-0.141	0.194	-0.084	0.442	-0.462	0.000	0.310	0.003
Manganese (Mn)	0.012	0.915	-0.183	0.090	-0.588	0.000	0.134	0.215
Mercury (Hg)	-0.225	0.078	-0.225	0.079	0.220	0.086	-0.132	0.305
Molybdenum (Mo)	-0.150	0.167	-0.164	0.129	-0.213	0.047	0.019	0.864
Nickel (Ni)	0.143	0.185	0.176	0.104	0.263	0.014	-0.166	0.125
Nitrate (NO3)	-0.306	0.004	-0.054	0.618	0.412	0.000	0.137	0.207
Ortho-phosphate	-0.187	0.198	-0.292	0.042	-0.245	0.089	0.001	0.994
pH	-0.093	0.390	-0.005	0.963	0.144	0.184	0.333	0.002
Phosphorustotal	-0.069	0.527	-0.273	0.011	-0.373	0.000	-0.064	0.556
Potassium (K)	0.032	0.771	-0.029	0.791	-0.425	0.000	-0.049	0.654
Redox/Eh	0.076	0.484	0.233	0.030	0.421	0.000	-0.137	0.207
Rubidium (Rb)	0.004	0.974	0.085	0.433	0.253	0.018	-0.216	0.045
Selenium (Se)	-0.056	0.662	-0.093	0.463	-0.242	0.054	-0.187	0.140
Silicate (Si)	-0.399	0.000	-0.397	0.000	-0.546	0.000	0.352	0.001
Silver (Ag)	-0.142	0.200	-0.001	0.995	-0.128	0.248	0.625	0.000
Sodium (Na)	-0.121	0.266	-0.296	0.005	-0.608	0.000	-0.123	0.258
Specific Conductivity	-0.325	0.002	-0.378	0.000	-0.514	0.000	0.017	0.879
Strontium (Sr)	0.108	0.321	-0.090	0.406	-0.588	0.000	-0.189	0.080
Sulfate (SO4)	0.134	0.216	0.106	0.330	-0.159	0.142	-0.317	0.003
Sulfur (S)	0.116	0.283	0.101	0.354	-0.139	0.200	-0.302	0.004
SWL	0.689	0.000	-	-	0.250	0.019	-0.020	0.853
Temperature	-0.228	0.034	-0.158	0.145	-0.354	0.001	0.465	0.000
Thallium (Tl)	-0.221	0.045	0.018	0.871	-0.060	0.588	0.130	0.242
Tin (Sn)	0.129	0.588	0.358	0.121	0.273	0.245	-0.352	0.128
Titanium (Ti)	0.045	0.677	0.182	0.092	0.319	0.003	-0.164	0.129
Total dissolved solids	-0.267	0.012	-0.321	0.002	-0.525	0.000	0.058	0.591
Total organic carbon	0.050	0.644	-0.161	0.161	-0.014	0.897	-0.366	0.000
Total phosphate	0.091	0.587	-0.046	0.046	-0.196	0.238	-0.012	0.946
Tritium	-0.584	0.000	-0.405	0.405	-0.022	0.886	0.408	0.005
Total suspended solids	0.063	0.563	-0.126	0.126	-0.408	0.000	-0.061	0.575
Vanadium (V)	0.084	0.441	0.144	0.144	0.256	0.017	0.022	0.837
Zinc (Zn)	0.333	0.002	0.450	0.450	0.243	0.023	-0.180	0.095
Zirconium (Zr)	-0.403	0.078	-0.308	0.308	0.403	0.078	0.390	0.089

[1] Insufficient sample size or no samples collected

Table D.92: Correlation coefficients between chemical parameters and well depth, static water level, and UTM coordinates, for the Precambrian aquifer group.

Parameter	Well Depth (ft)		Static water level (ft)		UTM-east		UTM-north	
	R^2	p	R^2	p	R^2	p	R^2	p
Alkalinity	0.207	0.068	0.301	0.007	-0.631	0.000	-0.300	0.008
Aluminum (Al)	0.066	0.563	-0.199	0.077	0.366	0.001	0.308	0.005
Antimony (Sb)	0.023	0.837	-0.035	0.761	0.067	0.555	-0.031	0.786
Arsenic (As)	0.018	0.877	0.368	0.001	-0.192	0.088	-0.247	0.027
Barium (Ba)	-0.104	0.358	0.148	0.189	-0.295	0.008	-0.085	0.455
Beryllium (Be)	0.274	0.014	-0.061	0.590	0.078	0.489	0.101	0.374
Bismuth (Bi)	0.174	0.247	0.062	0.682	0.129	0.392	-0.062	0.683
Boron (B)	0.408	0.000	0.111	0.328	-0.149	0.186	-0.204	0.069
Bromide (Br)	0.159	0.159	0.012	0.918	0.075	0.510	-0.085	0.456
Cadmium (Cd)	-0.037	0.746	0.086	0.447	-0.110	0.332	-0.104	0.360
Calcium (Ca)	0.059	0.602	0.261	0.019	-0.588	0.000	-0.277	0.013
Cesium (Cs)	0.390	0.007	0.055	0.716	0.023	0.877	0.148	0.327
Chloride (Cl)	0.253	0.024	-0.084	0.461	-0.210	0.062	0.001	0.992
Chromium (Cr)	0.025	0.828	0.082	0.469	-0.076	0.503	-0.126	0.267
Cobalt (Co)	0.042	0.713	0.265	0.018	-0.312	0.005	-0.106	0.348
Copper (Cu)	0.449	0.000	0.106	0.349	0.002	0.989	-0.019	0.867
Day	-0.179	0.112	-0.159	0.159	0.497	0.000	0.417	0.000
Depth	-	-	0.183	0.105	-0.105	0.352	-0.154	0.171
Diameter	0.234	0.037	0.145	0.199	-0.306	0.006	-0.350	0.001
Dissolved Oxygen	0.083	0.464	-0.002	0.987	-0.020	0.860	-0.063	0.581
Fluoride (F)	0.213	0.084	-0.076	0.539	0.017	0.890	0.062	0.617
Iron (Fe)	0.084	0.460	0.002	0.067	-0.139	0.218	-0.040	0.727
Lead (Pb)	0.174	0.122	0.045	0.691	-0.051	0.651	-0.049	0.664
Lithium (Li)	0.214	0.056	-0.306	0.030	-0.251	0.025	-0.091	0.420
Magnesium (Mg)	0.160	0.156	-0.020	0.005	-0.536	0.000	-0.339	0.002
Manganese (Mn)	0.003	0.976	0.017	0.051	-0.299	0.007	-0.025	0.829
Mercury (Hg)	0.123	0.676	0.497	0.680	0.119	0.685	0.274	0.343
Molybdenum (Mo)	0.142	0.210	0.162	0.152	-0.140	0.216	-0.135	0.234
Nickel (Ni)	0.125	0.270	0.217	0.053	-0.130	0.250	-0.023	0.842
Nitrate (NO3)	0.095	0.403	-0.103	0.363	-0.125	0.269	-0.128	0.258
Ortho-phosphate	-[1]	-	-	-	-	-	-	-
pH	0.066	0.563	-0.042	0.712	0.316	0.005	0.006	0.959
Phosphorustotal	0.117	0.300	0.491	0.000	-0.465	0.000	-0.332	0.003
Potassium (K)	0.237	0.034	-0.105	0.001	-0.598	0.000	-0.172	0.128
Redox/Eh	-0.127	0.267	-0.110	0.337	-0.142	0.211	0.156	0.169
Rubidium (Rb)	0.120	0.287	0.286	0.010	-0.152	0.178	-0.164	0.146
Selenium (Se)	0.073	0.522	0.034	0.767	-0.102	0.368	-0.111	0.326
Silicate (Si)	0.020	0.862	-0.029	0.799	-0.080	0.483	-0.087	0.443
Silver (Ag)	-0.032	0.780	-0.097	0.393	0.192	0.088	0.057	0.616
Sodium (Na)	0.429	0.000	0.171	0.130	-0.341	0.002	-0.260	0.020
Specific Conductivity	0.169	0.138	0.156	0.170	-0.407	0.000	-0.404	0.000
Strontium (Sr)	0.254	0.023	0.164	0.147	-0.387	0.000	-0.131	0.247
Sulfate (SO4)	0.120	0.291	-0.040	0.725	-0.247	0.027	-0.040	0.726
Sulfur (S)	0.103	0.361	-0.028	0.805	-0.280	0.012	-0.048	0.671
SWL	0.183	0.105	-	-	-0.384	0.000	-0.374	0.001
Temperature	0.128	0.261	0.441	0.000	-0.671	0.000	-0.649	0.000
Thallium (Tl)	0.119	0.295	0.204	0.070	-0.173	0.125	-0.256	0.022
Tin (Sn)	0.001	0.996	-0.014	0.928	-0.213	0.155	-0.260	0.082
Titanium (Ti)	0.230	0.040	0.244	0.029	-0.035	0.761	-0.075	0.509
Total dissolved solids	0.242	0.031	0.242	0.031	-0.667	0.000	-0.338	0.002
Total organic carbon	-0.008	0.943	-0.049	0.666	-0.219	0.051	0.148	0.191
Total phosphate	0.028	0.807	0.389	0.000	-0.355	0.001	-0.441	0.000
Tritium	-0.062	0.658	0.139	0.322	0.061	0.662	0.332	0.015
Total suspended solids	0.037	0.747	0.063	0.578	0.110	0.333	0.127	0.261
Vanadium (V)	0.257	0.021	0.271	0.015	-0.088	0.436	-0.101	0.375
Zinc (Zn)	0.143	0.205	0.104	0.358	-0.103	0.364	-0.002	0.986
Zirconium (Zr)	0.142	0.348	-0.083	0.584	-0.026	0.864	0.237	0.113

[1] Insufficient sample size or no samples collected

Table D.93: Correlation coefficients between chemical parameters and well depth, static water level, and UTM coordinates, for the buried Quaternary aquifer group.

Parameter	Well Depth (ft)		Static water level (ft)		UTM-east		UTM-north	
	R^2	p	R^2	p	R^2	p	R^2	p
Alkalinity	0.274	0.000	0.266	0.000	-0.374	0.000	-0.399	0.000
Aluminum (Al)	0.070	0.114	-0.037	0.401	0.099	0.025	0.060	0.176
Antimony (Sb)	-0.024	0.587	0.154	0.000	-0.043	0.335	-0.375	0.000
Arsenic (As)	0.021	0.630	0.044	0.324	-0.168	0.000	-0.130	0.003
Barium (Ba)	-0.020	0.656	-0.059	0.182	0.035	0.431	0.175	0.000
Beryllium (Be)	0.008	0.849	-0.156	0.000	-0.023	0.600	0.237	0.000
Bismuth (Bi)	0.109	0.188	-0.110	0.184	-0.140	0.090	0.100	0.231
Boron (B)	0.489	0.000	0.184	0.000	-0.516	0.000	-0.370	0.000
Bromide (Br)	0.144	0.001	-0.034	0.443	-0.222	0.000	0.098	0.027
Cadmium (Cd)	0.170	0.000	0.164	0.000	-0.213	0.000	-0.259	0.000
Calcium (Ca)	0.130	0.003	0.347	0.000	-0.388	0.000	-0.559	0.000
Cesium (Cs)	0.080	0.337	0.002	0.980	0.365	0.000	-0.065	0.434
Chloride (Cl)	-0.031	0.482	-0.087	0.050	-0.227	0.000	-0.072	0.105
Chromium (Cr)	-0.165	0.000	-0.056	0.204	-0.078	0.077	0.047	0.289
Cobalt (Co)	0.103	0.020	0.286	0.000	-0.135	0.002	-0.427	0.000
Copper (Cu)	0.078	0.076	0.127	0.004	-0.147	0.001	-0.221	0.000
Day	-0.168	0.000	-0.276	0.000	0.273	0.000	0.636	0.000
Depth	-	-	0.460	0.000	-0.134	0.002	-0.245	0.000
Diameter	0.213	0.000	0.292	0.000	-0.108	0.014	-0.533	0.000
Dissolved Oxygen	-0.170	0.000	0.112	0.011	0.004	0.921	-0.162	0.000
Fluoride (F)	0.222	0.000	-0.105	0.042	-0.418	0.000	0.085	0.100
Iron (Fe)	0.163	0.000	0.138	0.002	-0.235	0.000	-0.184	0.000
Lead (Pb)	-0.032	0.468	0.069	0.120	0.082	0.064	-0.152	0.001
Lithium (Li)	0.277	0.000	0.199	0.000	-0.557	0.000	-0.354	0.000
Magnesium (Mg)	0.200	0.000	0.281	0.000	-0.455	0.000	-0.483	0.000
Manganese (Mn)	0.023	0.608	0.193	0.000	0.023	0.604	-0.335	0.000
Mercury (Hg)	-0.028	0.668	-0.083	0.204	-0.020	0.760	0.286	0.000
Molybdenum (Mo)	0.200	0.000	0.053	0.232	-0.284	0.000	-0.120	0.007
Nickel (Ni)	0.061	0.169	-0.012	0.783	-0.202	0.000	-0.114	0.010
Nitrate (NO3)	-0.163	0.000	0.020	0.658	-0.014	0.749	-0.125	0.005
Ortho-phosphate	-0.226	0.214	-0.443	0.011	-0.289	0.109	0.259	0.153
pH	0.061	0.168	-0.281	0.000	0.248	0.000	0.444	0.000
Phosphorustotal	0.351	0.000	0.058	0.190	-0.301	0.000	-0.179	0.000
Potassium (K)	0.332	0.000	0.187	0.000	-0.552	0.000	-0.338	0.000
Redox/Eh	-0.257	0.000	0.006	0.897	0.142	0.001	0.018	0.681
Rubidium (Rb)	0.009	0.832	0.017	0.699	-0.153	0.001	-0.225	0.000
Selenium (Se)	-0.098	0.027	0.001	0.977	-0.067	0.133	-0.147	0.001
Silicate (Si)	0.121	0.006	0.167	0.000	-0.346	0.000	-0.370	0.000
Silver (Ag)	-0.103	0.020	-0.051	0.254	0.111	0.012	-0.059	0.182
Sodium (Na)	0.431	0.000	0.076	0.085	-0.398	0.000	-0.306	0.000
Specific Conductivity	0.289	0.000	0.288	0.000	-0.430	0.000	-0.564	0.000
Strontium (Sr)	0.421	0.000	0.221	0.000	-0.496	0.000	-0.466	0.000
Sulfate (SO4)	0.216	0.000	0.281	0.000	-0.407	0.000	-0.543	0.000
Sulfur (S)	0.228	0.000	0.280	0.000	-0.392	0.000	-0.547	0.000
SWL	0.460	0.000	-	-	-0.559	0.768	-0.504	0.000
Temperature	0.219	0.000	0.355	0.000	-0.148	0.966	0.018	0.000
Thallium (Tl)	0.018	0.681	0.078	0.075	-0.214	0.839	-0.164	0.000
Tin (Sn)	-0.062	0.459	-0.145	0.079	0.148	0.073	-0.205	0.013
Titanium (Ti)	0.051	0.253	-0.035	0.432	0.009	0.001	-0.311	0.690
Total dissolved solids	0.308	0.000	0.272	0.000	-0.002	0.000	-0.711	0.000
Total organic carbon	0.200	0.000	0.055	0.214	-0.122	0.000	-0.035	0.000
Total phosphate	0.195	0.000	0.010	0.828	-0.122	0.007	-0.035	0.448
Tritium	-0.399	0.003	-0.119	0.395	0.206	0.139	0.228	0.101
Total suspended solids	0.097	0.028	0.089	0.044	-0.171	0.000	-0.055	0.218
Vanadium (V)	0.097	0.029	0.070	0.113	-0.247	0.000	-0.132	0.003
Zinc (Zn)	0.116	0.009	0.203	0.000	-0.011	0.804	-0.350	0.000
Zirconium (Zr)	0.001	0.989	-0.170	0.040	-0.064	0.443	0.328	0.000

Table D.94: Correlation coefficients between chemical parameters and well depth, static water level, and UTM coordinates, for the surficial Quaternary aquifer group.

Parameter	Well Depth (ft)		Static water level (ft)		UTM-east		UTM-north	
	R^2	p	R^2	p	R^2	p	R^2	p
Alkalinity	0.028	0.761	-0.001	0.995	-0.585	0.000	-0.257	0.004
Aluminum (Al)	0.244	0.007	0.048	0.602	0.358	0.000	0.127	0.162
Antimony (Sb)	-0.171	0.060	-0.159	0.079	-0.398	0.000	-0.311	0.000
Arsenic (As)	0.122	0.180	-0.073	0.427	-0.015	0.869	-0.178	0.050
Barium (Ba)	-0.043	0.638	0.007	0.941	-0.274	0.002	-0.011	0.906
Beryllium (Be)	0.102	0.264	-0.068	0.455	0.189	0.037	0.337	0.000
Bismuth (Bi)	-[1]	-	-	-	-	-	-	-
Boron (B)	0.149	0.100	-0.098	0.282	-0.407	0.000	-0.229	0.011
Bromide (Br)	-	-	-	-	-	-	-	-
Cadmium (Cd)	-0.020	0.825	-0.141	0.122	-0.087	0.342	-0.095	0.300
Calcium (Ca)	-0.010	0.915	0.002	0.985	-0.610	0.000	-0.454	0.000
Cesium (Cs)	0.441	0.003	0.102	0.513	0.385	0.011	-0.141	0.367
Chloride (Cl)	-0.074	0.415	-0.026	0.779	-0.207	0.022	-0.531	0.000
Chromium (Cr)	-0.158	0.081	-0.095	0.298	-0.067	0.464	0.008	0.933
Cobalt (Co)	0.154	0.091	0.069	0.449	-0.150	0.100	-0.155	0.088
Copper (Cu)	0.128	0.157	0.021	0.822	-0.005	0.952	-0.251	0.005
Day	0.301	0.001	0.246	0.006	0.481	0.000	0.457	0.000
Depth	-	-	0.541	0.000	0.288	0.001	0.022	0.812
Diameter	-0.035	0.702	-0.185	0.040	-0.263	0.003	-0.373	0.000
Dissolved Oxygen	-0.100	0.271	0.074	0.415	-0.148	0.102	-0.233	0.009
Fluoride (F)	0.238	0.041	0.029	0.803	-0.238	0.041	-0.171	0.145
Iron (Fe)	0.082	0.368	-0.055	0.547	-0.059	0.517	0.197	0.029
Lead (Pb)	0.158	0.084	0.122	0.183	0.082	0.371	-0.153	0.095
Lithium (Li)	0.029	0.752	-0.079	0.382	-0.474	0.000	-0.201	0.026
Magnesium (Mg)	0.052	0.565	-0.053	0.562	-0.652	0.000	-0.417	0.000
Manganese (Mn)	0.013	0.885	-0.155	0.088	-0.012	0.892	-0.053	0.560
Mercury (Hg)	-0.241	0.130	-0.046	0.773	0.158	0.325	0.238	0.135
Molybdenum (Mo)	0.081	0.371	-0.042	0.645	-0.258	0.004	-0.112	0.219
Nickel (Ni)	0.042	0.647	-0.048	0.598	-0.208	0.021	0.017	0.849
Nitrate (NO3)	-0.221	0.014	-0.020	0.827	-0.185	0.041	-0.319	0.000
Ortho-phosphate	-0.841	0.036	0.044	0.934	0.232	0.658	-0.812	0.050
pH	0.283	0.002	0.153	0.092	0.286	0.001	0.199	0.028
Phosphorustotal	0.084	0.354	-0.026	0.774	-0.092	0.314	-0.081	0.373
Potassium (K)	0.151	0.095	-0.023	0.798	-0.432	0.000	-0.100	0.272
Redox/Eh	-0.108	0.234	-0.036	0.692	-0.086	0.347	-0.092	0.314
Rubidium (Rb)	0.146	0.107	-0.013	0.891	-0.131	0.149	-0.127	0.163
Selenium (Se)	-0.165	0.069	-0.108	0.238	-0.223	0.014	-0.214	0.018
Silicate (Si)	0.178	0.049	-0.091	0.315	-0.228	0.011	-0.283	0.002
Silver (Ag)	-0.131	0.150	-0.041	0.657	0.020	0.830	-0.134	0.140
Sodium (Na)	0.118	0.194	-0.102	0.262	-0.227	0.011	-0.270	0.003
Specific Conductivity	0.057	0.535	-0.009	0.921	-0.486	0.000	-0.541	0.000
Strontium (Sr)	0.125	0.169	-0.175	0.053	-0.511	0.000	-0.346	0.000
Sulfate (SO4)	-0.038	0.676	-0.026	0.773	-0.263	0.003	-0.586	0.000
Sulfur (S)	-0.048	0.599	-0.029	0.749	-0.273	0.002	-0.593	0.000
SWL	0.541	0.000	-	-	0.145	0.109	-0.005	0.960
Temperature	0.055	0.549	0.137	0.131	-0.167	0.065	-0.595	0.000
Thallium (Tl)	-0.053	0.565	-0.018	0.841	0.083	0.363	-0.235	0.009
Tin (Sn)	0.051	0.745	0.055	0.728	0.132	0.397	-0.125	0.423
Titanium (Ti)	0.141	0.121	-0.044	0.633	-0.063	0.487	0.125	0.167
Total dissolved solids	-0.006	0.949	-0.035	0.698	-0.591	0.000	-0.482	0.000
Total organic carbon	-0.138	0.129	-0.224	0.013	-0.272	0.002	-0.002	0.985
Total phosphate	-0.018	0.846	-0.063	0.497	-0.115	0.219	-0.042	0.651
Tritium	-0.595	0.120	0.071	0.867	-0.452	0.260	0.333	0.420
Total suspended solids	0.122	0.180	-0.117	0.196	-0.075	0.410	0.202	0.025
Vanadium (V)	0.066	0.468	-0.044	0.631	-0.228	0.011	-0.111	0.222
Zinc (Zn)	0.159	0.080	0.054	0.554	-0.112	0.219	-0.305	0.001
Zirconium (Zr)	-0.032	0.839	-0.417	0.005	0.085	0.587	0.296	0.054

[1] Insufficient sample size or no samples collected

Table D.95: Correlation coefficients between chemical parameters and well depth, static water level, and UTM coordinates, for the CFIG-CFRN-CIGL aquifer group.

Parameter	Well Depth (ft)		Static water level (ft)		UTM-east		UTM-north	
	R^2	p	R^2	p	R^2	p	R^2	p
Alkalinity	0.163	0.314	0.129	0.427	-0.645	0.000	-0.022	0.891
Aluminum (Al)	-0.368	0.021	-0.304	0.060	0.255	0.118	0.390	0.014
Antimony (Sb)	0.157	0.340	0.124	0.452	-0.179	0.275	-0.364	0.023
Arsenic (As)	-0.125	0.447	-0.044	0.791	-0.633	0.000	0.242	0.138
Barium (Ba)	0.001	0.995	0.112	0.491	-0.482	0.002	-0.123	0.451
Beryllium (Be)	0.194	0.237	-0.051	0.758	0.077	0.642	0.146	0.374
Bismuth (Bi)	0.051	0.846	0.409	0.103	-0.408	0.104	-0.255	0.323
Boron (B)	0.095	0.560	0.009	0.955	-0.833	0.000	0.021	0.899
Bromide (Br)	-[1]	-	-	-	-	-	-	-
Cadmium (Cd)	0.007	0.967	0.029	0.863	0.186	0.256	-0.396	0.013
Calcium (Ca)	0.103	0.526	0.071	0.663	-0.707	0.000	0.164	0.313
Cesium (Cs)	0.685	0.002	0.399	0.113	-0.236	0.362	-0.335	0.189
Chloride (Cl)	-0.287	0.072	-0.083	0.613	-0.044	0.787	0.406	0.009
Chromium (Cr)	0.236	0.149	0.141	0.392	0.321	0.046	0.024	0.887
Cobalt (Co)	-0.361	0.024	-0.402	0.011	-0.370	0.021	0.328	0.042
Copper (Cu)	-0.222	0.168	-0.181	0.264	0.214	0.184	0.147	0.364
Day	-0.341	0.032	-0.416	0.008	-0.474	0.002	0.759	0.000
Depth	-	-	0.670	0.000	0.068	0.679	-0.437	0.005
Diameter	0.114	0.483	0.086	0.597	-0.384	0.014	-0.268	0.095
Dissolved Oxygen	0.155	0.339	0.269	0.093	0.551	0.000	-0.114	0.482
Fluoride (F)	0.171	0.375	0.407	0.029	-0.209	0.278	-0.040	0.838
Iron (Fe)	0.210	0.193	-0.007	0.965	-0.499	0.001	-0.077	0.639
Lead (Pb)	0.079	0.632	0.243	0.137	0.619	0.000	-0.229	0.162
Lithium (Li)	-0.087	0.595	-0.106	0.515	-0.656	0.000	0.077	0.638
Magnesium (Mg)	0.304	0.057	0.288	0.072	-0.445	0.004	-0.117	0.474
Manganese (Mn)	-0.326	0.040	-0.339	0.033	-0.440	0.004	0.460	0.003
Mercury (Hg)	-0.175	0.437	-0.287	0.196	-0.299	0.176	0.424	0.049
Molybdenum (Mo)	-0.065	0.692	-0.088	0.588	-0.114	0.484	0.022	0.892
Nickel (Ni)	0.031	0.850	-0.017	0.915	0.341	0.031	-0.141	0.386
Nitrate (NO3)	-0.124	0.447	0.074	0.652	0.359	0.023	-0.042	0.797
Ortho-phosphate	0.201	0.555	0.300	0.370	0.200	0.555	-0.100	0.770
pH	0.025	0.878	-0.168	0.300	0.557	0.000	0.144	0.375
Phosphorustotal	-0.011	0.945	-0.076	0.639	-0.740	0.000	0.400	0.010
Potassium (K)	0.100	0.538	0.032	0.846	-0.833	0.000	0.072	0.657
Redox/Eh	-0.004	0.981	0.207	0.200	0.405	0.010	-0.361	0.022
Rubidium (Rb)	0.209	0.195	0.071	0.665	0.051	0.755	-0.023	0.888
Selenium (Se)	0.340	0.046	0.446	0.007	-0.190	0.275	-0.249	0.150
Silicate (Si)	-0.377	0.016	-0.229	0.156	-0.233	0.148	0.421	0.007
Silver (Ag)	-0.099	0.549	-0.133	0.421	0.051	0.760	-0.060	0.715
Sodium (Na)	0.060	0.715	0.037	0.821	-0.883	0.000	0.248	0.122
Specific Conductivity	0.150	0.355	0.218	0.177	-0.745	0.000	0.081	0.621
Strontium (Sr)	0.073	0.656	0.007	0.966	-0.905	0.000	0.222	0.168
Sulfate (SO4)	0.319	0.045	0.324	0.041	-0.508	0.001	-0.207	0.199
Sulfur (S)	0.311	0.050	0.311	0.051	-0.468	0.002	-0.240	0.136
SWL	0.670	0.000	-	-	0.082	0.614	-0.493	0.001
Temperature	0.254	0.115	0.205	0.206	-0.254	0.114	-0.141	0.387
Thallium (Tl)	-0.338	0.035	-0.445	0.005	0.255	0.118	0.344	0.032
Tin (Sn)	-0.429	0.086	-0.346	0.174	0.291	0.257	0.391	0.120
Titanium (Ti)	0.018	0.911	0.101	0.537	0.257	0.109	0.088	0.591
Total dissolved solids	0.146	0.376	0.163	0.323	-0.745	0.000	0.056	0.734
Total organic carbon	-0.018	0.914	-0.019	0.907	-0.155	0.340	-0.325	0.041
Total phosphate	-0.017	0.929	0.026	0.894	-0.308	0.104	-0.041	0.831
Tritium	-0.279	0.197	0.116	0.597	0.131	0.550	-0.030	0.891
Total suspended solids	0.103	0.534	0.011	0.950	-0.503	0.001	0.028	0.867
Vanadium (V)	-0.081	0.618	-0.165	0.308	-0.079	0.630	0.214	0.185
Zinc (Zn)	0.478	0.002	0.389	0.013	0.228	0.157	-0.508	0.001
Zirconium (Zr)	0.230	0.375	0.428	0.087	0.066	0.801	-0.039	0.883

[1] Insufficient sample size or no samples collected

Table D.96: Correlation coefficients between chemical parameters and well depth, static water level, and UTM coordinates, for the OSTP-OPDC-CJDN aquifer group.

Parameter	Well Depth (ft)		Static water level (ft)		UTM-east		UTM-north	
	R^2	p	R^2	p	R^2	p	R^2	p
Alkalinity	-0.234	0.026	-0.251	0.017	-0.531	0.000	-0.010	0.925
Aluminum (Al)	-0.072	0.510	-0.099	0.360	0.060	0.579	0.492	0.000
Antimony (Sb)	-0.107	0.323	-0.092	0.399	-0.279	0.009	-0.018	0.870
Arsenic (As)	-0.122	0.262	-0.238	0.026	-0.458	0.000	0.015	0.889
Barium (Ba)	-0.138	0.196	-0.135	0.206	-0.457	0.000	0.037	0.731
Beryllium (Be)	-0.206	0.056	-0.118	0.278	-0.279	0.009	0.080	0.463
Bismuth (Bi)	0.307	0.127	0.240	0.237	-0.307	0.128	0.147	0.475
Boron (B)	-0.025	0.812	-0.068	0.525	-0.600	0.000	-0.153	0.150
Bromide (Br)	-[1]	-	-	-	-	-	-	-
Cadmium (Cd)	0.233	0.030	0.297	0.005	0.428	0.000	-0.340	0.001
Calcium (Ca)	-0.375	0.000	-0.363	0.000	-0.460	0.000	-0.049	0.650
Cesium (Cs)	0.002	0.993	0.004	0.984	-0.015	0.941	-0.282	0.162
Chloride (Cl)	-0.308	0.003	-0.180	0.090	0.151	0.154	0.208	0.050
Chromium (Cr)	-0.113	0.296	0.023	0.834	0.262	0.014	0.059	0.586
Cobalt (Co)	-0.183	0.090	-0.275	0.010	-0.522	0.000	0.349	0.001
Copper (Cu)	0.129	0.226	0.161	0.130	0.211	0.046	-0.165	0.121
Day	-0.316	0.002	-0.419	0.000	-0.539	0.000	0.639	0.000
Depth	-	-	0.730	0.000	0.255	0.015	-0.333	0.001
Diameter	0.083	0.437	0.050	0.638	-0.076	0.477	-0.277	0.008
Dissolved Oxygen	-0.016	0.884	0.262	0.013	0.457	0.000	-0.131	0.220
Fluoride (F)	0.208	0.121	0.270	0.042	0.210	0.117	-0.069	0.610
Iron (Fe)	0.081	0.446	-0.067	0.530	-0.567	0.000	-0.067	0.528
Lead (Pb)	0.132	0.223	0.255	0.017	0.458	0.000	-0.274	0.010
Lithium (Li)	-0.062	0.562	-0.071	0.508	-0.509	0.000	-0.157	0.139
Magnesium (Mg)	-0.223	0.035	-0.248	0.019	-0.525	0.000	0.250	0.018
Manganese (Mn)	-0.035	0.745	-0.194	0.067	-0.728	0.000	0.178	0.093
Mercury (Hg)	-0.305	0.018	-0.266	0.040	0.172	0.189	-0.035	0.790
Molybdenum (Mo)	-0.055	0.606	-0.205	0.053	-0.165	0.120	0.250	0.018
Nickel (Ni)	0.183	0.085	0.232	0.028	0.218	0.039	-0.158	0.137
Nitrate (NO3)	-0.326	0.002	-0.068	0.524	0.462	0.000	0.002	0.989
Ortho-phosphate	-0.236	0.119	-0.028	0.855	0.184	0.227	-0.049	0.750
pH	0.097	0.361	0.045	0.676	0.212	0.045	0.298	0.004
Phosphorustotal	-0.210	0.047	-0.185	0.082	-0.506	0.000	0.086	0.421
Potassium (K)	-0.123	0.250	-0.132	0.215	-0.612	0.000	-0.042	0.692
Redox/Eh	0.041	0.701	0.265	0.012	0.512	0.000	-0.347	0.001
Rubidium (Rb)	0.075	0.484	0.107	0.316	0.124	0.246	-0.139	0.192
Selenium (Se)	-0.067	0.603	0.118	0.356	-0.231	0.069	-0.208	0.101
Silicate (Si)	-0.535	0.000	-0.472	0.000	-0.561	0.000	0.489	0.000
Silver (Ag)	-0.171	0.113	-0.212	0.049	-0.179	0.097	0.619	0.000
Sodium (Na)	-0.282	0.007	-0.310	0.003	-0.739	0.000	0.117	0.272
Specific Conductivity	-0.443	0.000	-0.386	0.000	-0.558	0.000	0.075	0.482
Strontium (Sr)	-0.064	0.552	-0.127	0.234	-0.684	0.000	-0.172	0.106
Sulfate (SO4)	-0.004	0.973	0.054	0.614	-0.264	0.012	-0.268	0.011
Sulfur (S)	-0.038	0.725	0.010	0.925	-0.232	0.028	-0.254	0.016
SWL	0.730	0.000	-	-	0.365	0.000	-0.383	0.000
Temperature	-0.174	0.101	-0.362	0.000	-0.310	0.003	0.428	0.000
Thallium (Tl)	-0.090	0.409	-0.045	0.677	0.077	0.477	0.113	0.299
Tin (Sn)	0.143	0.486	0.165	0.421	0.091	0.659	-0.336	0.093
Titanium (Ti)	0.178	0.093	0.242	0.022	0.188	0.077	-0.135	0.205
Total dissolved solids	-0.420	0.000	-0.355	0.001	-0.566	0.000	0.068	0.528
Total organic carbon	0.055	0.606	0.046	0.664	-0.138	0.196	-0.253	0.016
Total phosphate	-0.143	0.349	0.037	0.811	-0.392	0.008	-0.185	0.223
Tritium	-0.541	0.000	-0.373	0.005	-0.101	0.467	0.286	0.036
Total suspended solids	0.016	0.881	-0.032	0.769	-0.445	0.000	-0.035	0.744
Vanadium (V)	0.028	0.791	0.025	0.817	0.031	0.775	0.044	0.682
Zinc (Zn)	0.294	0.005	0.378	0.000	0.239	0.024	-0.365	0.000
Zirconium (Zr)	-0.055	0.790	-0.319	0.112	0.399	0.043	0.054	0.794

[1] Insufficient sample size or no samples collected

Table D.97: Correlation coefficients between chemical parameters and well depth, static water level, and UTM coordinates, for the CMSH-CMTS-PMHN aquifer group.

Parameter	Well Depth (ft)		Static water level (ft)		UTM-east		UTM-north	
	R^2	p	R^2	p	R^2	p	R^2	p
Alkalinity	0.552	0.003	0.302	0.133	-0.768	0.000	-0.790	0.000
Aluminum (Al)	-0.042	0.839	0.037	0.857	0.371	0.062	0.226	0.267
Antimony (Sb)	0.045	0.826	-0.008	0.968	-0.125	0.541	-0.150	0.464
Arsenic (As)	0.286	0.157	0.150	0.465	-0.180	0.379	-0.171	0.403
Barium (Ba)	0.257	0.205	0.364	0.067	-0.234	0.249	-0.189	0.356
Beryllium (Be)	0.371	0.062	0.371	0.062	-0.123	0.548	-0.201	0.325
Bismuth (Bi)	-[1]	-	-	-	-	-	-	-
Boron (B)	0.762	0.000	0.475	0.014	-0.262	0.196	-0.377	0.058
Bromide (Br)	0.333	0.096	0.334	0.096	-0.227	0.265	-0.307	0.128
Cadmium (Cd)	0.350	0.079	0.299	0.138	-0.095	0.646	-0.015	0.942
Calcium (Ca)	0.446	0.022	0.301	0.135	-0.800	0.000	-0.802	0.000
Cesium (Cs)	0.716	0.001	0.350	0.168	-0.104	0.692	-0.422	0.092
Chloride (Cl)	0.059	0.777	0.238	0.242	-0.079	0.703	0.028	0.892
Chromium (Cr)	0.038	0.854	0.377	0.058	-0.332	0.098	-0.203	0.321
Cobalt (Co)	0.211	0.300	-0.071	0.732	-0.306	0.129	-0.338	0.091
Copper (Cu)	-0.002	0.994	-0.058	0.779	0.196	0.338	0.237	0.243
Day	-0.155	0.449	-0.185	0.365	0.483	0.012	0.434	0.027
Depth	-	-	0.529	0.005	-0.356	0.075	-0.584	0.002
Diameter	0.187	0.361	0.174	0.396	-0.396	0.045	-0.415	0.035
Dissolved Oxygen	-0.315	0.117	-0.184	0.369	-0.195	0.340	-0.091	0.658
Fluoride (F)	0.679	0.001	0.563	0.008	-0.267	0.242	-0.435	0.049
Iron (Fe)	0.170	0.408	0.121	0.556	-0.262	0.197	-0.305	0.130
Lead (Pb)	0.081	0.695	-0.089	0.667	0.121	0.557	-0.085	0.679
Lithium (Li)	0.287	0.155	0.118	0.565	-0.044	0.830	0.015	0.942
Magnesium (Mg)	0.433	0.027	0.303	0.133	-0.786	0.000	-0.787	0.000
Manganese (Mn)	0.256	0.206	0.000	0.999	-0.134	0.515	-0.231	0.257
Mercury (Hg)	-	-	-	-	-	-	-	-
Molybdenum (Mo)	-0.132	0.522	0.031	0.882	0.172	0.402	0.335	0.094
Nickel (Ni)	-0.254	0.210	-0.138	0.501	0.366	0.066	0.423	0.031
Nitrate (NO3)	-0.355	0.075	-0.006	0.977	-0.130	0.528	0.119	0.563
Ortho-phosphate	-	-	-	-	-	-	-	-
pH	0.286	0.156	0.030	0.886	0.065	0.753	0.123	0.551
Phosphorustotal	0.316	0.116	0.201	0.324	-0.345	0.085	-0.452	0.021
Potassium (K)	0.731	0.000	0.582	0.002	-0.408	0.039	-0.503	0.009
Redox/Eh	-0.395	0.046	0.078	0.704	0.253	0.213	0.164	0.425
Rubidium (Rb)	-0.094	0.647	-0.065	0.751	0.266	0.190	0.371	0.062
Selenium (Se)	-0.143	0.487	0.018	0.929	-0.420	0.033	-0.229	0.261
Silicate (Si)	-0.565	0.003	-0.374	0.060	0.004	0.985	0.136	0.509
Silver (Ag)	0.384	0.053	0.167	0.415	-0.266	0.189	-0.216	0.289
Sodium (Na)	0.680	0.000	0.556	0.003	-0.403	0.041	-0.465	0.017
Specific Conductivity	0.451	0.021	0.347	0.082	-0.746	0.000	-0.790	0.000
Strontium (Sr)	0.686	0.000	0.447	0.022	-0.508	0.008	-0.554	0.003
Sulfate (SO4)	0.433	0.027	0.396	0.045	-0.387	0.051	-0.387	0.051
Sulfur (S)	0.457	0.019	0.413	0.036	-0.394	0.047	-0.413	0.036
SWL	0.529	0.005	-	-	-0.232	0.253	-0.329	0.101
Temperature	0.601	0.001	0.417	0.034	-0.469	0.016	-0.740	0.000
Thallium (Tl)	0.536	0.005	0.383	0.054	-0.277	0.170	-0.320	0.111
Tin (Sn)	-0.233	0.367	-0.170	0.514	0.099	0.705	0.112	0.670
Titanium (Ti)	-0.138	0.503	-0.023	0.911	0.249	0.220	0.354	0.076
Total dissolved solids	0.593	0.001	0.460	0.018	-0.752	0.000	-0.742	0.000
Total organic carbon	0.166	0.417	0.179	0.381	-0.031	0.881	-0.118	0.567
Total phosphate	0.031	0.882	0.057	0.783	-0.082	0.691	-0.156	0.446
Tritium	-0.185	0.493	0.157	0.560	-0.301	0.257	-0.091	0.738
Total suspended solids	-0.054	0.792	-0.167	0.416	0.022	0.915	-0.093	0.650
Vanadium (V)	-0.171	0.404	-0.093	0.653	0.269	0.185	0.371	0.062
Zinc (Zn)	0.444	0.023	0.362	0.069	-0.118	0.565	-0.435	0.026
Zirconium (Zr)	-0.004	0.988	0.181	0.486	0.286	0.266	0.003	0.991

[1] Insufficient sample size or no samples collected

Table D.98: Correlation coefficients between chemical parameters and well depth, static water level, and UTM coordinates, for the Upper Carbonate aquifer group.

Parameter	Well Depth (ft)		Static water level (ft)		UTM-east		UTM-north	
	R^2	p	R^2	p	R^2	p	R^2	p
Alkalinity	0.324	0.054	0.305	0.070	-0.629	0.000	-0.030	0.861
Aluminum (Al)	-0.095	0.582	0.090	0.601	-0.082	0.636	0.101	0.558
Antimony (Sb)	-0.039	0.820	0.056	0.744	-0.292	0.084	-0.122	0.477
Arsenic (As)	0.163	0.343	-0.105	0.541	-0.485	0.003	0.025	0.886
Barium (Ba)	-0.026	0.879	0.101	0.558	0.187	0.275	0.223	0.191
Beryllium (Be)	0.027	0.875	-0.055	0.750	-0.027	0.875	-0.301	0.075
Bismuth (Bi)	-1.000	1.000	-1.000	1.000	-1.000	1.000	-1.000	1.000
Boron (B)	0.220	0.196	0.201	0.241	-0.603	0.000	-0.097	0.574
Bromide (Br)	-[1]	-	-	-	-	-	-	-
Cadmium (Cd)	0.262	0.123	0.143	0.407	-0.060	0.728	-0.278	0.101
Calcium (Ca)	0.201	0.241	0.340	0.042	-0.025	0.884	-0.016	0.928
Cesium (Cs)	-1.000	1.000	-1.000	1.000	-1.000	1.000	-1.000	1.000
Chloride (Cl)	-0.327	0.055	-0.123	0.480	0.340	0.045	0.114	0.513
Chromium (Cr)	-0.270	0.111	-0.009	0.958	0.467	0.004	0.009	0.960
Cobalt (Co)	0.095	0.581	0.269	0.113	-0.265	0.119	-0.145	0.398
Copper (Cu)	-0.101	0.558	0.394	0.018	0.374	0.025	0.293	0.083
Day	0.072	0.677	-0.004	0.982	-0.849	0.000	-0.008	0.964
Depth	-	-	0.260	0.125	-0.099	0.565	-0.165	0.336
Diameter	0.071	0.683	-0.080	0.642	-0.074	0.670	0.002	0.989
Dissolved Oxygen	-0.209	0.221	-0.216	0.207	0.358	0.032	-0.062	0.720
Fluoride (F)	0.196	0.274	-0.040	0.827	0.024	0.895	-0.064	0.725
Iron (Fe)	0.276	0.103	-0.052	0.764	-0.352	0.035	-0.091	0.596
Lead (Pb)	-0.219	0.199	0.452	0.006	0.351	0.036	0.261	0.124
Lithium (Li)	0.382	0.022	0.166	0.333	-0.414	0.012	-0.289	0.087
Magnesium (Mg)	0.134	0.437	0.460	0.005	-0.246	0.148	0.293	0.083
Manganese (Mn)	-0.172	0.316	-0.065	0.708	-0.265	0.118	-0.198	0.248
Mercury (Hg)	-0.040	0.827	-0.102	0.571	-0.247	0.166	-0.137	0.447
Molybdenum (Mo)	0.027	0.874	-0.052	0.762	-0.263	0.121	0.115	0.504
Nickel (Ni)	0.120	0.485	0.358	0.032	0.386	0.020	-0.038	0.824
Nitrate (NO3)	-0.058	0.738	0.043	0.805	0.455	0.005	0.159	0.355
Ortho-phosphate	0.396	0.030	0.234	0.213	-0.419	0.021	0.111	0.558
pH	-0.172	0.317	-0.315	0.061	0.162	0.345	0.387	0.020
Phosphorustotal	0.312	0.064	0.155	0.368	-0.348	0.037	-0.040	0.815
Potassium (K)	0.162	0.346	0.141	0.414	-0.489	0.003	-0.025	0.886
Redox/Eh	-0.204	0.233	-0.050	0.773	0.489	0.002	-0.188	0.272
Rubidium (Rb)	0.018	0.918	0.189	0.269	0.360	0.031	0.098	0.571
Selenium (Se)	0.137	0.479	-0.391	0.036	-0.267	0.161	-0.091	0.638
Silicate (Si)	-0.101	0.558	0.184	0.282	-0.472	0.004	-0.083	0.630
Silver (Ag)	-0.343	0.041	0.139	0.419	0.144	0.403	0.040	0.816
Sodium (Na)	0.241	0.157	0.266	0.117	-0.599	0.000	-0.161	0.347
Specific Conductivity	0.209	0.222	0.233	0.172	-0.517	0.001	0.058	0.737
Strontium (Sr)	0.244	0.151	0.278	0.100	-0.641	0.000	-0.006	0.972
Sulfate (SO4)	0.160	0.357	-0.106	0.544	-0.178	0.307	-0.202	0.245
Sulfur (S)	0.134	0.435	-0.069	0.689	-0.168	0.326	-0.231	0.174
SWL	0.260	0.125	-	-	0.084	0.625	0.149	0.386
Temperature	-0.102	0.556	0.051	0.767	-0.514	0.001	0.098	0.569
Thallium (Tl)	-0.221	0.195	0.067	0.698	-0.130	0.450	-0.047	0.785
Tin (Sn)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Titanium (Ti)	-0.116	0.502	0.180	0.294	0.490	0.002	0.047	0.784
Total dissolved solids	0.264	0.125	0.233	0.177	-0.468	0.005	-0.029	0.867
Total organic carbon	0.211	0.218	-0.005	0.978	0.023	0.893	-0.123	0.476
Total phosphate	-0.232	0.658	-0.377	0.461	-0.029	0.957	0.203	0.700
Tritium	-0.340	0.279	0.035	0.914	0.119	0.712	0.399	0.198
Total suspended solids	0.118	0.498	0.064	0.714	-0.323	0.058	-0.234	0.176
Vanadium (V)	0.064	0.711	0.395	0.017	0.458	0.005	0.106	0.537
Zinc (Zn)	0.180	0.294	0.334	0.046	0.275	0.105	0.251	0.139
Zirconium (Zr)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

[1] Insufficient sample size or no samples collected

Table D.99: Correlation coefficients between chemical parameters and dissolved oxygen, iron, manganese, and oxidation-reduction potential for the Cambrian aquifer group.

Parameter	Dissolved Oxygen		Iron		Manganese		Redox potential	
	R^2	p	R^2	p	R^2	p	R^2	p
Alkalinity	-0.253	0.010	0.515	0.000	0.287	0.003	-0.216	0.029
Aluminum (Al)	0.094	0.351	-0.035	0.729	0.122	0.228	0.090	0.373
Antimony (Sb)	-0.212	0.034	0.274	0.006	0.144	0.153	-0.061	0.545
Arsenic (As)	-0.404	0.000	0.524	0.000	0.475	0.000	-0.359	0.000
Barium (Ba)	-0.313	0.001	0.515	0.000	0.386	0.000	-0.217	0.029
Beryllium (Be)	-0.317	0.001	0.388	0.000	0.311	0.002	-0.302	0.002
Bismuth (Bi)	-0.163	0.289	0.158	0.306	0.222	0.148	-0.093	0.547
Boron (B)	-0.497	0.000	0.521	0.000	0.435	0.000	-0.311	0.001
Bromide (Br)	-0.135	0.175	0.110	0.272	0.117	0.242	0.100	0.319
Cadmium (Cd)	0.038	0.709	-0.076	0.454	-0.057	0.573	0.178	0.077
Calcium (Ca)	-0.230	0.020	0.470	0.000	0.265	0.007	-0.212	0.033
Cesium (Cs)	-0.295	0.052	0.497	0.001	0.015	0.924	-0.137	0.375
Chloride (Cl)	0.106	0.288	-0.214	0.031	-0.100	0.319	0.139	0.164
Chromium (Cr)	0.482	0.000	-0.119	0.239	-0.301	0.002	0.040	0.691
Cobalt (Co)	-0.290	0.003	0.379	0.000	0.533	0.000	-0.154	0.126
Copper (Cu)	0.018	0.859	-0.110	0.272	-0.043	0.666	0.164	0.100
Day	-0.385	0.000	0.113	0.258	0.444	0.000	-0.428	0.000
Depth	0.007	0.941	0.114	0.254	-0.144	0.150	0.013	0.899
Diameter	-0.021	0.832	-0.009	0.927	-0.155	0.119	0.058	0.563
Dissolved Oxygen	-	-	-0.412	0.000	-0.543	0.000	0.468	0.000
Fluoride (F)	0.018	0.882	0.058	0.631	-0.106	0.383	-0.132	0.276
Iron (Fe)	-0.412	0.000	-	-	0.577	0.000	-0.479	0.000
Lead (Pb)	0.229	0.022	-0.191	0.057	-0.254	0.011	0.298	0.003
Lithium (Li)	-0.421	0.000	0.456	0.000	0.408	0.000	-0.164	0.100
Magnesium (Mg)	-0.070	0.482	0.405	0.000	0.141	0.157	-0.086	0.390
Manganese (Mn)	-0.543	0.000	0.577	0.000	-	-	-0.473	0.000
Mercury (Hg)	0.091	0.515	0.069	0.619	0.053	0.705	-0.150	0.280
Molybdenum (Mo)	-0.177	0.075	-0.021	0.835	0.107	0.286	-0.049	0.623
Nickel (Ni)	0.186	0.061	-0.044	0.661	-0.215	0.030	0.267	0.007
Nitrate (NO3)	0.561	0.000	-0.628	0.000	-0.639	0.000	0.509	0.000
Ortho-phosphate	0.410	0.034	-0.628	0.000	-0.677	0.000	0.494	0.009
pH	0.156	0.119	-0.326	0.001	-0.154	0.122	0.062	0.539
Phosphorustotal	-0.420	0.000	0.524	0.000	0.523	0.000	-0.354	0.000
Potassium (K)	-0.521	0.000	0.635	0.000	0.497	0.000	-0.365	0.000
Redox/Eh	0.468	0.000	-0.479	0.000	-0.473	0.000	-	-
Rubidium (Rb)	0.044	0.663	0.027	0.792	0.026	0.793	0.094	0.350
Selenium (Se)	0.131	0.229	0.010	0.925	-0.047	0.668	-0.042	0.704
Silicate (Si)	-0.067	0.505	0.120	0.229	0.403	0.000	-0.083	0.408
Silver (Ag)	-0.111	0.273	0.078	0.443	0.083	0.411	-0.067	0.507
Sodium (Na)	-0.474	0.000	0.419	0.000	0.411	0.000	-0.344	0.000
Specific Conductivity	-0.219	0.027	0.473	0.000	0.263	0.008	-0.204	0.040
Strontium (Sr)	-0.486	0.000	0.607	0.000	0.490	0.000	-0.362	0.000
Sulfate (SO4)	-0.185	0.062	0.353	0.000	0.037	0.714	-0.076	0.449
Sulfur (S)	-0.193	0.052	0.354	0.000	0.029	0.770	-0.083	0.409
SWL	0.228	0.021	-0.025	0.802	-0.237	0.016	0.343	0.000
Temperature	-0.168	0.091	0.088	0.382	0.009	0.932	0.095	0.341
Thallium (Tl)	-0.097	0.337	-0.103	0.306	0.046	0.649	-0.071	0.483
Tin (Sn)	0.047	0.760	0.000	0.000	0.163	0.291	-0.130	0.400
Titanium (Ti)	0.142	0.156	-0.023	0.815	0.009	0.931	0.118	0.240
Total dissolved solids	-0.230	0.021	0.418	0.000	0.238	0.017	-0.173	0.086
Total organic carbon	-0.130	0.193	0.452	0.000	0.173	0.083	-0.130	0.194
Total phosphate	-0.204	0.079	0.416	0.000	0.278	0.016	-0.186	0.110
Tritium	0.288	0.027	-0.142	0.282	-0.207	0.116	0.153	0.246
Total suspended solids	-0.179	0.074	0.812	0.000	0.405	0.000	-0.329	0.001
Vanadium (V)	-0.123	0.218	0.115	0.252	0.076	0.449	0.004	0.971
Zinc (Zn)	0.085	0.394	0.194	0.051	-0.107	0.284	0.249	0.012
Zirconium (Zr)	-0.091	0.555	0.373	0.013	0.084	0.588	-0.139	0.368

Table D.100: Correlation coefficients between chemical parameters and dissolved oxygen, iron, manganese, and oxidation-reduction potential for the Devonian aquifer group.

Parameter	Dissolved Oxygen		Iron		Manganese		Redox potential	
	R^2	p	R^2	p	R^2	p	R^2	p
Alkalinity	-0.413	0.235	0.450	0.192	-0.073	0.841	-0.201	0.578
Aluminum (Al)	-0.261	0.467	0.564	0.090	-0.006	0.987	-0.467	0.174
Antimony (Sb)	0.259	0.471	0.234	0.515	0.209	0.562	-0.665	0.036
Arsenic (As)	-0.127	0.726	0.297	0.405	-0.333	0.347	-0.358	0.310
Barium (Ba)	0.030	0.934	0.346	0.328	-0.261	0.467	-0.406	0.244
Beryllium (Be)	0.101	0.781	-0.266	0.457	-0.374	0.287	-0.076	0.835
Bismuth (Bi)	-[1]	-	-	-	-	-	-	-
Boron (B)	-0.285	0.425	0.067	0.855	-0.055	0.881	-0.200	0.580
Bromide (Br)	-	-	-	-	-	-	-	-
Cadmium (Cd)	-0.042	0.907	0.309	0.385	0.309	0.385	-0.067	0.855
Calcium (Ca)	-0.467	0.174	0.527	0.117	-0.176	0.627	-0.139	0.701
Cesium (Cs)	-	-	-	-	-	-	-	-
Chloride (Cl)	0.133	0.732	-0.217	0.576	0.267	0.488	0.667	0.050
Chromium (Cr)	-0.021	0.955	-0.370	0.292	-0.418	0.229	0.555	0.096
Cobalt (Co)	0.018	0.960	-0.333	0.347	0.006	0.987	0.018	0.960
Copper (Cu)	-0.418	0.229	0.103	0.777	0.018	0.960	-0.103	0.777
Day	-0.433	0.211	0.458	0.183	0.195	0.590	-0.389	0.267
Depth	-0.006	0.987	0.770	0.009	-0.430	0.214	-0.576	0.082
Diameter	-0.522	0.122	0.058	0.873	-0.058	0.873	-0.290	0.416
Dissolved Oxygen	-	-	-0.370	0.293	0.067	0.855	0.261	0.467
Fluoride (F)	0.729	0.026	-0.407	0.277	-0.203	0.600	0.661	0.053
Iron (Fe)	-0.370	0.293	-	-	-0.261	0.467	-0.721	0.019
Lead (Pb)	-0.127	0.726	-0.103	0.777	0.503	0.138	0.139	0.701
Lithium (Li)	-0.139	0.701	-0.164	0.651	-0.176	0.627	0.212	0.556
Magnesium (Mg)	-0.564	0.090	0.624	0.054	-0.249	0.489	-0.285	0.425
Manganese (Mn)	0.067	0.855	-0.261	0.467	-	-	0.152	0.676
Mercury (Hg)	-0.443	0.200	0.592	0.071	-0.378	0.282	-0.449	0.193
Molybdenum (Mo)	-0.522	0.122	0.522	0.122	-0.522	0.122	-0.522	0.122
Nickel (Ni)	-0.860	0.001	0.212	0.557	0.014	0.970	-0.123	0.735
Nitrate (NO3)	-	-	-	-	-	-	-	-
Ortho-phosphate	-0.369	0.294	0.554	0.097	0.172	0.634	-0.172	0.634
pH	0.407	0.243	0.109	0.763	0.286	0.424	-0.426	0.220
Phosphorustotal	-0.127	0.726	0.564	0.090	0.297	0.405	-0.309	0.385
Potassium (K)	-0.346	0.328	0.018	0.960	-0.006	0.987	0.042	0.907
Redox/Eh	0.261	0.467	-0.721	0.019	0.152	0.676	-	-
Rubidium (Rb)	-	-	-	-	-	-	-	-
Selenium (Se)	-0.577	0.134	0.577	0.134	-0.577	0.134	-0.577	0.134
Silicate (Si)	-0.442	0.200	-0.030	0.934	-0.030	0.934	0.249	0.489
Silver (Ag)	0.355	0.315	-0.528	0.117	0.355	0.315	0.035	0.924
Sodium (Na)	-0.346	0.328	0.042	0.907	0.103	0.777	-0.285	0.425
Specific Conductivity	-0.285	0.425	0.430	0.214	0.115	0.751	-0.079	0.829
Strontium (Sr)	-0.333	0.347	0.091	0.803	-0.030	0.934	-0.200	0.580
Sulfate (SO4)	0.000	0.000	-0.233	0.546	-0.267	0.488	0.400	0.286
Sulfur (S)	-0.018	0.960	-0.394	0.260	-0.200	0.580	0.491	0.150
SWL	0.236	0.511	0.079	0.829	0.224	0.533	-0.103	0.777
Temperature	-0.469	0.171	0.278	0.437	0.173	0.633	-0.420	0.227
Thallium (Tl)	0.162	0.656	-0.575	0.082	0.200	0.579	0.110	0.762
Tin (Sn)	-	-	-	-	-	-	-	-
Titanium (Ti)	-0.450	0.192	-0.112	0.757	0.156	0.668	0.208	0.565
Total dissolved solids	-0.400	0.286	0.450	0.224	-0.117	0.765	-0.117	0.765
Total organic carbon	-0.188	0.603	0.539	0.108	-0.018	0.960	-0.006	0.987
Total phosphate	-	-	-	-	-	-	-	-
Tritium	-0.500	0.667	-0.500	0.667	0.500	0.667	0.500	0.667
Total suspended solids	-0.715	0.030	0.826	0.006	-0.017	0.965	-0.349	0.357
Vanadium (V)	-0.679	0.031	0.071	0.845	0.045	0.901	0.097	0.790
Zinc (Zn)	-0.346	0.328	0.552	0.098	0.212	0.556	-0.176	0.627
Zirconium (Zr)	-	-	-	-	-	-	-	-

[1] Insufficient sample size or no samples collected

Table D.101: Correlation coefficients between chemical parameters dissolved oxygen, iron, manganese, and oxidation-reduction potential, for the Cretaceous aquifer group.

Parameter	Dissolved Oxygen		Iron		Manganese		Redox potential	
	R^2	p	R^2	p	R^2	p	R^2	p
Alkalinity	-0.267	0.100	0.067	0.687	0.122	0.458	-0.024	0.883
Aluminum (Al)	-0.065	0.695	-0.167	0.310	-0.078	0.637	0.084	0.611
Antimony (Sb)	0.083	0.617	-0.269	0.098	-0.214	0.190	0.599	0.000
Arsenic (As)	-0.368	0.021	-0.170	0.301	0.064	0.699	-0.212	0.194
Barium (Ba)	0.207	0.207	0.073	0.661	-0.054	0.746	0.193	0.238
Beryllium (Be)	-0.344	0.032	0.137	0.406	0.030	0.858	0.183	0.264
Bismuth (Bi)	-[1]	-	-	-	-	-	-	-
Boron (B)	-0.210	0.200	-0.073	0.660	-0.025	0.880	-0.368	0.021
Bromide (Br)	-0.359	0.025	-0.312	0.053	-0.305	0.059	-0.174	0.288
Cadmium (Cd)	-0.139	0.398	-0.072	0.662	0.003	0.985	0.377	0.018
Calcium (Ca)	0.107	0.515	0.499	0.001	0.671	0.000	0.293	0.070
Cesium (Cs)	-	-	-	-	-	-	-	-
Chloride (Cl)	-0.096	0.561	-0.550	0.000	-0.588	0.000	0.007	0.965
Chromium (Cr)	-0.152	0.355	-0.142	0.390	-0.268	0.099	-0.066	0.692
Cobalt (Co)	0.087	0.600	0.453	0.004	0.552	0.000	0.405	0.010
Copper (Cu)	0.129	0.434	-0.025	0.881	0.173	0.292	0.243	0.135
Day	-0.391	0.014	-0.207	0.206	-0.330	0.041	-0.137	0.407
Depth	-0.180	0.274	0.426	0.007	0.390	0.014	-0.460	0.003
Diameter	0.316	0.050	0.212	0.195	0.199	0.225	0.087	0.600
Dissolved Oxygen	-	-	-0.033	0.840	-0.113	0.495	0.260	0.109
Fluoride (F)	-0.165	0.420	-0.212	0.300	-0.321	0.110	-0.080	0.696
Iron (Fe)	- 0.033	0.840	-	-	0.687	0.000	-0.242	0.137
Lead (Pb)	0.167	0.309	-0.058	0.728	-0.032	0.848	0.147	0.371
Lithium (Li)	-0.261	0.108	0.169	0.303	0.336	0.037	0.090	0.588
Magnesium (Mg)	0.103	0.531	0.448	0.004	0.593	0.000	0.308	0.057
Manganese (Mn)	-0.113	0.495	0.687	0.000	-	-	-0.063	0.704
Mercury (Hg)	0.187	0.282	0.255	0.140	0.000	0.000	-0.238	0.169
Molybdenum (Mo)	-0.094	0.569	0.066	0.689	0.408	0.010	0.122	0.458
Nickel (Ni)	-0.001	0.996	0.186	0.256	0.483	0.002	0.177	0.281
Nitrate (NO3)	0.325	0.044	-0.545	0.000	-0.574	0.000	0.449	0.004
Ortho-phosphate	0.449	0.226	0.434	0.243	-0.077	0.845	-0.775	0.014
pH	-0.228	0.164	-0.349	0.030	-0.497	0.001	-0.339	0.035
Phosphorustotal	-0.107	0.517	0.088	0.594	0.314	0.052	-0.320	0.047
Potassium (K)	-0.252	0.121	0.093	0.574	0.200	0.222	-0.189	0.248
Redox/Eh	0.260	0.109	-0.242	0.137	-0.063	0.704	-	-
Rubidium (Rb)	-0.073	0.659	0.096	0.560	0.474	0.002	0.012	0.944
Selenium (Se)	-0.101	0.541	-0.313	0.052	-0.486	0.002	-0.042	0.802
Silicate (Si)	0.234	0.153	0.167	0.311	0.428	0.007	0.230	0.159
Silver (Ag)	-0.190	0.246	-0.268	0.099	-0.355	0.026	0.062	0.709
Sodium (Na)	-0.326	0.043	-0.170	0.302	0.021	0.901	-0.386	0.015
Specific Conductivity	-0.067	0.685	0.139	0.400	0.354	0.027	-0.077	0.640
Strontium (Sr)	0.059	0.721	0.404	0.011	0.501	0.001	-0.010	0.954
Sulfate (SO4)	-0.088	0.593	0.149	0.364	0.421	0.008	-0.039	0.813
Sulfur (S)	-0.100	0.546	0.178	0.278	0.454	0.004	-0.022	0.896
SWL	0.294	0.069	0.187	0.254	0.309	0.056	-0.141	0.391
Temperature	-0.147	0.371	0.231	0.157	0.432	0.006	-0.228	0.162
Thallium (Tl)	0.169	0.304	-0.129	0.435	0.062	0.707	0.281	0.083
Tin (Sn)	-	-	-	-	-	-	-	-
Titanium (Ti)	0.069	0.677	0.250	0.126	0.506	0.001	0.129	0.432
Total dissolved solids	-0.162	0.325	0.016	0.922	0.311	0.054	0.003	0.984
Total organic carbon	0.014	0.932	0.196	0.231	0.173	0.294	-0.049	0.768
Total phosphate	-0.328	0.077	0.163	0.390	0.289	0.122	-0.224	0.235
Tritium	0.866	0.333	-0.866	0.333	-0.866	0.333	0.866	0.333
Total suspended solids	-0.097	0.559	0.858	0.000	0.622	0.000	-0.155	0.346
Vanadium (V)	0.035	0.831	0.383	0.016	0.606	0.000	0.160	0.332
Zinc (Zn)	0.063	0.705	0.112	0.496	0.209	0.201	0.220	0.178
Zirconium (Zr)	-	-	-	-	-	-	-	-

[1] Insufficient sample size or no samples collected

Table D.102: Correlation coefficients between chemical parameters dissolved oxygen, iron, manganese, and oxidation-reduction potential, for the Ordovician aquifer group.

Parameter	Dissolved Oxygen		Iron		Manganese		Redox potential	
	R^2	p	R^2	p	R^2	p	R^2	p
Alkalinity	-0.260	0.015	0.461	0.000	0.489	0.000	-0.281	0.008
Aluminum (Al)	0.086	0.437	-0.164	0.138	-0.047	0.674	-0.102	0.361
Antimony (Sb)	0.146	0.187	-0.277	0.011	-0.051	0.647	0.306	0.005
Arsenic (As)	-0.238	0.030	0.528	0.000	0.420	0.000	-0.444	0.000
Barium (Ba)	-0.324	0.002	0.425	0.000	0.247	0.021	-0.418	0.000
Beryllium (Be)	-0.181	0.102	0.028	0.801	0.166	0.133	-0.112	0.312
Bismuth (Bi)	0.060	0.802	0.219	0.354	0.262	0.264	-0.020	0.934
Boron (B)	-0.224	0.037	0.385	0.000	0.364	0.001	-0.230	0.032
Bromide (Br)	-[1]	-	-	-	-	-	-	-
Cadmium (Cd)	0.174	0.117	0.068	0.539	-0.334	0.002	0.102	0.359
Calcium (Ca)	-0.001	0.989	0.240	0.025	0.318	0.003	0.045	0.682
Cesium (Cs)	0.199	0.400	-0.026	0.914	-0.269	0.252	0.029	0.902
Chloride (Cl)	0.325	0.002	-0.502	0.000	-0.284	0.008	0.272	0.011
Chromium (Cr)	0.444	0.000	-0.531	0.000	-0.464	0.000	0.436	0.000
Cobalt (Co)	-0.221	0.045	0.071	0.521	0.490	0.000	-0.113	0.308
Copper (Cu)	0.146	0.178	-0.058	0.594	-0.131	0.226	0.045	0.681
Day	-0.260	0.015	-0.006	0.954	0.328	0.002	-0.355	0.001
Depth	-0.101	0.353	0.086	0.427	0.012	0.915	0.076	0.484
Diameter	0.008	0.943	0.184	0.088	0.017	0.876	-0.029	0.792
Dissolved Oxygen	-	-	-0.419	0.000	-0.533	0.000	0.557	0.000
Fluoride (F)	0.236	0.062	-0.188	0.140	-0.278	0.028	0.143	0.263
Iron (Fe)	-0.419	0.000	-	-	0.613	0.000	-0.569	0.000
Lead (Pb)	0.276	0.011	-0.198	0.072	-0.338	0.002	0.413	0.000
Lithium (Li)	-0.158	0.145	0.332	0.002	0.349	0.001	-0.213	0.048
Magnesium (Mg)	-0.083	0.445	0.156	0.149	0.364	0.001	-0.167	0.123
Manganese (Mn)	-0.533	0.000	0.613	0.000	-	-	-0.527	0.000
Mercury (Hg)	0.261	0.041	-0.204	0.112	-0.179	0.163	0.185	0.150
Molybdenum (Mo)	-0.127	0.240	0.032	0.769	0.127	0.241	-0.207	0.054
Nickel (Ni)	-0.011	0.917	-0.210	0.051	-0.118	0.278	-0.018	0.871
Nitrate (NO3)	0.561	0.000	-0.701	0.000	-0.708	0.000	0.613	0.000
Ortho-phosphate	-0.070	0.633	0.157	0.281	0.030	0.837	-0.323	0.024
pH	0.019	0.862	-0.208	0.053	-0.137	0.205	-0.147	0.175
Phosphorustotal	-0.339	0.001	0.602	0.000	0.437	0.000	-0.620	0.000
Potassium (K)	-0.103	0.343	0.108	0.320	0.231	0.032	-0.146	0.179
Redox/Eh	0.557	0.000	-0.569	0.000	-0.527	0.000	-	-
Rubidium (Rb)	0.184	0.087	-0.256	0.017	-0.288	0.007	0.216	0.044
Selenium (Se)	0.120	0.346	0.129	0.309	0.107	0.401	0.124	0.329
Silicate (Si)	-0.244	0.023	0.148	0.172	0.324	0.002	-0.354	0.001
Silver (Ag)	-0.028	0.800	-0.249	0.023	0.035	0.751	-0.142	0.200
Sodium (Na)	-0.200	0.063	0.406	0.000	0.373	0.000	-0.287	0.007
Specific Conductivity	-0.122	0.261	0.313	0.003	0.306	0.004	-0.185	0.086
Strontium (Sr)	-0.299	0.005	0.498	0.000	0.453	0.000	-0.356	0.001
Sulfate (SO4)	0.213	0.047	-0.015	0.894	0.160	0.140	0.217	0.043
Sulfur (S)	0.191	0.076	-0.052	0.634	0.131	0.226	0.220	0.041
SWL	0.079	0.469	-0.204	0.059	-0.183	0.090	0.233	0.030
Temperature	-0.228	0.034	-0.012	0.910	0.235	0.028	-0.223	0.038
Thallium (Tl)	0.065	0.558	-0.326	0.003	0.001	0.991	0.076	0.493
Tin (Sn)	0.244	0.299	-0.234	0.322	-0.237	0.315	0.166	0.485
Titanium (Ti)	0.017	0.875	-0.251	0.019	-0.167	0.122	0.076	0.486
Total dissolved solids	-0.027	0.804	0.164	0.130	0.320	0.003	-0.098	0.368
Total organic carbon	-0.016	0.884	0.383	0.000	0.054	0.618	-0.069	0.527
Total phosphate	-0.246	0.137	0.489	0.002	0.218	0.189	-0.570	0.000
Tritium	0.300	0.043	-0.345	0.019	-0.375	0.010	0.170	0.258
Total suspended solids	-0.287	0.007	0.716	0.000	0.502	0.000	-0.410	0.000
Vanadium (V)	-0.008	0.943	-0.178	0.099	-0.080	0.462	-0.029	0.788
Zinc (Zn)	0.074	0.493	0.007	0.948	-0.036	0.743	0.346	0.001
Zirconium (Zr)	0.122	0.609	-0.098	0.681	-0.068	0.777	0.058	0.808

[1] Insufficient sample size or no samples collected

Table D.103: Correlation coefficients between chemical parameters dissolved oxygen, iron, manganese, and oxidation-reduction potential, for the Precambrian aquifer group.

Parameter	Dissolved Oxygen		Iron		Manganese		Redox potential	
	R^2	p	R^2	p	R^2	p	R^2	p
Alkalinity	-0.162	0.157	0.198	0.082	0.399	0.000	-0.007	0.951
Aluminum (Al)	0.034	0.764	0.371	0.001	-0.040	0.722	-0.147	0.197
Antimony (Sb)	0.046	0.682	0.146	0.195	-0.016	0.889	0.055	0.629
Arsenic (As)	-0.067	0.552	0.132	0.242	0.192	0.088	-0.061	0.593
Barium (Ba)	-0.074	0.513	0.177	0.116	0.275	0.014	-0.029	0.798
Beryllium (Be)	-0.034	0.762	0.405	0.000	0.195	0.084	-0.132	0.246
Bismuth (Bi)	0.208	0.166	0.152	0.315	0.062	0.683	-0.046	0.762
Boron (B)	-0.078	0.492	0.191	0.089	0.120	0.289	-0.276	0.014
Bromide (Br)	0.038	0.741	0.243	0.030	0.147	0.194	-0.216	0.056
Cadmium (Cd)	-0.195	0.084	0.128	0.259	0.045	0.692	-0.004	0.970
Calcium (Ca)	-0.109	0.337	0.165	0.143	0.489	0.000	0.250	0.026
Cesium (Cs)	0.094	0.533	0.329	0.026	0.161	0.285	-0.423	0.004
Chloride (Cl)	0.114	0.315	0.015	0.895	0.071	0.534	0.117	0.306
Chromium (Cr)	0.071	0.532	0.448	0.000	0.160	0.157	-0.121	0.289
Cobalt (Co)	0.005	0.968	0.594	0.000	0.676	0.000	0.047	0.679
Copper (Cu)	0.245	0.029	0.082	0.469	-0.052	0.648	0.111	0.329
Day	0.074	0.515	0.015	0.897	-0.007	0.951	-0.089	0.433
Depth	0.083	0.464	0.084	0.460	0.003	0.976	-0.127	0.267
Diameter	0.190	0.091	-0.161	0.154	-0.146	0.196	0.091	0.424
Dissolved Oxygen	-	-	-0.168	0.136	-0.261	0.020	0.254	0.024
Fluoride (F)	-0.019	0.879	0.164	0.185	0.102	0.412	-0.217	0.080
Iron (Fe)	-0.168	0.136	-	-	0.617	0.000	-0.380	0.001
Lead (Pb)	0.139	0.219	0.349	0.002	0.016	0.887	-0.198	0.080
Lithium (Li)	0.058	0.611	0.138	0.223	0.208	0.064	0.066	0.564
Magnesium (Mg)	-0.098	0.387	0.157	0.166	0.394	0.000	0.155	0.174
Manganese (Mn)	-0.261	0.020	0.617	0.000	-	-	-0.100	0.381
Mercury (Hg)	0.602	0.023	-0.079	0.787	-0.442	0.113	-0.022	0.941
Molybdenum (Mo)	0.092	0.419	0.191	0.089	0.186	0.099	0.020	0.864
Nickel (Ni)	0.193	0.086	0.247	0.027	0.183	0.104	0.090	0.430
Nitrate (NO3)	0.338	0.002	-0.373	0.001	-0.331	0.003	0.317	0.004
Ortho-phosphate	-[1]	-	-	-	-	-	-	-
pH	-0.154	0.176	-0.063	0.583	-0.257	0.022	-0.401	0.000
Phosphorustotal	0.058	0.608	0.589	0.000	0.516	0.000	-0.158	0.165
Potassium (K)	-0.046	0.687	0.378	0.001	0.495	0.000	0.099	0.384
Redox/Eh	0.254	0.024	-0.380	0.001	-0.100	0.381	-	-
Rubidium (Rb)	0.004	0.975	0.042	0.715	0.143	0.206	0.149	0.190
Selenium (Se)	-0.006	0.957	0.271	0.015	0.167	0.139	-0.141	0.214
Silicate (Si)	0.106	0.349	0.188	0.095	0.216	0.054	0.123	0.280
Silver (Ag)	-0.252	0.024	0.111	0.328	0.034	0.765	-0.083	0.465
Sodium (Na)	-0.046	0.688	0.138	0.221	0.095	0.401	-0.191	0.092
Specific Conductivity	0.142	0.213	-0.045	0.696	0.109	0.338	0.030	0.794
Strontium (Sr)	-0.066	0.559	0.214	0.057	0.415	0.000	0.061	0.595
Sulfate (SO4)	0.145	0.199	-0.027	0.816	0.161	0.153	0.301	0.007
Sulfur (S)	0.105	0.356	-0.012	0.919	0.189	0.093	0.311	0.005
SWL	-0.002	0.987	0.206	0.067	0.219	0.051	-0.110	0.337
Temperature	0.101	0.375	0.199	0.079	0.319	0.004	-0.081	0.479
Thallium (Tl)	0.119	0.294	-0.079	0.488	-0.009	0.936	0.058	0.614
Tin (Sn)	0.096	0.527	0.214	0.153	0.031	0.840	-0.253	0.093
Titanium (Ti)	0.228	0.042	0.411	0.000	0.153	0.177	-0.011	0.925
Total dissolved solids	-0.005	0.962	0.076	0.503	0.285	0.010	0.086	0.451
Total organic carbon	-0.227	0.042	0.258	0.021	0.457	0.000	0.008	0.948
Total phosphate	0.055	0.634	0.491	0.000	0.364	0.001	-0.228	0.046
Tritium	0.181	0.195	-0.012	0.933	0.057	0.684	0.250	0.074
Total suspended solids	-0.140	0.216	0.747	0.000	0.353	0.001	-0.295	0.008
Vanadium (V)	0.179	0.113	0.273	0.014	0.166	0.142	0.111	0.329
Zinc (Zn)	0.088	0.440	0.357	0.001	0.315	0.004	-0.119	0.295
Zirconium (Zr)	-0.128	0.229	0.552	0.000	0.375	0.010	-0.202	0.183

[1] Insufficient sample size or no samples collected

Table D.104: Correlation coefficients between chemical parameters dissolved oxygen, iron, manganese, and oxidation-reduction potential, for the buried Quaternary aquifer group.

Parameter	Dissolved Oxygen		Iron		Manganese		Redox potential	
	R^2	p	R^2	p	R^2	p	R^2	p
Alkalinity	-0.021	0.629	0.428	0.000	0.181	0.000	-0.147	0.001
Aluminum (Al)	-0.085	0.054	0.006	0.896	0.001	0.990	-0.037	0.403
Antimony (Sb)	0.044	0.321	-0.019	0.665	0.073	0.102	0.153	0.001
Arsenic (As)	-0.133	0.003	0.375	0.000	0.218	0.000	-0.152	0.001
Barium (Ba)	-0.100	0.023	0.148	0.001	0.004	0.935	-0.188	0.000
Beryllium (Be)	-0.205	0.000	0.069	0.119	-0.091	0.040	-0.008	0.851
Bismuth (Bi)	0.088	0.289	0.029	0.725	-0.008	0.925	-0.003	0.972
Boron (B)	-0.181	0.000	0.335	0.000	0.116	0.008	-0.202	0.000
Bromide (Br)	-0.069	0.117	-0.056	0.211	-0.123	0.005	-0.028	0.535
Cadmium (Cd)	-0.137	0.002	0.154	0.000	0.100	0.024	-0.046	0.302
Calcium (Ca)	0.162	0.000	0.451	0.000	0.431	0.000	0.003	0.953
Cesium (Cs)	0.055	0.512	0.107	0.197	0.201	0.015	0.004	0.959
Chloride (Cl)	0.104	0.018	-0.116	0.009	-0.010	0.814	0.058	0.187
Chromium (Cr)	0.194	0.000	0.038	0.394	-0.078	0.077	-0.068	0.123
Cobalt (Co)	0.106	0.017	0.364	0.000	0.521	0.000	0.084	0.058
Copper (Cu)	-0.014	0.745	0.119	0.007	0.183	0.000	0.058	0.190
Day	-0.140	0.001	-0.217	0.000	-0.197	0.000	0.077	0.082
Depth	-0.170	0.000	0.163	0.000	0.023	0.608	-0.257	0.000
Diameter	0.075	0.092	0.168	0.000	0.222	0.000	0.051	0.253
Dissolved Oxygen	-	-	-0.172	0.000	-0.014	0.755	0.274	0.000
Fluoride (F)	-0.143	0.005	0.058	0.264	-0.186	0.000	-0.120	0.020
Iron (Fe)	-0.172	0.000	-	-	0.413	0.000	-0.410	0.000
Lead (Pb)	0.095	0.033	-0.004	0.931	0.050	0.258	0.056	0.204
Lithium (Li)	-0.050	0.258	0.373	0.000	0.185	0.000	-0.086	0.053
Magnesium (Mg)	0.060	0.173	0.407	0.000	0.325	0.000	-0.075	0.092
Manganese (Mn)	-0.014	0.755	0.413	0.000	-	-	0.004	0.931
Mercury (Hg)	0.048	0.466	-0.088	0.178	-0.117	0.073	-0.076	0.244
Molybdenum (Mo)	-0.083	0.061	0.105	0.017	0.052	0.243	-0.101	0.022
Nickel (Ni)	-0.007	0.870	0.134	0.002	0.156	0.000	0.025	0.578
Nitrate (NO3)	0.340	0.000	-0.343	0.000	-0.205	0.000	0.283	0.000
Ortho-phosphate	-0.190	0.299	-0.123	0.503	-0.327	0.067	-0.255	0.159
pH	-0.240	0.000	-0.398	0.000	-0.355	0.000	-0.139	0.002
Phosphorustotal	-0.116	0.009	0.511	0.000	0.130	0.003	-0.382	0.000
Potassium (K)	-0.092	0.037	0.435	0.000	0.251	0.000	-0.135	0.002
Redox/Eh	0.274	0.000	-0.410	0.000	0.004	0.931	-	-
Rubidium (Rb)	-0.056	0.208	0.138	0.002	0.194	0.000	-0.050	0.260
Selenium (Se)	0.201	0.000	-0.099	0.025	-0.072	0.105	-0.030	0.494
Silicate (Si)	-0.031	0.491	0.484	0.000	0.304	0.000	-0.126	0.004
Silver (Ag)	-0.113	0.010	-0.044	0.324	-0.063	0.154	-0.041	0.353
Sodium (Na)	-0.153	0.000	0.212	0.000	-0.001	0.983	-0.177	0.000
Specific Conductivity	0.100	0.024	0.305	0.000	0.236	0.000	-0.120	0.006
Strontium (Sr)	-0.109	0.014	0.433	0.000	0.246	0.000	-0.205	0.000
Sulfate (SO4)	0.091	0.039	0.252	0.000	0.259	0.000	0.004	0.938
Sulfur (S)	0.080	0.071	0.264	0.000	0.273	0.000	-0.009	0.846
SWL	0.112	0.011	0.138	0.002	0.193	0.000	0.006	0.897
Temperature	0.052	0.242	0.165	0.000	0.251	0.000	-0.040	0.370
Thallium (Tl)	0.149	0.001	-0.019	0.669	0.148	0.001	0.070	0.115
Tin (Sn)	-0.149	0.073	0.052	0.532	0.154	0.063	0.005	0.949
Titanium (Ti)	-0.059	0.181	0.144	0.001	0.074	0.095	0.003	0.942
Total dissolved solids	0.046	0.303	0.383	0.000	0.238	0.000	-0.085	0.055
Total organic carbon	-0.086	0.053	0.405	0.000	0.186	0.000	-0.170	0.000
Total phosphate	-0.098	0.031	0.380	0.000	-0.024	0.597	-0.330	0.000
Tritium	0.155	0.269	-0.085	0.544	0.049	0.726	0.105	0.453
Total suspended solids	-0.132	0.003	0.829	0.000	0.310	0.000	-0.263	0.000
Vanadium (V)	-0.071	0.110	0.248	0.000	0.202	0.000	0.026	0.551
Zinc (Zn)	0.030	0.504	0.203	0.000	0.231	0.000	-0.031	0.482
Zirconium (Zr)	-0.085	0.307	0.483	0.000	0.069	0.410	-0.232	0.005

Table D.105: Correlation coefficients between chemical parameters dissolved oxygen, iron, manganese, and oxidation-reduction potential, for the surficial Quaternary aquifer group.

Parameter	Dissolved Oxygen R^2	Dissolved Oxygen p	Iron R^2	Iron p	Manganese R^2	Manganese p	Redox potential R^2	Redox potential p
Alkalinity	0.106	0.245	0.167	0.066	0.145	0.111	-0.050	0.588
Aluminum (Al)	-0.277	0.002	0.149	0.102	0.005	0.959	0.026	0.774
Antimony (Sb)	0.136	0.137	-0.292	0.001	-0.124	0.175	0.330	0.000
Arsenic (As)	-0.232	0.010	0.337	0.000	0.299	0.001	-0.253	0.005
Barium (Ba)	-0.188	0.037	0.425	0.000	0.278	0.002	-0.405	0.000
Beryllium (Be)	-0.323	0.000	0.342	0.000	0.090	0.327	-0.156	0.087
Bismuth (Bi)	-[1]	-	-	-	-	-	-	-
Boron (B)	-0.192	0.034	0.068	0.457	0.166	0.067	0.044	0.632
Bromide (Br)	-	-	-	-	-	-	-	-
Cadmium (Cd)	-0.128	0.160	-0.099	0.277	-0.023	0.798	0.100	0.273
Calcium (Ca)	0.196	0.030	0.023	0.800	0.153	0.092	0.060	0.510
Cesium (Cs)	-0.146	0.351	0.314	0.040	0.168	0.280	-0.195	0.211
Chloride (Cl)	0.300	0.001	-0.147	0.105	0.034	0.709	0.105	0.248
Chromium (Cr)	0.222	0.014	0.102	0.266	0.015	0.868	-0.014	0.880
Cobalt (Co)	0.056	0.544	0.164	0.071	0.295	0.001	0.050	0.584
Copper (Cu)	0.136	0.135	-0.141	0.121	-0.157	0.084	0.179	0.048
Day	-0.279	0.002	0.168	0.064	-0.039	0.669	-0.149	0.100
Depth	-0.100	0.271	0.082	0.368	0.013	0.885	-0.108	0.234
Diameter	0.165	0.069	-0.150	0.097	-0.116	0.203	0.209	0.021
Dissolved Oxygen	-	-	-0.259	0.004	-0.197	0.029	0.287	0.001
Fluoride (F)	-0.079	0.504	0.145	0.218	0.038	0.750	0.006	0.957
Iron (Fe)	-0.259	0.004	-	-	0.563	0.000	-0.549	0.000
Lead (Pb)	0.200	0.028	-0.114	0.214	-0.073	0.428	0.196	0.031
Lithium (Li)	-0.102	0.260	0.171	0.059	0.060	0.507	0.001	0.989
Magnesium (Mg)	0.115	0.206	0.041	0.656	0.086	0.342	0.019	0.832
Manganese (Mn)	-0.197	0.029	0.563	0.000	-	-	-0.230	0.011
Mercury (Hg)	0.206	0.197	-0.252	0.113	-0.200	0.210	0.166	0.299
Molybdenum (Mo)	0.058	0.521	0.004	0.965	0.000	0.997	0.152	0.093
Nickel (Ni)	-0.065	0.472	0.065	0.473	0.031	0.732	0.027	0.771
Nitrate (NO3)	0.397	0.000	-0.654	0.000	-0.464	0.000	0.544	0.000
Ortho-phosphate	-0.377	0.461	-0.899	0.015	-0.899	0.015	-0.058	0.913
pH	-0.200	0.027	-0.211	0.019	-0.230	0.011	-0.123	0.177
Phosphorustotal	-0.239	0.008	0.631	0.000	0.421	0.000	-0.315	0.000
Potassium (K)	-0.001	0.989	0.252	0.005	0.210	0.020	-0.010	0.913
Redox/Eh	0.287	0.001	-0.549	0.000	-0.230	0.011	-	-
Rubidium (Rb)	-0.021	0.818	0.033	0.720	0.073	0.422	-0.034	0.706
Selenium (Se)	0.103	0.260	0.033	0.717	0.125	0.171	-0.154	0.090
Silicate (Si)	0.007	0.942	0.425	0.000	0.258	0.004	-0.200	0.027
Silver (Ag)	-0.087	0.341	-0.052	0.572	-0.145	0.111	-0.108	0.239
Sodium (Na)	0.001	0.992	-0.131	0.148	0.024	0.796	0.150	0.099
Specific Conductivity	0.201	0.026	0.043	0.638	0.119	0.191	-0.007	0.940
Strontium (Sr)	-0.082	0.365	0.171	0.059	0.285	0.001	-0.040	0.665
Sulfate (SO4)	0.259	0.004	-0.314	0.000	-0.003	0.971	0.221	0.014
Sulfur (S)	0.264	0.003	-0.295	0.001	0.018	0.841	0.207	0.022
SWL	0.074	0.415	-0.055	0.547	-0.155	0.088	-0.036	0.692
Temperature	-0.048	0.600	0.021	0.818	0.161	0.075	-0.114	0.211
Thallium (Tl)	0.323	0.000	-0.258	0.004	-0.068	0.460	0.182	0.045
Tin (Sn)	0.414	0.006	-0.003	0.985	-0.003	0.985	-0.013	0.932
Titanium (Ti)	-0.151	0.095	0.152	0.092	-0.021	0.818	0.037	0.689
Total dissolved solids	0.170	0.060	0.006	0.944	0.140	0.122	0.061	0.500
Total organic carbon	-0.152	0.093	0.470	0.000	0.405	0.000	-0.084	0.356
Total phosphate	-0.052	0.575	0.446	0.000	0.233	0.011	-0.220	0.017
Tritium	0.048	0.910	0.095	0.823	0.244	0.560	-0.143	0.736
Total suspended solids	-0.309	0.001	0.818	0.000	0.511	0.000	-0.438	0.000
Vanadium (V)	-0.102	0.260	0.162	0.074	0.040	0.661	0.063	0.492
Zinc (Zn)	0.088	0.331	0.106	0.245	0.039	0.668	-0.063	0.486
Zirconium (Zr)	-0.182	0.244	0.732	0.000	0.405	0.007	-0.435	0.004

[1] Insufficient sample size or no samples collected

Table D.106: Correlation coefficients between chemical parameters dissolved oxygen, iron, manganese, and oxidation-reduction potential, for the CFIG-CFRN-CIGL aquifer group.

Parameter	Dissolved Oxygen		Iron		Manganese		Redox potential	
	R^2	p	R^2	p	R^2	p	R^2	p
Alkalinity	-0.350	0.027	0.515	0.001	0.371	0.018	-0.367	0.020
Aluminum (Al)	0.013	0.938	-0.136	0.409	0.326	0.043	-0.011	0.945
Antimony (Sb)	-0.269	0.097	0.189	0.249	-0.006	0.973	0.253	0.120
Arsenic (As)	-0.273	0.092	0.431	0.006	0.362	0.023	-0.284	0.079
Barium (Ba)	-0.361	0.022	0.479	0.002	0.212	0.189	-0.149	0.360
Beryllium (Be)	-0.239	0.143	0.357	0.026	0.261	0.109	-0.384	0.016
Bismuth (Bi)	-0.205	0.431	0.000	0.000	0.306	0.232	-0.204	0.432
Boron (B)	-0.567	0.000	0.552	0.000	0.277	0.084	-0.394	0.012
Bromide (Br)	-	-	-	-	-	-	-	-
Cadmium (Cd)	0.123	0.455	-0.219	0.180	-0.190	0.248	0.236	0.147
Calcium (Ca)	-0.276	0.085	0.348	0.028	0.208	0.197	-0.325	0.041
Cesium (Cs)	-0.553	0.021	0.572	0.016	-0.221	0.395	0.085	0.747
Chloride (Cl)	0.090	0.579	-0.443	0.004	-0.155	0.341	0.237	0.140
Chromium (Cr)	0.517	0.001	-0.159	0.335	-0.420	0.008	-0.132	0.423
Cobalt (Co)	-0.510	0.001	0.273	0.093	0.586	0.000	-0.239	0.143
Copper (Cu)	0.140	0.389	-0.282	0.078	-0.205	0.205	0.332	0.037
Day	-0.364	0.021	0.060	0.711	0.488	0.001	-0.315	0.048
Depth	0.155	0.339	0.210	0.193	-0.326	0.040	-0.004	0.981
Diameter	-0.336	0.034	0.207	0.200	-0.021	0.896	-0.130	0.425
Dissolved Oxygen	-	-	-0.434	0.005	-0.522	0.001	0.320	0.044
Fluoride (F)	0.293	0.123	0.011	0.954	-0.278	0.144	-0.162	0.400
Iron (Fe)	-0.434	0.005	-	-	0.414	0.008	-0.458	0.003
Lead (Pb)	0.207	0.206	-0.237	0.146	-0.191	0.245	0.225	0.168
Lithium (Li)	-0.524	0.001	0.425	0.006	0.337	0.034	-0.101	0.534
Magnesium (Mg)	-0.062	0.706	0.364	0.021	0.057	0.727	-0.187	0.248
Manganese (Mn)	-0.522	0.001	0.414	0.008	-	-	-0.416	0.008
Mercury (Hg)	-0.075	0.741	0.449	0.036	0.449	0.036	-0.498	0.018
Molybdenum (Mo)	-0.066	0.687	-0.009	0.956	-0.002	0.990	-0.029	0.860
Nickel (Ni)	0.173	0.286	-0.014	0.933	-0.303	0.057	0.302	0.058
Nitrate (NO3)	0.493	0.001	-0.624	0.000	-0.654	0.000	0.398	0.011
Ortho-phosphate	0.300	0.370	-0.300	0.370	-0.301	0.369	0.500	0.117
pH	0.247	0.124	-0.446	0.004	-0.249	0.121	0.239	0.137
Phosphorustotal	-0.446	0.004	0.394	0.012	0.438	0.005	-0.306	0.055
Potassium (K)	-0.598	0.000	0.573	0.000	0.293	0.066	-0.296	0.064
Redox/Eh	0.320	0.044	-0.458	0.003	-0.416	0.008	-	-
Rubidium (Rb)	-0.034	0.834	0.225	0.163	0.024	0.882	0.116	0.475
Selenium (Se)	0.188	0.281	0.223	0.199	-0.174	0.316	-0.228	0.188
Silicate (Si)	-0.165	0.310	-0.129	0.427	0.370	0.019	-0.110	0.499
Silver (Ag)	-0.089	0.591	0.028	0.865	0.137	0.406	0.261	0.108
Sodium (Na)	-0.481	0.002	0.327	0.039	0.279	0.081	-0.335	0.034
Specific Conductivity	-0.247	0.124	0.293	0.067	0.125	0.441	-0.316	0.047
Strontium (Sr)	-0.523	0.001	0.483	0.002	0.357	0.024	-0.378	0.016
Sulfate (SO4)	-0.196	0.226	0.417	0.007	-0.047	0.772	-0.065	0.690
Sulfur (S)	-0.221	0.171	0.449	0.004	-0.044	0.790	-0.096	0.555
SWL	0.269	0.093	-0.007	0.965	-0.339	0.033	0.207	0.200
Temperature	-0.055	0.738	0.071	0.665	-0.205	0.205	0.241	0.134
Thallium (Tl)	-0.104	0.530	-0.176	0.285	0.218	0.183	-0.169	0.304
Tin (Sn)	0.070	0.789	-0.196	0.452	0.471	0.056	-0.239	0.356
Titanium (Ti)	0.196	0.225	-0.160	0.325	-0.245	0.128	0.330	0.037
Total dissolved solids	-0.280	0.084	0.296	0.068	0.127	0.441	-0.298	0.066
Total organic carbon	-0.183	0.257	0.246	0.126	0.019	0.906	-0.279	0.081
Total phosphate	-0.107	0.581	0.407	0.028	0.176	0.362	-0.206	0.284
Tritium	0.457	0.028	-0.618	0.002	-0.657	0.001	0.364	0.088
Total suspended solids	-0.261	0.109	0.856	0.000	0.372	0.020	-0.367	0.022
Vanadium (V)	-0.135	0.406	-0.078	0.632	-0.069	0.671	0.180	0.268
Zinc (Zn)	0.069	0.671	0.279	0.082	-0.183	0.257	0.242	0.133
Zirconium (Zr)	0.079	0.764	0.410	0.102	0.100	0.701	-0.061	0.818

[1] Insufficient sample size or no samples collected

Table D.107: Correlation coefficients between chemical parameters dissolved oxygen, iron, manganese, and oxidation-reduction potential, for the OSTP-OPDC-CJDN aquifer group.

Parameter	Dissolved Oxygen		Iron		Manganese		Redox potential	
	R^2	p	R^2	p	R^2	p	R^2	p
Alkalinity	-0.226	0.032	0.506	0.000	0.504	0.000	-0.222	0.035
Aluminum (Al)	0.191	0.077	-0.114	0.294	-0.129	0.235	-0.038	0.729
Antimony (Sb)	-0.086	0.430	0.151	0.164	0.110	0.309	-0.041	0.707
Arsenic (As)	-0.198	0.065	0.414	0.000	0.431	0.000	-0.288	0.007
Barium (Ba)	-0.297	0.004	0.372	0.000	0.429	0.000	-0.294	0.005
Beryllium (Be)	-0.275	0.010	0.103	0.344	0.258	0.016	-0.153	0.158
Bismuth (Bi)	-0.013	0.948	0.333	0.096	0.229	0.261	0.040	0.846
Boron (B)	-0.275	0.009	0.473	0.000	0.549	0.000	-0.242	0.022
Bromide (Br)	-	-	-	-	-	-	-	-
Cadmium (Cd)	0.245	0.022	-0.116	0.284	-0.345	0.001	0.231	0.031
Calcium (Ca)	-0.168	0.114	0.456	0.000	0.411	0.000	-0.153	0.151
Cesium (Cs)	0.237	0.245	0.094	0.648	-0.184	0.369	0.014	0.945
Chloride (Cl)	0.234	0.026	-0.325	0.002	-0.297	0.004	0.143	0.179
Chromium (Cr)	0.454	0.000	-0.385	0.000	-0.487	0.000	0.281	0.009
Cobalt (Co)	-0.221	0.040	0.263	0.014	0.448	0.000	-0.175	0.105
Copper (Cu)	0.155	0.146	0.010	0.926	-0.107	0.318	0.087	0.414
Day	-0.404	0.000	0.114	0.283	0.343	0.001	-0.474	0.000
Depth	-0.016	0.884	0.081	0.446	-0.035	0.745	0.041	0.701
Diameter	0.085	0.425	-0.050	0.640	0.049	0.644	0.044	0.681
Dissolved Oxygen	-	-	-0.450	0.000	-0.604	0.000	0.565	0.000
Fluoride (F)	0.203	0.129	-0.180	0.181	-0.258	0.053	0.043	0.752
Iron (Fe)	-0.450	0.000	-	-	0.738	0.000	-0.550	0.000
Lead (Pb)	0.371	0.000	-0.179	0.098	-0.397	0.000	0.460	0.000
Lithium (Li)	-0.183	0.084	0.429	0.000	0.467	0.000	-0.269	0.010
Magnesium (Mg)	-0.096	0.366	0.305	0.003	0.403	0.000	-0.167	0.115
Manganese (Mn)	-0.604	0.000	0.738	0.000	-	-	-0.615	0.000
Mercury (Hg)	0.273	0.035	-0.197	0.132	-0.204	0.118	0.209	0.110
Molybdenum (Mo)	-0.146	0.169	-0.021	0.847	0.169	0.112	-0.219	0.038
Nickel (Ni)	0.035	0.741	-0.131	0.219	-0.068	0.526	0.002	0.984
Nitrate (NO3)	0.553	0.000	-0.638	0.000	-0.723	0.000	0.588	0.000
Ortho-phosphate	0.272	0.070	-0.317	0.034	-0.254	0.093	0.187	0.220
pH	0.137	0.197	-0.304	0.004	-0.236	0.025	-0.036	0.735
Phosphorustotal	-0.299	0.004	0.456	0.000	0.473	0.000	-0.388	0.000
Potassium (K)	-0.270	0.010	0.442	0.000	0.489	0.000	-0.330	0.001
Redox/Eh	0.565	0.000	-0.550	0.000	-0.615	0.000	-	-
Rubidium (Rb)	0.073	0.491	-0.147	0.166	-0.140	0.188	0.069	0.520
Selenium (Se)	0.063	0.625	0.109	0.397	0.136	0.286	0.175	0.170
Silicate (Si)	-0.147	0.167	0.112	0.293	0.296	0.005	-0.231	0.029
Silver (Ag)	-0.107	0.323	-0.058	0.593	0.022	0.839	-0.257	0.016
Sodium (Na)	-0.280	0.008	0.408	0.000	0.530	0.000	-0.323	0.002
Specific Conductivity	-0.226	0.032	0.473	0.000	0.426	0.000	-0.261	0.013
Strontium (Sr)	-0.379	0.000	0.596	0.000	0.611	0.000	-0.358	0.001
Sulfate (SO4)	-0.039	0.975	0.296	0.002	0.261	0.013	-0.063	0.556
Sulfur (S)	-0.003	0.713	0.327	0.005	0.241	0.022	-0.084	0.431
SWL	0.262	0.013	-0.067	0.530	-0.194	0.067	0.265	0.012
Temperature	-0.289	0.006	0.116	0.276	0.182	0.082	-0.305	0.003
Thallium (Tl)	0.032	0.769	-0.230	0.032	-0.042	0.698	-0.081	0.454
Tin (Sn)	0.057	0.783	-0.065	0.752	-0.107	0.602	0.140	0.494
Titanium (Ti)	0.061	0.570	-0.112	0.292	-0.057	0.595	-0.012	0.913
Total dissolved solids	-0.106	0.325	0.332	0.001	0.369	0.000	-0.146	0.171
Total organic carbon	0.082	0.444	0.307	0.003	0.145	0.173	0.045	0.672
Total phosphate	-0.320	0.032	0.449	0.002	0.293	0.051	-0.249	0.100
Tritium	0.191	0.167	-0.235	0.087	-0.358	0.008	0.117	0.399
Total suspended solids	-0.192	0.072	0.670	0.000	0.497	0.000	-0.278	0.008
Vanadium (V)	-0.086	0.419	0.042	0.692	0.090	0.398	-0.190	0.073
Zinc (Zn)	0.127	0.235	0.194	0.067	-0.022	0.841	0.258	0.014
Zirconium (Zr)	0.017	0.936	0.078	0.705	-0.099	0.631	-0.098	0.633

[1] Insufficient sample size or no samples collected

Table D.108: Correlation coefficients between chemical parameters dissolved oxygen, iron, manganese, and oxidation-reduction potential, for the CMSH-CMTS-PMHN aquifer group.

Parameter	Dissolved Oxygen		Iron		Manganese		Redox potential	
	R^2	p	R^2	p	R^2	p	R^2	p
Alkalinity	-0.009	0.966	0.319	0.112	0.143	0.485	-0.346	0.084
Aluminum (Al)	0.103	0.615	-0.007	0.975	0.143	0.487	0.296	0.142
Antimony (Sb)	0.019	0.927	0.071	0.732	0.090	0.661	-0.118	0.566
Arsenic (As)	-0.417	0.034	0.618	0.001	0.466	0.016	-0.278	0.169
Barium (Ba)	-0.089	0.664	0.386	0.051	0.133	0.517	-0.278	0.168
Beryllium (Be)	-0.136	0.509	0.517	0.007	0.273	0.178	-0.033	0.873
Bismuth (Bi)	-	-	-	-	-	-	-	-
Boron (B)	-0.258	0.203	0.379	0.056	0.232	0.254	-0.338	0.092
Bromide (Br)	-0.307	0.127	0.173	0.397	0.200	0.327	0.333	0.096
Cadmium (Cd)	-0.212	0.299	0.240	0.238	0.505	0.009	-0.068	0.743
Calcium (Ca)	0.129	0.531	0.370	0.063	0.226	0.266	-0.215	0.291
Cesium (Cs)	-0.019	0.943	0.203	0.434	0.088	0.737	-0.460	0.063
Chloride (Cl)	0.149	0.467	-0.067	0.746	-0.117	0.570	0.320	0.111
Chromium (Cr)	0.282	0.162	0.189	0.356	-0.027	0.895	-0.009	0.967
Cobalt (Co)	-0.367	0.065	0.511	0.008	0.738	0.000	-0.043	0.835
Copper (Cu)	-0.128	0.535	-0.187	0.360	0.277	0.171	-0.094	0.647
Day	0.028	0.894	-0.464	0.017	-0.016	0.938	0.076	0.712
Depth	-0.315	0.117	0.170	0.408	0.256	0.206	-0.395	0.046
Diameter	0.279	0.167	-0.059	0.776	-0.371	0.062	-0.051	0.806
Dissolved Oxygen	-	-	-0.193	0.345	-0.283	0.162	0.246	0.226
Fluoride (F)	-0.352	0.117	0.354	0.116	0.154	0.506	-0.315	0.165
Iron (Fe)	-0.193	0.345	-	-	0.536	0.005	-0.141	0.493
Lead (Pb)	0.083	0.686	-0.080	0.700	0.076	0.711	-0.110	0.594
Lithium (Li)	-0.255	0.209	0.157	0.445	0.240	0.238	-0.067	0.746
Magnesium (Mg)	0.102	0.621	0.411	0.037	0.220	0.280	-0.215	0.291
Manganese (Mn)	-0.283	0.162	0.536	0.005	-	-	0.024	0.908
Mercury (Hg)	-	-	-	-	-	-	-	-
Molybdenum (Mo)	-0.201	0.326	-0.162	0.430	0.143	0.487	0.101	0.624
Nickel (Ni)	0.042	0.838	0.074	0.719	0.055	0.789	0.220	0.281
Nitrate (NO3)	0.591	0.001	-0.570	0.002	-0.436	0.026	0.339	0.091
Ortho-phosphate	-	-	-	-	-	-	-	-
pH	-0.314	0.118	-0.247	0.224	-0.145	0.479	-0.423	0.031
Phosphorustotal	-0.037	0.859	0.523	0.006	0.450	0.021	-0.149	0.468
Potassium (K)	-0.138	0.502	0.362	0.069	0.153	0.455	-0.220	0.280
Redox/Eh	0.246	0.226	-0.141	0.493	0.024	0.908	-	-
Rubidium (Rb)	-0.181	0.377	-0.140	0.496	-0.022	0.917	-0.013	0.950
Selenium (Se)	0.249	0.220	-0.058	0.777	0.064	0.755	0.128	0.535
Silicate (Si)	0.342	0.088	0.292	0.148	0.374	0.060	0.163	0.426
Silver (Ag)	0.005	0.982	0.054	0.795	-0.005	0.979	-0.435	0.026
Sodium (Na)	-0.301	0.136	0.220	0.281	0.075	0.717	-0.234	0.250
Specific Conductivity	0.135	0.512	0.469	0.016	0.238	0.241	-0.137	0.505
Strontium (Sr)	-0.139	0.497	0.400	0.043	0.176	0.389	-0.265	0.191
Sulfate (SO4)	0.090	0.610	0.051	0.856	-0.154	0.450	-0.017	0.997
Sulfur (S)	0.105	0.662	0.037	0.805	-0.155	0.454	-0.001	0.934
SWL	-0.184	0.369	0.121	0.556	-0.0002	0.999	0.078	0.704
Temperature	-0.012	0.952	0.177	0.386	0.268	0.185	0.020	0.922
Thallium (Tl)	-0.244	0.229	0.059	0.773	-0.133	0.517	-0.357	0.073
Tin (Sn)	-0.017	0.947	0.248	0.337	-0.077	0.769	-0.303	0.237
Titanium (Ti)	-0.087	0.673	0.002	0.991	0.293	0.147	0.023	0.910
Total dissolved solids	0.049	0.811	0.303	0.132	0.176	0.391	-0.215	0.293
Total organic carbon	-0.237	0.243	0.726	0.000	0.317	0.114	0.082	0.690
Total phosphate	-0.049	0.814	0.342	0.087	0.337	0.093	-0.155	0.450
Tritium	0.561	0.024	-0.058	0.830	-0.036	0.896	0.459	0.074
Total suspended solids	0.132	0.520	0.662	0.000	0.252	0.214	-0.223	0.273
Vanadium (V)	-0.073	0.722	0.158	0.441	0.333	0.097	0.121	0.556
Zinc (Zn)	-0.161	0.433	0.412	0.036	0.503	0.009	-0.100	0.626
Zirconium (Zr)	-0.012	0.963	0.430	0.085	0.359	0.157	0.114	0.663

[1] Insufficient sample size or no samples collected

Table D.109: Correlation coefficients between chemical parameters dissolved oxygen, iron, manganese, and oxidation-reduction potential, for the Upper Carbonate aquifer group.

Parameter	Dissolved Oxygen		Iron		Manganese		Redox potential	
	R^2	p	R^2	p	R^2	p	R^2	p
Alkalinity	-0.383	0.021	0.196	0.252	0.111	0.520	-0.350	0.037
Aluminum (Al)	-0.213	0.213	0.206	0.228	0.157	0.360	-0.311	0.065
Antimony (Sb)	0.097	0.575	-0.186	0.277	0.139	0.419	0.070	0.686
Arsenic (As)	-0.317	0.059	0.215	0.208	0.153	0.372	-0.492	0.002
Barium (Ba)	-0.193	0.261	0.404	0.015	-0.104	0.547	-0.237	0.164
Beryllium (Be)	-0.130	0.452	0.196	0.252	0.008	0.964	-0.106	0.540
Bismuth (Bi)	1.000	0.000	1.000	0.000	1.000	0.000	1.000	0.000
Boron (B)	-0.418	0.011	0.040	0.819	0.067	0.696	-0.357	0.033
Bromide (Br)	-[1]	-	-	-	-	-	-	-
Cadmium (Cd)	-0.148	0.388	0.396	0.017	0.188	0.273	-0.252	0.138
Calcium (Ca)	-0.069	0.687	0.168	0.328	0.019	0.912	0.205	0.229
Cesium (Cs)	1.000	0.000	1.000	0.000	1.000	0.000	1.000	0.000
Chloride (Cl)	0.295	0.086	-0.483	0.003	0.017	0.924	0.492	0.003
Chromium (Cr)	0.395	0.017	-0.330	0.049	-0.328	0.051	0.555	0.000
Cobalt (Co)	-0.175	0.308	-0.245	0.149	0.323	0.055	-0.019	0.915
Copper (Cu)	0.032	0.854	-0.115	0.503	-0.178	0.299	0.084	0.627
Day	-0.377	0.023	0.176	0.306	0.241	0.157	-0.488	0.003
Depth	-0.209	0.221	0.276	0.103	-0.172	0.316	-0.204	0.233
Diameter	0.045	0.796	0.017	0.920	-0.330	0.049	0.243	0.153
Dissolved Oxygen	-	-	-0.255	0.134	-0.259	0.127	0.377	0.024
Fluoride (F)	0.264	0.138	-0.225	0.208	-0.164	0.361	0.324	0.066
Iron (Fe)	-0.255	0.134	-	-	0.122	0.480	-0.527	0.001
Lead (Pb)	0.031	0.856	-0.022	0.899	-0.068	0.692	0.128	0.457
Lithium (Li)	-0.208	0.223	-0.012	0.944	0.037	0.831	-0.064	0.710
Magnesium (Mg)	-0.170	0.322	0.012	0.944	-0.062	0.718	-0.131	0.446
Manganese (Mn)	-0.259	0.127	0.122	0.480	-	-	-0.028	0.873
Mercury (Hg)	0.009	0.960	0.208	0.245	-0.034	0.851	-0.115	0.523
Molybdenum (Mo)	-0.213	0.212	-0.081	0.639	-0.025	0.884	-0.259	0.127
Nickel (Ni)	-0.075	0.662	-0.309	0.067	-0.327	0.051	0.114	0.508
Nitrate (NO3)	0.545	0.001	-0.511	0.001	-0.530	0.001	0.521	0.001
Ortho-phosphate	-0.263	0.161	0.412	0.024	-0.185	0.327	-0.485	0.007
pH	0.114	0.507	-0.005	0.979	-0.123	0.474	-0.350	0.036
Phosphorustotal	-0.342	0.041	0.645	0.000	0.129	0.454	-0.568	0.000
Potassium (K)	-0.283	0.094	-0.149	0.385	0.027	0.876	-0.156	0.364
Redox/Eh	0.377	0.024	-0.527	0.001	-0.028	0.873	-	-
Rubidium (Rb)	0.468	0.004	-0.420	0.011	-0.432	0.009	0.433	0.008
Selenium (Se)	-0.003	0.987	-0.010	0.959	-0.257	0.178	0.107	0.582
Silicate (Si)	-0.292	0.084	-0.119	0.488	0.278	0.101	-0.214	0.211
Silver (Ag)	0.106	0.537	-0.305	0.070	0.200	0.242	-0.050	0.774
Sodium (Na)	-0.277	0.102	0.079	0.647	0.028	0.870	-0.277	0.102
Specific Conductivity	-0.082	0.634	0.032	0.855	-0.018	0.918	-0.005	0.979
Strontium (Sr)	-0.447	0.006	0.083	0.632	0.074	0.667	-0.402	0.015
Sulfate (SO4)	0.158	0.363	-0.238	0.168	0.126	0.472	0.322	0.059
Sulfur (S)	0.128	0.459	-0.288	0.088	0.156	0.365	0.351	0.036
SWL	-0.216	0.207	-0.052	0.764	-0.065	0.708	-0.050	0.773
Temperature	-0.274	0.106	-0.038	0.826	0.016	0.925	-0.168	0.327
Thallium (Tl)	0.187	0.275	-0.268	0.114	0.149	0.387	0.048	0.780
Tin (Sn)	-1.000	0.000	-1.000	0.000	-1.000	0.000	-1.000	0.000
Titanium (Ti)	0.096	0.578	-0.504	0.002	-0.300	0.076	0.337	0.045
Total dissolved solids	-0.143	0.414	0.045	0.798	-0.011	0.948	-0.067	0.704
Total organic carbon	-0.255	0.134	0.471	0.004	0.130	0.449	-0.144	0.401
Total phosphate	-0.029	0.957	0.319	0.538	-0.145	0.784	-0.609	0.200
Tritium	0.238	0.456	-0.270	0.397	-0.189	0.556	0.144	0.656
Total suspended solids	-0.358	0.035	0.809	0.000	0.261	0.131	-0.456	0.006
Vanadium (V)	-0.023	0.895	-0.356	0.033	-0.347	0.038	0.204	0.233
Zinc (Zn)	-0.072	0.678	-0.048	0.780	-0.092	0.593	0.171	0.319
Zirconium (Zr)	-1.000	0.000	-1.000	0.000	-1.000	0.000	-1.000	0.000

[1] Insufficient sample size or no samples collected

Table D.110: Summary of the number and sign of significant correlations, by chemical parameter, for age-based aquifer groups, for dissolved oxygen, iron, manganese, and redox potential. The average score is equal to (iron + manganese - dissolved oxygen - redox)/n.

Parameter	Dissolved Oxygen	Iron	Manganese	Redox potential	Average score
Alkalinity	-2	2	4	-3	2.75
Aluminum (Al)	-1	0	0	0	0.25
Antimony (Sb)	-1	-2	0	3	-1.00
Arsenic (As)	-5	4	4	-4	4.25
Barium (Ba)	-4	4	4	-4	4.00
Beryllium (Be)	-4	4	0	-1	2.25
Bismuth (Bi)	0	0	0	0	0.00
Boron (B)	-4	2	3	-5	3.50
Bromide (Br)	-1	1	-1	0	0.25
Cadmium (Cd)	-1	0	0	1	0.00
Calcium (Ca)	1	2	5	0	1.50
Cesium (Cs)	0	4	1	-1	1.50
Chloride (Cl)	3	-2	-2	2	-2.25
Chromium (Cr)	4	0	-2	1	-1.75
Cobalt (Co)	-1	3	6	0	2.50
Copper (Cu)	0	0	0	1	-0.25
Diameter	1	0	1	1	-0.25
Dissolved Oxygen	-	-4	-4	5	-4.33
Fluoride (F)	0	0	-2	-2	0.00
Iron (Fe)	-4	-	6	-5	5.00
Lead (Pb)	4	1	-2	3	-2.00
Lithium (Li)	-1	2	4	-1	2.00
Magnesium (Mg)	0	2	4	0	1.50
Manganese (Mn)	-4	6	-	-3	4.33
Mercury (Hg)	2	0	0	0	-0.50
Molybdenum (Mo)	0	0	1	-1	0.50
Nickel (Ni)	-1	1	1	1	0.50
Nitrate (NO3)	6	-6	-6	6	-6.00
Ortho-phosphate	1	-3	-2	-1	-1.25
pH	-2	-4	-4	-3	-0.75
Phosphorustotal	-4	6	5	-5	5.00
Potassium (K)	-2	4	4	-2	3.00
Redox/Eh	5	-6	-3	-	-4.67
Rubidium (Rb)	0	-1	1	1	-0.25
Selenium (Se)	1	1	-1	0	-0.25
Silicate (Si)	-1	2	5	-3	2.75
Silver (Ag)	-2	-1	0	0	0.25
Sodium (Na)	-3	2	2	-4	2.75
Specific Conductivity	1	2	4	-2	1.75
Strontium (Sr)	-3	3	6	-3	3.75
Sulfate (SO4)	3	-1	2	3	-1.25
Sulfur (S)	1	-1	2	3	-0.75
SWL	1	0	0	1	-0.50
Temperature	-1	0	4	0	1.25
Thallium (Tl)	2	-3	1	1	-1.25
Tin (Sn)	1	1	0	0	0.00
Titanium (Ti)	1	-1	1	0	-0.25
Total dissolved solids	-1	1	4	0	1.50
Total organic carbon	-1	5	3	-1	2.50
Total phosphate	-1	6	3	-4	3.50
Tritium	2	-1	-1	0	-1.00
Total suspended solids	-4	4	6	-5	4.75
Vanadium (V)	-1	2	2	0	1.25
Zinc (Zn)	0	2	2	2	0.50
Zirconium (Zr)	0	3	2	-2	1.75

Table D.111: Summary of water quality criteria, basis of criteria, and endpoints, by chemical parameter.

Parameter	Criteria	Basis of criteria	Endpoint
Alkalinity	-	-	-
Aluminum (Al)	50	MCL	-
Antimony (Sb)	6	HRL	-
Arsenic (As)	50	MCL	Cancer
Barium (Ba)	2000	HRL	Cardiovascular/blood
Beryllium (Be)	0.08	HRL	Cancer
Bismuth (Bi)	-	-	-
Boron (B)	600	HRL	Reproductive
Bromide (Br)	-	-	-
Cadmium (Cd)	4	HRL	Kidney
Calcium (Ca)	-	-	-
Cesium (Cs)	-	-	-
Chloride (Cl)	250000	SMCL	-
Chromium (Cr)	20000[1]	HRL	-
Cobalt (Co)	30	HBV	-
Copper (Cu)	1000	HBV	-
Dissolved Oxygen	-	-	-
Fluoride (F)	4000	MCL	-
Iron (Fe)	300	SMCL	-
Lead (Pb)	15	Action level at tap	-
Lithium (Li)	-	-	-
Magnesium (Mg)	-	-	-
Manganese (Mn)	100 (1000)[2]	HRL	Central nervous system
Mercury (Hg)	2	MCL	-
Molybdenum (Mo)	30	HBV	Kidney
Nickel (Ni)	100	HRL	-
Nitrate (NO3)	10000	HRL	Cardiovascular/blood
Ortho-phosphate	-	-	-
pH	-	-	-
$Phosphorus_{total}$	-	-	-
Potassium (K)	-	-	-
Redox/Eh	-	-	-
Rubidium (Rb)	-	-	-
Selenium (Se)	30	HRL	-
Silicate (Si)	-	-	-
Silver (Ag)	30	HRL	-
Sodium (Na)	250000	SMCL	-
Specific Conductivity	-	-	-
Strontium (Sr)	4000	HRL	Bone
Sulfate (SO4)	500000	MCL	-
Sulfur (S)	-	-	-
Temperature	-	-	-
Thallium (Tl)	0.6	HRL	Gastrointestinal/liver
Tin (Sn)	4000	HRL	Kidney; Gastrointestinal/liver
Titanium (Ti)	-	-	-
Total dissolved solids	-	-	-
Total organic carbon	-	-	-
Total phosphate	-	-	-
Total suspended solids	-	-	-
Vanadium (V)	50	HRL	-
Zinc (Zn)	2000	HRL	-
Zirconium (Zr)	-	-	-

Table D.111 continued

Parameter	Criteria	Basis of criteria	Endpoint
1,1,1-trichloroethane	600	HRL	gi/liv
1,1-dichloroethane	70	HRL	kid
1,1-dichloroethene	6	HRL	gi/liv
1,2-dichloroethane	4	HRL	cancer
1,2-dichloropropane	5	HRL	cancer
acetone	700	HRL	cv/bld; liv
benzene	10	HRL	cancer
bromodichloromethane	6	HRL	cancer
chlorodibromomethane	-	-	-
chloroform	60	HRL	cancer
dichlorodifluoromethane	1000	HRL	body weight
dichlorofluoromethane	-	-	-
ethyl ether	1000	HRL	body weight
isopropylbenzene	-	-	-
xylene	10000	HRL	cns/pns
methyl ethyl ketone	4000	HRL	repro
methylene chloride	50	HRL	cancer
naphthalene	300	HRL	cv/bld
tetrachloroethene	7	HRL	cancer
tetrahydrofuran	100	HRL	gi/liv
toluene	1000	HRL	kid; gi/liv
trichloroethene	30	HRL	cancer
1,2,4-trimethylbenzene	-	-	-
1,3,5-trimethylbenzene	-	-	-
cis-1,2 dichloroethene	70	HRL	cv/bld
ethyl benzene	700	HRL	kid; gi/liv
n-butylbenzene	-	-	-
n-propyl benzene	-	-	-
p-isopropyltoluene	-	-	-
styrene	-	-	-
trichlorofluoromethane	-	-	-

[1] Trivalent chromium

[2] The current HRL for manganese is 100, but calculations were made using a value of 1000 ug/L (MDH, 1997)

Table D.112: Summary of water quality exceedances for each chemical parameter, by aquifer and aquifer group.

Parameter	No. exceedances of criteria: Cambrian	Ordovician	Precambrian	buried Quaternary	surficial Quaternary	% of samples exceeding criteria: Cambrian	Ordovician	Precambrian	buried Quaternary	surficial Quaternary
Alkalinity	-[1]	-	-	-	-	-	-	-	-	-
Aluminum (Al)	1	0	19	30	7	1.0	0.0	23.8	5.8	5.7
Antimony (Sb)	0	0	0	1	0	0.0	0.0	0.0	0.2	0.0
Arsenic (As)	0	0	0	7	1	0.0	0.0	0.0	1.4	0.8
Barium (Ba)	0	0	0	0	1	0.0	0.0	0.0	0.0	0.8
Beryllium (Be)	0	3	4	13	1	0.0	3.4	5.0	2.5	0.8
Bismuth (Bi)	-	-	-	-	-	-	-	-	-	-
Boron (B)	0	0	10	40	20	0.0	0.0	12.5	7.8	16.3
Bromide (Br)	-	-	-	-	-	-	-	-	-	-
Cadmium (Cd)	1	3	0	0	0	1.0	3.4	0.0	0.0	0.0
Calcium (Ca)	-	-	-	-	-	-	-	-	-	-
Cesium (Cs)	-	-	-	-	-	-	-	-	-	-
Chloride (Cl)	0	0	1	4	2	0.0	0.0	1.3	0.8	1.6
Chromium (Cr)	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
Cobalt (Co)	0	0	1	0	0	0.0	0.0	1.3	0.0	0.0
Copper (Cu)	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
Dissolved Oxygen	-	-	-	-	-	-	-	-	-	-
Fluoride (F)	1	0	2	2	1	1.0	0.0	2.5	0.4	0.8
Iron (Fe)	67	58	37	367	80	65.7	66.7	46.3	71.5	65.0
Lead (Pb)	2	0	3	3	1	2.0	0.0	3.8	0.6	0.8
Lithium (Li)	-	-	-	-	-	-	-	-	-	-
Magnesium (Mg)	-	-	-	-	-	-	-	-	-	-
Manganese (Mn)	2	1	5	22	7	2.0	1.1	6.3	4.3	5.7
Mercury (Hg)	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
Molybdenum (Mo)	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
Nickel (Ni)	0	0	1	0	0	0.0	0.0	1.3	0.0	0.0
Nitrate (NO3)	0	3	2	16	7	0.0	3.4	2.5	3.1	5.7
Ortho-phosphate	-	-	-	-	-	-	-	-	-	-
pH	-	-	-	-	-	-	-	-	-	-
$Phosphorus_{total}$	-	-	-	-	-	-	-	-	-	-
Potassium (K)	-	-	-	-	-	-	-	-	-	-
Redox/Eh	-	-	-	-	-	-	-	-	-	-
Rubidium (Rb)	-	-	-	-	-	-	-	-	-	-
Selenium (Se)	0	0	2	3	2	0.0	0.0	2.5	0.6	1.6
Silicate (Si)	-	-	-	-	-	-	-	-	-	-
Silver (Ag)	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
Sodium (Na)	-	-	-	-	-	-	-	-	-	-
Specific Conductivity	-	-	-	-	-	-	-	-	-	-
Strontium (Sr)						0.0	0.0	0.0	0.0	0.0
Sulfate (SO4)	0	0	3	23	3	0.0	0.0	3.8	4.5	2.4
Sulfur (S)	-	-	-	-	-	-	-	-	-	-
Temperature	-	-	-	-	-	-	-	-	-	-
Thallium (Tl)	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
Tin (Sn)	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
Titanium (Ti)	-	-	-	-	-	-	-	-	-	-
Total dissolved solids	-	-	-	-	-	-	-	-	-	-
Total organic carbon	-	-	-	-	-	-	-	-	-	-
Total phosphate	-	-	-	-	-	-	-	-	-	-
Total suspended solids	-	-	-	-	-	-	-	-	-	-
Vanadium (V)	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
Zinc (Zn)	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
Zirconium (Zr)	-	-	-	-	-	-	-	-	-	-

Table D.112 continued

Parameter	No. exceedances of criteria								% of samples exceeding criteria							
	CFIG	CIGL	CFRN	CJDN	CMSH	CMTS	CSLF	CSTL	CFIG	CIGL	CFRN	CJDN	CMSH	CMTS	CSLF	CSTL
Alkalinity	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aluminum (Al)	1	0	0	0	0	0	0	0	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Antimony (Sb)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arsenic (As)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Barium (Ba)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Beryllium (Be)	0	1	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bismuth (Bi)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Boron (B)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bromide (Br)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cadmium (Cd)	0	0	0	1	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calcium (Ca)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cesium (Cs)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chloride (Cl)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chromium (Cr)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cobalt (Co)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Copper (Cu)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dissolved Oxygen	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride (F)	0	0	0	1	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Iron (Fe)	4	19	6	14	6	10	4	3	80.0	76.9	75.0	45.2	60.0	70.4	100	75.0
Lead (Pb)	0	1	0	0	0	0	0	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0
Lithium (Li)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Magnesium (Mg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Manganese (Mn)	1	0	0	0	1	0	0	0	20.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0
Mercury (Hg)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Molybdenum (Mo)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nickel (Ni)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitrate (NO3)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ortho-phosphate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
$Phosphorus_{total}$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potassium (K)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Redox/Eh	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rubidium (Rb)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Selenium (Se)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Silicate (Si)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silver (Ag)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sodium (Na)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Specific Conductivity	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Strontium (Sr)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sulfate (SO4)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sulfur (S)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thallium (Tl)	0	1	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tin (Sn)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Titanium (Ti)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total dissolved solids	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total organic carbon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total phosphate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total suspended solids	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vanadium (V)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zinc (Zn)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zirconium (Zr)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table D.112 continued

Parameter	No. exceedances of criteria								% of samples exceeding criteria							
	DCVA	KRET	OGAL	OMAQ	OPDC	OPVL	OSPC	OSTP	DCVA	KRET	OGAL	OMAQ	OPDC	OPVL	OSPC	OSTP
Alkalinity	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aluminum (Al)	0	4	0	0	0	0	-	0	0.0	10.3	0.0	0.0	0.0	0.0	-	0.0
Antimony (Sb)	0	0	0	0	0	0	-	0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0
Arsenic (As)	0	0	0	0	0	0	-	0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0
Barium (Ba)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Beryllium (Be)	0	1	0	0	0	0	-	0	0.0	2.6	0.0	0.0	0.0	0.0	-	0.0
Bismuth (Bi)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Boron (B)	0	13	0	0	0	0	0	0	0.0	33.3	0.0	0.0	0.0	0.0	0.0	0.0
Bromide (Br)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cadmium (Cd)	1	0	0	0	1	0	-	2	10.0	0.0	0.0	0.0	2.9	0.0	-	8.7
Calcium (Ca)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cesium (Cs)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chloride (Cl)	0	1	0	0	0	0	0	0	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0
Chromium (Cr)	0	0	0	0	0	0	-	0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0
Cobalt (Co)	0	0	0	0	0	0	-	0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0
Copper (Cu)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dissolved Oxygen	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride (F)	0	3	0	-	0	0	0	0	0.0	7.7	0.0	-	0.0	0.0	0.0	0.0
Iron (Fe)	9	30	19	0	20	3	1	15	90.0	76.9	86.4	0.0	55.6	100	50.0	65.2
Lead (Pb)	0	0	0	0	0	0	-	0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0
Lithium (Li)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Magnesium (Mg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Manganese (Mn)	0	1	0	0	0	0	0	1	0.0	2.6	0.0	0.0	0.0	0.0	0.0	4.3
Mercury (Hg)	0	0	0	0	0	0	-	0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0
Molybdenum (Mo)	0	1	0	0	0	0	0	0	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0
Nickel (Ni)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitrate (NO3)	0	3	1	0	2	0	0	0	0.0	7.7	4.5	0.0	5.6	0.0	0.0	0.0
Ortho-phosphate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phosphorus$_{total}$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potassium (K)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Redox/Eh	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rubidium (Rb)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Selenium (Se)	0	0	0	0	0	0	-	0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0
Silicate (Si)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silver (Ag)	0	0	0	0	0	0	-	0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0
Sodium (Na)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Specific Conductivity	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Strontium (Sr)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sulfate (SO4)	0	6	0	0	0	0	0	0	0.0	15.4	0.0	0.0	0.0	0.0	0.0	0.0
Sulfur (S)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thallium (Tl)	0	1	0	0	0	0	-	0	0.0	2.6	0.0	0.0	0.0	0.0	-	0.0
Tin (Sn)	0	0	0	0	0	0	0	0	-	-	-	-	-	-	-	-
Titanium (Ti)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total dissolved solids	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total organic carbon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total phosphate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total suspended solids	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vanadium (V)	0	1	0	0	0	0	0	0	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0
Zinc (Zn)	0	1	0	0	0	0	0	0	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0
Zirconium (Zr)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table D.112 continued

Parameter	No. exceedances of criteria								% of samples exceeding criteria							
	PCCR	PCCU	PEBI	PMDC	PMFL	PMHN	PMNS	PMSX	PCCR	PCCU	PEBI	PMDC	PMFL	PMHN	PMNS	PMSX
Alkalinity	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aluminum (Al)	7	0	0	1	1	0	8	0	26.9	0.0	0.0	100	50.0	0.0	47.1	0.0
Antimony (Sb)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arsenic (As)	1	0	0	0	0	0	0	0	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Barium (Ba)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Beryllium (Be)	3	1	0	1	0	0	5	1	3.8	33.3	0.0	100	0.0	0.0	29.4	25.0
Bismuth (Bi)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Boron (B)	2	1	0	1	0	0	4	1	11.5	33.3	0.0		0.0	0.0	23.5	25.0
Bromide (Br)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cadmium (Cd)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calcium (Ca)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cesium (Cs)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chloride (Cl)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chromium (Cr)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cobalt (Co)	0	0	0	0	0	0	1	0	0.0	0.0	0.0	0.0	0.0	0.0	5.9	0.0
Copper (Cu)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dissolved Oxygen	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride (F)	2	0	0	0	0	0	0	0	7.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Iron (Fe)	12	2	0	1	1	2	7	1	46.2	66.7	0.0	100	50.0	66.7	41.2	25.0
Lead (Pb)	0	0	0	1	1	0	1	0	0.0	0.0	0.0	100	50.0	0.0	5.9	0.0
Lithium (Li)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Magnesium (Mg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Manganese (Mn)	1	0	0	0	0	0	1	2	3.8	0.0	0.0	0.0	0.0	0.0	5.9	50.0
Mercury (Hg)	0	0	-	-	-	-	-	0	0.0	0.0	-	-	-	-	-	0.0
Molybdenum (Mo)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nickel (Ni)	0	0	0	0	0	0	1	0	0.0	0.0	0.0	0.0	0.0	0.0	5.9	0.0
Nitrate (NO3)	1	0	0	0	0	0	0	1	3.8	0.0	0.0	0.0	0.0	0.0	0.0	25.0
Ortho-phosphate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
$Phosphorus_{total}$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potassium (K)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Redox/Eh	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rubidium (Rb)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Selenium (Se)	1	0	0	0	0	0	0	0	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Silicate (Si)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silver (Ag)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sodium (Na)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Specific Conductivity	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Strontium (Sr)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sulfate (SO4)	1	0	0	0	0	0	0	2	3.8	0.0	0.0	0.0	0.0	0.0	0.0	50.0
Sulfur (S)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thallium (Tl)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tin (Sn)	0	0	0	0	0	0	0	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Titanium (Ti)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total dissolved solids	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total organic carbon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total phosphate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total suspended solids	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vanadium (V)	0	0	0	0	0	0	1	0	0.0	0.0	0.0	0.0	0.0	0.0	5.9	0.0
Zinc (Zn)	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zirconium (Zr)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table D.112 continued

Parameter	No. exceedances of criteria						% of samples exceeding criteria					
	PMUD	QBAA	QBUA	QBUU	QUUU	QWTA	PMUD	QBAA	QBUA	QBUU	QUUU	QWTA
Alkalinity	-	-	-	-	-	-	-	-	-	-	-	-
Aluminum (Al)	2	18	1	1	0	7	8.6	4.7	1.0	4.5	0.0	5.9
Antimony (Sb)	0	1	0	0	0	0	0.0	0.3	0.0	0.0	0.0	0.0
Arsenic (As)	0	7	0	0	0	0	0.0	1.8	0.0	0.0	0.0	0.0
Barium (Ba)	0	0	0	0	0	1	0.0	0.0	0.0	0.0	0.0	0.8
Beryllium (Be)	1	2	2	1	0	4	4.3	0.5	1.9	9.1	0.0	3.4
Bismuth (Bi)	-	-	-	-	-	-	-	-	-	-	-	-
Boron (B)	1	37	1	2	1	1	4.3	9.6	1.0	4.5	25.0	0.8
Bromide (Br)	-	-	-	-	-	-	-	-	-	-	-	-
Cadmium (Cd)	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Calcium (Ca)	-	-	-	-	-	-	-	-	-	-	-	-
Cesium (Cs)	-	-	-	-	-	-	-	-	-	-	-	-
Chloride (Cl)	1	3	1	0	0	2	4.3	0.8	1.0	0.0	0.0	1.7
Chromium (Cr)	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Cobalt (Co)	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Copper (Cu)	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Dissolved Oxygen	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride (F)	0	2	0	0	1	0	0.0	0.5	0.0	0.0	25.0	0.0
Iron (Fe)	11	293	54	19	1	79	47.8	76.1	51.9	86.3	25.0	66.4
Lead (Pb)	0	2	1	0	0	1	0.0	0.5	1.0	0.0	0.0	0.9
Lithium (Li)	-	-	-	-	-	-	-	-	-	-	-	-
Magnesium (Mg)	-	-	-	-	-	-	-	-	-	-	-	-
Manganese (Mn)	1	18	2	2	1	6	4.3	4.7	1.9	9.1	25.0	5.0
Mercury (Hg)	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Molybdenum (Mo)	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Nickel (Ni)	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Nitrate (NO3)	0	7	8	1	1	6	0.0	1.8	7.7	4.5	25.0	5.0
Ortho-phosphate	-	-	-	-	-	-	-	-	-	-	-	-
pH	-	-	-	-	-	-	-	-	-	-	-	-
$Phosphorus_{total}$	-	-	-	-	-	-	-	-	-	-	-	-
Potassium (K)	-	-	-	-	-	-	-	-	-	-	-	-
Redox/Eh	-	-	-	-	-	-	-	-	-	-	-	-
Rubidium (Rb)	-	-	-	-	-	-	-	-	-	-	-	-
Selenium (Se)	1	1	2	0	0	2	4.3	0.3	2.0	0.0	0.0	1.7
Silicate (Si)	-	-	-	-	-	-	-	-	-	-	-	-
Silver (Ag)	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Sodium (Na)	-	-	-	-	-	-	-	-	-	-	-	-
Specific Conductivity	-	-	-	-	-	-	-	-	-	-	-	-
Strontium (Sr)	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Sulfate (SO4)	0	24	2	1	2	1	0.0	6.2	2.0	4.5	50.0	0.8
Sulfur (S)	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	-	-	-	-	-	-	-	-	-	-	-	-
Thallium (Tl)	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Tin (Sn)	0	0	0	-	-	0	0.0	0.0	0.0	-	-	0.0
Titanium (Ti)	-	-	-	-	-	-	-	-	-	-	-	-
Total dissolved solids	-	-	-	-	-	-	-	-	-	-	-	-
Total organic carbon	-	-	-	-	-	-	-	-	-	-	-	-
Total phosphate	-	-	-	-	-	-	-	-	-	-	-	-
Total suspended solids	-	-	-	-	-	-	-	-	-	-	-	-
Vanadium (V)	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Zinc (Zn)	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Zirconium (Zr)	-	-	-	-	-	-	-	-	-	-	-	-

Table D.112 continued

Parameter	No. exceedances of criteria: CFIG-CFRN-CIGL	OSTP-OPDC-CJDN	CMSH-CMTS-PMHN	Upper Carbonate	% of samples exceeding criteria: CFIG-CFRN-CIGL	OSTP-OPDC-CJDN	CMSH-CMTS-PMHN	Upper Carbonate
Alkalinity	-	-	-	-	-	-	-	-
Aluminum (Al)	1	0	0	0	2.6	0.0	0.0	0.0
Antimony (Sb)	0	0	0	0	0.0	0.0	0.0	0.0
Arsenic (As)	0	0	0	0	0.0	0.0	0.0	0.0
Barium (Ba)	0	0	0	0	0.0	0.0	0.0	0.0
Beryllium (Be)	1	0	0	0	2.6	0.0	0.0	0.0
Bismuth (Bi)	-	-	-	-	-	-	-	-
Boron (B)	0	0	0	0	0.0	0.0	0.0	0.0
Bromide (Br)	-	-	-	-	-	-	-	-
Cadmium (Cd)	0	4	0	2	0.0	4.6	0.0	2.8
Calcium (Ca)	-	-	-	-	-	-	-	-
Cesium (Cs)	-	-	-	-	-	-	-	-
Chloride (Cl)	0	0	0	0	0.0	0.0	0.0	0.0
Chromium (Cr)	0	0	0	0	0.0	0.0	0.0	0.0
Cobalt (Co)	0	0	0	0	0.0	0.0	0.0	0.0
Copper (Cu)	0	0	0	0	0.0	0.0	0.0	0.0
Dissolved Oxygen	-	-	-	-	-	-	-	-
Fluoride (F)	0	1	0	0	0.0	1.4	0.0	0.0
Iron (Fe)	29	49	18	62	72.5	54.4	69.2	86.1
Lead (Pb)	1	0	0	0	2.6	0.0	0.0	0.0
Lithium (Li)	-	-	-	-	-	-	-	-
Magnesium(Mg)	-	-	-	-	-	-	-	-
Manganese (Mn)	1	1	1	0	1.1	2.5	3.8	0.0
Mercury (Hg)	0	0	0	0	0.0	0.0	0.0	0.0
Molybdenum (Mo)	0	0	0	0	0.0	0.0	0.0	0.0
Nickel (Ni)	0	0	0	0	0.0	0.0	0.0	0.0
Nitrate (NO3)	0	2	0	2	0.0	2.2	0.0	2.8
Ortho-phosphate	-	-	-	-	-	-	-	-
pH	-	-	-	-	-	-	-	-
$Phosphorus_{total}$	-	-	-	-	-	-	-	-
Potassium (K)	-	-	-	-	-	-	-	-
Redox/Eh	-	-	-	-	-	-	-	-
Rubidium (Rb)	-	-	-	-	-	-	-	-
Selenium (Se)	0	0	0	0	0.0	0.0	0.0	0.0
Silicate (Si)	-	-	-	-	-	-	-	-
Silver (Ag)	0	0	0	0	0.0	0.0	0.0	0.0
Sodium (Na)	-	-	-	-	-	-	-	-
Specific Conductivity	-	-	-	-	-	-	-	-
Strontium (Sr)	0	0	0	0	0.0	0.0	0.0	0.0
Sulfate (SO4)	0	0	0	0	0.0	0.0	0.0	0.0
Sulfur (S)	-	-	-	-	-	-	-	-
Temperature	-	-	-	-	-	-	-	-
Thallium (Tl)	1	0	0	0	2.6	0.0	0.0	0.0
Tin (Sn)	0	0	0	0	0.0	0.0	0.0	0.0
Titanium (Ti)	-	-	-	-	-	-	-	-
Total dissolved solids	-	-	-	-	-	-	-	-
Total organic carbon	-	-	-	-	-	-	-	-
Total phosphate	-	-	-	-	-	-	-	-
Total suspended solids	-	-	-	-	-	-	-	-
Vanadium (V)	0	0	0	0	0.0	0.0	0.0	0.0
Zinc (Zn)	0	0	0	0	0.0	0.0	0.0	0.0
Zirconium (Zr)	-	-	-	-	-	-	-	-

[1] Not sampled or no water quality criteria

Table D.113: Median background hazard indices for target endpoints, by aquifer group.

Aquifer	cv/bld	cancer	repro	kidn	gi/liv	cns/pns	body	skin	bone
Cambrian	0.142	0.085	0.043	0.150	0.110	0.058	0.059	0.0003	0.026
Ordovician	0.165	0.086	0.061	0.167	0.066	0.057	0.059	0.0003	0.041
Precambrian	0.083	0.183	0.096	0.152	0.080	0.073	0.059	0.0003	0.040
buried Quaternary	0.106	0.155	0.116	0.152	0.119	0.147	0.059	0.0003	0.064
surficial Quaternary	0.136	0.126	0.041	0.144	0.108	0.184	0.059	0.0003	0.027
CFIG	0.083	0.0820	0.1880	0.147	0.159	0.058	0.000	0.0003	0.091
CFRN	0.182	0.0890	0.0470	0.157	0.072	0.052	0.059	0.0003	0.028
CIGL	0.110	0.1390	0.0980	0.159	0.105	0.160	0.059	0.0003	0.056
CJDN	0.159	0.0760	0.0320	0.152	0.081	0.035	0.059	0.0003	0.017
CMSH	0.104	0.0800	0.0380	0.150	0.075	0.054	0.059	0.0003	0.027
CMTS	0.119	0.1450	0.0550	0.139	0.135	0.105	ins[1]	0.0003	0.040
CSLF	0.114	0.141	0.042	0.148	0.079	0.292	ins	0.0003	0.041
CSTL	0.283	0.249	0.236	0.186	0.091	0.099	0.060	0.0003	0.095
DCVA	0.148	0.187	0.073	0.501	0.077	0.101	0.059	0.0003	0.038
KRET	0.097	0.110	0.684	0.172	0.125	0.118	0.059	0.0003	0.188
OGAL	0.168	0.139	0.071	0.302	0.063	0.058	0.063	0.0003	0.058
OMAQ	ins	ins	ins	ins	ins	ins	ins	ins	ins
OPDC	0.184	0.072	0.050	0.158	0.072	0.041	0.059	0.0003	0.033
OPVL	0.165	0.146	0.051	0.169	0.169	0.192	0.059	0.0020	0.060
OSPC	0.106	ins	0.043	ins	ins	0.388	ins	ins	0.041
OSTP	0.129	0.082	0.070	0.164	0.066	0.057	0.059	0.0003	0.036
PCCR	0.083	0.281	0.091	0.149	0.086	0.114	0.059	0.0003	0.049
PCUU	0.062	0.118	0.451	0.139	0.078	0.292	0.059	0.0003	0.186
PEBI	ins	ins	ins	ins	ins	ins	ins	ins	ins
PMDC	ins	ins	ins	ins	ins	ins	ins	ins	ins
PMFN	0.138	0.171	0.036	0.189	0.144	0.150	ins	0.0020	0.013
PMHN	0.095	0.116	0.022	0.139	0.110	0.145	0.059	0.0003	0.011
PMNS	0.066	0.406	0.216	0.169	0.073	0.033	0.060	0.0003	0.030
PMSX	0.150	0.145	0.525	0.213	0.252	1.094	0.156	ins	0.185
PMUD	0.090	0.133	0.061	0.152	0.104	0.082	0.059	0.0040	0.031
QBAA	0.103	0.169	0.163	0.154	0.115	0.140	0.059	0.0003	0.076
QBUA	0.130	0.113	0.039	0.139	0.133	0.165	0.059	0.0003	0.028
QBUU	0.115	0.307	0.465	0.199	0.132	0.227	0.059	0.0003	0.140
QUUU	0.607	0.086	0.276	0.294	0.117	0.170	0.185	ins	0.251
QWTA	0.133	0.126	0.041	0.144	0.108	0.184	0.059	0.0003	0.026
CFIG-CFRN-CIGL	0.157	0.105	0.059	0.155	0.084	0.059	0.059	0.0003	0.032
CJDN-OPDC-OSTP	0.160	0.076	0.044	0.157	0.041	0.041	0.059	0.0003	0.029
CMSH-CMTS-PMHN	0.104	0.096	0.044	0.139	0.109	0.100	0.059	0.0003	0.030
Upper Carbonate	0.159	0.151	0.068	0.302	0.067	0.066	0.059	0.0003	0.055

Table D.114: Estimate of percent of samples exceeding a hazard index of 1.0.

Aquifer	cv/bld	cancer	repro	kidn	gi/liv	cns/pns	body	skin	bone
Cambrian	1 to 2	1 to 2	< 1	1 to 2	1 to 2	2	< 1	< 1	< 1
Ordovician	2 to 3	< 1	< 1	2 to 3	< 1	1 to 2	< 1	< 1	< 1
Precambrian	1 to 2	15	12	< 1	2 to 3	7	< 1	< 1	< 1
buried Quaternary	3 to 4	3 to 4	7	< 1	< 1	4	< 1	< 1	< 1
surficial Quaternary	7	4 to 5	1 to 2	< 1	2 to 3	5	< 1	< 1	< 1
CFIG	ins[1]	ins	ins	ins	ins	ins	ins	ins	ins
CFRN	1 to 4	1 to 4	< 4	< 4	5 to 6	< 1	< 1	< 1	< 1
CIGL	ins	ins	ins	ins	ins	ins	ins	ins	ins
CJDN	1 to 4	< 4	< 4	4 to 5	5 to 6	< 1	< 1	< 1	< 1
CMSH	ins	ins	ins	ins	ins	ins	ins	ins	ins
CMTS	ins	ins	ins	ins	ins	ins	ins	ins	ins
CSLF	ins	ins	ins	ins	ins	ins	ins	ins	ins
CSTL	ins	ins	ins	ins	ins	ins	ins	ins	ins
DCVA	< 1	< 1	< 1	11	1 to 2	< 1	< 1	< 1	< 1
KRET	12	4 to 5	35	3 to 4	4 to 5	7	< 1	< 1	< 1
OGAL	6 to 7	< 3	< 3	< 3	< 3	< 1	< 1	< 1	< 1
OMAQ	ins	ins	ins	ins	ins	ins	ins	ins	ins
OPDC	5 to 6	< 3	< 3	4 to 5	< 3	< 1	< 1	< 1	< 1
OPVL	ins	ins	ins	ins	ins	ins	ins	ins	ins
OSPC	ins	ins	ins	ins	ins	ins	ins	ins	ins
OSTP	< 5	< 5	< 5	11	< 5	6	< 1	< 1	< 1
PCCR	5 to 6	16	10	< 4	7 to 8	7	< 1	< 1	< 1
PCUU	ins	ins	ins	ins	ins	ins	ins	ins	ins
PEBI	ins	ins	ins	ins	ins	ins	ins	ins	ins
PMDC	ins	ins	ins	ins	ins	ins	ins	ins	ins
PMFN	ins	ins	ins	ins	ins	ins	ins	ins	ins
PMHN	ins	ins	ins	ins	ins	ins	ins	ins	ins
PMNS	ins	ins	ins	ins	ins	8	ins	ins	ins
PMSX	ins	ins	ins	ins	ins	ins	ins	ins	ins
PMUD	< 1	6 to 7	1 to 2	< 1	6 to 7	7	< 1	< 1	< 1
QBAA	2 to 3	2 to 3	9 to 10	< 1	< 1	5	< 1	< 1	< 1
QBUA	8 to 9	2 to 3	< 1	3 to 4	< 1	3	< 1	< 1	< 1
QBUU	< 6	16	10	< 6	< 6	13	< 1	< 1	< 1
QUUU	ins	ins	ins	ins	ins	ins	ins	ins	ins
QWTA	8 to 9	4 to 5	< 1	< 1	3 to 4	5	< 1	< 1	< 1
CFIG-CFRN-CIGL	< 4	< 4	< 4	< 4	4 to 5	3	< 1	< 1	< 1
CJDN-OPDC-OSTP	2 to 3	< 2	< 2	5 to 6	< 2	1	< 1	< 1	< 1
CMSH-CMTS-PMHN	< 4	< 4	< 4	< 4	< 4	6	< 1	< 1	< 1
Upper Carbonate	4 to 5	< 2	< 2	5 to 6	2 to 3	< 1	< 1	< 1	< 1

[1] ins = insufficient sample size

Table D.115: Assumed concentrations for solubility calculations. Concentrations represent the median concentration for all data. Standard deviations are for the entire data set.

Chemical	Concentration (ug/L)	Standard deviation	Molar concentration
Hydrogen	0.0575	0.198	$10^{-7.24}$
Bicarbonate	289949	106236	$10^{-2.32}$
Carbonate	-	-	$10^{-5.34}$
Sulfate	38835	81912	10^{-4}
Sulfide	-	-	10^{-4}
Silica	10766	3396	$10^{-3.92}$
Chloride	18892	167083	$10^{-3.27}$
Calcium	76176	66448	$10^{-2.72}$
Iron	947	5244	$10^{-4.77}$

Table D.116: Concentrations of chemicals in igneous rocks, various sedimentary rocks, soil, and air. Concentrations are in mg/kg (ppm) except for air.

Chemical	Igneous	Sandstones	Shale	Carbonates	Soil	Air (ng/m^3)
Aluminum	79500	32100	80100	8970	70000	-
Antimony	0.50	0.014	0.81	0.20	5	12
Arsenic	1.8	1.0	9.0	1.8	10	15
Barium	595	193	250	30	121	-
Beryllium	3.6	0.26	2.1	0.18	0.5-10	-
Bismuth	-	-	-	-	-	-
Boron	7.5	90	194	16	10	-
Bromide	2.4	1.0	4.3	6.6	1.0-10	-
Cadmium	0.19	0.020	0.18	0.048	0.20	1-41
Calcium	36200	22400	22500	272000	10000	-
Cesium	4.3	2.2	6.2	0.77	0.3-25	-
Chloride	305	15	170	305	100	-
Chromium	198	120	423	7.1	39	60
Cobalt	23	0.33	8.1	0.12	3	3
Copper	97	15	45	4.4	20	280
Fluoride	715	220	560	112	200	-
Iron	42200	18600	38800	8190	40000	-
Lead	16	14	80	16	11	2700
Lithium	32	15	46	5.2	10-300	-
Magnesium	17600	8100	16400	45300	6000	-
Manganese	937	392	575	842	800	150
Mercury	0.33	0.057	0.27	0.046	0.050	0.007-38
Molybdenum	1.2	0.50	4.2	0.75	8	1-10
Nickel	94	2.6	29	13	18	90
Nitrogen	46	-	600	-	1000	-
Phosphorus	1100	539	733	281	800	-
Potassium	25700	13200	24900	2390	10000	-
Rubidium	166	197	243	46	20-500	-
Selenium	0.050	0.52	0.60	0.32	0.01	5
Silica	285000	359000	260000	34	330000	-
Silver	0.15	0.12	0.27	0.19	0.01	1
Sodium	28100	3870	4850	393	7000	-
Strontium	368	28	290	617	600-1000	-
Sulfur	410	945	1850	4550	500	-
Thallium	11	3.9	13	0.20	0.12-12	0.22
Tin	2.5	0.15	4.1	0.17	10	10-70
Titanium	4830	1950	4440	377	5000	-
Vanadium	149	20	101	13	100	-
Zinc	80	16	130	16	50	500
Zirconium	160	204	142	18	60-2000	-

Table D.117: Summary of VOC detections by aquifer and aquifer group.

Aquifer Group or Subgroup	Number of Samples	No. of VOC Detections	% VOC Detections
CFIG	5	0	0
CFRN	27	1	4
CIGL	8	1	13
CJDN	31	2	6
CMSH	10	0	0
CMTS	13	0	0
CSLF	4	1	25
CSTL	4	1	25
OGAL	22	0	0
OMAQ	1	1	100
OPDC	36	1	3
OPVL	3	0	0
OSPC	2	0	0
OSTP	23	1	4
PCCR	26	7	27
PCUU	3	0	0
PEBI	1	0	0
PMDC	1	0	0
PMFL	2	1	50
PMHN	3	0	0
PMNS	17	4	24
PMSX	4	2	50
PMUD	23	3	13
QBAA	387	37	10
QBUA	104	14	13
QBUU	22	5	23
QUUU	4	0	0
QWTA	120	16	13
Cambrian	102	6	6
Devonian	10	2	20
Cretaceous	38	9	24
Ordovician	87	3	3
Precambrian	80	17	21
Quaternary, buried	513	56	11
Quaternary, surficial	124	16	13
CFIG-CFRN-CIGL	40	2	5
OSTP-OPDC-CJDN	90	4	4
CMSH-CMTS-PMHN	26	0	0
Upper carbonate	36	3	8
All wells	954	109	11

Table D.118: Summary of VOC detections by chemical class.

Aquifer Group or Subgroup	VOC Class 1	VOC Class 2	VOC Class 3	VOC Class 4	VOC Class 5	VOC Class 6	VOC Class 7
CFIG	0	0	0	0	0	0	0
CFRN	0	1	0	0	0	0	0
CIGL	0	0	0	1	0	0	0
CJDN	1	1	0	0	0	0	0
CMSH	0	0	0	0	0	0	0
CMTS	0	0	0	0	0	0	0
CSLF	1	1	0	0	0	0	0
CSTL	0	0	0	1	1	0	0
OGAL	0	0	0	0	0	0	0
OMAQ	0	2	0	0	0	0	0
OPDC	0	1	0	0	0	0	0
OPVL	0	0	0	0	0	0	0
OSPC	0	0	0	0	0	0	0
OSTP	1	1	0	0	0	0	0
PCCR	1	1	0	3	1	1	0
PCUU	0	0	0	0	0	0	0
PEBI	0	0	0	0	0	0	0
PMDC	0	0	0	0	0	0	0
PMFL	0	0	0	1	0	0	0
PMHN	0	0	0	0	0	0	0
PMNS	2	0	0	3	1	0	0
PMSX	0	0	0	2	0	1	0
PMUD	0	0	0	0	3	0	0
QBAA	11	6	1	20	1	2	1
QBUA	5	2	0	8	0	0	0
QBUU	3	2	0	0	0	1	0
QUUU	0	0	0	0	0	0	0
QWTA	4	2	0	9	1	0	1
Cambrian	2	3	0	2	1	0	0
Devonian	0	2	0	4	0	0	0
Cretaceous	4	1	2	3	0	3	0
Ordovician	1	4	0	0	0	0	0
Precambrian	3	1	0	9	5	2	0
Quaternary, buried	19	10	1	28	1	3	1
Quaternary, surficial	4	2	0	9	1	0	1
CFIG-CFRN-CIGL	0	1	0	1	0	0	0
OSTP-OPDC-CJDN	2	3	0	0	0	0	0
CMSH-CMTS-PMHN	0	0	0	0	0	0	0
Upper carbonate	0	2	0	2	0	0	0
All wells	33	23	3	55	8	8	2

Table D.119: Summary of chemical parameters and other factors which differed significantly between wells containing a detectable non-halogenated aromatic compound compared to wells with no detectable VOC. "-" represents a concentration or value for the parameter was lower in wells with the detectable VOC; "+" represents a concentration or value for the parameter was greater in wells with the detectable VOC.

Parameter	p-value	Greater or smaller in wells containing a detectable VOC
Zinc	0.0030	-
Well Diameter	0.0020	+
Vanadium	0.0157	-
Total suspended solids	0.0000	+
Tritium	0.0011	+
Total organic carbon	0.0003	+
Thallium	0.0025	+
Titanium	0.0006	-
Temperature	0.0225	+
Strontium	0.0003	+
Tin	0.0138	-
pH	0.0002	-
Nickel	0.0142	-
Sodium	0.0055	+
Month of sampling	0.0025	+
Molybdenum	0.0019	-
Lithium	0.0254	-
Potassium	0.0002	+
Mercury	0.0433	-
Calcium	0.0331	+
Boron	0.0007	+
Alkalinity	0.0462	+
Silver	0.0002	-

Table D.120: Summary of chemical parameters and other factors which differed significantly between wells containing a detectable halogenated aliphatic compound (non-THM or CFC) compared to wells with no detectable VOC. "-" represents a concentration or value for the parameter was lower in wells with the detectable VOC; "+" represents a concentration or value for the parameter was greater in wells with the detectable VOC.

Parameter	p-value	Greater or smaller in wells containing a detectable VOC
Oxidation-reduction potential	0.0002	+
Zirconium	0.0071	-
Well diameter	0.0009	+
UTM-north	0.0000	-
UTM-east	0.0062	+
Total suspended solids	0.0024	-
Tritium	0.0043	+
Total phosphate	0.0366	-
Temperature	0.0000	+
Lead	0.0009	+
Nitrate	0.0075	+
Sampling month	0.0215	+
Molybdenum	0.0060	-
Manganese	0.0010	-
Lithium	0.0028	-
Dissolved oxygen	0.0094	+
Cesium	0.0003	+
Chloride	0.0001	+
Cadmium	0.0033	+
Arsenic	0.0027	-
Aluminum	0.0048	+

Table D.121: Summary of chemical parameters and other factors which differed significantly between wells containing a detectable trihalomethane compound compared to wells with no detectable VOC. "-" represents a concentration or value for the parameter was lower in wells with the detectable VOC; "+" represents a concentration or value for the parameter was greater in wells with the detectable VOC.

Parameter	p-value	Greater or smaller in wells containing a detectable VOC
Rubidium	0.0276	+
Well diameter	0.0064	+
Tritium	0.0156	+
pH	0.0261	-
Lead	0.0002	+
Nitrate	0.0010	+
Fluoride	0.0405	+
Dissolved oxygen	0.0043	+
Well depth	0.0232	-
Copper	0.0018	+
Barium	0.0306	-
Alkalinity	0.0162	-
Aluminum	0.0012	+

Table D.122: Summary of chemical parameters and other factors which differed significantly between wells containing a detectable chlorofluorocarbon compound compared to wells with no detectable VOC. "-" represents a concentration or value for the parameter was lower in wells with the detectable VOC; "+" represents a concentration or value for the parameter was greater in wells with the detectable VOC.

Parameter	p-value	Greater or smaller in wells containing a detectable VOC
Aluminum	0.0360	+
Alkalinity	0.0000	-
Arsenic	0.0199	-
Barium	0.0004	-
Calcium	0.0003	-
Cobalt	0.0428	-
Copper	0.0270	+
Specific Conductivity	0.0000	-
Mercury	0.0000	+
Potassium	0.0020	-
Lithium	0.0018	-
Magnesium	0.0001	-
Molybdenum	0.0461	-
Sodium	0.0428	-
Nitrate	0.0055	+
Phosphorus	0.0065	-
Lead	0.0030	+
Sulfate	0.0420	-
Strontium	0.0022	-
Static water level	0.0078	-
Total dissolved solids	0.0001	-
Temperature	0.0165	-
Total phosphate	0.0086	-
Tritium	0.0159	+
UTM-east	0.0013	+
UTM-north	0.0107	+
Sulfur	0.0376	-

Table D.123: Summary of chemical parameters and other factors which differed significantly between wells containing a detectable ketone or aldehyde compound compared to wells with no detectable VOC. "-" represents a concentration or value for the parameter was lower in wells with the detectable VOC; "+" represents a concentration or value for the parameter was greater in wells with the detectable VOC.

Parameter	p-value	Greater or smaller in wells containing a detectable VOC
Silicate	0.0285	-
Selenium	0.0452	-
Sampling month	0.0475	-
Dissolved oxygen	0.0134	+

Table D.124: Summary of chemical parameters and other factors which differed significantly between wells containing an ether compound compared to wells with no detectable VOC. "-" represents a concentration or value for the parameter was lower in wells with the detectable VOC; "+" represents a concentration or value for the parameter was greater in wells with the detectable VOC.

Parameter	p-value	Greater or smaller in wells containing a detectable VOC
Sulfur	0.0007	+
Rubidium	0.0000	+
Zinc	0.0333	+
Well diameter	0.0001	+
Vanadium	0.0006	+
UTM-north	0.0038	-
UTM-east	0.0232	-
Titanium	0.0046	+
Total dissolved solids	0.0006	+
Strontium	0.0003	+
Sulfate	0.0007	+
Selenium	0.0154	-
pH	0.0008	-
Lead	0.0004	+
Nickel	0.0148	+
Sodium	0.0016	+
Molybdenum	0.0122	+
Manganese	0.0193	+
Magnesium	0.0005	+
Lithium	0.0006	+
Potassium	0.0006	+
Specific conductivity	0.0005	+
Well depth	0.0186	+
Copper	0.0007	+
Cobalt	0.0013	+
Cadmium	0.0151	+
Calcium	0.0005	+
Barium	0.0002	-
Boron	0.0018	+

Table D.125: Summary of VOC exceedances of the HRL.

PARAMETER	Concentration	HRL	Endpoint	Aquifer
Tetrachloroethene	8.6	7	cancer	QBUA
Benzene	22	10	cancer	QWTA
1,1-Dichloroethene	12	6	gi/liv	DCVA
Tetrahydrofuran	480	100	gi/liv	QBAA

APPENDIX E

Figure E.1 Baseline Network Sampling Grid

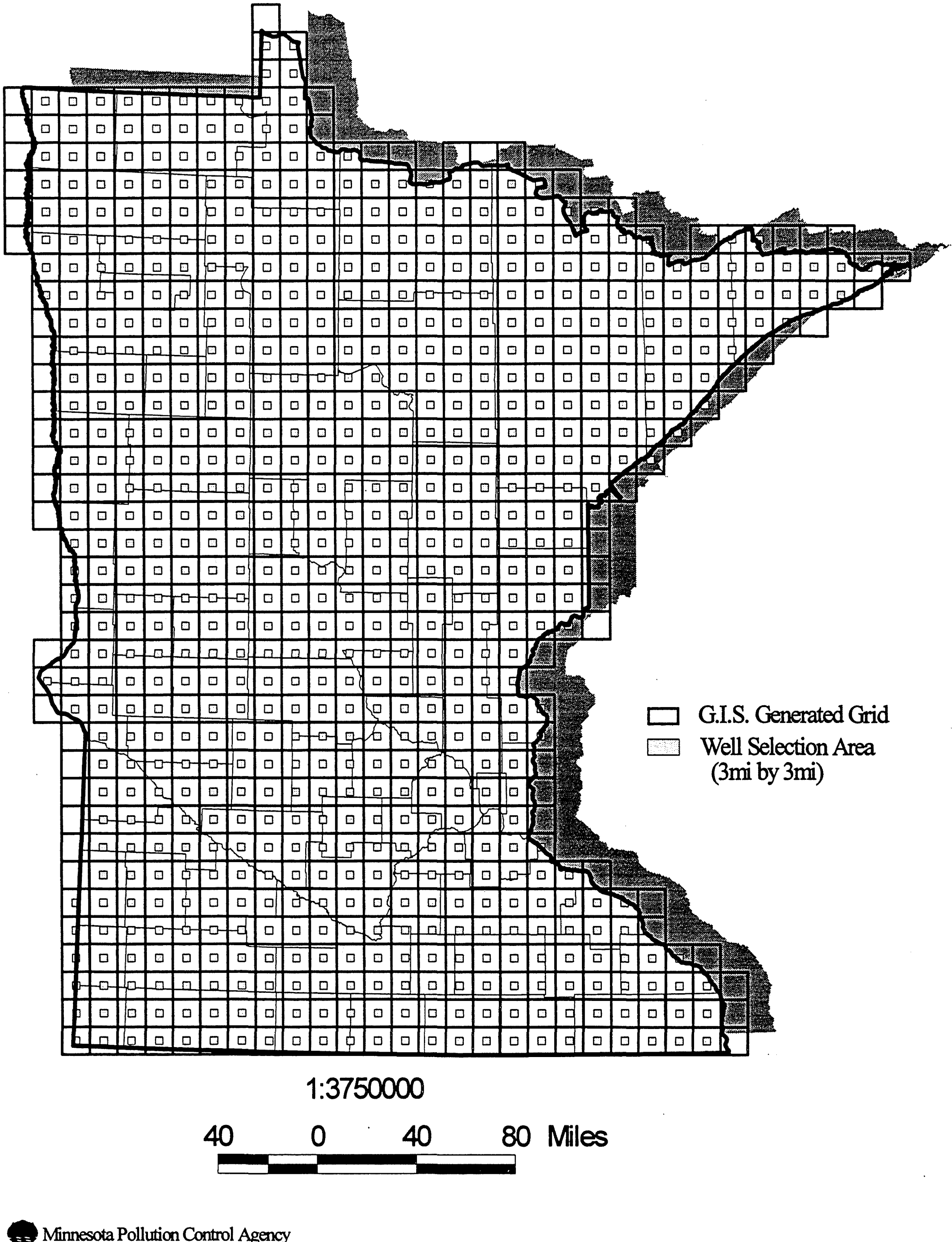


Figure E.2

SAMPLING PROTOCOL

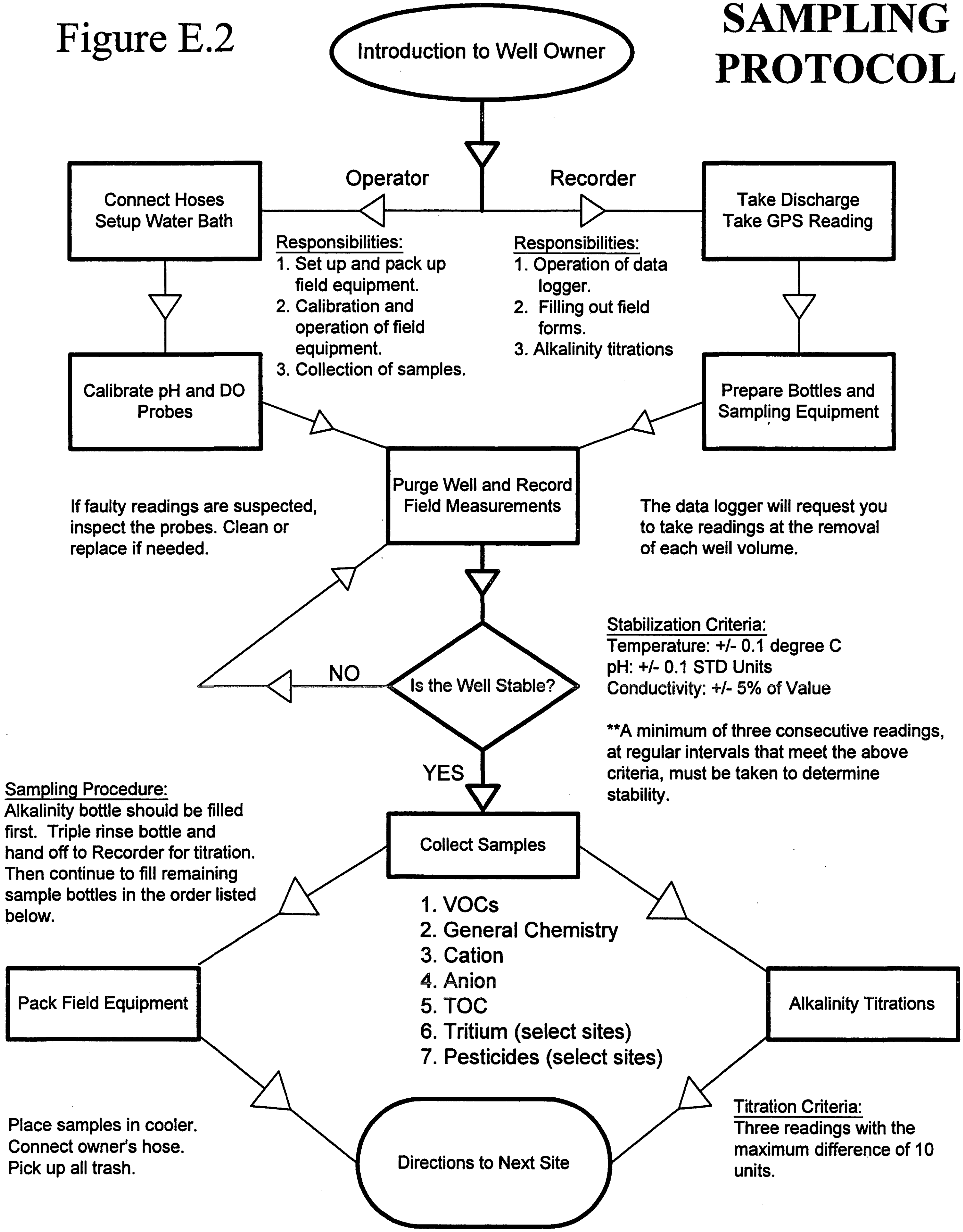


Figure E.3 Sample Locations by Year

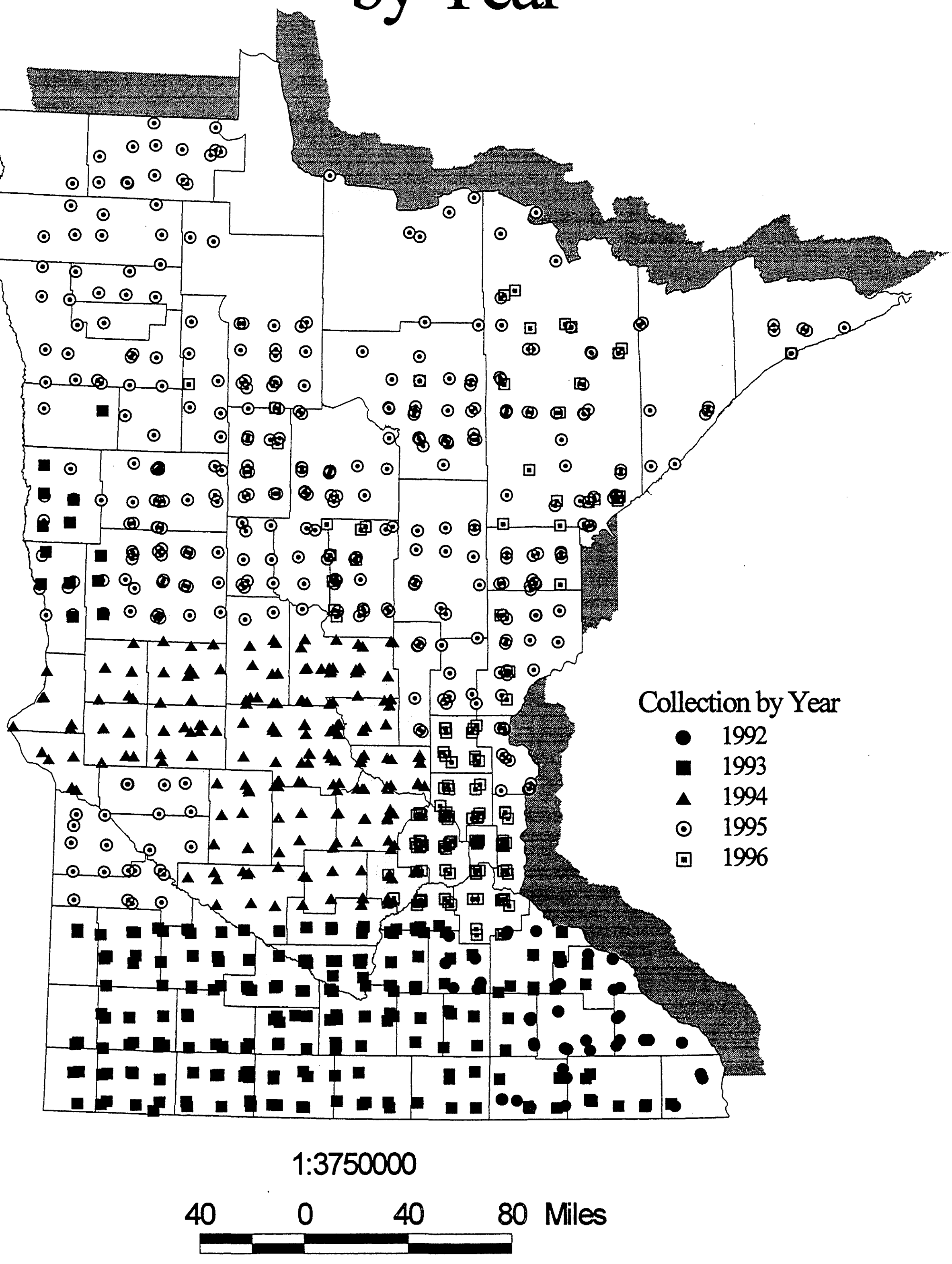


Figure E.4 Wells Sampled in the Cambrian Aquifers

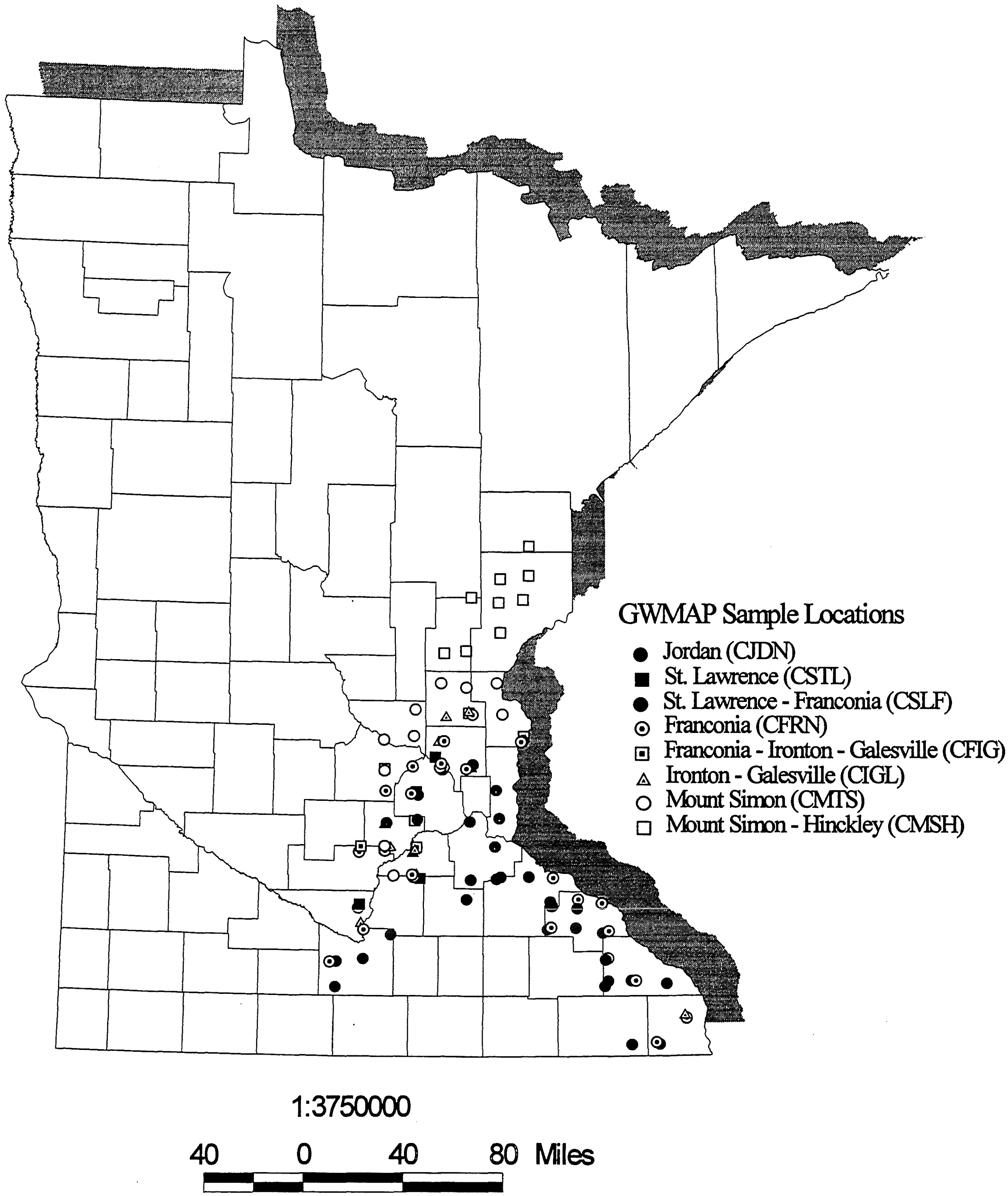


Figure E.5 Wells Sampled in the Devonian Aquifer

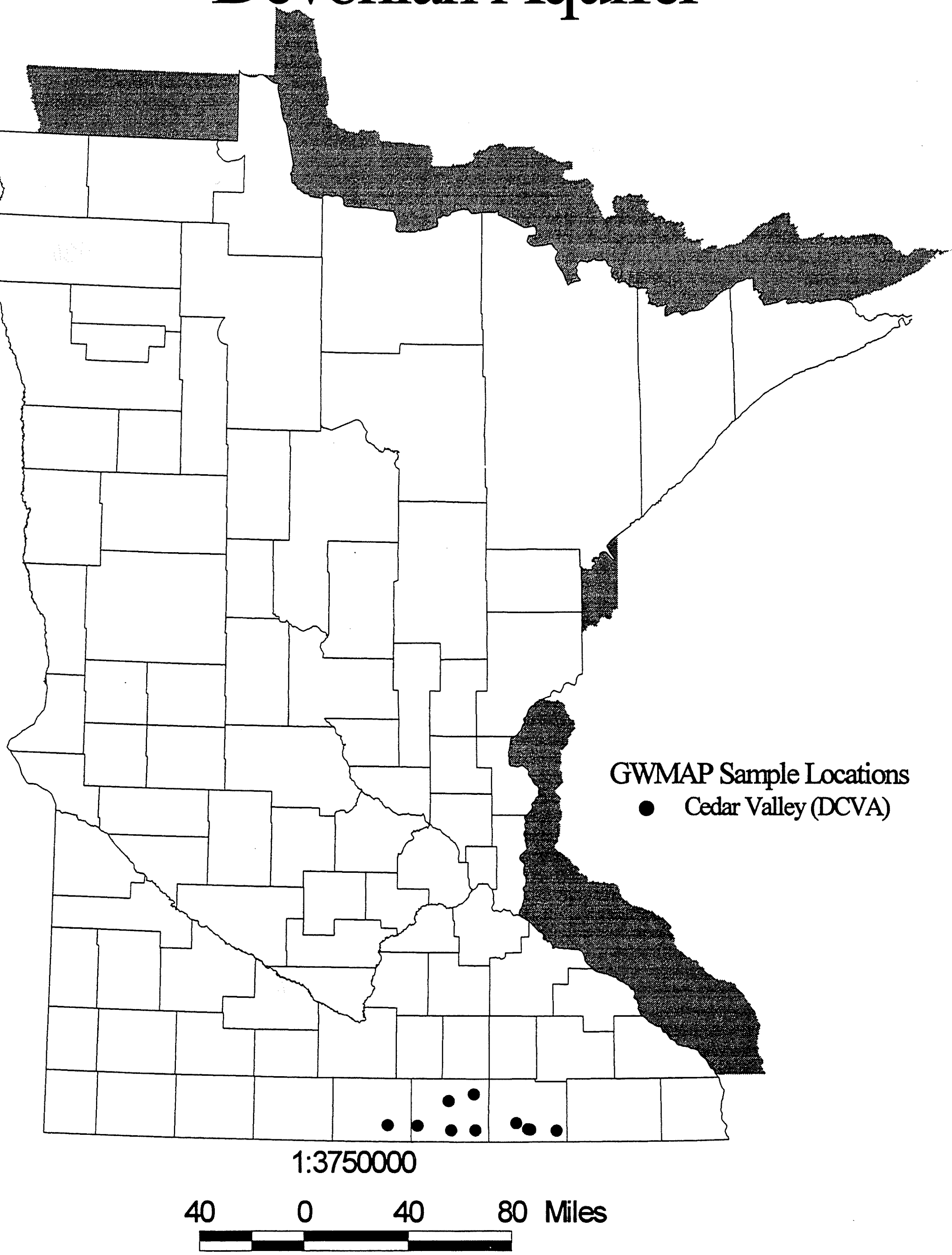
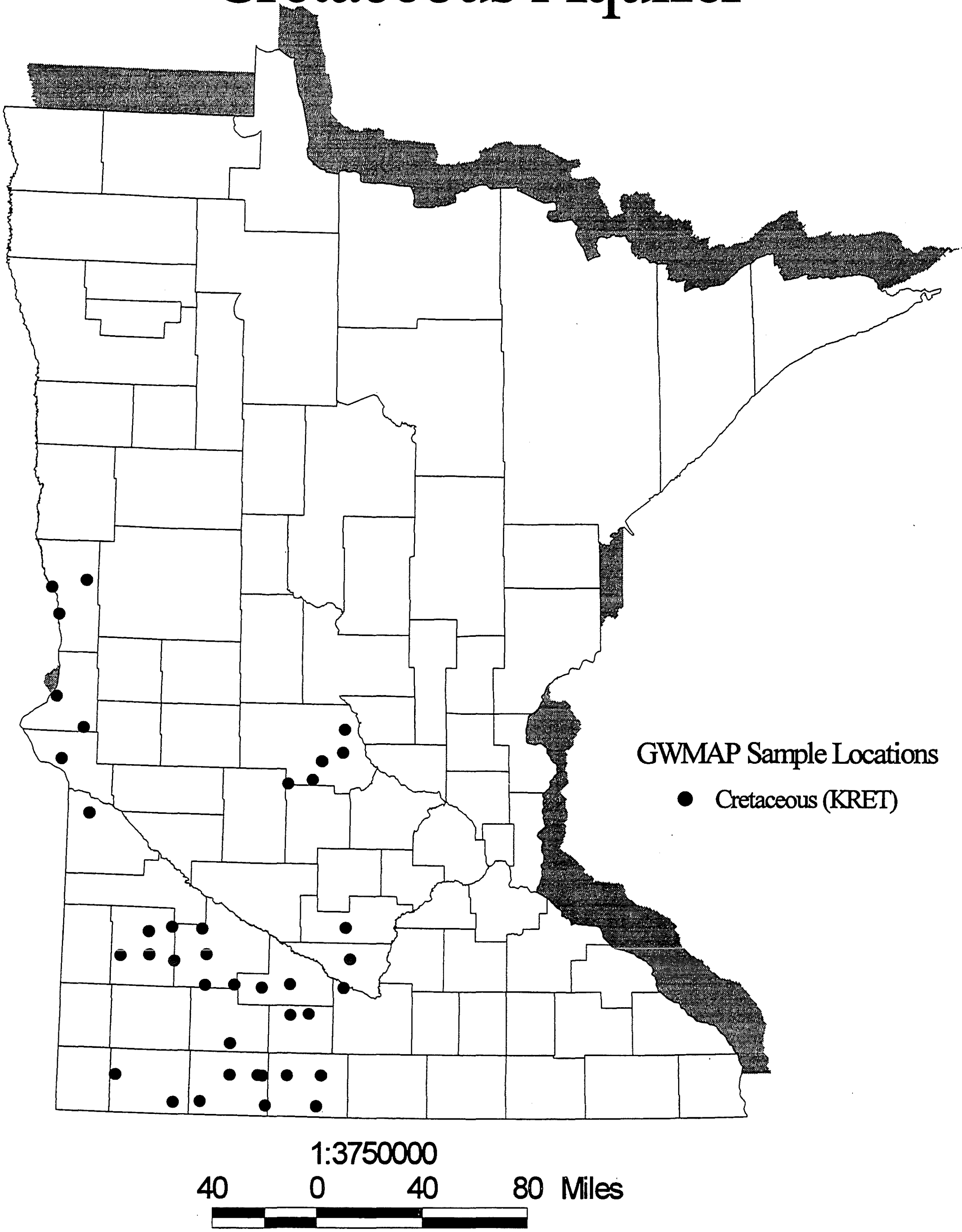


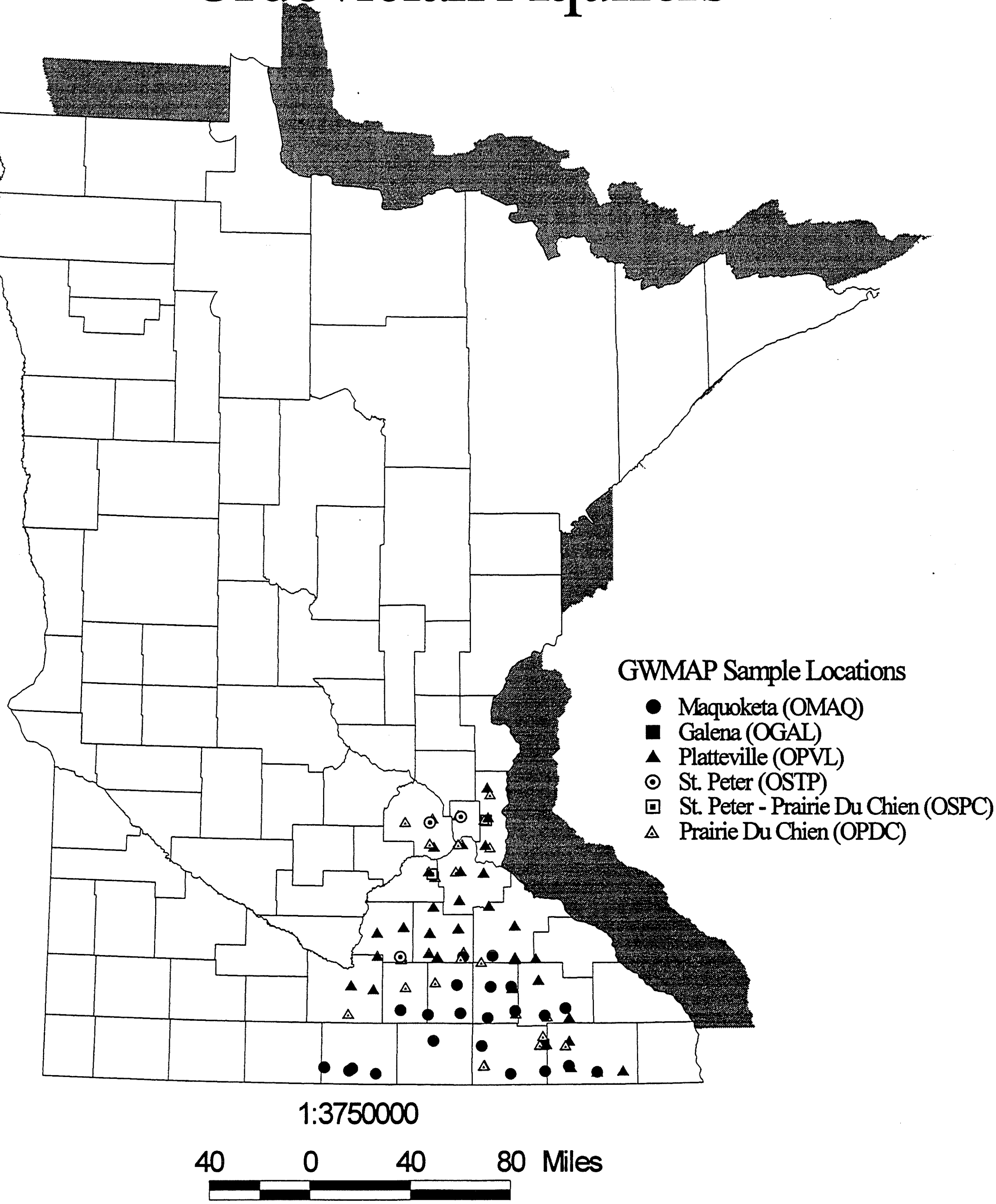
Figure E.6 Wells Sampled in the Cretaceous Aquifer



Minnesota Pollution Control Agency
Ground Water Monitoring and Assessment Program

January 1998

Figure E.7 Wells Sampled in the Ordovician Aquifers



Minnesota Pollution Control Agency
Ground Water Monitoring and Assessment Program

January 1998

Figure E.8 Wells Sampled in the Precambrian Aquifers

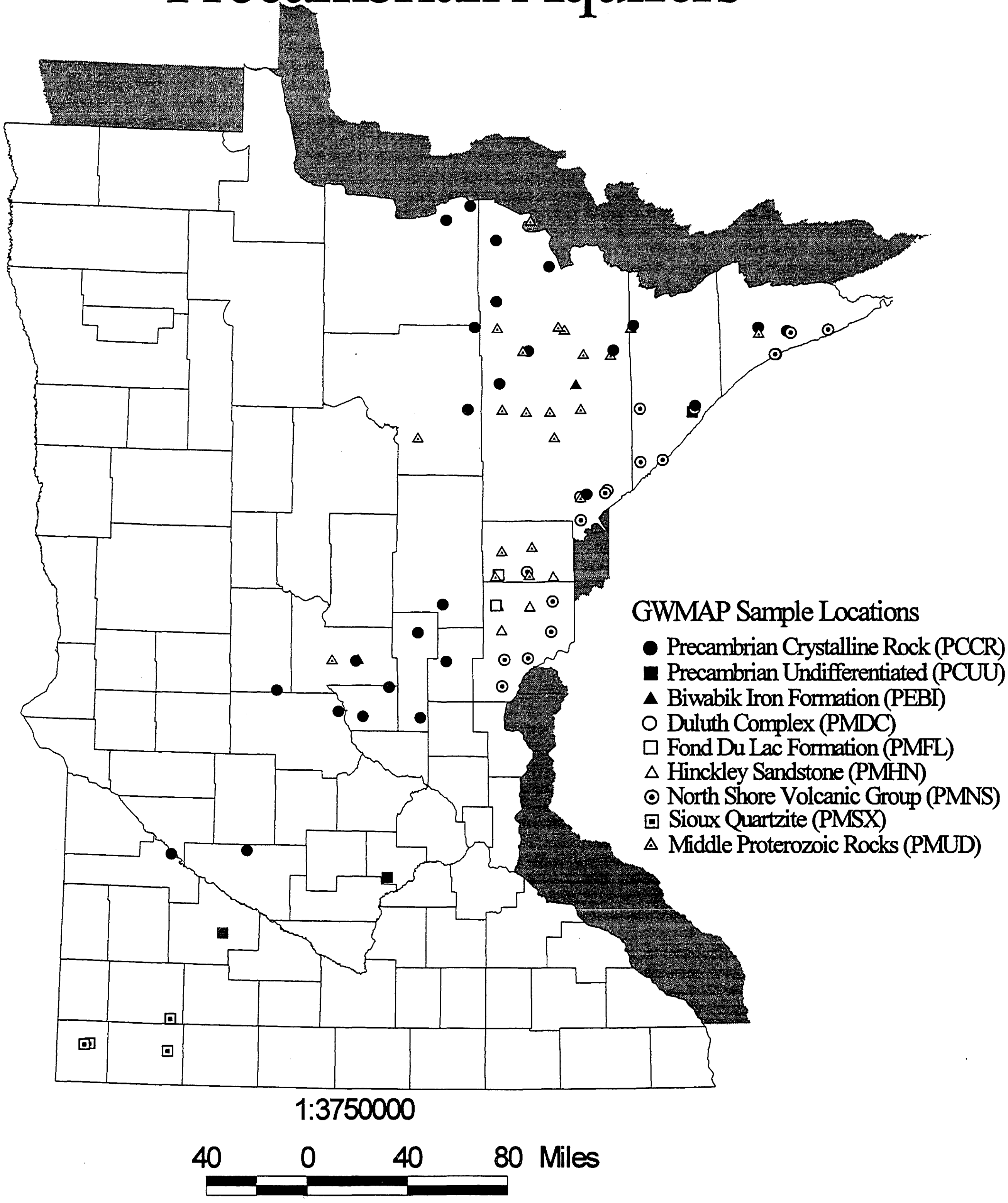


Figure E.9 Wells Sampled in the Buried Quaternary Aquifers

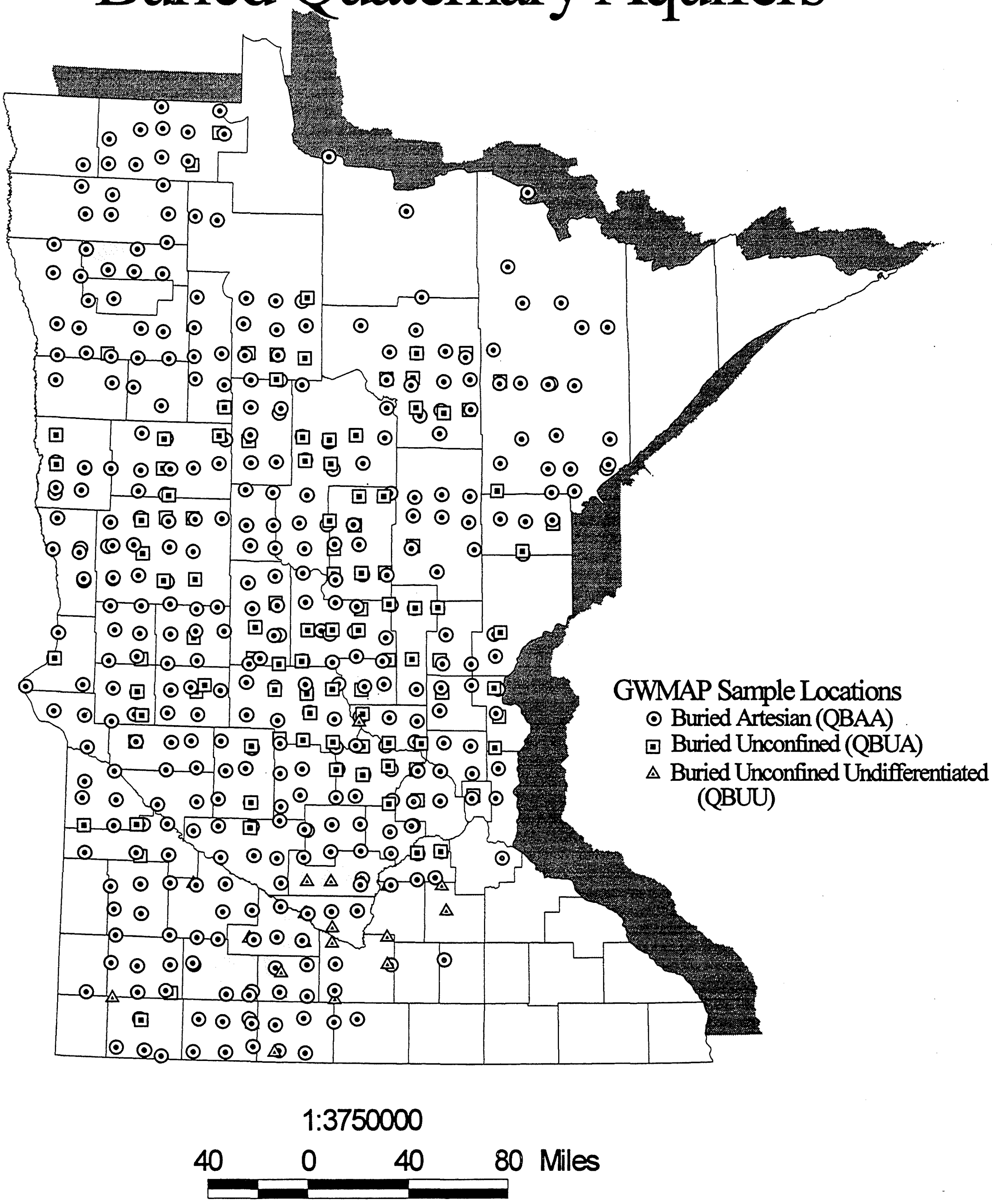
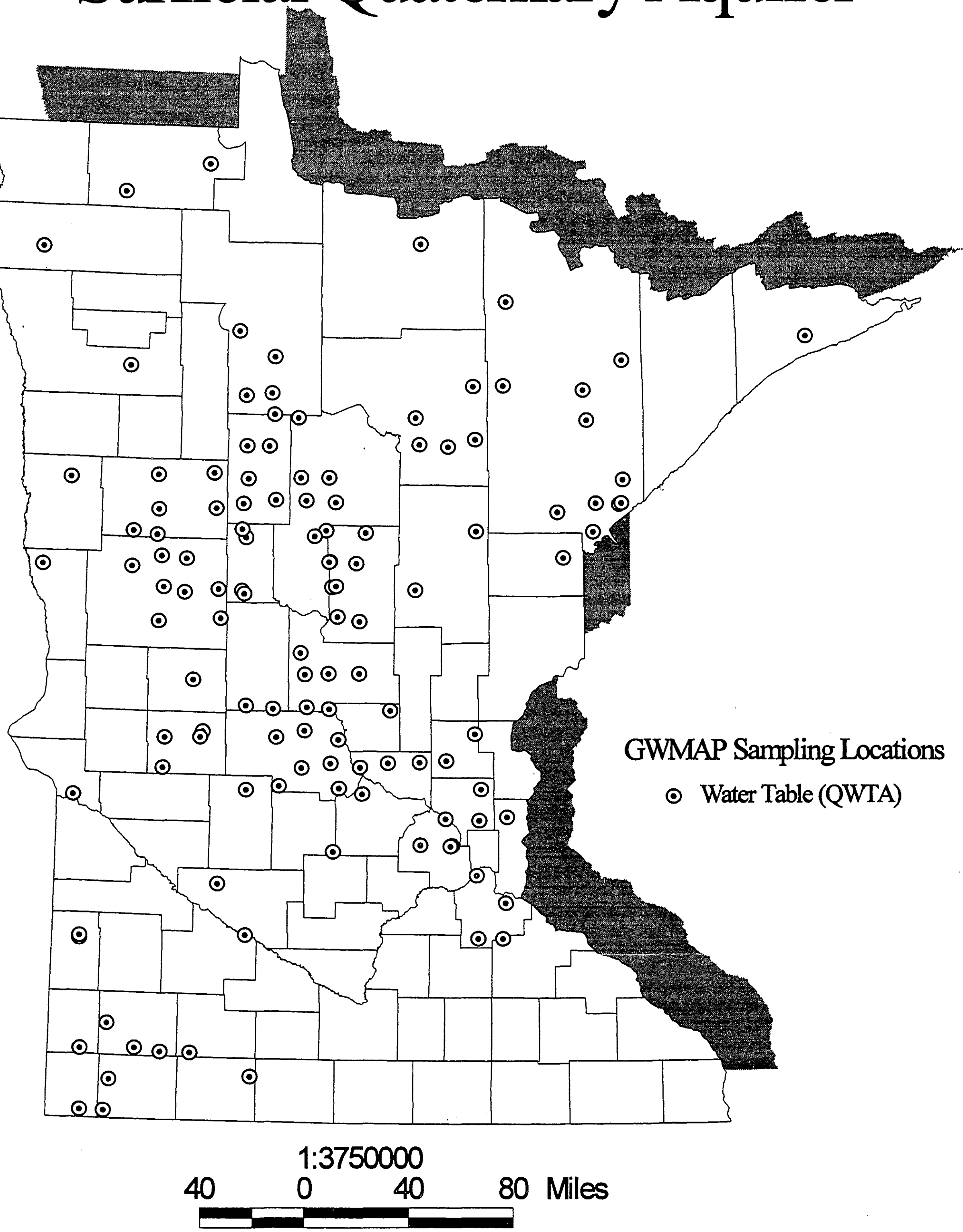


Figure E.10 Wells Sampled in the Surficial Quaternary Aquifer



Minnesota Pollution Control Agency
Ground Water Monitoring and Assessment Program

January 1998