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Dunn County, North Dakota Retrospective Case Study Site Characterization Report

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ABBREVIATIONS AND ACRONYMS

AST	above ground storage tank
bgs	below ground surface
BOD	biochemical oxygen demand
BTEX	benzene, toluene, ethylbenzene, and xylene
CA	critical analyte
COC	constituent of concern
CWA	Clean Water Act
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
FSP	Field Sampling Plan
gpm	gallons per minute
HUC	Hydrologic unit code
IOGCC	Interstate Oil & Gas Compact Commission
M	measured
Mcf	thousand cubic feet
MCL	maximum contaminant limit
MSU	Missouri Slope Upland
NDAC	North Dakota Administrative Code
NDCC	North Dakota Century Code
NDDH	North Dakota Department of Health
NDIC	North Dakota Industrial Commission
NDSWC	North Dakota State Water Commission
NDWC	North Dakota Water Commission
NORM	naturally-occurring radioactive materials
NPDES	National Pollutant Discharge Elimination System
NURE	National Uranium Evaluation
NWIS	National Water Information System
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PWS	public water system
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RCRA	Resource Conservation and Recovery Act

SDWA	Safe Drinking Water Act
SMCL	secondary maximum contaminant limit
STORET	EPA STOrage and RETrieval Data Warehouse
SVOC	semivolatile organic compound
TDS	total dissolved solids
TMDL	total maximum daily load
TRI	Toxic Releases Inventory
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UST	underground storage tank
VOC	volatile organic compound
WWTF	wastewater treatment facility

EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency (EPA) is conducting a retrospective case study in Dunn County, North Dakota to determine if there is a relationship between hydraulic fracturing and drinking water resources. EPA selected this site in response to a blowout during a hydraulic fracturing operation that resulted in a release of hydraulic fracturing fluid and oil to the environment (EPA, 2011b). EPA and the North Dakota Department of Health are collecting data through installation and sampling of monitoring wells to characterize groundwater quality and assess results for potential impacts on groundwater and surface water quality.

An understanding of background water quality conditions is required to determine if a relationship exists between hydraulic fracturing and drinking water resources at the location of the blowout or in other areas of the county. An absence of background water quality data necessitates a rigorous investigation of potential sources for any observed impacts prior to source attribution. This report is intended to provide an initial understanding and characterization of water quality conditions in Dunn County based upon publically available information on land use, known surface water impairments, and water quality data from the U.S. Geological Survey (USGS), U.S. Department of Agriculture (USDA), Dunn County and the state of North Dakota. Key findings from this report include:

- Oil and gas production has been consistently regulated since the 1940s by the state of North Dakota. The North Dakota Industrial Commission (NDIC), Department of Mineral Resources, Division of Oil and Gas, regulates the drilling and production of oil and gas in the state. Rules and regulations for oil and gas are set forth in the North Dakota Century Code (NDCC) Chapter Title 38. Authority to administer the oil and gas rules and regulations is given to the NDIC in Title 43 of the North Dakota Administrative Code (NDAC).

- Samples collected during nine monitoring events spanning March 2011 through November 2012 have shown no impacts to groundwater in the Killdeer aquifer that indicate significant release of petroleum or hydraulic fracturing fluids to groundwater. No impacts were detected in the nearest surface water body, Spring Creek.

- Both groundwater and surface water in Dunn County have been impaired by historical land uses that occurred long before shale gas and shale oil drilling was introduced in 1987. These historical activities could provide sources for a large number of pollutants that may exist in groundwater and/or surface water in the study area. The most significant cause of water quality impairments in Dunn County is agriculture. Other land uses known to impact water quality in the county include urban, residential, and road runoff; habitat modification; and municipal and industrial wastewater discharges. Land uses and parameters commonly associated with these land uses include:
    - Agricultural runoff: insecticides, herbicides, fungicides, fertilizers (e.g., nitrogen and phosphorous), metals (e.g., arsenic), and other constituents (e.g., dissolved solids, bromide, selenium) have been applied for agricultural activities. In addition, algal blooms caused by agricultural runoff of nitrogen and phosphorous can be a source of organic carbon that promotes the formation of disinfection byproducts (DBPs) upon chlorination of surface water in water treatment plants (EPA, 2005). Approximately 43 miles of streams are documented to be impaired by agricultural runoff including crop and grazing activities in Dunn County.

- Non point sources, urban runoff, and industrial activities: suspended solids, nutrients (i.e., phosphorous), heavy metals (e.g., iron, lead, and zinc), volatile organic compounds (VOCs) (benzene, toluene, ethylbenzene, and xylene [BTEX] related to automobile use), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), metals, and salts depending upon the types of activities in the area. Many of these inputs occur with rainfall and the concentrations have been found to be dependent on the length of the preceding dry period (Hewitt and Rashed, 1992).
- Municipal and industrial wastewater discharges: In the absence of adequate treatment, wastewater discharges may contain pathogens, household and industrial chemicals, suspended solids, biochemical oxygen demand (BOD), and nutrients into receiving waters. It is estimated that 25% of these chemicals may pass in the discharge to receiving waters even after treatment at a wastewater treatment facility (WWTF) (EPA, 1997).
- Conventional oil and gas development: petroleum hydrocarbons, BTEX and methane. Metals, salts and naturally-occurring radioactive materials (NORM) may also be associated with conventional oil and gas development. Historical records indicate at least 1,095 conventional oil and gas wells have been completed in Dunn County between 1953 and 2012. Of the 734 wells with a reported completion date, 298 were completed prior to 1983, when NCSC Title 43 was introduced to provide additional regulations regarding oil and gas production.
- Approximately 168 miles of impaired streams and rivers occur within Dunn County Approximately 125 miles are impaired by mercury from atmospheric deposition, and the remaining are impaired by E. coli and/or coliform, most likely resulting from agriculture (EPA, 2012a).

- Historical data on water quality within the study area are extremely limited. Of the 237 parameters that EPA describes in its quality assurance project plan (QAPP), only 27 groundwater parameters (15 measured and 12 critical analytes), 28 surface water parameters (19 measured and 9 critical analytes), and 16 spring water parameters (eight measured and eight critical analytes) provide enough results (from eight or more locations) to estimate background water quality.
- Determining a relationship between hydraulic fracturing and drinking water will be challenging given the lack of adequate data to characterize background water quality conditions. Water quality data presented to characterize conditions prior to hydraulic fracturing in this report should only be used in the context of providing an understanding of the observed range in parameter concentrations for the study area (e.g., Dunn County). As noted by the USGS (DeSimone, 2009; Ayotte et al., 2011) and observed in the data presented here, natural variability, land use patterns and other factors affect observed water quality. These factors have to be understood at the local level or specific areas of interest before a good understanding of background water quality can be determined for those areas. Without adequate background water quality, impacts observed as part of the EPA study will require a rigorous investigation before relating those impacts to hydraulic fracturing.

1.0: INTRODUCTION

The U.S. Environmental Protection Agency (EPA) has initiated five retrospective case studies to evaluate potential relationships between hydraulic fracturing and drinking water resources (EPA, 2011a). One of the retrospective case studies selected by EPA is located in Dunn County, North Dakota. According to the EPA Quality Assurance Project Plan (QAPP) for the Dunn County Retrospective Case Study (EPA, 2011b), this area was selected in response to an uncontrolled blowout that occurred at well Franchuk 44-20SWH during the hydraulic fracturing stage of the well development process, which resulted in the release of approximately 84,000 gallons of hydraulic fracturing fluids (EPA, 2011b).

During the retrospective case study, EPA is investigating a drinking water aquifer to determine whether and to what extent the aquifer is contaminated. As part of the study, EPA is collecting groundwater and surface water quality data in the vicinity of the well and the City of Killdeer. Samples collected during nine monitoring events spanning March 2011 through November 2012 have shown no impacts to groundwater in the Killdeer aquifer that indicate significant release of petroleum or hydraulic fracturing fluids to groundwater. No impacts were detected in the nearest surface water body, Spring Creek (North Dakota Industrial Commission [NDIC], 2012).

To enable evaluation of the EPA case study water sampling and analysis results within the context of regional spatial and temporal variability, American Petroleum Institute and America's Natural Gas Alliance requested Battelle characterize land use, groundwater quality and surface water quality in the Dunn County study area. This report summarizes historical water resource quality data within the Dunn County study area for use in comparing the future data to be generated as part of EPA's retrospective case study.

1.1 Scope of Work

The primary objective of this report is to develop an understanding of and characterize background groundwater, spring and surface water quality within the study area prior to the onset of unconventional oil and gas development and highlight potential adverse impacts that may have resulted from former land use activities. This was accomplished by:

- Defining the spatial and temporal boundaries and attributes of the Dunn County study area.
- Identifying land use and water quality data that could be used to provide historical context for characterizing water resources in the defined study area, along with identifying associated analytical parameters that could be used to evaluate potential impacts on drinking water resources.
- Developing a list of available chemicals and water quality parameters monitored in the study area and comparing them to EPA QAPP requirements.
- Developing and applying quality assurance (QA) criteria to assess the quality of the historical water quality data.
- Conducting summary statistical analyses on the water quality data and comparing the results to relevant state and federal screening criteria.

Battelle utilized EPA's data quality objective (DQO) process to help ensure that an appropriate type and quantity of data needed to meet the study objective was collected (EPA, 2006). An in-depth evaluation of water quality data by individual surface water bodies, springs, aquifers, or wells is beyond the scope of this report.

1.2 Report Organization

Section 2 presents the technical approach to defining the study area boundaries; identifying, collecting, and organizing the secondary data; QA procedures for data assessment; and a discussion of relevant regulations and regulatory screening levels applicable to the water quality parameters of interest. Section 3 provides the land use, groundwater quality, and surface water quality data collected for this report. Key conclusions and findings are presented in Section 4.

1.3 Background

The focus of the retrospective case study in Dunn County is the Franchuk 44-20SWH well, which is located near Killdeer in North Dakota. On September 1, 2010, the Franchuk 44-20SWH well experienced an uncontrolled blowout during the fifth stage of a 23 stage hydraulic fracturing operation. The surface casing was compromised at about 38.5 feet below ground surface (bgs) with fluids possibly migrating down and around the conductor casing at 60 ft bgs, then discharging to the surface (NDIC, 2012; Terracon, 2012). Well fluids began flowing from several locations around the wellhead when the 7-inch-diameter casing burst. A stream of water, oil and gas was released for approximately five days until September 6 when a plug was placed in the well. Except for a portion of the fluids flowing to the northwest, fluids released at the surface were captured on the well pad which was double-lined and diked to contain spills at the surface. Approximately 2,000 barrels (84,000 gallons) of hydraulic fracturing fluid and oil were released into the environment of which approximately 125 barrels (5,250 gallons) of the fracturing fluid and oil was recovered after the spill (EPA, 2011b). Impacted soils from the well pad were excavated and disposed offsite (1,889 tons initially followed by another 81 cubic yards from two smaller areas at the pad [Terracon, 2012]).

As a result of the spill, the North Dakota Industrial Commission (NDIC) fined Denbury $237,500 for violation of several sections of the North Dakota Administrative Code (NDAC). Specific infractions included not controlling subsurface pressure during completion activities (NDAC Section 43-02-03-28), allowing oil to flow over and pool on the surface of the land (NDAC Section 43-02-03-49), and allowing brine to flow over and pool on the surface of the land (NDAC Section 43-02-03-53) .

The objectives of EPA's investigation are to determine if the Killdeer Aquifer was impacted by the blowout and, if there was an impact, to determine the mechanisms of how the aquifer was impacted. EPA is performing its investigation in two phases. During the first phase of its investigation, selected wells were sampled and analyzed for a range of components of crude oil such as gasoline range organics, diesel range organics, volatile organic compounds (VOCs), dissolved gases including methane, ethane, propane, and butane; and various hydraulic fracturing fluid constituents including potassium, alcohols, naphthalene, boron, and glycols and barium. Naturally occurring chemicals such as arsenic, selenium, strontium and other trace metals also were monitored along with changes in routine water quality parameters including dissolved organic and inorganic carbon, major anions and major cations.

Groundwater sampling locations include eight monitoring wells (one of which is screened at two depths) that have been installed within an approximate 11 acre area in the immediate vicinity of the drilling pad to monitor the impacts of the blowout. Four monitoring wells were installed in September 2010 and the remaining wells were installed in April 2011. The locations of only four of the wells are known at the time of this report, which are designated by the red circles in Figure 1-1. Latitude and longitude coordinates were not provided for the monitoring wells installed in April 2011. EPA also is evaluating data from eight groundwater wells within a 1 mile radius from the pad, and two city drinking water supply wells in the City of Killdeer located about 2.5 miles from the site of the release. The approximate locations of EPA's sampling points are designated by the yellow circles shown in Figure 1-1.

Once the gas well was repaired, one additional monitoring well was installed immediately adjacent to the gas well. Samples collected from the wells during nine monitoring events spanning March 2011 through November 2012 have shown no impacts to groundwater in the Killdeer aquifer indicating a release of petroleum or hydraulic fracturing fluid. No impacts were detected in the nearest surface water body, Spring Creek (NDIC, 2012). Transducers installed in the nine monitoring wells showed no significant changes in groundwater levels or temperature during hydraulic fracturing activities in the repaired gas well (Terracon, 2012).

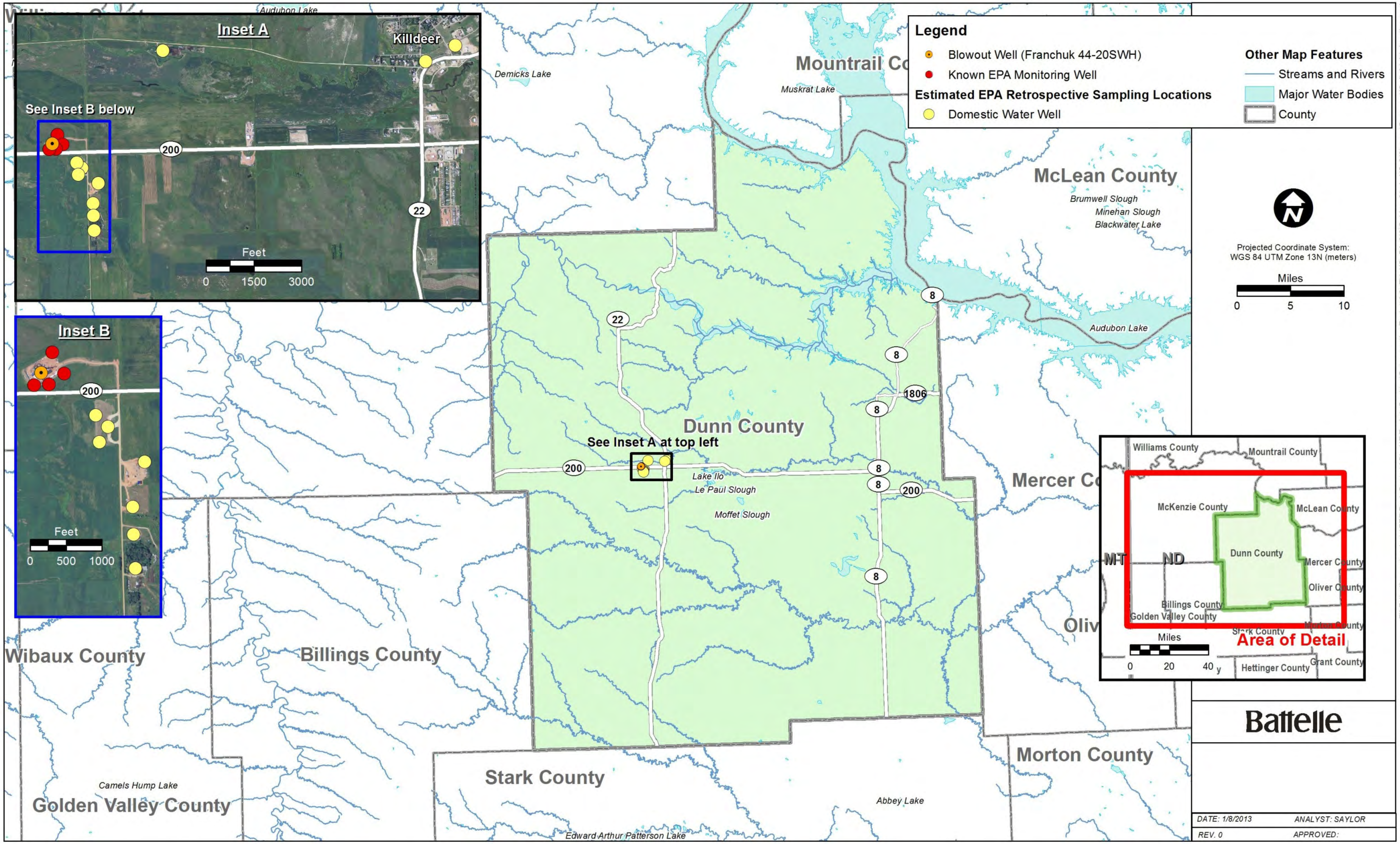


Figure 1-1. Dunn County Study Area

2.0: TECHNICAL APPROACH

This section provides background information and the technical approach to defining the study area boundaries, data collection, QA processes and the applicable environmental regulatory framework.

2.1 Retrospective Case Study Area Boundaries

The Battelle study area is Dunn County located within the footprint of the Bakken Shale play in West Central North Dakota (Figure 1-1). This area is greater than the retrospective case study area being investigated by EPA, which focuses on the portion of the county in the vicinity of the Franchuk 44-20SWH blowout. However, consideration of the larger area provides a context within which to evaluate background land use and water quality data for spatial and temporal changes for future comparison with data collected for the EPA retrospective case study.

Dunn County is located on the Missouri Slope Uplands (MSUs) of the Great Plains Province. The MSUs are characterized by gently rolling topography interrupted by isolated buttes. The northern portion of the county is drained by the Missouri and Little Missouri Rivers. Erosion by the Little Missouri has created the Little Missouri River Badland, which extends approximately 3 to 5 miles on either side of the Little Missouri River. The Little Knife, Knife and Green Rivers form the major drainage systems in the southern part of the county. Figure 2-1 shows the four hydrologic unit code (HUC) 8 subbasins as well as the approximate location of EPA's retrospective study area. The County itself encompasses approximately 2,082 square miles and has a population of 3,536 (U.S. Census Bureau, 2010).

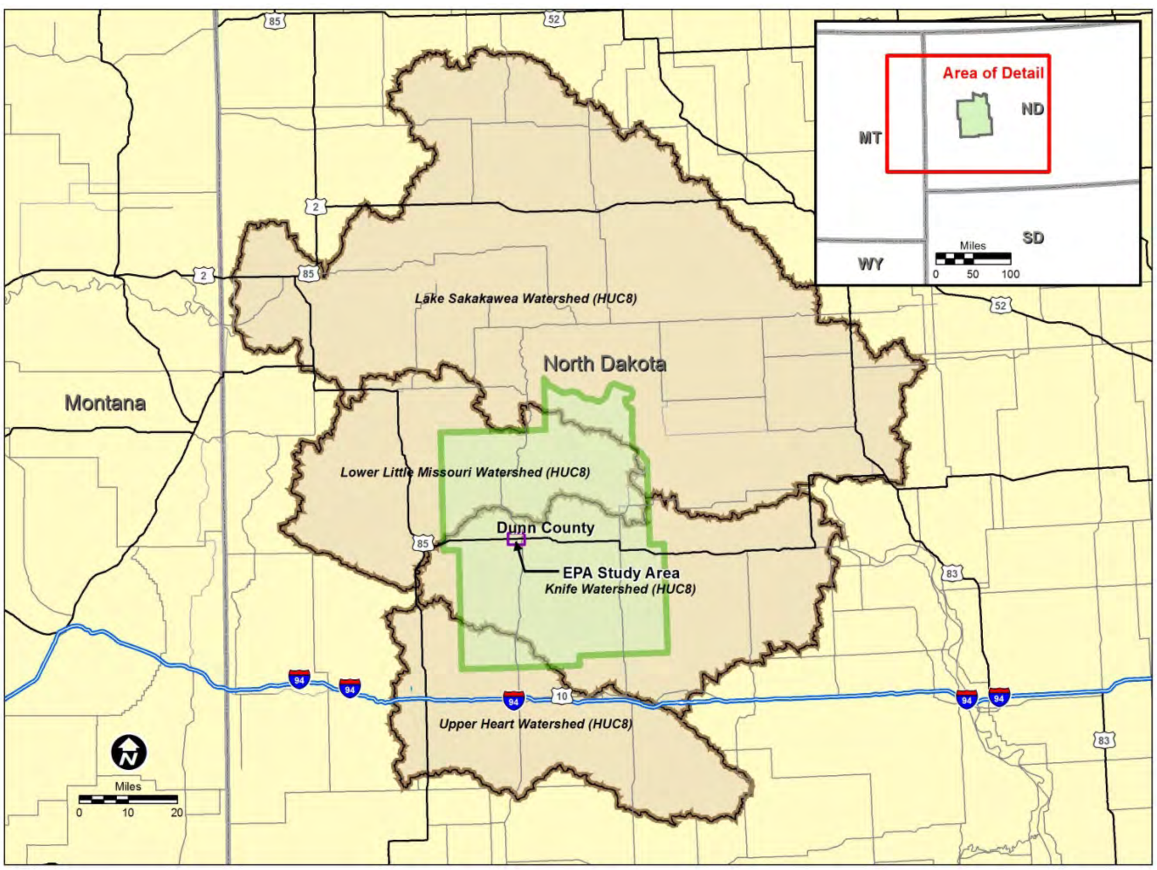


Figure 2-1. Location of Dunn County HUC 8 Watersheds

The study area is vertically constrained by near-surface geological formations in Dunn County that serve as drinking water sources. The deepest of these formations, Fox Hills, ranges in depth from 1,330 to 1,960 ft bgs across the county (U.S. Geological Survey [USGS], 1979). The depth to the underlying Bakken shale formation ranges from 7,000 to 10,000 ft bgs in the Williston Basin (USGS, 1988).

2.2 Data Sources, Collection, and Organization

The data contained in this report are secondary data collected from publically available federal government and state of North Dakota records. Secondary data are defined as "data that were originally collected for another project or purpose." This section describes the sources of the secondary data for land use and water quality and how the existing data were collected and managed. The data collected focused on the following:

- Land uses in potentially contributing to water quality conditions
- Groundwater quality conditions
- Surface water quality conditions.

2.2.1 Land Use Data Collection. The land use data are qualitative in nature and rely upon the original quality and documentation of the primary source of the data sets. These primary sources are summarized in Table 2-1. Both historic and current land use information was compiled to evaluate conditions associated with baseline water quality within Dunn County. This information also provides a context within which to evaluate both the water quality for spatial and temporal changes and for future comparison with data collected for the EPA retrospective case study.

Table 2-1. Summary of Land Use Data Sources for Dunn County

Data Source	Timeframe	Type of Data
ND Department of Health[1]	1991 - 2012	Underground storage tank and Brownfield cleanup locations
ND Oil and Gas Commission[2]	1996	Historic conventional oil and gas fields
EPA[3]	2012	Total maximum daily load (TMDL) impaired waters
USDA[4]	2011	Cropland information for Dunn County
EPA Envirofacts[5]	2012	Recognized pre-existing environmental activities that may affect air, water, and land resources
Dunn County Planning and Zoning Commission[6]	2005	Dunn County Comprehensive Plan including historical chronology, land use, and economy
USGS[7]	1986	Land use map

2.2.2 Water Quality Data Review. Water quality data were collected from U.S. federal government and state of North Dakota sources characterizing baseline groundwater and surface water

[1] http://www.ndhealth.gov/wm/UndergroundStorageTankProgram/
[2] https://www.dmr.nd.gov/oilgas/
[3] http://www.epa.gov/waters/ir/index.html
[4] http://nassgeodata.gmu.edu/CropScape/
[5] http://www.epa.gov/enviro/index.html
[6] http://dunncountyplanning.com/
[7] http://water.usgs.gov/GIS/dsdl/ds240/index.html

quality. The spatial boundaries for the data collection were Dunn County and include portions of the Lake Sakakawea, Lower Little Missouri, Knife, and Upper Heart watersheds (Figure 2-1).

Existing groundwater and surface water quality data were collected from the following sources:

- USGS National Water Information System (NWIS)
- EPA STOrage and RETrieval Data Warehouse (STORET)
- USGS National Uranium Evaluation (NURE)
- North Dakota State Water Commission (NDSWC).

Table 2-2 provides an overview of the types of water quality data that were collected. The data were then subsetted to those stations within Dunn County for use in characterizing background water quality for the retrospective case study location. The data sources listed in Table 2-2 are considered secondary data and by definition were not originally collected for the specific purposes of this report. However, these databases are commonly used to define background or baseline groundwater or surface water quality. The data were uploaded into a Microsoft® SQL Server database, processed, assessed according to the QA procedures described in Section 2.3, and qualified based on the results of the QA assessment.

Table 2-2. Summary of Water Quality Data Sources for Dunn County

Data Source	Time Frame	Number of Monitoring Locations	Parameters
USGS National Water Information System (NWIS)[8]	1950-2004	18 surface water 352 wells 29 springs	Major Ions, Minor Ions, Nutrients, PAHs, Pesticides, Radionuclides, VOCs, Water Characteristics
EPA STOrage and RETrieval Data Warehouse (STORET)[9]	1992-2004	28 surface water	Major Ions, Minor Ions, Nutrients, PAHs, Pesticides, Radionuclides, VOCs, Water Characteristics
USGS National Uranium Resource Evaluation (NURE)[10]	1979	3 wells 1 spring	Major Ions, Minor Ions, Radionuclides, Water Characteristics
North Dakota State Water Commission (NDSWC)[11]	1937-2004	31 surface water 356 wells	Major Ions, Minor Ions, Nutrients, Water Characteristics

2.2.3 Data Management. Groundwater, spring water and surface water data collected prior to 2005 represent conditions in Dunn County prior to significant development of the Bakken Shale through hydraulic fracturing and serve to define the background conditions discussed in this report. Therefore, no data collected after 2004 are included in this report.

Summary tables were prepared for groundwater, spring water and surface water data for a range of parameters. For the purposes of Battelle's evaluation, a minimum of one result from eight discrete locations was selected as the criterion for the minimum number needed to characterize water quality for a

[8] http://waterdata.usgs.gov/nwis/qw
[9] http://www.epa.gov/storet/
[10] http://tin.er.usgs.gov/geochem/doc/nure_analyses.htm
[11] http://www.swc.state.nd.us/4dlink2/4dcgi/wellsearchform/Map%20and%20Data%20Resources

given parameter. When evaluating the quantity of water quality data, EPA's guidance on statistical analysis of Resource Conservation and Recovery Act (RCRA) groundwater monitoring data (EPA, 2009) recommends that a minimum of at least eight to 10 independent background observations be collected before running most statistical analysis methods. Although still a small sample size by statistical standards, these sample requirements allow for minimally acceptable estimates of variability and evaluation of trend and goodness-of-fit. This approach is not meant to imply that eight sample results are sufficient to characterize water quality, only to note that this number was selected as the lower bound for the number of results included. Notwithstanding, it should be taken into consideration that larger sample sizes still may not necessarily constitute a representative data set for characterizing background water quality for specific formations or locations. Additional evaluation of spatial and temporal conditions should be performed prior to completing quantitative comparisions with other collected water quality data (e.g. EPA or operator). Parameters with results at fewer than eight locations were excluded from the summary data tables and associated discussion, but are included in Appendix B.

Two separate sets of summary data tables were produced for groundwater, springs and surface water. One set of data tables includes applicable data from the databases identified in Table 2-2. A duplicate set excludes the STORET data because these data may be indicative of environmental impact monitoring that could potentially skew the background water quality results; these STORET data and other data with geographic location issues as summarized in Table 2-3. A comparison between the two surface water summary data tables is provided below. The spring water quality database did not include data from the STORET database, so only one summary data table was produced.

Within each dataset, summary statistics (mean, median, standard deviation) were derived. To ensure that spatial locations receive equal weighting and that locations with multiple results over time are not weighted higher, the average of parameter-specific multiple temporal results was used to represent the specific parameter at that location. In the event that duplicate sample results exist, the duplicate sample is represented as a separate result and included in calculating the average for the sampling location. Two separate sets of summary statistics are calculated: one set includes all available data, with non-detect values included in the calculations at half of the detection limit; the second set includes only detected values.

Table 2-3. Summary of Data Included in Reduced Dunn County Water Quality Data Set

Data Source	Initial Number of Monitoring Locations	Reduced Number of Monitoring Locations	Reason for Removal
NWIS	18 surface water 352 wells 29 springs	18 surface water 352 wells 29 springs	No locations removed.
STORET	28 surface water	0 surface water	Data may be indicative of environmental impact monitoring
NURE	3 wells 1 spring	3 wells 1 spring	No locations removed.
NDSWC	31 surface water 356 wells	31 surface water 356 wells	No locations removed.

Groundwater and surface water quality regulatory standards and screening criteria were compiled and used for comparison against the assembled water quality characterization data; surface water regulatory benchmarks were used for comparison against the spring water data. When making these comparisons, only detected values were included when calculating the number of samples above regulatory levels; non-detect values were excluded. A summary of the water quality regulations that were utilized to compile applicable screening criteria is provided in Section 2.5.1.

2.3 Quality Assurance Procedures

A systematic approach was used to assess the quality of secondary analytical data in accordance with EPA QA/R-5, which requires that data be reviewed and acceptance criteria and limitation of use be defined (EPA, 2001). To this end, prior to initiating the site characterization study, Battelle developed overall DQOs to establish the study objective, problem being investigated, study goals, data input, boundaries, analytical approach, a plan for obtaining data and data acceptance criteria. The DQOs established the following criteria for data acceptance:

- Data were collected by an agency and organization known to have a rigorous quality system which was verified through screening of each source.
- Data were collected under an approved QAPP/Field Sampling Plan (FSP).
- The analytical methods were identified and appropriate.
- For non-detect values, the detection limits were defined and sensitive enough for the parameter in question.
- If quality control (QC) data were available, accuracy was demonstrated to be ≥80% and precision was demonstrated to be ±30%. Accuracy is determined using the results of spiked sample analysis where percent recovery can be quantified. Precision is determined using field or laboratory duplicate samples by calculating the relative percent difference.

Due to the nature of the source web sites and the lack of available QC data and metadata, many of these criteria could not be directly assessed. An exhaustive review of comment fields was conducted to determine if the comments provided additional information such as sample preservation or processing procedures, holding times or titration endpoints, or other data quality issues. In some cases, Battelle was able to assign the following data qualifiers based on the comments:

- U qualifier was assigned if the comment indicated that the value was less than a specific value (e.g., "<0.05 µg/L)."
- J qualifier was assigned if the value was deemed an estimate. Data were classified as estimates if they were less than the reporting limit, if samples did not meet holding time or holding condition requirements, or a QC failure was noted. This is consistent with national validation guidelines.
- S qualifier (suspect) was assigned if the data entry comment indicated that it was suspect; if the parameter was marked as a highly variable compound; if the method high range was exceeded; or if processing errors were noted.

However, the lack of metadata that would enable an assessment of data quality (e.g., analytical laboratories, quality control data, and assignment of data qualifiers) left the majority of data without clear "proof" of quality using the DQO criteria. Although the DQOs specified that such data be flagged as estimated values to be used with caution, the study team determined that too much data would be lost using this approach. Therefore, data were evaluated using the approach described in Appendix A.

Based on the data quality assessment, the quality of groundwater, surface water and spring water data cannot be verified and should be used with care for the following reasons: the analytical laboratories, analytical methods and laboratory quality control data or quality-related qualifiers are unknown or not reported. Quality system elements that support the data include collection organizations with known quality systems (surface and spring water data) and detection limits adequate for comparison with regulatory and screening values (with the exception of arsenic in groundwater).

2.4 Applicable Regulatory Framework

A brief discussion of federal and state regulations is relevant because such regulations influence various activities related to local environmental conditions and set water quality standards. A chronology of relevant laws is provided in Figure 2-2. These include laws related to groundwater and surface water quality and environmental restoration. Regulations that have been in place in North Dakota to regulate oil and gas activities also are presented in Figure 2-3.

2.4.1 Relevant Water Quality Regulations. For comparison purposes, historical data are compared to water quality criteria from various sources. Although these values may not be directly relevant or applicable, they are used in this document as screening values. Results above screening criteria do not indicate that corrective action (e.g., remediation) is required, but may suggest that water quality is different from what would be expected, possibly due to anthropogenic or natural conditions. A detection above water quality criteria should not be interpreted as indicative of an impact. In order to assess if an impact has occurred, or if corrective action is suggested, a thorough investigation would have to be performed; this is beyond the scope of this desktop study. Relevant water quality statutes, regulations and guidance used to select screening criteria are summarized below.

North Dakota Water Commission (NDWC). The NDWC was established in 1937 in response to prolonged drought that occurred in the state. The legislation was codified as the North Dakota Century Code Chapter 61-02. The commission fosters water resource management and water resource project development. It provides coordination in water resource programs with federal agencies and local entities. The commission also is responsible for the collection, storage, interpretation, and dissemination of hydrologic and water quality data. In 1945, the state legislature combined the Office of the State Engineer with the State Water Commission.

U.S. Clean Water Act. The Clean Water Act (CWA) was passed in 1972 and established regulations for the discharge of pollutants into U.S. waters and set water quality standards for surface water. It expanded upon the original 1948 law called the United States Water Pollution Control Act. The CWA regulates point sources through the National Pollutant Discharge Elimination System (NPDES) permit program. It also established the concept of total maximum daily load (TMDL), which is a calculation of the maximum amount of a pollutant that a water body can receive and still meet designated water quality standards. TMDLs are specific to the impaired water body and regulate the maximum amount of contaminant loading from both point and non point sources. Since 1975, North Dakota has had delegated authority to enforce the CWA.

U.S. Safe Drinking Water Act. The Safe Drinking Water Act (SDWA) was enacted in 1974 and amended in 1986 and 1996 to establish maximum contaminant levels (MCLs) and secondary maximum contaminant levels (SMCLs). MCLs are established to protect public health from contaminants in drinking water by balancing potential health risks and the cost of treatment. An MCL represents the maximum allowable amount of a contaminant that can be delivered to a consumer by a public water system (PWS). An SMCL is a non-enforceable water quality standard for constituents that may cause taste, odor, or color concerns in drinking water. These non-mandatory SMCLs are established as

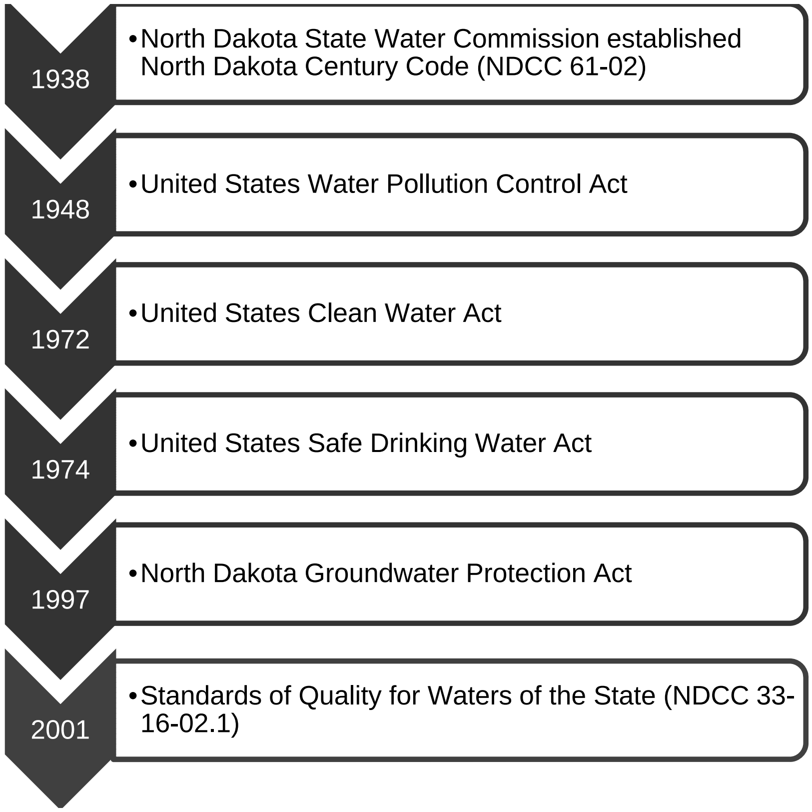


Figure 2-2. Timeline of Environmental Statutes and Regulations

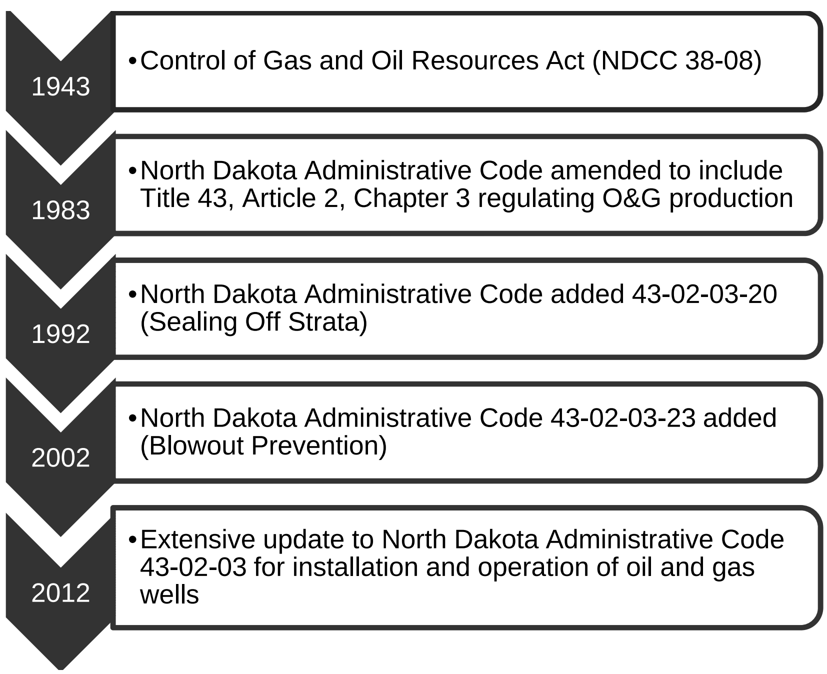


Figure 2-3. Timeline of Statutes and Regulations Associated with Oil and Gas Activities

guidelines for PWSs to address aesthetic and taste issues and do not represent a health risk. North Dakota has primacy to enforce the SDWA.

North Dakota Groundwater Protection Act. This act establishes a degradation prevention program for the purpose of protecting groundwater resources, encouraging the wise use of agricultural chemicals, providing for groundwater protection, providing for public education regarding preservation of groundwater resources, and providing for safe disposal of wastes in a manner that will not endanger the state's groundwater resource (North Dakota Century Code (NDCC) 23-33-01). The law contains chapters on groundwater standards, groundwater monitoring, public wellhead protection, and pollution prevention criteria.

Other State Environmental Regulations. Several other environmental laws have been enacted by the state of North Dakota, including those that set water quality standards and criteria. Effective in 2001, the NDCC, Chapter 33-16-02.1, Standards of Quality for Water of the State was enacted to establish a system to classify waters of the state, provide standards of water quality for waters of the state, establish effluent limits, and protect existing and potential beneficial uses of waters of the state. This chapter states that appropriate action will be taken by the state health department following procedures approved by the EPA if any public or private project or development causes a detrimental change to the quality of water. Class 1 streams are defined as streams having a quality of water suitable for the propagation and/or protection of resident fish species and other aquatic biota and for recreation purposes such as swimming and boating. The chapter establishes separate criteria for chronic aquatic life impacts and human health impacts. The chronic aquatic life standards are defined as the four-day average concentration not exceeding the listed concentration more than once every three years. The chapter lists human health values based on two routes of exposure comprising ingestion of contaminated aquatic organisms and drinking water, and a value based on only ingestion of contaminated aquatic organisms. The latter has the higher human health value and was established for streams that generally have low average flows and prolonged periods of no flow.

2.4.2 Oil and Gas Related Laws and Regulations. State laws regulating the oil and gas industry in North Dakota have been in place since 1943. Oil and gas rules and regulations are stated in Title 38 of the NDCC, 38-08, Control of Gas and Oil Resources, and Title 43, Article 2, Chapter 3 of the North Dakota Administrative Code (NDAC 43-02-03). These chapters contain general rules of statewide application which have been adopted by the NDIC to conserve the natural resources of North Dakota, to prevent waste, and to provide for operation in a manner as to protect correlative rights of all owners of crude oil and natural gas. In 1983, Title 43, Article Chapter 38-08 (Control of Gas and Oil Resources) of the North Dakota Revised Code was enacted by the Legislative Assembly in 1943. It was amended in 1992 to include regulations pertaining to sealing off strata (NDCC 43-02-03-20), again in 2002 to add a section on blowout prevention to ensure proper and necessary precautions are taken to keep the well under control. NDCC 43-02-03-20 was recently amended again in August 2011. The law requires that a permit be obtained from the NDIC prior to the drilling of an oil and gas well. Title 38 of the NDCC also regulates:

- 38-08.1: Geophysical exploration requirements (amended August 2009)
- 38-11.1: Oil and gas production damage compensation (amended August 2011)
- 38-11.2: Subsurface exploration damages (amended August 2011)
- 38-22: Carbon dioxide underground storage (amended April 2010)

NDAC 43-02-03 regulates the drilling and plugging of wells, oil and gas production operating practices, oil proration and allocation, secondary recovery practices, and purchasing, transporting and refining. In response to the recent exponential growth in oil and gas exploration and production in North Dakota, the NDIC has promulgated significant changes to NDAC 43-02-03 to ensure the oil industry remains good stewards of the land, while maintaining an attractive business climate in North Dakota (NDIC, 2012). A summary of some key components of this rule, which became effective on April 1, 2012, are provided in Table 2-4.

Table 2-4. Summary of Select Rule Changes to NDAC 43-02-03

Rule	Key Change
Permit to Drill	• Considers embrittlement due to hydrogen sulfide when considering recompletions
Drilling Units	• Allows temporary spacing order effective for up to 3 years instead of 1 ½ years
Site Construction	• Amends rule to address only initial well site construction • Soil stabilization additives and materials require approval from Director • Must reduce size of well site after completion if not used f/well operations
Disposal of Waste Material	• Requires all waste material from undesirable events to be immediately disposed
Drilling Pits	• Creates new section addressing pits allowing cuttings, but no fluids • Must reclaim pit w/in 30 days after drilling well; however Director may grant exceptions • Allows small lined pit for trench water and rig wash, but must be reclaimed • Must dike pit to keep surface water from entering
Reserve Pits	• Creates new section allowing reserve pits only for wells < 5000 ft deep or salt water disposal • Must reclaim pit within one year after completing well • Must slope surface to promote surface drainage away from reclaimed area
Casing, Tubing, and Cementing	• Requires remedial work for inadequate surface casing job to be approved by Director • Requires surface casing pressure test after cementing
Hydraulic Fracturing Stimulation	• Creates new section addressing hydraulic fracture stimulation • Must use pop-off valves, rupture disk, remote valve • Use hydraulic fracturing string, no chemical disclosure if > 350 psi on annulus after fracturing • Fracturing down casing: run casing evaluation for thickness of casing and cement with chemical disclosure
Safety Regulation	• Incorporates language removed from 43-02-03-05 on well shut in for public safety • Requires automatic shutdown of equipment if well is threat to public health or safety • Prohibits injection equipment from being installed < 500 ft from occupied dwelling
Leak and Spill Cleanup	• Creates new section and incorporates language from 43-02-03-49 & 53 • Requires operators to respond with appropriate resources to contain and clean up spills

Source: NDIC, 2011

Most of the regulations were in place at the time of the Franchuk 44-20SWH incident; the only significant change was that NDAC 43-02-03-30.1, Leak and Spill Cleanup was enacted (April 1, 2012). This regulation specifies that spills or leaks not be allowed to flow over, pool, or rest on the surface of the land or infiltrate the soil, that discharged fluids are properly removed and not allowed to remain standing within or outside of diked areas, and that operators must respond with appropriate resources to contain and clean up spills. This regulation replaced clauses in previous regulations that were in place to regulate spilling and pooling of liquids.

3.0: DATA ANALYSIS

The quality of groundwater and surface water is affected by a range of factors including land use patterns, watershed characteristics, hydrology, geohydrology, and water resource management practices. The role of land use is discussed below, along with a review of historical groundwater and surface water quality across Dunn County.

3.1 Land Use

Dunn County was formed in 1883. The total population in the county is 3,536 within 2,008 square miles of land, which yields a density of 1.8 persons per square mile (U.S. Census Bureau, 2010). This represents a 1.8% decrease from the population of 3,600 in 2000 (U.S. Census Bureau, 2010).

Dunn County was initially settled by farmers and ranchers; therefore, agriculture has always been a principal industry. Figure 3-1 shows the most recent land use map compiled by the USGS (USGS, 2010). The corresponding area for each land use type was determined and used to generate the percentage of land use dedicated to each category. These categories are tabulated in Table 3-1. Agriculture is the predominant land use, comprising over 90% of the total. Rangeland represents about 48% of the agricultural land use while cropland and pastures represent about 44%.

Table 3-1. Summary of Land Use Statistics for Dunn County in 1986

Category	Area (mi^2)	Percentage
Industrial, Commercial and Services	1.3	< 0.1%
Cropland and Pasture	909	43.6%
Deciduous Forest Land	90.1	4.3%
Wetlands	17.5	0.8%
Rangeland	995	47.7%
Water Bodies	68.5	3.3%
Residential	0.7	< 0.1%
Strip Mines, Quarries, and Gravel Pits	0.1	< 0.1%
Transportation, Communications, and Services	0.2	< 0.1%

Conventional oil and gas extraction began in 1960 and produced a relatively small quantity of oil during the 1960s and early 1970s (a few hundred to a few thousand barrels per month). Oil production increased by an order of magnitude during the late 1970s. Horizontal drilling and hydraulic fracturing were introduced in 1987 and have contributed to another boom in the oil and gas exploration and production industry in recent years (beginning around 2005). Currently, more than 2 million barrels are produced in Dunn County each month (NDIC, 2012). It should be noted that although coal is present beneath Dunn County, mining has never been a substantial industry.

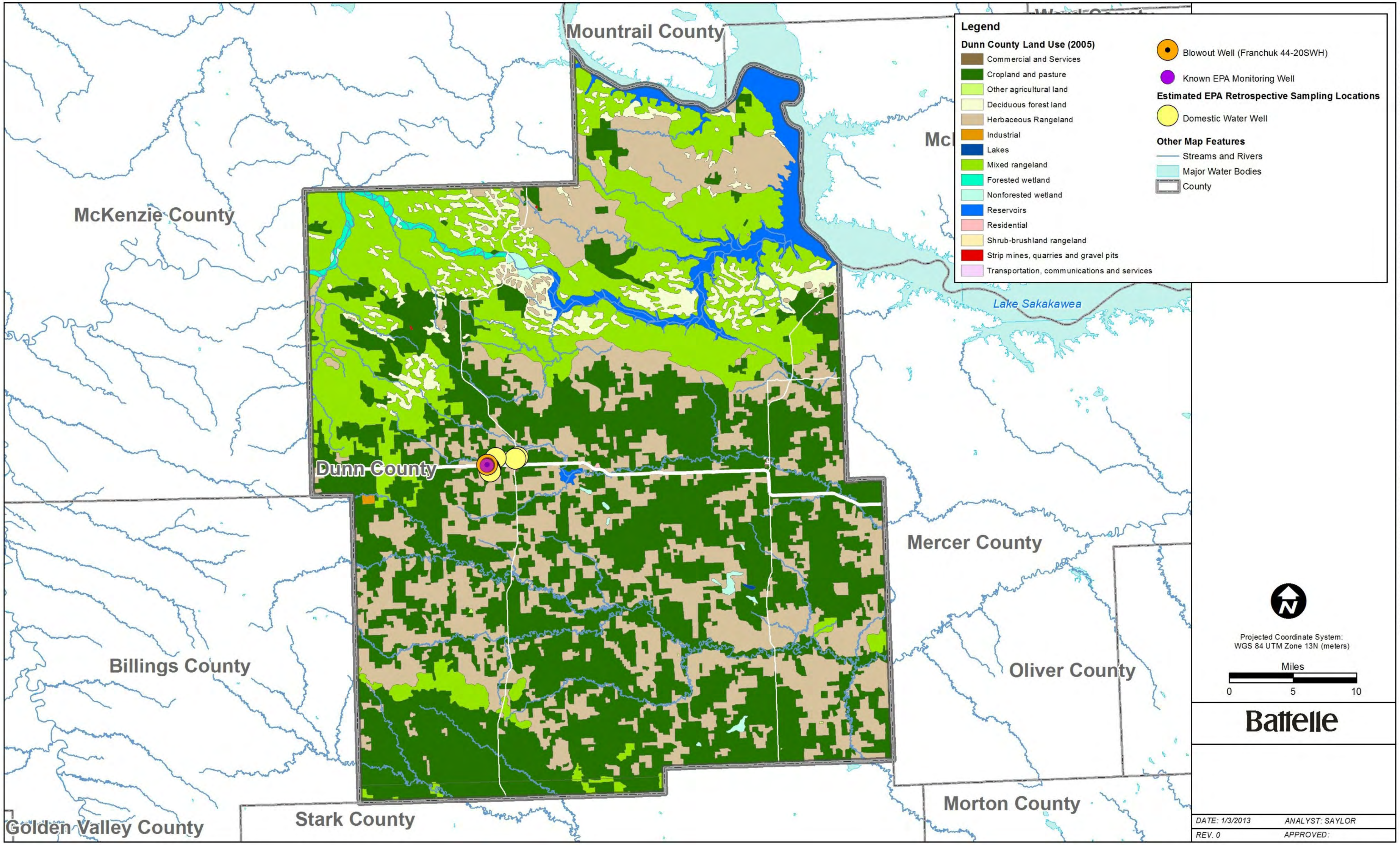


Figure 3-1. Land Use Map for Dunn County (USGS, 1986)

The causes of water quality impairments in the county are attributed to agriculture including grazing and feeding of animals and atmospheric deposition (EPA, 2012a). However, other non point sources and stormwater runoff, oil and gas exploration and production activities, and municipal and other wastewater discharges may influence water quality. These various land use activities are discussed below.

3.1.1 Agriculture. Agriculture is the largest industry in Dunn County. Approximately 1,800 square miles of the county were dedicated to agricultural activities in 2011 (USDA, 2011), which is similar to the land use data reported for 1986 (Table 3-1). This includes land dedicated to crop production where herbicides, insecticides, fungicides, and fertilizers may be applied, as well as pastures for livestock production where manure may be a source of nutrients and pathogens. Crop production in Dunn County represents about 25% of the agricultural land use[12] and is predominantly wheat (about 52%) (USDA, 2011). Acreage utilized for crops was fairly similar at the turn of the 20th century (approximately 28%); however, at that time the predominant crop (about 70%) consisted of “other small grains” (USDA, 2011).

Livestock production primarily includes cattle, hogs, sheep and poultry. Approximately 130,000,000 gallons of waste, containing 6,300,000 lb of nitrogen and 1,700,000 lb of phosphorous were produced from livestock in 1997 (Scorecard, 2012). Although this represents a 6% reduction compared to waste produced in 1987, Dunn County is ranked in the 80 to 90 percentile for counties producing the most animal waste in the United States (Scorecard, 2012).

There are approximately 168 miles of impaired streams and rivers located within Dunn County, representing a relatively small portion of the total length of streams and rivers in the county. Of the 168 miles of impaired waterways, approximately 43 miles are impaired by E. coli and/or fecal coliform, most likely resulting from agriculture (EPA, 2012a).

3.1.2 Other Non-point Sources and Stormwater Runoff. Runoff from impervious surfaces and other non point source discharges can affect the quantity and quality of surface water and groundwater recharge. Stormwater runoff from urban areas, suburban residential areas, and roads are known to have caused surface water impairments in the Knife Watershed. These include 26.4 miles of stream impairments caused by urban runoff/storm sewers, combined sewer overflow and sanitary sewer overflow (EPA, 2012a). EPA does not identify impairments due to these types of discharges for the other three watersheds that cross Dunn County.

Urban runoff may contain suspended solids, nutrients (e.g., phosphorous), heavy metals (e.g., arsenic, cadmium, mercury), organic contaminants (lawn pesticides, chlorinated solvents), and pathogens. Road runoff from road salt application may contain chloride and bromide (Solars et al., 1982). Runoff from impervious roadways also can be a source of heavy metals (e.g., iron, lead, zinc) and VOCs (e.g., benzene, toluene, ethylbenzene, and xylene [BTEX]) related to automobile use (EPA, 1995). These inputs occur with rainfall and the concentrations have been found to be dependent on the length of the preceding dry period (Hewitt and Rashed, 1992).

3.1.3 Municipal and Other Wastewater Discharges. Human waste disposal methods include centralized wastewater treatment facilities (WWTFs), decentralized small systems and on-site sewage disposal. In rural areas and older homes, on-site sewage treatment and disposal may include septic systems and cesspools. There are currently five NPDES permitted locations in Dunn County with allowable discharges of effluent, including four city wastewater treatment facilities and one school located on a Native American reservation. Although these are permitted discharges, violations of these permits can occur along with accidental releases above regulatory levels.

[12] Assumes all grassland herbaceous is used for agriculture and includes fallow/idle cropland.

Most recently, North Dakota is experiencing tremendous population growth due to oil exploration and production. Many cities are reporting a strain on water infrastructure. For instance, the City of Williston located in Williams County, has exceeded the capacity of its WWTF and sewage has been discharged directly to the environment. According to North Dakota Department of Health (NDDH), Watford City located in McKenzie County is in the process of designing and upgrading its WWTF to meet anticipated future needs (NDDH, 2012a).

Recently, temporary housing communities called "man camps" have spread throughout various counties in North Dakota (including Dunn County) in response to the booming oil and gas industry combined with a lack of available housing. Although the NDDH requires application of a direct discharge permit for any wastewater discharge leaving property via surface drainage, these camps are reported to be straining water and sewer systems (NDDH, 2012b).

In the absence of adequate treatment, all of these wastewater disposal methods may discharge pathogens, household and industrial chemicals, suspended solids, increased biochemical oxygen demand (BOD), and nutrients into receiving waters. It is estimated that 25% of household and industrial chemicals may pass in the discharge to receiving waters even after treatment at a WWTF (EPA, 1997). Septic systems and on-site disposal also can directly impact water quality in nearby downgradient drinking water wells. Municipal point source discharges and municipal (urbanized high density) areas contribute approximately 71 miles of impairment in the Knife and Upper Heart sub basins, respectively (EPA, 2012a). No impairments due to these types of discharges are identified for the Lake Sakakawea and Lower Little Missouri sub basins.

3.1.4 Industrial, Manufacturing, and Commercial Activities. The primary industry in Dunn County other than agriculture is the oil and gas industry, which is described in Section 3.1.5. Other commercial activity includes construction, transportation, and repair and maintenance. Manufacturing appears to be very limited.

There are 128 facilities or locations with recognized environmental impacts and/or sites that are subject to applicable federal and state environmental regulations. Figure 3-2 shows the location of these facilities[13] across Dunn County. A few of these locations had very similar (if not the same) coordinates, which may indicate multiple impacts or a duplication in the database. The facilities with environmental impacts include five storage tank incident sites. About 15% (12) of the sites listed are schools while about 20% (16) of the sites are oil and gas related based on the names of listed companies. The oil and gas related entries include seven pipeline sites, three exploration sites, two gas plants and two compressor stations, and one site each is owned by an oil company and an oil field service company. There are no brownfield sites reported for Dunn County nor was there any reported release of chemicals (through March 2012) to the environment regulated under the Toxic Release Inventory (TRI) program through on- or off-site disposal or other releases (EPA, 2012b).

Constituents of concern (COCs) from these types of industrial operations might include metals (e.g., aluminum, arsenic, barium, cadmium, chromium, lead, and mercury), acids, caustics, cyanides, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and chlorinated solvents. In addition, leaking underground storage tanks (USTs) and above ground storage tanks (ASTs) may be associated with contamination of soil and groundwater with petroleum hydrocarbons, BTEX, and oxygenates. Petroleum hydrocarbons released from storage tanks can degrade to methane, but methane is not routinely included in groundwater investigations at USTs and ASTs. Therefore, methane is typically lacking in the secondary data at these sites.

[13] Location coordinates were not available for 42 sites; hence, those sites are not depicted on Figure 3-3.

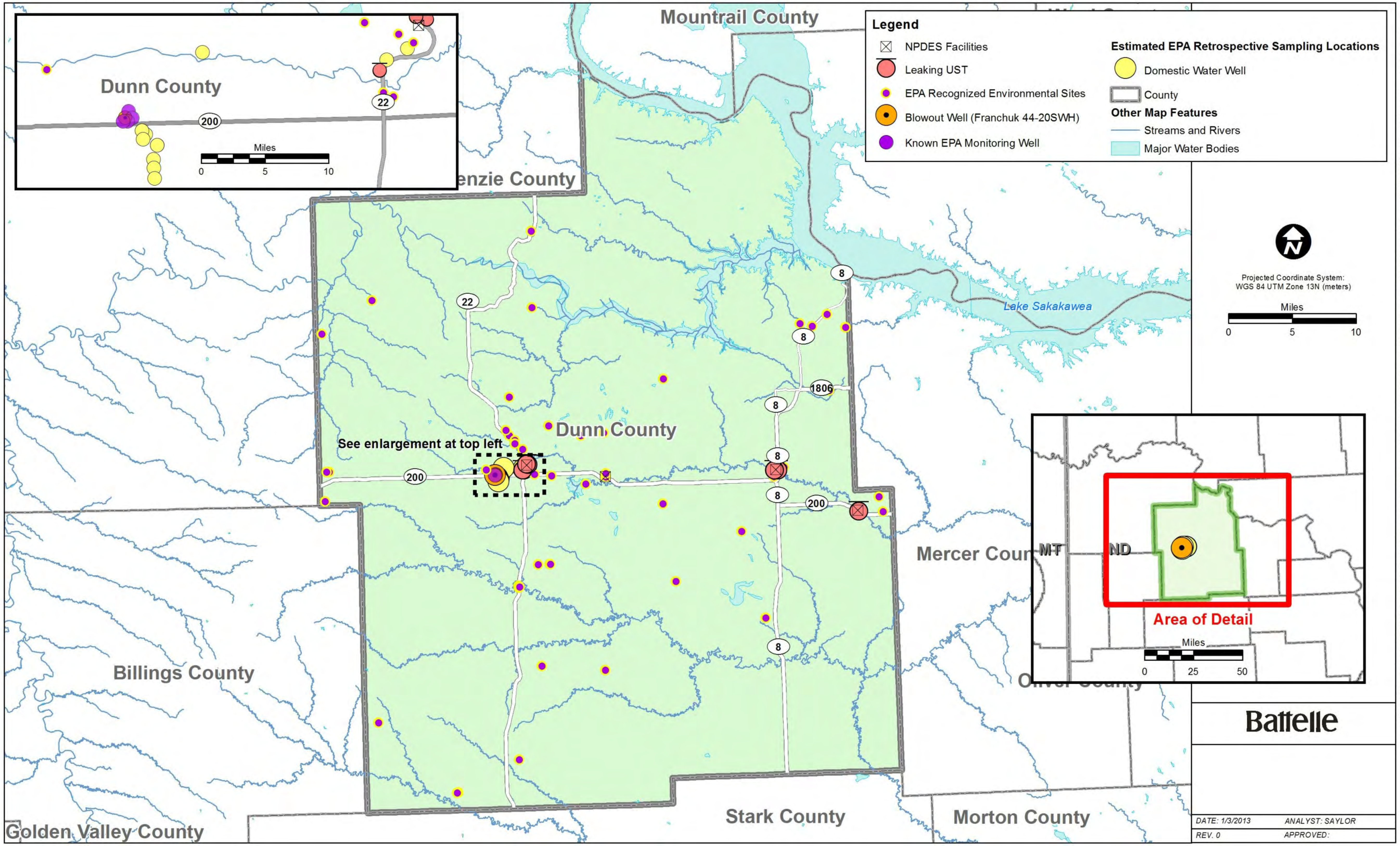


Figure 3-2. Sites with Recognized Environmental Conditions in Dunn County

3.1.5 Conventional and Unconventional Oil and Gas Development. The existence of petroleum hydrocarbons in North Dakota formations has been known for over a century. The first reported discovery of natural gas was in 1892 from a Dakota Sandstone water supply well near Edgeley (Heck et al., 2012). Shallow gas was recovered in the early 1900s and supplied several small towns in Bottineau County. The oldest commercial production was in 1929 with the establishment of the Cedar Creek gas field (Heck et al., 2012).

Oil was not discovered in North Dakota until 1951 when the Amerada Hess Corporation completed the Clarence Iverson #1 on the Nesson anticline (Heck et al., 2012). Since then oil production has been nearly continuous over the last 60 years. Oil has been recovered from 35 formations, the most prominent being the Madison and the Bakken formations, which have produced about 46% and 16%, respectively, of the oil recovered. North Dakota oil production peaked in 1984 at about 440,000 barrels per month (NDIC, 2012), but declined and remained consistent throughout the 1990s, ranging from about 240,000 to 300,000 barrels per month. In Dunn County, from the 1990s through about 2006, production rates fluctuated between about 60,000 to 160,000 barrels of oil per month recovered from around 100 wells. From 1990 through 2005, between 4,000,000 and 5,000,000 thousand cubic feet (Mcf) of natural gas was recovered monthly; however, production began to exponentially increase in 2005 with the advent of horizontal drilling, increasing to a monthly recovery of greater than 13,000,000 Mcf in 2011(NDIC, 2011). Figure 3-3 shows the locations of 1,095 conventional oil and gas wells completed in Dunn County. Because of the lack of complete historical records, well numbers and locations have some inherent uncertainty. There are 21 conventional salt water disposal wells within Dunn County. Of the 21 disposal wells, 18 are active, two are inactive, and one is abandoned. The depth of the wells ranges from 5,782 to 14,430 ft..

Horizontal drilling began in North Dakota in 1987 when Meridian Oil, Inc. installed the first horizontal well in the Bakken formation. Horizontal drilling was attained at about 10,700 feet bgs and horizontal displacement of about 2,600 ft (Wordpress, 2011). Upon completion, the well produced 258 barrels per day. This initial success prompted a flurry of application for permits for horizontal wells.

Of particular importance to oil and gas development in North Dakota and in particular Dunn County is the development of the Bakken formation. Estimates of oil in this formation have ranged from 10 to 400 billion barrels of oil (LeFever, 2005). Much of this oil is trapped in a relatively thin layer of dense rock located about 2 miles bgs, making it difficult and costly to recover. However, recent advances in horizontal drilling technology and hydraulic fracturing have made recovery in this formation cost effective. As a result of horizontal drilling, recovery from this formation has increased to more than 2,500,000 barrels between 2006 and 2012 (NDIC, 2012), and as stated above, the recovery of natural gas has increased substantially. As of early 2012, 519 horizontal wells have been installed. Figure 3-4 shows the location of unconventional oil wells drilled into the Bakken formation in Dunn County.

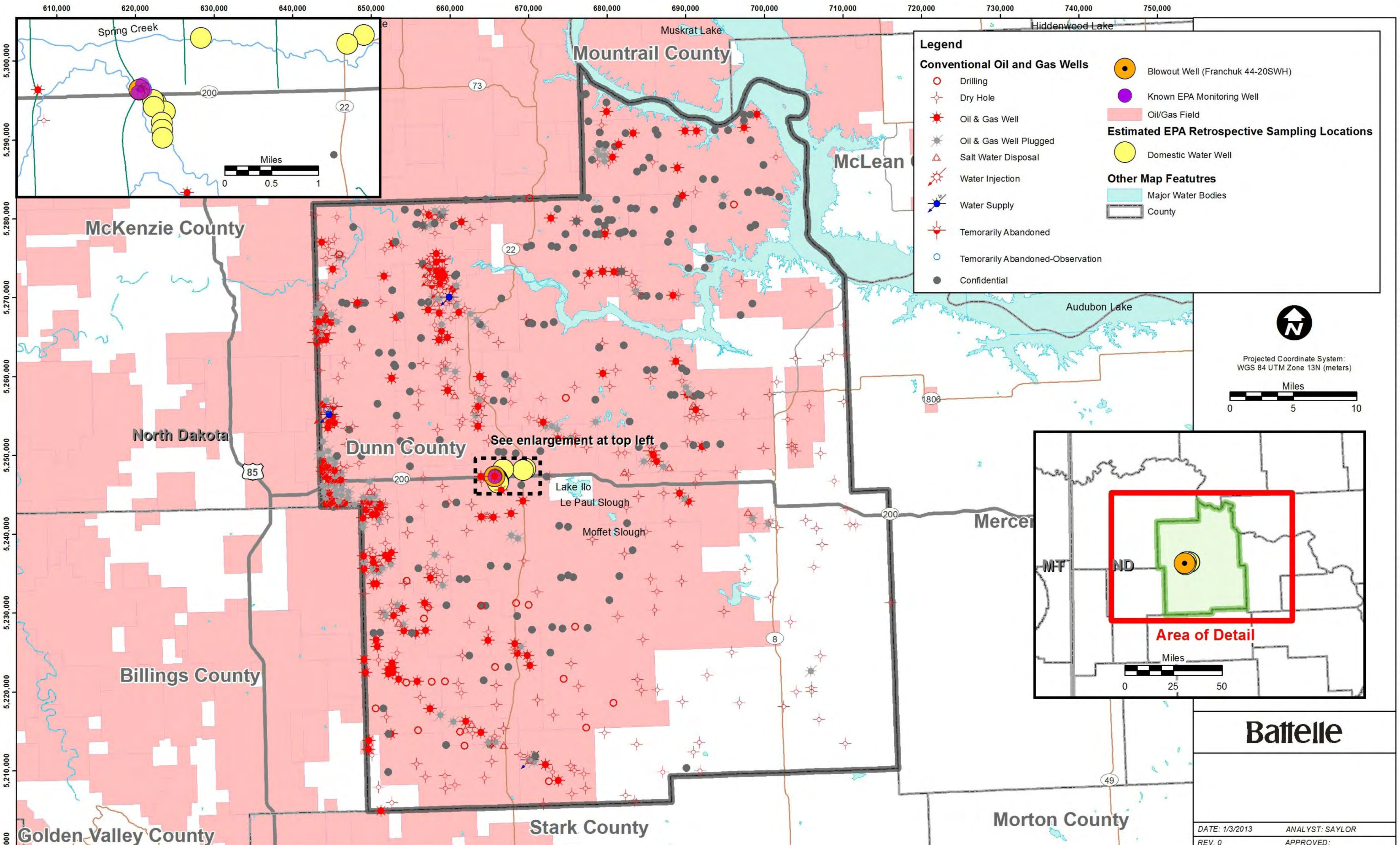


Figure 3-3. Historic Oil and Gas Fields and Conventional Oil and Gas Well Locations

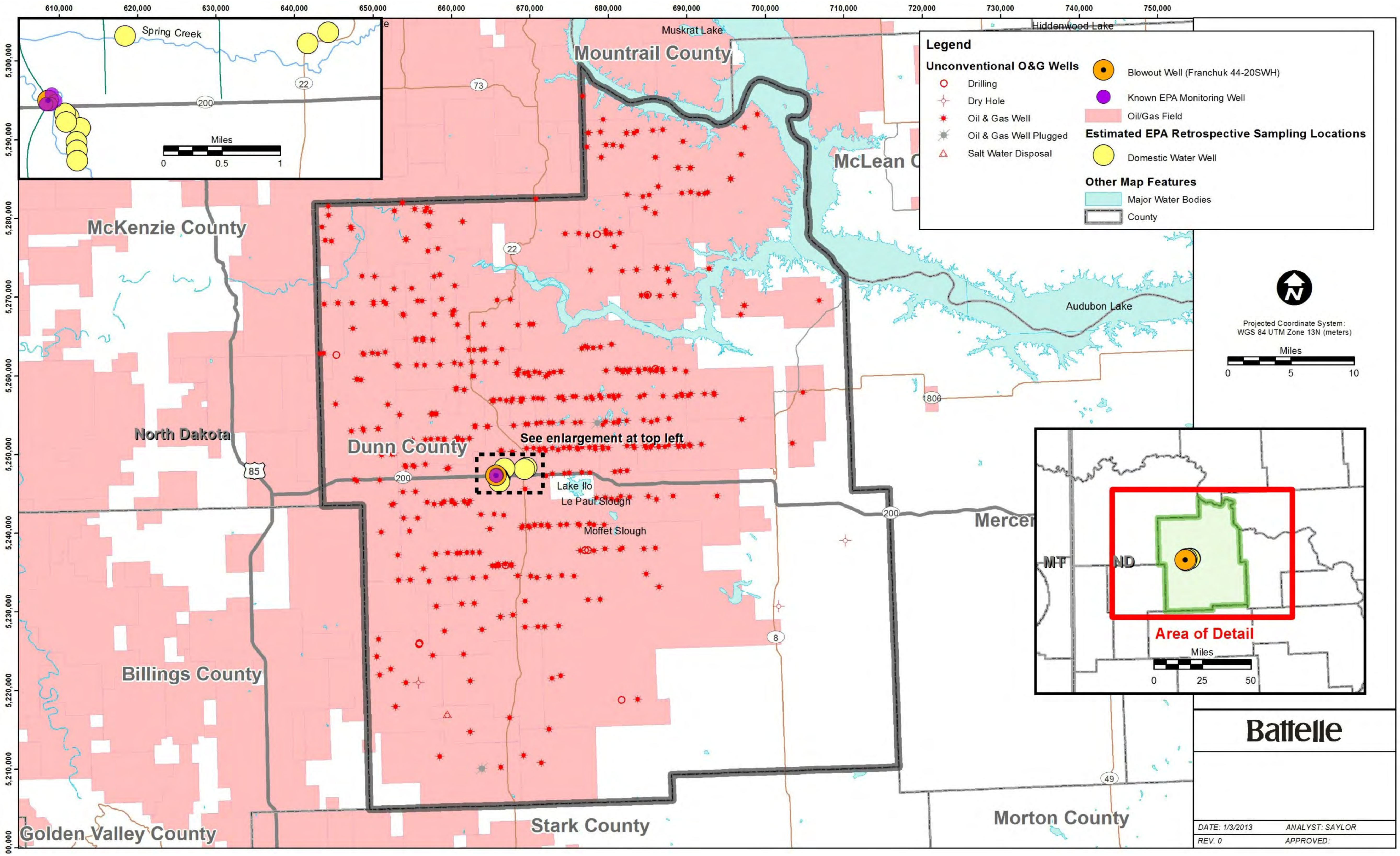


Figure 3-4. Unconventional Well Locations within Dunn County

Petroleum hydrocarbons can migrate in the environment in close proximity to oil and gas deposits and seeps, whether such migration is naturally occurring or from abandoned or poorly constructed wells that penetrate hydrocarbon-bearing zones. Metals, salts and naturally-occurring radioactive materials (NORM) also may be present in the environment near these deposits and seeps. Due to the high level of historic oil and gas drilling in Dunn County, migration pathways undoubtedly exist from the historic producing horizons to shallow groundwater aquifers. The oil and gas industry is aware of potential pathways associated with historic oil and gas wells, and has identified several approaches for evaluating these pathways (e.g., using remote sensing technologies and on-the-ground field surveys [e.g., McKee, 2012]). Oil and gas regulatory agencies in producing states proactively manage orphan wells within their jurisdiction, generally evaluating the potential risk posed by each identified well, and mitigating the highest risk wells first. The Interstate Oil & Gas Compact Commission (IOGCC) formed an Orphan Well Task Force to address the requirements in Section 349 of the Energy Policy Act of 2005. This Task Force provides for the establishment of a program to provide technical and financial assistance to oil and gas producing states to deal with environmental issues associated with abandoned or orphan wells. In summary, while the potential for pathways exist, industry and state agencies are well aware of the situation and are taking steps to mitigate those risks.

3.2 Groundwater Quality

This section summarizes groundwater resources in Dunn County including the major groundwater-bearing units and groundwater quality data in comparison to relevant regulatory standards and criteria.

3.2.1 Groundwater Resources and Monitoring Wells. Most of the water used in Dunn County is obtained from wells tapping sandstone and lignite aquifers in the upper portion of the Sentinel Butte formation, which is present at ground surface throughout the majority of the county. The rural population of Dunn County relies upon groundwater for domestic and livestock use. Groundwater wells range up to 2,000 ft deep, but most wells are less than 200 ft deep. The city of Halliday obtains a portion of its municipal water supply from a 1,555 ft well in the consolidated Fox Hills aquifer, while the city of Killdeer obtains its water supply from a 70 ft well in the unconsolidated Killdeer aquifer.

There have been 447 permitted water wells installed in Dunn County since 1912 (NDSWC, 2012). These wells are subdivided based on purpose: 12 domestic, 10 industrial, seven municipal, 187 observational, and 217 of unknown use. Of the observational wells, 130 are listed as either plugged or destroyed. Of the remaining 57 observational wells, 28 are screened in the glacial fluvial sand and gravel deposits, 20 are screened in the Sentinel Butte and/or Tongue River formation and one well is screened in the Fox Hills formation. The formations in which the remaining eight wells are installed are undefined. The locations of these wells are shown on Figure 3-5.

3.2.2 Hydrogeology. Groundwater resources in Dunn County occur within unconsolidated Quaternary glacial drift deposits and consolidated Tertiary and Upper Cretaceous sedimentary rocks (Table 3-2). Water from the unconsolidated deposits is hard to very hard and predominantly a sodium bicarbonate type. Water from the sedimentary rocks is generally soft and also of a sodium bicarbonate type.

Figure 3-5 depicts the shallow groundwater-bearing formations found in the county. The unconsolidated Quaternary glacial drift deposits consist of till and glaciofluvial sand and gravel deposits. The till is not known to yield water to wells in Dunn County. The glaciofluvial sand and gravel deposits are contained in glacial melt-water channels and contain large quantities of groundwater. Unconsolidated aquifers in the county include the Killdeer Aquifer, the Horse Nose Butte Aquifer, the Knife River Aquifer, the Goodman Creek Aquifer, and undifferentiated sand and gravel aquifers. Characteristics of these aquifers are presented in Table 3-3 (USGS, 1979). In general, depth to groundwater in the discontinuous areas

Table 3-2. Generalized Geologic Sections and Water Yielding Characteristics of Lithologic Units in Dunn County, North Dakota

System	Series	Lithologic Unit, Group, or Formation		Maximum Thickness (ft)	Lithology	Water-Yielding Characteristics
Quaternary	Holocene	Alluvium		40	silt, sand and gravel	Maximum yield of 50 gpm to individual wells from thicker and more permeable sand and gravel deposits
	Pleistocene	Glacial drift		310	till, silt, sand and gravel	Yields as much as 1,000 gpm to individual wells from thicker and more permeable sand and gravel deposits
Tertiary	Eocene	Golden Valley formation		375	Sandstone, silt, clay, claystone, lignite, and carbonaceous shale	Yields 1 to 20 gpm from springs
	Paleocene	Fort Union Group	Sentinel Butte formation	670	Clay, claystone, shale, sandstone, siltstone, and lignite	Individual wells in sandstone will yield 5 to 100 gpm. Individual wells in lignite will yield 1 to 200 gpm
			Tongue River formation	490	Clay, claystone, shale, sandstone, siltstone, and lignite	Yields to individual wells in sandstone generally less than 100 gpm
			Cannonball and Ludlow formations, undifferentiated	660	Cannonball - marine sandstone, clay, shale, and siltstone Ludlow - continental siltstone, sandstone, shale, clay and lignite	Yields to individual wells in sandstone generally less than 50 gpm.
Upper Cretaceous		Hell Creek formation		300	Siltstone, sandstone, shale, claystone, and lignite	Yields from 5 to 100 gpm to individual well sin sandstone
		Montana Group	Fox Hills formation	300	Sandstone, shale, and siltstone	Yields to individual wells generally less than 200 gpm from thicker sandstone beds. Locally, yields to individual wells may be as much as 400 gpm
			Pierre formation	2,300	Shale and silt	Not known to yield water to wells

Source: USGS, 1979

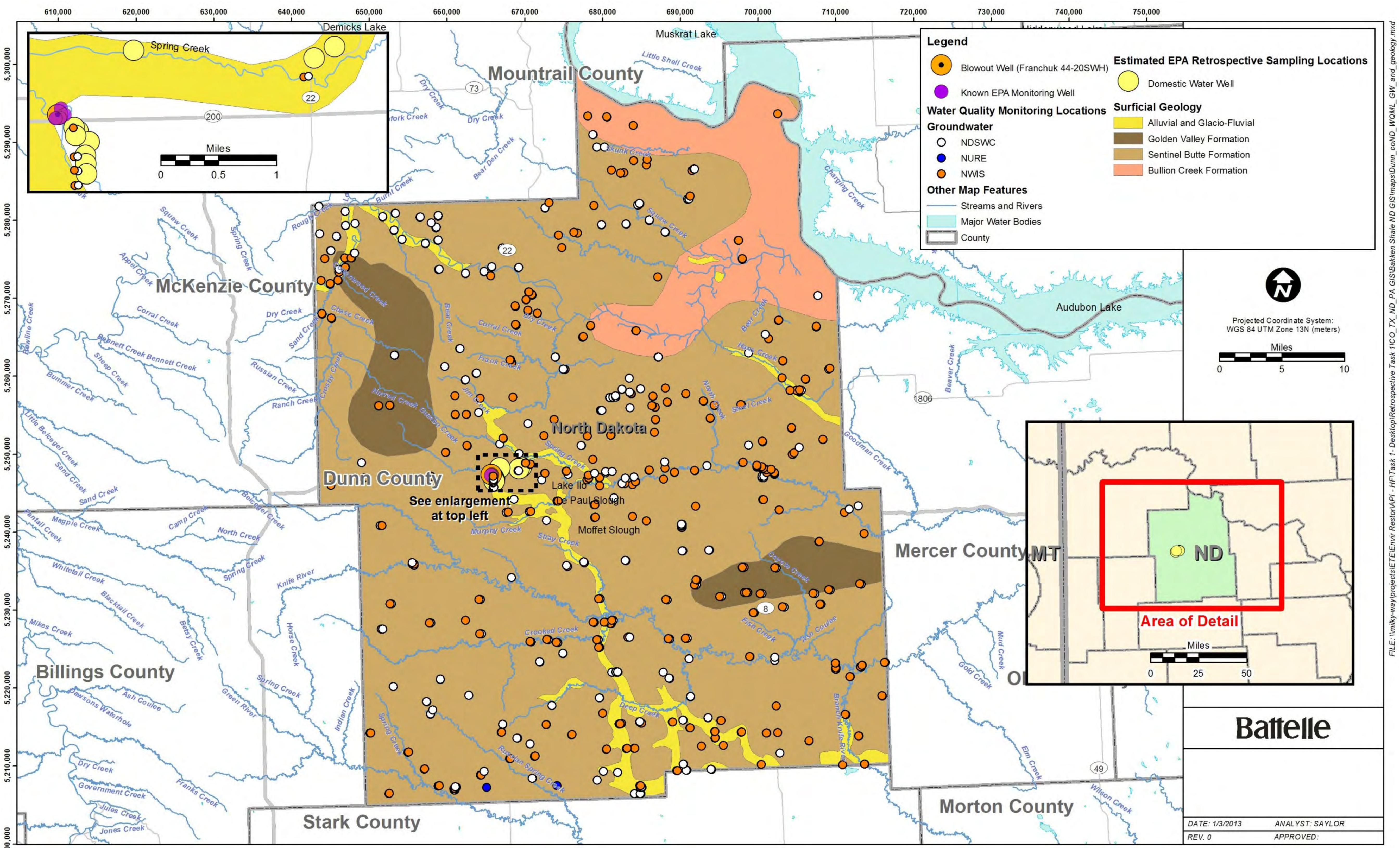


Figure 3-5. Monitoring Locations and Shallow Groundwater Bearing Formations Dunn County, ND

Table 3-3. Characteristics of Unconsolidated Aquifers in Dunn County, ND

Aquifer	Underlain Area (mi^2)	Lithology	Well Yields (gpm)	Depth to Groundwater (ft)	Water Quality
Killdeer Aquifer	74	fine to medium sand	50 to 1,000	0 to 40	very hard; sodium bicarbonate or sodium sulfate
Horse Nose Butte Aquifer	10	very fine to very coarse sand	50 to 500	0 to >100	very hard; sodium bicarbonate
Knife River Aquifer	9	very fine to very coarse sand	50 to 1,000	3 to 20	hard to very hard; sodium bicarbonate
Goodman Creek Aquifer	6	sand and gravel with intervening clay layer	50 to 1,000	15 to 40	very hard; calcium bicarbonate, sodium bicarbonate, or sodium sulfate
Undifferentiated sand and gravel aquifers	limited	sand and gravel	5 to 10	10 to 60	hard to very hard; sodium bicarbonate or sodium sulfate

corresponding to these unconsolidated aquifers is zero to 100 feet. Well yields are generally 50 to 1,000 gallons per minute (gpm). Water is hard to very hard and generally of a sodium bicarbonate type, with calcium bicarbonate and sodium sulfate in some areas

The pre-glacial sedimentary rocks in Dunn County include (with increasing depth) the Tertiary Golden Valley, Sentinel Butte, Tongue River, Cannonball and Ludlow formations and the Upper Cretaceous Hell Creek and Fox Hills formations. These formations each contain varying amounts of sandstone, claystone, shale, siltstone, and lignite. Thick aquifer sections are present within the sandstone beds in each formation except the Golden Valley formation. Aquifers also occur within fractured lignite in the Sentinel Butte and Golden Valley formations, although those in the latter are small in areal extent and not known to be tapped by water supply wells (USGS, 1979). Yields from wells in aquifers within the Sentinel Butte formation and below are expected to be up to 50 to 200 gpm. Yields from the lignite aquifers within the Sentinel Butte formation are controlled by the degree of fracturing and the transmissivity of the adjacent rocks. Water in the sedimentary rocks is generally soft and of a sodium bicarbonate type, although water from the Sentinel Butte formation is hard to very hard.

More Recent USGS studies (DeSimone, 2009; Ayotte et al., 2011) examined water quality in principal aquifers across the U.S. from data collected in the 1991-2004 timeframe prior to substantial development of the Bakken in North Dakota via hydraulic fracturing. While not specific to Dunn County, both studies demonstrate the importance of understanding factors that contribute to observed water quality and identify important considerations for making comparisons between data collected from different locations and times.

DeSimone (2009) assessed contamination in domestic wells, variation among and within aquifers, and the co-occurrence of contaminants. Compounds found most frequently at concentrations greater than human health benchmarks were naturally occurring (radon, fluoride, gross alpha- and beta-particle radioactivity, arsenic, iron, manganese, strontium, boron, and uranium), with the exception of nitrate and fecal indicator bacteria. Patterns of occurrence related to rock type, land use, and geochemical conditions were also noted.

Ayotte et al. (2011) provided a comprehensive analysis of trace element occurrence in groundwater across the U.S. This study illustrates the importance of understanding how climate, well construction, geologic composition of aquifer and aquifer geochemistry affect trace elements detected in water quality. For example, arsenic, barium, boron, chromium, copper, molybdenum, nickel, selenium, strontium, uranium, vanadium and zinc were detected in greater concentrations in dry regions (Dunn County is characterized in the drier region) relative to humid regions due most likely to processes such as chemical evolution, complexation reactions, evaporation and geochemical processes acting to mobilize these elements. Concentrations of arsenic, barium, lead, lithium, strontium, vanadium, and zinc were significantly greater in drinking water wells than in monitoring wells. In agricultural areas, groundwater contained higher concentrations of arsenic, molybdenum and uranium in both dry and humid regions. Boron, chromium, selenium, silver, strontium and vanadium were elevated in drier regions while urban areas contained higher levels of cobalt, iron, lead, lithium, manganese, and specific conductance. Land use (e.g., agricultural vs. urban), aquifer composition, and geochemistry were major factors affecting trace element concentrations in groundwater. Ayotte et al. (2011) also noted glacial and non-glacial unconsolidated sand and gravel aquifers (such as the Killdeer aquifer) had the greatest percentage of trace elements above screening criteria. Overall, 19% of the wells had at least one trace element above screening criteria.

3.2.3 Data Summary. Groundwater quality data from sources identified in Table 2-2 were compiled by Battelle into a database to characterize Dunn County groundwater quality prior to unconventional oil and gas development (i.e., pre-2005). Figure 3-5 shows the 711 unique groundwater sampling locations, which are overlain on a map of the shallow groundwater-bearing formations in Dunn County. The data represent samples collected from 1937 through 2003. Groundwater data consist primarily of dissolved gas, general water quality parameters, major ions, metals, and nutrients. No samples were analyzed for VOCs or semi-volatile organic compounds (SVOCs).

Table 3-4 provides a pre-2005 list of inorganic parameters detected, number of samples, minimum, maximum, median, mean, standard deviation, date range for sample collection, and comparison against screening criteria, including the number of results above each criteria. Organic parameters are not included in this table since limited organic data are available. For groundwater, screening criteria include the MCL, SMCL, and EPA Region III carcinogenic and non-carcinogenic criteria. Section 2 provides an explanation of these relevant water quality benchmarks and how summary statistics were calculated. Table 3-4 also identifies those parameters monitored by EPA in the retrospective case study and including whether the parameter is a critical analyte (CA) or a measured (M) parameter per the EPA QAPP (EPA, 2011b). Appendix B includes a listing of all groundwater data collected for Dunn County.

As indicated in Table 3-4, the observed concentration is above one or more of screening criteria for two general water quality parameters: pH and total dissolved solids (TDS). For major ions (i.e., chloride, fluoride, sulfate, and sodium), the maximum, median, and/or mean observed concentration are above one or more relevant screening criteria. Chloride, sodium, and sulfate are identified as EPA critical analytes, whereas fluoride is identified as a EPA measured analyte. Chloride was above the SMCL of 250 mg/L in 11 samples, with a maximum concentration of 340 mg/L and a mean concentration of 30 mg/L. Sodium was higher than the EPA Health Advisory level of 20 mg/L in 778 samples, with a maximum concentration of 2,400 mg/L and a mean concentration of 446 mg/L. Sulfate was higher than the SMCL of 250 mg/L in 382 samples, having a maximum concentration of 5,520 mg/L and a mean concentration of 562 mg/L. The minimum, maximum, and/or mean observed concentration was higher in one or more of the screening criteria for several metals, including aluminum, arsenic, beryllium, boron, iron, manganese, mercury, phosphorus, and strontium. Observed arsenic concentrations were higher than the MCL, EPA carcinogenic risk screening levels, and non-carinogenic risk screening levels.

Table 3-4. Dunn County Groundwater Data Summary

Class	Parameter	Field Results	Frac.	Units	EPA Class	No. Samples	No. Locations	No. ND	Min	Max	Including NDs Median	Including NDs Mean	Including NDs SD	Excluding NDs Median	Excluding NDs Mean	Excluding NDs SD	Begin Sample Date	End Sample Date	MCL	N Above MCL (no NDs)	SMCL	SMCL High	N Above SMCL (no NDs)	EPA Carc.	N Above EPA Carc. (no NDs)	EPA Non-Carc.	N Above EPA NonCarc. (no NDs)
Dissolved Gas	Carbon dioxide	No	Tot.	mg/l	M	370	349	0	0.1	202	12	17.1	18.9	12	17.1	18.9	Oct-50	Sep-03									
Gen WQ	Alkalinity as CaCO3	No	Tot.	mg/l	M	20	19	0	240	1320	378	458	245	378	458	245	Jun-85	Sep-03									
Gen WQ	Alkalinity as CaCO3	Yes	Dis.	mg/l	M	12	12	0	228	610	365	384	104	365	384	104	Sep-94	Nov-94									
Gen WQ	Alkalinity as CaCO3	Yes	Tot.	mg/l	M	361	340	0	41	2060	623	727	457	623	727	457	Oct-50	Aug-78									
Gen WQ	Hardness as CaCO3	No	Tot.	mg/l	-	378	349	1	4.555	4400	170	320	529	170	320	529	Oct-50	Sep-03									
Gen WQ	Hardness, non-carbonate as CaCO3	Yes	Tot.	mg/l	-	80	79	0	5	4000	150	470	807	150	470	807	Jul-71	Mar-76									
Gen WQ	pH	No	Tot.	std units	M	440	369	0	4.5	10.1	8	7.96	0.483	8	7.96	0.483	Jan-37	Sep-03			6.5	8.5	22				
Gen WQ	pH	Yes	Tot.	std units	M	382	359	0	6.17	10.2	8	7.95	0.451	8	7.95	0.451	Oct-50	Sep-03			6.5	8.5	16				
Gen WQ	Specific conductance	No	Tot.	umho/cm	M	234	227	0	212	10000	1980	2120	1530	1980	2120	1530	Jan-58	Sep-03									
Gen WQ	Specific conductance	Yes	Tot.	umho/cm	M	595	511	0	174	10000	2130	2220	1380	2130	2220	1380	Oct-50	Sep-03									
Gen WQ	Temperature, water	No	Tot.	deg C	M	330	306	0	4.5	27	9	10.1	3.6	9	10.1	3.6	Nov-50	Sep-03									
Gen WQ	Total dissolved solids	No	Dis.	mg/l	-	807	708	0	133	9090	1420	1610	1270	1420	1610	1270	Jan-37	Sep-03				500	689				
Inorganics, Major, Non-metals	Silica	No	Dis.	mg/l	-	744	693	2	0.2	53	14	14.8	5.83	14	14.8	5.81	Oct-50	Sep-03									
Major Anions	Chloride	No	Dis.	mg/l	CA	744	650	2	0.05	340	6	30.3	60.3	6	30.4	60.3	Jan-37	Sep-03				250	11				
Major Anions	Fluoride	No	Dis.	mg/l	M	795	697	0	0.1	6.8	0.8	1.41	1.53	0.8	1.41	1.53	Oct-50	Sep-03	4	77		2	161			0.62	476
Major Anions	Sulfate	No	Dis.	mg/l	CA	782	685	5	0.4	5520	250	562	831	254	566	832	Jan-37	Sep-03				250	382				
Major Cations	Calcium	No	Dis.	mg/l	CA	798	700	2	1	661	36	65.8	97.6	36	65.9	97.6	Oct-50	Sep-03									
Major Cations	Magnesium	No	Dis.	mg/l	CA	797	699	3	0.05	690	20	41.6	82	20	41.7	82.1	Oct-50	Sep-03									
Major Cations	Potassium	No	Dis.	mg/l	CA	798	700	0	0.6	90	4.3	5.72	7.25	4.3	5.72	7.25	Oct-50	Sep-03									
Major Cations	Sodium	No	Dis.	mg/l	CA	802	703	0	4.9	2400	445	446	342	445	446	342	Oct-50	Sep-03	20	778							
Metals	Aluminum	No	Dis.	ug/l	M	13	12	8	5	230	50	49.7	61.7	10	67.2	95.4	May-73	Jun-79				200	1			16000	0
Metals	Arsenic	No	Dis.	ug/l	CA	20	19	6	0.25	14	2	3.51	4.07	2	4.94	4.23	May-73	Sep-03	10	1				0.045	14	4.7	6
Metals	Barium	No	Dis.	ug/l	CA	13	12	7	16	300	50	90.3	90.3	117	131	119	May-73	Jun-79	2000	0						2900	0
Metals	Beryllium	No	Dis.	ug/l	M	13	12	11	0.5	10	5	4.5	2.84	10	10	0	May-73	Jun-79	4	2						16	0
Metals	Boron	No	Dis.	ug/l	CA	669	625	8	10	3700	390	558	588	390	564	588	Oct-50	Oct-94								3100	2
Metals	Iron	No	Dis.	ug/l	M	662	577	24	1.5	31000	350	1120	2300	390	1170	2340	Oct-50	Sep-03				300	350			11000	9
Metals	Lithium	No	Dis.	ug/l	-	21	20	0	7.11	170	70	80	54.1	70	80	54.1	May-73	Sep-03									
Metals	Manganese	No	Dis.	ug/l	M	758	667	25	5	16000	55	195	684	60	201	693	Oct-70	Sep-03				50	398			320	114
Metals	Mercury	No	Dis.	ug/l	M	15	14	10	0.05	2.4	0.25	0.607	0.873	2.1	1.68	1.07	May-73	Sep-03	2	3						0.63	4
Metals	Molybdenum	No	Dis.	ug/l	M	20	19	6	0.5	66	2	9.71	20.1	4	13.6	23.5	May-73	Sep-03								78	0
Metals	Phosphorus	No	Dis.	ug/l	M	10	10	3	20	380	50	95	113	90	127	124	May-73	Jun-79								0.31	7
Metals	Selenium	No	Dis.	ug/l	CA	19	18	11	0.1	27.9	0.5	3.1	6.54	3	6.46	8.99	May-73	Sep-03	50	0						78	0
Metals	Strontium	No	Dis.	ug/l	CA	22	21	2	2	13334	740	2210	3280	1200	2440	3360	May-73	Sep-03								9300	1
Metals	Vanadium	No	Dis.	ug/l	M	12	11	2	0.2	12	1.2	2.26	3.34	1.2	2.32	3.74	May-73	Jun-79								78	0
Metals	Zinc	No	Dis.	ug/l	M	13	12	4	10	698	25	84.8	195	32.5	122	234	May-73	Jun-79				5000	0			4700	0
Nutrients	Nitrate as N	No	Dis.	mg/l	CA	350	333	0	0.02	150	0.23	3.41	14.1	0.23	3.41	14.1	Oct-50	Jun-85	10	19						25	15

M = measured, as defined in EPA QAPP for Dunn County Retrospective Case Study (EPA, 2011b).
CA = Critical Analyte, as defined in EPA QAPP for Dunn County Retrospective Case Study (EPA, 2011b).
A red highlight indicates the value exceeded a screening criteria.
Shading indicates parameter was detected above one or more screening criteria.
MCL: EPA Maximum Contaminant Levels (National Primary Drinking Water Regulation)
SMCL: EPA Secondary MCL (Non-enforaceable guidance for drinking water)
EPA Carc./EPA Non-Carc.: The carcinogenic and non-carcinogenic screening limits established by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
Note: Sodium does not have an MCL; the value listed in the MCL column represents the EPA Health Advisory Level.
ND = non detect
SD = standard deviation

Mercury concentrations were above the MCL and EPA non-carcinogenic risk screening level. Boron, manganese, phosphorus, and strontium all were above the EPA non-carcinogenic risk screening levels. Beryllium was higher than the MCL, while aluminum and iron both were above their SMCL. In addition, iron was higher than the EPA non-carcinogenic risk screening level. Of the metals noted here, all are EPA measured analytes with the exception of arsenic, boron, and strontium, which are critical analytes. Nitrate as N was higher than the MCL of 10 mg/L in 19 samples and was above the EPA non-carcinogenic risk screening level of 25 mg/L in 15 samples. Figure 3-6 shows the spatial distribution of parameters in groundwater detected above the screening criteria. There were no groundwater data identified as indicative of environmental impact monitoring, so a reduced data summary table was not prepared.

3.2.4 Temporal Comparison. The groundwater quality data were analyzed to evaluate whether significant differences occur in observed groundwater quality over time. The compiled database was sorted and searched to identify the groundwater monitoring wells for which time-series data are available and the range of dates that the data span. Five groundwater wells containing time-series data were identified[14] and are shown on Figure 3-7. These include:

- Wells 126373 and 126374, located 1,900 ft southeast of the Franchuk 44-20SWH well. These wells are located in the vicinity of EPA's retrospective study sample well Missouri Basin Depot. Well 126373 is screened from 90 to 175 ft bgs and Well 126374 is screened from 120 to 170 ft bgs.
- Wells 126375 and 126376, located approximately 2.5 miles east by northeast of the Franchuk 44-20SWH well and immediately to the southwest of the City of Killdeer. These wells appear to be co-located with EPA's retrospective study sample wells CW#4 and CW#5. Well 126375 is screened from 115 to 140 ft bgs and Well 126376 is screened from 140 to 165 ft bgs.
- Well 34193, which is an irrigation well located almost 3 miles northeast of the Franchuk 44-20SWH well and on the northeast side of Killdeer. It is screened from 49 to 89 ft bgs.

The data from all of these wells were collected from late 2009 through early 2011. Hence, it was not possible to use these data to compare pre- and post-hydraulic fracturing periods. However, this time period does encompass the time of the Franchuk 44-20SWH well blowout, which occurred in September 2010.

Time-series data for five parameters including calcium, chloride, magnesium, sodium, and sulfate, which are identified as EPA critical analytes, were plotted for each of the monitoring wells for which data were available. These parameters were selected because they are commonly detected in groundwater, they could exhibit changes as a result of the blowout and release of hydraulic fracturing fluids, and are also expected to be present in any future groundwater quality data collected as part of the EPA case study or provided with data collected by operators. The intent with this comparison is to determine if there are significant differences between the two time periods (i.e., before and after the blowout) and to provide a better understanding of Dunn County groundwater quality. The plot for Well 126374 is shown in Figure 3-8. Plots for all five wells are provided in Appendix C-1.

3.2.5 Formation and Depth Comparison. Groundwater data for calcium, chloride, magnesium, sodium, and sulfate were reviewed by formation and depth to determine if there was reason to separate and assess data by formation. Groundwater dissolved fraction concentrations of these compounds were available at 400 locations across Dunn County. Using aquifer and formation information provided for the majority of samples within the database made it possible to divide the data into seven principal groupings

[14] Selection criteria required data for at least two of the five parameters monitored at 12 different time points (on different days).

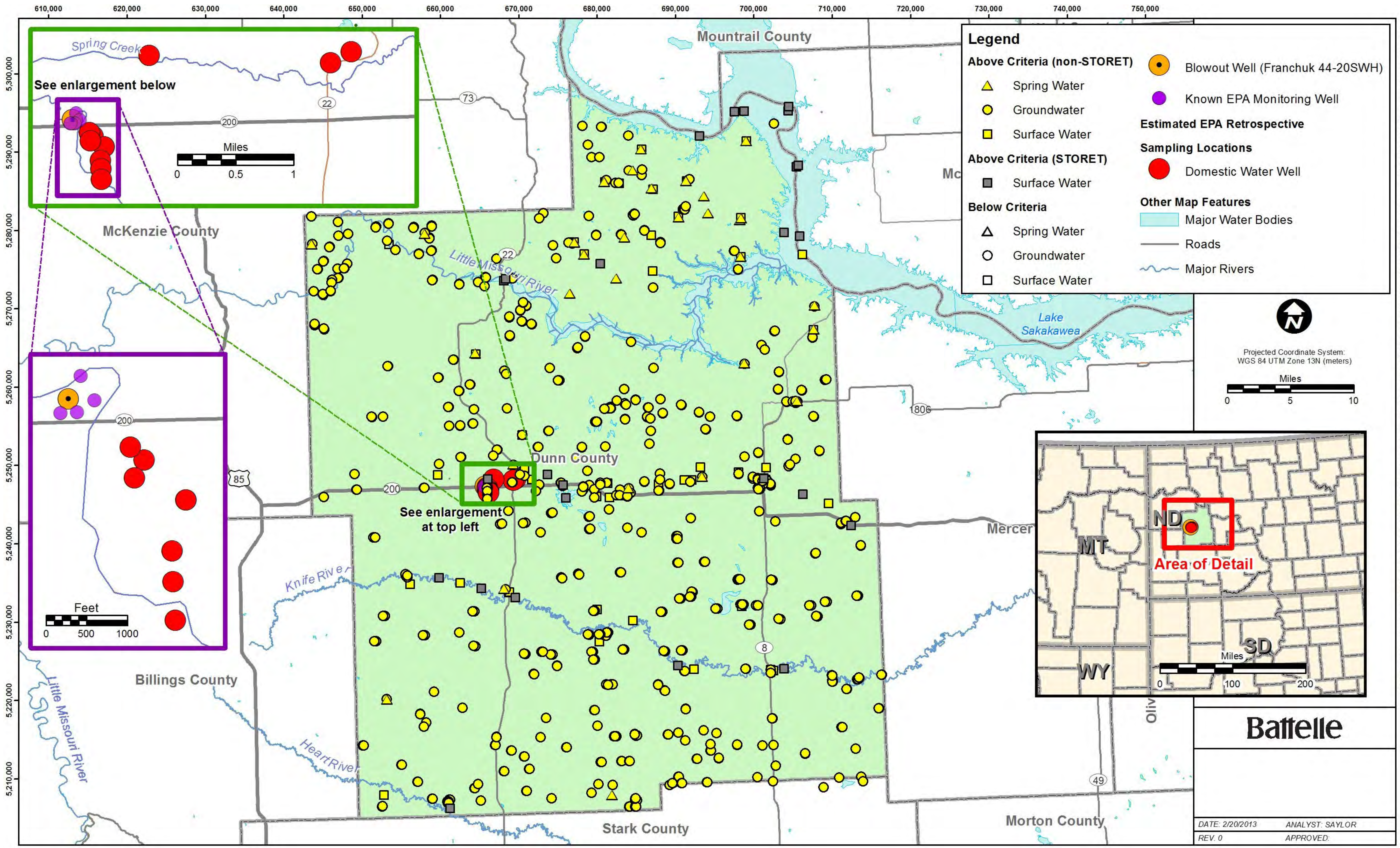


Figure 3-6. Groundwater, Surface Water, and Spring Detections above Screening Criteria, Dunn County, ND

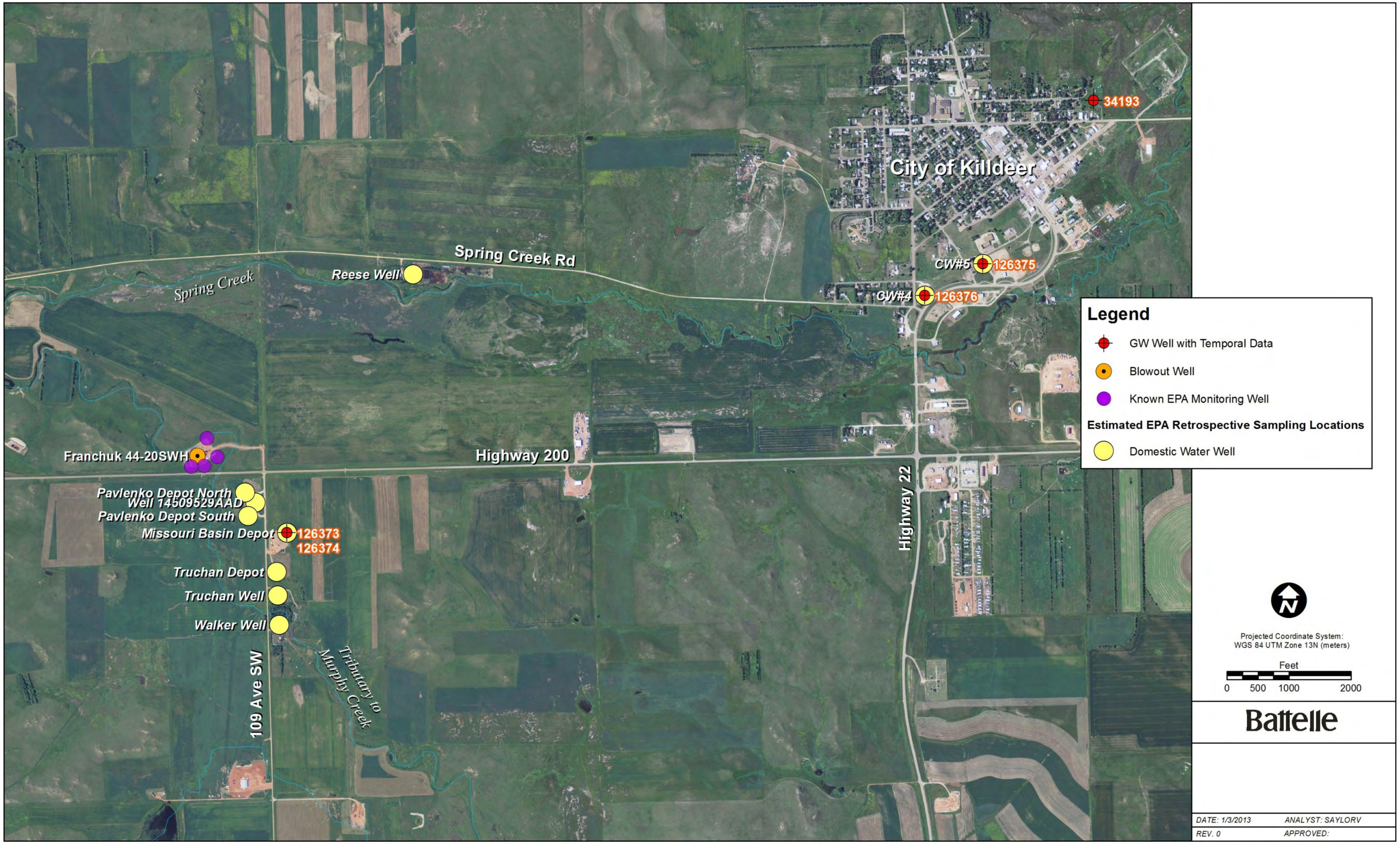


Figure 3-7. Groundwater Well Locations with Temporal Water Quality Data within the Vicinity of Franchuk Well 44-20SWH

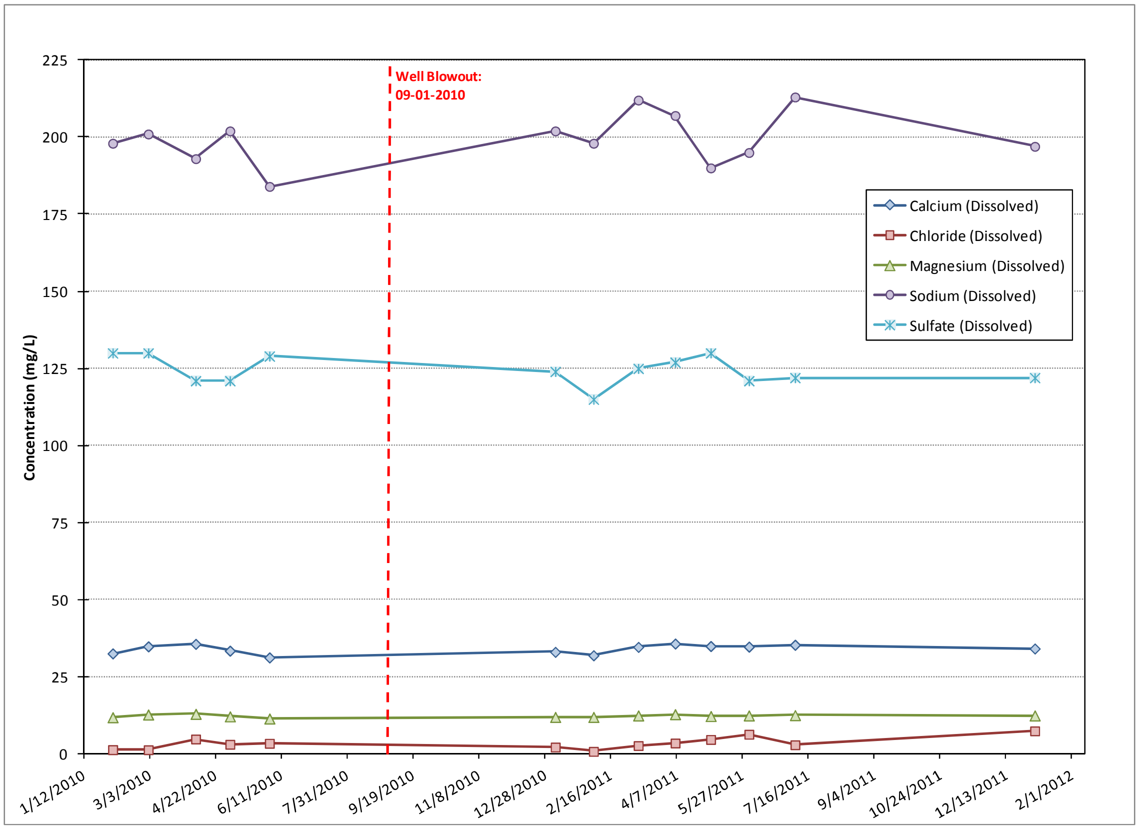


Figure 3-8. Time-Series Concentrations for Calcium, Chloride, Magnesium, Sodium, and Sulfate in Groundwater in Well 126374

based on the formation in which the well was located. These groupings and the number of locations within each grouping are presented in Table 3-5. The formations provided in Table 3-5 are listed in order of increasing depth and correspond with the generalized geologic sections that are provided in Table 3-2. The approximate locations of the wells used to perform the comparison of concentrations with formation and depth are provided in Figure 3-9.

Scatter plots that compare the impact of formation and depth with the concentrations of the five parameters of interest were generated and are presented as Figures 3-10a through 3-10e. The depths presented in these plots represent the maximum depth of each well. Typically, the well screen interval is located immediately above the bottom of the well and, per EPA sampling protocol, samples are typically collected in the middle or slightly above the middle of the screened interval (EPA, 1996).

Table 3-5. Summary of Distribution of Number of Locations by Formation Grouping

Grouping	Calcium	Chloride	Magnesium	Sodium	Sulfate
Alluvium	4	3	4	4	4
Glaciofluvial Sand & Gravel Deposits	173	167	173	173	173
Sentinel Butte Formation	157	139	157	158	160
Tongue River Formation	24	23	24	24	19
Cannonball & Ludlow Formations	3	3	3	3	2
Hell Creek Formation	10	10	10	10	10
Fox Hills Formation	26	26	26	26	23

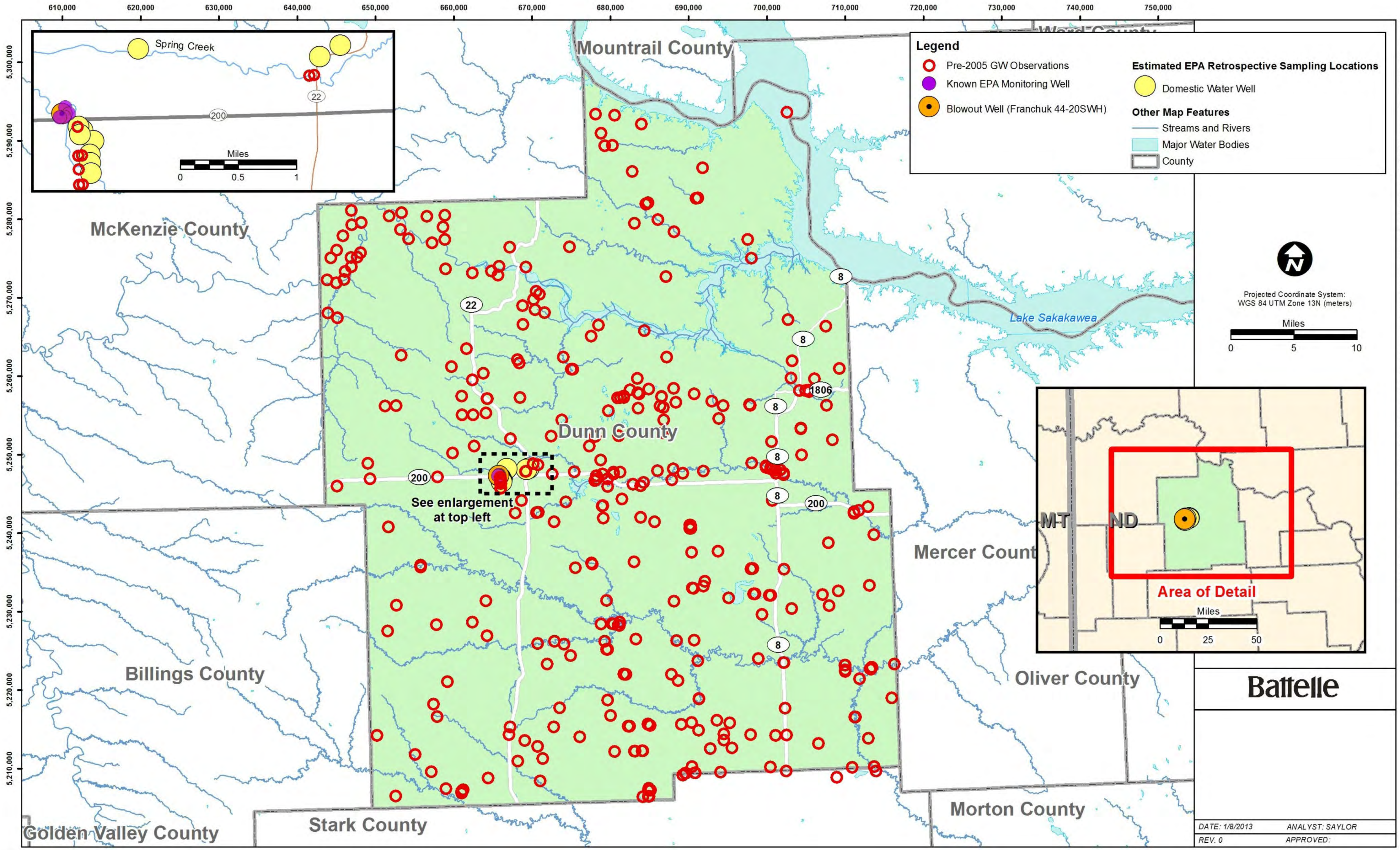


Figure 3-9. Approximate Locations of Groundwater Observations for Calcium, Chloride, Magnesium, Sodium, and Sulfate

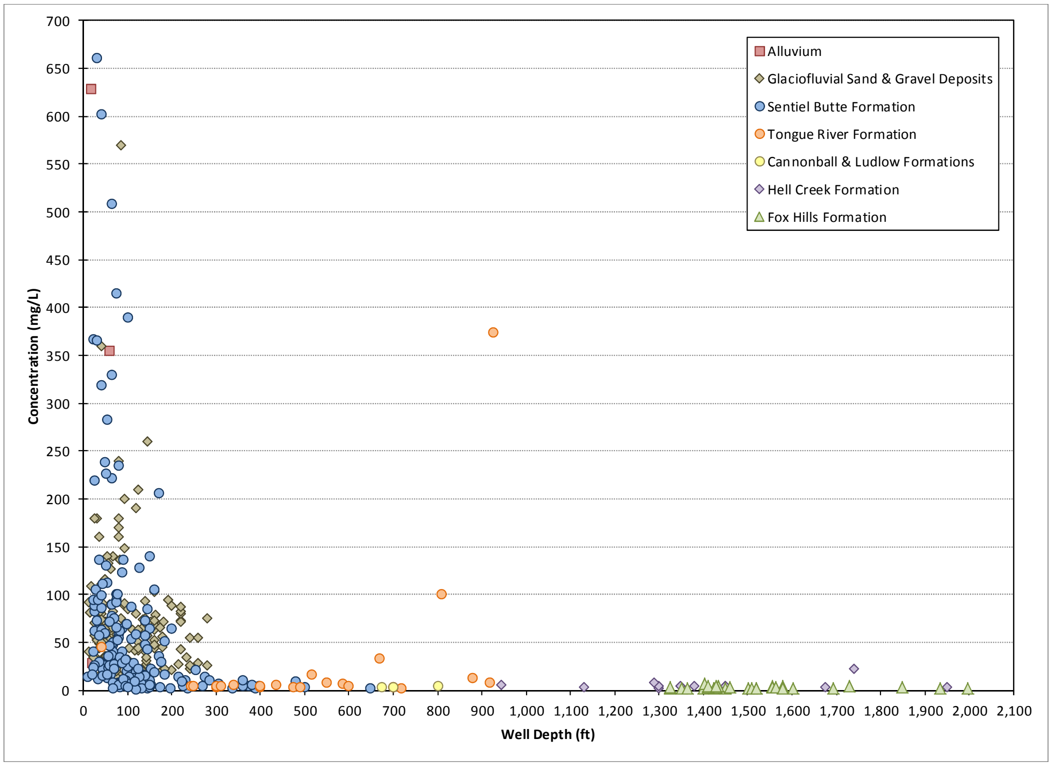


Figure 3-10a. Correlation of Depth and Formation with Concentrations of Calcium

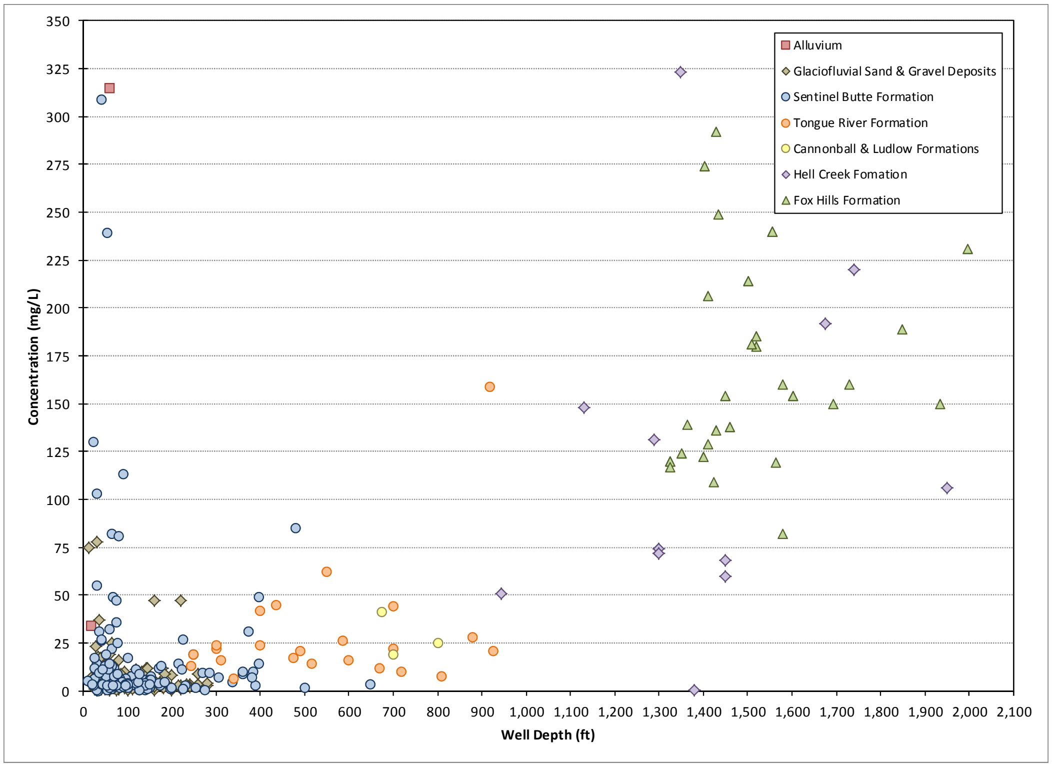


Figure 3-10b. Correlation of Depth and Formation with Concentrations of Chloride

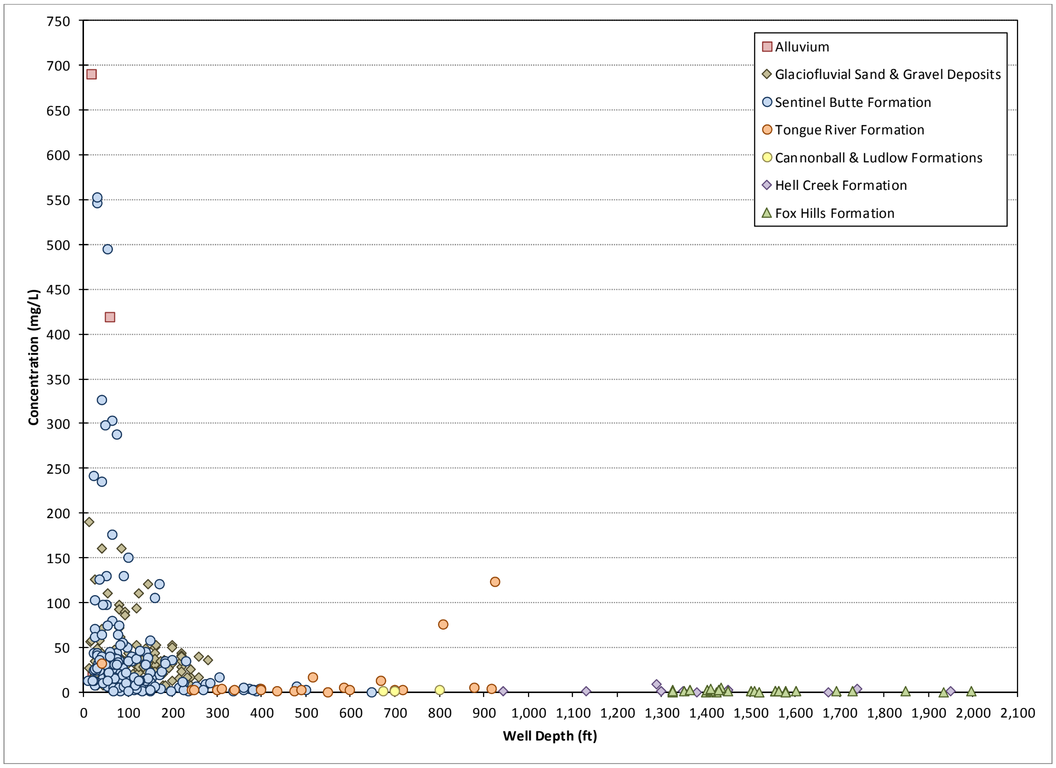


Figure 3-10c. Correlation of Depth and Formation with Concentrations of Magnesium

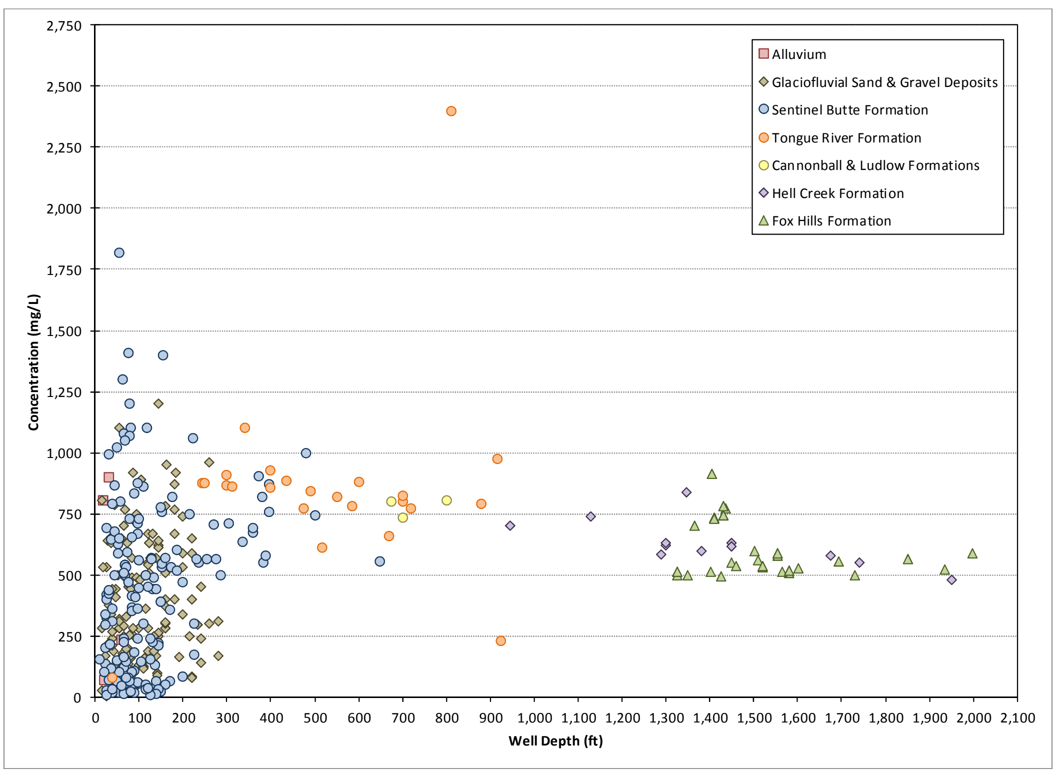


Figure 3-10d. Correlation of Depth and Formation with Concentrations of Sodium

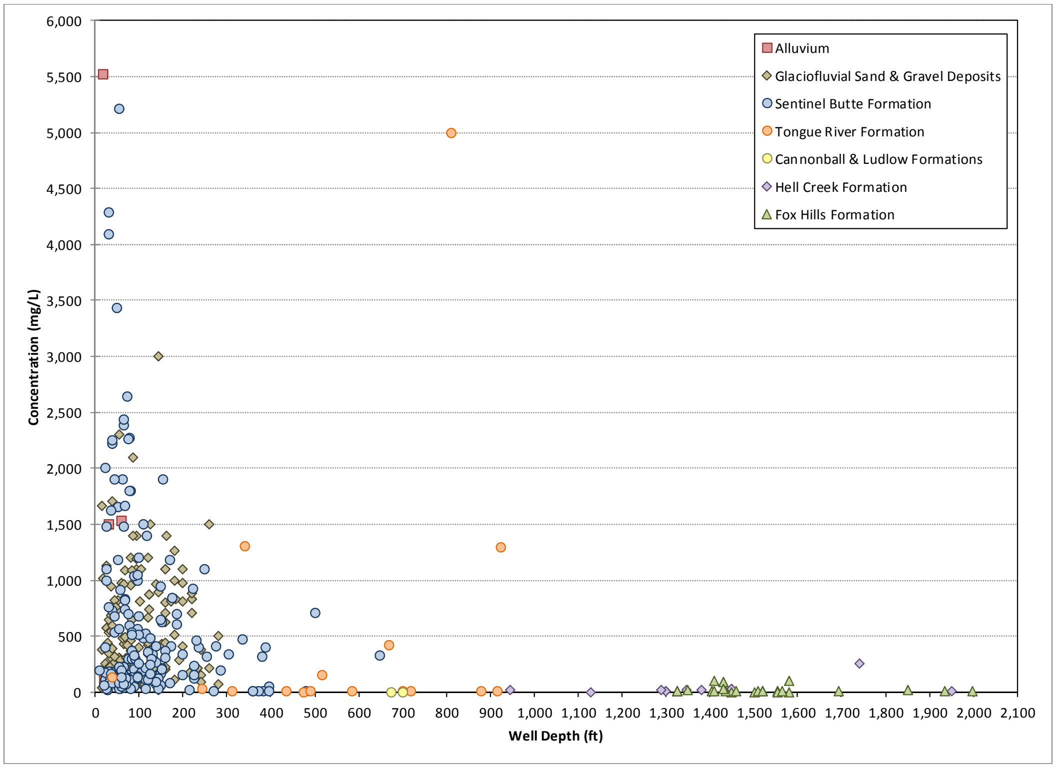


Figure 3-10e. Correlation of Depth and Formation with Concentrations of Sulfate

The most notable observation from these plots is that the chloride concentration is much greater at greater depths, which include the Hells Creek and Fox Hills formations. It also is noted that the average sodium concentration is greater in the deeper formations including the Tongue River, Hells Creek and Fox Hills formations. Magnesium, calcium and sulfate tend to be greatest in the shallower alluvium, glacial drift, and Sentinel Butte formations.

3.2.6 Coverage of EPA QAPP Analytes. Of the parameters identified in the EPA Dunn County retrospective case study QAPP (EPA, 2011b), 237 are designated as either CA (77) or M parameters (160). Table 3-4 summarizes the publically available groundwater quality data for the EPA parameters (12 CA and 15 M parameters). Table 3-6 summarizes 195 EPA parameters for which no groundwater quality data are available (62 CA and 130 M) and 15 parameters (0 CA and 15 M) for which the number of results was from <8 locations. Therefore, no water quality characterization is available for comparison should these parameters be detected in future sampling efforts.

Table 3-6. List of EPA Parameters Not Present in Dunn County Groundwater Quality Characterization Database

Parameter - Measured		Parameter - Critical Analyte	
NOT FOUND			
.alpha.-Endosulfan	Endrin aldehyde	Butane	Diethyl phthalate
.alpha.-Hexachlorocyclohexane	Endrin ketone	Ethane	Dimethyl phthalate
.beta.-Endosulfan	Ethanol	Methane	Fluoranthene
.beta.-Hexachlorocyclohexane	Ethyl tert-butyl ether	Propane	Fluorene
.delta.-Hexachlorocyclohexane	Ethylbenzene	Nitrite as N	Hexachlorobenzene
1,1,1-Trichloroethane	Ethylene	1,2,4-Trichlorobenzene	Hexachlorobutadiene
1,1,2-Trichloroethane	formate	2,4,5-Trichlorophenol	Hexachloroethane
1,1-Dichloroethane	Heptachlor	2,4,6-Trichlorophenol	Indeno[1,2,3-cd]pyrene
1,1-Dichloroethylene	Heptachlor epoxide	2,4-Dichlorophenol	Isophorone
1,2,3-Trimethylbenzene	Hexachlorocyclopentadiene	2,4-Dimethylphenol	m-Cresol
1,2,4,5-Tetrachlorobenzene	Hydrogen	2,4-Dinitrophenol	m-Dichlorobenzene
1,2,4-Trimethylbenzene	Inorganic carbon	2,4-Dinitrotoluene	m-Nitroaniline
1,2-Dibromo-3-chloropropane	Iron, ion (Fe2+)	2-Methylnaphthalene	Naphthalene
1,2-Dichloroethane	isobutyrate	4,6-Dinitro-o-cresol	Nitrobenzene
1,2-dinitrobenzene	Isopropyl ether	4-methylphenol	o-Chlorophenol
1,2-Diphenylhydrazine	Lactic acid	Acenaphthene	o-Cresol
1,3,5-Trimethylbenzene	Lindane	Acenaphthylene	o-Dichlorobenzene
1,3-dimethyl adamantane	Malathion	Anthracene	o-Nitroaniline
1,4-dinitrobenzene	Endrin	Benz[a]anthracene	o-Nitrophenol
1-chloronaphthalene	m-Dinitrobenzene	Benzo(b)fluoranthene	p-Bromophenyl phenyl ether
2,3,4,6-Tetrachlorophenol	Methoxychlor	Benzo[a]pyrene	p-Chloro-m-cresol
2,4,6-tribromophenol (surrogate)	Methyl tert-butyl ether	Benzo[ghi]perylene	p-Chloroaniline
2,6-Dichlorophenol	Methylene chloride	Benzo[k]fluoranthene	p-Chlorophenyl phenyl ether
2,6-Dinitrotoluene	Mevinphos	Bis(2-chloroethoxy)methane	p-Dichlorobenzene
2-butoxyethanol	m-Xylene	Bis(2-chloroethyl) ether	p-Nitroaniline
2-Chloronaphthalene	nitrobenzene-d5 (surrogate)	Bis(2-chloroisopropyl) ether	Pentachlorophenol
2-fluorobiphenyl (surrogate)	N-Nitrosodiethylamine	Butyl benzyl phthalate	Phenanthrene
2-fluorophenol (surrogate)	N-Nitrosodimethylamine	Carbazole	Pyrene
3,3'-Dichlorobenzidine	N-Nitrosodi-n-butylamine	Chrysene	Diesel range organics
4,4'-methylenebis (2-chloroaniline)	N-Nitrosodi-n-propylamine	Di(2-ethylhexyl) phthalate	Gasoline range organics
4,4'-methylenebis (N,Ndimethylaniline)	N-Nitrosodiphenylamine	Di-n-octyl phthalate	isopropyl alcohol
Acetate	N-Nitrosomethylethylamine	Dibenz[a,h]anthracene	tert-Butanol
Acetone	Oxygen-18/Oxygen-16 ratio	Dibenzofuran	
Acetophenone	o-Xylene		
Acetylene	p,p'-DDD		
Adamantane	p,p'-DDE		
Aldrin	p,p'-DDT		
Aniline	Parathion		
Antimony	Pentachlorobenzene		
Azinphos-methyl	Phenol		
Azobenzene	Phorate		
Benzene	p-Nitrophenol		
Benzoic acid	Pronamide		
Benzyl alcohol	Propionic acid		
Bromide	p-Xylene		
Butyric acid	Pyridine		
Carbaryl	Redox Potential		
Carbon disulfide	squalene		
Carbon tetrachloride	Sulfide		

Table 3-6. List of EPA Parameters Not Present in Dunn County Groundwater Quality Characterization Database (Continued)

Parameter - Measured		Parameter - Critical Analyte
NOT FOUND		
Chlorobenzene	Sulfur	
Chlorobenzilate	Terbufos	
Chloroform	terphenyl-d14 (surrogate)	
cis-1,2-Dichloroethylene	terpineol	
Cumene	tert-Amyl methyl ether	
Cyclohexene, 1-methyl-4-(1-methylethenyl)-, (4R)-	Tetrachloroethylene	
d2H	tetraethylene glycol	
d87/86Sr	Thallium	
Dibutyl phthalate	Toluene	
Dichlorvos	trans-1,2-Dichloroethylene	
Dieldrin	tri(2-butoxethyl)phosphate	
Diethylene glycol monobutyl ether acetate	Trichloroethylene	
Dinoseb	triethylene glycol	
Diphenylamine	Trifluralin	
Disulfoton	Vinyl chloride	
Endosulfan sulfate	Xylene	
SAMPLE SIZE < 8 OR ALL SAMPLES NON-DETECT		
Ammonia-nitrogen as N	Organic carbon	
Cadmium	Oxygen	
Cerium	Silicon	
Chromium	Silver	
Cobalt	Titanium	
Copper	Turbidity	
Lead	Uranium	
Nickel		

3.3 Surface and Spring Water Quality

This section summarizes the characteristics of surface and spring water resources in Dunn County. An analysis of available surface and spring water quality data in comparison to relevant regulatory levels and screening criteria also is provided.

3.3.1 Watershed Characteristics. Dunn County is located within the Little Missouri and Oahe River Basins. Within Dunn County, these basins comprise four HUC 8 subbasins (Table 3-7). Located from north to south are the Lake Sakakawea, Lower Little Missouri, Knife, and the Upper Heart subbasins. Figure 3-11 shows the location of named streams and rivers that comprise these basins within Dunn County. Spring Creek drains the central part, and the Little Knife, Knife and Green Rivers drain the southern part of the county (NDGS, 2001). More than one half of Dunn County (55% or 1,150 square miles) is occupied by the Knife sub basin. Well Franchuk 44-20SWH, where the blowout occurred, is located in the Knife sub basin.

Table 3-7. Definitions of HUCs for Dunn County, PA

HUC Code	Definition	Size (mi^2)	Location	% of County Occupied by HUC
1011	Subregion	17,300	Missouri - Little Missouri	39.4%
1013	Subregion	37,400	Missouri - Oahe	60.6%
10110101	Subbasin (HUC 8)	6,790	Lake Sakakawea	7.1%
10110205	Subbasin (HUC 8)	1,800	Lower Little Missouri	32.3%
10130201	Subbasin (HUC 8)	2,530	Knife	55.2%
10130202	Subbasin (HUC 8)	1,730	Upper Heart	5.4%

Source: EPA, 2012c

As part of its authority under the CWA, the NDDH monitors and assesses its surface water resources (NDDH, 2009). The NDDH prepares a biennial report that assesses the extent to which beneficial uses of the state's rivers, streams, lakes, reservoirs and wetlands are met. It also identifies streams that are impaired for their intended beneficial use and describes the causes of the impairment (i.e., the COCs) and the probable sources of the impairment (i.e., the activities that led to the contaminant loading to the surface water). Data included in these reports are electronically uploaded to STORET (NDDH, 2009). In addition, assessment data are uploaded to an assessment database to manage water quality information, which allows for the graphical presentation of water quality assessment information (NDDH, 2009). Upon review and approval of the information contained in the reports, this information can be accessed through EPA's watershed tracking, assessment, and environmental results Web site (EPA, 2012c). Although the most recent report submitted by the state of North Dakota includes data collected during the 2010 and 2011 reporting period (NDDH, 2012c), the data used to evaluate impairment to Dunn County surface water were download from EPA's watershed tracking and assessment Web site, which EPA has referenced as the most recent report available (EPA, 2012c).

Figure 3-11 includes the location of streams and rivers within Dunn County that are CWA Section 303(d) listed impaired waters for the 2010 reporting year. Impaired waters with an EPA approved TMDL are differentiated in Figure 3-11 from threatened or impaired waters for which a TMDL has yet to be established. There are approximately 168 miles of impaired streams and rivers located within Dunn County, representing a very small portion of the total length of streams and rivers in the county. This value was determined by adding the miles for each impaired segment, which was downloaded from EPAs GIS Watershed Tracking and Environmental Results database (EPA, 2012c). These data were further sub-setted to only include those impairments located within Dunn County. Of the 168 miles of impaired waterways, only 38% (63 miles) have an established TMDL; the remaining 105 miles are still in need of one as of 2010. Approximately 125 miles are impaired by mercury from atmospheric deposition, and the remaining are impaired by E. coli and/or fecal coliform, most likely resulting from agricultural practices (EPA, 2012a).

The causes and probable sources of the surface water impairments are presented in Tables 3-8 and 3-9, respectively. As shown in Figure 3-11, the majority of the impaired streams are located in the northeastern part of the county in the vicinity of Lake Sakakawea, where methyl mercury due to atmospheric deposition have impaired 125 miles of the lake's tributaries. In addition to the tributary impairment, Lake Sakakawea (368,231 acres) itself is also impaired by methyl mercury due to atmospheric deposition. Of this, approximately 142,841 acres (about 223 square miles) are located in Dunn County. The remaining 43 miles of impaired waters are located in the central and southeastern portions of Dunn County (see Figure 3-11). Pathogens, such as fecal coliform and E. coli, have been identified as the only cause of impairment within these waters. The probable sources of fecal coliform and E. coli include agricultural activities (i.e., animal feeding operations and grazing in riparian or shoreline zones) and natural/wildlife (i.e., wildlife other than waterfowl). No probable sources were provided for approximately 13 miles of water located in the Knife sub basin.

Table 3-8. Causes of Impairment to Surface Water within Dunn County

Cause of Impairment	Extent of Impairment (miles)
Pathogens: Fecal Coliform	19.0
Pathogens: Escherichia Coli	24.2
Mercury: Methyl Mercury	125.1

Table 3-9. Probable Sources of Impairments in the Watersheds Crossing Dunn County

	Extent of Impairment (miles)[1]				
Probable Source	Lake Sakakawea[3]	Lower Little Missouri	Knife	Upper Heart	Total
Animal Feeding Operations (NPS)	NA	6.5	24.1	NA	30.6
Grazing in Riparian or Shoreline Zones	NA	6.5	24.1	NA	30.6
Wildlife Other Than Waterfowl	NA	6.5	NA	NA	6.5
Other[2]	NA	NA	12.6	NA	12.6
Atmospheric Deposition - Toxics	125.1	NA	NA	NA	125.1

NA - No recognized impairments

1. Multiple sources of impairment may exist within the same stretch of stream/river or water body; therefore, impairments within a subbasin cannot be added to determine the total extent of impairment.
2. Probable source of impairment not provided.
3. The area of Lake Sakakawea that lies within Dunn County could not accurately be determined since large portions of the lake lie outside of the county.

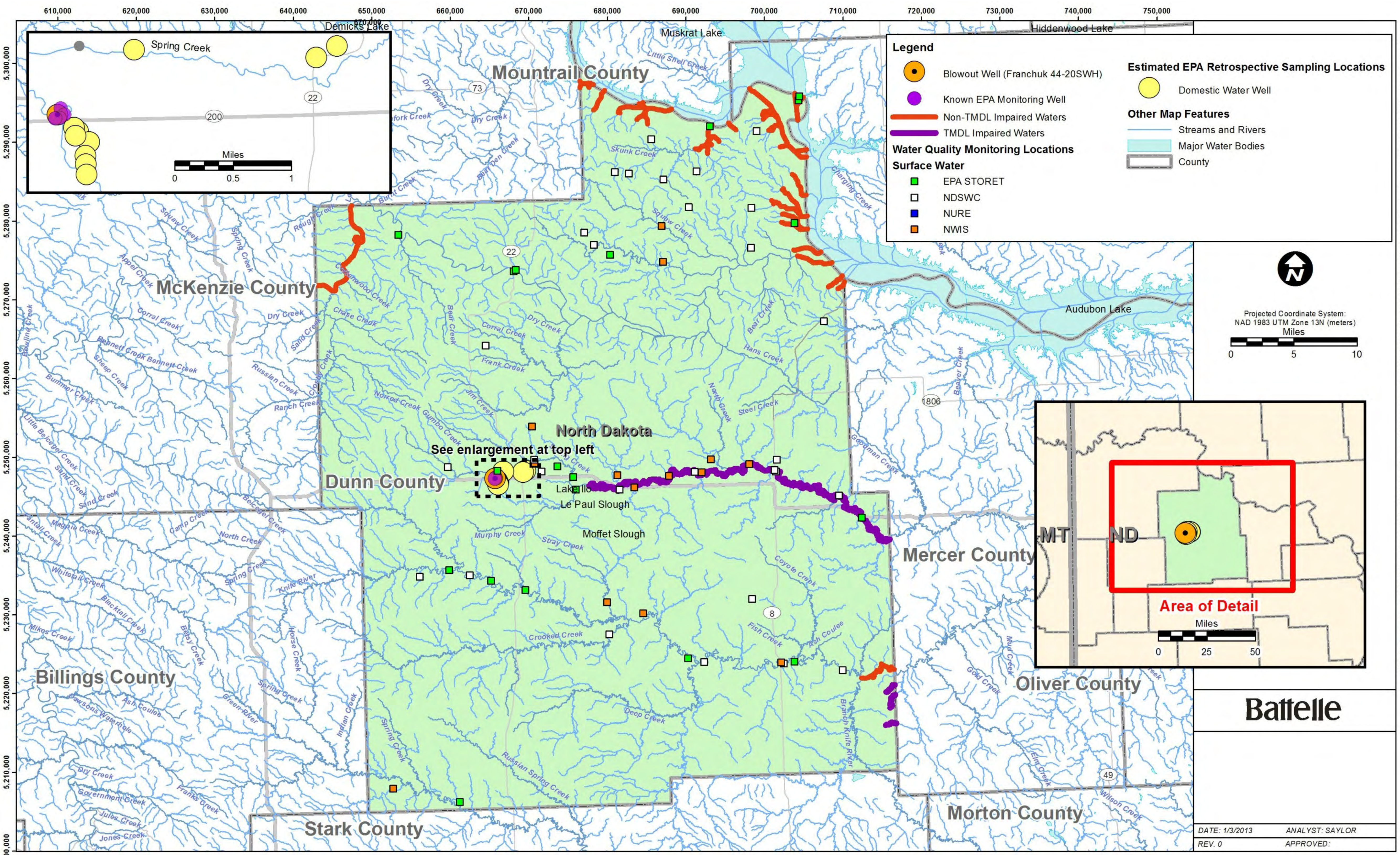


Figure 3-11. Surface Water Quality Monitoring Stations and Impairments in Dunn County

3.3.2 Surface Water Data Summary. Surface water quality data (from sources identified in Section 2.0) were compiled into a database to characterize the condition of surface water resources within Dunn County. Figure 3-11 shows the locations of the 77 surface water quality monitoring locations represented in the database. The dates of the sampling events range from 1961 to 2004. The monitored parameters include dissolved gas, general water quality parameters, inorganics (major, non-metal), major ions, metals, and nutrients. No samples were analyzed for VOCs or SVOCs. Table 3-10 provides a pre-2005 list of inorganic parameters detected, number of samples, minimum, maximum, median, mean, standard deviation, date range for sample collection, and comparison against screening criteria, including the number of results above each threshold. Organic parameters are not included in this table since the organic data were limited, and were excluded. For surface water, the screening criteria include EPA MCL and SMCL, North Dakota human health and aquatic life chronic values for Class 1 streams, and CWA freshwater surface water quality criteria (chronic). Section 2 provides an explanation of these screening criteria and how summary statistics were calculated. Table 3-10 also identifies those parameters monitored by EPA and includes a designation of whether the parameter is a critical analyte (CA) or a measured (M) parameter per the EPA QAPP (EPA, 2012b). Appendix B includes a listing of all surface water data collected for Dunn County.

As indicated in Table 3-10, observed concentrations were higher for one or more of the relevant screening criteria for the general water quality parameters including alkalinity, dissolved oxygen, pH, and TDS. For major ions, sulfate and sodium (total and dissolved), the observed concentrations were higher than one or more of the screening criteria. Sulfate was above the SMCL (250 mg/L) in 364 samples. Sodium, dissolved and total, was higher than the EPA Health Advisory level of 20 mg/L in 428 samples (dissolved) and 241 samples (total). Sulfate and sodium are both identified as EPA critical analytes. The observed concentrations were higher than one or more of the relevant comparison criteria for the following 10 metals: aluminum, arsenic, cadmium, chromium, copper, iron, lead, manganese, selenium, and zinc. Of the 10 metals noted , only two, arsenic and selenium, are identified as EPA critical analytes. The remaining eight are identified as EPA measured analytes. Arsenic (total) was above the MCL of 10 µg/L in six samples and also was above the North Dakota surface water human screening level of 10 µg/L in six samples. Selenium (dissolved) was above the CWA chronic screening level of 5 µg/L in two samples and also was above the North Dakota surface water aquatic screening level of 5 µg/L in two samples. Results above MCLs occurred forchromium (total) and lead (total) in two and eight samples, respectively. Aluminum (total), iron (total and dissolved) and manganese (total and dissolved) all were higher than the SMCL in 45, 205, and 268 samples, respectively. The following metals were above the CWA chronic screening levels: aluminum (88 samples), cadmium (nine samples), iron (57 samples), lead (25 samples), selenium (two samples) and zinc (10 samples). Results above the North Dakota surface water human and/or aquatic screening levels occurred for aluminum, arsenic, cadmium, chromium, copper, lead, selenium and zinc. Figure 3-6 shows the spatial distribution of parameters in surface water detected above the screening criteria.

3.3.2.1 Comparison Against Reduced Data Table. Table 3-11 provides a summary of pre-2005 surface water data in similar format to Table 3-10, with the exception of 28 locations there were removed (all from STORET) based on the reasoning provided in Table 2-3. This summary data table was created for comparison against the complete background surface water quality summary table (Table 3-10) to determine whether the data identified as indicative of environmental impact monitoring has a significant effect on background water quality.

Table 3-10. Dunn County Surface Water Data Summary

Class	Parameter	Field Results	Frac.	Units	EPA Class	No. Samples	No. Locations	No. ND	Min	Max	Including NDs Median	Including NDs Mean	Including NDs SD	Excluding NDs Median	Excluding NDs Mean	Excluding NDs SD	Begin Sample Date	End Sample Date	MCL	N Above MCL (no NDs)	SMCL	SMCL High	N Above SMCL (no NDs)	CWA Chronic	N Above CWA Chronic (no NDs)	NDak SW Human	N Above NDak Human (no NDs)	NDak SW Aquatic	N Above NDak SW Aquatic (no NDs)
Dissolved Gas	Carbon dioxide	No	Tot.	mg/l	M	296	16	0	0.1	63	7.41	8.81	7.96	7.41	8.81	7.96	Sep-71	Sep-04											
Gen WQ	Alkalinity as CaCO3	No	Tot.	mg/l	M	316	19	0	46	1330	276	342	195	276	342	195	Oct-80	Sep-04						20	0				
Gen WQ	Alkalinity as CaCO3	Yes	Tot.	mg/l	M	222	14	0	24	1060	401	392	167	401	392	167	Sep-71	Sep-80						20	0				
Gen WQ	Carbonate (CO3)	No	Tot.	mg/l	-	174	10	49	0.5	38	7.42	9.34	6.37	8.68	10.5	6.47	Nov-80	Sep-04											
Gen WQ	Hardness as CaCO3	No	Tot.	mg/l	-	425	23	0	18	3700	262	409	728	262	409	728	Sep-71	Sep-04											
Gen WQ	Organic carbon	No	Dis.	mg/l	M	190	16	0	2.1	110	14.8	15	5.92	14.8	15	5.92	Apr-75	Aug-04											
Gen WQ	Oxygen	No	Dis.	mg/l	M	511	16	0	2.5	16.2	9.6	9.89	1.43	9.6	9.89	1.43	Apr-75	Feb-97								5	15		
Gen WQ	Oxygen	Yes	Dis.	mg/l	M	631	23	0	1.2	20.58	8.18	8.64	2.45	8.18	8.64	2.45	Mar-93	Sep-04								5	51		
Gen WQ	pH	No	Tot.	std units	M	375	50	0	6.6	9.08	8.11	7.99	0.475	8.11	7.99	0.475	Sep-71	Sep-04			6.5	8.5	34						
Gen WQ	pH	Yes	Tot.	std units	M	1204	38	0	4.5	9.6	8.22	8.19	0.751	8.22	8.19	0.751	Sep-71	Sep-04			6.5	8.5	118						
Gen WQ	Specific conductance	No	Tot.	umho/cm	M	382	50	0	144	6900	1440	1540	752	1440	1540	752	Jan-61	Sep-04											
Gen WQ	Specific conductance	Yes	Tot.	umho/cm	M	1656	46	0	75	7170	1630	1600	1030	1630	1600	1030	Sep-71	Sep-04											
Gen WQ	Temperature, water	No	Tot.	deg C	M	913	20	0	0.1	28.5	9.97	10.7	3.97	9.97	10.7	3.97	Sep-71	Sep-04								29.44	0		
Gen WQ	Temperature, water	Yes	Tot.	deg C	M	627	24	0	2	26.3	17.1	16.9	4.4	17.1	16.9	4.4	Mar-93	Sep-04								29.44	0		
Gen WQ	Total dissolved solids	No	Dis.	mg/l	-	681	60	0	54	6810	1120	1120	936	1120	1120	936	Jan-61	Sep-04				500	396						
Inorganics, Major, Non-metals	Silica	No	Dis.	mg/l	-	423	53	2	0.00232	53	9.3	10	7.92	9.3	10	7.91	Sep-71	Sep-04											
Major Anions	Chloride	No	Dis.	mg/l	CA	667	48	0	0.5	63	7.18	7.43	4.34	7.18	7.43	4.34	Sep-71	Sep-04				250	0	230	0	100	0		
Major Anions	Fluoride	No	Dis.	mg/l	M	434	47	3	0.05	1.4	0.5	0.46	0.25	0.5	0.478	0.239	Sep-71	Sep-04	4	0		2	0			4	0		
Major Anions	Sulfate	No	Dis.	mg/l	CA	555	54	0	5.5	4700	438	506	652	438	506	652	Sep-71	Sep-04				250	364						
Major Cations	Calcium	No	Dis.	mg/l	CA	435	48	0	4.9	403	50.5	61.6	56	50.5	61.6	56	Sep-71	Sep-04											
Major Cations	Calcium	No	Tot.	mg/l	CA	241	9	0	18.3	114	45	46.2	11	45	46.2	11	Mar-93	Sep-04											
Major Cations	Magnesium	No	Dis.	mg/l	CA	435	48	0	1.3	642	29	47.6	89.4	29	47.6	89.4	Sep-71	Sep-04											
Major Cations	Magnesium	No	Tot.	mg/l	CA	241	9	0	9	52.9	19.9	20.8	4.18	19.9	20.8	4.18	Mar-93	Sep-04											
Major Cations	Potassium	No	Dis.	mg/l	CA	435	48	0	1.2	21	7.14	6.92	2.8	7.14	6.92	2.8	Sep-71	Sep-04											
Major Cations	Potassium	No	Tot.	mg/l	CA	241	9	0	2.4	15.8	3.75	5.33	2.44	3.75	5.33	2.44	Mar-93	Sep-04											
Major Cations	Sodium	No	Dis.	mg/l	CA	435	48	0	2.8	1700	290	278	189	290	278	189	Sep-71	Sep-04	20	428									
Major Cations	Sodium	No	Tot.	mg/l	CA	241	9	0	31.4	325	55.1	140	108	55.1	140	108	Mar-93	Sep-04	20	241									
Metals	Aluminum	No	Tot.	ug/l	M	118	10	4	25	10000	229	1560	3200	229	1560	3200	Apr-75	Sep-04				200	45	87	88	750	4		
Metals	Arsenic	No	Dis.	ug/l	CA	113	8	12	0.5	9	2.19	2.19	0.813	2.13	2.22	0.807	Sep-75	Sep-04	10	0				150	0	10	0	150	0
Metals	Arsenic	No	Tot.	ug/l	CA	227	19	2	0.5	30.5	2.35	4.04	4.06	2.41	4.05	4.05	Apr-75	Sep-04	10	6				150	0	10	6	150	0
Metals	Barium	No	Tot.	ug/l	CA	221	14	14	34.8	611	100	123	84.5	113	144	97.3	Apr-78	Sep-04	2000	0									
Metals	Beryllium	No	Tot.	ug/l	M	97	13	92	0.5	20	5	4.25	2.28	10	8.68	7.07	Apr-75	Sep-04	4	4						4	4		
Metals	Boron	No	Dis.	ug/l	CA	392	44	4	10	2700	445	520	419	445	520	419	Sep-71	Aug-94											
Metals	Cadmium	No	Tot.	ug/l	M	119	14	99	0.01	10	0.929	3.05	3.89	0.684	0.557	0.295	Apr-75	Sep-04	5	0				0.25	9	5	0	0.27	9
Metals	Chromium	No	Tot.	ug/l	M	153	18	88	0.1	106	9.86	11.1	11.9	14	13.6	12.9	Apr-75	Sep-04	100	2						100	2		
Metals	Cobalt	No	Tot.	ug/l	M	19	10	16	1	250	50	35.1	30.6	77.5	77.5	81.3	Apr-75	Jun-80											
Metals	Copper	No	Tot.	ug/l	M	183	15	19	1	127	10	18.5	22.6	14.2	24	29.6	Apr-75	Sep-04	1300	0		1000	0			1000	0	9.3	19
Metals	Iron	No	Dis.	ug/l	M	424	40	15	5	3800	230	399	494	230	400	494	Sep-71	Sep-04				300	81	1000	22				
Metals	Iron	No	Tot.	ug/l	M	304	20	0	7	116000	833	5210	10600	833	5210	10600	Apr-75	Sep-04				300	124	1000	35				
Metals	Lead	No	Tot.	ug/l	M	114	15	63	0.1	200	33.6	49.7	46.2	18.1	59.7	87.7	Apr-75	Sep-04	15	8				2.5	25	15	8	3.2	20
Metals	Lithium	No	Dis.	ug/l	-	108	8	5	0.5	100	45	43.1	11.1	45	43.7	10.5	Sep-75	Sep-04											
Metals	Lithium	No	Tot.	ug/l	-	44	10	4	5	110	47.5	43.4	24.9	54.2	54	15.8	Apr-75	Apr-81											
Metals	Manganese	No	Dis.	ug/l	M	300	41	15	0.5	16000	63.5	464	2490	66.9	465	2490	Sep-71	Sep-04				50	144						
Metals	Manganese	No	Tot.	ug/l	M	293	20	36	1	1680	112	186	230	112	187	229	Apr-75	Sep-04				50	124						
Metals	Mercury	No	Tot.	ug/l	M	47	10	19	0.05	0.8	0.25	0.215	0.050	0.233	0.235	0.043	Apr-75	Sep-82	2	0				0.77	1	0.05	28	0.012	28
Metals	Molybdenum	No	Dis.	ug/l	M	103	8	39	0.5	12.5	3.98	3.9	1.8	2.71	2.96	0.842	Sep-75	Sep-04											
Metals	Molybdenum	No	Tot.	ug/l	M	34	10	8	0.5	7	2.73	2.36	1.37	3.23	3.2	1.09	Apr-75	Jul-80											
Metals	Nickel	No	Tot.	ug/l	M	123	10	5	0.5	25	3.62	9.35	10.9	3.56	3.4	0.363	Apr-75	Sep-04						52	0	100	0	52	0
Metals	Phosphorus	No	Dis.	ug/l	M	186	9	8	5	470	40.1	45.1	29	42.6	45.9	28.8	Sep-75	Aug-04											

Table 3-10. Dunn County Surface Water Data Summary (Continued)

											Including NDs			Excluding NDs															
Class	Parameter	Field Results	Frac.	Units	EPA Class	No. Samples	No. Locations	No. ND	Min	Max	Median	Mean	SD	Median	Mean	SD	Begin Sample Date	End Sample Date	MCL	N Above MCL (no NDs)	SMCL	SMCL High	N Above SMCL (no NDs)	CWA Chronic	N Above CWA Chronic (no NDs)	NDak SW Human	N Above NDak Human (no NDs)	NDak SW Aquatic	N Above NDak SW Aquatic (no NDs)
Metals	Phosphorus	No	Tot.	ug/l	M	197	15	0	5	4800	91.2	402	1030	91.2	402	1030	Apr-75	Aug-04											
Metals	Selenium	No	Dis.	ug/l	CA	108	9	88	0.2	8.07	0.5	0.701	0.56	1	1.33	0.886	Sep-75	Sep-04	50	0				5	2	50	0	5	2
Metals	Selenium	No	Tot.	ug/l	CA	184	14	69	0.1	4.59	0.871	0.902	0.458	1.33	1.29	0.559	Apr-78	Sep-04	50	0				5	0	50	0	5	0
Metals	Zinc	No	Dis.	ug/l	M	54	12	32	1.5	50	13.4	14.3	9.37	20	19.1	9.55	Sep-75	Jul-04				5000	0	120	0	7400	0	120	0
Metals	Zinc	No	Tot.	ug/l	M	199	17	28	0.1	550	28.6	61.2	71	34	65.6	71.3	Apr-75	Sep-04				5000	0	120	10	7400	0	120	10
Nutrients	Ammonia-nitrogen as N	No	Dis.	mg/l	M	201	15	14	0.005	126	0.135	1.39	2.04	0.33	1.68	2.21	Apr-75	Aug-04											
Nutrients	Kjeldahl nitrogen	No	Tot.	mg/l	-	233	8	0	0.08	5.7	0.267	1.03	1.77	0.267	1.03	1.77	Jun-93	Sep-04											
Nutrients	Kjeldahl nitrogen	No	Tot.	mg/l as N	-	192	13	0	0.14	8.1	1.3	1.27	0.582	1.3	1.27	0.582	Apr-75	Aug-93											
Nutrients	Nitrogen	No	Tot.	mg/l	-	258	16	14	0.17	8.7	1.15	1.15	0.769	1.23	1.19	0.804	Apr-75	Sep-04											
Nutrients	Organic nitrogen	No	Tot.	mg/l	-	192	13	1	0.13	7.6	1.2	1.15	0.535	1.2	1.24	0.464	Apr-75	Aug-93											
Nutrients	Phosphate as P	No	Dis.	mg/l	-	171	9	64	0.002	0.22	0.0179	0.0288	0.0256	0.0205	0.033	0.0242	Apr-72	Sep-04											
Nutrients	Phosphate as P	No	Tot.	mg/l	-	99	13	0	0.004	3.36	0.15	0.272	0.376	0.15	0.272	0.376	May-79	Aug-04											

M = measured, as defined in EPA QAPP for Dunn County Retrospective Case Study (EPA, 2011b).
CA = Critical Analyte, as defined in EPA QAPP for Dunn County Retrospective Case Study (EPA, 2011b).
A red highlight indicates the value exceeded a screening criteria.
Shading indicates parameter was detected above one or more screening criteria.
MCL: EPA Maximum Contaminant Levels (National Primary Drinking Water Regulation)
SMCL: EPA Secondary MCL (Non-enforaceable guidance for drinking water)
CWA Chron.: National suggested aquatic life water quality criteria for chronic exposure as established by the Clean Water Act
NDak SW Human High/Low: North Dakota human health chronic values for Class I streams as established by NDAC Chapter 33-16-02.1
NDak SW Aquatic: North Dakota aquatic life chronic values for Class I streams as established by NDAC Chapter 33-16-02.1
Note: Sodium does not have an MCL; the value listed in the MCL column represents the EPA Health Advisory Level.
ND = non-detect
SD = standard deveation

Table 3-11. Dunn County Surface Water Data Summary (Reduced Dataset)

											Including NDs			Excluding NDs															
Class	Parameter	Field Results	Frac.	Units	EPA Class	No. Samples	No. Locations	No. ND	Min	Max	Median	Mean	SD	Median	Mean	SD	Begin Sample Date	End Sample Date	MCL	N Above MCL (no NDs)	SMCL	SMCL High	N Above SMCL (no NDs)	CWA Chronic	N Above CWA Chronic (no NDs)	NDak SW Human	N Above NDak Human (no NDs)	NDak SW Aquatic	N Above NDak SW Aquatic (no NDs)
Dissolved Gas	Carbon dioxide	No	Tot.	mg/l	M	296	16	0	0.1	63	7.41	8.81	7.96	7.41	8.81	7.96	Sep-71	Sep-04											
Gen WQ	Alkalinity as CaCO3	No	Tot.	mg/l	M	71	8	0	46	1330	481	478	191	481	478	191	Oct-80	Sep-04						20	0				
Gen WQ	Alkalinity as CaCO3	Yes	Tot.	mg/l	M	222	14	0	24	1060	401	392	167	401	392	167	Sep-71	Sep-80						20	0				
Gen WQ	Hardness as CaCO3	No	Tot.	mg/l	-	332	18	0	18	3700	286	467	818	286	467	818	Sep-71	Sep-04											
Gen WQ	Organic carbon	No	Dis.	mg/l	M	183	10	0	2.1	110	17	17.9	5.13	17	17.9	5.13	Apr-75	Sep-82											
Gen WQ	Oxygen	No	Dis.	mg/l	M	495	13	0	2.5	16.2	9.4	9.89	1.41	9.4	9.89	1.41	Apr-75	Feb-97								5	15		
Gen WQ	pH	No	Tot.	std units	M	198	39	0	6.6	8.7	8.02	7.86	0.452	8.02	7.86	0.452	Sep-71	Sep-04			6.5	8.5	14						
Gen WQ	pH	Yes	Tot.	std units	M	650	20	0	4.5	9.6	8.13	7.9	0.89	8.13	7.9	0.89	Sep-71	Sep-04			6.5	8.5	57						
Gen WQ	Specific conductance	No	Tot.	umho/cm	M	136	36	0	144	6900	1850	1680	783	1850	1680	783	Jan-61	Sep-04											
Gen WQ	Specific conductance	Yes	Tot.	umho/cm	M	1081	24	0	75	7170	1710	1770	1260	1710	1770	1260	Sep-71	Sep-04											
Gen WQ	Temperature, water	No	Tot.	deg C	M	897	17	0	0.1	28.5	10	10.5	4.13	10	10.5	4.13	Sep-71	Sep-04								29.44	0		
Gen WQ	Total dissolved solids	No	Dis.	mg/l	-	436	49	0	54	6810	1280	1210	996	1280	1210	996	Jan-61	Sep-04				500	372						
Inorganics, Major, Non-metals	Silica	No	Dis.	mg/l	-	416	46	2	0.4	53	9.75	11.4	7.6	9.75	11.4	7.6	Sep-71	Sep-04											
Major Anions	Chloride	No	Dis.	mg/l	CA	426	39	0	0.5	63	6.7	6.87	4.63	6.7	6.87	4.63	Sep-71	Sep-04				250	0	230	0	100	0		
Major Anions	Fluoride	No	Dis.	mg/l	M	434	47	3	0.05	1.4	0.5	0.46	0.25	0.5	0.478	0.239	Sep-71	Sep-04	4	0		2	0			4	0		
Major Anions	Sulfate	No	Dis.	mg/l	CA	435	48	0	5.5	4700	470	531	685	470	531	685	Sep-71	Sep-04				250	352						
Major Cations	Calcium	No	Dis.	mg/l	CA	435	48	0	4.9	403	50.5	61.6	56	50.5	61.6	56	Sep-71	Sep-04											
Major Cations	Magnesium	No	Dis.	mg/l	CA	435	48	0	1.3	642	29	47.6	89.4	29	47.6	89.4	Sep-71	Sep-04											
Major Cations	Potassium	No	Dis.	mg/l	CA	435	48	0	1.2	21	7.14	6.92	2.8	7.14	6.92	2.8	Sep-71	Sep-04											
Major Cations	Sodium	No	Dis.	mg/l	CA	435	48	0	2.8	1700	290	278	189	290	278	189	Sep-71	Sep-04	20	428									
Metals	Arsenic	No	Dis.	ug/l	CA	113	8	12	0.5	9	2.19	2.19	0.813	2.13	2.22	0.807	Sep-75	Sep-04	10	0				150	0	10	0	150	0
Metals	Arsenic	No	Tot.	ug/l	CA	47	10	0	1	10	2.73	3.12	1.37	2.73	3.12	1.37	Apr-75	Sep-82	10	0				150	0	10	0	150	0
Metals	Beryllium	No	Tot.	ug/l	M	48	10	44	5	20	5	5.38	0.917	12.5	12.5	3.54	Apr-75	Sep-82	4	4						4	4		
Metals	Boron	No	Dis.	ug/l	CA	392	44	4	10	2700	445	520	419	445	520	419	Sep-71	Aug-94											
Metals	Cadmium	No	Tot.	ug/l	M	31	8	31	ND	ND	ND	ND	ND	ND	ND	ND	Apr-75	Sep-82	5	0				0.25	0	5	0	0.27	0
Metals	Chromium	No	Tot.	ug/l	M	50	9	24	1	60	10.2	12.6	4.05	15	16.9	3.88	Apr-75	Sep-82	100	0						100	0		
Metals	Cobalt	No	Tot.	ug/l	M	19	10	16	1	250	50	35.1	30.6	77.5	77.5	81.3	Apr-75	Jun-80											
Metals	Iron	No	Dis.	ug/l	M	423	39	15	5	3800	250	408	497	250	409	497	Sep-71	Sep-04				300	81	1000	22				
Metals	Iron	No	Tot.	ug/l	M	62	10	0	220	41000	1290	3160	4120	1290	3160	4120	Apr-75	Sep-82				300	59	1000	21				
Metals	Lithium	No	Dis.	ug/l	-	108	8	5	0.5	100	45	43.1	11.1	45	43.7	10.5	Sep-75	Sep-04											
Metals	Lithium	No	Tot.	ug/l	-	44	10	4	5	110	47.5	43.4	24.9	54.2	54	15.8	Apr-75	Apr-81											
Metals	Manganese	No	Dis.	ug/l	M	299	40	15	0.5	16000	63.9	476	2520	67.8	476	2520	Sep-71	Sep-04				50	144						
Metals	Manganese	No	Tot.	ug/l	M	90	10	0	40	1200	158	176	85.4	158	176	85.4	Apr-75	Sep-82				50	84						
Metals	Mercury	No	Tot.	ug/l	M	47	10	19	0.05	0.8	0.25	0.215	0.050	0.233	0.235	0.043	Apr-75	Sep-82	2	0				0.77	1	0.05	28	0.012	28
Metals	Molybdenum	No	Dis.	ug/l	M	103	8	39	0.5	12.5	3.98	3.9	1.8	2.71	2.96	0.842	Sep-75	Sep-04											
Metals	Molybdenum	No	Tot.	ug/l	M	34	10	8	0.5	7	2.73	2.36	1.37	3.23	3.2	1.09	Apr-75	Jul-80											
Metals	Phosphorus	No	Tot.	ug/l	M	193	13	0	5	1100	91.2	147	135	91.2	147	135	Apr-75	Aug-93											
Metals	Selenium	No	Dis.	ug/l	CA	107	8	88	0.5	8.07	0.519	0.764	0.564	1.55	1.61	0.717	Sep-75	Sep-04	50	0				5	2	50	0	5	2
Metals	Zinc	No	Tot.	ug/l	M	46	8	6	5	550	49.3	63	48.8	70	72.3	45.5	Apr-75	Sep-82				5000	0	120	4	7400	0	120	4
Nutrients	Ammonia-nitrogen as N	No	Dis.	mg/l	M	198	13	14	0.005	126	0.13	1.56	2.15	0.33	1.93	2.32	Apr-75	Aug-93											
Nutrients	Kjeldahl nitrogen	No	Tot.	mg/l as N	-	192	13	0	0.14	8.1	1.3	1.27	0.582	1.3	1.27	0.582	Apr-75	Aug-93											
Nutrients	Nitrogen	No	Tot.	mg/l	-	192	13	14	0.17	8.7	1.3	1.34	0.726	1.35	1.4	0.752	Apr-75	Aug-93											
Nutrients	Organic nitrogen	No	Tot.	mg/l	-	192	13	1	0.13	7.6	1.2	1.15	0.535	1.2	1.24	0.464	Apr-75	Aug-93											

M = measured, as defined in EPA QAPP for Dunn County Retrospective Case Study (EPA, 2011b).
A red highlight indicates the value exceeded a screening criteria.
MCL: EPA Maximum Contaminant Levels (National Primary Drinking Water Regulation)
CWA Chron.: National suggested aquatic life water quality criteria for chronic exposure as established by the Clean Water Act
NDak SW Aquatic: North Dakota aquatic life chronic values for Class I streams as established by NDAC Chapter 33-16-02.1
ND = non-detect

CA = Critical Analyte, as defined in EPA QAPP for Dunn County Retrospective Case Study (EPA, 2011b).
Shading indicates parameter was detected above one or more screening criteria.
SMCL: EPA Secondary MCL (Non-enforaceable guidance for drinking water)
NDak SW Human High/Low: North Dakota human health chronic values for Class I streams as established by NDAC Chapter 33-16-02.1
Note: Sodium does not have an MCL; the value listed in the MCL column represents the EPA Health Advisory Level.
SD = standard deviation

The parameters that are above relevant comparison criteria in the reduced summary data table (Table 3-11) are less than those in the comprehensive data summary table (Table 3-10), and only include alkalinity, dissolved oxygen, pH, TDS, sulfate, sodium (dissolved), iron (dissolved and total), manganese (dissolved and total), and zinc. The maximum value was observed to change when comparing the datasets for the following analytes: pH , total iron and total manganese. When comparing datasets, the mean was observed to change for the following analytes: alkalinity (increase), TDS (increase), sulfate (increase), dissolved iron (increase), total iron (decrease), dissolved manganese (increase), total manganese (decrease), and zinc (increase). The median value changed when the datasets were compared for the following analytes: alkalinity (increase), TDS (increase), sulfate (increase), dissolved iron (increase), total iron (increase), total manganese (increase), and zinc (increase). A change in standard deviation was observed when comparing the two datasets for the following analytes: TDS (increased), sulfate (increase), total iron (decrease), dissolved manganese (increase), total manganese (decrease), and zinc (decrease). If an analyte is not listed above, no changes were found when comparing its summary statistics (mean, median, and standard deviation) between the two datasets. The total number of samples decreased from 19,196 to 11,478 when EPA STORET data were omitted from the surface water database; this is approximately a 40% reduction in the total number of samples presented in the comprehensive table (Table 3-10).

3.3.3 Temporal Comparison. Temporal trends in surface water quality data were examined for five constituents (calcium, chloride, magnesium, sodium and sulfate) and were plotted for eight surface water stations. Data for the two stations closest to the blowout are provided as Figures 3-12a and 3-12b. Station USGS-06339800 is located about 8.9 miles immediately to the east of the blowout and Station USGS-06339100 is located about 8.6 miles to the south of the blowout. The data for the remaining stations are included in Appendix C-2.

Sampling was performed at different time periods at each station. At four locations, data are available from the mid 1970s through 1981, which coincides with the time of the rapid growth of conventional oil exploration and production, but is well before the time when hydralic fracturing was first performed in North Dakota. Two stations (USGS-06339100 and 21NDHDWQ WQX-382038) include data from before and after hydraulic fracturing was performed with great frequency in Dunn County. It is not readily apparent from these figures that there is any significant change between the two periods for the concentrations of the plotted analytes. However, at Station 21NDHDWQ WQX-382038, values did exhibit an increase during two events after 2005. The surface water data are highly variable and exhibit very different patterns depending on the location of the monitoring station and period the data were collected; hence, it is difficult to assess any impacts to water quality due to hydraulic fracturing.

3.3.4 Spring Water Data Summary. Spring water quality data (from sources identified in Section 2.0) were compiled into a database to characterize the condition of springs within Dunn County. Figure 3-13 shows the locations of the 30 spring water quality monitoring stations. The dates of the sampling events range from 1950 to 1994. The monitored parameters include dissolved gas, general water quality parameters, inorganics (major, non-metal), major ions, metals, and nutrients.

A summary data table is provided with a list of detected parameters, number of samples (total number and number of locations), minimum, maximum, median, mean, standard deviation, date range for sample collection, and comparison against relevant screening criteria. Table 3-12 provides a summary of spring water quality parameters in surface water prior to 2005. Spring water quality parameters were compared to surface water regulatory criteria, including EPA MCL and SMCL, North Dakota human health and aquatic life chronic values for Class 1 streams, and CWA freshwater surface water quality criteria (chronic).

As indicated in Table 3-12, the minimum, maximum, median, and/or mean observed concentrations were higher than one or more of the relevant comparison criteria for the following three general water quality parameters: alkalinity, and TDS. For major ions, chloride, sulfate and sodium, the minimum, maximum, median, and/or mean observed concentations were above one or more comparison criteria. Chloride, which is an EPA indentified critical analyte, was higher than the SMCL of 250 mg/L in one sample and the CWA chronic screeningl level of 230 mg/L in one sample. Chloride was also above the North Dakota human health chronic value of 100 mg/L in one sample. Sulfate, an identified EPA critical analyte, was above the SMCL of 250 mg/L in 15 samples. The EPA critical analyte sodium was higher than the EPA Health Advisory level of 20 mg/L in 28 samples. The minimum, maximum, median, and/or mean observed concentations of iron and manganese were higher in one or more comparison criteria. Iron was above the SMCL of 300 µg/L and the CWA chronic screening level of 1,000 µg/L in 10 samples and two samples, respectively. Manganese was above the SMCL of 50 µg/L in 14 samples. Figure 3-6 shows the spatial distribution of parameters in spring water detected above the screening criteria.

There were no spring water data identified as indicative of environmental impact monitoring, so a reduced data summary table was not prepared.

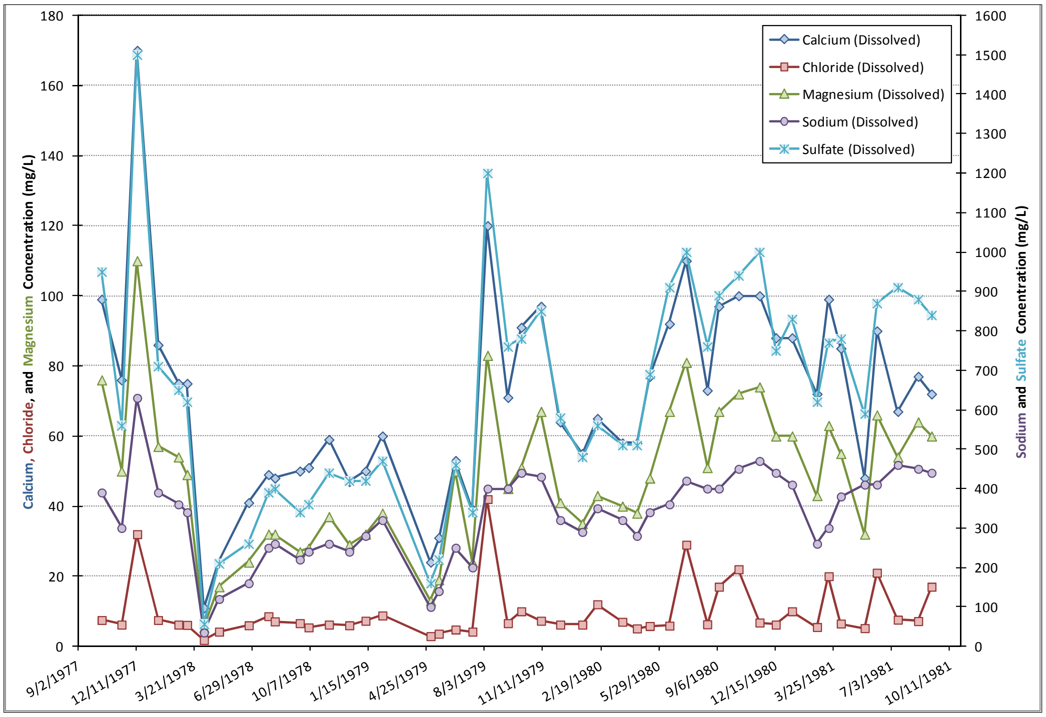


Figure 3-12a. Surface Water Quality Measured at USGS Station 06339800

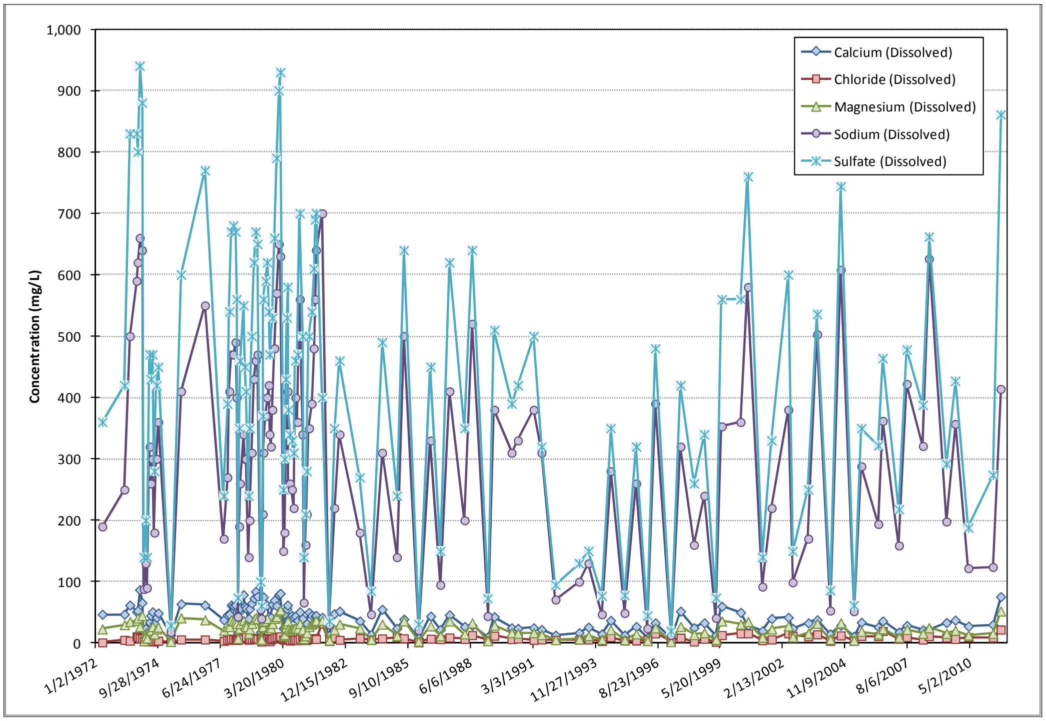


Figure 3-12b. Surface Water Quality Measured at USGS Station 06339100

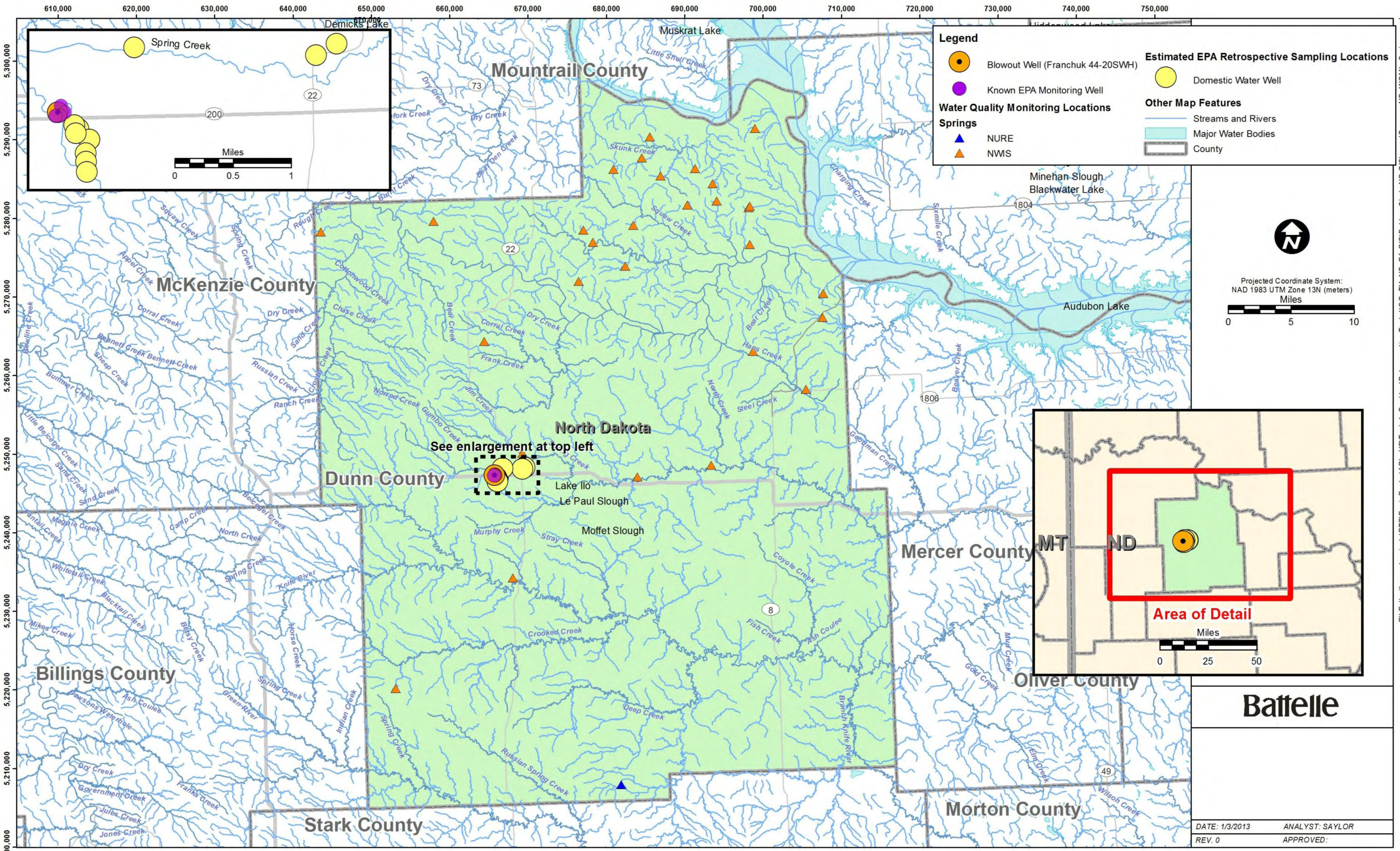


Figure 3-13. Spring Water Quality Monitoring Locations in Dunn County

Table 3-12. Dunn County Spring Water Summary Data

											Including NDs			Excluding NDs															
Class	Parameter	Field Results	Frac.	Units	EPA Class	No. Samples	No. Locations	No. ND	Min	Max	Median	Mean	SD	Median	Mean	SD	Begin Sample Date	End Sample Date	MCL	N Above MCL (no NDs)	SMCL	SMCL High	N Above SMCL (no NDs)	CWA Chronic	N Above CWA Chronic (no NDs)	NDak SW Human	N Above NDak Human (no NDs)	ND SW Aquatic	N Above NDak SW Aquatic (no NDs)
Dissolved Gas	Carbon dioxide	No	Tot.	mg/l	M	30	29	0	3.3	120	30	37.4	29	30	37.4	29	Aug-50	Nov-94											
Gen WQ	Alkalinity as CaCO3	Yes	Tot.	mg/l	M	29	28	0	188	707	327	369	144	327	369	144	Aug-50	Jun-73						20	0				
Gen WQ	Bicarbonate	Yes	Tot.	mg/l	-	29	28	0	229	862	399	449	175	399	449	175	Aug-50	Jun-73											
Gen WQ	Hardness as CaCO3	No	Tot.	mg/l	-	30	29	0	40	910	250	333	198	250	333	198	Aug-50	Nov-94											
Gen WQ	Hardness, non-carbonate as CaCO3	Yes	Tot.	mg/l	-	13	13	0	5	560	98	129	156	98	129	156	Aug-50	Jun-73											
Gen WQ	Hydrogen ion	No	Tot.	mg/l	-	29	28	0	1.00E-05	0.00025	0.00005	0.000062	0.0000546	0.00005	0.000062	0.0000546	Aug-50	Nov-94											
Gen WQ	pH	Yes	Tot.	std units	M	31	30	0	6.6	8.5	7.3	7.42	0.449	7.3	7.42	0.449	Aug-50	Nov-94			6.5	8.5	0						
Gen WQ	Specific conductance	Yes	Tot.	umho/cm	M	31	30	0	447	2500	1110	1220	650	1110	1220	650	Aug-50	Nov-94											
Gen WQ	Temperature, water	No	Tot.	deg C	M	28	27	0	7	13	9.5	9.31	1.45	9.5	9.31	1.45	Aug-50	Jun-73								29.44	0		
Gen WQ	Total dissolved solids	No	Dis.	mg/l	-	30	29	0	278	1770	706	798	455	706	798	455	Aug-50	Nov-94				500	20						
Inorganics, Major, Non-metals	Silica	No	Dis.	mg/l	-	30	29	0	6.5	28	15	16.3	4.52	15	16.3	4.52	Aug-50	Nov-94											
Major Anions	Chloride	No	Dis.	mg/l	CA	22	22	0	0.5	340	2.15	18.9	71.9	2.15	18.9	71.9	Aug-50	Nov-94				250	1	230	1	100	1		
Major Anions	Fluoride	No	Dis.	mg/l	M	29	28	0	0.1	0.8	0.3	0.348	0.183	0.3	0.348	0.183	Aug-50	Nov-94	4	0		2	0			4	0		
Major Anions	Sulfate	No	Dis.	mg/l	CA	30	29	0	41	767	239	293	230	239	293	230	Aug-50	Nov-94				250	15						
Major Cations	Calcium	No	Dis.	mg/l	CA	31	30	0	6.8	206	53.5	66.2	41.2	53.5	66.2	41.2	Aug-50	Nov-94											
Major Cations	Magnesium	No	Dis.	mg/l	CA	31	30	0	4.9	120	29	38.2	25	29	38.2	25	Aug-50	Nov-94											
Major Cations	Potassium	No	Dis.	mg/l	CA	31	30	0	2.3	12	4.25	4.59	1.98	4.25	4.59	1.98	Aug-50	Nov-94											
Major Cations	Sodium	No	Dis.	mg/l	CA	31	30	0	9.2	538.6	116	164	152	116	164	152	Aug-50	Nov-94	20	28									
Metals	Boron	No	Dis.	ug/l	CA	28	27	0	40	1100	360	359	235	360	359	235	Aug-50	Jun-79											
Metals	Iron	No	Dis.	ug/l	M	28	27	0	24	21000	270	1130	3980	270	1130	3980	Aug-50	Nov-94				300	10	1000	2				
Metals	Manganese	No	Dis.	ug/l	M	24	24	1	1	510	85	113	114	90	118	114	Aug-71	Nov-94				50	14						
Nutrients	Nitrate	No	Dis.	mg/l	-	29	28	0	0.5	2.7	1	1.19	0.571	1	1.19	0.571	Aug-50	Jun-73											
Nutrients	Nitrate as N	No	Dis.	mg/l	CA	29	28	0	0.11	0.61	0.23	0.27	0.127	0.23	0.27	0.127	Aug-50	Jun-73	10	0									

M = measured, as defined in EPA QAPP for Dunn County Retrospective Case Study (EPA, 2011b).
CA = Critical Analyte, as defined in EPA QAPP for Dunn County Retrospective Case Study (EPA, 2011b).
A red highlight indicates the value exceeded a screening criteria.
Shading indicates parameter was detected above one or more screening criteria.
MCL: EPA Maximum Contaminant Levels (National Primary Drinking Water Regulation)
SMCL: EPA Secondary MCL (Non-enforaceable guidance for drinking water)
CWA Chron.: National suggested aquatic life water quality criteria for chronic exposure as established by the Clean Water Act
NDak SW Human High/Low: North Dakota human health chronic values for Class I streams as established by NDAC Chapter 33-16-02.1
NDak SW Aquatic: North Dakota aquatic life chronic values for Class I streams as established by NDAC Chapter 33-16-02.1
Note: Sodium does not have an MCL; the value listed in the MCL column represents the EPA Health Advisory Level.
ND = non-detect
SD = standard deviation

3.3.5 **Coverage of EPA QAPP Analytes.** Tables 3-13 and 3-14 list whether or not the monitored parameters are part of the EPA QAPP for Dunn County for surface water and springs, respectively. Of the parameters identified in the QAPP, 237 are designated as either critical analytes (77) or measured parameters (177). Upon review of the surface water data (Table 3-13), there are 177 parameters (63 CA and 114 M) listed in the EPA QAPP for the retrospective study that are not covered by the data gathered for Dunn County, and an additional 27 (4 CA and 23 M) for which there was not a sufficient sample size (results from less than eight locations). Upon review of the spring data (Table 3-14), there are 201 parameters (65 CA and 136 M) listed in the EPA QAPP for the retrospective study that are not covered by the data gathered for Dunn County, and an additional 20 (4 CA and 16 M) for which there was not a sufficient sample size (results from less than eight locations). Therefore, no water quality characterization is available for comparison should these parameters be detected in future sampling efforts.

Table 3-13. List of EPA Parameters Not Present in Dunn County Surface Water Quality Characterization

Parameters - Measured		*Parameter - Critical Analyte*	
NOT FOUND			
.beta.-Hexachlorocyclohexane	Endrin aldehyde	1,2,4-Trichlorobenzene	Fluoranthene
.delta.-Hexachlorocyclohexane	Endrin ketone	2,4,5-Trichlorophenol	Fluorene
1,1,1-Trichloroethane	Ethanol	2,4,6-Trichlorophenol	Gasoline range organics
1,1,2-Trichloroethane	Ethyl tert-butyl ether	2,4-Dichlorophenol	Hexachlorobenzene
1,1-Dichloroethane	Ethylbenzene	2,4-Dimethylphenol	Hexachlorobutadiene
1,1-Dichloroethylene	Ethylene	2,4-Dinitrophenol	Hexachloroethane
1,2,3-Trimethylbenzene	formate	2,4-Dinitrotoluene	Indeno[1,2,3-cd]pyrene
1,2,4,5-Tetrachlorobenzene	Hexachlorocyclopentadiene	2-Methylnaphthalene	Isophorone
1,2,4-Trimethylbenzene	Hydrogen	4-methylphenol	isopropyl alcohol
1,2-Dibromo-3-chloropropane	Inorganic carbon	Acenaphthene	m-Cresol
1,2-Dichloroethane	Iron, ion (Fe2+)	Acenaphthylene	m-Dichlorobenzene
1,2-dinitrobenzene	isobutyrate	Anthracene	Methane
1,2-Diphenylhydrazine	Isopropyl ether	Benz[a]anthracene	m-Nitroaniline
1,3,5-Trimethylbenzene	Lactic acid	Benzo(b)fluoranthene	Naphthalene
1,3-dimethyl adamantane	m-Dinitrobenzene	Benzo[a]pyrene	Nitrobenzene
1,4-dinitrobenzene	Methyl tert-butyl ether	Benzo[ghi]perylene	o-Chlorophenol
1-chloronaphthalene	Methylene chloride	Benzo[k]fluoranthene	o-Cresol
2,3,4,6-Tetrachlorophenol	Mevinphos	Bis(2-chloroethoxy)methane	o-Dichlorobenzene
2,4,6-tribromophenol (surrogate)	m-Xylene	Bis(2-chloroethyl) ether	o-Nitroaniline
2,6-Dichlorophenol	nitrobenzene-d5 (surrogate)	Bis(2-chloroisopropyl) ether	o-Nitrophenol
2,6-Dinitrotoluene	N-Nitrosodiethylamine	Butane	p-Bromophenyl phenyl ether
2-butoxyethanol	N-Nitrosodimethylamine	Butyl benzyl phthalate	p-Chloroaniline
2-Chloronaphthalene	N-Nitrosodi-n-butylamine	Carbazole	p-Chloro-m-cresol
2-fluorobiphenyl (surrogate)	N-Nitrosodi-n-propylamine	Chrysene	p-Chlorophenyl phenyl ether
2-fluorophenol (surrogate)	N-Nitrosodiphenylamine	Di(2-ethylhexyl) phthalate	p-Dichlorobenzene
3,3'-Dichlorobenzidine	N-Nitrosomethylethylamine	Dibenz[a,h]anthracene	Pentachlorophenol
4,4'-methylenebis (2-chloroaniline)	Oxygen-18/Oxygen-16 ratio	Dibenzofuran	Phenanthrene
4,4'-methylenebis (N,Ndimethylaniline)	o-Xylene	Diesel range organics	p-Nitroaniline
acetate	Parathion	Diethyl phthalate	Propane
Acetone	Pentachlorobenzene	Dimethyl phthalate	Pyrene
Acetophenone	Phenol	Di-n-octyl phthalate	tert-Butanol
acetylene	Phorate	Ethane	
adamantane	p-Nitrophenol		
Aniline	Pronamide		

Table 3-13. List of EPA Parameters Not Present in Dunn County Surface Water Quality Characterization (Continued)

Parameters - Measured		***Parameter - Critical Analyte***	
NOT FOUND			
Azinphos-methyl	Propionic acid		
Azobenzene	p-Xylene		
Benzene	Pyridine		
Benzoic acid	Redox Potential		
Benzyl alcohol	Silicon		
Bromide	squalene		
Butyric acid	Sulfide		
Carbon disulfide	Sulfur		
Carbon tetrachloride	Terbufos		
Cerium	terphenyl-d14 (surrogate)		
Chlorobenzene	terpineol		
Chlorobenzilate	tert-Amyl methyl ether		
Chloroform	Tetrachloroethylene		
cis-1,2-Dichloroethylene	tetraethylene glycol		
Cumene	Titanium		
Cyclohexene, 1-methyl-4-(1-methylethenyl)-, (4R)-	Toluene		
d2H	trans-1,2-Dichloroethylene		
d87/86Sr	tri(2-butoxethyl)phosphate		
Dibutyl phthalate	Trichloroethylene		
Dichlorvos	triethylene glycol		
Diethylene glycol monobutyl ether acetate	Uranium		
Diphenylamine	Vinyl chloride		
Disulfoton	Xylene		
SAMPLE SIZE < 8 OR ALL SAMPLES NON-DETECT			
.alpha.-Endosulfan	Lindane	4,6-Dinitro-o-cresol	Nitrite as N
.alpha.-Hexachlorocyclohexane	Malathion	Nitrate as N	Strontium
.beta.-Endosulfan	Methoxychlor		
Aldrin	p,p'-DDD		
Antimony	p,p'-DDE		
Carbaryl	p,p'-DDT		
Dieldrin	Silver		
Dinoseb	Thallium		
Endosulfan sulfate	Trifluralin		
Endrin	Turbidity		
Heptachlor	Vanadium		
Heptachlor epoxide			

Table 3-14. List of EPA Parameters Not Present in Dunn County Spring Water Quality Characterization

Parameters - Measured		***Parameter - Critical Analyte***	
NOT FOUND			
.alpha.-Endosulfan	Endrin aldehyde	1,2,4-Trichlorobenzene	Fluoranthene
.alpha.-Hexachlorocyclohexane	Endrin ketone	2,4,5-Trichlorophenol	Fluorene
.beta.-Endosulfan	Ethanol	2,4,6-Trichlorophenol	Gasoline range organics
.beta.-Hexachlorocyclohexane	Ethyl tert-butyl ether	2,4-Dichlorophenol	Hexachlorobenzene
.delta.-Hexachlorocyclohexane	Ethylbenzene	2,4-Dimethylphenol	Hexachlorobutadiene
1,1,1-Trichloroethane	Ethylene	2,4-Dinitrophenol	Hexachloroethane
1,1,2-Trichloroethane	formate	2,4-Dinitrotoluene	Indeno[1,2,3-cd]pyrene
1,1-Dichloroethane	Heptachlor	2-Methylnaphthalene	Isophorone
1,1-Dichloroethylene	Heptachlor epoxide	4,6-Dinitro-o-cresol	isopropyl alcohol
1,2,3-Trimethylbenzene	Hexachlorocyclopentadiene	4-methylphenol	m-Cresol
1,2,4,5-Tetrachlorobenzene	Hydrogen	Acenaphthene	m-Dichlorobenzene
1,2,4-Trimethylbenzene	Inorganic carbon	Acenaphthylene	Methane
1,2-Dibromo-3-chloropropane	Iron, ion (Fe2+)	Anthracene	m-Nitroaniline
1,2-Dichloroethane	isobutyrate	Benz[a]anthracene	Naphthalene
1,2-dinitrobenzene	Isopropyl ether	Benzo(b)fluoranthene	Nitrite as N
1,2-Diphenylhydrazine	Lactic acid	Benzo[a]pyrene	Nitrobenzene
1,3,5-Trimethylbenzene	Lead	Benzo[ghi]perylene	o-Chlorophenol
1,3-dimethyl adamantane	Lindane	Benzo[k]fluoranthene	o-Cresol
1,4-dinitrobenzene	Malathion	Bis(2-chloroethoxy)methane	o-Dichlorobenzene
1-chloronaphthalene	m-Dinitrobenzene	Bis(2-chloroethyl) ether	o-Nitroaniline
2,3,4,6-Tetrachlorophenol	Mercury	Bis(2-chloroisopropyl) ether	o-Nitrophenol
2,4,6-tribromophenol (surrogate)	Methoxychlor	Butane	p-Bromophenyl phenyl ether
2,6-Dichlorophenol	Methyl tert-butyl ether	Butyl benzyl phthalate	p-Chloroaniline
2,6-Dinitrotoluene	Methylene chloride	Carbazole	p-Chloro-m-cresol
2-butoxyethanol	Mevinphos	Chrysene	p-Chlorophenyl phenyl ether
2-Chloronaphthalene	m-Xylene	Di(2-ethylhexyl) phthalate	p-Dichlorobenzene
2-fluorobiphenyl (surrogate)	nitrobenzene-d5 (surrogate)	Dibenz[a,h]anthracene	Pentachlorophenol
2-fluorophenol (surrogate)	N-Nitrosodiethylamine	Dibenzofuran	Phenanthrene
3,3'-Dichlorobenzidine	N-Nitrosodimethylamine	Diesel range organics	p-Nitroaniline
4,4'-methylenebis (2-chloroaniline)	N-Nitrosodi-n-butylamine	Diethyl phthalate	Propane
4,4'-methylenebis (N,Ndimethylaniline)	N-Nitrosodi-n-propylamine	Dimethyl phthalate	Pyrene
acetate	N-Nitrosodiphenylamine	Di-n-octyl phthalate	tert-Butanol
Acetone	N-Nitrosomethylethylamine	Ethane	
Acetophenone	Organic carbon		
acetylene	Oxygen-18/Oxygen-16 ratio		
adamantane	o-Xylene		
Aldrin	p,p'-DDD		
Ammonia-Nitrogen as N	p,p'-DDE		
Aniline	p,p'-DDT		
Antimony	Parathion		
Azinphos-methyl	Pentachlorobenzene		
Azobenzene	Phenol		
Benzene	Phorate		
Benzoic acid	p-Nitrophenol		
Benzyl alcohol	Pronamide		
Bromide	Propionic acid		
Butyric acid	p-Xylene		
Cadmium	Pyridine		

Table 3-14. List of EPA Parameters Not Present in Dunn County Spring Water Quality Characterization (Continued)

Parameters - Measured		Parameter - Critical Analyte	
NOT FOUND			
Carbaryl	Redox Potential		
Carbon disulfide	squalene		
Carbon tetrachloride	Sulfide		
Chlorobenzene	Sulfur		
Chlorobenzilate	Terbufos		
Chloroform	terphenyl-d14 (surrogate)		
cis-1,2-Dichloroethylene	terpineol		
Cumene	tert-Amyl methyl ether		
Cyclohexene, 1-methyl-4-(1-methylethenyl)-, (4R)-	Tetrachloroethylene		
d2H	tetraethylene glycol		
d87/86Sr	Thallium		
Dibutyl phthalate	Toluene		
Dichlorvos	trans-1,2-Dichloroethylene		
Dieldrin	tri(2-butoxethyl)phosphate		
Diethylene glycol monobutyl ether acetate	Trichloroethylene		
Dinoseb	triethylene glycol		
Diphenylamine	Trifluralin		
Disulfoton	Turbidity		
Endosulfan sulfate	Vinyl chloride		
Endrin	Xylene		
SAMPLE SIZE < 8 OR ALL SAMPLES NON-DETECT			
Aluminum	Oxygen	Arsenic	Selenium
Beryllium	Phosphorus	Barium	Strontium
Cerium	Silicon		
Chromium	Silver		
Cobalt	Titanium		
Copper	Uranium		
Molybdenum	Vanadium		
Nickel	Zinc		

4.0: CONCLUSIONS AND KEY FINDINGS

EPA is conducting a retrospective case study in Dunn County, North Dakota as part of its evaluation of whether a relationship exists between hydraulic fracturing and drinking water. EPA selected this site in response to a blowout at Franchuk 44-20SWH, located approximately 2 miles to the southwest of Killdeer, North Dakota. To investigate the potential impacts from the blowout, EPA is collecting groundwater and surface water quality data in the vicinity of the well and the City of Killdeer. Samples collected during nine monitoring events spanning March 2011 through November 2012 have shown no impacts to groundwater in the Killdeer aquifer that indicate significant release of petroleum or hydraulic fracturing fluids to groundwater. No impacts were detected in the nearest surface water body, Spring Creek.

To assess potential water quality effects, existing water quality conditions in the area in the vicinity of the blowout as well as other areas in the county where a relationship to hydraulic fracturing may be postulated must first be understood. This report provides an initial understanding and characterization of water quality in Dunn County based upon readily available information and data from government agencies including the USGS, EPA, and state of North Dakota.

The primary objective of this report is to help understand and characterize groundwater and surface water conditions within the study area prior to unconventional oil and gas development and identify parameters that may be present due to historic land use activities. This objective was satisfied by systematically conducting the steps outlined below.

- **Define the spatial boundaries and attributes of the Dunn County study area.** The Killdeer aquifer is present beneath the site and is the source of drinking water for the City of Killdeer as well as a source of water from nearby domestic wells. Four monitoring wells were installed in September 2010 and an additional four wells, one of which was screened at two depths, were installed in April 2011 to monitor the impacts of the blowout. The locations of the wells installed in 2010 are shown in Figure 1-1; however, the locations of the remaining four wells were not available at the time this report was prepared.

  Two spatial boundaries have been defined for the evaluation presented in this document. The first is the area around the blowout well and the city of Killdeer (Figure 1-1), which can be used to make a direct comparison of the results from the EPA study. The second boundary is Dunn County in its entirety. Evaluation of data throughout Dunn County will help to assess a baseline condition, which is used to compare to the area immediately surrounding the Franchuk 44-20SWH blowout or other areas in Dunn County should the need arise. No other incidents involving the failure of hydraulically fractured wells have occurred in Dunn County or North Dakota prior to or following the blowout of Franchuk 44-20SWH

- **Identify existing land use and water quality data that can be used to provide historical context for characterizing water resources in the defined study area, along with identifying associated parameters that could impact drinking water resources.** Land use patterns can impact water quality. Agriculture is the largest industry in Dunn County; approximately 1,800 square miles of the county, representing about 90% of the land area, were dedicated to agricultural activities in 2011. Other land uses that may impact water quality in the county include urban, residential and road runoff, habitat modification, and municipal and industrial wastewater discharges. Also, atmospheric deposition has been documented to impair water quality in the northeaster portion of the county in the Lake Sakakawea water sub basin.

There are a number of recognized environmental sites within the county and, in particular, in the vicinity of the blowout well, including one NPDES permitted facility, three leaking USTs, and 15 sites with recognized environmental conditions. Conventional oil exploration and production have been performed in this area over the last several decades. Based on the names of the companies associated with the sites, 16 are oil and gas related including seven pipeline sites, three exploration sites, two gas plants and two compressor stations, and one site owned by an oil company and one site owned by an oil field service company.

Agricultural practices such as the application of herbicides and pesticides and addition of fertilizers contribute to the presence of organophosphates and elevated levels of nitrogen and phosphorous. In addition, handling of livestock is a suspected pathway for the presence of E. coli and other bacteria in surface water. Although conventional oil and gas development as well as leaking USTs that contained petroleum products are potential sources of petroleum hydrocarbons and BTEX, these constituents were not reported in the referenced data sources.

There are numerous regulations and permitting requirements in place to protect water resources for different land uses. The NDIC has promulgated changes to ensure the oil industry remains good stewards of the land.

- **Develop a comprehensive list of water quality parameters detected or monitored for in the study area, and compare to EPA QAPP requirements.**
  A comprehensive list of water quality parameters monitored for and detected in Dunn County was established using information collected in the databases discussed in Section 2.2. One limitation of these databases is that water quality focused on general inorganic parameters, and, as such, little data on organic water quality parameters were available. Another limitation is that the data were not collected with the intended purpose of baseline water quality for evaluation of potential impacts from hydraulic fracturing or the specific blowout incident. An effort was made to evaluate data from wells and surface water monitoring stations in the vicinity of the blowout and compare them to data from wells and stations located at other locations within Dunn County.

- **Conduct summary statistical analyses and comparing the water quality summary statistics to relevant state and federal screening criteria.**
  - Groundwater quality data summary
    - Groundwater quality data were compiled to characterize Dunn County groundwater quality prior to unconventional oil and gas development (i.e., pre-2005). The data represent samples collected from 1937 to 2003 (no data are available for 2004).
    - Paramaters above one or more screening criteria and the number and percentage of results above each criteria are presented in Table 4-1
      - General water quality parameters pH and TDS are above one or more screening criteria. Both are identified as EPA measured analytes.
      - Major ions chloride, fluoride, sodium and sulfate are above one or more screening criteria. Chloride, sodium and sulfate are identified as EPA critcal analytes.

        - Metals including aluminum, arsenic, beryllium, boron, iron, manganese, mercury, phosphorous and strontium were above one or more screening criteria. The metals noted here are EPA measured analytes with the exception of arsenic, boron, and strontium, which are EPA critical analytes.
        - One nutrient, nitrate as N, is above one screening criteria and is identified as an EPA critcal analyte.
        - No sample results are available for organic compounds.
    - Groundwater quality data including calcium, chloride, manganese, sodium, and sulfate were evaluated based on varying hydrogeologic conditions including geologic formation and depth. Results of regression analyses indicate that there is a relationship between the parameters of interest and location beneath the ground surface. Most pronounced were the high chloride concentrations at greater depths.
    - Of the 237 parameters identified in the EPA QAPP for the Dunn County retrospective case study, 27 parameters (15 measured, 12 critical analytes) are included in the database with results from at least eight locations; 15 parameters (15 measured, 0 critical analytes) are not included in the database due to results from less than eight locations; and 195 parameters (130 measured, 65 critical analytes) have no results.

- Surface water quality data summary
    - Parameters above one or more screening criteria and the number and percentage of results above each criteria are presented in Table 4-2
        - General water quality parameters including alkalinity, pH, dissolved oxygen, , and TDS are above one or more screening criteria. Elevated levels of TDS may be related to agriculture. Alkalinity, pH, and dissolved oxygen are identified as EPA measured analytes.
        - Major ions chloride, sodium and sulfate are above one or more screening criteria. Elevated levels of chloride and sodium are likely a result of the application of road salt. Elevated levels of sulfate may be related to agriculture. All three are identified as EPA critical analytes.
        - Metals including aluminum, arsenic, cadmium, chromium, copper, iron, lead, manganese, selenium and zinc are above one or more relevant comparison criteria. The metals noted here are all identified as EPA measured analytes, with the exceptions of arsenic and selenium, which are identified as EPA critical analytes.
        - No sample results are available for organic compounds.
    - The removal of 28 surface water monitoring locations due to potential issues associated with environmental impact monitoring results in a 40% reduction in the number of surface water sample results. As a result of the removal of these data, there are fewer parameters detected above screening criteria. As noted in Table 4-2, removal of data associated with impact monitoring does not result in a consistent change (improvement) in background water quality.
    - Of the 237 parameters identified in the EPA QAPP for the Dunn County retrospective case study, 28 parameters (19 measured, 9 critical analytes) are included in the database with results from at least eight locations; 27 parameters

(23 measured, four critical analytes) are not included in the database due to results from less than eight locations; and 177 parameters (114 measured, 63 critical analytes) have no results.

- Spring water quality data summary
  - Spring water quality data were available at 30 locations.
  - Parameters above one or more screening criteria and the number and percentage of results above each criteria are presented in Table 4-3
    - General water quality parameters including alkalinity, dissolved oxygen, pH, and TDS are above one or more screening criteria. Alkalinity, pH, and dissolved oxygen are identified as EPA measured analytes.
    - Major ions chloride, sodium, and sulfate are above one or more screening criteria. All are identified as EPA critcal analytes.
    - Metals including iron, manganese, and zinc are above one or more screening criteria. The metals noted here are EPA measured analytes.
    - No sample results are available for organic compounds.
  - Of the 237 parameters identified in the EPA QAPP for the Dunn County retrospective case study, 16 parameters (eight measured, eight critical analytes) are included in the database with results from at least eight locations; 20 parameters (16 measured, four critical analytes) are not included in the database due to results from less than eight locations; and 201 parameters (136 measured, 65 critical analytes) have no results.

Determining a relationship between hydraulic fracturing and drinking water will be challenging given the lack of adequate data to characterize background water quality conditions. Water quality data presented to characterize conditions prior to hydraulic fracturing in this report should only be used in the context of providing an understanding of the observed range in parameter concentrations for the study area (e.g., Dunn County). As noted by the USGS (DeSimone, 2009; Ayotte et al., 2011) and observed in the data presented here, natural variability, land use patterns and other factors affect observed water quality. These factors have to be understood at the local level or specific areas of interest before a good understanding of background water quality can be determined for those areas. Without adequate background water quality, impacts observed as part of the EPA study will require a rigorous investigation before relating those impacts to hydraulic fracturing.

Table 4-1. Pre-2005 Groundwater Quality Summary of Parameters Above Screening Criteria

				Complete Dataset		
Class	Parameter	Fraction	EPA	N	No. Above Screening Criteria	% Above Screening Criteria
Gen WQ	pH	Total	M	440	22	5.0
Gen WQ	pH (field)	Total	M	382	16	4.2
Gen WQ	TDS	Dissolved	-	807	689	85
Major Anions	Chloride	Dissolved	CA	744	11	1.5
Major Anions	Fluoride	Dissolved	M	795	476	60
Major Anions	Sulfate	Dissolved	CA	782	382	49
Major Cations	Sodium	Dissolved	CA	802	778	97
Metals	Aluminum	Dissolved	M	13	1	7.7
Metals	Arsenic	Dissolved	CA	20	14	70
Metals	Beryllium	Dissolved	M	13	2	15
Metals	Boron	Dissolved	CA	669	2	0.3
Metals	Iron	Dissolved	M	662	350	53
Metals	Manganese	Dissolved	M	758	398	53
Metals	Mercury	Dissolved	M	15	4	27
Metals	Phosphorus	Dissolved	M	10	7	70
Metals	Strontium	Dissolved	CA	22	1	4.5
Nutrients	Nitrate as N	Dissolved	CA	350	19	5.4

M = measured, as defined in EPA QAPP for Dunn County Retrospective Case Study (EPA, 2011b).
CA = critical analyte, as defined in EPA QAPP for Dunn County Retrospective Case Study (EPA, 2011b).
N = number of samples

Table 4-2. Pre-2005 Surface Water Quality Summary of Parameters Above Screening Criteria

				Complete Dataset			Reduced Dataset		
Class	Parameter	Fraction	EPA	N	No. Above Screening Criteria	% Above Screening Criteria	N	No. Above Screening Criteria	% Above Screening Criteria
Gen WQ	Oxygen	Dissolved	M	511	15	3	495	15	3
Gen WQ	Oxygen (field)	Dissolved	M	631	51	8	0	0	0
Gen WQ	pH	Total	M	375	34	9.1	198	14	7.1
Gen WQ	pH (field)	Total	M	1,204	118	9.8	650	57	8.8
Gen WQ	TDS	Dissolved	-	681	396	58	436	372	85
Major Anions	Sulfate	Dissolved	CA	555	364	66	435	352	81
Major Cations	Sodium	Dissolved	CA	435	428	98	435	428	98
Major Cations	Sodium	Total	CA	241	241	100	0	0	0
Metals	Aluminum	Total	M	118	88	75	5	5	100
Metals	Arsenic	Total	CA	227	6	2.6	24	0	0
Metals	Beryllium	Total	M	97	4	4	48	4	8.3
Metals	Cadmium	Total	M	119	9	7.6	0	0	0
Metals	Chromium	Total	M	153	2	1.3	54	0	0
Metals	Copper	Total	M	183	19	10	31	0	0
Metals	Iron	Dissolved	M	424	81	19	423	81	19
Metals	Iron	Total	M	304	124	41	62	59	96
Metals	Lead	Total	M	114	25	22	10	0	0
Metals	Manganese	Dissolved	M	300	144	48	299	144	48
Metals	Manganese	Total	M	293	124	42	90	84	93
Metals	Mercury	Total	M	47	28	60	47	28	60
Metals	Selenium	Dissolved	CA	108	2	1.9	107	2	1.9
Metals	Zinc	Total	M	199	10	5.0	46	4	8.7

M = measured, as defined in EPA QAPP for Dunn County Retrospective Case Study (EPA, 2011b).
CA = critical analyte, as defined in EPA QAPP for Dunn County Retrospective Case Study (EPA, 2011b).
N = number of samples

Table 4-3. Pre-2005 Spring Water Quality Summary of Parameters Above Screening Criteria

				Complete Dataset		
Class	Parameter	Fraction	EPA	N	No. Above Screening Criteria	% Above Screening Criteria
Gen WQ	TDS	Dissolved	-	30	20	67
Major Anions	Chloride	Dissolved	CA	22	1	4.5
Major Anions	Sulfate	Dissolved	CA	30	15	50
Major Cations	Sodium	Dissolved	CA	31	28	90
Metals	Iron	Dissolved	M	28	10	36
Metals	Manganese	Dissolved	M	24	14	58

M = measured, as defined in EPA QAPP for Dunn County Retrospective Case Study (EPA, 2011b).
CA = critical analyte, as defined in EPA QAPP for Dunn County Retrospective Case Study (EPA, 2011b).
N = number of samples

5.0: REFERENCES

Ayotte, J.D. Gronberg, J.M., and Apodaca, L.E., 2011, Trace Elements and Radon in Groundwater Across the United States: U.S. Geological Survey Scientific Investigations Report 2011-5059, 115 p.

EPA, see United States Environmental Protection Agency

DeSimone, L. A. 2009. Quality of Water from Domestic Wells in Principal Aquifers of the United States, 1991-2004. USGS Scientific Investigations Report 2008-5227. http://fracfocus.org/sites/default/files/publications/quality_of_water_from_domestic_wells_in_principal_aquifers_of_the_united_states_1991-2004.pdf

Heck, Thomas J., LeFever, Richard D., Fischer, David W., and LeFever, Julie. Accessed 2012. Overview of the Petroleum Geology of the North Dakota Williston Basin. Accessed from the North Dakota Geologic Survey website. Available at https://www.dmr.nd.gov/ndgs/Resources/WBPetroleumnew.asp

Hewitt, C.N. and M.B. Rashed. 1992. Removal rates of selected pollutants in the runoff waters from a major rural highway. Water Research, no. 26(3): 311-319.

LeFever, Julie. 2005. Oil Production from the Bakken Formation: A Short History. NDGS Newsletter. Vol. 32, Number 1. Available at: https://www.dmr.nd.gov/ndgs/newsletter/NL05w/pdf/Bakken%20Formation.pdf. Accessed June 2012.

NDIC see North Dakota Industrial Commission

NDGS see North Dakota Geologic Survey

North Dakota Department of Health (NDDH), Division of Water Quality, Surface Water Quality Management Program. 2009. North Dakota's Water Quality Monitoring Strategy for Surface Waters 2008 – 2019 (Final). October. Available at: http://water.epa.gov/type/wetlands/upload/nddh_wpp.pdf

North Dakota Department of Health (NDDH). 2012a. *Much Needed Oil Field Wastewater Infrastructure.* Presented at the North Dakota Water and Pollution Control Conference. October 11. Available at: http://www.ndhealth.gov/MF/NDWPCC.html

North Dakota Department of Health (NDDH). 2012b. Housing in the Oil Field, Environmental and Permitting Issues. Available at: http://www.ndhealth.gov/wm/News/HousingInTheOilfield.pdf

North Dakota Department of Health (NDDH), Division of Water Quality. 2012c. North Dakota 2012 Integrated Section 305(b) Water Quality Assessment Report and Section 303(d) List of Waters Needing Total Maximum Daily Loads. April.

North Dakota Geological Survey. 2001. Geology of Dunn County. Prepared by Murphy, Edward C. ISSN 0546-5001.

North Dakota Industrial Commission (NDIC), Department of Mineral Resources, Oil and Gas Division. 2011. North Dakota Oil and Gas and Coal Producing Counties, Summary of Proposed 2012 Rules. Available at: https://www.dmr.nd.gov/oilgas/presentations/NDOGCPC2011-10-06.pdf

North Dakota Industrial Commission (NDIC), Department of Mineral Resources, Oil and Gas Division. 2012. Monthly Oil Product for Local Counties Chart. Available at: https://www.dmr.nd.gov/oilgas/stats/Dunn.pdf

North Dakota Industrial Commission (NDIC), personal communication, December 6, 2012.

North Dakota State Water Commission (NDSWC). 2012. Water Query Permit Database. Available at: http://www.swc.state.nd.us/4dlink7/4dcgi/permitsearchform/Map%20and%20Data%20Resources

Solars, C.J. Peters, C.J., and R. Perry. 1982. Bromide in Urban Runoff Water Quality Considerations. Effects of Waste Disposal on Groudnwater and Surface Water. Proceedings of Exeter Symposium. IAIIS Publication No. 139. July.

Scorecard. 2012. The Pollution Information Site. Available at: http://scorecard.goodguide.com/env-releases/us-main-map.tcl

Terracon. 2012. Franchuk 44-20 SWH Well Release Killdeer, North Dakota. April 2012 Semi-Annual Report. November 5, 2012.

United States Census Bureau. 2010. *Census of Population and Housing*. Available at: http://2010.census.gov/2010census.

United States Department of Agriculture (USDA). 2011. CropScape Cropland Data Layer. National Agricultural Statistics Service. Available at: http://nassgeodata.gmu.edu/CropScape/

United States Environmental Protection Agency (EPA).1995. Controlling Nonpoint Source Runoff Pollution from Roads, Highways and Bridges. epa.gov.

United States Environmental Protection Agency (EPA). 1996. Groundwater Issue, Low-Flow (Minimal Drawdown Ground-Water Sampling Procedures. Prepared by Robert W. Puls and Michael J. Barcelona. EPA/540/S-95/504. April.

United States Environmental Protection Agency (EPA). 1997. Community Water System Survey, Volume I: Overview. 815-R-97-001a. Washington, DC: Office of Water.

United States Environmental Protection Agency (EPA). 2001. EPA Requirements for Quality Assurnace Project Plans. EPA QA/R-5. EPA/240/B-01/003. March.

United States Environmental Protection Agency (EPA). 2005. Effect of Ozone on Disinfection Byproduct Formation of Algae. Available at: http://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract/6641/report/0

United States Environmental Protection Agency (EPA). 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA QA/G-4.

United States Environmental Protection Agency (EPA). 2009. Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities. Unified Guidance. EPA 530/R-09-007. March. http://www.epa.gov/osw/hazard/correctiveaction/resources/guidance/sitechar/gwstats/unified-guid.pdf

United States Environmental Protection Agency (EPA). 2011a. "Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources," EPA/600/R-11/122, November.

United States Environmental Protection Agency. 2011b. "GWERD Quality Assurance Project Plan, Hydraulic Fracturing Retrospective Case Study, Bakken Shale, Killdeer and Dunn County, ND." Prepared by Shaw Environmental. Available at: http://www.epa.gov/hfstudy/bakken-qapp.pdf

United States Environmental Protection Agency. 2012a. Water Quality Assessment and TMDL information. Available at http://www.epa.gov/waters/ir/index.html.

United States Environmental Protection Agency. 2012b. Envirofacts. Available at http://www.epa.gov/enviro/

United States Environmental Protection Agency. 2012c. Watershed Tracking, Assessment, and Environmental Results. North Dakota Water Quality Assessment Report. Database accessed at: http://ofmpub.epa.gov/waters10/attains_state.control?p_state=ND&p_cycle=2010

United States Geological Survey (USGS). 1979. *Ground-water Resources of Dunn County, North Dakota*. Lead author, Robert L. Klausing.

United States Geological Survey (USGS). 1988. *Geologic Summary and Hydrocarbon Plays, Williston Basin, Montana, North and South Dakota, and Sioux Arch, South Dakota and Nebraska, U.S.* Lead author, James A. Patterson

United States Geological Survey (USGS). 2010. "USGS DS 240: Enhanced Historical Land-Use and Land-Cover Data Sets of the U.S. Geological Survey," May 7. Available at: http://water.usgs.gov/GIS/dsdl/ds240/index.html.

Wordpress. 2011. The Start of Horizontal Drilling in North Dakota in 1987, Accessed at:http://northdakotaoil.wordpress.com/2011/05/14/the-start-of-horizontal-drilling-in-north-dakota-in-1987/

Appendix A

QA/QC Review

BAKKEN SHALE, KILLDEER AND DUNN COUNTY, ND DATA QUALITY ASSESSMENT

The site characterization data quality objectives (DQOs) were followed to assess the quality of the Bakken Shale, Killdeer, and Dunn County, North Dakota site characterization data and inform a general assessment of data quality. This assessment was performed on the full site database to assess the overall quality of available data. In general, it was determined that the available metadata and supporting information were not sufficient to make definitive statements about the quality of the data; therefore, no data were eliminated from the site characterization based on this data quality assessment. Table A-1 summarizes the review and the results of the data quality assessment. The assessment process is described below.

Table A-1. Summary of Data Quality Assessment[15]

DQO Assessment Criteria	DATA TYPE Groundwater	Surface Water	Springs
Organizations contributing data	ND State Water Commission (NDSWC); USGS (NWIS, NURE)	NDSWC, USGS (NWIS), STORET	USGS (NWIS, NURE)
• Data were collected by an agency known to implement a rigorous quality system. • Data were collected under approved Quality Assurance Project Plan (QAPP)/Field Sampling Plan (FSP)	No	Yes	Yes
Data were collected by laboratories known to have a rigorous quality system.	Unknown	Unknown	Unknown
The analysis methods were identified and appropriate	Unknown	No	Unknown
For non-detect values, the detection limits were defined and sensitive enough for the parameter.	Yes Except for Arsenic	Yes	Yes
If quality control data were available, accuracy was demonstrated to be ≥80% and precision was demonstrated to be ±30%. Otherwise, is there evidence that quality-related qualifiers were applied to the data.	Unknown	Unknown	Unknown

[15] Assessment Criteria: **Yes** (DQO assessment criteria achieved for ≥90% of data in full dataset).
Variable (DQO assessment criteria achieved for 50-90% of data in full dataset). **No** (DQO assessment criteria achieved for <50% of data in full dataset). **Unknown** (information was not provided ≥90% of data in full dataset).

Organization and Quality Documentation

The existence and application of a quality system is a critical aspect of collecting high-quality data because it indicates that an organization has a documented, systematic approach to apply quality principles to data collection. A review of the website of each organization collecting data for the study was reviewed to for evidence that a quality system was in place. Evidence could include a reference or link to a quality management plan, quality assurance (QA) project plan, sampling and analysis plan, standard operating procedures (SOPs), a discussion of quality control, or other elements of a QA document.

- **Groundwater**. Groundwater data were gathered from three sources; these sources and the approximate percent of data contributed by each are as follows:
    - ND State Water Commission (SWC) (54%)
    - USGS NURE (1%)
    - USGS NWIS/USGS ND Water Science Center (45%)

  Data collected by USGS are supported by a documented quality system. Field samples and measurement data are collected under the USGS National Field Manual for the Collection of Water-Quality Data and National Field Quality Assurance Program, respectively. Based on the available information, it does not appear that the NDSWC has an overall quality system that establishes requirements for the collection of environmental data. Data may be contributed by a number of organizations. Therefore, the quality of groundwater data is considered variable. Overall, approximately half of the groundwater data were likely collected under a documented and rigorous quality system.

- **Surface Water**. Surface water data were gathered from four sources; these sources and the approximate percent of data contributed by each are as follows:
    - EPA STORET (65%)
        - EPA National Aquatic Resource Survey (0.2%)
        - ND Dept. of Heath (50%)
        - US Army Corps of Engineers (USACE) Omaha District (15%)
    - ND SWC (5%)
    - USGS NWIS/USGS ND Water Science Center (30%)

  As noted above, data collected by USGS are supported by a quality system. Similarly, the ND Dept. of Heath appears to have a quality system for the collection of environmental samples although the rigor of the program may vary depending on the program that sampling is intended to support. Sampling by the USACE Omaha District followed a sampling and analysis plan. As noted above, the NDSWC does not appear to have documented standards for the collection of environmental data EPA National Aquatic Resource Survey appears to have a documented quality system that establishes quality assurance and quality control (QA/QC) procedures for sample and data collection (http://water.epa.gov/type/rsl/monitoring/riverssurvey/index.cfm). It is likely that program-specific procedures are defined for some of these data, but the programs associated with the data pulled from the database are not defined. Therefore, the quality of these data is not known. Overall, approximately 80% of the surface water data were likely collected under a documented and rigorous quality system.

- **Spring**. Springs data were gathered from two sources; these sources and the approximate percent of data contributed by each are as follows:
    - USGS NURE (5%)

- o USGS NWIS/ND Water Science Center (95%)

As noted above, data collected by USGS are supported by a quality system.

Laboratories
The qualifications of analytical laboratories are critical in supporting the quality of data produced. Laboratory accreditation by an independent body such as the National Environmental Laboratory Accreditation Program (NELAP) indicates that the laboratory has a quality system in place.

- **Groundwater**
  The analytical laboratories were not defined for 21982 (99%) of the 22176 groundwater results and therefore the qualifications of the laboratory cannot be assessed.

- **Surface Water**
  The analytical laboratories were not defined for 49681 (98%) of the 50570 surface water results and therefore the qualifications of the laboratory cannot be assessed.

- **Springs**
  The analytical laboratories were not defined for any of the 775 spring results and therefore the qualifications of the laboratory cannot be assessed.

Methods
Many water quality parameters can be collected and measured using more than one method. For example, methods for collection and analysis of water samples for total organic carbon (TOC) analysis are described EPA SW846 method 9060, EPA waste water method 415.2 and Standard Methods 5310. Each method is appropriate for specific applications but may yield different results or have different detection limits. Therefore, it is important to know the sample collection and analytical methods used for analysis so that the appropriateness of the method for the current application can be determined.

- **Groundwater**
  Analytical methods were reported for less than 4% of the groundwater data. NWIS was the only organization reporting the methods associated with the analytical results of which all appear to be organizational SOPs. Therefore it is not possible to assess data quality based on the method used for analysis.

- **Surface Water**
  Analytical methods are reported for approximately 36% of the surface water data. EPA STORET and NWIS were the only organizations reporting methods associated with the analytical results. All of the methods in EPA STORET are standard EPA methods. All of the NWIS methods are organizational SOPs. Most of the internal SOP references are associated with analyses for which the analytical laboratory is not identified. However, the fact that internal SOPs exist for the analysis indicates that the methods are established and standardized. Based on this assessment, the quality of surface water data based on defined analytical methods is variable.

- **Spring**
  Analytical methods were reported for approximately 6% of the springs data. NWIS was the only organization reporting the methods associated with the analytical results of which all are to be organizational SOPs. Therefore it is not possible to assess data quality based on the method used for analysis.

Detection Limits

Laboratory detection limits must be appropriate for the intended use of the data. While detection limits may be appropriate for the initial data collection purpose, they may not be appropriate for a secondary use, such as this report. Therefore, the detection limits of the data set were reviewed vs. State and Federal regulatory limits and screening criteria applicable to Bakken Shale, Killdeer, and Dunn County. The results are summarized in Tables A-2 and A-3.

- **Groundwater**
  For groundwater, of the 7361 results for EPA chemicals of interest, 162 were detected below the laboratory detection limits. Laboratory detection limits were reported for all "U" values with the exception of 27 metals values which were not included in the data analysis procedures because no result could be inferred. Laboratory detection limits for 30 arsenic results were above either/or both the EPA carcinogen threshold and the EPA non-carcinogen threshold (Table A-2).

- **Surface Water**
  For surface water, of the 7645 results for EPA chemicals of interest, 473 were detected below the laboratory detection limits. For 2196 of these values no detection limit was defined; these values were not included in the data analysis procedures because no result could be inferred. One laboratory detection limit for selenium was above the CWA Chronic value, and the ND aquatic threshold (Table A-3).

- **Spring**
  For springs, of the 237 results for EPA chemicals of interest, only one result was reported below the laboratory detection limit, however, it was within the regulatory or screening criteria.

Quality Control

Quality control samples collected in the field (field blanks and field duplicates) and in the laboratory (method blanks and spiked samples) are used to identify potential field or laboratory contamination and to quantify the bias, accuracy and precision of the entire measurement system. None of the data sets used in this report included quality control samples. Therefore, the assessment of quality control results could not be used to inform the quality of data used for this report.

- **Groundwater**
  For groundwater, no laboratory QC, field equipment blank, or field duplicate data were reported. Overall, there is insufficient QC data available to assess data quality, therefore on the basis of QC data, data quality is unknown.

- **Surface Water**
  For surface water, no laboratory QC, field equipment blank, or field duplicate data were reported. Overall, there is insufficient QC data available to assess data quality, therefore on the basis of QC data, data quality is unknown.

- **Springs**
  For springs, no laboratory QC, field equipment blank, or field duplicate data were reported. Overall, there is insufficient QC data available to assess data quality, therefore on the basis of QC data, data quality is unknown.

Data Qualifiers

Data qualifiers assigned by either a laboratory or independent validation provide information about the reported results. Of primary interest are qualifiers that indicate problems with sample collection, handling, analysis, or quality control samples that could influence the accuracy or precision of the reported results. For the data sets examined for this report, laboratory comments also provide valuable information about the data when no qualifiers are assigned. An exhaustive review of comment fields was conducted as part of this review. In some cases, the comments provided addition information about sample preservation or processing procedures, such as acidification or filter size; most comments documented data quality issues. These comments were used to assign three qualifiers to the data: U (detected below reporting limits); J (estimated value); and S (suspect).

- U qualifiers were assigned if the comment indicated a value (a) was less than (<) another number, assumed to be the reporting limit; (b) was less than a practical quantitation limit or reporting limit, or (c) was between the reporting limit and method detection limit.
- J qualifiers were applied if the comment indicated problems with quality control sample results, blank contamination, holding time or temperature deviations, or if the values were estimated.
- S qualifier (suspect) was assigned if the data entry comment indicated that it was suspect; if the parameter was marked as a highly variable compound; if the method high range was exceeded; or if processing errors were noted.

If more than one qualifier applied to the same value the qualifiers were assigned according to the hierarchy: U > S > J. The assessment of data qualifiers is summarized below.

For the Bakken Shale, Killdeer, and Dunn County data, the data set did not provide comments that could be used to assess data quality. Without data qualifiers or quality control data it is not possible to determine if the results of quality control samples analyzed with the field samples demonstrated that the analytical quantification system was in control. A summary of the qualifiers applied by the laboratories is presented below.

Overall, a small percentage of the data were assigned qualifiers (Table A-4). The qualifiers were primarily assigned by the laboratories with a few additional qualifiers assigned by Battelle based on the text comment analysis described above. Of the qualifiers assigned, the vast majority were "U" qualifiers, indicating that a compound was not detected above the detection limit. "H" qualifiers were assigned to 9 results provided by the USACE Omaha District but the definition of this qualifier was not provided. Overall, less than 0.1% of the data were qualified with data quality-related qualifier J (estimated). No (suspect) qualifiers were assigned to the data set. However, because it is evident that laboratory qualifiers were not assigned to the vast majority of data, the actual data qualifiers that might apply to the data are unknown.

- **Groundwater**
  Overall, 5% of the groundwater data were assigned qualifiers (Table A-4). Of the qualifiers assigned, the vast majority were "U" qualifiers, indicating that a compound was not detected above the reporting limit. One value (pH result of 18 standard units) was qualified with a data quality-related qualifier R (rejected).

- **Surface Water**
  Overall, 11% of the surface water data were assigned qualifiers (Table A-5). Of the qualifiers assigned, the vast majority were "U" qualifiers, indicating that a compound was not detected above the reporting limit. Twenty-two values (less than 0.1% of the data) were qualified with a data quality-related qualifier J (estimated) and H (holding time exceeded).

- **Spring**
  Overall, less than 2% of the spring data were assigned qualifiers, of which all were “U” qualifiers, indicating that a compound was not detected above the reporting limit (Table A-6).

Table A-2. Groundwater Non-Detected Values with Detection Limits Equal to Above Screening Criteria (All units are µg/L)

Data Source	EPA Chemical of Interest	Fraction	Lab Detection Limit (ug/l)	Non-Detected Values (U) > Screening Criteria	MCL	SMCL high	EPA Carc	EPA NonCarc
NDSWC	Arsenic	Dissolved	1	1	10		**0.045**	4.7
NDSWC	Arsenic	Dissolved	5	18	10		**0.045**	**4.7**
NDSWC	Arsenic	Dissolved	10	1	10		**0.045**	**4.7**
NURE	Arsenic	Dissolved	0.5	2	10		**0.045**	4.7
NWIS	Arsenic	Dissolved	1	5	10		**0.045**	4.7
NWIS	Arsenic	Dissolved	5	3	10		**0.045**	**4.7**
Total				30				

Bolded value indicates that detection limits above regulatory or screening values.

Table A-3. Surface Water Non-Detected Values with Detection Limits Equal to or Above Screening Criteria (All units are µg/L)

Data Source	EPA Chemical of Interest	Fraction	Lab Detection Limit (ug/l)	Non-Detected Values (U) > Screening Criteria	MCL	SMCL high	CWA Chronic	ND Aquatic	ND Human high
NWIS	Selenium	Dissolved	10	1	50		**5**	**5**	50
Total				1					

Bolded value indicates that detection limits above regulatory or screening values.

Table A-4. Groundwater Data Qualifiers Based on Data Source and Chemicals Listed in the EPA QAPP

	R	U	No Qualifier Assigned	Total
GROUNDWATER				
EPA Chemicals of Interest				
NDSWC		100	4158	4258
USGS NURE		5	28	33
USGS NWIS		57	3013	3070
Total Qualifiers		**162**	**7199**	**7361**
Chemicals Measured by EPA But Not Chemicals of Interest				
NDSWC	1	87	3120	3208
USGS NURE		26	34	60
USGS NWIS		217	3084	**3301**
Total Qualifiers	**1**	**330**	**6238**	**6569**
Chemicals Not Measured by EPA				
NDSWC		557	4038	4595
USGS NURE		7	14	21
USGS NWIS		33	3597	3630
Total Qualifiers		**597**	**7649**	**8246**
GW Grand Total	**1**	**1089**	**21086**	**22176**

Table A-5. Surface Water Data Qualifiers Based on Data Source and Chemicals Listed in the EPA QAPP

	H	J	U	No Qualifier Assigned	Total
SURFACE WATER					
EPA Chemicals of Interest					
EPA STORET		6	247	3529	3782
NDSWC			14	845	859
USGS NWIS			212	2792	3004
Total Qualifiers		**6**	**473**	**7166**	**7645**
Chemicals Measured by EPA But Not Chemicals of Interest					
EPA STORET	4	9	2290	17665	19968
NDSWC			39	648	687
USGS NWIS		1	819	6409	7229
Total Qualifiers	**4**	**10**	**3148**	**24722**	**27884**
Chemicals Not Measured by EPA					
EPA STORET	5	6	1339	7682	9032
NDSWC			25	766	791
USGS NWIS			440	4778	5218
Total Qualifiers	5	6	1804	13226	15041
SW Grand Total	**9**	**22**	**5425**	**45114**	**50570**

Table A-6. Spring Water Data Qualifiers Based on Data Source and Chemicals Listed in the EPA QAPP

Data Source	U	No Qualifier Assigned	Grand Total
EPA Chemicals of Interest			
USGS NURE	1	10	11
USGS NWIS		226	226
Total Qualifiers	1	236	237
Chemicals Measured by EPA But Not Chemicals of Interest			
USGS NURE	10	10	20
USGS NWIS		230	230
Total Qualifiers	10	240	250
Chemicals Not Measured by EPA			
USGS NURE	1	6	7
USGS NWIS		281	281
Total Qualifiers	1	287	288
Spring Grand Total	**12**	**763**	**775**

Conclusion for Groundwater Data:
Based on the data quality assessment, the groundwater data should be used with care for the following reasons: the quality systems applied to data collection, analytical laboratories, analytical methods and laboratory quality control data and quality-related qualifiers are unknown or not reported. Quality system elements that support the data include acceptable laboratory detection limits with the exception of arsenic.

Conclusion for Surface Water Data:
Based on the data quality assessment, the quality of surface water data cannot be verified and should be used with care for the following reasons: the analytical laboratories, analytical methods and laboratory quality control data and quality-related qualifiers are unknown or not reported. Quality system elements that support the data include collection organizations with known quality systems and detection limits adequate for comparison with regulatory and screening values.

Conclusion for Spring Data:
Based on the data quality assessment, the spring water data should be used with care for the following reasons: the analytical laboratories, analytical methods and laboratory quality control data and quality-related qualifiers are unknown or not reported. Quality system elements that support the data include collection organizations with known quality systems and acceptable laboratory detection limits.

Appendix B

Dunn County Water Quality Data

DUNN COUNTY WATER QUALITY DATA

The groundwater, surface water and spring water quality data collected for this report were collected from several different databases. Often the parameter name for a compound was provided in a slightly different form or in different units. Where appropriate, the data were standardized to consistent units and parameter names prior to developing summary statistics for each parameter. Further screening of the parameters was performed prior to inclusion in the Section 3 summary data tables. For example, there had to be sufficient data for a parameter to be included in the summary tables. In this case, sufficient data were defined as having a result from at least eight distinct locations (note distinct locations were selected to reduce the influence of having multiple results from a single sampling location on the reported baseline data set). Prior to inclusion in Section 3 summary data tables, the collected data were aggregated by media (groundwater, surface water, spring water) initially, then screened for inclusion; data were removed from the summary tables if:

- There were less than eight distinct locations having at least one result (as noted above, this screen was included to minimize the influence of multiple results for a parameter from a single location).
- All results for a parameter are non-detect. Note for EPA parameters (M or CA), if the number of locations (N) with at least one result is eight or more, the parameter is identified as having sufficient baseline data for this effort and is included in the Section 3 summary data tables; if N < 8 the parameter is identified as having <8 results (insufficient baseline data for this effort).
- Results for a parameter are identified as redundant, meaning there are more than one reported result for the parameter for an individual sample (for example, total dissolved solids is reported both as a calculated and laboratory measured result by sample; the calculated values are identified as redundant and are not included in the summary data tables).

There were also several parameters for which result fractions were reported in a number of different ways depending upon the different data sources queried, even after the initial data standardization. In these cases, the result fraction with the greatest number of results is included in the Section 3 summary tables for EPA parameters (M or CA). Professional judgment was further used to reduce the number of non-EPA parameters included in Section 3 summary tables to exclude data that are of little or no concern to understanding baseline water quality conditions. Table B-1 summarizes data removed based upon the parameter name, result fraction, or reported units by media. This same screen was used for each characterization report; therefore, some of the parameters, result fractions, or units specified in Table B-1 may not be included within the raw data collected for this report.

All removed data are retained in this appendix for potential future use in electronic format. The electronic data are also provided by media. Four Excel files are included:

- Table B-2 Dunn Removed 20121218.xls
- Table B-3 Dunn GW Data Dump 20121218.xls
- Table B-4 Dunn SW Data Dump 20121218.xls
- Table B-5 Dunn SPR Data Dump 20121218.xls

Table B-2 contains three worksheets for data that were not included (data removed) from the Section 3 summary data tables, one each for the groundwater, surface water, and spring water quality data. Tables B-3, B-4, and B-5 contain the collected groundwater, surface water, and spring data for Dunn County. This information represents all of the data used to characterize the water quality in Dunn County, ND.

Table B-1. Data removed based on parameter, result fraction, or result units by media

All Media		
Result Fraction	Supernate	
Result Fraction	Suspended - as long as parameter name is not total suspended solids	
Result units	ueq/l, %, meq/l, none, or nu	
Surface and Spring Water		
Parameter Name	**Result Fraction**	**Result Units**
Acidity	Total	mg/l as H
Acidity	Total	mg/L $CaCO_3$
Ammonia and Ammonium	Dissolved	mg/l NH_4
Ammonia and Ammonium	Total	mg/l NH_4
Bicarbonate		
Hydrogen ion		
Gross alpha radioactivity	Dissolved	pCi/l
Thorium-230 ref std	Dissolved	pCi/l
Cesium-137 ref std	Dissolved	pCi/l
Inorganic nitrogen (nitrate and nitrite)	Total	
Inorganic nitrogen (nitrate and nitrite) as N	Total	
Inorganic nitrogen (nitrate and nitrite) as N	Dissolved	
Nitrate	Dissolved	mg/l
Nitrate-nitrite	Total	
Nitrogen, mixed forms (NH3), (NH4), organic, (NO2) and (NO3)	Total	mg/l NO_3
Phosphate	Dissolved	mg/l
Phosphate	Dissolved	mg/l as P
Phosphorous as PO4	Total	mg/l
Sodium adsorption ratio		
Sodium plus potassium		
Sodium, percent total cations		
Strontium	Dissolved	ug/l
Surfactants -- CWA304B		
Total Solids		
Turbidity	Total	FNU
Turbidity	Total	JTU
Groundwater		
Parameter Name	**Result Fraction**	**Result Units**
Acidity	Total	mg/l as H
Acidity	Total	mg/L $CaCO_3$
Carbonate (CO3)		
Hydrogen ion		
Bicarbonate		
Sodium adsorption ratio		
Sodium plus potassium		
Sodium, percent total cations		
Nitrate	Dissolved	mg/l
Nitrate-Nitrite	Dissolved	mg/l

Table B-1. Data removed based on parameter, result fraction, or result units by media (Continued)

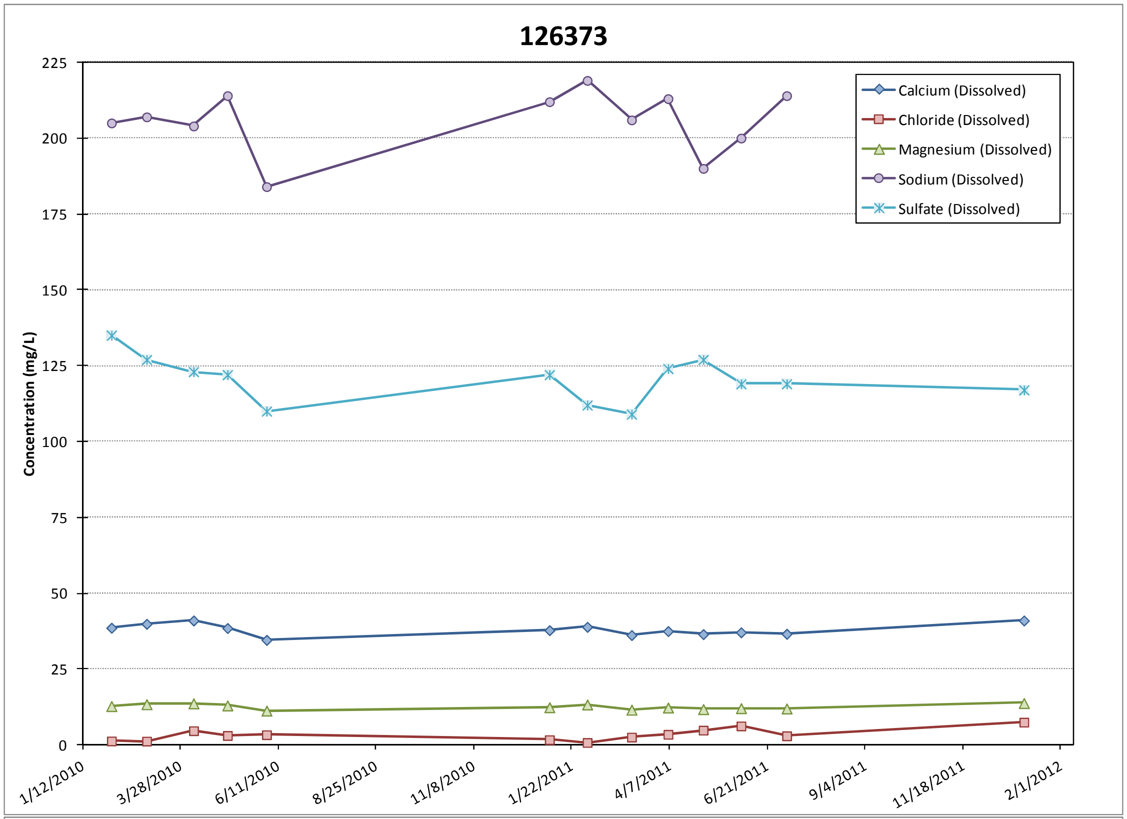
Nitrite	Dissolved	mg/l
Phosphate	Dissolved	mg/l
Phosphorous as PO4	Total	mg/l
Orthophosphate as PO4	Total	mg/l
Settleable solids	Total	mg/l
ammonia and ammonium	Dissolved	mg/l as NH_4
ammonia and ammonium	Total	mg/l as NH_4
d13C DIC		

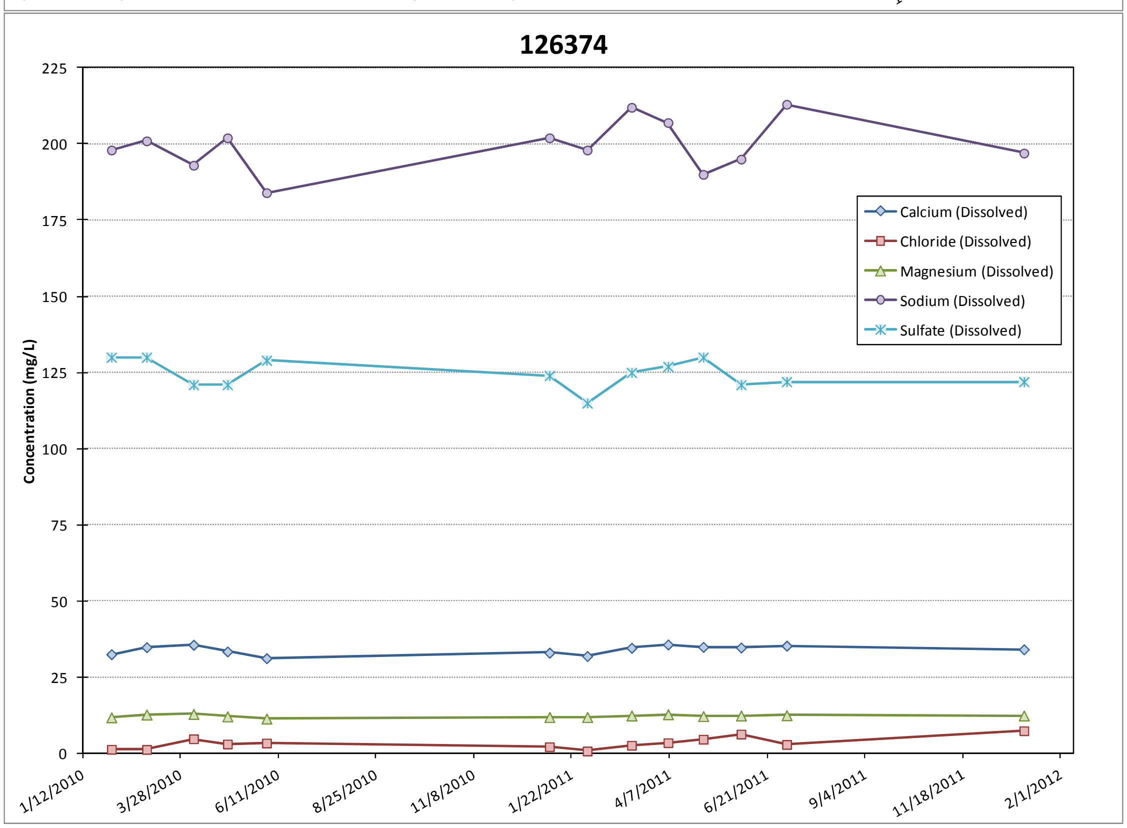
Appendix C

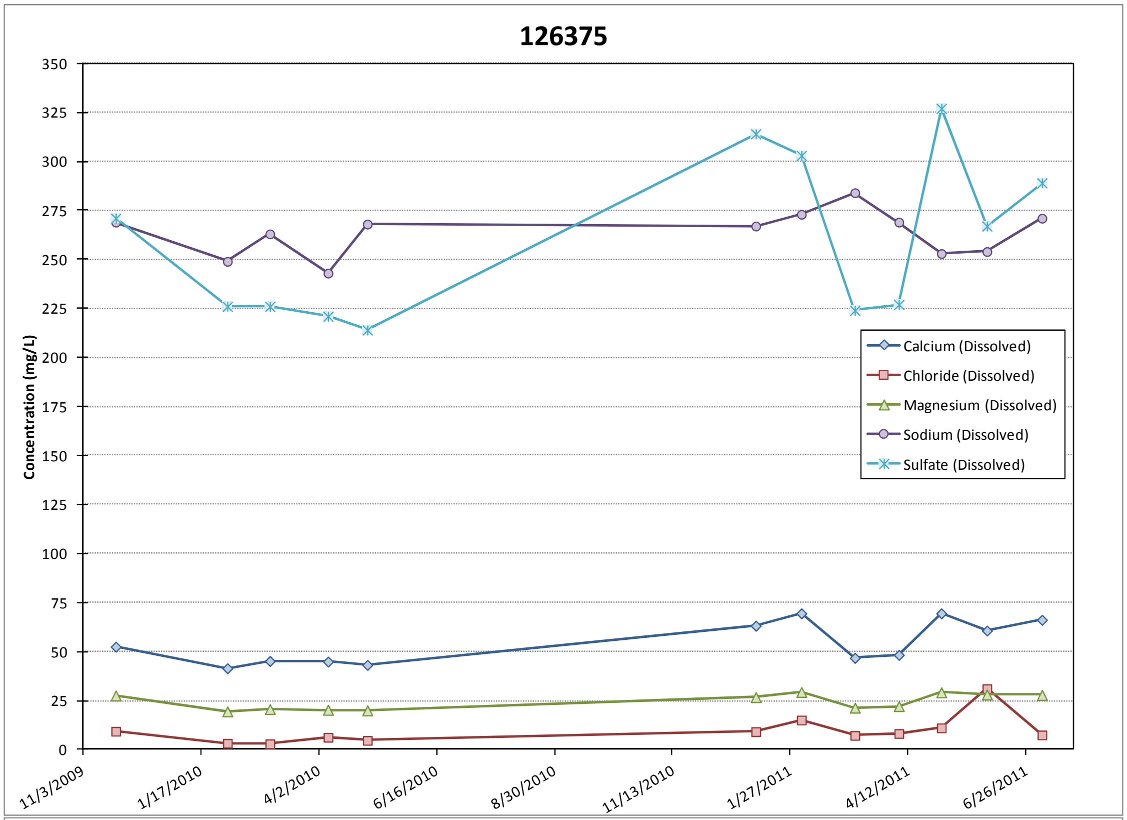
Time-Series Plots for Calcium, Chloride, Magnesium, Sodium and Sulfate

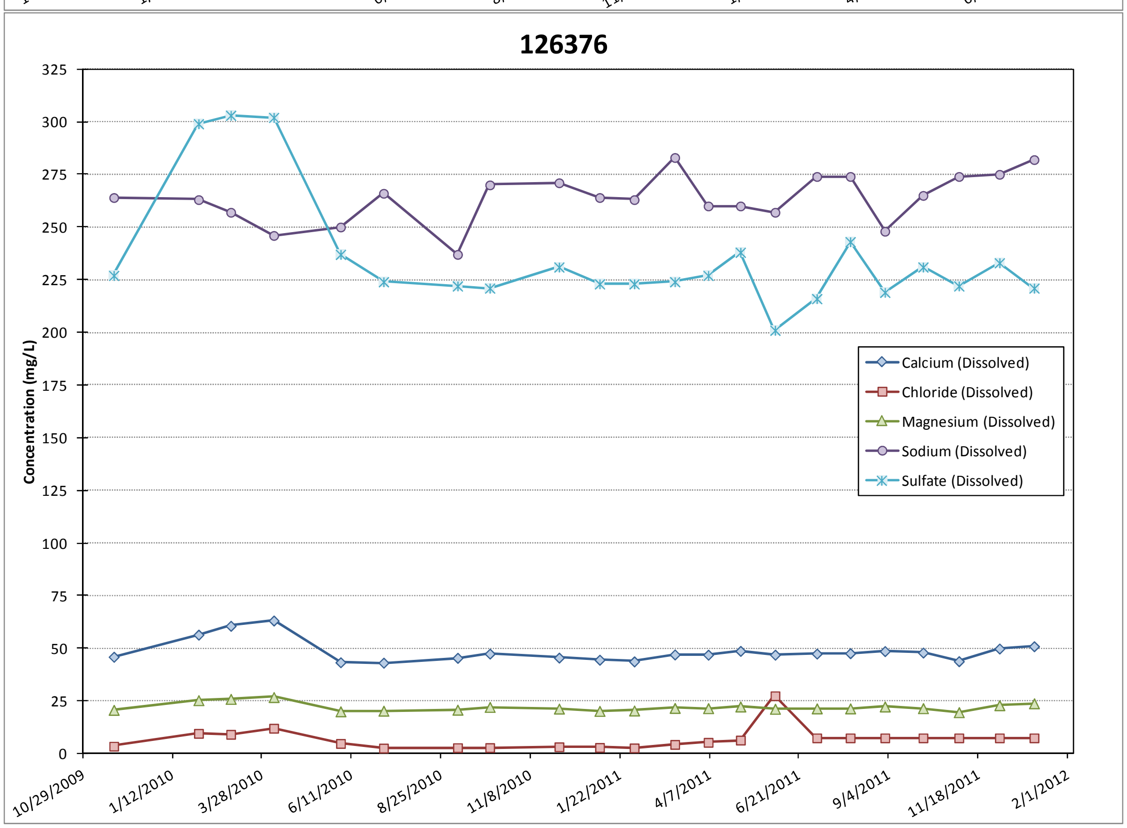
Appendix C-1

Groundwater


126373
Concentration (mg/L)
Calcium (Dissolved)
Chloride (Dissolved)
Magnesium (Dissolved)
Sodium (Dissolved)
Sulfate (Dissolved)
225
200
175
150
125
100
75
50
25
0
1/12/2010
3/28/2010
6/11/2010
8/25/2010
11/8/2010
1/22/2011
4/7/2011
6/21/2011
9/4/2011
11/18/2011
2/1/2012


126374
Concentration (mg/L)
Calcium (Dissolved)
Chloride (Dissolved)
Magnesium (Dissolved)
Sodium (Dissolved)
Sulfate (Dissolved)
225
200
175
150
125
100
75
50
25
0
1/12/2010
3/28/2010
6/11/2010
8/25/2010
11/8/2010
1/22/2011
4/7/2011
6/21/2011
9/4/2011
11/18/2011
2/1/2012


126375
Concentration (mg/L)
Calcium (Dissolved)
Chloride (Dissolved)
Magnesium (Dissolved)
Sodium (Dissolved)
Sulfate (Dissolved)
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
11/3/2009
1/17/2010
4/2/2010
6/16/2010
8/30/2010
11/13/2010
1/27/2011
4/12/2011
6/26/2011


126376
Concentration (mg/L)
Calcium (Dissolved)
Chloride (Dissolved)
Magnesium (Dissolved)
Sodium (Dissolved)
Sulfate (Dissolved)
0
25
50
75
100
125
150
175
200
225
250
275
300
325
10/29/2009
1/12/2010
3/28/2010
6/11/2010
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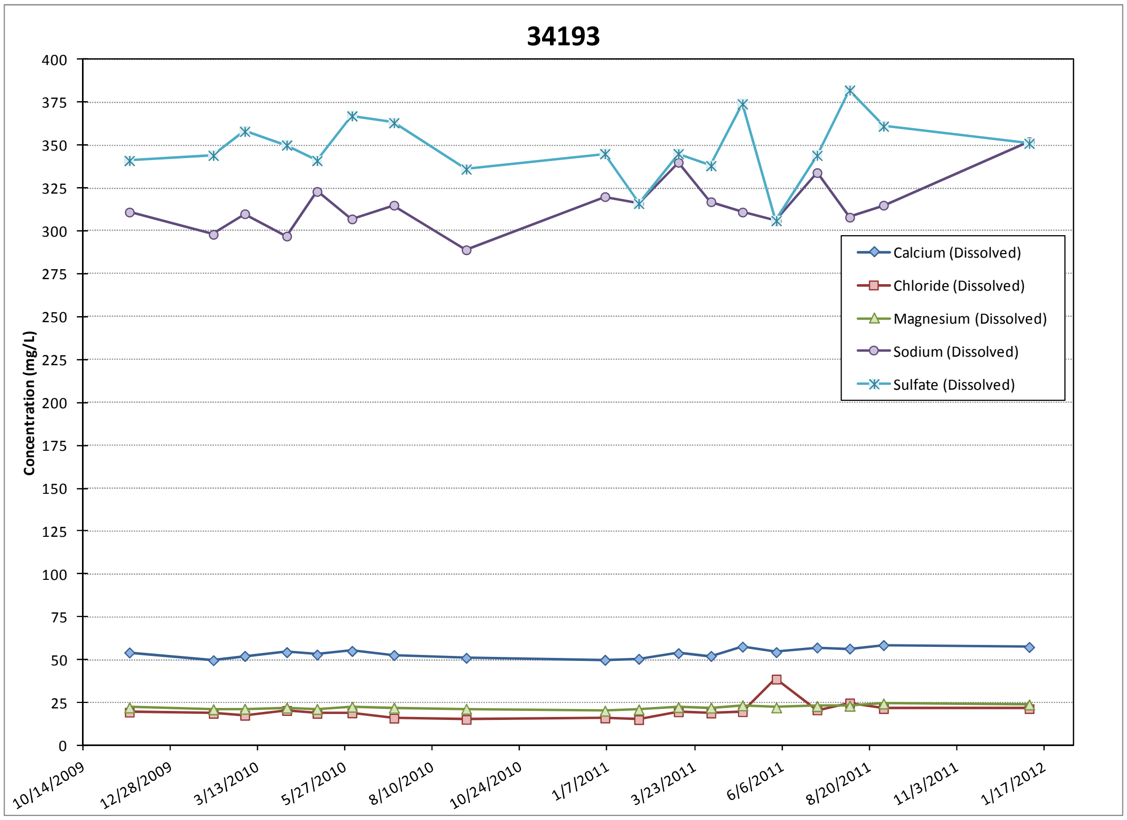
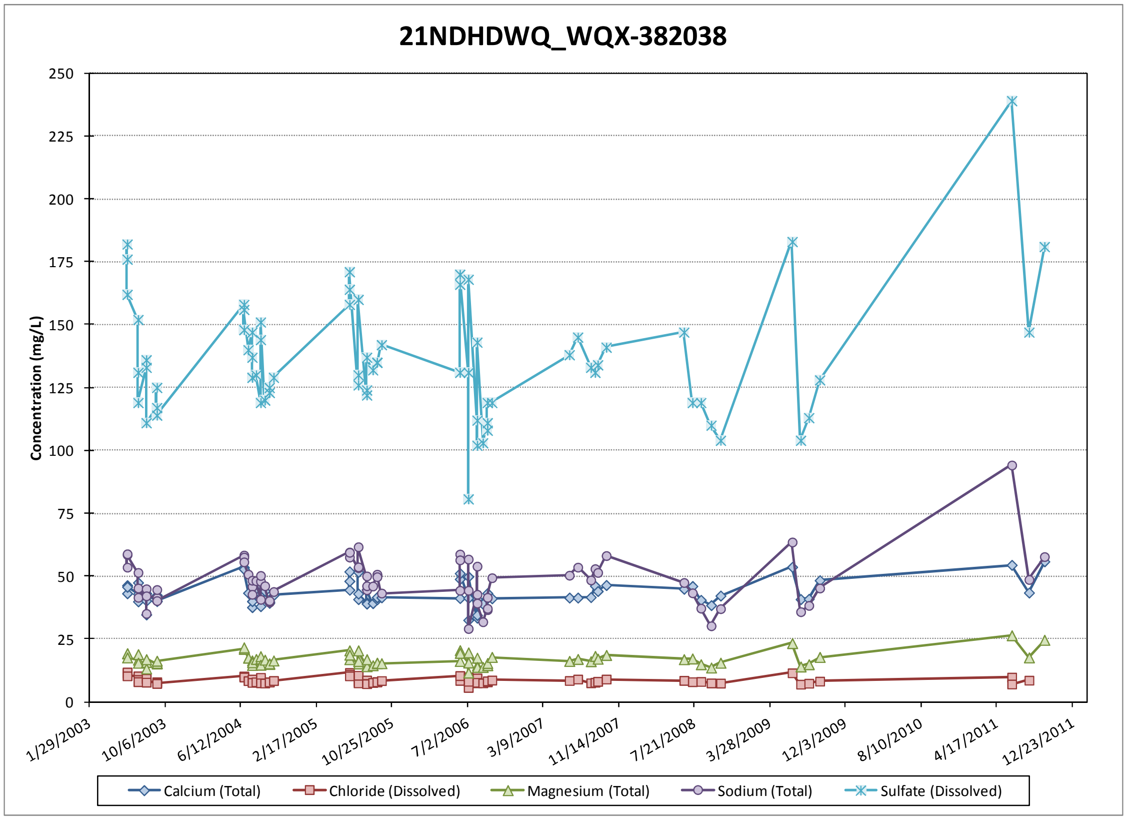
11/18/2011
2/1/2012

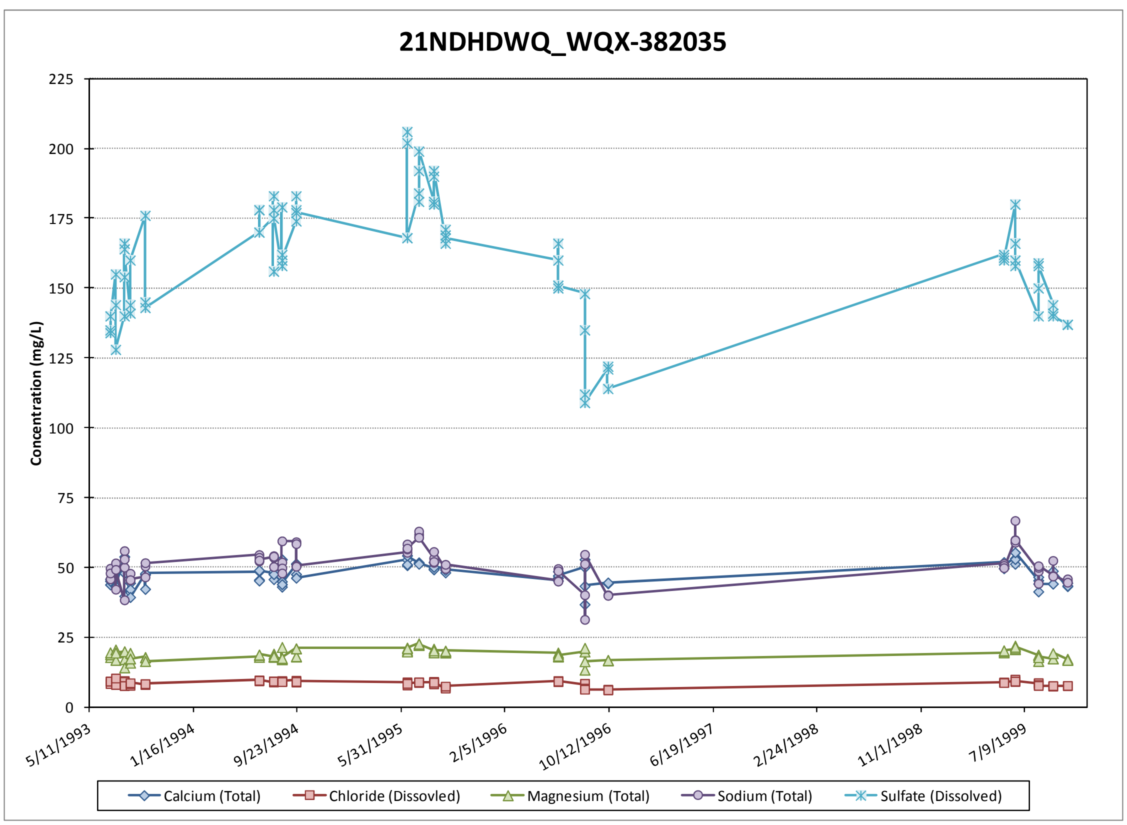

34193
Concentration (mg/L)
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
10/14/2009
12/28/2009
3/13/2010
5/27/2010
8/10/2010
10/24/2010
1/7/2011
3/23/2011
6/6/2011
8/20/2011
11/3/2011
1/17/2012
Calcium (Dissolved)
Chloride (Dissolved)
Magnesium (Dissolved)
Sodium (Dissolved)
Sulfate (Dissolved)

Appendix C-2

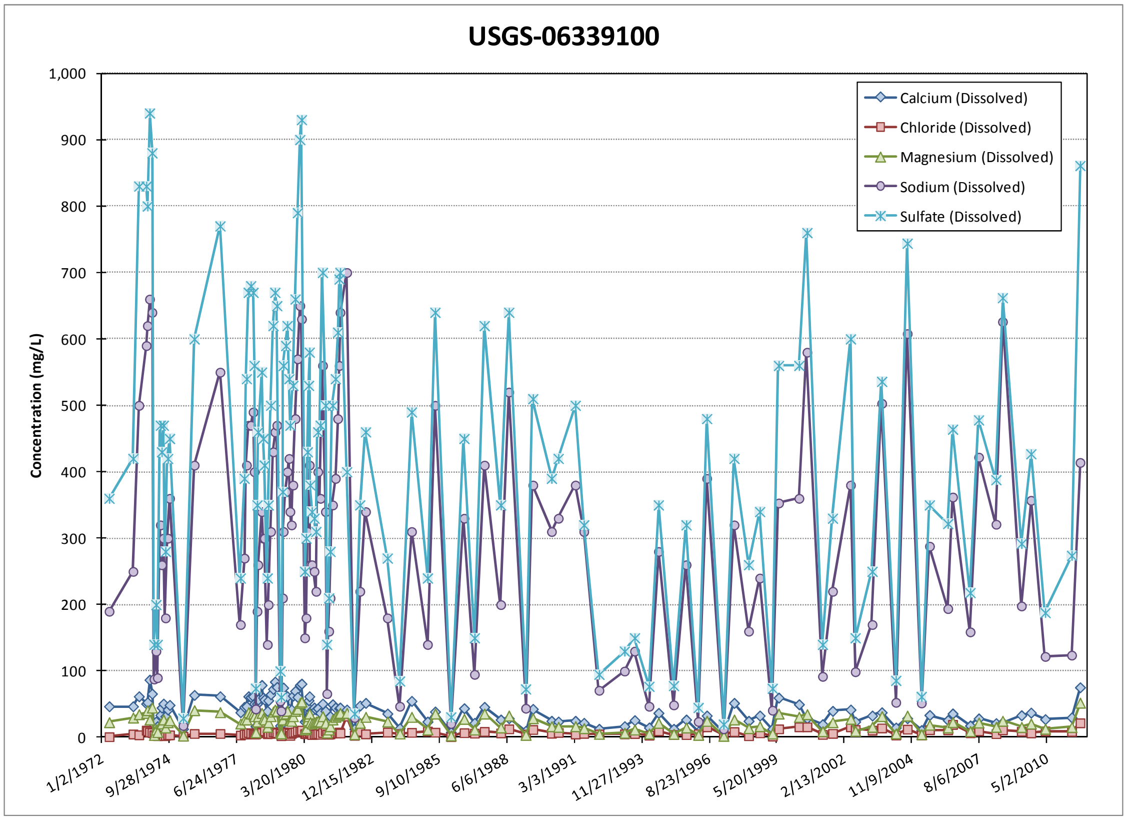
Surface Water



21NDHDWQ_WQX-382038
Concentration (mg/L)
250
225
200
175
150
125
100
75
50
25
0
1/29/2003
10/6/2003
6/12/2004
2/17/2005
10/25/2005
7/2/2006
3/9/2007
11/14/2007
7/21/2008
3/28/2009
12/3/2009
8/10/2010
4/17/2011
12/23/2011
Calcium (Total)
Chloride (Dissolved)
Magnesium (Total)
Sodium (Total)
Sulfate (Dissolved)



21NDHDWQ_WQX-382035
Concentration (mg/L)
225
200
175
150
125
100
75
50
25
0
5/11/1993
1/16/1994
9/23/1994
5/31/1995
2/5/1996
10/12/1996
6/19/1997
2/24/1998
11/1/1998
7/9/1999
Calcium (Total)
Chloride (Dissovled)
Magnesium (Total)
Sodium (Total)
Sulfate (Dissolved)


USGS-06339100
Concentration (mg/L)
Calcium (Dissolved)
Chloride (Dissolved)
Magnesium (Dissolved)
Sodium (Dissolved)
Sulfate (Dissolved)
1/2/1972
9/28/1974
6/24/1977
3/20/1980
12/15/1982
9/10/1985
6/6/1988
3/3/1991
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8/23/1996
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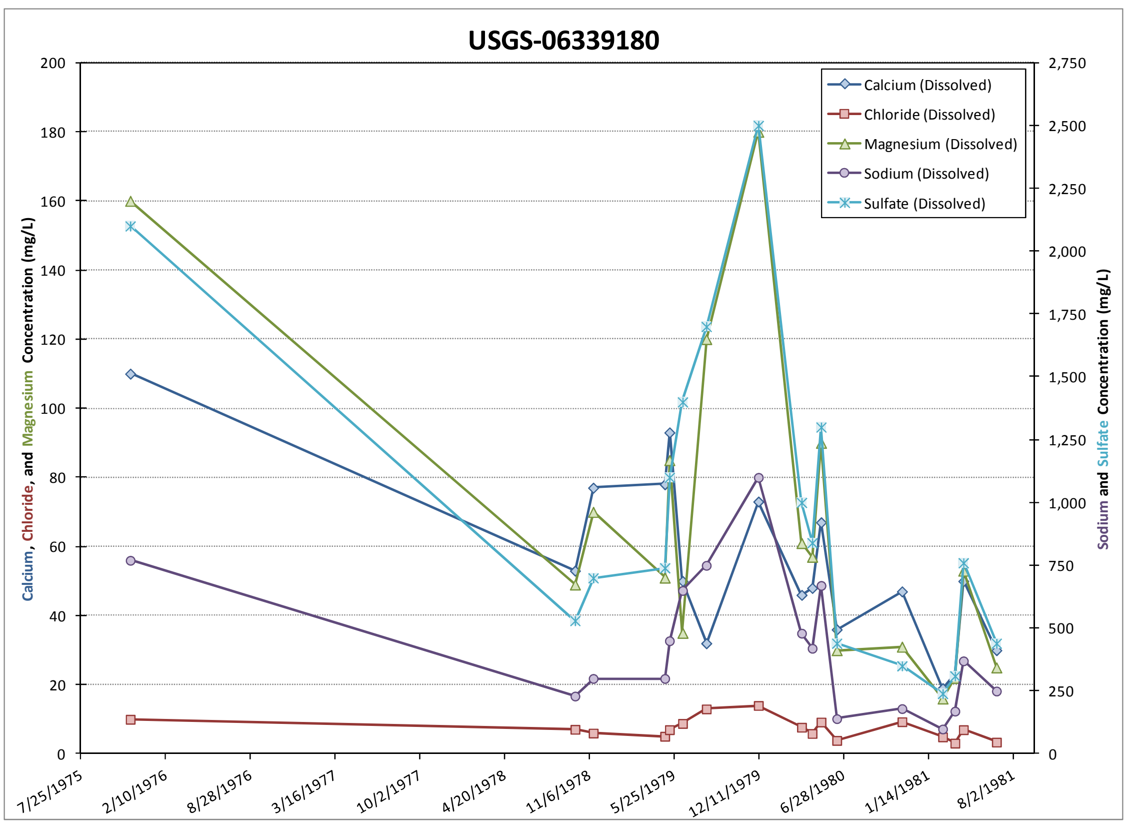
11/9/2004
8/6/2007
5/2/2010


USGS-06339180
Calcium, Chloride, and Magnesium Concentration (mg/L)
Sodium and Sulfate Concentration (mg/L)
Calcium (Dissolved)
Chloride (Dissolved)
Magnesium (Dissolved)
Sodium (Dissolved)
Sulfate (Dissolved)
7/25/1975
2/10/1976
8/28/1976
3/16/1977
10/2/1977
4/20/1978
11/6/1978
5/25/1979
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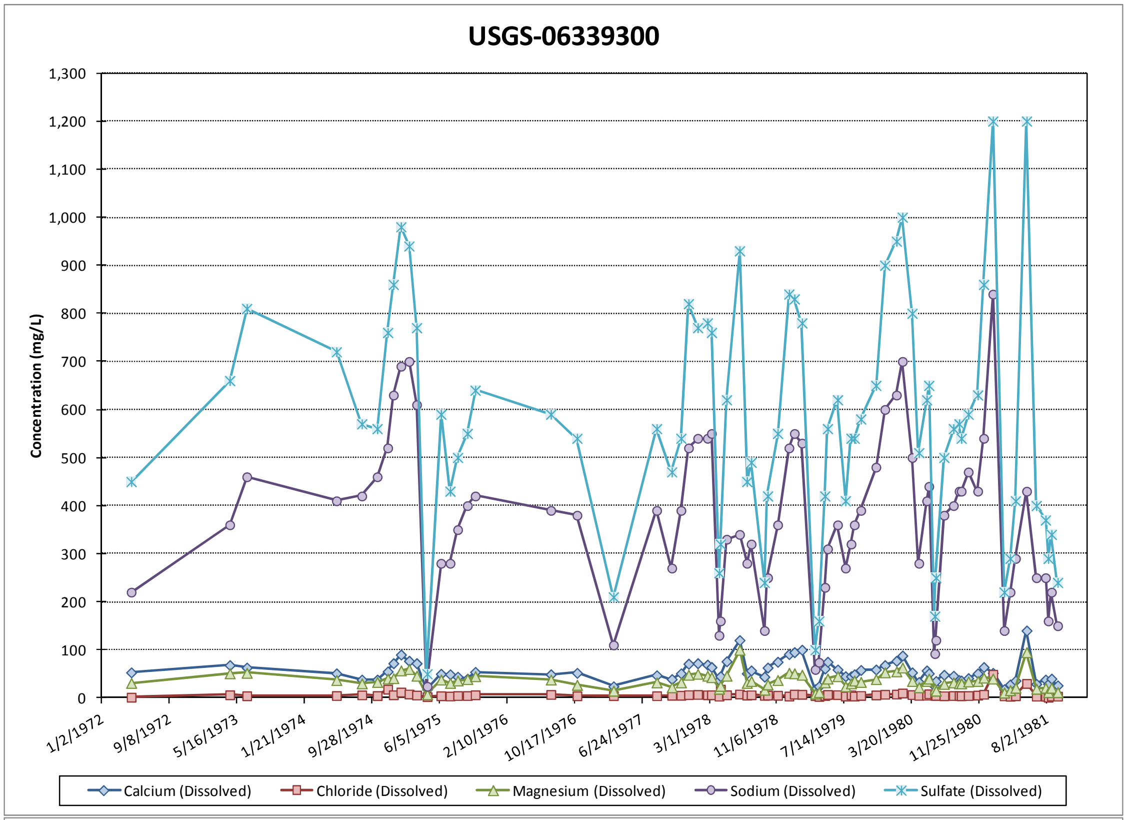
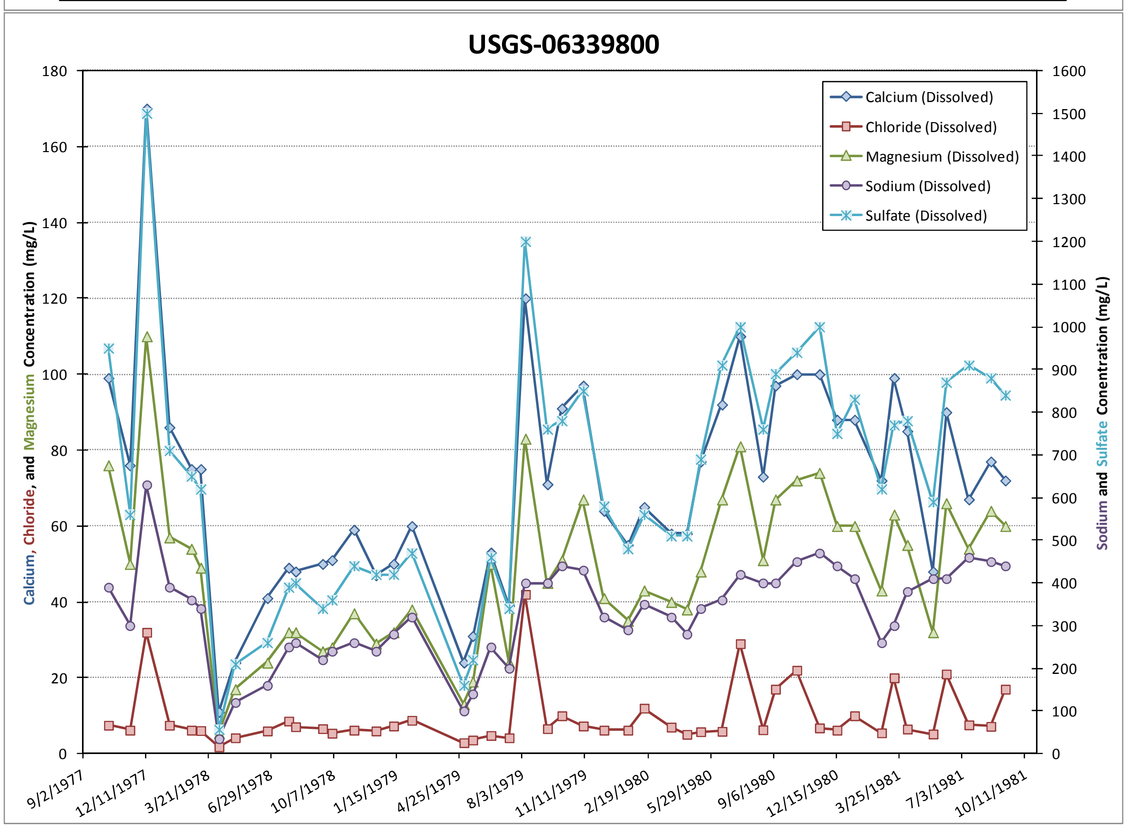
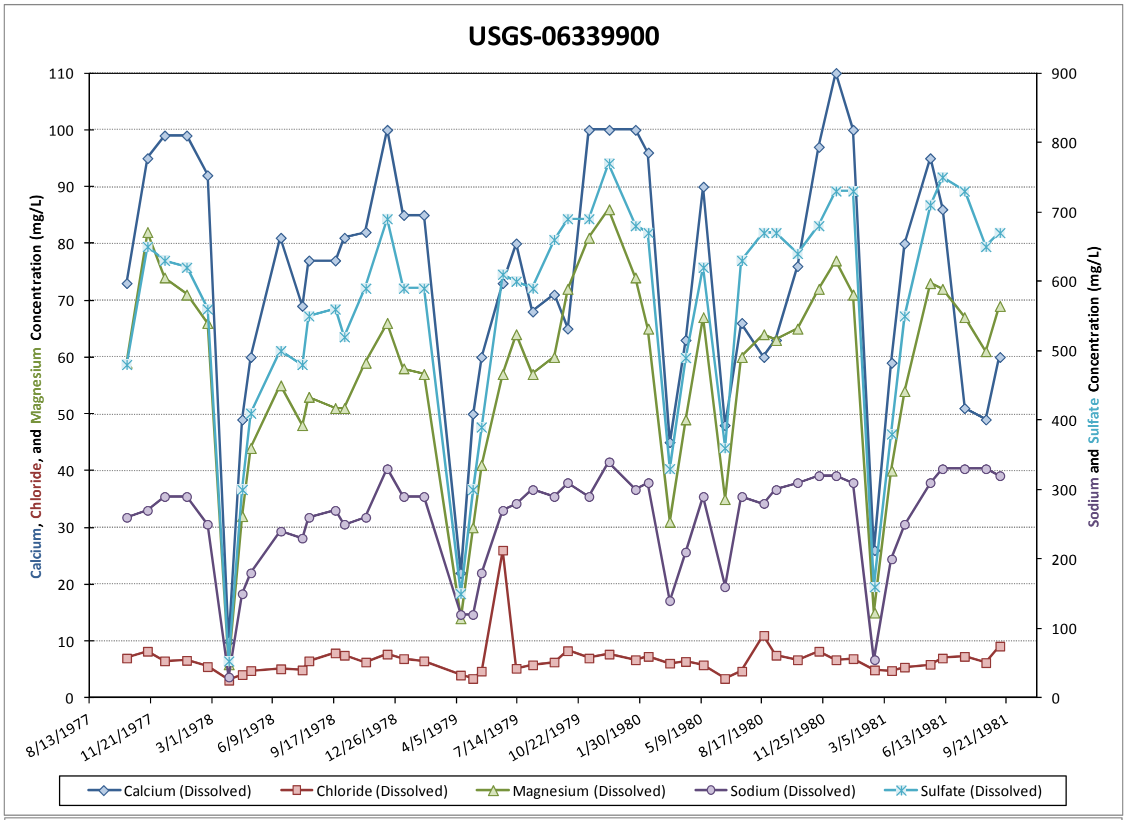
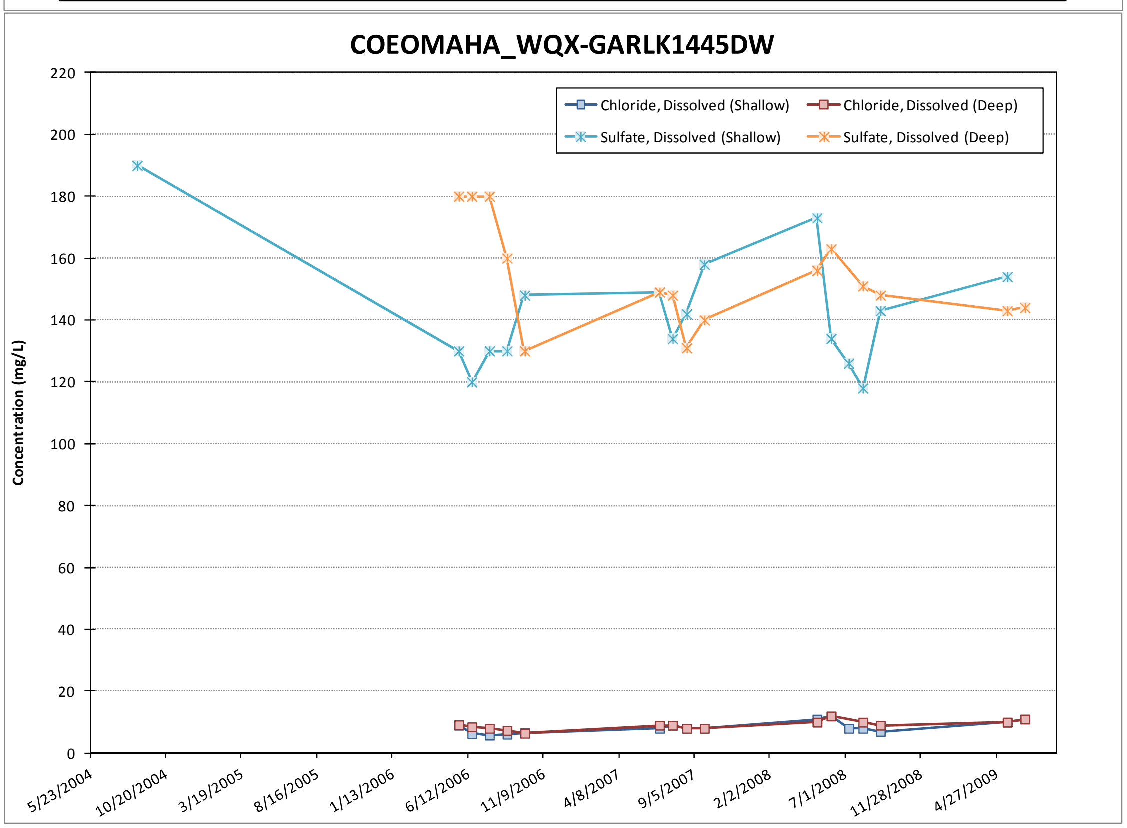
6/28/1980
1/14/1981
8/2/1981


USGS-06339300
Concentration (mg/L)
1,300
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
0
1/2/1972
9/8/1972
5/16/1973
1/21/1974
9/28/1974
6/5/1975
2/10/1976
10/17/1976
6/24/1977
3/1/1978
11/6/1978
7/14/1979
3/20/1980
11/25/1980
8/2/1981
Calcium (Dissolved)
Chloride (Dissolved)
Magnesium (Dissolved)
Sodium (Dissolved)
Sulfate (Dissolved)


USGS-06339800
Calcium, Chloride, and Magnesium Concentration (mg/L)
Sodium and Sulfate Conentration (mg/L)
180
160
140
120
100
80
60
40
20
0
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
9/2/1977
12/11/1977
3/21/1978
6/29/1978
10/7/1978
1/15/1979
4/25/1979
8/3/1979
11/11/1979
2/19/1980
5/29/1980
9/6/1980
12/15/1980
3/25/1981
7/3/1981
10/11/1981
Calcium (Dissolved)
Chloride (Dissolved)
Magnesium (Dissolved)
Sodium (Dissolved)
Sulfate (Dissolved)


USGS-06339900
Calcium, Chloride, and Magnesium Concentration (mg/L)
Sodium and Sulfate Concentration (mg/L)
Calcium (Dissolved)
Chloride (Dissolved)
Magnesium (Dissolved)
Sodium (Dissolved)
Sulfate (Dissolved)


COEOMAHA_WQX-GARLK1445DW
Concentration (mg/L)
Chloride, Dissolved (Shallow)
Chloride, Dissolved (Deep)
Sulfate, Dissolved (Shallow)
Sulfate, Dissolved (Deep)