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Wise and Denton County Retrospective Case Study Characterization Report

Submitted to:

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EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency (EPA) is conducting a retrospective case study in Wise and Denton Counties, TX to determine if there is a relationship between hydraulic fracturing and drinking water resources. EPA selected this site "in response to complaints about appearance, odors and taste associated with water in domestic wells" (EPA, 2012a). To investigate these complaints, EPA is collecting groundwater and surface water quality data in response to complaints about appearance, odors and taste associated with water in domestic wells (EPA, 2012b).

An understanding of background water quality conditions prior to or in the absence of hydraulic fracturing is required to determine if a relationship exists between hydraulic fracturing and drinking water resources. Absence of background water quality 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 Wise and Denton Counties based upon publically available information on land use, known surface water impairments and water quality data from the U.S. Geological Survey (USGS), EPA, and the state of Texas. Key findings from this report include:

- Water quality data collected prior to 1998 were selected as the temporal boundary for defining background conditions for Wise and Denton Counties. Prior to 1998, a single horizontal shale gas well with multi-staged hydraulic fractured stimulations was completed in Wise and Denton Counties; after 1998, horizontal shale gas wells were completed every year in the study area.
- Background water quality data for groundwater and surface water were characterized and compared to screening criteria (e.g., maximum contaminant limits [MCLs], secondary maximum contaminant limit [SMCLs], etc…). Groundwater results showed several EPA study parameters present in the background water quality data and significant trends with depth for select constituents:
    - General background water quality parameter concentrations (pH and total dissolved solids [TDS]), major ions [chloride, fluoride and sulfate] and metals [aluminum, arsenic, beryllium, boron, cobalt, iron, manganese, phosphorus, uranium and vanadium]) were greater than one or more screening criteria. Of these, chloride, sulfate, arsenic and boron are identified by EPA as critical analytes; the remainder is identified as measured parameters.
    - Quantitative review of major ions shows significant trends with depth including a decrease of calcium, chloride and magnesium and increase of alkalinity, fluoride, sodium (dissolved and total fraction) and TDS results over the available range of well depths (10 to 2,420 feet) reported in the data. The increasing trend for alkalinity, fluoride, sodium and TDS with depth is atypical. More research is required to explain the concentration trend of the data.
- Surface water results showed several EPA parameters present in the background water quality data and a slight (~1% per year), yet significant, decline in average annual chloride levels:
    - General water quality parameters (TDS), major ions (chloride and sulfate) and metals (arsenic, boron and selenium) are above one or more screening criteria. Of these, chloride, sulfate, arsenic, boron and selenium are identified by EPA as critical analytes; the remainder are identified as measured parameters.
    - Data for chloride show a decreasing trend (~1% per year) in the average annual concentration for the entire dataset. Data for arsenic, sulfate and TDS show no significant trends (neither increasing nor decreasing) in the average annual concentrations.

- Of the 188 parameters that EPA includes in its quality assurance project plan (QAPP; EPA, 2012b), 81 are identified as critical analytes and 107 as measured parameters. However, only 71 analytes for groundwater and 24 for surface water) are identified in a sufficient number of historical samples (results from eight or more locations) to characterize background water quality data for groundwater or surface water.

- Oil and gas production has been consistently and rigorously regulated since the 1930s by the Railroad Commission of Texas (RRC), which has held a leading role in the regulation of oil and gas. The Texas Commission on Environmental Quality (TCEQ) is responsible for the control of air emissions, required depth of each well's steel casing and cement, and ensuring that off-site impacts are consistent with standards developed to protect public health and safety.

- Both groundwater and surface water in Wise and Denton Counties have been impaired by historical land uses, which could provide sources for a large number of parameters in groundwater and/or surface water in the study area. The most significant causes of water quality impairment in Wise and Denton Counties are agriculture, livestock, oil and gas activities and construction (crushed stone factory, limestone quarry plants, asphalt, brick and concrete manufacturing). 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 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.
    - Non-point sources, stormwater runoff and industrial activities: general water quality, polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), metals; salts, pH; siltation; suspended solids; and nutrients depending upon the types of activities in the area.
    - Oil and gas development: petroleum hydrocarbons, benzene, toluene, ethylbenzene, xylene (BTEX), and methane. Over 3,500 oil and gas wells that were new drills (a combination of horizontal, vertical and directional wells) were permitted over the past 35 years (1977 to 2012) in Wise and Denton Counties, many of which were drilled prior to the existence of modern techniques or regulations.
        - Between 1993 and 2008, over 16,000 horizontal shale gas wells with multi-staged hydraulic fracturing stimulations were completed in Texas. The RRC did not identify a single groundwater contamination incident (including Wise and Denton Counties) resulting from site preparation, drilling, well construction, completion and hydraulic stimulation or production operations at any of the (>16,000) horizontal shale gas wells during the same period (Groundwater Protection Council [GWPC], 2011).
        - 211 groundwater contamination issues caused by oilfield activities were noted in Texas between 1993 and 2008; the majority of these incidents resulted from waste management and disposal activities, including legacy incidents caused by produced water disposal pits that were banned in 1969 and closed no later than 1984 and production phase activities including storage tank or flow line leaks.
    - Groundwater overdrafts have resulted in substantial water level declines and may have contributed to observed water quality impacts (elevated TDS, chloride, sodium, and sulfate) in Wise and Denton Counties through possible leakage between formations or migration of poorer water quality into higher water quality areas.
    - Due to the lack of historical data, it is notably difficult to obtain a good baseline. In addition, source attribution is difficult due to the lack of historical water quality data.

  - Known surface water quality impairments occur in Wise (96 miles of impaired streams or 7% of the total stream length) and Denton (22 miles or 2%) Counties. Parameters causing these impairments include TDS, dissolved oxygen, chloride and bacteria.

- Determining a relationship between hydraulic fracturing and drinking water will be difficult given both the known impairments from other activities and the lack of adequate data to characterize background water quality conditions. Without adequate background water quality, impacts observed as part of the EPA study will require a rigorous investigation to properly apportion the causes of such impacts.

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ABBREVIATIONS AND ACRONYMS

amsl	above mean sea level
AST	above ground storage tank
BEG	Bureau of Economic Geology
bgs	below ground surface
BOD	biochemical oxygen demand
BTEX	benzene, toluene, ethylbenzene, and xylene
CA	critical analyte
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
COC	constituent of concern
CSO	combined sewer overflow
CWA	Clean Water Act
DBP	disinfection byproduct
DQO	data quality objective
EIA	Energy Information Administration
EPA	U.S. Environmental Protection Agency
FSP	Field Sampling Plan
gpm	gallons per minute
GWPC	Groundwater Protection Council
HUC	Hydrologic unit code
IOGCC	Interstate Oil & Gas Compact Commission
M	measured
MCL	maximum contaminant limit
NLCD	National Land Cover Database
NORM	naturally-occurring radioactive materials
NPDES	National Pollutant Discharge Elimination System
NURE	National Uranium Evaluation
NWIS	National Water Information System
OCP	Operator Cleanup Program
PWS	public water system
QA	quality assurance
QAPP	Quality Assurance Project Plan
RBEL	risk-based exposure limit
RCRA	Resource Conservation and Recovery Act
RRC	Texas Railroad Commission

SDWA	Safe Drinking Water Act
SMCL	secondary maximum contaminant limit
STORET	EPA STOrage and RETrieval Data Warehouse
SVOC	semivolatile organic compound
TCEQ	Texas Commission on Environmental Quality
TNRCC	Texas Natural Resource Conservation Commission
TMDL	total maximum daily load
TRI	Toxic Releases Inventory
TRRP	Texas Risk Reduction Program
TSS	total suspended solids
TWDB	Texas Water Development Board
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UST	underground storage tank
VCP	Voluntary Cleanup Program
VOC	volatile organic compound
WWTP	wastewater treatment plant

1.0: INTRODUCTION

The U.S. Environmental Protection Agency (EPA) has initiated five retrospective case studies as part of the agency's evaluation of the potential relationships between hydraulic fracturing and drinking water (EPA, 2011).

One of the retrospective case studies selected by EPA is located in Wise and Denton Counties, Texas (EPA, 2012a). According to the EPA Quality Assurance Project Plan (QAPP) for the Wise and Denton Counties Retrospective Case Study, this area was selected based on homeowner complaints and information collected by EPA Region VI staff (EPA, 2012b). Complaints received concerned appearance, odors and taste of water from domestic drinking water wells as well as concerns over leaks and spills that may have impacted surface waters (EPA, 2012b). To investigate these complaints, EPA is collecting samples from 10 domestic wells and two surface water bodies in three separate areas within Wise County and analyzing them for a range of water quality parameters.

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 that Battelle characterize land use, groundwater quality and surface water quality within the Wise and Denton County study area. This report summarizes historical water resources quality data within the 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 obtain an understanding of and characterize background groundwater and surface water quality conditions 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 Wise and Denton County study area.
- Identifying historic and current 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 impact 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 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, aquifers, or wells is beyond the scope of this report.

1.2 Report Organization

Section 2 of this report discusses 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 an analysis of 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 Site Description

EPA's investigation is focused "in three different locations within Wise County, TX". The sites were selected based on homeowner complaints, site visitation and information collected by EPA Region VI staff. The homeowner complaints are related to appearance, odors and taste associated with water in domestic wells associated with activities such as leaking or abandoned pits, gas well completion and enhancement techniques.

For the purpose of further discussion within this report, the three locations are designated as Locations A (northeastern Wise County near county border), B (central Wise County) and C (north central Wise County) as shown in Figure 1-1. Figure 1-1 also shows the estimated locations of the 10 groundwater and two surface water samples based on the EPA QAPP. Although the EPA sampling locations are all within Wise County, Denton County is included in the assessment because of the close proximity of Location A to the county border.

Location A comprises the occupants of four properties that have reported concerns primarily associated with drinking water, surface water, odors and leaks and spills (drilling fluids, drill cuttings and drilling muds spilling into adjoining properties). There were reports of produced water overflowing the containment berm and flowing into an adjacent creek. The main complaints at Location B are changes in the taste and appearance of drinking water; other impacts reported are corroding of appliances and the water smelling of rotten eggs. The complaint in Location C relates to changes in the taste, quality, color and odor of the water supply.

As stated in the EPA QAPP, the three locations underwent Phase I investigations that included analyzing domestic wells and surface water bodies to determine if contamination was present. Sampling events were conducted in September 2011, March 2012 and September 2012. The sampling data from the September 2011 event have been released to well owners and indicate that two wells at Location B had high chloride concentrations (in range of 5,000 mg/L) that were confirmed during the March 2012 sampling event. The September 2012 event involved sampling of two groundwater wells and produced water from a nearby production well. It was reported that the collected samples will undergo isotopic analysis to determine whether the source of elevated chloride is from hydraulic fracturing activities (Texas Railroad Commission [RRC], 2012g). Since the Phase 1 sampling indicated that there was no aquifer contamination at Locations A and C, these locations are no longer being sampled. Phase 2 sampling activities involving biannual sampling will continue at Location B.

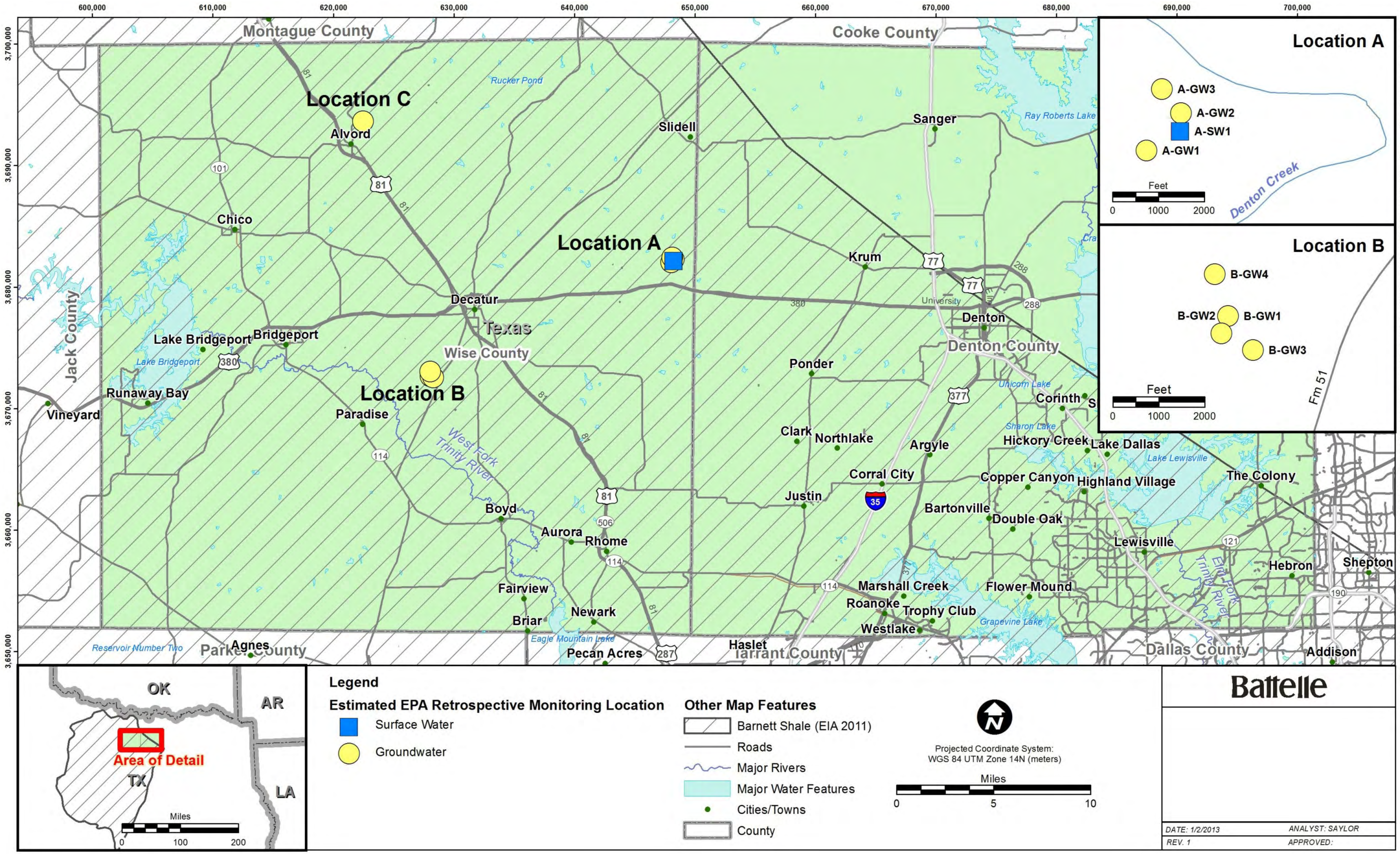


Figure 1-1. EPA Retrospective Sampling Locations in Wise County, TX

2.0: TECHNICAL APPROACH

This section provides 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 subject study area of interest is Wise and Denton Counties in Texas (see Figure 1-1), which are located in the northeast portion of Texas within the Barnett Shale play. Wise County encompasses approximately 904 square miles with a current population of 59,127 (U.S. Census Bureau, 2010b). Denton County encompasses approximately 878 square miles with a current population of 662,614 (U.S. Census Bureau, 2010a).

Wise County is located in the Cross Timbers eco region of Texas. The topography of Cross Timbers is characterized by irregular plains with some low hills and tablelands. Denton County is located in the Texas Blackland Prairie eco region of Texas. The Texas Blackland Prairie topography is characterized by clayey soils and prairie vegetation (EPA, 2012c). Wise and Denton Counties are located within the Trinity River Basin. The three subbasins that cross Wise and Denton Counties are Upper West Trinity, Denton and Elm Fork Trinity. Figure 2-1 shows these three subbasins and associated surface water resources in Wise and Denton Counties.

The Trinity Aquifer which outcrops in Wise County is the primary groundwater—bearing unit in the study area. Groundwater is also derived from Paleozoic units that outcrop in localized areas west of the Trinity Aquifer outcrop in Wise County. The aquifers dip to the east southeast and become confined by the Fredricksburg Group beneath Denton County. The bottom of the study volume is defined as the base of the Trinity Aquifer, more specifically the Antlers and Twin Mountains Formations. The combined thickness of the units comprising the Trinity Aquifer is roughly 600 ft in the study area. The bottom elevation is at about 1000 ft above mean sea level (amsl) at the western edge of Wise County, and drops to 0 feet amsl at the Wise/Denton county line. The depth to the top of the Barnett Shale ranges from roughly 5,000 feet below ground surface (bgs) to 8,000 feet bgs beneath Wise and Denton Counties.

The date for onset of unconventional oil and gas development via hydraulic fracturing in the study area was selected based on information collected from RRC data. The RRC data show that one unconventionally developed well was installed in 1992; however, it was not until 1998 that another well of this type was completed. From 1998, completions were made every year, increasing to 75 in 2003, 710 in 2005, and to a high of 2,901 completions in 2008. Based on this trend, the 1992 completion is an isolated occurrence with significant production from unconventional horizontal wells and hydraulic fracturing to beginning in 1998 (RRC, 2010). Accordingly, groundwater and surface water data collected prior to 1998 are considered by Battelle to represent conditions prior to significant development of the Barnett Shale through unconventional hydraulic fracturing and serve to define the temporal limit for background conditions.

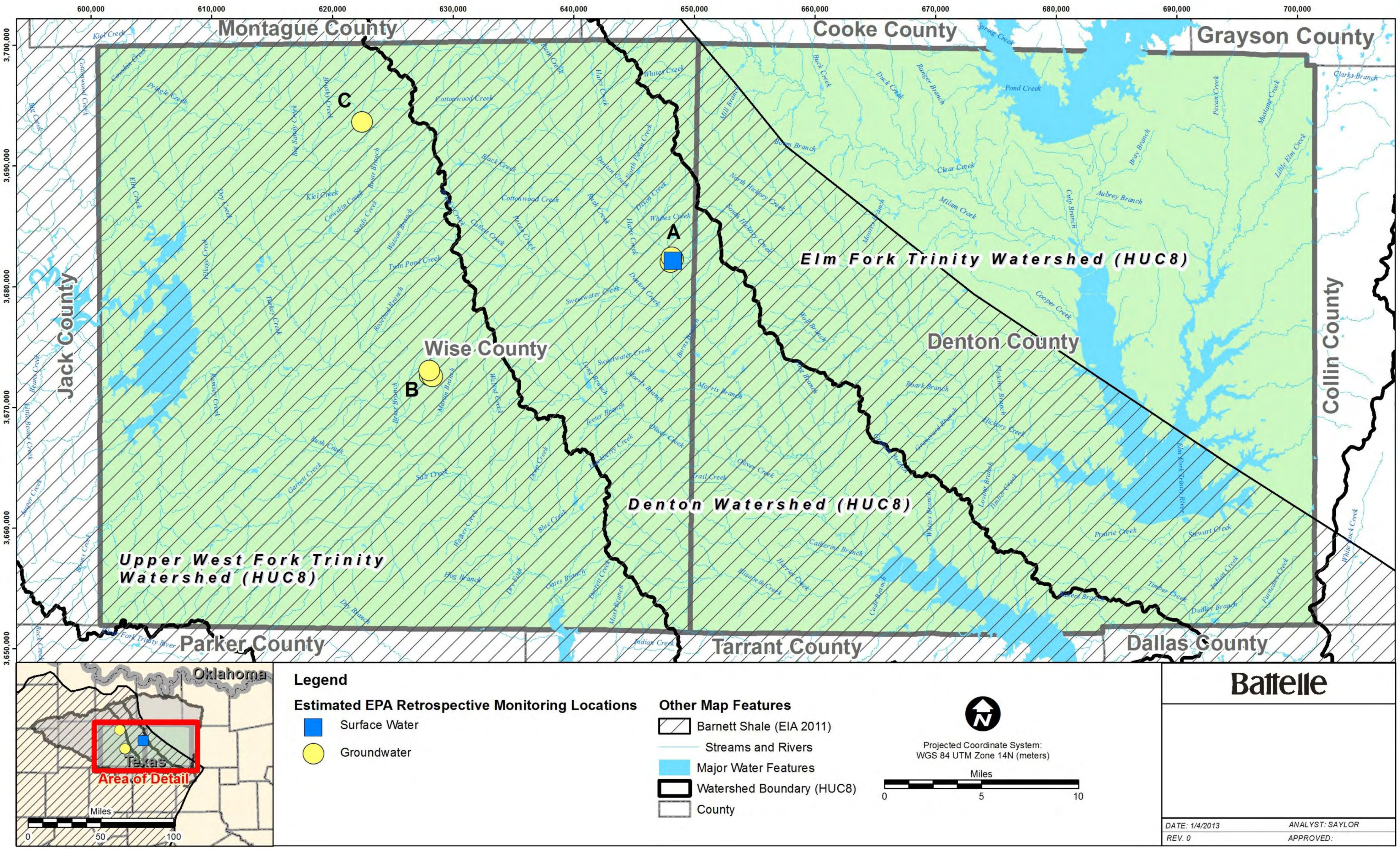


Figure 2-1. Location of Watershed Subbasins within Wise and Denton Counties

2.2 Data Sources, Collection, and Organization

The data contained in this report are secondary data obtained by Battelle from publically available U.S. federal government and state of Texas records that were available in accessible, electronic format. Secondary data are defined as “data that were originally collected for another project or purpose.” This section describes the sources of the secondary land use and water quality data and how the data were collected and evaluated by Battelle. The data collected focused on the following:

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

2.2.1 Land Use Data Collection. The land use data collected are qualitative in nature and rely upon the original quality and documentation of the primary source of the datasets. The primary sources of the land use data are summarized in Table 2-1. Both historic and current land use information was collected to better evaluate conditions associated with water quality within Wise and Denton Counties. 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.

2.2.2 Water Quality Data Review. Data were collected from U.S. federal government and state of Texas sources to characterize groundwater and surface water quality. The spatial boundaries for the data collection effort were Wise and Denton Counties. Hydrologic unit code (HUC) 8 watershed boundaries for the three HUC 8 watersheds present in Wise and Denton Counties, including the Upper West Fork Trinity, Denton and Elm Fork Trinity (see Figure 2-1) were investigated for the evaluation of surface water quality.

Historic water quality data are available from several sources. For example, the U.S. Geological Survey (USGS) monitors groundwater and surface water at a number of locations throughout Texas, although the frequency of the measurements and the time period when they were taken vary. 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)
- Texas Water Development Board (TWDB)
- USGS National Uranium Resource Evaluation (NURE).

Table 2-2 provides an overview of the types of secondary water quality data that were considered by Battelle. All of the data sources listed in Table 2-2 are considered secondary data, and by definition were not originally collected for the specific purpose of this report. However, these databases are commonly used to characterize groundwater or surface water quality.

A reference sheet was used to document the data collected by file name, type of data, data source, date of downloading, hyperlink to the source Web site, storage location on the project network drive and any relevant comments. The data were subsequently uploaded into a Microsoft® SQL Server database, processed, assessed according to the QA procedures described in Section 2.3, and qualified, as necessary, based on the results of the QA assessment.

Table 2-1. Summary of Land Use Data Sources

Data Source	Timeframe	Type of Data
EPA[1]	1998-2010	Total maximum daily load (TMDL) impaired waters
USGS[2]	1986	Land use map
NLCD/MRLC [3]	2006	Land use map
Texas Railroad Commission[4]	Various	Locations of historic oil and gas wells; unconventional oil and gas wells
Texas Commission on Environmental Quality[5]	Various	Petroleum Storage Tanks
EPA[6]	2012	EPA Recognized Environmental Sites
Texas Railroad Commission [7]	Pre-1930 to 2012	Historic coal mining locations and information
Texas Railroad Commission[8]	2012	Brownfield and Voluntary Cleanup Program Locations

[1] http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/index.cfm
[2] http://water.usgs.gov/GIS/dsdl/ds240/index.html
[3] http://www.arcgis.com/home/item.html?id=6a719252755b4aa5b13cd59c40076796
[4] http://www.rrc.state.tx.us/forms/maps/digital/digmapcty.php
[5] Leaking Petroleum Storage Tanks:
http://www.tceq.texas.gov/remediation/pst_rp/pstquery.html
Registered Petroleum Storage Tanks:
http://www.tceq.texas.gov/permitting/registration/pst/pst_query.html
[6] http://www.epa.gov/enviro/html/frs_demo/geospatial_data/geo_data_state_combined.html
[7] http://www.rrc.state.tx.us/forms/maps/historical/historicalcoal.php
[8] http://www.rrc.state.tx.us/environmental/environsupport/brownfield/index.php

Table 2-2. Summary of Water Quality Data Sources for Wise and Denton Counties

Data Source	Timeframe	Number of Monitoring Locations	Parameters
Surface Water			
USGS National Water Information System (NWIS)[9]	1961-1997	29	Major Ions, Minor Ions, Nutrients, PAHs, Pesticides, Radionuclides, VOCs, Water Characteristics
EPA STOrage and RETrieval Data Warehouse (STORET)[10]	1968-1997	32	Major Ions, Minor Ions, Nutrients, PAHs, Pesticides, Radionuclides, VOCs, Water Characteristics
Texas Water Development Board[11]	1972-1997	6	Major Ions, Minor Ions, Nutrients, Metals, Water Quality Characteristics
Groundwater			
Data Source	**Timeframe**	**Number of Monitoring Locations**	**Parameters**
USGS National Water Information System (NWIS)[1]	1994	12	Major Ions, Minor Ions, Nutrients, Water Characteristics
Texas Water Development Board[3]	1931-1997	353	Major Ions, Minor Ions, Nutrients, Metals, Water Quality Characteristics
USGS National Uranium Resource Evaluation (NURE)[12]	1978	167	Major Ions, Minor Ions, Radionuclides, Water Characteristics

2.2.3 Data Management. Summary tables were prepared for groundwater 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 of results needed to characterize water quality for a given parameter. When evaluating the quantity of water quality data, it is noted that EPA's guidance on statistical analysis of RCRA groundwater monitoring data (EPA, 2009) recommends that a minimum of at least 8 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 location results are sufficient to characterize water quality for the Wise and Denton County study area, 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 dataset 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 (e.g., EPA or operator) collected water quality data. Parameters with results at fewer than eight locations were excluded from the summary data tables and associated discussion, but are included in Appendix B.

[9] http://waterdata.usgs.gov/nwis/qw
[10] http://www.epa.gov/storet/
[11] http://www.twdb.state.tx.us/groundwater/data/ and http://www.twdb.state.tx.us/data/surfacewater/surfacewater_toc.asp
[12] http://tin.er.usgs.gov/geochem/doc/nure_analyses.htm

Two separate sets of summary data tables were produced for groundwater 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 dataset and other data with data location issues as summarized in Table 2-3.

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 were used to represent the specific parameter at that location. In the event that duplicate sample results exist, the duplicate sample is included 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, with non-detect values having been excluded.

Groundwater and surface water quality regulatory standards and screening criteria were compiled and used for comparison against the assembled water quality characterization data. When making these comparisons, only detected values are included when calculating the number of samples above screening criteria; non-detect values were excluded. A summary of the water quality regulations that were utilized to compile selected screening criteria are summarized in Section 2.4.1.

Table 2-3. Summary of Data Included in Reduced Wise and Denton County Water Quality Dataset

Data Source	Initial Number of Monitoring Locations	Reduced Number of Monitoring Locations	Reason for Removal
NWIS	29 surface water 12 groundwater	29 surface water 12 groundwater	No locations removed.
STORET	32 surface water	0 surface water	Data may be indicative of environmental impact monitoring
Texas Water Development Board	6 surface water 353 groundwater	4 surface water 349 groundwater	Latitude and/or longitude coordinate was reported with ≤2 decimal places.
NURE	167 groundwater	128 groundwater	Latitude and/or longitude coordinate was reported with ≤2 decimal places.

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, 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.
- Data were collected under an approved QAPP/Field Sampling Plan (FSP)

- Data were produced by laboratories known to implement a rigorous quality system
- Analytical methods were identified and appropriate.
- For non-detect values, the detection limits were defined and sensitive enough for each parameter.
- If 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 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 inserted as the detection limit (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 (EPA, 2002).
- 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 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, groundwater and surface water data should be used with care for the following reasons: the analytical laboratories, laboratory quality control data, quality-related qualifiers and analytical methods (for groundwater results) were not reported for most data. Quality system elements that support the data include collection organizations with known quality systems and acceptable laboratory detection limits with the exception of: arsenic and naphthalene in groundwater, for which all reported detection limits were greater than the Clean Water Act (CWA) chronic value.

2.4 Applicable Statutory Regulatory Framework

A brief discussion of federal and state statutes and regulations is relevant because of their role in setting water quality standards and criteria. A chronology of relevant laws and regulations related to groundwater quality, surface water quality, and environmental restoration is provided in Figure 2-2. The statutes and regulations that have been in place in Texas to regulate oil and gas activities are also discussed.

2.4.1 Relevant Water Quality Statutes, Regulations and Guidance. 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 result 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.

U.S. Clean Water Act (CWA). The CWA is the common name for the Federal Water Pollution Control Act of 1972 [33 U.S.C. §1251 et seq. (1972)]. It established the basic structure for regulating the discharge of pollutants into U.S. waters and setting water quality standards for surface water. It expanded upon the original 1948 law called the United States Water Pollution Control Act. Under the authorities granted by the CWA, EPA has implemented the National Pollutant Discharge Elimination System (NPDES) permit program. It also established the concept of 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 each impaired water body and regulate the maximum amount of contaminant loading from both point and non-point sources.

U.S. Safe Drinking Water Act (SDWA). The SDWA was enacted in 1974 and amended in 1986 and 1996. Under SDWA, EPA established 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 guidelines for PWSs to address aesthetic and taste issues and do not represent a health risk.

Resource Conservation and Recovery Act (RCRA). The RCRA was enacted in 1976 and amended in 1984 and 1986. The RCRA gave EPA the authority to control hazardous waste from “cradle-to-grave.” The 1984 Hazardous and Solid Waste Amendment, worked towards waste minimization. The 1986 amendment gave the EPA authority to handle environmental problems resulting from underground storage tanks (USTs).

EPA Region 6 South Central Regional Screening Levels for Chemical Contaminants at Superfund Sites. Under the authority of Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, EPA Region VI has set screening levels related to carcinogenic and non-carcinogenic human health effects in tap water. Although these levels are only guidance, these are useful benchmarks for compounds that do not have established MCLs and SMCLs. These risk-based screening levels (last updated 2012) are based upon calculations that set concentration limits using carcinogenic or systemic toxicity values under specific exposure scenarios.

TEXAS OIL AND GAS STATUTES AND REGULATIONS

- **1919** • Conservation and Regulation of Oil and Gas **(**Including Texas Statewide Rule 37 and Rule 20)
- **1965** • State of Texas Well Plugging Program
- **1969** • Texas Statewide Rule 8
- **1976** • Texas State Wide Rule Oil and Gas Division- Latest amendment 2010
- **2002** • Texas Voluntary Cleanup Program
- **2011** • Texas House of Representatives Bill HB 3328/ Texas Administrative Code Title 16 Rule § 3.29 (chemical disclosure requirements)

ENVIRONMENTAL STATUTES AND REGULATIONS

- **1948** • United States Water Pollution Control Act
- **1972** • United States Clean Water Act
- **1974** • United States Safe Drinking Water Act
- **1976** • Resource Conservation and Recovery Act
- **1980** • Comprehensive Environmental Response, Compensation, and Liability Act
- **1988** • Texas Surface Water Quality Standard, Title 30, Chapter 307 - Amended in 2010
- **1989** • Texas Water Code, Chapter 26, Subchapter J (established Texas Groundwater Protection Committee)
- **1999** • Texas Risk Reduction Program (TRRP)
- **2005** • Texas Water Quality Control

Figure 2-2. Timeline of Statutes and Regulations Related to Oil and Gas Activities

Texas Surface Water Quality Standard. The Texas Surface Water Quality Standards establish explicit goals for the quality of streams, rivers, lakes, and bays throughout the state. The standards are developed to maintain the quality of surface waters in Texas so that they support public health and enjoyment and protect aquatic life consistent with the sustainable economic development of the state. The Texas Surface Water Quality Standards are codified in Title 30, Chapter 307 of the Texas Administrative Code. The standards are written by the Texas Commission on Environmental Quality (TCEQ) under the authority of the CWA and the Texas Water Code. Risk-based exposure limits (RBELs) are established for human health (TCEQ, 2011a) and aquatic life (TCEQ, 2011b) and surface waters must comply with the standards. These standards are used as guidance for cleanup under the jurisdiction of RRC.

Texas Water Code, Chapter 26, Subchapter J. In 1989, the Texas Groundwater Protection Committee (GWPC) was established by the Texas Water Code. The GWPC is an interagency collaboration including the RRC, TCEQ and eight other agencies that work towards coordinating groundwater protection in Texas. The GWPC must publish an annual groundwater monitoring and contamination report and submit the report to the Texas legislature. The GWPC's annual report for 2010, entitled "Joint Groundwater Monitoring and Contamination Report-2010" is discussed further in Section 3.2 Groundwater Quality (GWPC, 2011).

Texas Risk Reduction Program (TRRP). The TRRP rule (30 TAC 350) was first published on September 17, 1999 and went into effect on September 23, 1999 under the TCEQ. The rule provides a corrective action process directed toward protection of human health and the environment balanced with the economic welfare of the citizens of Texas. Groundwater data were compared for residential ingestion of groundwater (carcinogenic and non-carcinogenic) levels (TRRP). This rule is used as guidance for cleanup under the jurisdiction RRC.

Texas Water Quality Control. Title 2 Water Administration of the Texas Water Code contains subtitle D Water Quality Control in Chapter 26, which provides guidance for watershed monitoring and assessment of water quality, water quality management and water quality standards and specifies that the TCEQ has the authority to set water quality standards. This regulation also includes guidance for management of accidental discharges and spills which states that the safety and preventive measures that may be required shall be commensurate with the potential harm which could result from the escape of the waste or other substances. Monitoring and reporting guidelines are also included.

- The state of Texas water pollution control compact – The compact, which was approved by Order of the Texas Water Quality Board on March 26, 1971, is included in Section 26.043. This compact consists of a series of signatures of agencies that have agreed to pay not less than 25 percent of the estimated costs of all water pollution control projects in the state.
- Oil and Hazardous substance spill prevention and control – Subchapter G of Chapter 26 provides guidelines for the response to spills within and off shore of the state of Texas. This subsection states that any on-shore or off-shore facility that has caused a spill shall immediately undertake all reasonable actions to abate and remove the discharge or spill subject to federal and state requirements.
- Under and above ground storage tanks – The purpose of this Subsection I is to protect the groundwater of Texas from leaking underground tanks containing hazardous or harmful substances which refers to any substance regulated under CERCLA and also petroleum. All tanks should meet performance standards and tanks located in the vicinity of certain aquifers should have secondary containment. A leak detection system should be maintained. Risk-based corrective action should be adopted in the event of a spill.

2.4.2 Oil and Gas Related Statutes, Regulations, and Guidance. Two organizations in the state of Texas are responsible for establishing standards and enforcing regulations for oil and gas exploration and production: the RRC and TCEQ. The RRC's responsibility lies in overseeing all aspects of drilling activities such as well spacing, well design, groundwater protection during drilling and operational and public safety. The control of air emissions, required depth of each well's steel casing and cement, and ensuring that off-site impacts are consistent with standards developed to protect public health and safety is TCEQ's primary role. The RRC and the TCEQ, formerly the Texas Natural Resource Conservation Commission (TNRCC), have entered into a Memorandum of Understanding to clarify jurisdiction over oil field wastes generated from oil and gas exploration, development and production.

Conservation and Regulation of Oil and Gas - Subtitle B under Title 3 of the Natural Resource Code became effective on June 18, 1919. This rule provides guidelines for the allowable production of oil and gas, and restrictions on unexplored territory which limits exploration to areas known to produce oil and gas. This law includes Rule 37, which addresses well spacing protocols and Rule 20, which protects fresh water.

Well Plugging Program - The RRC has had a well plugging fund since 1965 to plug wells when the owner cannot be determined. In 1984, the funding was increased and the RRC was given authority to regulate all oil and gas wastes. The program was further amended in 1991 and 2001. The latest enhancement gave the RRC authority to investigate citizen complaints about contamination, repair contaminated sites and manage the Voluntary Cleanup Program (VCP) and Operator Cleanup Program (OCP) (GWPC, 2011).

Statewide Rules relative to oil and gas operations under the jurisdiction of the RRC are found in Title 16 (Economic Regulation), Part 1 RRC, Chapter 3 (Oil and Gas Division) of the Texas Administrative Code.

- **Texas Statewide Rule 8-Surface Waste Management.** Effective January 1, 1969, the RRC prohibited the disposal of produced water from oil and gas operations in earthen evaporation pits and surface waters. The rule was amended in 1984 and included new permit regulations for pit and disposal methods. It was further amended in 1986, 1987, 1992, 1996 and 1997. Notably, the 1987 amendment addressed salt water hauler permits, and the 1996 amendment addressed oil and gas waste haulers.
- **Texas Statewide Rule 20** first became effective in 1919 and its goal was to protect fresh water when drilling or plugging wells. It was amended in 1931 and required the protection of fresh water during produced water disposal. It was further amended in 2003 to require operators to immediately report any oil spill greater than five barrels to the RRC (GWPC, 2011).

Rules, §3.1 to §3.106, cover many aspects of oil and gas exploration.

- <u>Rule §3.7 (Strata to be sealed off)</u> governs the confinement of fluid from hydrocarbon and geothermal source to its original stratum until it can be produced and utilized without waste. Each such stratum shall be adequately protected from infiltrating waters. The commission will require each stratum to be cased off and protected.
- <u>Rule §3.8 (Water Protection)</u> provides various disposal methods that do not require a permit including disposal of certain low chloride drilling fluids by land farming and disposal of other drilling fluids down a producing well or down the borehole of a dry or abandoned well before plugging as long as the wastes have been generated at that specific well site.

- Rule §3.9 (Disposal Wells) governs the permitting, operating, monitoring and testing of disposal by injection into a porous formation not productive of oil, gas, or geothermal resources. Prior to disposing, permits are required from the RRC. This includes disposal into highly porous cap rock formations along the Gulf Coast as well as disposal into salt caverns.
- Rule §3.13 (Casing, Cementing, Drilling and Completion Requirements) governs all operations at the well. The operations include casing, cementing, drilling and completion requirements. An operator shall set and cement sufficient surface casing to protect all usable-quality water strata, as defined by the TCEQ. An operator shall obtain a letter from the TCEQ stating the protection depth. Surface casing cannot be set deeper than 200 feet below the specified depth without prior approval from the commission.
- Rule §3.14 (Plugging Wells) requires the operator to present a notice of its intention to plug any well or wells drilled for oil, gas, or geothermal resources or for any other purpose over which the Commission has jurisdiction prior to plugging. The Commission or its delegate is authorized to mix and pump cement for the purpose of plugging a well in accordance with the provisions of this section and use an alternate material other than cement to plug a well.
- Rule §3.29 Hydraulic Fracturing Chemical Disclosure Requirements states that within 15 days of fracturing, all information on the chemical additives used including ingredients and concentrations should be provided. The rule states that well completion reports be provided and specifies the type of information that should be included in the reports. The rule provides guidelines for determining whether additives are trade secrets.

The statewide rules also provide guidance on gas reservoirs and gas well allowable (Rule §3.31), well densities (Rule §3.38), and fluid injection into productive reservoirs (Rule §3.46).

Texas Voluntary Cleanup Program (VCP) - This program is described in Subchapter D of Chapter 4 Environmental Protection of the Texas administrative code, Title 16. This program was adopted in June 2002. This subchapter provides 11 rules to provide incentive for the cleanup of property contaminated by activities under the jurisdiction of the RRC. The rule provides guidelines on the documentation that is required when conducting a cleanup, including work plans and reports, and determines when a site is considered cleaned up.

Texas House of Representatives Bill HB 3328 - This Bill became effective on September 1, 2011 and was finalized by RRC on December 13, 2011. It required that oil and gas operators disclose the ingredients in additives used in hydraulic fracturing; it is applicable to drilling permits obtained on or after February 1, 2012. This was one of the first laws that required disclosure of fracturing chemicals and has served as a template for others.

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 groundwater and surface water quality in Wise and Denton Counties.

3.1 Land Use

The total population of Wise County is 59,127 within 904 square miles, which yields a population density of 65 persons per square mile. This represents a 21% increase from the population of 48,789 in 2000 (U.S. Census Bureau, 2010b). The total population of Denton County is 662,614 within 878 square miles, which yields a population density of 754 persons per square mile. This represents a 53% increase from the population of 433,065 in 2000 (U.S. Census Bureau, 2010a).

Land use information was available for the years 1986 and 2006. Figure 3-1 shows the 1986 land use map for Wise and Denton Counties (USGS, 1986). Figure 3-2 shows the 2006 land cover (National Land Cover Database [NLCD], 2006). The land use categories were different between the 1986 and 2006 maps and have been reclassified into a common set of categories to facilitate comparison between the two years (Table 3-1). Agriculture (e.g., cropland, pasture and orchards) was a major land use at 40% and 70% in 1986 for Wise and Denton Counties, respectively. In 2006, agriculture remained a major land use; however, the ratio decreased dramatically to 14.7% for Wise County and 25.5% for Denton County. Between 1986 and 2006, there was an increase in industrial, commercial and service activities in Wise (0.2% to 0.5%) and Denton (0.8% to 5.2%) Counties, although it still represents a relatively small percentage of total land use. Historically, the total land use in higher intensity development was less than 1% on a county-wide basis including urban; industrial; commercial and services; and transportation areas (USGS, 1986). In 2006, data on transportation and communication were not available and therefore cannot be compared to 1986 data.

Table 3-1. Summary of Land Use Statistics for Wise and Denton Counties

Category	Wise County (1986)	Wise County (2006)	Denton County (1986)	Denton County (2006)
Agriculture (Crop, Pasture, Orchard)	39.7%	14.7%	70.7%	25.5%
Surface Extraction (Strip Mine, Gravel Pit, Quarry, Barren)	0.7%	0.7%	0.2%	0.2%
Industrial, Commercial, and Services	0.2%	0.5%	0.8%	5.2%
Mixed Forest	14.1%	14.8%	7.9%	9.2%
Mixed Rangeland	41.7%	58.9%	9.3%	35.9%
Urban	0.1%	0.1%	0.8%	1.6%
Residential	0.9%	2.1%	3.7%	6.9%
Transitional	0.5%	5.8%	1.1%	6.4%
Transportation and Communication	0.2%	N/A	0.6%	N/A
Water Bodies	1.4%	2.2%	4.2%	8.1%
Wetlands	0.6%	0.1%	1.0%	1.1%

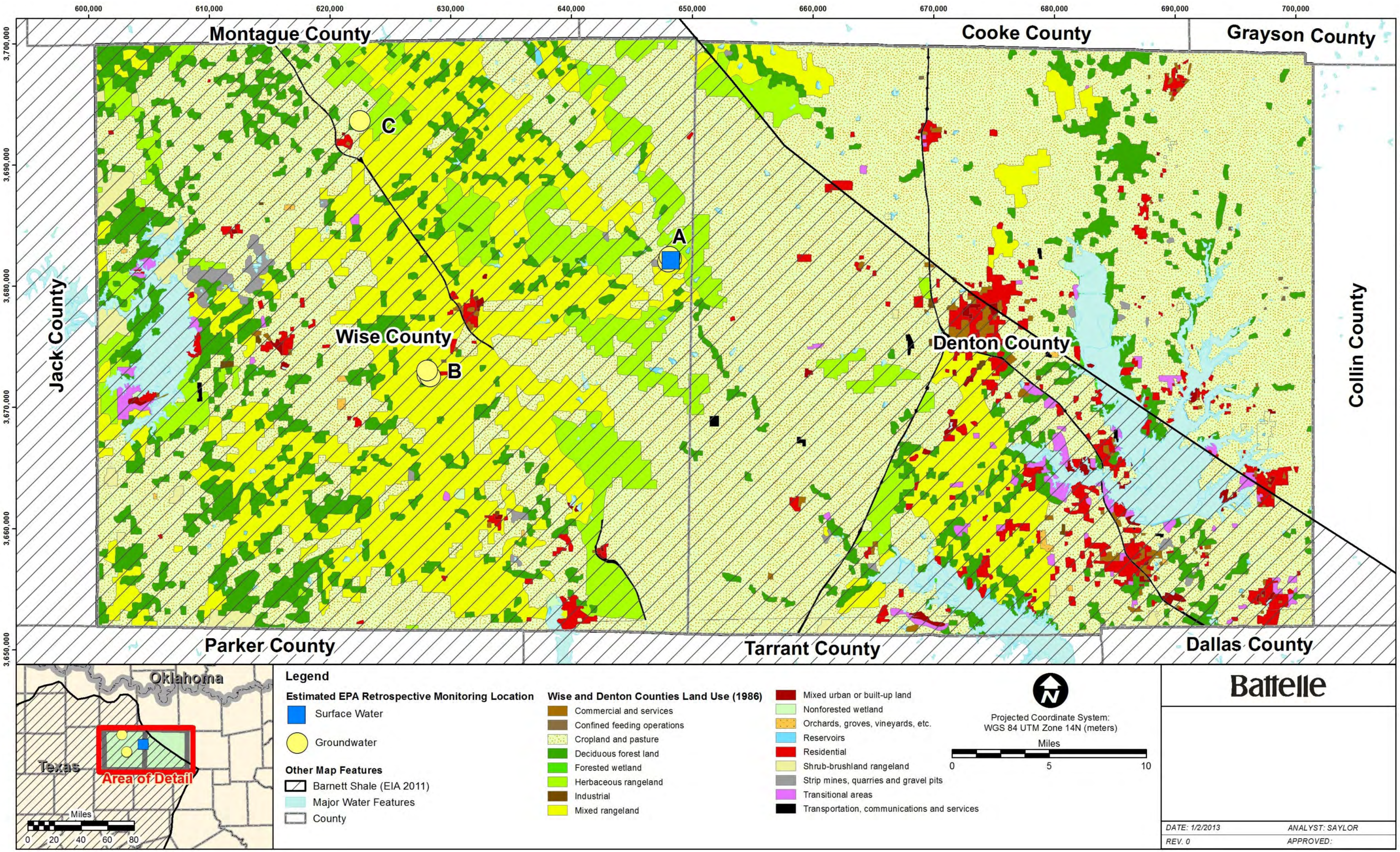


Figure 3-1. Land Use Map for Wise and Denton Counties (1986)

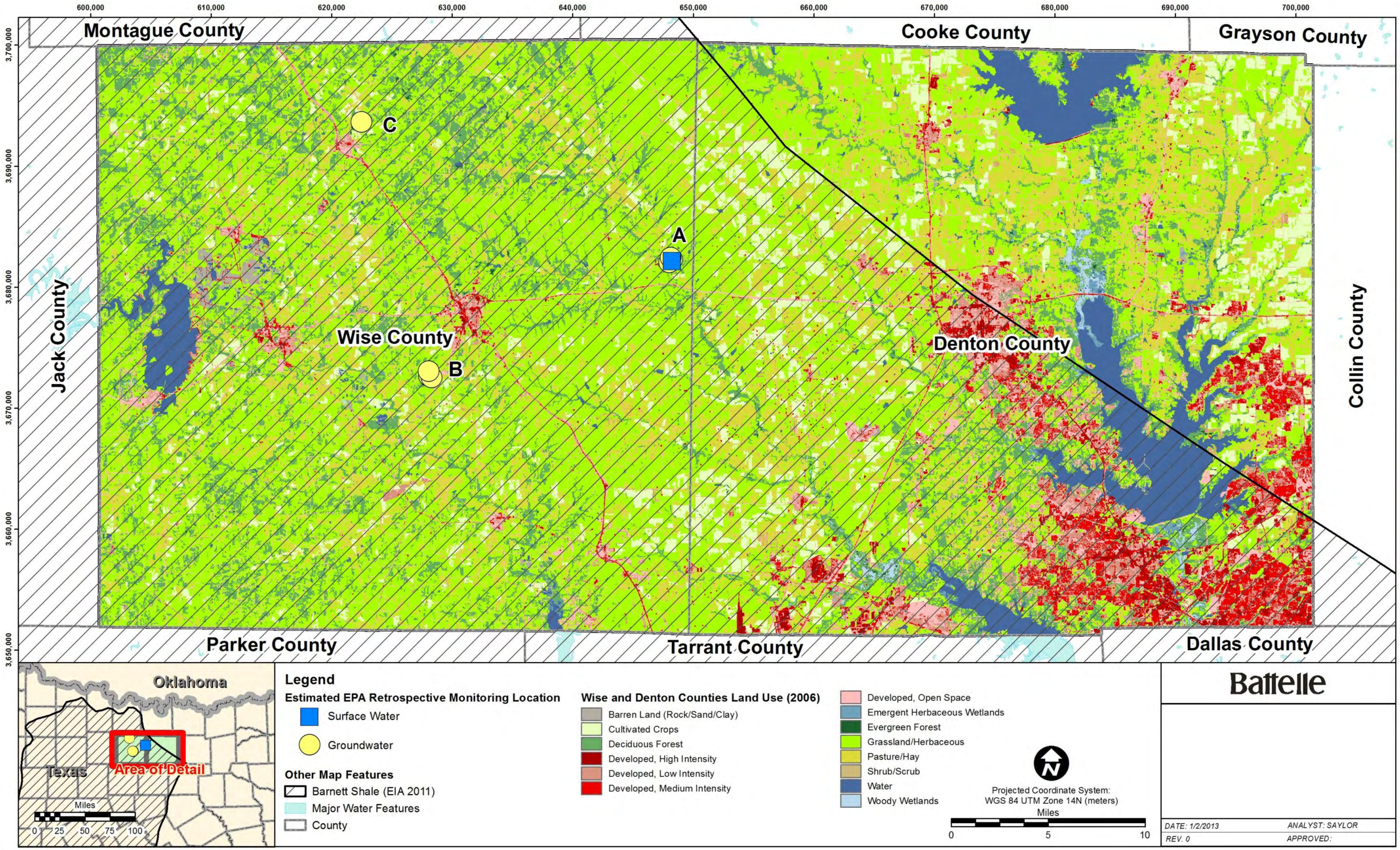


Figure 3-2. Land Use Map for Wise and Denton Counties (2006)

Agriculture and livestock have been important industries in Wise and Denton Counties (England, 2012). Mining was also an important industry in the history of Wise County, although coal mining operations ceased in the 1930s and only represent a small percentage of land use in both 1986 and 2006. Conventional oil and gas extraction has been ongoing since the late 1800s in both counties. These widespread land use activities have influenced water quality as discussed below.

3.1.1 Mining. The first coal mining in Texas was near the Sabine River in eastern Texas (southeast of Wise and Denton Counties) in 1819. Most of the coal extraction consisted of small operations until the 1880s. Coal mining carried out from the 1800s to 1944 used underground methods. After the 1940s, oil began to replace coal as a fuel source in Texas (RRC, 1991).

The closest surface mines to the Counties are at least 70 miles away (RRC, 2007). The Bridgeport Coal Company had mines in Wise County beginning in the 1880s. Coal mining activities were regulated after August 1977 under the Federal Surface Mining Control and Reclamation Act. Before 1977, there were a total of 31 coal mines in Wise County. No underground mining has occurred in Texas since the 1930s. There are no records of any coal mining activity in Denton County (RRC, 2007).

Although iron ore and uranium mining is prevalent in Texas, there are no active or historic iron ore or uranium mining operations in Wise and Denton Counties (Olien, 2012; RRC, 2011).

Sand and gravel mining is an important industry in Wise County. Sand and gravel deposits of commercial value are found adjacent to the major rivers that flow across the county. They are mined primarily as a source for construction materials (Garner, 2012). In addition, there are several clay and shale mining operations in Denton County for manufacturing bricks.

Overall, water quality parameters that may be influenced by these types of activities could include sulfate, total suspended solids (TSS), turbidity, temperature changes, pH, aluminum, nitrate, nitrite and iron from sand/gravel mining (TNRCC, 2001).

3.1.2 Agriculture. Agriculture has continually been a major industry in north central Texas. For example, Wise County was a major milk producer in the 1980s. As of 2007, over 442,753 acres of Wise County were dedicated to farming. This is an increase of 9.8% compared to 1987. Cropland represented 30% of land in farms, the top crop being forage (land used for hay, haylage, grass silage and greenchop). Over 350,274 acres of Denton County were dedicated to farming in 2007. This is a decrease of 11.5% compared to 1987. Cropland represented 40% of land in farms, the top crop being forage (land used for all hay, haylage, grass silage and greenchop) (U.S. Department of Agriculture [USDA], 2011).

Agricultural runoff may include insecticides, herbicides, fungicides, fertilizers (e.g., nitrogen and phosphorous), metals (e.g., arsenic) and other constituents (e.g., dissolved solids, bromide, selenium). In addition, algae 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). Similarly, pastures for livestock production may consist of manure that serves as a source of nutrients and pathogens. Livestock production includes primarily cattle, goats, horses and sheep (USDA, 2011). Agricultural and livestock activities can also be a source of methane (King, 2012).

3.1.3 Other Non point Sources and Stormwater Runoff. Runoff from impervious surfaces and other nonpoint source discharges can affect the quantity and quality of groundwater recharge and surface water. Nonpoint source pollution refers to pollution that comes from many sources caused by rainfall runoff transporting contaminants into waterways. Nonpoint sources may include residential lawns, construction areas, farm or highways (TCEQ, 2012a).

Stormwater runoff or nonpoint source pollution from urban areas, suburban residential areas, and roads are known to have caused surface water impairments in 2010 in the watersheds that Wise County occupies. These include 98.8 miles of river and stream impairments in 2010 caused by nonpoint sources specifically in the Upper West Fork Trinity watershed (EPA, 2012f). There are no impairments reported in 2010 for Denton and Elm Fork Trinity watersheds (EPA, 2012f). There are no known impaired waterways in Denton County in 2010 (EPA, 2012f). Habitat modification and uncontrolled runoff from construction sites may cause soil erosion and sediment pollution in nearby streams.

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 (Solars et al., 1982). Runoff from impervious roadways can also be a source of heavy metals (e.g., iron, lead, zinc) and volatile organic compounds (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).

3.1.4 Municipal and Other Wastewater Discharges. Human waste disposal methods in Wise and Denton Counties include centralized wastewater treatment plants (WWTPs) such as Decatur Sewer Treatment Plant, Denton Creek Waste Water Plant and Lewisville Wastewater Treatment Plant; decentralized small systems, or on-site sewage disposal. As of 2010, there were 167 (Wise) and 406 (Denton) on-site sewage facilities in the study area (TCEQ, 2010a). There have been numerous cited failures where inadequate treatment has resulted in contamination of surface or groundwater due to neglect/lack of homeowner education, seasonal wetness and heavy rain, but the main reasons for failure are antiquated systems and cesspools (Macrellis and Douglas, 2009). In addition, water quality problems have been associated with population growth and aging infrastructure of WWTPs in some areas such as the southeast corner of Wise County, specifically Eagle Mountain Lake (Roth, 2010). In rural areas, the most common conventional types of septic systems include graveled systems or low-pressure dosage systems. If conditions are not suitable for conventional septic systems, a common alternative is utilization of aerobic treatment unit (Aerobic Septic Service Company, 2012). There are no recorded combined sewer overflows (CSOs) in Wise or Denton Counties (EPA, 2008).

In the absence of adequate treatment, these wastewater disposal methods may discharge pathogens, household and industrial chemicals, suspended solids, excessive biochemical oxygen demand (BOD), and nutrients into receiving waters. An estimated 25% of the household and industrial chemicals may pass through in the discharge to receiving waters even after treatment at a WWTP (EPA, 1997). Septic systems and on-site disposal can also directly impact water quality in nearby downgradient drinking water wells.

3.1.5 Industrial, Manufacturing, and Commercial Activities. Most common industrial and manufacturing activities in Wise County over the years include construction, manufacturing, transportation equipment, carbon and graphite, mining, quarrying and support activities for oil/ gas extraction. Common industries in Denton County include construction, manufacturing, transportation equipment, education, support activities for oil/gas extraction. In addition, education institutes (for example, Texas Women’s University, University of North Texas) provide major employment in Denton County. Some examples of companies in the county are Frito Lay, American Airlines, Xerox, Peterbilt Motors and Boeing Electronics (aerospace, aircraft manufacturers, aircraft painting, service and repair, aircraft parts and equipment wholesale and manufacturer) (Wells, 2011). As a result of these various activities, there are over 3,600 facilities or locations with recognized environmental impacts. The type of facilities include construction (crushed stone factory, limestone quarry plants, asphalt, brick and concrete manufacturing, glass blowing), sewage treatment plants, gas compressor stations, WWTPs and dry cleaners. In addition, both Wise and Denton Counties have EPA recognized environmental sites caused by companies related to oil and gas operations.

Figure 3-3 shows the location of sites with recognized environmental impacts across Wise and Denton Counties. Environmental restoration sites include a total of 358 storage tank incident sites (73 sites in Wise County and 285 sites in Denton County). Facilities that handle wastes subject to RCRA and the Toxic Releases Inventory (TRI) regulations are shown, including 36 NPDES permits in Wise County and 180 NPDES permits in Denton County with allowable discharges of industrial effluent from activities such as brick and concrete manufacturing and other sources; sewerage systems, construction material manufacturing; and storm water discharges from industrial activities. (Note: Locations for six NPDES permits in Wise County and 81 NPDES permits in Denton County were not mapped on Figure 3-3 as there were incomplete datasets on these locations.) Although these are permitted discharges, violations of these permits can occur along with accidental releases above regulatory levels. Figure 3-3 shows the location of environmental incidents that occurred around the vicinity of two of the EPA sampling locations. The Aspen Oil Spill that occurred in June 2010 involved an oil spill of more than 100 barrels of oil from a 4-inch production pipeline that is owned by Aspen Oil. Oil was known to have migrated from the pipeline into Walker Branch Creek. Walker Branch Creek flows into Big Sandy Creek and Eagle Mountain Lake. The Decatur Gas Well Explosion occurred in March 2010, where a tank at a gas production facility owned by Devon Energy exploded (EPA, 2012g). Although natural gas condensate was reportedly involved in the explosion, it could not be determined for certain.

State agencies such as TCEQ and RRC have been tracking locations of groundwater contamination across Wise and Denton Counties. Figure 3-4 shows the locations of groundwater contamination across the two counties between 1988 and 2010. Since Figure 3-3 lists all environmental sites regardless of media, Figure 3-4 contains some overlap as the latter only lists groundwater contamination. The details of groundwater contamination such as case descriptions, location by address, contamination, date of occurrence(s), enforcement and activity status and data quality are detailed in Appendix D.

There are no brownfield sites and VCP sites in Wise or Denton Counties (RRC, 2012f).

In 2010, 8,913 tons of chemicals regulated under the TRI program were discharged into the environment in Wise County through on- and off-site disposal, discharge or other forms of releases (EPA, 2012d). This includes seven different organic and inorganic chemical constituents (certain glycol ethers, cobalt, copper, lead, methanol, nickel and styrene). The waste releases were from industrial activities involving fabricated metals, transportation equipment manufacturing and chemical wholesale.

Similarly, 82,918 tons of chemicals regulated under the TRI program were discharged into the environment in Denton County in 2010 (EPA, 2012d). This includes over 23 different organic and inorganic chemical constituents. Constituents of concern (COCs) from these types of industrial operations include metals (e.g., cobalt, copper, lead, nickel, manganese, chromium, antimony), hydrogen fluoride, hydrochloric acids, ethylene glycol, chlorine, 1,2,4-trimethylbenzene, ammonia, diisocyanates, chlorodifluoromethane and methanol. The waste releases were from industrial activities involving fabricated metals, food and beverages, manufacturing (transportation equipment, brick, chemical and jewelry), and material recovery. In addition, leaking 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.

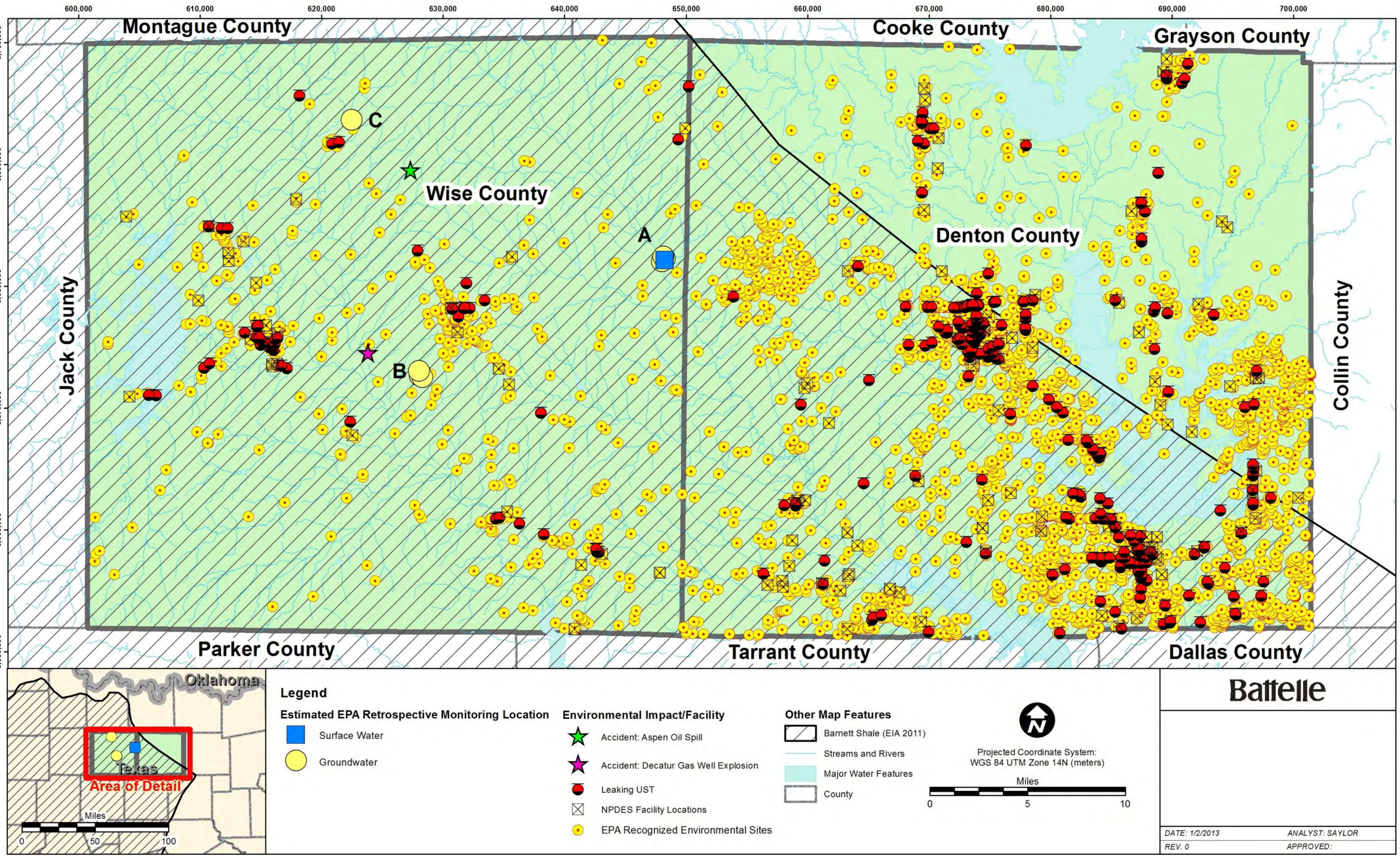


Figure 3-3. Sites with Recognized Environmental Impacts in Wise and Denton Counties

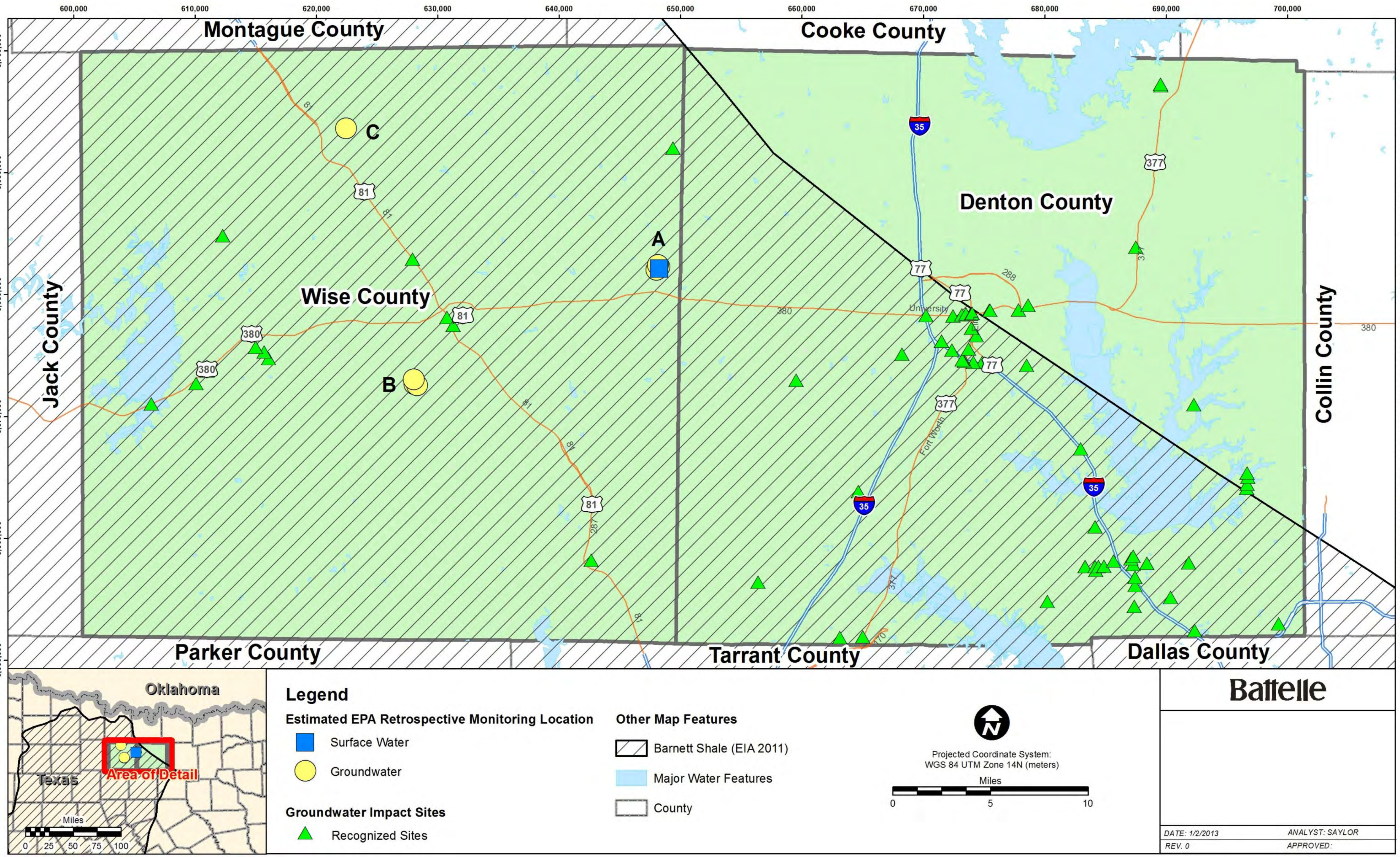


Figure 3-4. Sites with Recognized Groundwater Impacts in Wise and Denton Counties

The National Academies (2012) estimates that there are at least 126,000 known hazardous waste sites across the U.S. including Superfund sites. It also estimates that approximately 10 percent of Superfund facilities impact public water supply systems, but similar information for other programs is largely not available. Therefore, there is also the potential for existing impacts to water quality from industrial, manufacturing, commercial or other activities that have not yet been documented.

3.1.6 Conventional and Unconventional Oil and Gas Development. Texas is the leading crude oil-producing state in the nation (U.S. Energy Information Administration [EIA], 2009). Oil drilling in Texas began in 1866 at Oil Springs near Nacogdoches in east Texas, but it was not until 1901 that the oil industry boomed (GWPC, 2011; Olien, 2012).

Texas has more than 216,000 active oil and gas wells statewide (RRC, 2012a; RRC, 2012d). Conventional oil and gas drilling has been ongoing in Wise and Denton Counties for a long time. Wise and Denton Counties have more than 18,000 conventional oil and gas wells as shown in Figure 3-5. Because of the lack of complete historic records, well numbers and locations have some inherent uncertainty.

Natural gas in Texas was discovered as a byproduct of oil drilling. In the earlier years it was wasted without being produced. Texas banned flaring after World War II, which led oil producers to find new markets for natural gas. Texas natural gas production in 1972 was more than 9.6 billion cubic feet of annual production (U.S. EIA, 2012). In 1982, with the passage of the natural gas tax incentive under the Federal Natural Gas Policy Act, a record level of drilling activity began (GWPC, 2011).

Texas leads in natural gas production where approximately three-tenths of total U.S. natural gas production occurs. In 2011, the annual statewide natural gas production was 7.016 trillion cubic feet (U.S. EIA, 2012). Specifically, Wise and Denton Counties produced 240,690,271 million cubic feet and 253,389,690 million cubic feet, respectively, in 2011 (RRC, 2012a).

Major natural gas fields in Texas include Barnett (Newark, East Field) in Fort Worth Basin (depth between 5,000 to 8,000 feet), Carthage field in East Texas (2,064 feet depth); Panhandle, West, field in the Anadarko Basin (depth ranging from 2,100 to no greater than 3,500 feet); and Giddings field in Gulf Coast Basin (average depth of 8,600 feet) (Bureau of Economic Geology [BEG], 2005; Olien, 2012; RRC, 2012c).

The Newark East Field, or Barnett Shale, was initially developed in southeast Wise County by Mitchell Energy in 1981. It is a hydrocarbon-producing geological formation located 7,500 to 8,000 feet bgs, consisting of sedimentary rocks that are up to 1,000 feet thick in some areas. The productive part of the formation is estimated to cover 5,000 square miles (13,000 km^2) (RRC, 2012c). The Barnett Shale is present in 16 counties in north Texas. Hydraulic fracturing is used in the recovery of the gas due to the low permeability of the shale. In 1997, the first slick water frac (or light sand frac) was performed to stimulate the Barnett Shale (RRC, 2012c).

The occurrence of horizontal drilling grew in the 1990s when gas prices increased (RRC, 2012c). In 1992, the first horizontal well was installed in the Barnett Shale and the next was installed in 1998. Between 1998 and 2002, less than four horizontal wells per year were drilled. Between 2003 and 2009, 9,094 horizontal wells and 2,624 vertical wells were drilled in the Barnett Shale (Powell Barnett Shale Newsletter, 2010). As of March 2012, there were 15,731 total gas wells in the RRC records with an additional 3,112 permitted locations that are pending (RRC, 2012b). All producing wells in the Barnett Shale have been hydraulically fractured (Gwyn, 2012). As of February 2012, oil and gas companies have been required to disclose chemical information on hydraulic fracturing fluids.

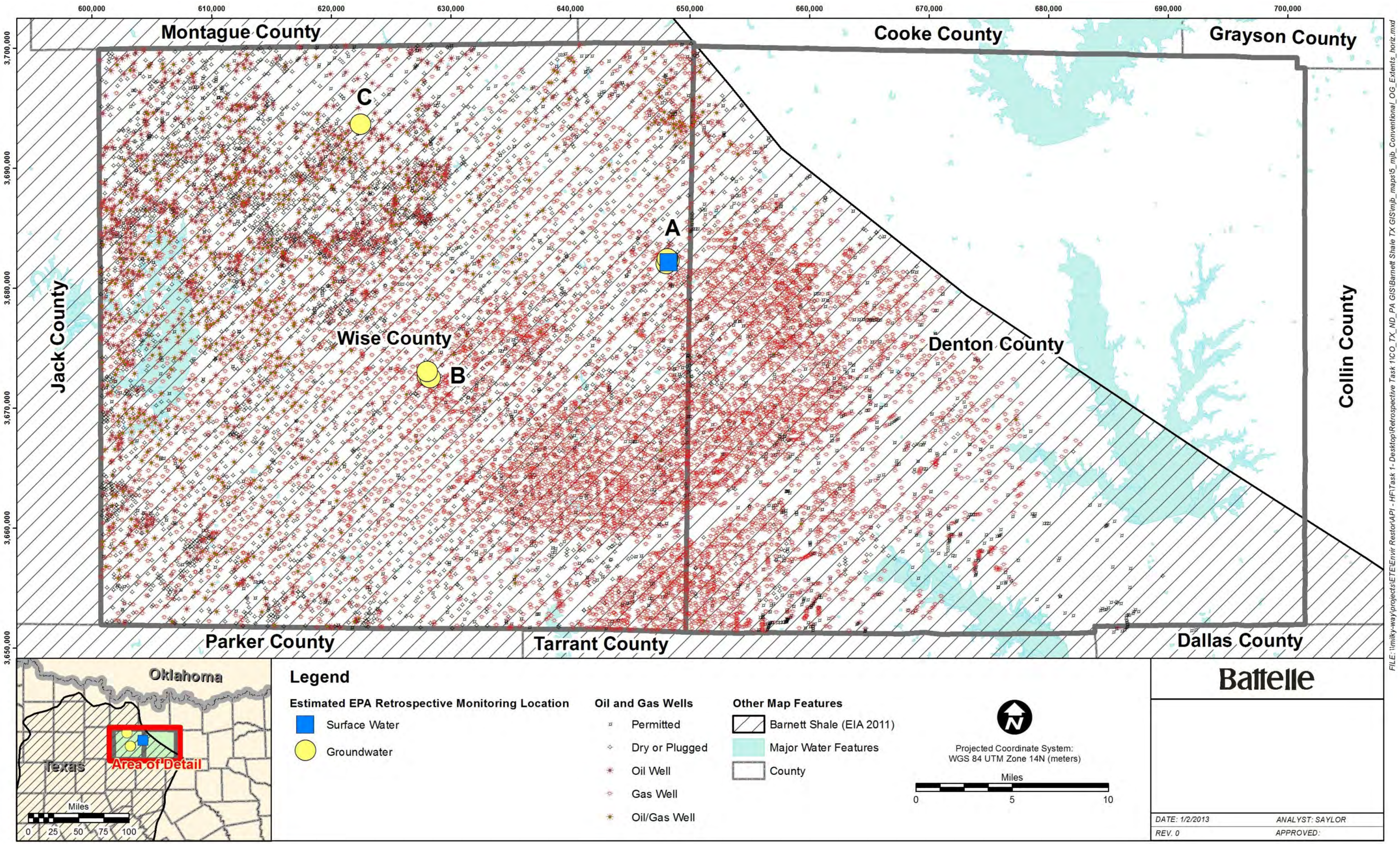


Figure 3-5. Conventional Oil and Gas Well Locations

There are over 3,000 unconventional shale gas wells in Wise and Denton Counties as shown in Figure 3-6. The first producing Barnett shale well in Wise County was completed in 1981. The first horizontal well in Wise County was permitted in 1991. The first horizontal well in Denton County was permitted in 2003 (RRC, 2012e). Based on a RRC Drilling Permit Application Query, there are 2,526 oil or gas wells that are new drill permits since 1977 in Wise County. This includes 1,908 vertical wells, 29 directional wells, 588 horizontal wells and one horizontal side tracked well. Similarly, there are 1,021 oil or gas wells that are new drill permits since 1977 in Denton County; this includes 499 vertical wells, 13 directional wells and 509 horizontal wells (RRC, 2012e).

Regulations for oil and gas wells existed in the 1800s and early 1900s but were not strictly enforced. It was not until the 1930s that the regulations took hold, although little is known about the construction, production and abandonment procedures for these historic oil and gas wells (RRC, 1991). It was known that the abandoned wells may pose environmental issues. As a result, Texas initiated a Well Plugging Program in 1965, which was updated in 1983 to plug abandoned wells, and in 1984 to regulate oil and gas wastes (Williams et al., 2000). 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.

Historically, wastewater generated during oil and gas operations was disposed of in evaporation pits and surface waters. In the 1950s, Texas began to realize the potential impacts of this practice and, as a result, the RRC prohibited the disposal of oil and gas wastewater in pits in 1969 (Tintera and Savage, 2006). Sites polluted by pre-1969 release and storage in pits have been recorded and are known to have impacted groundwater resources (GWPC, 2011). Currently, wastewater disposal of oil and gas operations is usually conducted by injecting water into deep dry wells serving as natural depositories. Dry wells are underground disposal wells or natural gas wells that failed to produce natural gas upon completion. Texas has natural saltwater depositories with limestone caps over a mile below drinking water resources, making underground disposal possible (Roberson, 2012). Texas has more than 50,000 permitted brine disposal wells (Carillo et al., 2010). The number of currently permitted commercial disposal wells in Wise and Denton County is 497 and three, respectively (RRC, 2010). Currently, all wells require steel casing and cement in zones above the disposal zone to isolate them from aquifers used for drinking water.

Petroleum hydrocarbons and BTEX constituents are naturally occurring in the environment in close proximity to natural oil and gas deposits and seeps. Metals, salts, and naturally-occurring radioactive materials (NORM) may also be present in the environment near these deposits. Between 1993 and 2008, over 16,000 horizontal shale gas wells with multi-staged hydraulic fracturing stimulations were completed in Texas. The RRC has documented 211 groundwater contamination issues caused by oilfield activities in Texas (GWPC, 2011). More than 35% (75) of the incidents resulted from waste management and disposal activities, including 57 legacy incidents caused by produced water disposal pits that were banned in 1969 and closed no later than 1984. Production phase activities accounted for 26.5% (56) of the incidents (GWPC, 2011). However, it is also noted by RRC that not a single groundwater contamination incident has resulted from site preparation, drilling, well construction, completion and hydraulic stimulation or production operations at any of the horizontal shale gas wells during the same period (GWPC, 2011). Brine injection wells may pose a contamination risk due to seepage. There have been six

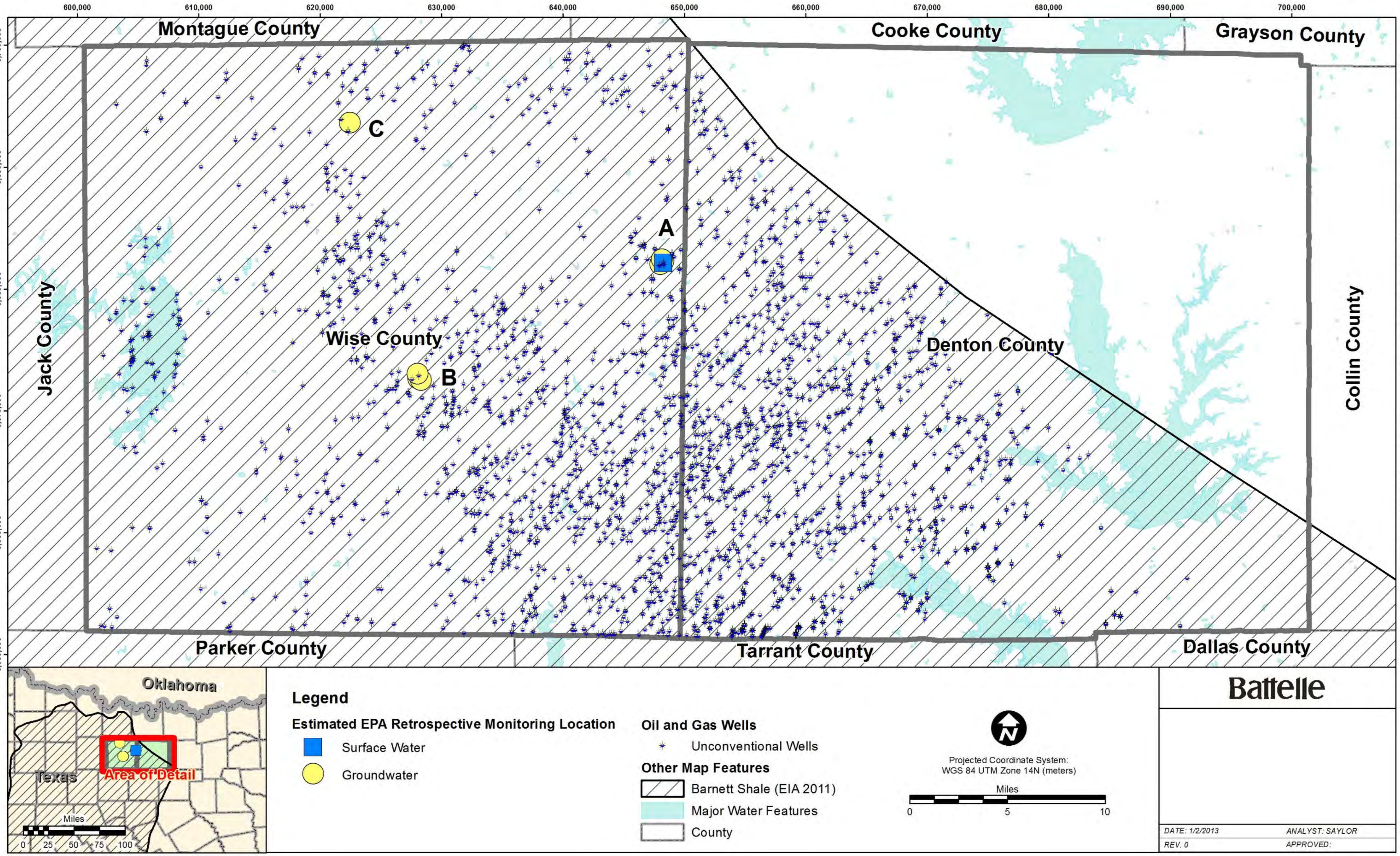


Figure 3-6. Unconventional Shale Gas Well Locations

cases of contamination caused by injection operations in Texas as identified by RRC (GWPC, 2011). GWPC (2011) noted that due to the level of historic oil and gas drilling in Wise and Denton Counties, possible pathways exist from the historic producing horizons to shallow groundwater aquifers.

3.2 Groundwater Quality

This section summarizes the groundwater resources in Wise and Denton Counties, including the major groundwater-bearing units and available groundwater quality data in comparison to screening criteria.

3.2.1 Hydrogeology. The Trinity Aquifer, the largest and most productive water-bearing unit in north-central Texas, underlies most of Wise and Denton Counties. Groundwater resources occur within these consolidated Cretaceous deposits. Part of the Trinity Group, the Trinity Aquifer consists of several formations that form aquifers of varying thickness and extents. The main formations of the Trinity Aquifer are the Antlers Formation, the Paluxy Formation, the Glen Rose Formation (an aquitard), and the Twin Mountains Formation. The Trinity Group outcrops in Wise County (Figure 3-7) and extends below Wise and Denton Counties, dipping toward the east and southeast (Nordstrom, 1982). In the north and northwestern portions of Wise and Denton Counties, the Trinity Aquifer is comprised of the Antlers Sand. A southwest-to-northeast-trending line defines the northern extent of the Glen Rose Formation. South of this line, the Trinity Aquifer consists of the Paluxy Formation overlying the Glen Rose Formation, which in turn overlies the Twin Mountains Formation. West of the Trinity Group in Wise County are Paleozoic units that occur stratigraphically beneath the Trinity Group. Thirteen groundwater quality monitoring locations occur within these Paleozoic units.

The Trinity Group formations are summarized in Table 3-2. The Antlers Formation is approximately 400 feet thick in Wise County and typically consists of a basal conglomerate of gravel overlain by fine, poorly consolidated sand in massive, cross bedded layers interbedded with layers of clay in lenses scattered throughout the formation (Nordstrom, 1982). The middle section has more clay lenses than the lower or upper sections; the upper section of the Antlers Formation contains limestone beds and friable sand with thin beds of clay and gravel. The Twin Mountains Formation is 200 feet thick or less where it outcrops in the northwestern area of Wise County; it reaches up to 1,000 feet in thickness near the down-dip limit of fresh to slightly saline water toward the east/southeast. The Twin Mountains Formation consists of medium to coarse grained sands, silty clays, and conglomerates of chert, quartzite, and quartz pebbles (Nordstrom, 1982). The Paluxy Formation thickness varies considerably from zero to over 250 feet thick in Wise and Denton Counties and is composed predominately of fine-to-coarse grained friable, homogeneous white quartz sand with interbedded sandy, silty, calcareous, or waxy clay and shale (Nordstrom, 1982). Properly constructed wells in these three aquifers can produce up to 400 to 500 gallons per minute (gpm) if completed in the more conductive portions of the aquifers. The Glen Rose Formation confining unit is primarily limestone and the thickness usually does not exceed 100 ft beneath Wise and Denton Counties. Several other overlying geologic groups outcrop in Wise and Denton Counties (Figure 3-7), including the Fredericksburg, Washita, Woodbine, Eagle Ford, and Austin Groups. These groups, which are not primary sources of drinking water, are summarized in Table 3-2. Two Upper Pennsylvanian series (Missourian and Virgilian Series) occur beneath the Trinity Group.

Groundwater in the Trinity Aquifer is under unconfined conditions if in or near outcrop. The formations dip to the east and southeast, extending under Wise and then Denton County further to the east. The Trinity Aquifer is overlain and confined by the Fredricksburg Group. The Washita formation in turn overlies the Fredericksburg.

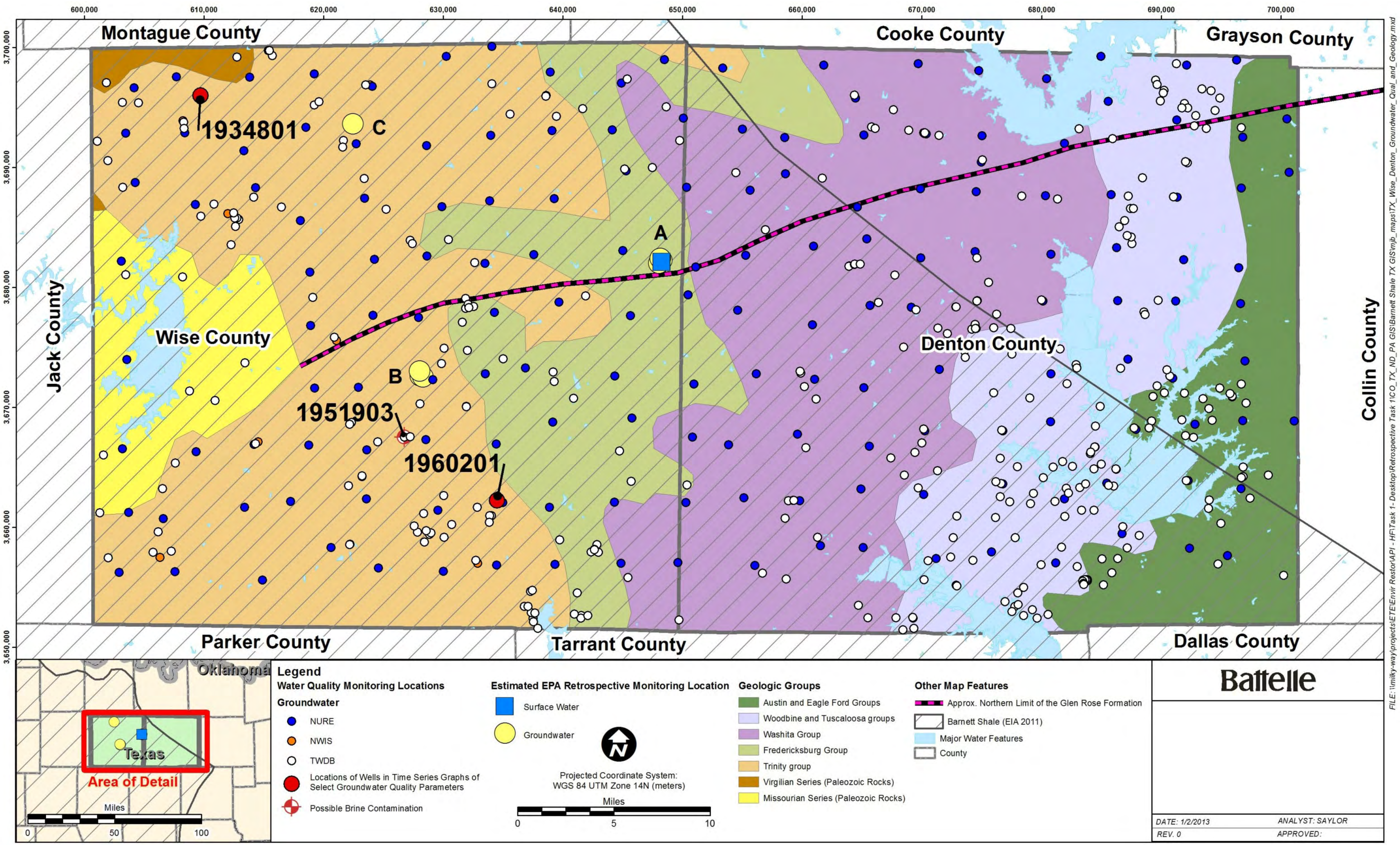


Figure 3-7. Groundwater Quality Monitoring Locations and Shallow Groundwater-Bearing Formations, Wise and Denton Counties, TX

Table 3-2. Selected Geologic Units Underlying Wise and Denton Counties (Nordstrom, 1982)

<table>
<tr><th>Group</th><th colspan="2">Formation</th><th colspan="2">Approximate Maximum Thickness[2] (ft)</th><th>Description</th><th>Water-Bearing Characteristics[3]</th></tr>
<tr><td>Austin</td><td colspan="2">-</td><td colspan="2">700</td><td>Chalk, limestone, and marl; fine to medium sand</td><td>Yields small to moderate quantities of water, very limited as an aquifer</td></tr>
<tr><td>Eagle Ford</td><td colspan="2">-</td><td colspan="2">650</td><td>Shale; thin beds of sandstone and limestone</td><td>Yields small quantities of water to shallow wells</td></tr>
<tr><td>Woodbine</td><td colspan="2">-</td><td colspan="2">700</td><td>Sand, sandstone, clay</td><td>Yields moderate to large quantities of water; fresh to slightly saline</td></tr>
<tr><td>Washita</td><td colspan="2">-</td><td colspan="2">1,000</td><td>Limestone, marl, and clay</td><td>Yields small quantities of water to shallow wells</td></tr>
<tr><td>Fredericksburg</td><td colspan="2">-</td><td colspan="2">250</td><td>Limestone, clay, marl, shale, and shell agglomerates</td><td>Yields small quantities of water to shallow wells</td></tr>
<tr><td rowspan="3">Trinity[1]</td><td rowspan="3">Antlers Formation</td><td>Paluxy</td><td rowspan="3">900</td><td>400</td><td>Fine sand, sandy shale, and shale</td><td>Yields small to moderate quantities of water; fresh to slightly saline</td></tr>
<tr><td>Glen Rose</td><td>1,500</td><td>Limestone, marl, shale, and anhydrite</td><td>Yields small quantities of water in localized areas</td></tr>
<tr><td>Twin Mountains</td><td>1,000</td><td>Fine-to-coarse sand, shale, clay, basal gravel, and conglomerate</td><td>Yields moderate to large quantities of water to wells; fresh to slightly saline</td></tr>
<tr><td colspan="5">Paleozoic rocks undifferentiated</td><td>Sandstone, limestone, shale, and conglomerate</td><td>Yields small quantities of water in/near outcrop</td></tr>
</table>

[1]Primary groundwater-bearing group within Wise and Denton Counties.
[2]Approximate maximum thickness in north central Texas.
[3]Yield of wells: small – less than 100 gpm; moderate – 100 to 1000 gpm; large – more than 1000 gpm
[3]Chemical Quality of water: fresh – <1,000 mg/l; slightly saline – 1,000 to 3,000 mg/l; moderate salinity – 3,000 to 10,000 mg/l

The Washita is also a confining unit and is shown to outcrop over the western half of Denton County in Figure 3-7. Directly overlying the Washita is the Woodbine Group, an aquifer of sufficient quality for use as irrigation and industrial purposes. The eastern most units outcropping in Denton County are the Austin/Eagle Ford Groups; these are confining units.

Aquifer recharge for all three formations is primarily from infiltration by precipitation and surface water bodies on the outcrop areas. Groundwater discharge occurs predominantly via pumpage and, to a lesser extent, via springs and evapotranspiration. Groundwater withdrawal estimates for 2006 are 12,059 acre-feet in Denton County and 6,445 acre-feet for Wise County (Freese and Nichols et al., 2011). Groundwater flows from the recharge areas at the outcrops in Wise County toward the east-southeast. A large cone of depression is present to the south of Denton County under the city of Dallas. This cone of depression has increased in depth over the last 20 years because more groundwater is being withdrawn than recharged to aquifers in the north-central Texas area. These withdrawals have resulted in aquifer water level reductions of up to 400 feet in parts of the north-central Texas area and over 100 feet in southern Wise County. Groundwater in the Trinity Aquifer is managed by state groundwater conservation districts. Groundwater overdrafts continue to be a common problem, but the districts have implemented conservation practices and are actively seeking surface water sources to supplement the growing water demands.

Groundwater Quality Impairments. The USGS completed several studies as part of its National Water-Quality Assessment program that are important to the understanding of groundwater quality in the study area. As part of the program (Land et al., 1998), groundwater samples were collected from 24 wells less than 280 feet deep where the Trinity Aquifer outcrops, including 13 domestic wells in Wise County. The samples were collected from 1992-1995, prior to substantial development of the Barnett Shale through hydraulic fracturing. Groundwater quality was not above 1996 EPA MCLs, but did have higher than acceptable dissolved solids (salinity) from half of the wells. At the time, the USGS noted the salinity may be from brines associated with oil and gas production, or naturally occurring.

Pesticides (diazinon, *p,p'*-DDE [a DDT derivative], atrazine or its metabolite di-ethylatrazine) and one VOC (benzene) were also found at low levels in the Trinity groundwater samples. Diazinon, an insecticide, was found in nearly half of the wells sampled. These compounds may have migrated to the groundwater with recharge or downward along well casings that were not completely sealed at the surface.

The USGS (Land et al., 1998) note the Woodbine Aquifer as a minor aquifer in the basin, but important in understanding water quality because it underlies the Dallas-Fort Worth area. Water quality data were collected from 28 specially constructed monitoring wells less than 50 feet deep and from 10 domestic wells 50 to 150 feet in depth. All of the wells are located in Tarrant County, adjacent and south of Wise and Denton Counties. Reutter (1996) noted the Woodbine Aquifer can be naturally high in salinity, iron, and sulfate. Samples from 27 of 38 wells were above the SMCL for dissolved solids; 23 of 27 were above the SMCLs for iron and sulfate, and five were above the MCL for nitrate. Pesticides were detected in 11 of the 38 wells. VOCs were detected in seven wells including the gasoline additive methyl tert-butyl ether and solvents (tetrachloroethylene, trichloroethylene, *cis*-1,2-dichloroethylene, and vinyl chloride) with some results above their respective MCLs.

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. While not specific to Wise and Denton Counties, 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.

Simone (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 elements 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 (Wise and Denton Counties are characterized in the drier region) relative to humid regions due most likely to processes such as chemical evolution, complexation reactions, evaporation and geochemical processes act 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.

The TCEQ, which monitors and records groundwater contamination cases within the state, issued a Joint Groundwater Contamination Report in 2010 (GWPC, 2011). The report deals with groundwater contamination cases on a county by county basis and also by the individual member of the joint committee which first logged the case. It includes detailed case descriptions that include the location by address, the nature of contamination, the date of occurrence, associated enforcement, activity status and data quality. Appendix D contains the TCEQ cases for Denton and Wise Counties. The Denton County cases (Figure 3-4) consisted of 31 petroleum hydrocarbon contamination, six unknown contamination cases, and 12 VOC/semivolatile organic compound (SVOC)/chlorinated solvent cases. In addition, there were six cases that were associated with metals, VOCs, SVOCs and chlorinated solvents, including three at landfills/disposal facility where the contamination was detected in groundwater monitoring wells. Of the 57 total cases, 19 have had remedial actions completed as of 2010. The Wise County cases (Figure 3-4) consisted of six associated with petroleum hydrocarbon contamination and three cases with an unknown cause. The RRC (another member of the joint committee) has reported four cases in Wise County (see Appendix D). For three of these four cases, the contaminant was found to be condensate; the other case (crude/condensate) was associated with natural gas. These cases are directly related to compression stations or pipeline leaks, where a condensate is commonly produced from gas and or oil wells and contains intermediate to short chained hydrocarbons that are collected at the wellhead. The four RRC cases were ongoing in 2010, and their status was either investigating the case, or planning, or implementing a remedial action. Appendix D lists the contamination cases and also contains the closed cases from all members of the joint committee. All of the closed cases have been fully remediated (GWPC, 2011).

An area in southeastern Wise County and adjoining parts of Denton and Tarrant Counties had elevated levels of TDS, chloride and sodium, suggesting possible brine contamination (TWDB, 1990). Well 1951903 (Figure 3-7) in Wise County is identified as potentially impacted by brine in this area. Two water quality samples were available from this well in 1983, prior to substantial development of the Barnett Shale. Water quality results from this location contained chloride levels in excess of 1,000 mg/L, sodium levels in excess of 700 mg/L and TDS just under 2,000 mg/L. More recent water quality data are not available from this location. The TWDB (1990) noted that poorly abandoned oil and gas wells can be conduits allowing poor quality water to impact fresh water sands.

TWDB (1990) also noted two anomalies in water quality in the Twin Mountains Formation in southeastern Wise, southwestern Denton and Tarrant Counties, where higher than normal TDS concentrations may be the result of large groundwater declines from over pumping. The increased concentrations may be due to leakage of water from overlying Glen Rose Formation, which is usually high in sodium, chloride and sulfate content. Leakage between formations would be increased in areas where poor well completions occur in areas of higher groundwater withdrawals (TWDB, 1990). An additional source of the contamination may be from lateral migration of poorer water quality into the area. Possible sources are difficult to assess due to the lack of historical data for comparison and the potential for poor historical well construction to further confound the situation.

3.2.2 Data Summary. Groundwater quality data from sources identified in Table 2-2 were compiled into a database to characterize groundwater quality prior to unconventional oil and gas development (i.e., pre-1998) in the study area. The data compiled in the database represent samples collected from 532 locations between 1931 and 1997. Figure 3-7 shows the groundwater database sampling locations and EPA retrospective case study sampling locations overlain on a map of shallow groundwater-bearing formations in Wise and Denton Counties.

The available groundwater quality data consist primarily of general water quality parameters including major ions, metals and nutrients, together with VOCs, SVOCs, and other organics such as pesticides. There are limited results for VOCs and SVOCs, nutrients, and other organics. Table 3-3 provides a pre-1998 listing of parameters detected, number of samples, minimum, maximum, median, mean, standard deviation, date range for sample collection, and comparison against water quality standards and criteria, including the number of results above each screening criteria for the comprehensive data set. For groundwater, the standards and criteria include the MCL, SMCL, Texas carcinogenic and non-carcinogenic criteria, EPA Region VI carcinogenic and EPA Region VI non-carcinogenic criteria. Section 2 provides an explanation of these water quality screening criteria, and how summary statistics were calculated. Table 3-3 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 groundwater data collected by Battelle for Wise and Denton Counties.

Inorganic Summary As indicated in Table 3-3, the maximum observed concentration is above one or more of the screening criteria for pH and TDS, major ions, chloride, fluoride, sulfate and sodium. Chloride, sulfate and sodium are identified as EPA CAs, whereas fluoride is identified as an EPA M parameter. Chloride is above the SMCL of 250 mg/L in 76 samples with a maximum concentration of 2,485 mg/L and mean concentration of 98 mg/L. Sulfate is above the SMCL of 250 mg/L in 33 samples, with a maximum detection of 530 mg/L and mean concentration of 91 mg/L. Average sulfate concentrations in produced water associated with oil and gas development are typically less than 10 mg/L. Dissolved and total sodium are above the EPA Health Advisory level of 20 mg/L in 164 and 625 samples, respectively. Dissolved sodium has maximum and mean concentrations of 713 and 163 mg/L, respectively, and total sodium has maximum and mean concentrations of 1,489 and 214 mg/L, respectively. Fluoride concentrations are above the MCL, SMCL and the EPA Region VI non-carcinogenic criteria.

The minimum, maximum, and/or mean observed concentration is above one or more of the screening criteria for several metals, including aluminum, arsenic, beryllium, boron, cobalt, iron, manganese, phosphorus, uranium and vanadium. For both beryllium and uranium, observed concentrations were above only the MCL. Aluminum, iron and manganese were above the SMCL, and arsenic, boron, cobalt, manganese and phosphorus were above EPA Region VI carcinogenic criteria. Arsenic also was above the EPA Region VI carcinogenic criteria. Cobalt and vanadium were above the Texas non-carcinogenic levels. Of the metals noted here, all are EPA M parameters with the exception of arsenic, selenium, strontium, barium, and boron (which are EPA CAs). Figure 3-8 shows the spatial distribution of inorganic chemicals detected above the screening criteria.

Organic Summary. There are limited detections for organic compounds, including one VOC (benzene) and one SVOC (p,p-DDE) each with only 11 sample results available. Benzene (0.4 μg/L) was marginally higher than the EPA non-carcinogenic level of 0.39 μg/L. Twenty-eight other organic compounds having 10 or 11 samples (each from discrete locations) were below detection limits for all samples. Figure 3-8 shows the spatial distribution of organic chemicals detected above the screening criteria.

Table 3-3. Groundwater Critical and Measured Analytes Summary in Wise and Denton Counties, TX

											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)	EPA Carc.	N Above EPA Carc. (no NDs)	EPA Non-Carc.	N Above EPA NonCarc. (no NDs)	TX Carc.	N Above TX Carc. (no NDs)	TX Non-Carc.	N Above TX NonCarc. (no NDs)
Dissolved Gas	Carbon dioxide	No	Tot.	mg/l	-	21	11	0	0.7	133	38	44.3	28.3	38	44.3	28.3	Feb-94	Mar-94													
Gen WQ	Alkalinity as CaCO3	No	Tot.	mg/l	M	359	209	0	1	405	19.8	36.9	70.1	19.8	36.9	70.1	Dec-38	Oct-97													
Gen WQ	Alkalinity as CaCO3	Yes	Dis.	mg/l	M	21	11	0	130	420	330	320	88.7	330	320	88.7	Feb-94	Mar-94													
Gen WQ	Alkalinity as CaCO3	Yes	Tot.	mg/l	M	19	16	0	245	515	413	394	73.9	413	394	73.9	Feb-38	Oct-64													
Gen WQ	Hardness as CaCO3	No	Tot.	mg/l	-	655	364	0	1	1539	20.8	119	188	20.8	119	188	Jun-31	Oct-97													
Gen WQ	Organic carbon	No	Dis.	mg/l	M	11	11	0	0.2	1.3	0.5	0.527	0.29	0.5	0.527	0.29	Feb-94	Mar-94													
Gen WQ	Oxygen	Yes	Dis.	mg/l	M	166	166	0	1.1	12.1	4.4	4.61	2.17	4.4	4.61	2.17	Feb-78	May-78													
Gen WQ	pH	No	Tot.	std units	M	643	362	0	6.2	10.4	8.37	8.24	0.651	8.37	8.24	0.651	Feb-38	Oct-97			6.5	8.5	280								
Gen WQ	pH	Yes	Tot.	std units	M	187	177	0	6	9.7	7.8	8.01	0.948	7.8	8.01	0.948	Feb-78	Mar-94			6.5	8.5	68								
Gen WQ	Specific conductance	No	Tot.	umho/cm	M	12	12	0	511	2410	982	1080	526	982	1080	526	Feb-78	Mar-94													
Gen WQ	Specific conductance	Yes	Tot.	umho/cm	M	750	512	0	170	5248	994	1190	688	994	1190	688	Feb-44	Oct-97													
Gen WQ	Temperature, water	No	Tot.	deg C	M	21	11	0	13.5	20.5	19	18.5	2.11	19	18.5	2.11	Feb-94	Mar-94													
Gen WQ	Total dissolved solids	No	Dis.	mg/l	M	650	364	0	122	4376	580	664	342	580	664	342	Jun-31	Oct-97				500	445								
Inorganic	Sodium carbonate	No	-	mg/l CaCO3	-	524	284	0	0.03	17.76	6.79	6.33	2.92	6.79	6.33	2.92	Jun-31	Oct-97													
Inorganics, Major, Non-metals	Silica	No	-	mg/l	-	432	282	1	0.11	42	13	14.7	5.26	13	14.8	5.2	Jun-31	Oct-97													
Inorganics, Major, Non-metals	Silica	No	Dis.	mg/l	-	11	11	0	9.1	26	20	18.8	4.98	20	18.8	4.98	Feb-94	Mar-94													
Major Anions	Bromide	No	Dis.	mg/l	M	11	11	0	0.12	3	0.38	0.696	0.837	0.38	0.696	0.837	Feb-94	Mar-94													
Major Anions	Chloride	No	Dis.	mg/l	CA	652	364	0	3	2485	31	98.1	161	31	98.1	161	Jun-31	Oct-97				250	76								
Major Anions	Fluoride	No	-	mg/l	M	624	347	23	0.005	4.1	0.49	0.78	0.805	0.5	0.796	0.804	Feb-38	Oct-97	4	2		2	55			0.62	219				
Major Anions	Fluoride	No	Dis.	mg/l	M	11	11	3	0.05	1.2	0.1	0.268	0.349	0.2	0.35	0.382	Feb-94	Mar-94	4	0		2	0			0.62	1				
Major Anions	Sulfate	No	-	mg/l	CA	641	353	1	2	530	70.7	91.2	75.7	70.8	91.5	75.7	Jun-31	Oct-97				250	33								
Major Anions	Sulfate	No	Dis.	mg/l	CA	178	178	14	2.5	1704	44	83.2	152	46	90.1	157	Feb-78	Mar-94				250	10								
Major Cations	Calcium	No	-	mg/l CaCO3	CA	644	353	2	0.5	472	4.33	30.8	49.4	4.33	30.8	49.4	Jun-31	Oct-97													
Major Cations	Calcium	No	Dis.	mg/l	CA	177	177	1	0.05	260	8	40.9	53.5	8.45	41.1	53.6	Feb-78	Mar-94													
Major Cations	Magnesium	No	-	mg/l CaCO3	CA	637	350	69	0.03	142	2	9.09	17.7	2.25	9.78	18.1	Feb-38	Oct-97													
Major Cations	Magnesium	No	Dis.	mg/l	CA	177	177	7	0.05	89.9	2.9	11.4	17.6	3.1	11.9	17.8	Feb-78	Mar-94													
Major Cations	Potassium	No	Dis.	mg/l	CA	176	176	10	0.05	18	1.25	1.89	2.1	1.4	2.01	2.11	Feb-78	Mar-94													
Major Cations	Potassium	No	Tot.	mg/l	CA	161	134	9	0.05	20	2	2.65	2.53	2.13	2.76	2.54	Feb-44	Oct-97													
Major Cations	Sodium	No	Dis.	mg/l	CA	177	177	0	7.2	713	163	163	123	163	163	123	Feb-78	Mar-94	20	164											
Major Cations	Sodium	No	Tot.	mg/l	CA	643	353	0	7	1489	211	214	143	211	214	143	Jun-31	Oct-97	20	625											
Metals	Aluminum	No	Dis.	ug/l	M	177	177	145	1	325	5	8.28	24.6	13	23.2	56.1	Feb-78	Mar-94				200	1			16000	0			24442	0
Metals	Arsenic	No	Dis.	ug/l	CA	178	178	128	0.25	5.4	0.25	0.709	0.994	1.4	1.84	1.32	Feb-78	Mar-94	10	0				0.045	50	4.7	1				
Metals	Barium	No	Dis.	ug/l	CA	177	177	24	1	367	16	45.2	60.9	34	52.1	62.8	Feb-78	Mar-94	2000	0						2900	0				
Metals	Beryllium	No	Dis.	ug/l	M	177	177	175	0.5	6	0.5	0.545	0.453	4.5	4.5	2.12	Feb-78	Mar-94	4	1						16	0				
Metals	Boron	No	Dis.	ug/l	CA	166	166	1	2	3848	151	444	719	151	447	721	Feb-78	May-78								3100	5			4888.4	0
Metals	Chromium	No	Dis.	ug/l	M	177	177	158	0.5	7	2	2.18	0.923	4	4.11	1.79	Feb-78	Mar-94	100	0											
Metals	Cobalt	No	Dis.	ug/l	M	177	177	131	0.5	18	1	1.69	2.02	3	3.78	3.15	Feb-78	Mar-94								4.7	8			7.3	3
Metals	Copper	No	Dis.	ug/l	M	177	177	128	0.5	290	1	6.61	27.1	4	21.3	48.8	Feb-78	Mar-94	1300	0		1000	0			620	0				
Metals	Iron	No	Dis.	ug/l	M	177	177	160	1.5	320	5	11.6	38.8	19	73.9	109	Feb-78	Mar-94				300	2			11000	0				
Metals	Lead	No	Dis.	ug/l	M	11	11	9	0.5	4	0.5	0.864	1.05	2.5	2.5	2.12	Feb-94	Mar-94	15	0											
Metals	Lithium	No	Dis.	ug/l	-	166	166	1	1	154	19	22.8	17.8	19	23	17.7	Feb-78	May-78													
Metals	Manganese	No	Dis.	ug/l	M	187	177	87	0.5	610	2	18.7	65.5	8.5	35.9	88.7	Feb-78	Mar-94				50	12			320	2			1148.8	0
Metals	Molybdenum	No	Dis.	ug/l	M	177	177	138	0.5	11	2	2.66	1.76	5	5.28	2.2	Feb-78	Mar-94								78	0			122.2	0
Metals	Nickel	No	Dis.	ug/l	M	177	177	126	0.5	22	2	3.12	2.63	5	6.02	3.46	Feb-78	Mar-94								300	0			488.8	0
Metals	Niobium	No	Dis.	ug/l	-	166	166	132	2	11	2	2.75	1.68	5	5.65	1.79	Feb-78	May-78													
Metals	Phosphorus	No	Dis.	ug/l	M	177	177	156	5	811	20	51.7	132	117	291	291	Feb-78	Mar-94								0.31	21				
Metals	Scandium	No	Dis.	ug/l	-	166	166	163	0.5	5	0.5	0.539	0.369	2	2.67	2.08	Feb-78	May-78													

Table 3-3. Groundwater Critical and Measured Analytes Summary in Wise and Denton Counties, TX (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)	EPA Carc.	N Above EPA Carc. (no NDs)	EPA Non-Carc.	N Above EPA NonCarc. (no NDs)	TX Carc.	N Above TX Carc. (no NDs)	TX Non-Carc.	N Above TX NonCarc. (no NDs)
Metals	Selenium	No	Dis.	ug/l	CA	178	178	78	0.1	14	0.2	0.712	1.55	0.3	1.17	1.95	Feb-78	Mar-94	50	0						78	0				
Metals	Silicon	No	Dis.	ug/l	M	165	165	0	1000	20500	4900	5910	2970	4900	5910	2970	Feb-78	May-78													
Metals	Silver	No	Dis.	ug/l	M	177	177	172	0.5	3	1	1	0.247	2	2.2	0.447	Feb-78	Mar-94				100	0			71	0			122.2	0
Metals	Strontium	No	Dis.	ug/l	CA	165	165	0	6	7913	286	947	1510	286	947	1510	Feb-78	May-78								9300	0			14665.2	0
Metals	Strontium	No	Tot.	ug/l	CA	44	42	0	0.04	8.55	0.36	1.13	1.96	0.36	1.13	1.96	Jun-89	Oct-97								9300	0			14665.2	0
Metals	Titanium	No	Dis.	ug/l	M	166	166	156	1	4	1	1.08	0.348	2	2.3	0.675	Feb-78	May-78												122209.8	0
Metals	Uranium	No	Dis.	ug/l	M	178	178	80	0.1	93	0.27	2.1	7.6	0.7	3.71	9.98	Feb-78	Mar-94	30	1											
Metals	Vanadium	No	Dis.	ug/l	M	166	166	155	2	7	2	2.18	0.733	4	4.73	1.1	Feb-78	May-78								78	0			1.7	11
Metals	Yttrium	No	Dis.	ug/l	-	166	166	143	0.5	6	0.5	0.611	0.49	1	1.3	1.11	Feb-78	May-78													
Metals	Zinc	No	Dis.	ug/l	M	177	177	45	2	2601	24	123	294	44	165	331	Feb-78	Mar-94				5000	0			4700	0			7332.6	0
Metals	Zirconium	No	Dis.	ug/l	-	166	166	147	1	5	1	1.16	0.543	2	2.42	0.902	Feb-78	May-78													
Nutrients	Ammonia-nitrogen as N	No	Dis.	mg/l	M	11	11	1	0.005	1.1	0.04	0.252	0.385	0.045	0.277	0.397	Feb-94	Mar-94													
Nutrients	Kjeldahl nitrogen	No	Dis.	mg/l as N	-	11	11	8	0.1	1	0.1	0.282	0.325	0.7	0.767	0.208	Feb-94	Mar-94													
Nutrients	Nitrate as N	No	Dis.	mg/l	CA	11	11	3	0.025	6.28	0.99	1.71	2.01	2.1	2.35	2.02	Feb-94	Mar-94	10	0						25	0				
Nutrients	Nitrite as N	No	Dis.	mg/l	CA	11	11	10	0.005	0.02	0.005	0.00636	0.00452	0.02	0.02		Feb-94	Mar-94	1	0						1.6	0				
Nutrients	Nitrogen, mixed forms (NH3), (NH4), organic, (NO2) and (NO3)	No	Dis.	mg/l	-	11	11	10	0.125	3.25	0.99	1.09	0.925	0.99	0.99		Feb-94	Mar-94													
Nutrients	Organic nitrogen	No	Dis.	mg/l	-	9	9	8	0.03	0.1	0.085	0.075	0.0266	0.03	0.03		Feb-94	Mar-94													
Nutrients	Phosphate as P	No	Dis.	mg/l	-	11	11	6	0.005	0.04	0.005	0.0155	0.0146	0.03	0.028	0.013	Feb-94	Mar-94													
Organic	Surfactants -- CWA 304B	No	Tot.	mg/l	-	11	11	9	0.01	0.07	0.01	0.0164	0.018	0.045	0.045	0.0354	Feb-94	Mar-94													
Organics, other	Phenols and phenolic compounds	No	Tot.	ug/l	-	10	10	6	0.5	4	0.5	1.3	1.27	2.5	2.5	1.29	Mar-94	Mar-94													
Organics, pesticide	Bromacil	No	Dis.	ug/l	-	10	10	9	0.02	0.33	0.02	0.051	0.098	0.33	0.33		Feb-94	Mar-94												2444.2	0
Organics, pesticide	Diazinon	No	Dis.	ug/l	-	11	11	9	0.001	0.015	0.001	0.00327	0.0051	0.0135	0.0135	0.00212	Feb-94	Mar-94								7.9	0			22	0
Radioactive, metal	Thorium - NURE	No	Dis.	ug/l	-	166	166	109	2.5	22	2.5	4.8	3.85	8	9.19	3.7	Feb-78	May-78													
SVOCs	p,p'-DDE	No	Dis.	ug/l	-	11	11	10	0.001	0.003	0.003	0.00282	0.000603	0.001	0.001		Feb-94	Mar-94						0.2	0			2.684	0		
VOCs	Benzene	No	Tot.	ug/l	M	11	11	10	0.1	0.4	0.1	0.127	0.0905	0.4	0.4		Feb-94	Mar-94	5	0				0.39	1	29	0				

M = Measured, as defined in EPA QAPP for Wise and Denton Counties Retrospective Case Study (EPA, 2012b).
CA = Critical Analyte, as defined in EPA QAPP for Wise and Denton Counties Retrospective Case Study (EPA, 2012b).

A red highlight indicates the value was above a screening criteria. Shading indicates detections above one or more screening criteria. All non EPA parameters (non CA and non M) summary results along with the entire results are presented in Appendix B and are retained in the database.
Note: Sodium does not have an MCL; the value listed in the MCL column represents the EPA Health Advisory Level. N = number of samples
ND = non-detect
SD = Standard Deviation

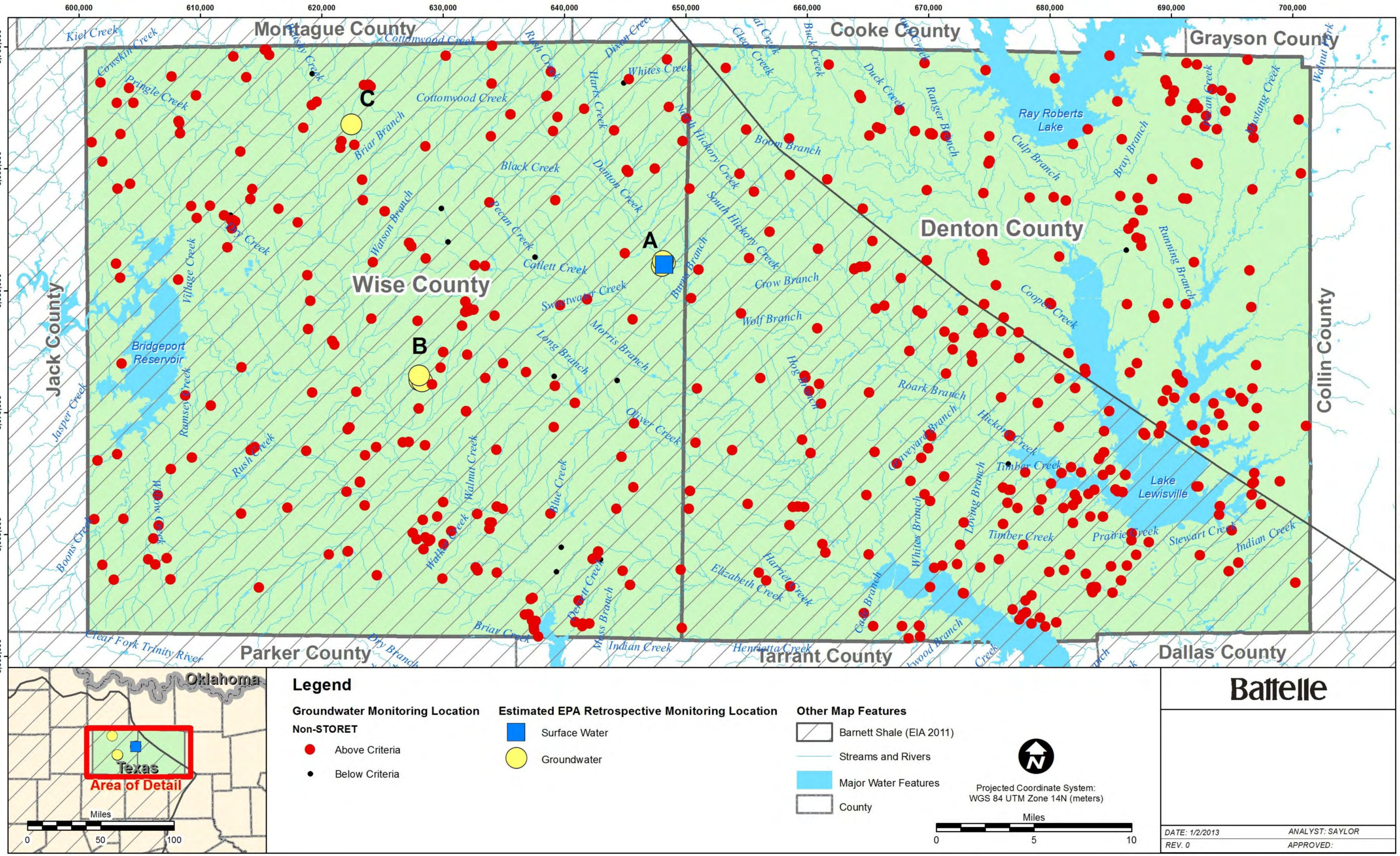


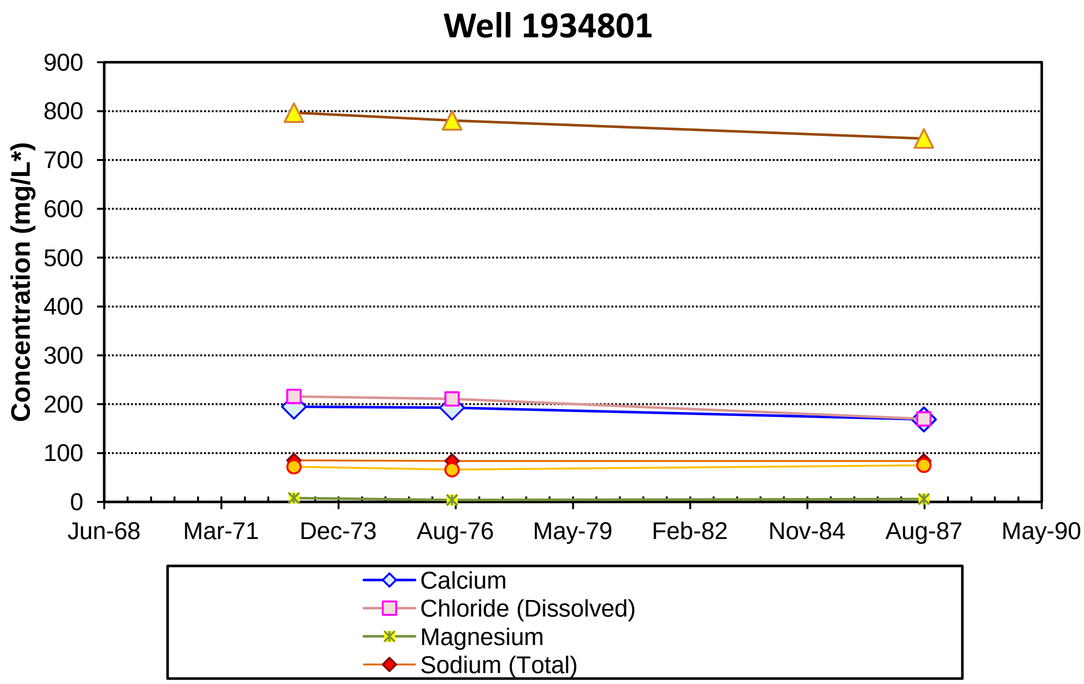
Figure 3-8. Groundwater Detections above Regulatory Levels, Wise and Denton Counties, TX

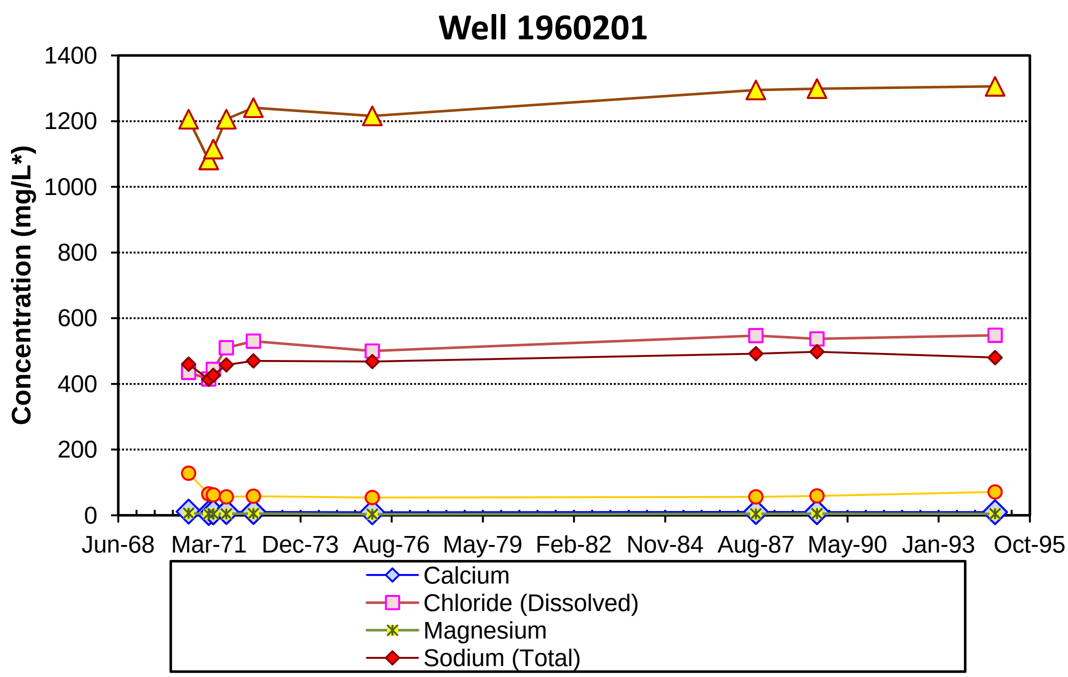
Many of the wells within this dataset contain results from a single groundwater sample, however some of the wells have samples from up to 11 sampling events. Figure 3-9 shows groundwater sampling results for two wells in Wise County as a time series versus concentration plot for selected anions, cations, and general water quality parameters. Well 1960201 shows relatively consistent concentrations over time except for chloride and TDS. The chloride and TDS concentrations show a gradual increase from 1976 to 1994. Southern Wise County has recently experienced significant groundwater level reductions (>100 feet) likely related to a combination of population increase and over pumping of the aquifer, and it is believed that the increases in chloride and TDS concentrations could be a result of this drop in groundwater level. Well 1934801 has a shorter record of groundwater quality measurements than Well 1960201, but results extending from 1973 to 1987 show groundwater quality for the selected parameters has changed very little. It is important to note that out of the almost 600 wells providing groundwater quality data, only two of the wells had enough historic data to construct these graphs. The remaining wells did not have sufficient data to construct a time series plot, or the ranges of dates for the data were too short to provide a meaningful evaluation.

3.2.2.1 Comparison Against Reduced Data Table. Table 3-4 provides a summary of pre-1998 groundwater data in similar format to Table 3-3, with the exception that 43 locations (four from TWDB and 39 from NURE) were removed based on uncertainty in sampling location coordinates (Table 2-3). This summary data table was created for comparison against the complete background groundwater quality summary data table (Table 3-3) to determine whether the data identified as having uncertainty associated with sampling location coordinates have a significant effect on background water quality values.

The parameters that are above screening criteria in the reduced summary data table (Table 3-4) are identical to those in the comprehensive data summary table with the exception of aluminum, which was not detected above screening criteria. The chemicals that are detected above regulatory levels in the reduced dataset include pH, TDS, chloride, fluoride, sodium (total and dissolved), sulfate, arsenic, beryllium, boron, cobalt, iron, manganese, phosphorous, uranium, vanadium, and benzene. With the exception of dissolved sodium, cobalt and phosphorous, which had lower maximum values in the reduced dataset, the maximum detected values for these parameters also are identical when comparing the two datasets. For pH, TDS, chloride, total sodium, sulfate, fluoride, arsenic, beryllium, cobalt, uranium, vanadium and benzene, there is minimal or no difference between the two datasets when comparing the summary statistics (mean, median and standard deviation). For dissolved sulfate, the mean and median values are higher in the reduced dataset, suggesting the removed data had lower chemical concentrations. For dissolved sodium, aluminum, boron, iron, managanese and phosphorous, the mean and median values are lower in the reduced dataset, indicating the removed data had higher chemical concentrations.

3.2.2.2 Analysis of Variance (ANOVA) Comparison. The available groundwater quality data span the period 1931 to 1998 and contain data from both the Trinity Aquifer and Paleozoic units. An initial assessment was made comparing pre-1998 water quality data from the Paleozoic units in western Wise County against Trinity Aquifer water quality to determine if significant differences exist between the datasets. There are a total of 13 wells completed in the Paleozoic units ranging in depths from 10 to 413 feet; 586 wells are completed in the Trinity Aquifer at depths ranging from a few tens of feet to 2,420 feet. Parameters analyzed included alkalinity, chloride, fluoride, sodium and TDS in the dissolved fractions. These parameters were selected because they are commonly detected in both datasets 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. Results indicate significant differences in water quality. Median chloride levels in the Trinity Aquifer are 3.5 times lower than median levels in the Paleozoic units. Sodium (50%) and sulfate (75%) median levels in the Trinity Aquifer are higher than the Paleozoic units. Differences for fluoride and TDS were not significant.





* Calcium and Magnesium concentrations are in mg/L $CaCO_3$

Figure 3-9. Time Series Groundwater Quality Graphs for Selected Wells

Table 3-4. Groundwater Critical and Measured Analytes Summary (Reduced Dataset) in Wise and Denton Counties, TX

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)	TX Carc.	N Above TX Carc. (no NDs)	TX Non-Carc.	N Above TX NonCarc. (no NDs)
Dissolved Gas	Carbon dioxide	No	Tot.	mg/l	-	21	11	0	0.7	133	38	44.3	28.3	38	44.3	28.3	Feb-94	Mar-94													
Gen WQ	Alkalinity as CaCO3	No	Tot.	mg/l	M	358	208	0	1	405	19.9	37	70.3	19.9	37	70.3	Dec-38	Oct-97													
Gen WQ	Alkalinity as CaCO3	Yes	Dis.	mg/l	M	21	11	0	130	420	330	320	88.7	330	320	88.7	Feb-94	Mar-94													
Gen WQ	Alkalinity as CaCO3	Yes	Tot.	mg/l	M	19	16	0	245	515	413	394	73.9	413	394	73.9	Feb-38	Oct-64													
Gen WQ	Hardness as CaCO3	No	Tot.	mg/l	-	651	360	0	1	1539	20.6	120	189	20.6	120	189	Jun-31	Oct-97													
Gen WQ	Organic carbon	No	Dis.	mg/l	M	11	11	0	0.2	1.3	0.5	0.527	0.29	0.5	0.527	0.29	Feb-94	Mar-94													
Gen WQ	Oxygen	Yes	Dis.	mg/l	M	127	127	0	1.1	12.1	4.4	4.65	2.35	4.4	4.65	2.35	Feb-78	May-78													
Gen WQ	pH	No	Tot.	std units	M	639	358	0	6.2	10.4	8.38	8.24	0.653	8.38	8.24	0.653	Feb-38	Oct-97			6.5	8.5	279								
Gen WQ	pH	Yes	Tot.	std units	M	148	138	0	6	9.7	7.8	8.01	0.985	7.8	8.01	0.985	Feb-78	Mar-94			6.5	8.5	56								
Gen WQ	Specific conductance	No	Tot.	umho/cm	M	12	12	0	511	2410	982	1080	526	982	1080	526	Feb-78	Mar-94													
Gen WQ	Specific conductance	Yes	Tot.	umho/cm	M	707	469	0	170	5248	994	1170	648	994	1170	648	Feb-44	Oct-97													
Gen WQ	Temperature, water	No	Tot.	deg C	M	21	11	0	13.5	20.5	19	18.5	2.11	19	18.5	2.11	Feb-94	Mar-94													
Gen WQ	Total dissolved solids	No	Dis.	mg/l	M	646	360	0	122	4376	580	664	343	580	664	343	Jun-31	Oct-97				500	443								
Inorganic	Sodium carbonate	No	-	mg/l CaCO3	-	520	280	0	0.03	17.76	6.79	6.34	2.89	6.79	6.34	2.89	Jun-31	Oct-97													
Inorganics, Major, Non-metals	Silica	No	-	mg/l	-	429	279	1	0.11	42	13	14.8	5.27	13	14.8	5.21	Jun-31	Oct-97													
Inorganics, Major, Non-metals	Silica	No	Dis.	mg/l	-	11	11	0	9.1	26	20	18.8	4.98	20	18.8	4.98	Feb-94	Mar-94													
Major Anions	Bromide	No	Dis.	mg/l	M	11	11	0	0.12	3	0.38	0.696	0.837	0.38	0.696	0.837	Feb-94	Mar-94													
Major Anions	Chloride	No	Dis.	mg/l	CA	648	360	0	3	2485	30.7	98.2	162	30.7	98.2	162	Jun-31	Oct-97				250	76								
Major Anions	Fluoride	No	-	mg/l	M	620	343	22	0.005	4.1	0.48	0.777	0.805	0.5	0.791	0.804	Feb-38	Oct-97	4	2		2	55			0.62	216				
Major Anions	Fluoride	No	Dis.	mg/l	M	11	11	3	0.05	1.2	0.1	0.268	0.349	0.2	0.35	0.382	Feb-94	Mar-94	4	0		2	0			0.62	1				
Major Anions	Sulfate	No	-	mg/l	CA	637	349	1	2	530	70	90.8	76.1	70	91.1	76	Jun-31	Oct-97				250	33								
Major Anions	Sulfate	No	Dis.	mg/l	CA	139	139	10	2.5	1704	45	84.9	163	48	91.3	167	Feb-78	Mar-94				250	8								
Major Cations	Calcium	No	-	mg/l CaCO3	CA	640	349	2	0.5	472	4.1	31	49.6	4.1	31	49.6	Jun-31	Oct-97													
Major Cations	Calcium	No	Dis.	mg/l	CA	138	138	0	0.1	260	11.5	44	56.1	11.5	44	56.1	Feb-78	Mar-94													
Major Cations	Magnesium	No	-	mg/l CaCO3	CA	633	346	68	0.03	142	2	9.15	17.8	2.2	9.83	18.2	Feb-38	Oct-97													
Major Cations	Magnesium	No	Dis.	mg/l	CA	138	138	3	0.05	89.9	3.45	12	18.2	4.3	12.3	18.3	Feb-78	Mar-94													
Major Cations	Potassium	No	Dis.	mg/l	CA	138	138	9	0.05	18	1.4	1.97	2.23	1.7	2.1	2.25	Feb-78	Mar-94													
Major Cations	Potassium	No	Tot.	mg/l	CA	160	133	9	0.05	20	2	2.66	2.53	2.2	2.78	2.54	Feb-44	Oct-97													
Major Cations	Sodium	No	Dis.	mg/l	CA	138	138	0	7.2	428.9	151	151	96.2	151	151	96.2	Feb-78	Mar-94	20	129											
Major Cations	Sodium	No	Tot.	mg/l	CA	639	349	0	7	1489	211	214	143	211	214	143	Jun-31	Oct-97	20	621											
Metals	Aluminum	No	Dis.	ug/l	M	138	138	113	1	48	5	6.3	5.63	11	12.2	11.7	Feb-78	Mar-94				200	0			16000	0			24442	0
Metals	Arsenic	No	Dis.	ug/l	CA	139	139	105	0.25	5.4	0.25	0.663	0.977	1.65	1.88	1.4	Feb-78	Mar-94	10	0				0.045	34	4.7	1				
Metals	Barium	No	Dis.	ug/l	CA	138	138	17	1	367	18.5	48.5	64.6	38	55.2	66.3	Feb-78	Mar-94	2000	0						2900	0				
Metals	Beryllium	No	Dis.	ug/l	M	138	138	136	0.5	6	0.5	0.558	0.513	4.5	4.5	2.12	Feb-78	Mar-94	4	1						16	0				
Metals	Boron	No	Dis.	ug/l	CA	127	127	1	2	3848	142	334	503	143	337	505	Feb-78	May-78								3100	1			4888.4	0
Metals	Chromium	No	Dis.	ug/l	M	138	138	123	0.5	7	2	2.14	0.934	4	3.93	1.94	Feb-78	Mar-94	100	0											
Metals	Cobalt	No	Dis.	ug/l	M	138	138	102	0.5	15	1	1.61	1.69	3	3.47	2.5	Feb-78	Mar-94								4.7	6			7.3	2
Metals	Copper	No	Dis.	ug/l	M	138	138	97	0.5	97	1	3.93	10.8	4	10.9	18.2	Feb-78	Mar-94	1300	0		1000	0			620	0				
Metals	Iron	No	Dis.	ug/l	M	138	138	123	1.5	320	5	12.8	43.4	16	77	116	Feb-78	Mar-94				300	2			11000	0				
Metals	Lead	No	Dis.	ug/l	M	11	11	9	0.5	4	0.5	0.864	1.05	2.5	2.5	2.12	Feb-94	Mar-94	15	0											
Metals	Lithium	No	Dis.	ug/l	-	127	127	1	1	154	19	22.3	17.5	19	22.5	17.5	Feb-78	May-78													
Metals	Manganese	No	Dis.	ug/l	M	148	138	68	0.5	610	1.5	19	67.8	8	36.4	92.2	Feb-78	Mar-94				50	10			320	1			1148.8	0
Metals	Molybdenum	No	Dis.	ug/l	M	138	138	109	0.5	11	2	2.56	1.67	5	5.07	2.19	Feb-78	Mar-94								78	0			122.2	0
Metals	Nickel	No	Dis.	ug/l	M	138	138	99	0.5	22	2	3.08	2.75	5	6	3.83	Feb-78	Mar-94								300	0			488.8	0
Metals	Niobium	No	Dis.	ug/l	-	127	127	104	2	11	2	2.68	1.64	5	5.74	1.84	Feb-78	May-78													
Metals	Phosphorus	No	Dis.	ug/l	M	138	138	123	5	783	20	44.8	117	112	254	286	Feb-78	Mar-94								0.31	15				

Table 3-4. Groundwater Critical and Measured Analytes Summary (Reduced Dataset) in Wise and Denton Counties, TX (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)	EPA Carc.	N Above EPA Carc. (no NDs)	EPA Non-Carc.	N Above EPA NonCarc. (no NDs)	TX Carc.	N Above TX Carc. (no NDs)	TX Non-Carc.	N Above TX NonCarc. (no NDs)
Metals	Scandium	No	Dis.	ug/l	-	127	127	125	0.5	5	0.5	0.547	0.42	3.5	3.5	2.12	Feb-78	May-78													
Metals	Selenium	No	Dis.	ug/l	CA	139	139	65	0.1	14	0.2	0.686	1.58	0.3	1.17	2.05	Feb-78	Mar-94	50	0						78	0				
Metals	Silicon	No	Dis.	ug/l	M	127	127	0	1800	17700	4900	5900	2720	4900	5900	2720	Feb-78	May-78													
Metals	Silver	No	Dis.	ug/l	M	138	138	135	0.5	3	1	0.989	0.252	2	2.33	0.577	Feb-78	Mar-94				100	0			71	0			122.2	0
Metals	Strontium	No	Dis.	ug/l	CA	127	127	0	13	7913	254	965	1470	254	965	1470	Feb-78	May-78								9300	0			14665.2	0
Metals	Strontium	No	Tot.	ug/l	CA	44	42	0	0.04	8.55	0.36	1.13	1.96	0.36	1.13	1.96	Jun-89	Oct-97								9300	0			14665.2	0
Metals	Titanium	No	Dis.	ug/l	M	127	127	118	1	4	1	1.09	0.387	2	2.33	0.707	Feb-78	May-78												122209.8	0
Metals	Uranium	No	Dis.	ug/l	M	139	139	58	0.1	93	0.32	2.54	8.52	1.02	4.25	10.9	Feb-78	Mar-94	30	1											
Metals	Vanadium	No	Dis.	ug/l	M	127	127	117	2	7	2	2.2	0.759	4	4.6	1.07	Feb-78	May-78								78	0			1.7	10
Metals	Yttrium	No	Dis.	ug/l	-	127	127	109	0.5	6	0.5	0.626	0.553	1	1.39	1.24	Feb-78	May-78													
Metals	Zinc	No	Dis.	ug/l	M	138	138	36	2	2601	22	114	278	42.5	153	314	Feb-78	Mar-94				5000	0			4700	0			7332.6	0
Metals	Zirconium	No	Dis.	ug/l	-	127	127	113	1	5	1	1.16	0.541	2	2.43	0.938	Feb-78	May-78													
Nutrients	Ammonia-nitrogen as N	No	Dis.	mg/l	M	11	11	1	0.005	1.1	0.04	0.252	0.385	0.045	0.277	0.397	Feb-94	Mar-94													
Nutrients	Kjeldahl nitrogen	No	Dis.	mg/l as N	-	11	11	8	0.1	1	0.1	0.282	0.325	0.7	0.767	0.208	Feb-94	Mar-94													
Nutrients	Nitrate as N	No	Dis.	mg/l	CA	11	11	3	0.025	6.28	0.99	1.71	2.01	2.1	2.35	2.02	Feb-94	Mar-94	10	0						25	0				
Nutrients	Nitrite as N	No	Dis.	mg/l	CA	11	11	10	0.005	0.02	0.005	0.00636	0.00452	0.02	0.02		Feb-94	Mar-94	1	0						1.6	0				
Nutrients	Nitrogen, mixed forms (NH3), (NH4), organic, (NO2) and (NO3)	No	Dis.	mg/l	-	11	11	10	0.125	3.25	0.99	1.09	0.925	0.99	0.99		Feb-94	Mar-94													
Nutrients	Organic nitrogen	No	Dis.	mg/l	-	9	9	8	0.03	0.1	0.085	0.075	0.0266	0.03	0.03		Feb-94	Mar-94													
Nutrients	Phosphate as P	No	Dis.	mg/l	-	11	11	6	0.005	0.04	0.005	0.0155	0.0146	0.03	0.028	0.013	Feb-94	Mar-94													
Organic	Surfactants -- CWA 304B	No	Tot.	mg/l	-	11	11	9	0.01	0.07	0.01	0.0164	0.018	0.045	0.045	0.0354	Feb-94	Mar-94													
Organics, other	Phenols and phenolic compounds	No	Tot.	ug/l	-	10	10	6	0.5	4	0.5	1.3	1.27	2.5	2.5	1.29	Mar-94	Mar-94													
Organics, pesticide	Bromacil	No	Dis.	ug/l	-	10	10	9	0.02	0.33	0.02	0.051	0.098	0.33	0.33		Feb-94	Mar-94												2444.2	0
Organics, pesticide	Diazinon	No	Dis.	ug/l	-	11	11	9	0.001	0.015	0.001	0.00327	0.0051	0.0135	0.0135	0.00212	Feb-94	Mar-94								7.9	0			22	0
Radioactive, metal	Thorium - NURE	No	Dis.	ug/l	-	127	127	84	2.5	22	2.5	4.73	3.8	8	9.09	3.71	Feb-78	May-78													
SVOCs	p,p'-DDE	No	Dis.	ug/l	-	11	11	10	0.001	0.003	0.003	0.00282	0.000603	0.001	0.001		Feb-94	Mar-94						0.2	0			2.684	0		
VOCs	Benzene	No	Tot.	ug/l	M	11	11	10	0.1	0.4	0.1	0.127	0.0905	0.4	0.4		Feb-94	Mar-94	5	0				0.39	1	29	0				

M = Measured, as defined in EPA QAPP for Wise and Denton Counties Retrospective Case Study (EPA, 2012b).
CA = Critical Analyte, as defined in EPA QAPP for Wise and Denton Counties Retrospective Case Study (EPA, 2012b).
A red highlight indicates the value was above a screening criteria. All non EPA parameters (non CA and non M) summary results along with the entire results are presented in Appendix B and are retained in the database.
Note: Sodium does not have an MCL; the value listed in the MCL column represents the EPA Health Advisory Level.
N = number of samples
ND = non-detect
SD = Standard Deviation

3.2.2.3 Depth Comparison. Groundwater quality data for 10 constituents (calcium, chloride, magnesium, manganese, alkalinity [as $CaCO_3$], fluoride, sodium, sulfate, iron and TDS) were plotted against the well depth and visually observed for trends (Figure 3-10). These constituents were chosen primarily because they are commonly reported water quality parameters that can be indicative of water quality impacts, including those associated with brines. These parameters are also expected to be present in future groundwater quality data collected as part of the EPA case study or provided with data collected by operators. Well depths included in the database ranged from 10 to 2,420 feet. All but 89 records (21,500 total records) included information on the well depth.

The analysis indicated that concentration is significantly associated with well depth for alkalinity, calcium, chloride, fluoride, magnesium, sodium and TDS. The concentrations of calcium, chloride and magnesium are estimated to decrease with increasing well depth. Concentrations of alkalinity, fluoride, sodium (dissolved and total fractions) and TDS are estimated to increase with increasing well depth. A complete description of the statistical depth comparison is provided in Appendix C.

3.2.3 Coverage of EPA QAPP Analytes. Parameters identified by EPA for the Wise and Denton Counties Retrospective Case Study were identified in the EPA QAPP for the study (EPA, 2012b). Of the parameters identified in the QAPP, 188 are designated as either CA (81) or M parameters (107). Tables 3-3 and 3-4 summarize the publically available groundwater quality data for the EPA parameters (13 CA and 28 M parameters) used for analysis. Table 3-5 shows 30 parameters (7 CA and 23 M) for which the number of locations having results was >8 and all results were non-detect. Table 3-5 also summarizes 117 EPA parameters for which no groundwater quality data are available (61 CA and 56 M). Therefore, no water quality characterization is available for comparison should any of these 117 parameters be detected in future sampling efforts.

3.3 Surface Water Quality

This section summarizes the characteristics of surface water resources in the vicinity of Wise and Denton Counties. An analysis is also provided of available surface water quality data in comparison screening criteria.

3.3.1 Watershed Characteristics. Wise and Denton Counties are located within the Trinity River Basin, which has a total drainage of 17,969 square miles. Figure 3-11 shows the location of named streams and rivers within Wise and Denton Counties. The Trinity River is composed of four forks that drain a large portion of north central Texas and then combine into a south-southeast flow into Eagle Mountain Lake in Tarrant County. Table 3-6 summarizes the HUC 8 subbasins crossing Wise and Denton Counties; these are shown graphically in Figure 3-11. The western portion of Wise County is located in the Upper West Fork Trinity HUC 8 subbasin with a total size of 1,970 square miles. The eastern portion of Wise County, as well as the southwestern portion of Denton County, is located in the Denton HUC 8 subbasin with a total size of 1,840 square miles. The remaining portion of Denton County is located in the Elm Fork Trinity HUC 8 subbasin with a total size of 727 square miles.

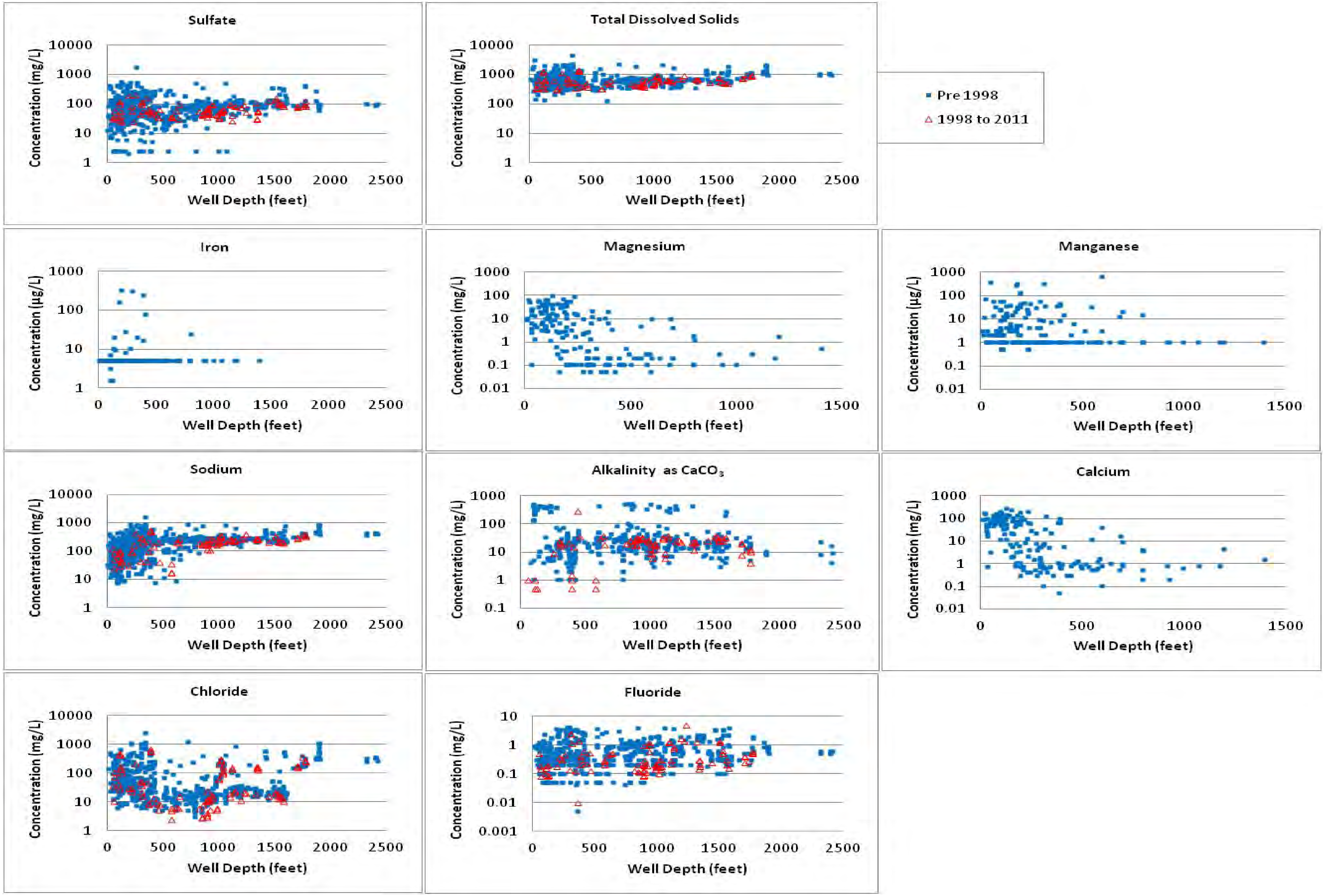


Figure 3-10. Data Plots Showing Dissolved Concentration vs. Depth for Selected Groundwater Quality Constituents

Table 3-5. List of EPA Parameters Not Included in Wise and Denton Counties Groundwater Quality Characterization

Parameter - Measured		Parameter - Critical Analyte	
NOT FOUND			
Inorganic carbon	2.3.5.6-Tetrachlorophenol	Butane	Dibenz[a,h]anthracene
Iron, ion (Fe2+)	adamantane	Ethane	Dibenzofuran
Redox Potential	Aniline	Methane	Dibutyl phthalate
Sulfide	Azobenzene	Propane	Diethyl phthalate
Turbidity	Benzoic acid	2,4,5-Trichlorophenol	Dimethyl phthalate
Diethylene glycol monobutyl ether acetate	bis(2-ethylhexyl) adipate	2,4,6-Trichlorophenol	Fluoranthene
Tetraethylene glycol	Cyclohexene, 1-methyl-4-(1-methylethenyl)-, (4R)-	2,4-Dichlorophenol	Fluorene
Triethylene glycol	Diphenylamine	2,4-Dimethylphenol	Hexachloroethane
d2H	Hexachlorobenzene	2,4-Dinitrotoluene	Indeno[1,2,3-cd]pyrene
d87/86Sr	Hexachlorocyclopentadiene	2,6-Dinitrotoluene	Isophorone
Oxygen-18/Oxygen-16 ratio	m-Dinitrobenzene	2-Chloronaphthalene	m-Cresol
Acetate	N-Nitrosodimethylamine	2-Methylnaphthalene	m-Nitroaniline
Butyric acid	p-Nitrophenol	3,3'-Dichlorobenzidine	N-Nitrosodi-n-propylamine
Formate	Phenol	4-methylphenol	Nitrobenzene
Isobutyrate	Pyridine	Acenaphthene	o-Chlorophenol
Lactic acid	Squalene	Acenaphthylene	o-Cresol
Propionic acid	Terpineol	Anthracene	o-Nitroaniline
Cerium	tri(2-butoxethyl)phosphate	Benz[a]anthracene	o-Nitrophenol
Mercury	1,2,3-Trimethylbenzene	Benzo(b)fluoranthene	p-Bromophenyl phenyl ether
Sulfur	Acetone	Benzo[a]pyrene	p-Chloro-m-cresol
Thallium	Carbon disulfide	Benzo[ghi]perylene	p-Chloroaniline
1,2-dinitrobenzene	Ethanol	Benzo[k]fluoranthene	p-Chlorophenyl phenyl ether
1,3-dimethyl adamantane	Ethyl tert-butyl ether	Benzyl alcohol	p-Nitroaniline
1,4-dinitrobenzene	Isopropyl ether	Bis(2-chloroethoxy)methane	Pentachlorophenol
1-Methylnaphthalene	m-Xylene	Bis(2-chloroethyl) ether	Phenanthrene
2,3,4,6-Tetrachlorophenol	o-Xylene	Bis(2-chloroisopropyl) ether	Pyrene
2,4-Dinitrophenol	p-Xylene	Butyl benzyl phthalate	Diesel range organics
2-butoxyethanol	tert-Amyl methyl ether	Carbazole	Gasoline range organics
		Chrysene	Isopropyl alcohol
		Di(2-ethylhexyl) phthalate	tert-Butanol
		Di-n-octyl phthalate	
N>8, ALL ND			
Antimony	*cis*-1,2-Dichloroethylene	1,2,4-Trichlorobenzene	Naphthalene
Cadmium	Cumene	4,6-Dinitro-o-cresol	o-Dichlorobenzene
1,1,1-Trichloroethane	Ethylbenzene	Hexachlorobutadiene	p-Dichlorobenzene
1,1,2-Trichloroethane	Methyl tert-butyl ether	m-Dichlorobenzene	
1,1-Dichloroethane	Methylene chloride		
1,1-Dichloroethylene	Tetrachloroethylene		
1,2,4-Trimethylbenzene	Toluene		
1,2-Dichloroethane	*trans*-1,2-Dichloroethylene		
1,3,5-Trimethylbenzene	Trichloroethylene		
Carbon tetrachloride	Vinyl chloride		
Chlorobenzene	Xylene		
Chloroform			

Table 3-6. Definitions of HUCs for Wise and Denton Counties, TX

HUC Code	Definition	Size, square miles*	Location
12030101	Subbasin (HUC 8)	1,970	Upper West Fork Trinity
12030103	Subbasin (HUC 8)	1,840	Elm Fork Trinity
12030104	Subbasin (HUC 8)	727	Denton

* USGS, 1994 (total subbasin area, not just the area within Wise and Denton Counties)

As part of its authority under the CWA, every two years the TCEQ reviews water quality conditions in order to evaluate the nature and extent of water pollution across the state and provides the information to the EPA's Watershed Quality Assessment Report (EPA, 2012f). The most current information gathered is reported in the *2010 Texas Integrated Report* (TCEQ, 2010b). Under the CWA, TCEQ identifies streams that are impaired for their intended beneficial use and describes the sources of the impairment (e.g., the COCs) and the potential causes of the impairment (e.g., the activities that led to the contaminant loading to the surface water).

Figure 3-11 shows the location of streams and rivers within Wise and Denton Counties that have been on the 303(d) list due to known surface water quality impairments between 1998 and 2010. Figure 3-11 was generated using information available from the Watershed Quality Assessment Report (EPA, 2012f). There were no impairment data available within Wise and Denton Counties prior to 1998 in the Watershed Quality Assessment Report (EPA, 2012f). However, TCEQ had impairment data for the years 1992, 1994 and 1996 (TCEQ, 2010c). In 1992, West Fork Trinity above Bridgeport Reservoir had depressed dissolved oxygen and bacterial impairment. In the same year, West Fork Trinity below Bridgeport Reservoir had bacterial impairment. There were no impairments in the year 1994 for the two counties. In 1996, Elm Fork Trinity below Lewisville Lake was impaired with depressed dissolved oxygen, bacteria and elevated concentrations of lead and zinc.

According to data from the Watershed Quality Assessment Report for the period 1998-2010 (as shown in Figure 3-11), there have been over 96 miles of impaired streams and rivers in Wise County, representing approximately 7% of the total stream length in the county. There have been over 22 miles of impaired streams and rivers in Denton County, representing approximately 2% of the total stream length in the county. Table 3-7 presents the several impaired waterways in Wise and Denton Counties between 1998 and 2010 (EPA, 2012f). The West Fork Trinity River (below Bridgeport Reservoir) includes the Big Sandy Creek, Garrett Creek, Salt Creek and Martin Branch and has shown impairments caused by bacteria from 1998 up through 2010. The creeks feed into the West Fork Trinity River, which then runs south-southwest through an urban area in the center of Wise County.

Impairments of TDS, chloride and dissolved oxygen have also been recorded for the West Fork Trinity below the Bridgeport Reservoir from 1998-2010. The portion of the West Fork Trinity above the Bridgeport Reservoir in west central Wise County, a relatively large stream in an urban area, has shown impairments in TDS, dissolved oxygen and chloride from 1998-2010. The probable source of contamination is unknown or a nonpoint source for the waterway.

In the southeast corner of Denton County, the Elm Fork Trinity River was impaired by bacteria in 2006 and 2008. Flowing from the northeast corner of Denton County, Little Elm Creek showed impairments by bacteria from 2002-2006. The Little Elm Creek and Elm Fork Trinity River also have unknown or nonpoint sources of contamination. Table 3-7 shows the COCs that have caused these surface water impairments in Wise and Denton Counties due to bacteria, chloride, TDS and dissolved oxygen (EPA, 2012f).

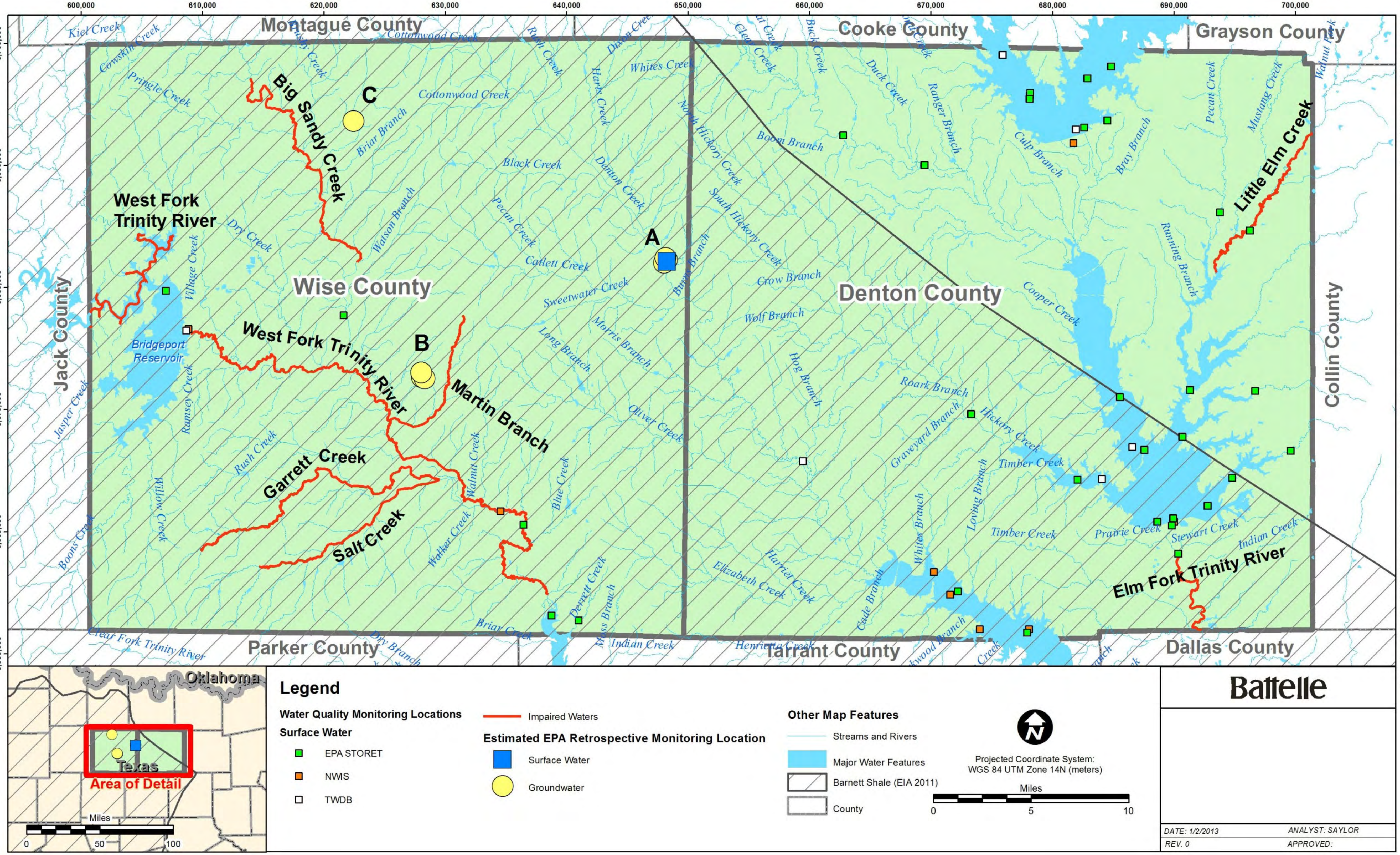


Figure 3-11. Surface Water Monitoring Locations and Impairments in Wise and Denton Counties, TX

Table 3-7. Sources of Impairment to Surface Water within Wise County (1998-2010)

Year	Water body Name	Water body Location	Mileage	Causes of Impairment
West Fork Trinity River Below Bridgeport Reservoir Lower 25 Miles Of Segment-Wise County				
2010	Big Sandy Creek (Unclassified Water Body)	Fifteen Mile Stretch Of Big Sandy Creek Running From Confluence With Waggoner Creek To Fm 1810 West Of Alvord, Wise Co.	6.84	Bacteria
2010	Garrett Creek (Unclassified Water Body)	Eighteen Mile Stretch Of Garrett Creek Running Upstream From Confluence With Salt Creek To Wise County Road Approximately 14 Miles Upstream Of Sh114, Wise Co.	23.85	Bacteria
2010	Martin Branch (Unclassified Water Body)	Eight Mile Stretch Of Martin Branch Running Upstream From Confluence With Center Creek To Fm 730 South Of Decatur, Wise County.	9.76	Bacteria
2010	Salt Creek (Unclassified Water Body)	Eleven Mile Stretch Of Salt Creek Running Upstream From Confluence With Garrett Creek, Wise County.	20.28	Bacteria
2010	West Fork Trinity River Below Bridgeport Reservoir	Lower 25 Miles Of Segment	25.69	Bacteria
2008	Big Sandy Creek (Unclassified Water Body)	Fifteen Mile Stretch Of Big Sandy Creek Running From Confluence With Waggoner Creek To Fm 1810 West Of Alvord, Wise Co.	15	Bacteria
2008	Garrett Creek (Unclassified Water Body)	Eighteen Mile Stretch Of Garrett Creek Running Upstream From Confluence With Salt Creek To Wise County Road Approximately 14 Miles Upstream Of Sh114, Wise Co.	18	Bacteria
2008	Martin Branch (Unclassified Water Body)	Eight Mile Stretch Of Martin Branch Running Upstream From Confluence With Center Creek To Fm 730 South Of Decatur, Wise County.	8	Bacteria
2008	Salt Creek (Unclassified Water Body)	Eleven Mile Stretch Of Salt Creek Running Upstream From Confluence With Garrett Creek, Wise County.	11	Bacteria
2008	West Fork Trinity River Below Bridgeport Reservoir	Lower 25 Miles Of Segment	25	Bacteria
2006	Big Sandy Creek (Unclassified Water Body)	Fifteen Mile Stretch Of Big Sandy Creek Running From Confluence With Waggoner Creek To Fm 1810 West Of Alvord, Wise Co.	15	Bacteria
2006	Garrett Creek (Unclassified Water Body)	Eighteen Mile Stretch Of Garrett Creek Running Upstream From Confluence With Salt Creek To Wise County Road Approximately 14 Miles Upstream Of Sh114, Wise Co.	18	Bacteria
2006	Martin Branch (Unclassified Water Body)	Eight Mile Stretch Of Martin Branch Running Upstream From Confluence With Center Creek To Fm 730 South Of Decatur, Wise County.	8	Bacteria
2006	Salt Creek (Unclassified Water Body)	Eleven Mile Stretch Of Salt Creek Running Upstream From Confluence With Garrett Creek, Wise County.	11	Bacteria
2006	West Fork Trinity River Below Bridgeport Reservoir	Lower 25 Miles Of Segment	25	Bacteria
2004	West Fork Trinity River Below Bridgeport Reservoir	From A Point 0.6 Km (0.4 Miles) Downstream Of The Confluence Of Oates Branch In Wise County To Bridgeport Dam In Wise County	36	Bacteria
2002	West Fork Trinity River Below Bridgeport Reservoir		36	Bacteria
2000	West Fork Trinity River Below Bridgeport Reservoir		36	Bacteria
1998	West Fork Trinity River Below Bridgeport Reservoir		36	Pathogens
West Fork Trinity River Above Bridgeport Reservoir Lower 25 Miles Of Segment-Wise County				
2010	West Fork Trinity River Above Bridgeport Reservoir	Lower 25 Miles Of Segment	49.61	DO; Chloride
2008	West Fork Trinity River Above Bridgeport Reservoir	Lower 25 Miles Of Segment	25	TDS; Chloride; DO
2006	West Fork Trinity River Above Bridgeport Reservoir	Lower 25 Miles Of Segment	25	TDS; Chloride; DO
2006	West Fork Trinity River Above Bridgeport Reservoir	Upper 60 Miles Of Segment	60	TDS; Chloride
2004	West Fork Trinity River Above Bridgeport Reservoir	From A Point Immediately Upstream Of The Confluence Of Bear Hollow In Jack County To State Route 79 In Archer County	85	TDS; Chloride; DO
2002	West Fork Trinity River Above Bridgeport Reservoir		85	TDS; Chloride; DO
2000	West Fork Trinity River Above Bridgeport Reservoir		85	TDS; Chloride; DO
1998	West Fork Trinity River Above Bridgeport Reservoir		85	TDS; Chloride; DO
West Fork Trinity River Above Bridgeport Reservoir Upper 60 Miles Of Segment-Wise County				
2010	West Fork Trinity River Above Bridgeport Reservoir	Upper 60 Miles Of Segment	49.22	Chloride
2008	West Fork Trinity River Above Bridgeport Reservoir	Upper 60 Miles Of Segment	60	TDS; Chloride
2006	West Fork Trinity River Above Bridgeport Reservoir	Lower 25 Miles Of Segment	25	TDS; Chloride; DO
2006	West Fork Trinity River Above Bridgeport Reservoir	Upper 60 Miles Of Segment	60	TDS; Chloride
2004	West Fork Trinity River Above Bridgeport Reservoir	From A Point Immediately Upstream Of The Confluence Of Bear Hollow In Jack County To Sh 79 In Archer County	85	TDS; Chloride; DO
2002	West Fork Trinity River Above Bridgeport Reservoir		85	TDS; Chloride; DO
2000	West Fork Trinity River Above Bridgeport Reservoir		85	TDS; Chloride; DO
1998	West Fork Trinity River Above Bridgeport Reservoir		85	TDS; Chloride; Organic Enrichment/LowDO
Little Elm Creek-Denton County				
2006	Little Elm Creek (Unclassified Water Body)	From The Confluence With Lake Lewisville In Denton Co., Up To Fm 455 In Collin Co. (Lower 12 Miles Of Segment).	27	Bacteria
2004	Little Elm Creek (Unclassified Water Body)	Perennial Stream From Fm 455 In Collin County Up To 1.4 Km Above Fm 121 In Grayson County Near Gunter	27	Bacteria
2002	Little Elm Creek (Unclassified Water Body)	Perennial Stream From Fm 455 In Collin County Up To 1.4 Km Above Fm 121 In Grayson County Near Gunter	27	Bacteria
Elm Fork Trinity River-Denton County				
2008	Elm Fork Trinity River Below Lewisville Lake	4.5 Miles Upstream To 7.5 Miles Downstream Intake	12	Bacteria
2006	Elm Fork Trinity River Below Lewisville Lake	4.5 Miles Upstream To 7.5 Miles Downstream Intake	12	Bacteria

Table 3-8 provides the causes of these impairments as determined by EPA (EPA, 2012f), which is listed for the various waterways in the state of Texas such as rivers and streams; lakes, reservoirs, and ponds; bays and estuaries, coastal shoreline and ocean and near coastal areas. This information was not available at the Wise and Denton County level, so is discussed here at the state level. As indicated, the causes for identified impairments in surface waters in Texas are largely unknown. The impairments with largest miles are unknown and nonpoint sources.

Table 3-8. Causes of Impairments in the Watersheds in Texas (2010)

	Size of Impairment	
Probable Cause	**Rivers and Streams (miles)**	**Lakes, Reservoirs, and Ponds (Acres)**
Agriculture	2,456.5	16,866.6
Aquaculture	49	
Atmospheric Deposition	318.7	338,869.3
Construction	30.2	2,433.7
Habitat Alterations (Other Than Hydromodification)	10.4	
Hydromodification	452.1	232.8
Industrial	441.3	3,510.4
Land Application/ Waste Sites/ Tanks	18.6	
Legacy/ Historical Pollutants		1,385.3
Military Bases		2,433.7
Municipal Discharges/ Sewage	2,730.2	38,138.3
Natural/ Wildlife	2,414.2	127,609.6
Other	1,569.5	26,666.0
Recreation And Tourism (Non-Boating)	12.7	
Resource Extraction	253.5	7,115.3
Spills/Dumping	68.5	
Unknown	5,473.9	510,566.7
Unspecified Nonpoint Source	5,960.9	98,377.7
Urban-Related Runoff/Stormwater	1,543.0	4,174.7

(EPA, 2012f)

3.3.2 Data Summary. Surface water quality data (from the sources identified in Section 2.0) were compiled into a database to characterize the condition of surface water resources within Wise and Denton Counties. Figure 3-11 shows the location of the 67 surface water quality monitoring locations represented in the database. The dates of the sampling events (temporal boundary) range from 1961 to 1998. The parameters monitored for surface water quality include general water quality parameters, major ions, metals, radio nuclides and organics including VOCs and SVOCs.

Summary data tables are provided with a list of detected parameters, number of samples, minimum, maximum, median, mean, standard deviation, date range for sample collection and comparison against screening criteria. Table 3-9 provides a summary of baseline water quality parameters in surface water prior to 1998 for the comprehensive data set. Surface water quality parameters were compared to EPA MCLs and SMCLs as well as CWA freshwater surface water quality criteria (chronic). Several Texas-specific screening criteria were also used to assess the surface water quality. Texas human health RBEL values for surface water and fish (Texas human health surface water RBEL) as well as aquatic life surface water RBELs (chronic) were used.

Table 3-9. Surface Water Critical and Measured Analytes Summary in Wise and Denton Counties, TX

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)	TX SW Human	N Above TX SW Human (no NDs)	TX SW Aquatic	N Above TX SW Aquatic (no NDs)
Dissolved Gas	Carbon dioxide	No	Tot.	mg/l	-	1102	22	0	0.1	110	6	7.15	4.6	6	7.15	4.6	Oct-61	Dec-97											
Gen WQ	Alkalinity as CaCO3	No	Dis.	mg/l	M	77	9	0	46	282	110	127	41.9	110	127	41.9	Mar-96	Dec-97						20	0				
Gen WQ	Alkalinity as CaCO3	No	Tot.	mg/l	M	643	25	0	12	448	133	147	45.4	133	147	45.4	Jan-75	Dec-97						20	2				
Gen WQ	Alkalinity as CaCO3	Yes	Dis.	mg/l	M	439	13	0	46	450	113	139	45.3	113	139	45.3	Oct-89	Dec-97						20	0				
Gen WQ	Alkalinity as CaCO3	Yes	Tot.	mg/l	M	639	21	0	46	443	118	131	34.8	118	131	34.8	Oct-65	Mar-90						20	0				
Gen WQ	Carbonate (CO3)	Yes	Tot.	mg/l	-	21	9	0	2	33	3	4.11	3.29	3	4.11	3.29	Dec-69	Aug-80											
Gen WQ	Hardness as CaCO3	No	Tot.	mg/l	-	1160	30	0	38	540	137	164	59.5	137	164	59.5	Oct-61	Dec-97											
Gen WQ	Hardness, non-carbonate as CaCO3	Yes	Dis.	mg/l	-	360	13	0	1	159	11.6	22.8	19.3	11.6	22.8	19.3	Oct-89	Dec-97											
Gen WQ	Hardness, non-carbonate as CaCO3	Yes	Tot.	mg/l	-	357	19	0	1	180	20	27.3	18.3	20	27.3	18.3	Nov-61	Mar-83											
Gen WQ	Organic carbon	No	Dis.	mg/l	M	108	10	0	0.5	18	6.32	7.06	4.55	6.32	7.06	4.55	May-81	Aug-95											
Gen WQ	Organic carbon	No	Tot.	mg/l	M	618	17	0	0.2	33	6.68	7.19	3.02	6.68	7.19	3.02	Mar-74	Dec-97											
Gen WQ	Oxygen	No	Dis.	mg/l	M	6223	66	0	0.1	16.6	7.55	7.61	1.01	7.55	7.61	1.01	Sep-68	Dec-97											
Gen WQ	pH	No	Tot.	std units	M	3538	57	0	2.6	9.2	7.97	7.94	0.197	7.97	7.94	0.197	Sep-68	Dec-97			6.5	8.5	160						
Gen WQ	pH	Yes	Tot.	std units	M	4031	29	0	5.5	9.2	7.86	7.82	0.18	7.86	7.82	0.18	Oct-61	Dec-97			6.5	8.5	130						
Gen WQ	Specific conductance	No	Tot.	umho/cm	M	3556	57	0	3	11180	362	492	504	362	492	504	Sep-68	Dec-97											
Gen WQ	Specific conductance	Yes	Tot.	umho/cm	M	4055	29	0	30	1450	350	395	118	350	395	118	Oct-61	Dec-97											
Gen WQ	Temperature, water	No	Tot.	deg C	M	4692	52	0	1	38	18.8	18.9	1.9	18.8	18.9	1.9	Oct-65	Dec-97											
Gen WQ	Total dissolved solids	No	Dis.	mg/l	M	1266	36	2	68	9000	221	507	1460	221	507	1460	Oct-61	Dec-97				500	96						
Gen WQ	Total suspended solids	No	Non-filterable	mg/l	-	393	12	5	0.5	1350	39.5	54.8	43.3	40.5	55.8	44.3	Oct-73	Dec-97											
Gen WQ	Total suspended solids	No	Suspended	mg/l	-	472	22	5	0.5	1350	30.2	48.3	45.6	30.2	49.4	46.4	Apr-72	Dec-97											
Gen WQ	Turbidity	No	-	JTU	M	189	9	3	0.5	840	22	55.4	55.2	22	56.3	54.8	Sep-68	Aug-87											
Gen WQ	Turbidity	No	Tot.	NTU	M	295	10	0	0.9	810	29.3	40.4	35.4	29.3	40.4	35.4	Nov-78	Dec-97											
Inorganics, Major, Non-metals	Carbon	No	Tot.	mg/l	-	119	11	0	1.1	34.6	5	6.27	2.88	5	6.27	2.88	May-74	Jul-97											
Inorganics, Major, Non-metals	Silica	No	-	mg/l	-	455	12	0	0.1	42	7.79	7.29	2.99	7.79	7.29	2.99	Nov-81	Jul-97											
Inorganics, Major, Non-metals	Silica	No	Dis.	mg/l	-	1217	32	0	0.1	42	4.58	6.21	3.18	4.58	6.21	3.18	Oct-61	Dec-97											
Major Anions	Chloride	No	Dis.	mg/l	CA	1998	50	0	1.8	268	24.4	32.8	19.1	24.4	32.8	19.1	Oct-61	Dec-97				250	1	230	3			230	3
Major Anions	Fluoride	No	Dis.	mg/l	M	1407	36	7	0.05	8.2	0.267	0.36	0.507	0.267	0.361	0.507	Oct-61	Dec-97	4	1		2	3			4	1		
Major Anions	Sulfate	No	Dis.	mg/l	CA	1909	50	0	2	6500	33.6	81.8	298	33.6	81.8	298	Oct-61	Dec-97				250	20						
Major Cations	Calcium	No	Dis.	mg/l	CA	1675	38	0	8.8	169	44.6	51.7	14.9	44.6	51.7	14.9	Oct-61	Dec-97											
Major Cations	Magnesium	No	Dis.	mg/l	CA	1675	38	0	1.2	41	4.38	6.81	4.51	4.38	6.81	4.51	Oct-61	Dec-97											
Major Cations	Potassium	No	-	mg/l	CA	457	12	0	1.4	12	4.44	4.47	0.971	4.44	4.47	0.971	Oct-81	Jul-97											
Major Cations	Potassium	No	Dis.	mg/l	CA	1106	32	2	0.05	9.7	4.36	4.24	0.662	4.36	4.25	0.662	Jun-62	Dec-97											
Major Cations	Sodium	No	Dis.	mg/l	CA	1619	38	0	3.1	3310	23.5	65.4	223	23.5	65.4	223	Oct-61	Dec-97	20	875									
Metals	Arsenic	No	Dis.	ug/l	CA	299	14	6	0.5	11	1.88	1.85	0.718	2.03	2.02	0.667	Oct-73	Dec-97	10	2				150	0	10	2	150	0
Metals	Barium	No	Dis.	ug/l	CA	318	14	2	19	300	76.3	71.6	22.8	76.3	72.5	24	Oct-76	Dec-97	2000	0						2000	0	16000	0
Metals	Cadmium	No	Dis.	ug/l	M	180	12	10	0.5	100	2.06	2.4	1.5	2.25	8.12	11.3	May-74	Dec-97	5	4				0.25	27	5	4	0.15	27
Metals	Chromium	No	Dis.	ug/l	M	175	15	10	0.5	20	3.35	5.45	3.91	3.5	5.89	5.04	May-74	Dec-97	100	0								42	0
Metals	Copper	No	Dis.	ug/l	M	151	11	9	0.5	170	4.86	5.03	1.4	4.5	5.82	3.88	May-74	Dec-97	1300	0		1000	0			1300	0	5.24	11
Metals	Iron	No	Dis.	ug/l	M	1693	39	28	1.5	4000	52.3	73.5	79.5	59.8	97.7	99.8	Jun-73	Dec-97				300	103	1000	40	300	103	1000	40
Metals	Lead	No	Dis.	ug/l	M	154	12	10	0.5	50	13.4	20.3	18.2	5.5	7.4	5.93	May-77	Dec-97	15	2				2.5	12	1.15	12	1.17	12
Metals	Lithium	No	Dis.	ug/l	-	155	11	6	2	99	8	9.82	8.45	8.7	11	8.33	Oct-73	Dec-97											
Metals	Manganese	No	Dis.	ug/l	M	1649	39	26	0.5	3200	59.7	111	112	81.4	138	136	Jun-73	Dec-97				50	406			50	406	120	285
Metals	Nickel	No	Dis.	ug/l	M	87	10	8	3	40	5.6	12.2	11.5	10	13.8	12.9	Oct-89	Dec-97						52	0	332	0	28.93	1
Metals	Phosphorus	No	-	ug/l	M	665	28	1	5	6000	79.5	178	279	79.5	178	279	Apr-72	Dec-97											
Metals	Phosphorus	No	Dis.	ug/l	M	508	26	23	5	770	23.9	41.5	40.2	47.8	60.8	39.5	Feb-86	Dec-97											
Metals	Phosphorus	No	Tot.	ug/l	M	1356	25	12	5	5100	71.7	136	155	79.6	140	155	Dec-69	Dec-97											
Metals	Selenium	No	Dis.	ug/l	CA	172	12	10	0.5	21	0.5	2.31	5.89	1.08	5.07	8.91	Oct-76	Dec-97	50	0				5	1	50	0	5	1
Metals	Silver	No	Dis.	ug/l	M	158	11	10	0.5	7	0.758	0.975	0.545	1.71	2.05	1.04	Mar-78	Dec-97				100	0					0.8	24
Metals	Zinc	No	Dis.	ug/l	M	176	10	9	1.5	190	12.6	14.1	5.52	16.1	17.9	6.34	Oct-73	Dec-97				5000	0	120	3	7400	0	65.66	7

Table 3-9. Surface Water Critical and Measured Analytes Summary in Wise and Denton Counties, TX (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)	TX SW Human	N Above TX SW Human (no NDs)	TX SW Aquatic	N Above TX SW Aquatic (no NDs)
Nutrients	Ammonia	No	-	mg/l	-	143	13	0	0.01	5.81	0.1	0.246	0.454	0.1	0.246	0.454	Aug-72	Jul-97											
Nutrients	Ammonia-nitrogen as N	No	Dis.	mg/l	M	2013	38	26	0.005	6.3	0.0994	0.116	0.0716	0.126	0.126	0.0697	Dec-69	Dec-97											
Nutrients	Inorganic nitrogen (nitrate and nitrite)	No	-	mg/l	-	452	13	0	0.05	9.8	0.519	0.735	0.55	0.519	0.735	0.55	Nov-81	Jul-97											
Nutrients	Kjeldahl nitrogen	No	Dis.	mg/l as N	-	521	26	11	0.1	3	0.379	0.405	0.163	0.4	0.422	0.16	Jan-81	Dec-97											
Nutrients	Kjeldahl nitrogen	No	Tot.	mg/l as N	-	1140	21	5	0.1	10	0.878	1.03	0.459	0.878	1.05	0.46	Mar-74	Dec-97											
Nutrients	Nitrate as N	No	Dis.	mg/l	CA	1245	26	20	0.005	9.45	0.258	0.371	0.324	0.361	0.439	0.33	Oct-61	Dec-97	10	0						10	0		
Nutrients	Nitrite	No	Dis.	mg/l	-	811	37	13	0.01	6.02	0.0496	0.147	0.429	0.0677	0.162	0.439	Jul-80	Dec-97											
Nutrients	Nitrite as N	No	Dis.	mg/l	CA	1247	29	28	0.005	0.53	0.0194	0.0236	0.0163	0.0268	0.031	0.0164	Dec-69	Dec-97	1	0									
Nutrients	Nitrogen	No	Dis.	mg/l	-	290	11	0	0.2	4.7	0.452	0.814	1.17	0.452	0.814	1.17	Jun-85	Jul-97											
Nutrients	Nitrogen	No	Tot.	mg/l	-	1473	38	19	0.1	13	1.03	1.34	0.866	1.19	1.46	0.904	Dec-72	Dec-97											
Nutrients	Nitrogen, mixed forms (NH3), (NH4), organic, (NO2) and (NO3)	No	Dis.	mg/l	-	400	15	10	0.1	8.5	0.597	0.822	0.615	0.72	0.922	0.607	Jun-85	Dec-97											
Nutrients	Organic nitrogen	No	Dis.	mg/l	-	400	15	11	0.075	2.9	0.291	0.332	0.163	0.311	0.38	0.153	Jun-85	Dec-97											
Nutrients	Organic nitrogen	No	Tot.	mg/l	-	894	19	14	0.06	9.7	0.71	0.825	0.449	0.738	0.863	0.44	Oct-72	Dec-97											
Nutrients	Orthophosphate	No	-	mg/l	-	439	24	0	0.006	18.36	0.0641	0.255	0.615	0.0641	0.255	0.615	Apr-72	Jul-97											
Nutrients	Phosphate as P	No	Dis.	mg/l	-	533	26	20	0.005	0.69	0.0199	0.0367	0.0307	0.039	0.0473	0.0284	Apr-85	Dec-97											
Nutrients	Phosphate as P	No	Tot.	mg/l	-	606	15	11	0.005	3.37	0.0817	0.191	0.237	0.147	0.212	0.228	May-79	Dec-92											
Physical	Total volatile solids	No	-	mg/l	-	364	16	0	1	192	8.04	11.2	9.1	8.04	11.2	9.1	Apr-72	Jul-97											
Physical	Volatile Suspended Solids	No	-	mg/l	-	37	8	1	0.5	50	9.2	11.4	6.62	9.53	11.7	6.36	Apr-72	Dec-97											
Radiochemical	Potassium-40	No	Dis.	pCi/L	-	27	9	0	2.3	4.6	3.6	3.59	0.352	3.6	3.59	0.352	Jan-81	Jul-81											

M = Measured, as defined in EPA QAPP for Wise and Denton Counties Retrospective Case Study (EPA, 2012b).
CA = Critical Analyte, as defined in EPA QAPP for Wise and Denton Counties Retrospective Case Study (EPA, 2012b).
A red highlight indicates the value was above a screening criteria. All non EPA parameters (non CA and non M) summary results along with the entire results are presented in Appendix B and are retained in the database.
Note: Sodium does not have an MCL; the value listed in the MCL column represents the EPA Health Advisory Level.N = number of samples
ND = non-detect
SD = Standard Deviation

Inorganic Summary. As indicated in Table 3-9, observed results were above one or more of the screening criteria for three general water quality parameters (TDS, alkalinity [total and dissolved] and pH) and four major anions (chloride, fluoride, sulfate and sodium). Chloride detections are higher than the SMCL, the CWA freshwater surface water quality criteria (chronic), and the Texas aquatic life surface water RBEL. Fluoride is higher than the MCL, SMCL, and the Texas human health surface water RBEL. Sulfate is higher than the SMCL, and sodium is higher than the EPA Health Advisory level of 20 mg/L.

Observed concentrations were above one or more of the screening criteria for several metals, including arsenic, cadmium, copper, iron, lead, manganese, nickel, selenium, silver and zinc. Arsenic is above the MCL and the Texas human health surface water RBEL. Cadmium and lead are above the MCL, the CWA freshwater surface water quality criteria (chronic), the Texas human health surface water RBEL, and the Texas aquatic life surface water RBEL. Copper and silver are above the Texas aquatic life surface water RBEL. Iron is above the SMCL, the CWA freshwater surface water quality criteria (chronic), the Texas human health surface water RBEL and the Texas aquatic life surface water RBEL. Manganese is above the SMCL and the Texas human health surface water RBEL and the Texas aquatic life surface water RBEL. Nickel is above the Texas aquatic life surface water RBEL. Selenium and zinc are above the CWA freshwater surface water quality criteria (chronic) and the Texas aquatic life surface water RBEL. Figure 3-12 shows the spatial distribution of inorganic chemicals detected above the screening criteria.

Organic Summary. No organic constituents in surface water were detected in eight or more sample locations.

3.3.2.1 Comparison Against Reduced Data Table. Table 3-10 provides a summary of pre-2005 surface water data in similar format to Table 3-9, with the exception of 32 locations that were removed (32 from STORET and two from TWDB) based on the reasoning provided in Table 2-3. This summary data table was created for comparison against the comprehensive background groundwater quality summary data table (Table 3-9) to determine whether the data identified as indicative of environmental impact monitoring or having location issues has a significant effect of background water quality.

Five parameters (cadmium, lead, nickel, selenium and silver) identified as being above screening criteria in Table 3-9, are not included in the reduced summary data table (Table 3-10). Twelve parameters (alkalinity, pH, TDS, chloride, fluoride, sodium, sulfate, arsenic, copper, iron, manganese and zinc) are above screening criteria in Table 3-9 and in the reduced summary data table (Table 3-10). The maximum detected values for alkalinity, pH, chloride, arsenic, copper, iron, manganese and zinc are identical in both summary datasets, whereas the maximum detected values for TDS, fluoride, sulfate and sodium are lower in the reduced dataset. The 12 parameters in both datasets above respective screening criteria are identical, with the exception of fluoride which is not above the MCL or Texas human health surface water RBEL in the reduced dataset. For alkalinity, pH, fluoride, arsenic and copper there is minimal or no difference between the two datasets when comparing the summary statistics. For TDS, sulfate and sodium, the mean and median values are lower in the reduced dataset, suggesting the removed data had higher chemical concentrations. For iron, manganese and zinc, the mean and median values are higher in the reduced dataset, suggesting the removed data had lower chemical concentrations

3.3.2.2 Temporal Comparison. The amount of data available to effectively analyze temporal trends is limited. Evaluations of temporal trends were attempted for the analytes that are considered CAs (chloride, sulfate, arsenic, boron and selenium) by EPA and were also detected above screening criteria. Trend analysis was conducted for TDS, an analyte that was responsible for designating an EPA-determined impairment in surface water within the study area. Plots were developed where data are available for the analyte in monitoring locations within the counties of interest and also within the footprint of the Barnett Shale. The analytes that fall into these categories are chloride, sulfate, TDS and arsenic. Plots were prepared for two locations in Denton County, Denton Creek near Justin, TX (USGS-

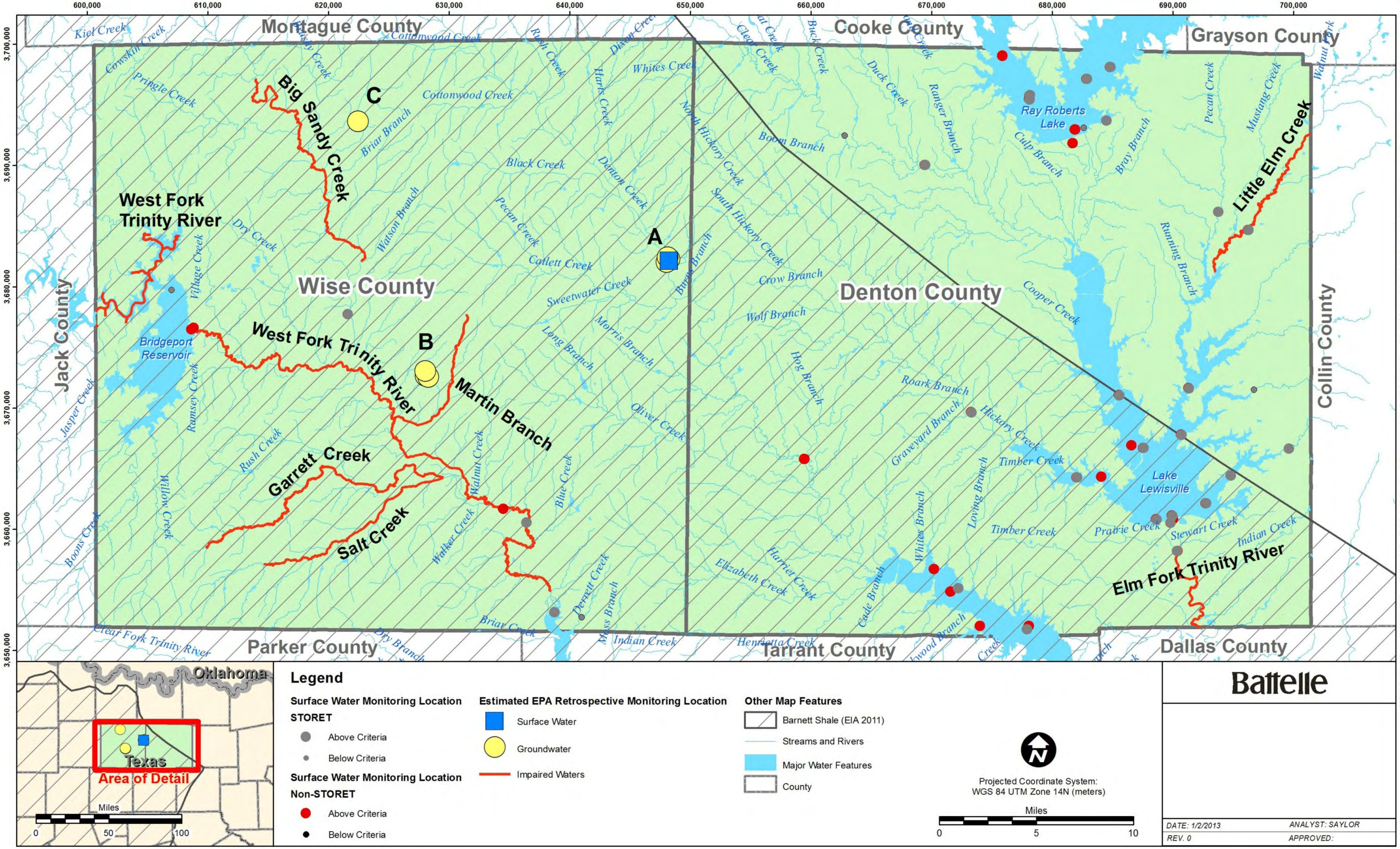


Figure 3-12. Surface Water Impairments and Detections above Regulatory Levels, Wise and Denton Counties, TX

Table 3-10. Surface Water Critical and Measured Analytes Summary (Revised Dataset) in Wise and Denton Counties, TX

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 AboveS MCL (no NDs)	CWA Chronic	N Above CWA Chronic (no NDs)	TX SW Human	N Above TX SW Human (no NDs)	TX SW Aquatic	N Above TX SW Aquatic (no NDs)
Dissolved Gas	Carbon dioxide	No	Tot.	mg/l	-	1102	22	0	0.1	110	6	7.15	4.6	6	7.15	4.6	Oct-61	Dec-97											
Gen WQ	Alkalinity as CaCO3	Yes	Dis.	mg/l	M	439	13	0	46	450	113	139	45.3	113	139	45.3	Oct-89	Dec-97						20	0				
Gen WQ	Alkalinity as CaCO3	Yes	Tot.	mg/l	M	639	21	0	46	443	118	131	34.8	118	131	34.8	Oct-65	Mar-90						20	0				
Gen WQ	Carbonate (CO3)	Yes	Tot.	mg/l	-	21	9	0	2	33	3	4.11	3.29	3	4.11	3.29	Dec-69	Aug-80											
Gen WQ	Hardness as CaCO3	No	Tot.	mg/l	-	1133	23	0	38	414	137	150	40.7	137	150	40.7	Oct-61	Dec-97											
Gen WQ	Hardness, non-carbonate as CaCO3	Yes	Dis.	mg/l	-	360	13	0	1	159	11.6	22.8	19.3	11.6	22.8	19.3	Oct-89	Dec-97											
Gen WQ	Hardness, non-carbonate as CaCO3	Yes	Tot.	mg/l	-	357	19	0	1	180	20	27.3	18.3	20	27.3	18.3	Nov-61	Mar-83											
Gen WQ	Organic carbon	No	Tot.	mg/l	M	309	9	0	1.8	33	6.68	7.12	2.54	6.68	7.12	2.54	Mar-74	Dec-97											
Gen WQ	Oxygen	No	Dis.	mg/l	M	3727	33	0	0.1	16.6	7.44	7.62	0.996	7.44	7.62	0.996	Dec-69	Dec-97											
Gen WQ	pH	No	Tot.	std units	M	931	24	0	2.6	9.2	7.98	7.97	0.191	7.98	7.97	0.191	Mar-72	Dec-97			6.5	8.5	32						
Gen WQ	pH	Yes	Tot.	std units	M	4031	29	0	5.5	9.2	7.86	7.82	0.18	7.86	7.82	0.18	Oct-61	Dec-97			6.5	8.5	130						
Gen WQ	Specific conductance	No	Tot.	umho/cm	M	932	24	0	140	1430	368	433	161	368	433	161	Mar-72	Dec-97											
Gen WQ	Specific conductance	Yes	Tot.	umho/cm	M	4055	29	0	30	1450	350	395	118	350	395	118	Oct-61	Dec-97											
Gen WQ	Temperature, water	No	Tot.	deg C	M	4268	34	0	1	38	18.7	18.7	2.08	18.7	18.7	2.08	Oct-65	Dec-97											
Gen WQ	Total dissolved solids	No	Dis.	mg/l	M	1125	23	2	68	877	206	243	76.3	206	243	76.1	Oct-61	Dec-97				500	77						
Gen WQ	Total suspended solids	No	Non-filterable	mg/l	-	393	12	5	0.5	1350	39.5	54.8	43.3	40.5	55.8	44.3	Oct-73	Dec-97											
Inorganics, Major, Non-metals	Silica	No	Dis.	mg/l	-	1157	26	0	0.1	42	4.9	6.47	3.09	4.9	6.47	3.09	Oct-61	Dec-97											
Major Anions	Chloride	No	Dis.	mg/l	CA	1176	28	0	1.8	268	24.4	30.7	16	24.4	30.7	16	Oct-61	Dec-97				250	1	230	3			230	3
Major Anions	Fluoride	No	Dis.	mg/l	M	899	24	7	0.05	2.3	0.266	0.269	0.0564	0.266	0.271	0.0556	Oct-61	Dec-97	4	0		2	1			4	0		
Major Anions	Sulfate	No	Dis.	mg/l	CA	1166	28	0	2	320	30.1	35.9	19.2	30.1	35.9	19.2	Oct-61	Dec-97				250	1						
Major Cations	Calcium	No	Dis.	mg/l	CA	1158	26	0	12	120	43.9	49.9	13.5	43.9	49.9	13.5	Oct-61	Dec-97											
Major Cations	Magnesium	No	Dis.	mg/l	CA	1158	26	0	1.2	40	4.35	6.48	4.18	4.35	6.48	4.18	Oct-61	Dec-97											
Major Cations	Potassium	No	Dis.	mg/l	CA	1046	26	2	0.05	9.7	4.31	4.23	0.566	4.32	4.24	0.567	Jun-62	Dec-97											
Major Cations	Sodium	No	Dis.	mg/l	CA	1102	26	0	4.3	274	21.8	27.6	14.7	21.8	27.6	14.7	Oct-61	Dec-97	20	566									
Metals	Arsenic	No	Dis.	ug/l	CA	177	8	6	0.5	11	1.58	1.69	0.8	2.03	1.97	0.759	Oct-73	Dec-97	10	1				150	0	10	1	150	0
Metals	Barium	No	Dis.	ug/l	CA	165	8	2	19	300	82.6	74.4	24	82.6	75.9	25.9	Oct-76	Dec-97	2000	0						2000	0	16000	0
Metals	Copper	No	Dis.	ug/l	M	137	8	7	0.5	170	4.34	4.81	1.48	4.5	5.92	4.49	May-74	Dec-97	1300	0		1000	0			1300	0	5.24	10
Metals	Iron	No	Dis.	ug/l	M	1340	27	21	1.5	4000	56.7	85.7	88.7	73.1	120	110	Jun-73	Dec-97				300	98	1000	39	300	98	1000	39
Metals	Manganese	No	Dis.	ug/l	M	1267	27	20	0.5	3200	60	118	117	85	156	146	Jun-73	Dec-97				50	310			50	310	120	223
Metals	Phosphorus	No	Dis.	ug/l	M	422	18	16	5	770	24.7	43.9	44.8	49.5	66.6	42.7	Feb-86	Dec-97											
Metals	Phosphorus	No	Tot.	ug/l	M	1356	25	12	5	5100	71.7	136	155	79.6	140	155	Dec-69	Dec-97											
Metals	Zinc	No	Dis.	ug/l	M	165	8	7	1.5	190	13.4	15.2	5.53	19.5	19.4	6.14	Oct-73	Dec-97				5000	0	120	3	7400	0	65.66	7
Nutrients	Ammonia-nitrogen as N	No	Dis.	mg/l	M	1457	25	20	0.005	6.3	0.0988	0.118	0.0752	0.129	0.133	0.0716	Dec-69	Dec-97											
Nutrients	Kjeldahl nitrogen	No	Dis.	mg/l as N	-	435	18	6	0.1	3	0.4	0.418	0.182	0.406	0.432	0.181	Jan-81	Dec-97											
Nutrients	Kjeldahl nitrogen	No	Tot.	mg/l as N	-	1140	21	5	0.1	10	0.878	1.03	0.459	0.878	1.05	0.46	Mar-74	Dec-97											
Nutrients	Nitrate as N	No	Dis.	mg/l	CA	1222	22	18	0.005	9.45	0.258	0.365	0.324	0.361	0.435	0.336	Oct-61	Dec-97	10	0						10	0		
Nutrients	Nitrite	No	Dis.	mg/l	-	375	14	13	0.0165	1.15	0.0557	0.0606	0.0337	0.0809	0.0891	0.0313	Feb-93	Dec-97											
Nutrients	Nitrite as N	No	Dis.	mg/l	CA	1161	21	20	0.005	0.53	0.0201	0.0266	0.018	0.0283	0.0347	0.018	Dec-69	Dec-97	1	0									
Nutrients	Nitrogen	No	Tot.	mg/l	-	1138	21	19	0.125	13	1.02	1.43	0.853	1.28	1.65	0.887	Mar-74	Dec-97											
Nutrients	Nitrogen, mixed forms (NH3), (NH4), organic, (NO2) and (NO3)	No	Dis.	mg/l	-	400	15	10	0.1	8.5	0.597	0.822	0.615	0.72	0.922	0.607	Jun-85	Dec-97											
Nutrients	Organic nitrogen	No	Dis.	mg/l	-	400	15	11	0.075	2.9	0.291	0.332	0.163	0.311	0.38	0.153	Jun-85	Dec-97											
Nutrients	Organic nitrogen	No	Tot.	mg/l	-	894	19	14	0.06	9.7	0.71	0.825	0.449	0.738	0.863	0.44	Oct-72	Dec-97											
Nutrients	Phosphate as P	No	Dis.	mg/l	-	447	18	13	0.005	0.69	0.0194	0.037	0.0333	0.039	0.0491	0.031	Apr-85	Dec-97											
Nutrients	Phosphate as P	No	Tot.	mg/l	-	606	15	11	0.005	3.37	0.0817	0.191	0.237	0.147	0.212	0.228	May-79	Dec-92											
Radiochemical	Potassium-40	No	Dis.	pCi/L	-	27	9	0	2.3	4.6	3.6	3.59	0.352	3.6	3.59	0.352	Jan-81	Jul-81											

M = Measured, as defined in EPA QAPP for Wise and Denton Counties Retrospective Case Study (EPA, 2012b).
CA = Critical Analyte, as defined in EPA QAPP for Wise and Denton Counties Retrospective Case Study (EPA, 2012b).
A red highlight indicates the value was above a screening criteria. All non EPA parameters (non CA and non M) summary results along with the entire results are presented in Appendix B and are retained in the database.
Note: Sodium does not have an MCL; the value listed in the MCL column represents the EPA Health Advisory Level.
N = number of samples
ND = non-detect
SD = Standard Deviation

08053500) and Denton Creek at FM 156 (TCEQMAIN-14483). These two locations were selected because data were available across the pre-1998 timeframe and the locations were within the Barnett footprint. Due to similarities of the plots, only the plots for Denton Creek near Justin, TX, are shown.

TDS and chloride were compared to EPA SMCLs of 500 mg/L, and 250 mg/L respectively. Chloride concentrations at Denton Creek near Justin, TX show fluctuations across the timeframe (Figure 3-13 and Figure 3-14). Chloride concentrations at this location were never above the EPA SMCL of 250 mg/L. Data spanning pre-1998 were not available to plot the locations where chloride was detected above the regulatory levels. TDS showed a similar trend at Denton Creek near Justin, TX. A slight increase in concentration over time with concentrations closely approaching the EPA SMCL of 500 mg/L was observed. During one sampling time pre-1998, TDS was detected above the EPA SMCL. Denton Creek was not one of the creeks reported as impaired due to TDS. Sulfate, a critical analyte, was above screening criteria pre-1998. Sulfate was also plotted for Denton Creek near Justin, TX and was compared to EPA SMCLs of 250 mg/L. Sulfate concentrations at this location were never above EPA SMCLs. Arsenic concentrations at Denton Creek near Justin, TX showed minor fluctuations far below the screening criteria (Texas surface water human health RBEL 10 µg/L) with no increase in concentration after 1997 (Figure 3-15).

3.3.3 Coverage of EPA QAPP Analytes. Table 3-11 lists whether the monitored parameters are part of the EPA QAPP for Wise and Denton Counties. Of the parameters identified in the QAPP, 188 are designated as either CA (81) or M parameters (107). Table 3-10 summarizes the publically available surface water quality data for the EPA parameters (10 CA and 14 M parameters) in the reduced data set used for analysis. Upon review of the data in Table 3-11, there are 148 parameters (67 CA and 81 M) listed in the EPA QAPP for the retrospective study that are not covered by the data gathered for Wise and Denton Counties and an additional 16 (four CA and 12 M) for which there was not a sufficient sample size <8 locations with one or more results) or were non-detect. Therefore, no water quality characterization is available for comparison should any of these 164 parameters be detected in future sampling efforts.

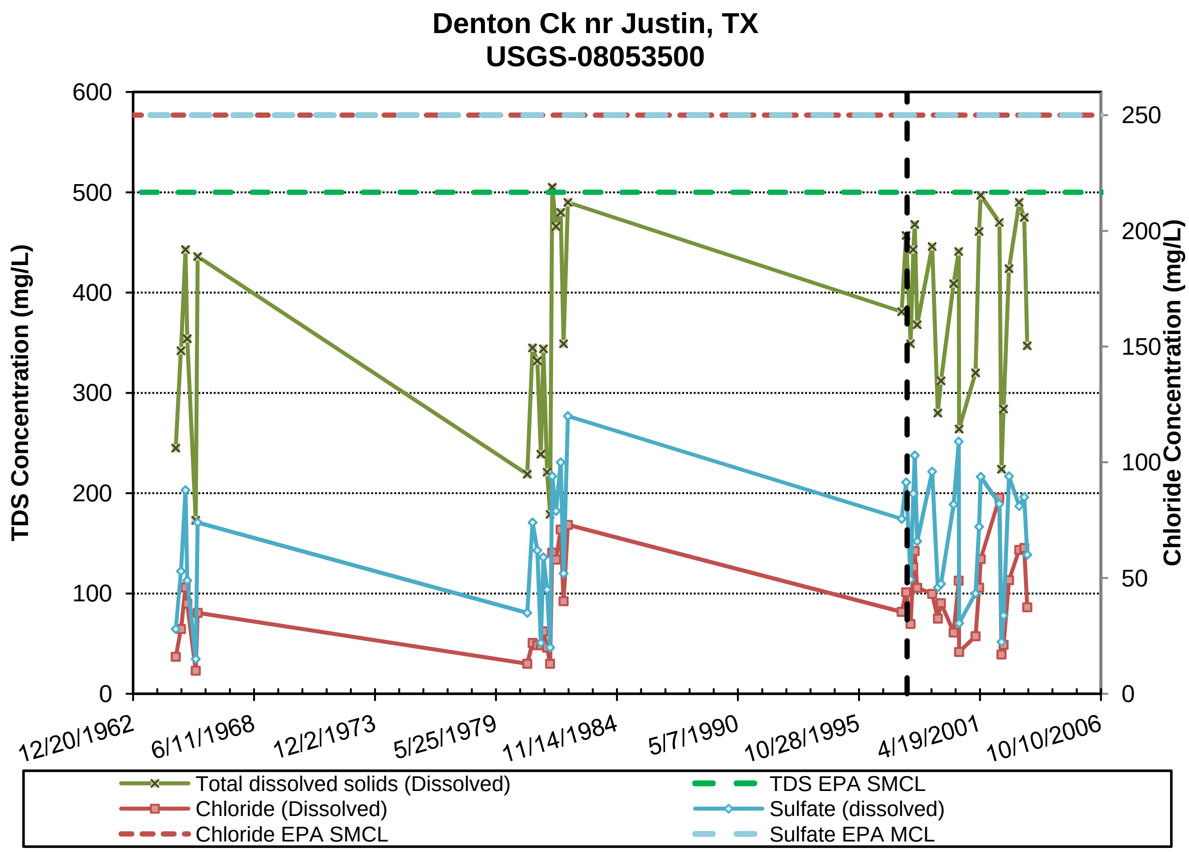


Figure 3-13. TDS and Chloride Concentration Trends Showing Regulatory Criteria and Trend Lines of the Data

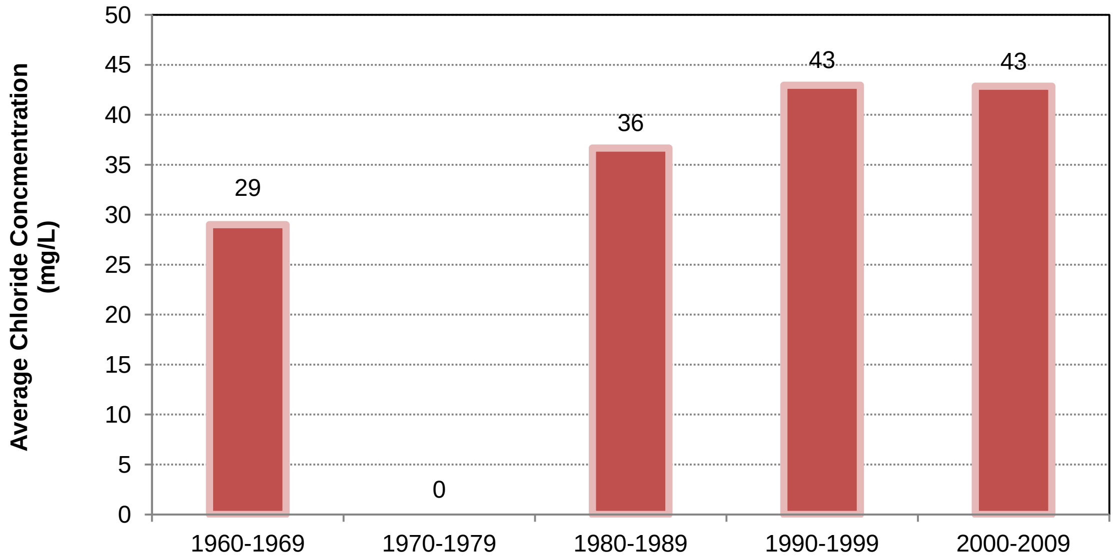


Figure 3-14. Average Chloride Concentrations over Time at Denton Creek near Justin, TX
(Data was available for years 1964, 1965, 1980,1981, 1982, 1997, 1998, 1999,2000, 2001, 2002 and 2003)

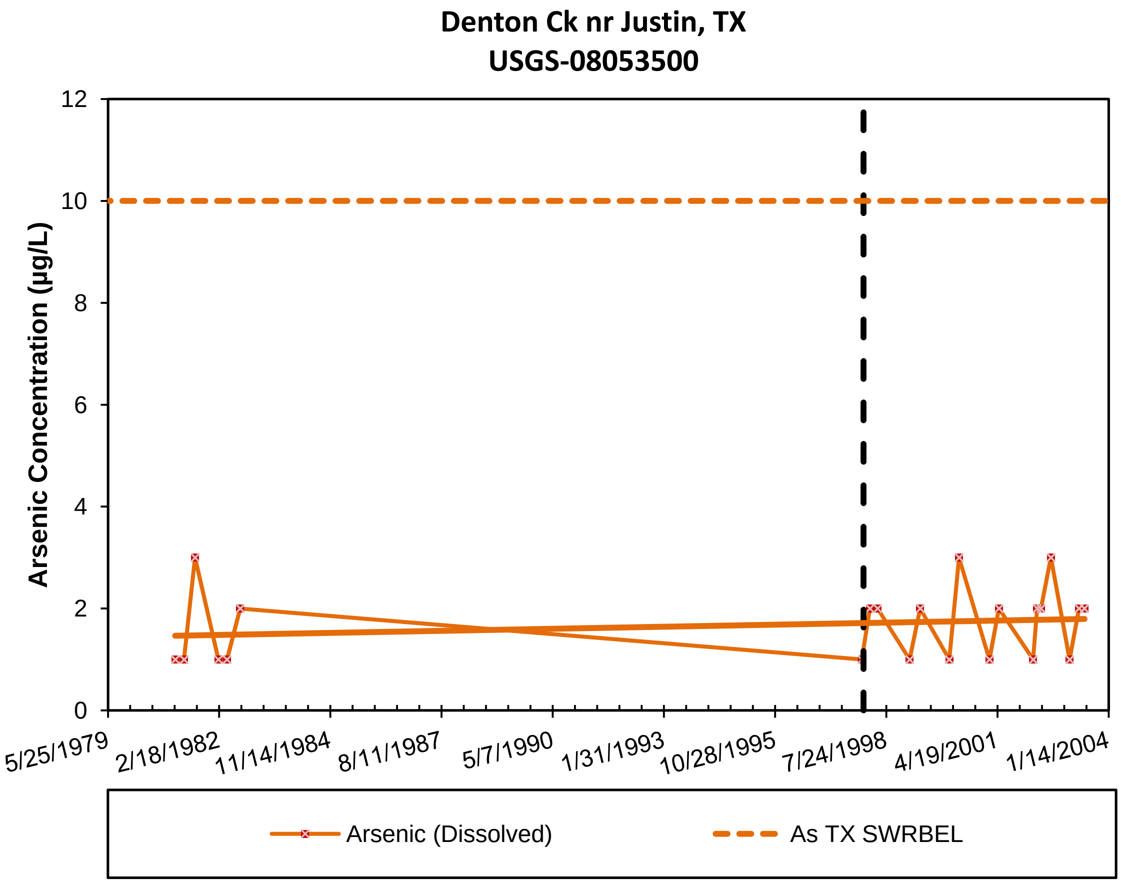


Figure 3-15. Arsenic Concentrations Showing Regulatory Criteria

Table 3-11. List of EPA Parameters Not Included in Wise and Denton Counties Surface Water Quality Characterization Database

Parameter - Measured		Parameter - Critical Analyte	
NOT FOUND			
Inorganic carbon	m-Dinitrobenzene	Butane	Dibutyl phthalate
Iron, ion (Fe2+)	N-Nitrosodimethylamine	Ethane	Diethyl phthalate
Redox Potential	p-Nitrophenol	Methane	Dimethyl phthalate
Sulfide	Phenol	Propane	Fluoranthene
Diethylene glycol monobutyl ether acetate	Pyridine	1,2,4-Trichlorobenzene	Fluorene
Tetraethylene glycol	Squalene	2,4,5-Trichlorophenol	Hexachlorobutadiene
Triethylene glycol	Terpineol	2,4,6-Trichlorophenol	Hexachloroethane
d2H	tri(2-butoxethyl)phosphate	2,4-Dichlorophenol	Indeno[1,2,3-cd]pyrene
d87/86Sr	1,1,1-Trichloroethane	2,4-Dimethylphenol	Isophorone
Oxygen-18/Oxygen-16 ratio	1,1,2-Trichloroethane	2,4-Dinitrotoluene	m-Cresol
Acetate	1,1-Dichloroethane	2,6-Dinitrotoluene	m-Dichlorobenzene
Butyric acid	1,1-Dichloroethylene	2-Chloronaphthalene	m-Nitroaniline
Formate	1,2,3-Trimethylbenzene	2-Methylnaphthalene	N-Nitrosodi-n-propylamine
Isobutyrate	1,2,4-Trimethylbenzene	3,3'-Dichlorobenzidine	Naphthalene
Lactic acid	1,2-Dichloroethane	4-methylphenol	Nitrobenzene
Propionic acid	1,3,5-Trimethylbenzene	Acenaphthene	o-Chlorophenol
Bromide	Acetone	Acenaphthylene	o-Cresol
Antimony	Benzene	Anthracene	o-Dichlorobenzene
Cerium	Carbon disulfide	Benz[a]anthracene	o-Nitroaniline
Silicon	Carbon tetrachloride	Benzo(b)fluoranthene	o-Nitrophenol
Sulfur	Chlorobenzene	Benzo[a]pyrene	p-Bromophenyl phenyl ether
Thallium	Chloroform	Benzo[ghi]perylene	p-Chloro-m-cresol
Titanium	*cis*-1,2-Dichloroethylene	Benzo[k]fluoranthene	p-Chloroaniline
Uranium	Cumene	Benzyl alcohol	p-Chlorophenyl phenyl ether
1,2-dinitrobenzene	Ethanol	Bis(2-chloroethoxy)methane	p-Dichlorobenzene
1,3-dimethyl adamantane	Ethyl tert-butyl ether	Bis(2-chloroethyl) ether	p-Nitroaniline
1,4-dinitrobenzene	Ethylbenzene	Bis(2-chloroisopropyl) ether	Pentachlorophenol
1-Methylnaphthalene	Isopropyl ether	Butyl benzyl phthalate	Phenanthrene
2,3,4,6-Tetrachlorophenol	m-Xylene	Carbazole	Pyrene
2,4-Dinitrophenol	Methyl tert-butyl ether	Chrysene	Diesel range organics
2-butoxyethanol	Methylene chloride	Di(2-ethylhexyl) phthalate	Gasoline range organics
2.3.5.6-Tetrachlorophenol	o-Xylene	Di-n-octyl phthalate	Isopropyl alcohol
Adamantane	p-Xylene	Dibenz[a,h]anthracene	tert-Butanol
Aniline	tert-Amyl methyl ether	Dibenzofuran	
Azobenzene	Tetrachloroethylene		
Benzoic acid	Toluene		
bis(2-ethylhexyl) adipate	*trans*-1,2-Dichloroethylene		
Cyclohexene, 1-methyl-4-(1-methylethenyl)-, (4R)-	Trichloroethylene		
Diphenylamine	Vinyl chloride		
Hexachlorobenzene	Xylene		
Hexachlorocyclopentadiene			
SAMPLE SIZE < 8 or ALL ND			
Cadmium	Beryllium	Selenium	Strontium
Chromium	Cobalt	Boron	4,6-Dinitro-o-cresol
Lead	Mercury		
Silver	Molybdenum		
Turbidity	Nickel		
Aluminum	Vanadium		

4.0: CONCLUSIONS AND KEY FINDINGS

EPA is conducting a retrospective case study in Wise and Denton Counties, TX to determine if there is a relationship between hydraulic fracturing and drinking water resources. EPA selected this site "in response to complaints about appearance, odors and taste associated with water in domestic wells" (EPA, 2012b). To investigate these complaints, EPA is collecting groundwater and surface water quality data. To assess potential water quality effects from post-hydraulic fracturing in the appropriate context, existing water quality conditions in the county must first be understood. To this end, this report provides an initial understanding and characterization of water quality conditions in Wise and Denton Counties based upon readily available data and information from the USGS, EPA and the state of Texas.

The primary objective of this report is to help understand and characterize background groundwater and surface water conditions within the study area prior to substantial development of the Barnett Shale through hydraulic fracturing. Water quality parameters monitored, but not detected, were also identified. This objective was satisfied by systematically conducting the steps outlined below.

- **Define the spatial boundaries and attributes of the Wise and Denton Counties study area.**
  EPA is currently collecting groundwater and surface water samples at three locations in Wise County. The Barnett Shale extends beneath both Wise and Denton Counties, as does the primary drinking water aquifer (Trinity Aquifer). Accordingly, the lateral spatial boundary is defined as Wise and Denton Counties for this characterization report. Vertically, the boundaries of the study area extend from ground surface to the base of the Trinity Aquifer. Temporally, 1998 was selected as the boundary between the period of little development of the Barnett Shale (prior to 1998) and the period of substantial development of the Barnett Shale through hydraulic fracturing based upon oil and gas well drilling data. Available information summarized in this report on land use, groundwater and surface water quality define the attributes of the study area.

- **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.**
  The most significant causes of water quality impairment based on land use in Wise County are agriculture, livestock, oil and gas activities, construction (crushed stone factory, limestone quarry plants, asphalt, brick and concrete manufacturing) and historical coal mining. The most significant causes of water quality impairment in Denton County are agriculture, livestock, construction (crushed stone factory, limestone quarry plants, asphalt, brick and concrete manufacturing) and oil and gas support activities. In addition, brine injection wells and historic oil and gas wastewater disposal methods prior to 1969 are known to have caused groundwater contamination (GWPC, 2011). There were no brine injection wells in Wise County prior to 1969. Denton County had 15 brine injections wells prior to 1969 (RRC, 2012g). Other land uses that are known to impact water quality in the counties include urban, residential and road runoff; habitat modification; and municipal and industrial wastewater discharges. Numerous recognized environmental sites were noted across both counties. Each of these land uses occurred within Wise and Denton Counties prior to unconventional oil and gas development and many still continue. Water quality parameters commonly associated with these land uses are summarized below:

  - Agriculture 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, algae blooms caused by agricultural runoff of nitrogen and phosphorous can be a source of organic carbon that promotes the formation of DBPs upon chlorination of surface water in water treatment plants (EPA, 2005). Agricultural and livestock activities can also be a source of methane (King, 2012).

- Nonpoint sources, stormwater runoff and industrial activities have impacted general water quality parameters such as chloride, TDS, bacteria and dissolved oxygen.
- Based on information from the Watershed Quality Assessment Report (EPA, 2012f), over 96 miles of impaired streams exist in Wise County, representing approximately 7% of the total stream length in the county from 1998 to 2010. Over 22 miles of impaired streams exist in Denton County, representing 2% of the total stream length in the county over the same duration. The parameters that have caused these surface water impairments in Wise and Denton Counties include chloride, total suspended solids, bacteria and dissolved oxygen.
- Conventional Oil and Gas Development: The potential main contaminants associated with oil and gas operations are petroleum hydrocarbons and BTEX. Over 20,000 oil and gas wells have been drilled in Wise and Denton Counties, many of which were drilled prior to the existence of modern techniques or regulations.
    - Between 1993 and 2008, over 16,000 horizontal shale gas wells with multi-staged hydraulic fracturing stimulations were completed in Texas. Specifically, there are 895 and 1379 horizontal shale gas wells in Wise and Denton Counties, respectively, during the same period. Not a single groundwater contamination incident has resulted from site preparation, drilling, well construction, completion and hydraulic stimulation or production operations at any of the (>2,000) horizontal shale gas wells during the same period in Wise and Denton counties (GWPC, 2011).
- Groundwater overdrafts likely due to drought and population increases have resulted in substantial phreatic level declines and may have contributed to observed water quality impacts (elevated TDS, chloride, sodium, and sulfate) in Wise and Denton Counties through possible leakage between formations or migration of poorer water quality into higher water quality areas. Source attribution is notably difficult due the lack of historical water quality data.

- **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 Wise and Denton Counties was established using information collected in the databases discussed in Section 2.2. One limitation of these databases is that the water quality data were focused on general water quality parameters; data on organic water quality parameters are limited. The data sources used are considered secondary data and by definition were not originally collected for the specific purposes of this report. However, these data sources are commonly used to define background or baseline groundwater and surface water quality. For this study, data collected prior to 1998 represent conditions prior to significant development of the Barnett Shale through unconventional oil and gas development activities and were considered to be representative of background conditions.

  The majority of the parameters have insufficient data to adequately characterize background water quality. Of the 188 parameters listed as M or CA in the EPA QAPP, the evaluation identified 117 groundwater quality and 164 surface water quality parameters that have no results or results from fewer than eight locations. This lack of historical water quality data in conjunction with historical land use and known impairments will make it challenging to determine whether recent hydraulic fracturing has impacted water quality without further investigation.

- **Conduct summary statistical analyses and comparing the water quality summary statistics to state and federal water quality standards and criteria.**
  - Groundwater quality data summary
    - Groundwater samples were collected from 532 locations in the study area.
    - Parameters above one or more screening criteria and the number and percentage of results above criteria are presented in Table 4-1.
      - General water quality parameters, pH and TDS, and major ions, chloride, fluoride, sulfate and sodium, were above one or more screening criteria. Chloride and sulfate are identified as EPA CA.
      - Metals including aluminum, arsenic, beryllium, boron, cobalt, iron, manganese, phosphorus, uranium and vanadium were above one or more screening criteria. The metals noted here are EPA measured analytes with the exception of arsenic and boron (CA).
      - Two organic compounds, p-p'-DDE (SVOC) and benzene (VOC), were detected in groundwater with 11 sample results each; only benzene was slightly above the screening criteria in one sample.
    - Inclusion of chemical data from 43 locations identified as potentially being associated with impact monitoring or having location issues may bias background groundwater quality conditions. With the exception of aluminum, the respective regulatory levels that are not met also are identical between the two datasets. For pH, TDS, chloride, total sodium, sulfate, fluoride, arsenic, beryllium, cobalt, uranium, vanadium and benzene, there is minimal or no difference between the two datasets when comparing the summary statistics (mean, median and standard deviation). For dissolved sulfate, the mean and median values are higher in the reduced dataset, suggesting the removed data had lower chemical concentrations. For dissolved sodium, aluminum, boron, iron, managanese and phosphorous, the mean and median values are lower in the reduced dataset, suggesting the removed data had higher chemical concentrations.
    - Quantitative comparisons between formations were not performed due to the limited number of sample results with assigned formations. Additional effort to assign formations in the database may be warranted for future work pending the outcome of EPA case study sampling results.
    - Results of an ANOVA analysis indicate significant differences in water quality. Median chloride levels in the Trinity Aquifer are 3.5 times lower than median levels in the Paleozoic units. Sodium (50%) and sulfate (75%) median levels in the Trinity Aquifer are higher than the Paleozoic units. Differences for fluoride and TDS were not significant.
    - Quantitative review of major ions show significant trends with increasing depth including decrease of calcium, chloride, and magnesium and increases of alkalinity, fluoride, sodium (dissolved and total fraction) and TDS.
    - Of the 188 parameters identified in the EPA QAPP for the Wise and Denton Counties retrospective case study, 41 parameters (28 M, 13 CA) are included in the database with detected results from eight or more locations; 30 parameters (23M, 7 CA) with

no detected results from eight or more locations; 117 parameters (56 M, 61 CA) have results from <8 locations or no results.

- Surface water quality data summary
  - Parameters above one or more screening criteria and the number and percentage of results above criteria are presented in Table 4-2.
    - General water quality parameters, pH, alkalinity (total and dissolved), TDS and major ions, chloride, fluoride, sulfate, and sodium, were above one or more screening criteria. Chloride, sulfate, and sodium are identified as EPA CA.
    - Metals including arsenic, cadmium, copper, iron, lead, manganese, nickel, selenium, silver, and zinc were above one or more screening criteria. These metals are EPA M analytes with the exception of arsenic and selenium (CA).
    - Data for organic compounds are extremely limited and are insufficient to characterize surface water quality.
  - Inclusion of chemical data from 32 locations identified as potentially being associated with impact monitoring or having location issues may bias background surface water quality conditions. Five parameters (cadmium, lead, nickel, selenium and silver) identified as being above screening criteria in the complete dataset are not included in the reduced summary data table. The 12 parameters in both datasets above respective screening criteria are identical, with the exception of fluoride which does is not above the MCL or Texas human health surface water RBEL in the reduced dataset. For alkalinity, pH, fluoride, arsenic and copper there is minimal or no difference between the two datasets when comparing the summary statistics. For TDS, sulfate and sodium, the mean and median values are lower in the reduced dataset, suggesting the removed data had higher chemical concentrations. For iron, manganese and zinc, the mean and median values are higher in the reduced dataset, suggesting the removed data had lower chemical concentrations.
  - EPA critical analytes chloride, sulfate, arsenic, boron and selenium were above applicable screening criteria. TDS, an analyte detected in impaired streams, also were above screening criteria. Chloride also was detected in impaired streams.
  - Data for chloride show a decreasing trend (~1% per year) in the average annual concentration for the entire dataset. Data for arsenic, sulfate and TDS show no significant trends in the average annual concentrations.
  - Surface water quality data were available at 67 locations. Temporal data at individual monitoring locations are limited; as a result, characterizing changes in background surface water quality at individual locations over time is also limited.
    - At Denton Creek near Justin, TX, TDS, chloride and sulfate fluctuated over time with no overall increase or decrease in concentration. TDS concentrations approached the EPA MCL screening crteria and were above it only once.
    - Arsenic concentrations at Denton Creek near Justin, TX, also fluctuated with no overall increase and concentrations were much lower than the Texas surface water RBEL screening criteria.
  - Of the 188 parameters identified in the EPA QAPP for the Wise and Denton Counties retrospective case study, 24 parameters (14 M and 10 CA) are included in the database with at least a single result; 164 parameters (93 M and 71 CA) have results from <8 locations or no results.

The data included in this report can be used to assess or provide context for future water quality data collected as part of the EPA study or data collected by operators. Reported concentrations of constituents must consider relevant factors such as land use, existing water quality impairments, domestic well completion practices and a host range of other considerations prior to attributing source for constituents detected.

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

				Complete Dataset				Reduced Dataset			
Class	Parameter	Fraction	EPA	N	No. ND	No. Above Regulatory Level	% Above Regulatory Level	N	No. ND	No. Above Regulatory Level	% Above Regulatory Level
Gen WQ	pH	Total	M	643	0	280	44	639	0	279	44
Gen WQ	pH (field)	Total	M	187	0	68	36	148	0	56	38
Gen WQ	TDS	Dissolved	M	650	0	445	68	646	0	443	69
Major Anions	Chloride	Dissolved	CA	652	0	76	12	648	0	76	12
Major Anions	Fluoride	-	M	624	23	219	35	620	22	216	35
Major Anions	Fluoride	Dissolved	M	11	3	1	9.1	11	3	1	9.1
Major Anions	Sulfate	-	CA	641	1	33	5.1	637	1	33	5.2
Major Anions	Sulfate	Dissolved	CA	178	14	10	5.6	139	10	8	5.8
Major Cations	Sodium	Dissolved	CA	177	0	164	93	138	0	129	93
Major Cations	Sodium	Total	CA	643	0	625	97	639	0	621	97
Metals	Aluminum	Dissolved	M	177	145	1	0.6	138	113	0	0
Metals	Arsenic	Dissolved	CA	178	128	50	28	139	105	34	24
Metals	Beryllium	Dissolved	M	177	175	1	0.6	138	136	1	0.7
Metals	Boron	Dissolved	CA	166	1	5	3.0	127	1	1	0.8
Metals	Cobalt	Dissolved	M	177	131	8	4.5	138	102	6	4.3
Metals	Iron	Dissolved	M	177	160	2	1.1	138	123	2	1.4
Metals	Manganese	Dissolved	M	187	87	12	6.4	148	68	10	6.8
Metals	Phosphorus	Dissolved	M	177	156	21	12	138	123	15	11
Metals	Uranium	Dissolved	M	178	80	1	0.6	139	58	1	0.7
Metals	Vanadium	Dissolved	M	166	155	11	6.7	127	117	10	7.9
VOCs	Benzene	Total	M	11	10	1	9.1	11	10	1	9.1

M = Measured, as defined in EPA QAPP for Wise and Denton Counties Retrospective Case Study (EPA, 2012b).
CA = Critical Analyte, as defined in EPA QAPP for Wise and Denton Counties Retrospective Case Study (EPA, 2012b).
N = number of samples
ND = non-detect

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

Class	Parameter	Fraction	EPA	Complete Dataset N	Complete Dataset No. ND	Complete Dataset No. Above Regulatory Level	Complete Dataset % Above Regulatory Level	Reduced Dataset N	Reduced Dataset No. ND	Reduced Dataset No. Above Regulatory Level	Reduced Dataset % Above Regulatory Level
Gen WQ	Alkalinity as CaCO3	Total	M	643	0	2	0.3	639	0	0	0
Gen WQ	pH	Total	M	3,538	0	160	4.5	931	0	32	3.4
Gen WQ	pH (field)	Total	M	4,031	0	130	3.2	4,031	0	130	3.2
Gen WQ	TDS	Dissolved	M	1,266	2	96	7.6	1,125	2	77	6.8
Major Anions	Chloride	Dissolved	CA	1,998	0	3	0.2	1,176	0	3	0.3
Major Anions	Sulfate	Dissolved	CA	1,909	0	20	1.0	1,166	0	1	0.1
Major Anions	Fluoride	Dissolved	M	1,407	7	3	0.2	899	7	1	0.1
Major Cations	Sodium	Dissolved	CA	1,619	0	875	54	1,102	0	566	51
Metals	Arsenic	Dissolved	CA	299	6	2	0.7	177	6	1	0.6
Metals	Cadmium	Dissolved	M	180	10	27	15	8	8	0	0
Metals	Copper	Dissolved	M	151	9	11	7.3	137	7	10	7.3
Metals	Iron	Dissolved	M	1,693	28	103	6.1	1,340	21	98	7.3
Metals	Lead	Dissolved	M	154	10	12	7.8	139	139	0	0
Metals	Manganese	Dissolved	M	1,649	26	406	25	1,267	20	310	24.5
Metals	Nickel	Dissolved	M	87	8	1	1.1	70	70	0	0
Metals	Selenium	Dissolved	CA	172	10	1	0.6	156	156	0	0
Metals	Silver	Dissolved	M	158	10	24	15	143	143	0	0
Metals	Zinc	Dissolved	M	176	9	7	4.0	165	7	7	4.2

M = Measured, as defined in EPA QAPP for Wise and Denton Counties Retrospective Case Study (EPA, 2012b).
CA = Critical Analyte, as defined in EPA QAPP for Wise and Denton Counties Retrospective Case Study (EPA, 2012b).
N = number of samples
ND = non-detect

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Appendix A

QA/QC Review

WISE AND DENTON COUNTY, TX DATA QUALITY ASSESSMENT

The site characterization data quality objectives (DQOs) were followed to assess the quality of the Wise and Denton County, Texas (TX) 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[1]

DQO Assessment Criteria	DATA TYPE Groundwater	 Surface Water
Organizations contributing data	Texas Water Development Board (TWDB), U.S. Geological Survey (USGS; NURE, NWIS, TX Water Science Center)	USGS (NWIS, TX Water Science Center), EPA STORET, TWDB
• 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)	Yes	Yes
Data were collected by laboratories known to implement a rigorous quality system.	Unknown	Unknown
The analysis methods were identified and appropriate	No	No
For non-detect values, the detection limits were defined and sensitive enough for the parameter.	Yes Except for arsenic and naphthalene	Yes Except for a few specific exceptions
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

[1] 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 conducted 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:
  - Texas Water Development Board (TWDB) (59%)
  - USGS NURE (28%)
  - USGS NWIS / USGS TX Water Science Center (13%)

  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 appears that the TWDB has an overall quality system. The web site references both Quality Assurance Project Plans (QAPP) and Quality Management Plans (QMP) that establishes requirements for the collection of environmental data. However, neither the TWDB or USGS NURE databases identified the organizations that contributed data posted on the websites. Further, none of the websites identified the laboratories performing analysis. Due to these unknowns, the quality of groundwater data is considered variable.

- **Surface Water**. Surface water data were gathered from three sources; these sources and the approximate percent of data contributed by each are as follows:
  - EPA STORET (30%)
    - EPA National Aquatic Resource Survey (0.1%)
    - TX Commission on Environmental Quality (30%)
  - USGS NWIS /USGS TX Water Science Center (66%)
  - TWDB (4%)

  As noted above, data collected by USGS and TWDB are supported by a quality system. Similarly, the TX Commission on Environmental Quality (TCEQ) appears to have a quality system for the collection of environmental samples; the website posts both the organization’s QMP and QAPPs for various water collection programs. Although the laboratories performing analysis are not defined for most data, the quality of these data is supported by the quality systems of the collection organizations and requirements of the source databases.

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 any of the 21,500 groundwater results and therefore the qualifications of the laboratory cannot be assessed.

- **Surface Water**
  The analytical laboratories were not defined for 98% of the 118,623 surface water 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 only 13% of the groundwater data. NWIS was the only organization reporting the methods associated with the analytical results. All of the methods reported were internal SOPs. However, the fact that internal SOPs exist for the analysis indicates that the methods are established and standardized. The groundwater data are considered variable for this assessment element.

- **Surface Water**
  Analytical methods were reported for 58% of the surface water data. The analytical methods for approximately 64% of EPA STORET results were reported as "N/A Calculation"; <0.01% reported used of an EPA method and the remainder (approximately 36% did not report the method associated with analytical results. The analytical methods were reported for approximately 58% of the EPA NWIS results. The methods cited are primarily organizational SOPs 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. The surface water data are considered variable for this assessment element.

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 dataset were reviewed vs. State and Federal regulatory limits and screening criteria applicable to Wise and Denton County. The results are summarized in Table A-2.

- **Groundwater**
  For groundwater, of the 5980 results for EPA chemicals of interest, results for 487 samples were below the laboratory detection limits ("U" qualified). Laboratory detection limits were reported for all EPA chemicals of interest and chemicals measured by EPA. Laboratory detection limits for 128 arsenic results (72%) and all 12 naphthalene results were above the EPA carcinogen criteria (Table A-2). Data quality based on laboratory detection limits is acceptable except for arsenic and naphthalene.

- **Surface Water**
  For surface water, of the 18025 results for EPA chemicals of interest, 1360 were measured below the laboratory detection limits. All reported laboratory detection limits were lower than any applicable screening criteria. However, detection limits were not reported for 72 "U" qualified metals that EPA is measuring representing Data quality based laboratory detection limits is acceptable with a few specific exceptions that were excluded from the statistical analysis because detection limits were not reported.

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. Neither the USGS data nor STORET data included quality control results.

- **Groundwater**
  For groundwater, no laboratory QC or field equipment blank data were reported. However, one pair of laboratory duplicates was collected. In general, the two samples did not share parameter lists, but 12 parameters were common to both. Of these, precision was 100% for all laboratory results measured above the detection limit and 100% for each of the field duplicate results. Overall, there is insufficient QC data available to assess data quality, therefore, on the basis of the QC data, data quality is unknown.
- **Surface Water**
  For surface water, no laboratory QC data or field equipment blank 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 datasets 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); S (suspect); and J (estimated value).

- 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 Wise and Denton County dataset, the laboratories 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.

- **Groundwater**
  Overall, a small percentage of the data were assigned qualifiers (Table A-3). Of the qualifiers assigned, the vast majority were “U” qualifiers, indicating that a compound was not detected above the detection limit. Battelle assigned some data qualifiers based on the text comment analysis described above. No “J” or “S” qualifiers were assigned to EPA compounds or interest; 18 “S” qualifiers were assigned to parameters not of interest but measured by EPA, and 2 “J” qualifiers were assigned to chemicals not measured by EPA. Overall, less than 0.1% of the data were qualified with data quality-related qualifier J or S. However, because it appears that laboratory qualifiers were not assigned to the vast majority of data, the actual data quality is considered variable.

- **Surface Water**
  As with groundwater, only a small percentage of the surface water 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 detection limit. Battelle assigned some data qualifiers based on the text comment analysis described above. Within the USGS NWIS dataset, 30 “J” qualifiers were assigned to EPA compounds of interest, 137 “J” qualifiers were assigned to parameters not of interest but measured by EPA, and 130 “J” qualifiers were assigned to chemicals not measured by EPA. For parameters not of interest but measured by EPA, 32 “R” qualifiers were assigned to field and laboratory pH results within the EPA STORET data because the measured values are >14 and not scientifically possible. Fifteen (15) “S” qualifiers were assigned within the USGS NWIS dataset for chemicals not measured by EPA and for which the parameters were found to be “highly variable.” Overall, less than 0.5% of the data were qualified with data quality-related qualifier (R, S or J). However, because it appears that laboratory qualifiers were not assigned to the vast majority of data, the actual data quality is considered variable.

Table A-2. Groundwater 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	EPA Carc	EPA NonCarc	TX Carc	TX NonCarc
NURE	Arsenic	Dissolved	0.5	120	10	-	**0.045**	4.7	-	-
NWIS	Arsenic	Dissolved	1	8	10		**0.045**	4.7	-	-
NWIS	Naphthalene	Total	0.2	12	-	-	**0.14**	6.1	-	488.8
Total				140						

Bolded value indicates that detection limits are above screening criteria.

Table A-3. Groundwater Data Qualifiers Based on Data Source and Chemicals Listed in the EPA QAPP

	J	S	U	No Qualifier Assigned	Total
EPA Chemicals of Interest					
EPA Chemicals of Interest					
USGS NURE			249	1412	1661
USGS NWIS			115	104	219
TWDB			123	3977	4100
Total Qualifiers			487	5493	5980
Chemicals Measured by EPA But Not Chemicals of Interest					
USGS NURE			1942	1213	3155
USGS NWIS		18	404	282	704
TWDB			36	3268	3304
Total Qualifiers		**18**	**2382**	**4763**	**7163**
Chemicals Not Measured by EPA					
USGS NURE			695	468	1163
USGS NWIS	2		1803	184	1989
TWDB			322	4883	5205
Total Qualifiers	2		2820	5535	8357
GW Grand Total	**2**	**18**	**5689**	**15791**	**21500**

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

	J	R	S	U	No Qualifier Assigned	Total
EPA Chemicals of Interest						
EPA STORET				161	5704	5865
USGS NWIS	30			1108	10216	11354
TWDB				91	715	806
Total Qualifiers	30			1360	16635	18025
Chemicals Measured by EPA But Not Chemicals of Interest						
EPA STORET		32		580	21592	22204
USGS NWIS	137		2	3017	31237	34393
TWDB				361	2296	2657
Total Qualifiers	137	32	2	3958	**55125**	**59254**
Chemicals Not Measured by EPA						
EPA STORET				1435	6707	8142
USGS NWIS	130		15	7803	24510	32458
TWDB				145	599	744
Total Qualifiers	130		15	9383	31816	41344
SW Grand Total	**297**	**32**	**17**	**14701**	**103576**	**118623**

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

Conclusion for Surface Water Data:
Based on the data quality assessment, the surface water data should be used with care for the following reasons: the analytical laboratories and laboratory quality control data or quality-related qualifiers are unknown for the majority of the data; and analytical methods are not reported for about half the data. Quality system elements that support the data include collection organizations with known quality systems and acceptable laboratory detection limits (with a few specific exceptions).

Appendix B

Wise and Denton Counties Water Quality Data

WISE-DENTON COUNTIES WATER QUALITY DATA

The groundwater and surface water quality data (note there is no spring water 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, TDS 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. Three Excel files are included:

- Table B-2 Wise-Denton Removed 20121218.xls
- Table B-3 Wise-Denton GW Data Dump 20121218.xls
- Table B-4 Wise-Denton SW 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 and surface water quality data. Tables B-3 and B-4 in contain the collected groundwater and surface water data for Wise-Denton Counties. This information represents all of the data used to characterize the water quality in Wise-Denton Counties, TX.

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
Nitrite	Dissolved	mg/l

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

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

Statistical Analyses for Groundwater and Surface Water

Wise and Denton Counties Groundwater Analysis

Quantitative methods were used to assess groundwater quality data for Wise and Denton Counties. The assessments included

- Comparison of select parameters between groundwater data from the Trinity Aquifer and from wells completed in Paleozoic units that outcrop in limited areas along the western boundary of Wise County.
- Comparison of Trinity Aquifer data with depth.

Trinity Aquifer Data Compared With Paleozoic Units Data

Groundwater dissolved fraction concentrations of alkalinity as $CaCO_3$, calcium, chloride, fluoride, magnesium, sodium, manganese, sulfate, iron and total dissolved solids were available at 13 locations in the Paleozoic Units and at 546 locations across Wise and Denton counties. Results of the comparison indicate there were no significant differences in the median concentration for all but chloride, sodium (dissolved) and sulfate. Median chloride levels in the Paleozoic units were nearly 3.5X the median levels in the Trinity Aquifer. Median concentrations in the Paleozoic units were lower by 55% for sodium and 25% for sulfate.

Table C-1. Comparison of Paleozoic Units Data to Trinity Aquifer Data

Constituent	Fraction	Significance & Direction	% Change	p.value
Alkalinity as $CaCO_3$	Total	Not Significant		0.185
Calcium	Dissolved	Not Significant		0.184
Chloride	Dissolved	Increase	347.9%	0.003
Magnesium	Dissolved	Not Significant		0.077
Sodium	Dissolved	Not Significant		0.989
Sodium	Total	Decrease	54.6%	0.039
Manganese	Dissolved	Not Significant		0.495
Sulfate	Dissolved	Decrease	24.6%	0.027
Iron	Dissolved	Not Significant		0.103
Total dissolved solids	Dissolved	Not Significant		0.207

Trinity Aquifer Groundwater Data & Objective

Groundwater dissolved fraction concentrations of alkalinity as $CaCO_3$, calcium, chloride, fluoride, magnesium, sodium, manganese, sulfate, iron and total dissolved solids were available at 546 locations across Wise and Denton counties. The last figures in the report show schematics of the locations for each constituent. All available data were utilized in this analysis, including 60 locations with data collected after December 1997. Locations with observations on or after January 1998 are represented on the figures with red circles. For the majority of the data, geologic formation is unspecified. Table C-2 provides a summary of number of locations with observations for each constituent, by period. This objective of the statistical analysis was to assess the association of concentrations with well depth.

Table C-2. Number of Locations with Groundwater Water Quality Data

Parameter	Dissolved		Total		Unspecified	
	Pre 1998	1998-2011	Pre 1998	1998-2011	Pre 1998	1998-2011
Alkalinity as $CaCO_3$	12		213	46		
Calcium	174					
Chloride	356	60				
Fluoride*	12				338	60
Iron	174					
Magnesium	174					
Manganese	174					
Sodium	174		344	59		
Sulfate	175				344	60
Total dissolved solids	356	60				

*Because there were only a dozen fluoride observations with a specified fraction, the analysis was performed on observations with no fraction specified. This was only done for fluoride.

Methods

The association between concentrations and well depth and potential association with the initiation of change in extraction activity was assessed with a regression analysis. The regression model includes a term for log-transformed well depth as a covariate and an indicator for period. To account for grouping of observations by location, the model includes random component for location. The model for analysis is as follows:

$$C_{ij} = \mu + WellDepth_j + Period_{ij} + Location_j + \varepsilon_{ij}$$

where

- C_{ij} is the log-transformed observed response for the i^{th} observation at the j^{th} location
- μ is an overall constant
- $WellDepth_j$ is the log-transformed well depth of the j^{th} location
- $Period_{ij}$ is an indicator for whether the *i*th observation was taken prior to January 1998
- $Location_j$ is a random effect of the j^{th} location, assumed to be normally distributed with mean 0 and variance τ^2
- and ε_{ij} are the random error terms, assumed to be normally distributed with mean 0 and variance σ^2.

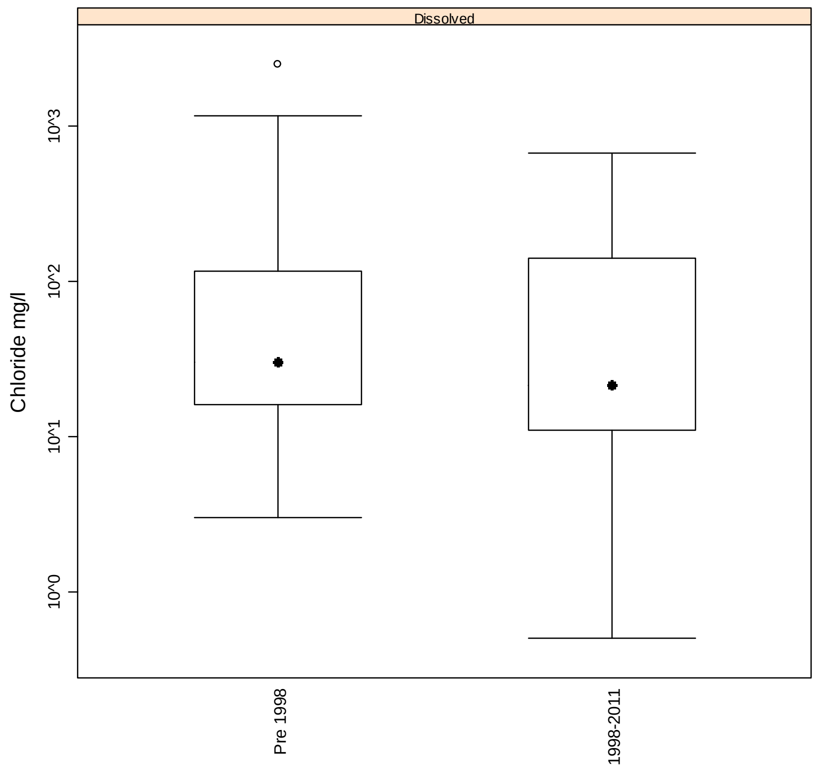
Results

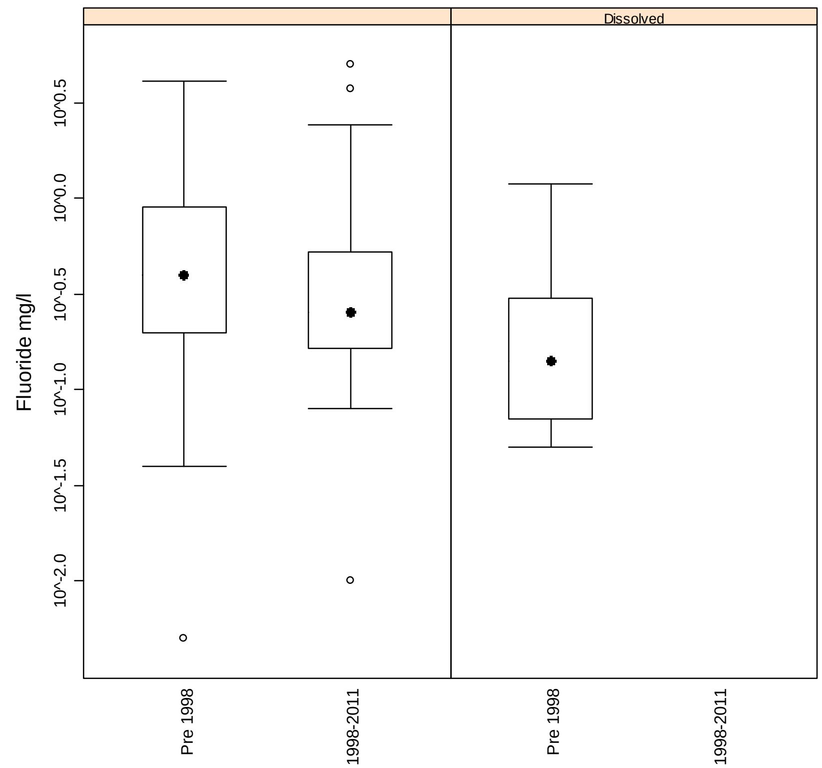
The figures on the following pages show, for each parameter, box plots of the log concentrations by fraction and period. Following the box plot figures, the next figure shows concentration vs. well depth, coded by period, for each constituent. Table C-3 summarizes the estimated percent increase or decrease and p-value for the effects of well depth for each constituent and fraction.

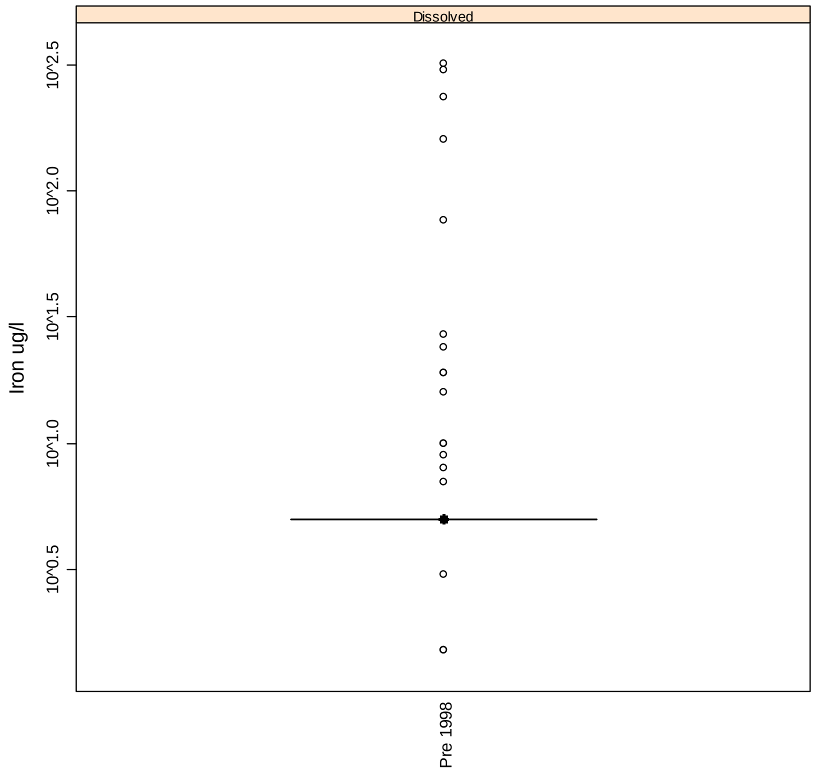
Log concentration is significantly associated with log-transformed well depth for alkalinity, calcium, chloride, fluoride, magnesium, sodium (both fractions), and total dissolved solids. The concentrations of calcium, chloride and magnesium are estimated to decrease by 80%, 17% and 78% per log-unit increase in well depth, respectively. Concentrations of alkalinity, fluoride, sodium (dissolved and total fractions) and total dissolved solids are estimated to increase by 135%, 7%, 71%, 60% and 7% per log-unit increase in well depth, respectively.

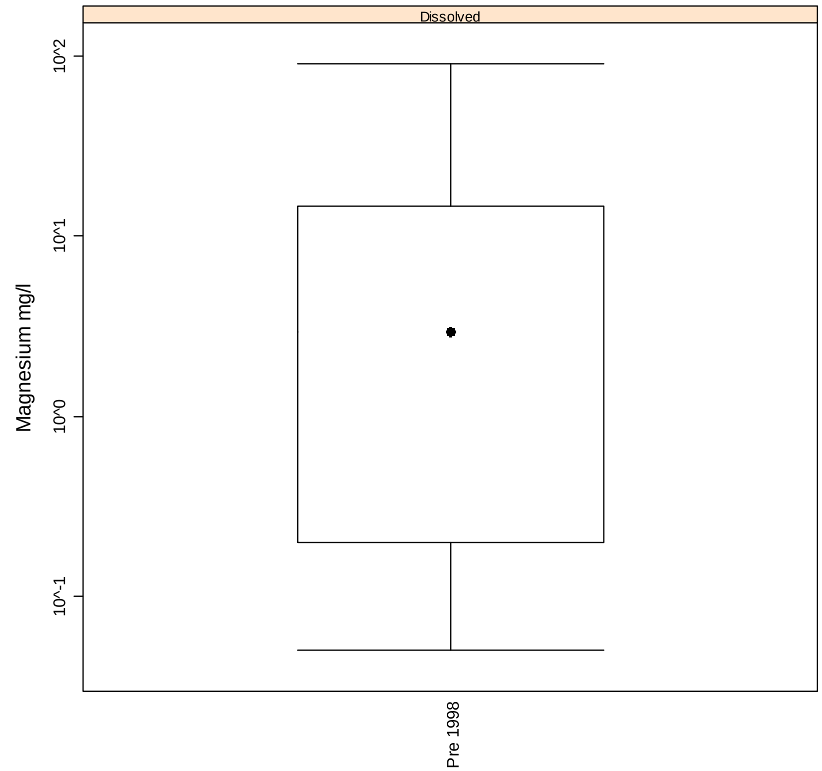
Table C-3. Summary of Model with Location Random Effect

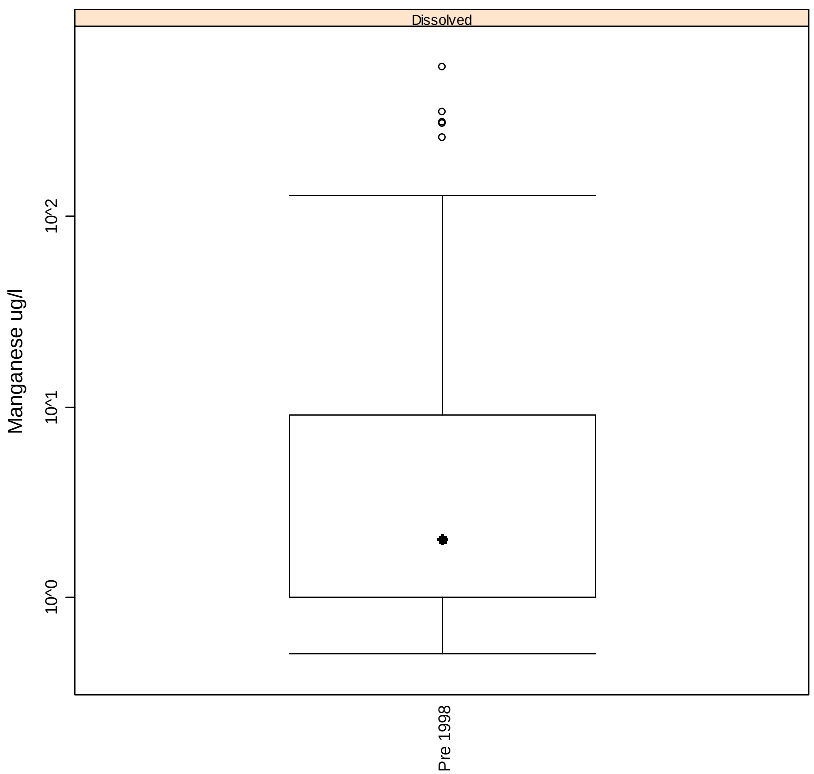
Constituent	Fraction	Coefficient	Significance & Direction	Pct Change (95% LB)	Pct Change (95% UB)	p value
Alkalinity as CaCO3	Dissolved					
		log(Well Depth)	Increasing	60.9	242.4	0.001
Alkalinity as CaCO3	Total					
		log(Well Depth)	Not significant			0.316
Calcium	Dissolved					
		log(Well Depth)	Decreasing	73.6	85.4	<0.001
Chloride	Dissolved					
		log(Well Depth)	Decreasing	6	26.8	0.002
Fluoride	(Unspecified)					
		log(Well Depth)	Increasing	1.9	11.2	0.003
Iron	Dissolved					
		log(Well Depth)	Not significant			0.300
Magnesium	Dissolved					
		log(Well Depth)	Decreasing	69.7	83.9	<0.001
Manganese	Dissolved					
		log(Well Depth)	Not significant			0.090
Sodium	Dissolved					
		log(Well Depth)	Increasing	47.5	97.5	<0.001
Sodium	Total					
		log(Well Depth)	Increasing	48.4	73.2	<0.001
Sulfate	Dissolved					
		log(Well Depth)	Not significant			0.580
Total dissolved solids	Dissolved					
		log(Well Depth)	Increasing	2.6	12.1	0.003

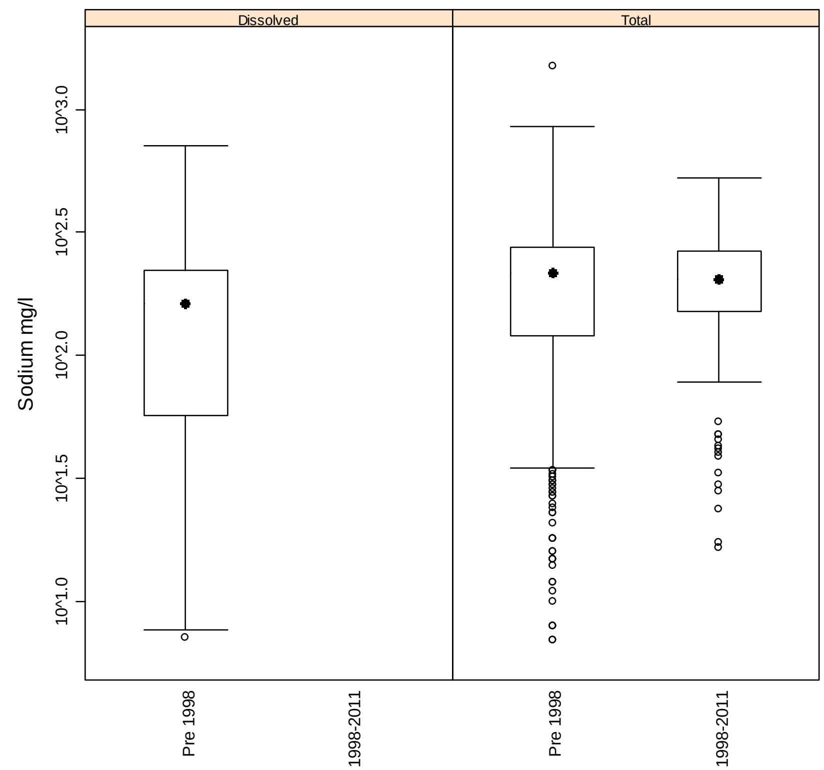

Dissolved
Chloride mg/l
10^0
10^1
10^2
10^3
Pre 1998
1998-2011

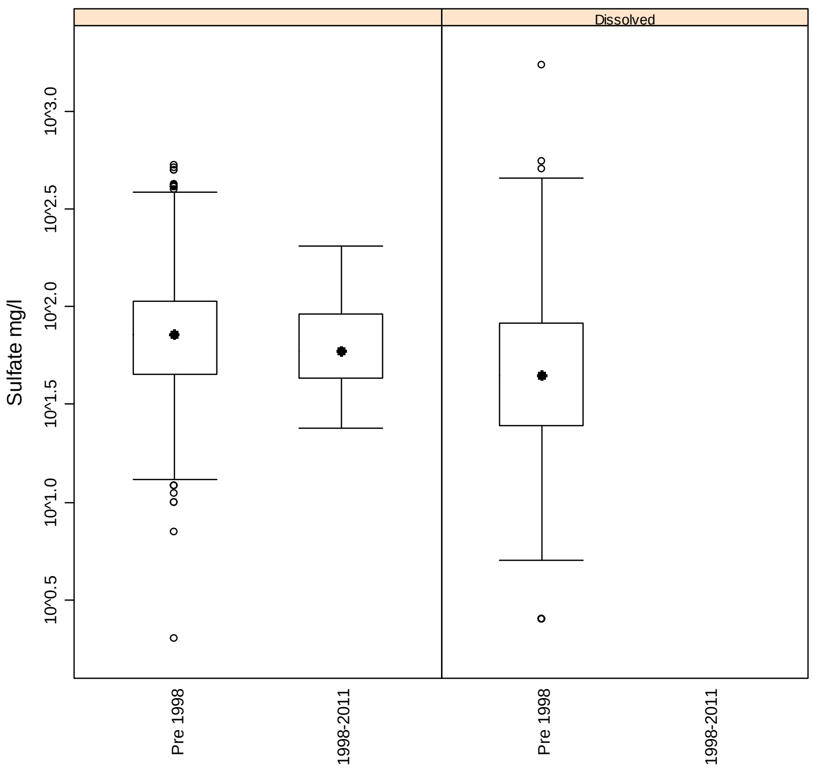

Dissolved
Fluoride mg/l
10^-2.0
10^-1.5
10^-1.0
10^-0.5
10^0.0
10^0.5
Pre 1998
1998-2011
Pre 1998
1998-2011

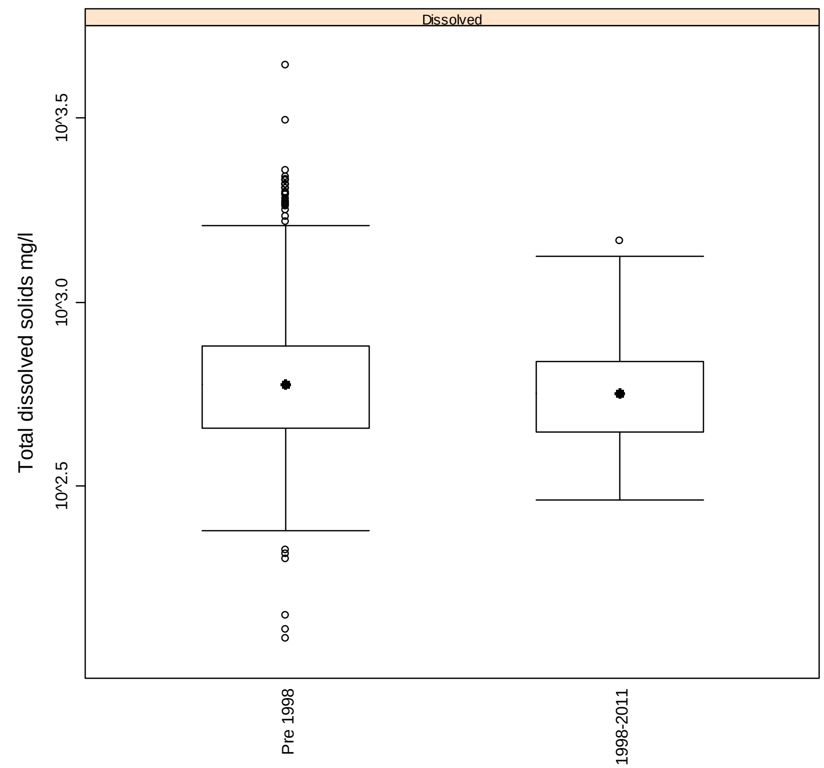

Dissolved
Iron ug/l
10^0.5
10^1.0
10^1.5
10^2.0
10^2.5
Pre 1998

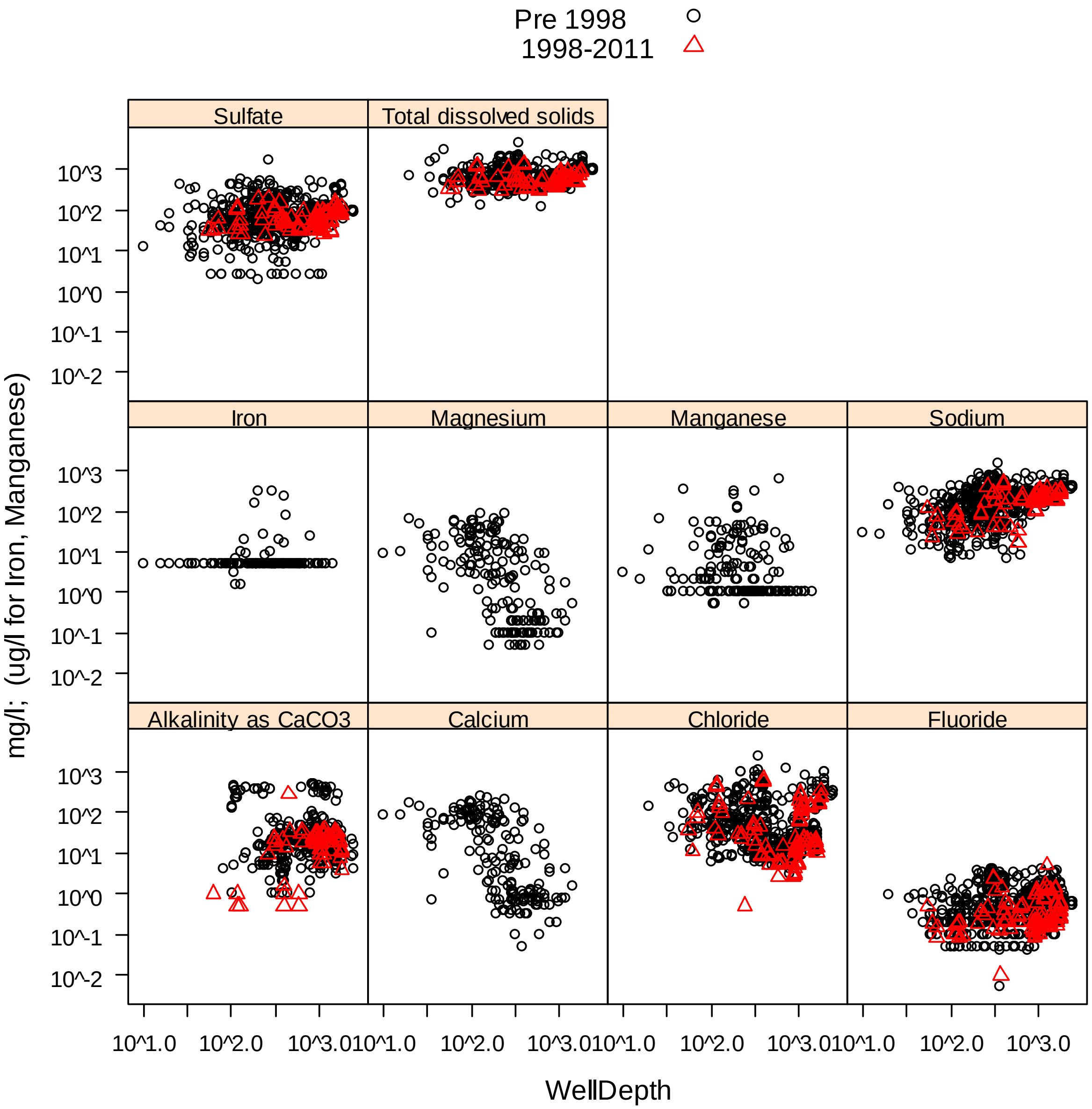

Dissolved
Magnesium mg/l
10^-1
10^0
10^1
10^2
Pre 1998


Dissolved
Manganese ug/l
10^0
10^1
10^2
Pre 1998

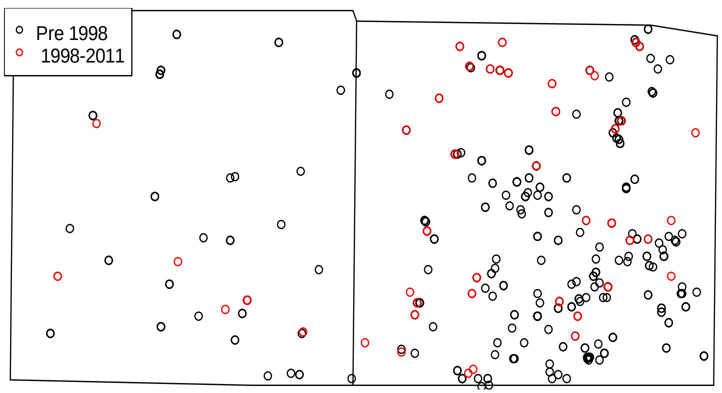

Dissolved
Total
Sodium mg/l
10^1.0
10^1.5
10^2.0
10^2.5
10^3.0
Pre 1998
1998-2011
Pre 1998
1998-2011


Dissolved
Sulfate mg/l
10^0.5
10^1.0
10^1.5
10^2.0
10^2.5
10^3.0
Pre 1998
1998-2011
Pre 1998
1998-2011

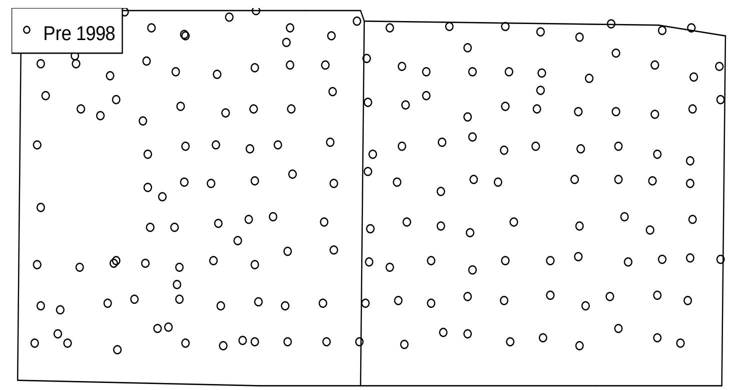

Dissolved
Total dissolved solids mg/l
10^2.5
10^3.0
10^3.5
Pre 1998
1998-2011


Pre 1998
1998-2011
Sulfate
Total dissolved solids
Iron
Magnesium
Manganese
Sodium
Alkalinity as CaCO3
Calcium
Chloride
Fluoride
10^3
10^2
10^1
10^0
10^-1
10^-2
mg/l; (ug/l for Iron, Manganese)
10^1.0
10^2.0
10^3.0
WellDepth

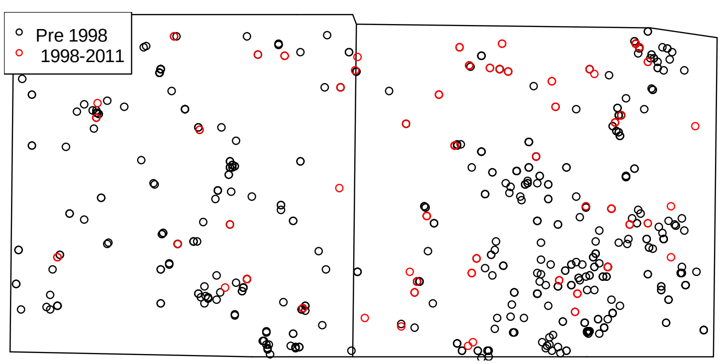
Locations of Groundwater Alkalinity as CaCO3 Observations



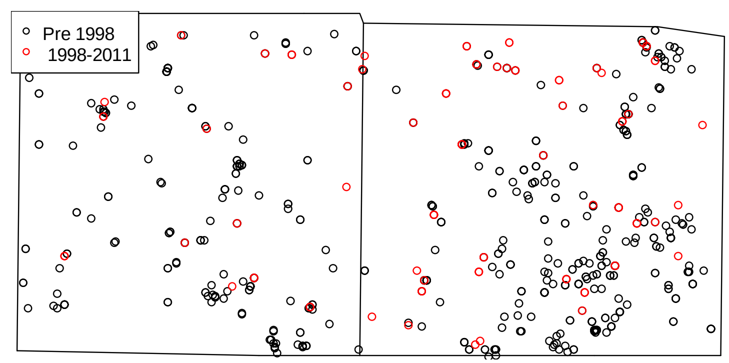
Locations of Groundwater Calcium Observations



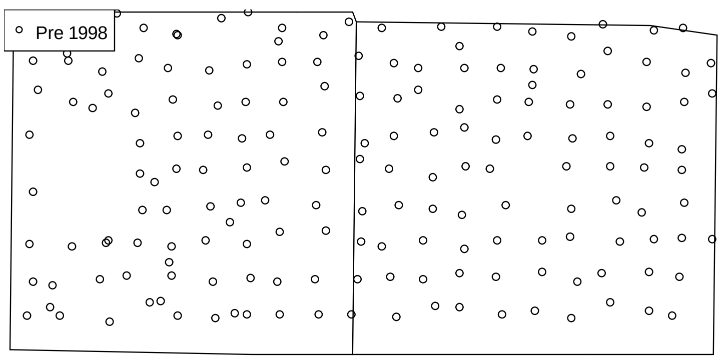
Locations of Groundwater Chloride Observations



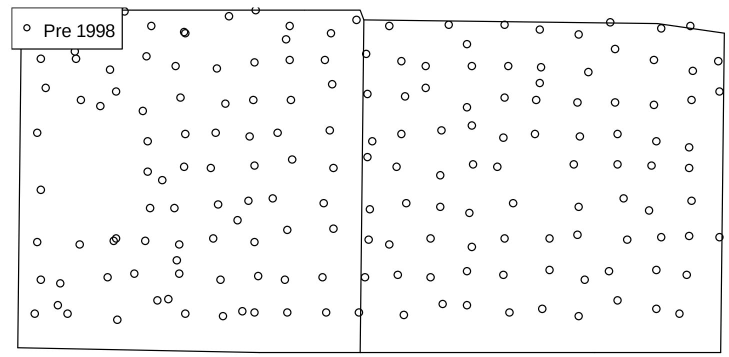
Locations of Groundwater Fluoride Observations



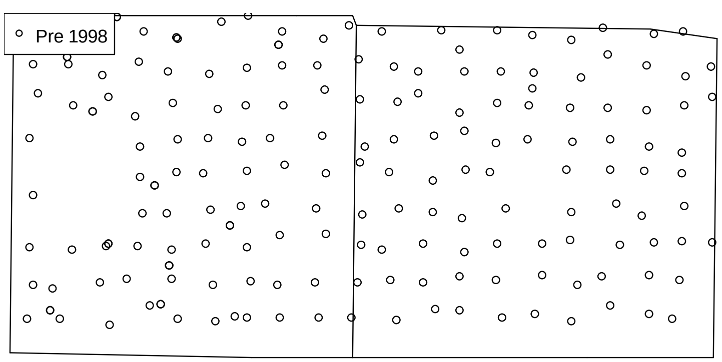
Locations of Groundwater Iron Observations



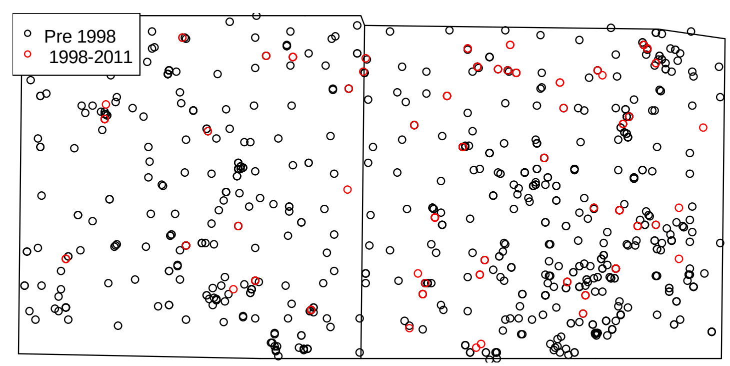
Locations of Groundwater Magnesium Observations



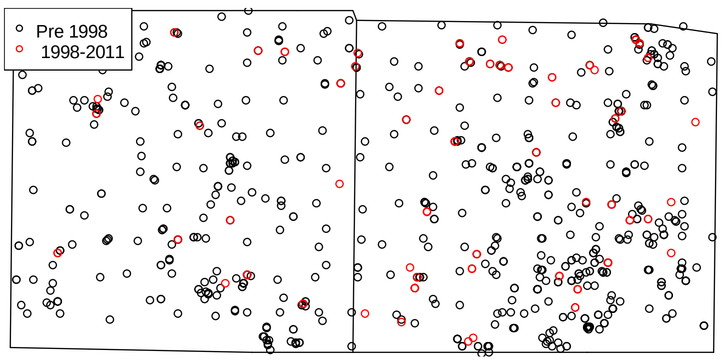
Locations of Groundwater Manganese Observations



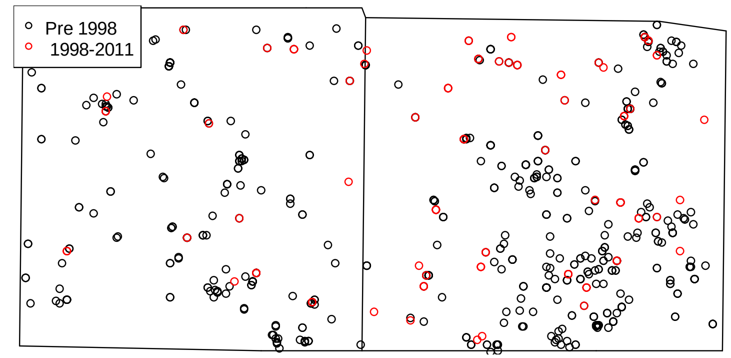
Locations of Groundwater Sodium Observations



Locations of Groundwater Sulfate Observations



Locations of Groundwater Total dissolved solids Observations



Wise and Denton Counties, Texas Surface Water Quality Analysis

Surface Data & Objective

There are 72 water quality station locations for surface water in Wise and Denton counties, Texas for which concentrations for arsenic, selenium, chloride and total dissolved solids were available. The locations of stations by constituent are shown in the schematic in Figures A1-A5. The 25 locations with observations on or after January 1998 are represented with red circles. The data are from three sources: EPA STORET (31 locations); NWIS (32 locations) and TWDB (9 locations). Most of the observations are the concentrations in the dissolved fraction. There were only a few locations with total fraction observations. Because there were only a few locations with total fraction, this analysis was done for the dissolved fraction only.

Table C-4. Summary of Dissolved Fraction Water Quality Source Locations

Source	EPA STORET		NWIS		TWDB	
Constituent	Pre 1998	1998-2011	Pre 1998	1998-2011	Pre 1998	1998-2011
Arsenic	6	2	7	2	1	2
Selenium*	4	2	7	2	1	1
Chloride	21	8	23	13	6	5
Sulfate	21	7	23	13	6	5
Total dissolved solids	13	8	23	13		4

*Note: dissolved selenium results – Pre 1998: 152/173 results are ND; 1998-2011: 60/62 results are ND

Entries in the table indicate the number of locations with observations from the two periods, by source.

Methods

Regression analyses were performed for each constituent's log concentrations with a regression model that includes as covariates: an indicator for source of data, an indicator for period (pre or post January 1998), and a covariate for linear trend. The trend covariate was included in the model to adjust for a general linear trend seen in several stations with observations taken over several decades. Profiles of available data over time are plotted in Figures B1-B5 for a sample of locations for each constituent. A random effect is included for location to location variability in trend.

The model for analysis is as follows:

$$C_{ij} = \mu + Source_{ij} + Period_{ij} + Day_{ij} + Location_j + Day_{i(j)} + \varepsilon_{ij}$$

where

- C_{ij} is the log-transformed observed response for the i^{th} observation at the j^{th} location
- μ is an overall constant
- $Source_{ij}$ is an indicator for data source of *i*th observation at the j^{th} location
- $Period_{ij}$ is an indicator for whether the *i*th observation was taken prior to January 1998
- Day_{ij} is the effect of an overall trend in log concentration over time

- *Location$_j$* is a random effect representing between-location variability, of the j^{th} location, assumed to be normally distributed with mean 0 and variance τ^2
- *Day$_{i(j)}$* is a random effect of trend slope offset, assumed to be normally distributed with mean 0 and variance η^2
- and ε_{ij} are the random error terms, assumed to be normally distributed with mean 0 and variance σ^2.

Results

Figure C1-C5 are box plots of the log concentrations for each constituent by source and period. Table C-5 summarizes the estimated 95% confidence bounds of relative changes, expressed on the natural scale, for those coefficients that were statistically significantly different from zero. The p-value indicates the significance of each factor (source, period or trend) as determined by an ANOVA extra sum of squares F test, for the significance of the factor in reducing the residual variance in the model.

For all constituents except selenium, source was not a significant factor, although for TDS and sulfate, concentrations of NWIS and TWDB, respectively, are estimated to be less than those from EPA STORET (when all other factors are equal). For total dissolved solids, the coefficient for the offset for NWIS data indicates that concentrations reported from this source are between 3-32% less than those from EPA STORET (all other factors being equal). For sulfate, the coefficient for TWDB data indicates that concentrations are between 2-61% less than those from EPA STORET (all other factors being equal). Concentrations for selenium recorded in NWIS are estimated to be 30% less than EPA STORET (all other factors being equal). Although selenium concentrations for TWDB are estimated to be 8% less than EPA STORET, the coefficient for the TWDB indicator covariate is not significantly different from 0.

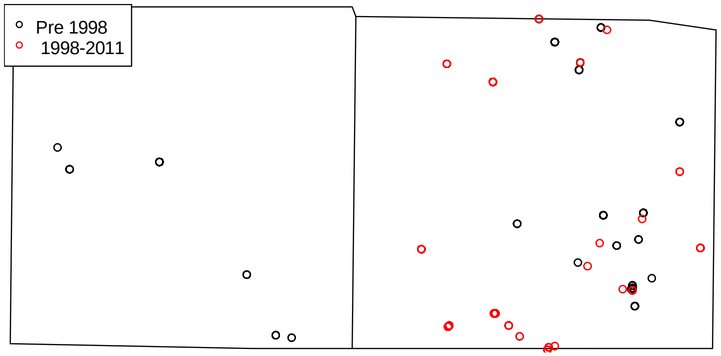
There is an apparent decreasing trend in concentrations for chloride. Concentrations are estimated to decrease by 1% per year.

Several locations have multiple observations over the course of each year for which data were collected. Some of the concentrations are temporally correlated. Depending on the constituent, some half-dozen to a dozen stations have monthly data. Typically, the observations were taken at irregular intervals in time. There are also some stations with only a single observation. Due to the structure of the dataset, it was not practical to model temporal correlation in the structure for residuals. As a result, the significance of some of the effects may be overstated.

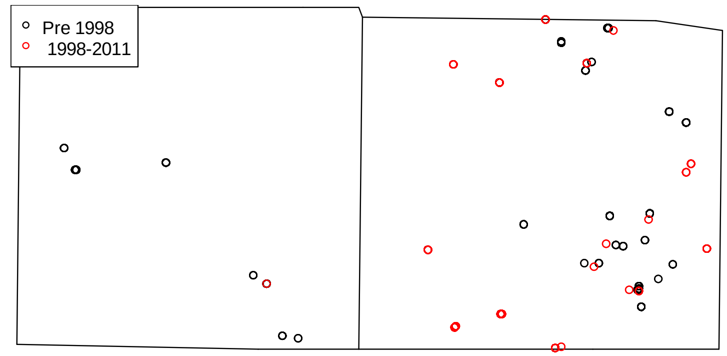
Constituent	Coefficient	Significance & Direction	Relative Change 95% lower	Relative Change 95% upper	Factor	ANOVA p value
Arsenic						
	Source NWIS	Not significant			Source	0.154
	Source TWDB	Not significant				
					Period	0.183
	Trend	Not significant			Trend	0.426
Selenium						
	Source NWIS	**NA**	**NA**	**NA**	**NA**	**NA**
	Source TWDB	NA	NA	NA	NA	NA
	Trend	NA	NA	NA	NA	NA
Chloride						
	Source NWIS	Not significant			Source	0.924
	Source TWDB	Not significant				
	Trend (per year)	**Decrease**	0.2	1.7	Trend	0.011
TDS						
	Source NWIS	**Decrease**	3.2	32.1	Source	0.085
	Source TWDB	Not significant				
	Trend (per year)	Not significant			Trend	0.678
Sulfate						
	Source NWIS	Not significant			Source	0.093
	Source TWDB	**Decrease**	2.2	61.3		
	Trend (per year)	Not significant			Trend	0.553

NA: Insufficient detected results for analysis

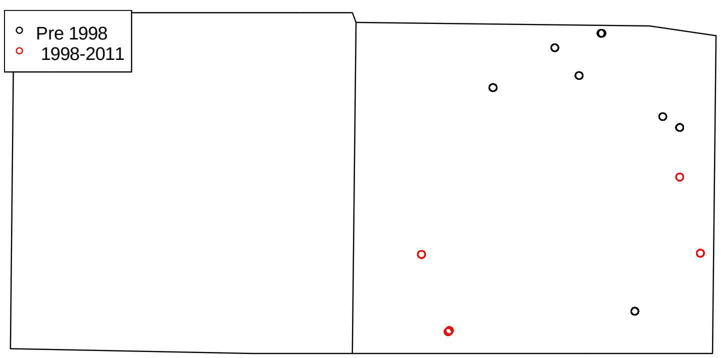
Locations of Surface Water Total dissolved solids Observations



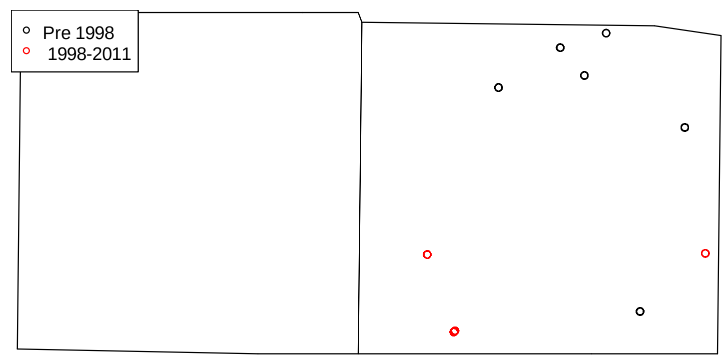
Locations of Surface Water Chloride Observations



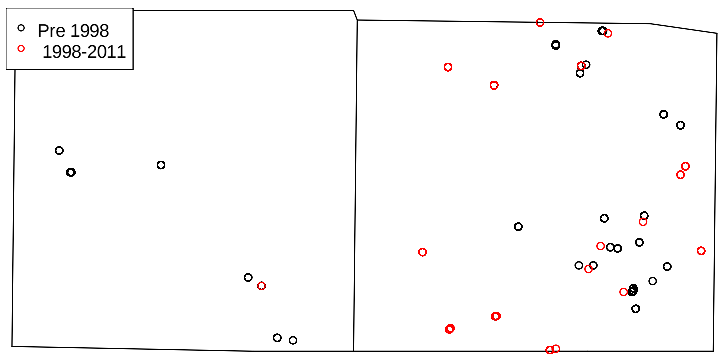
Locations of Surface Water Arsenic Observations



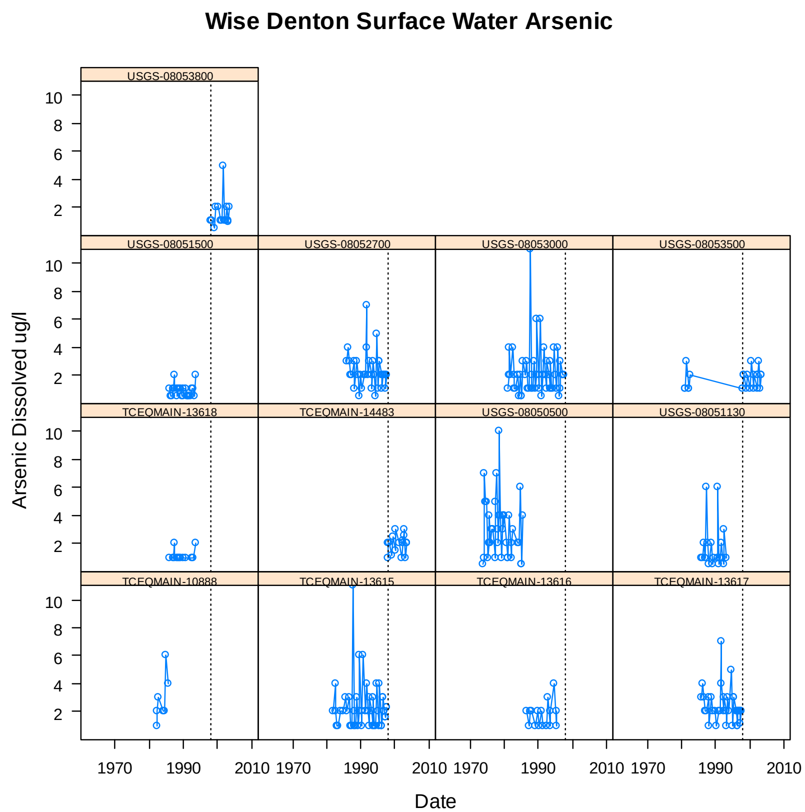
Locations of Surface Water Selenium Observations

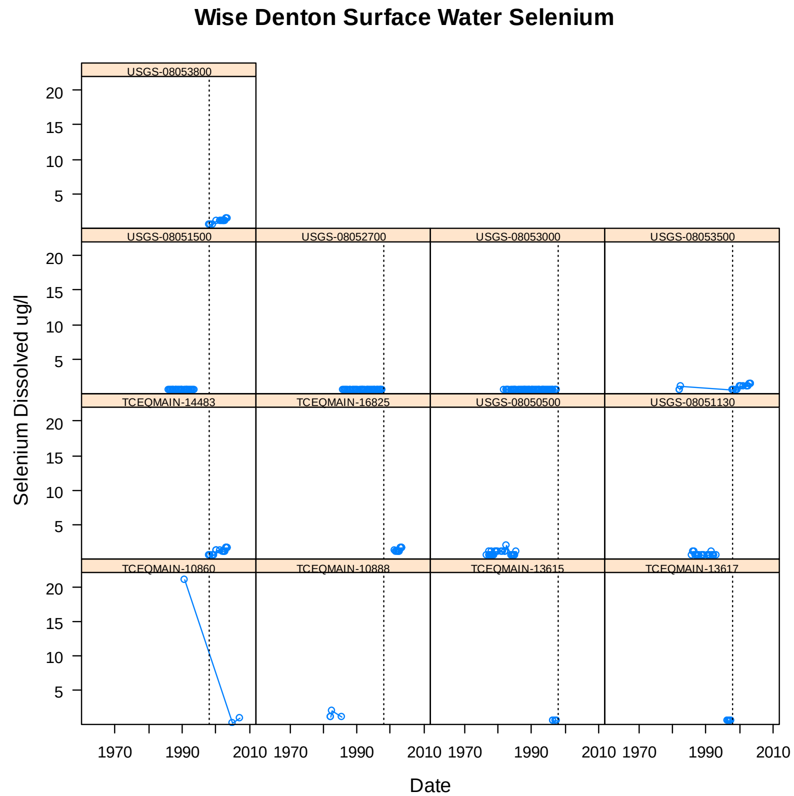


Locations of Surface Water Sulfate Observations



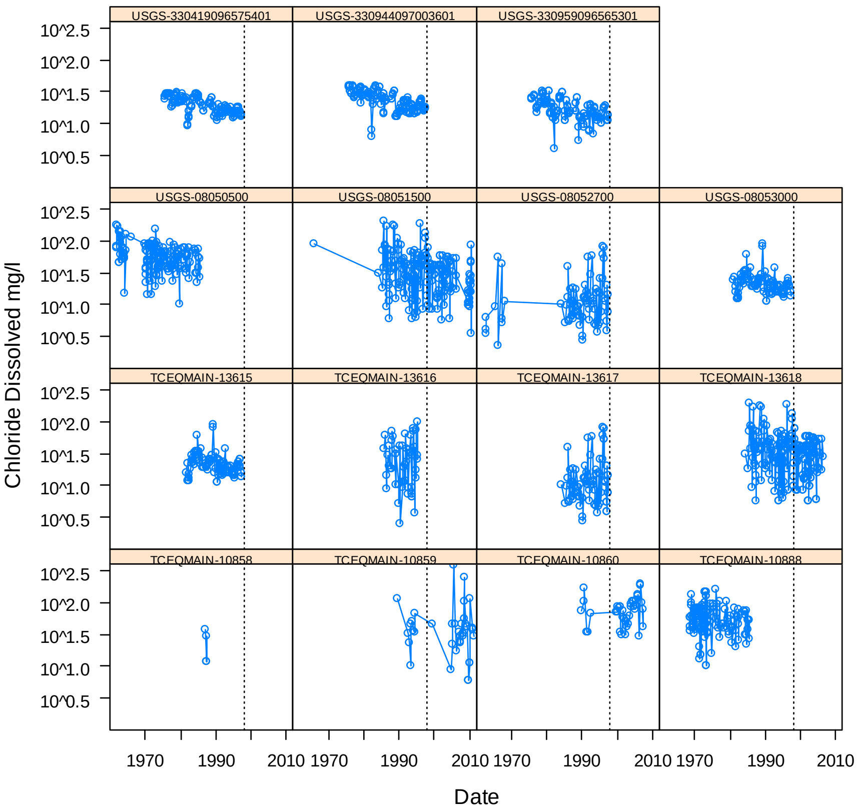
)



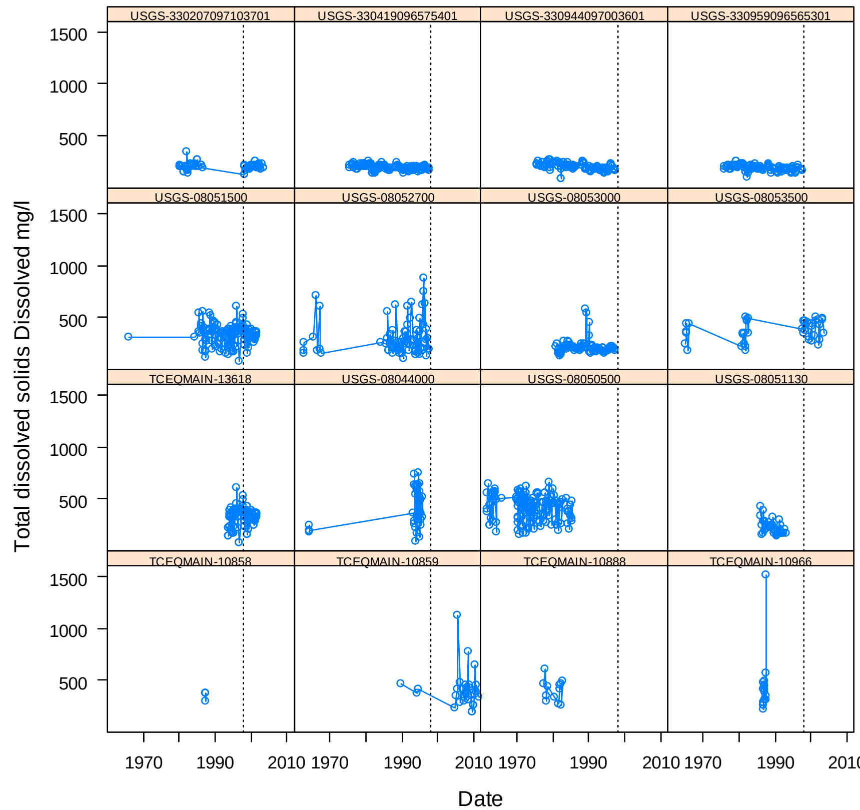


Figures B1-B5. Profiles of arsenic, selenium, chloride, TDS and sulfate dissolved fraction concentrations for a sample of locations. Locations with data collected since the 1970's have profiles that suggest that there may have been a decreasing trend in the concentrations of some of the constituents over the last decades.

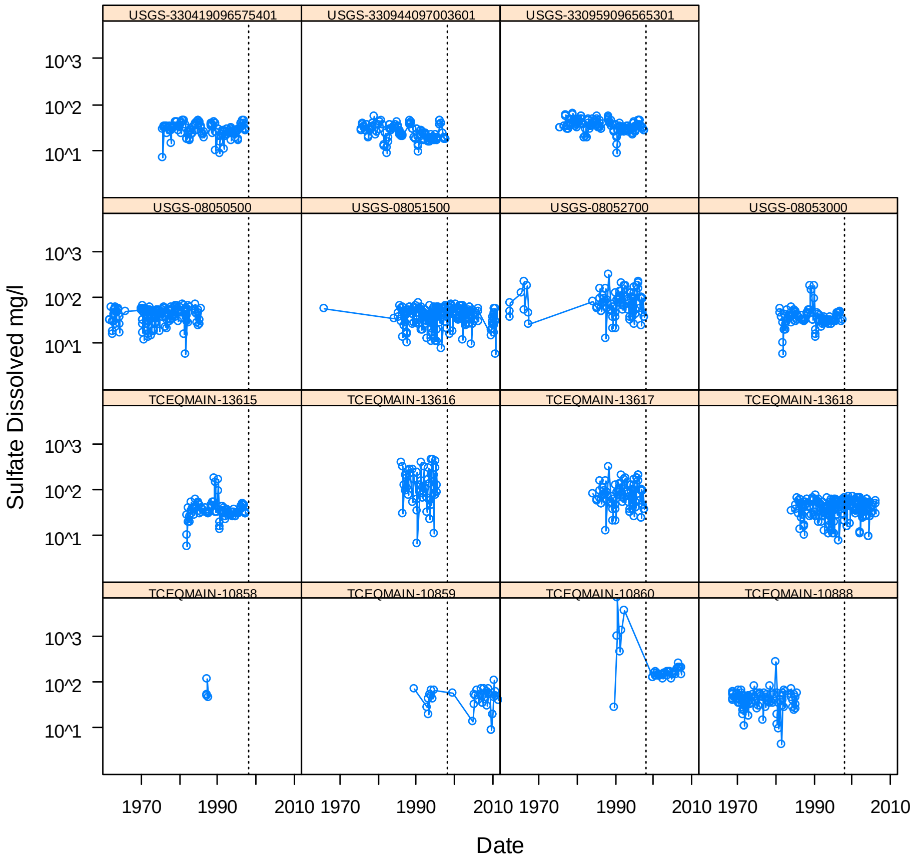
Wise Denton Surface Water Chloride

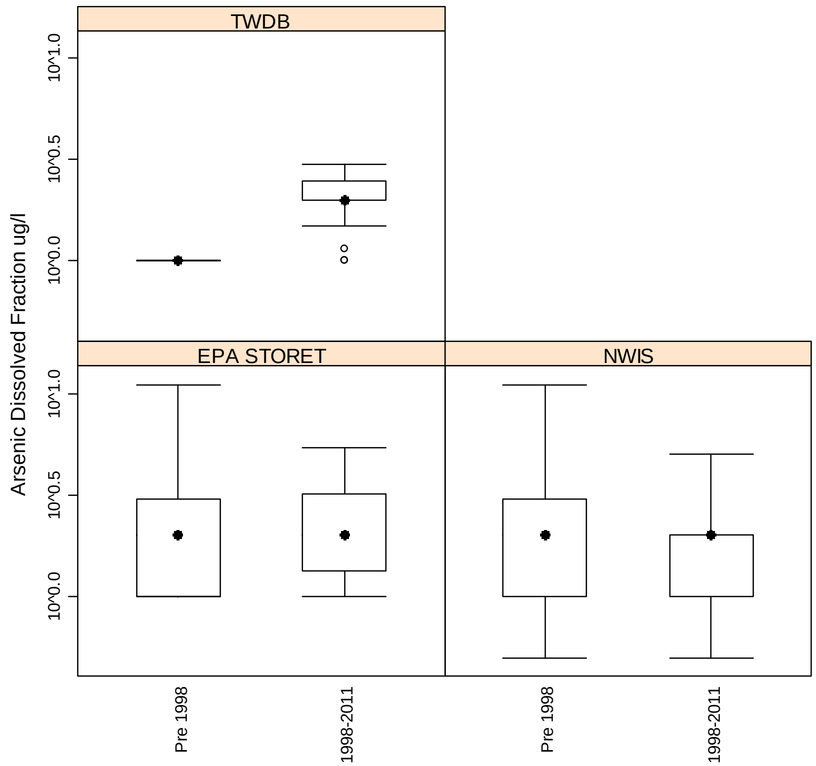


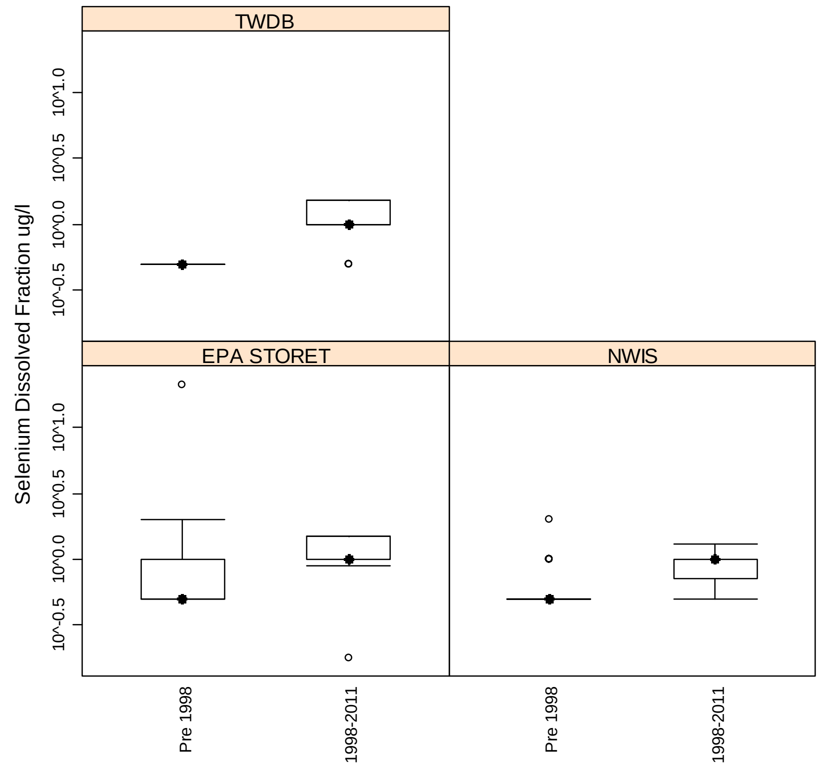
Wise Denton Surface Water Total dissolved solids

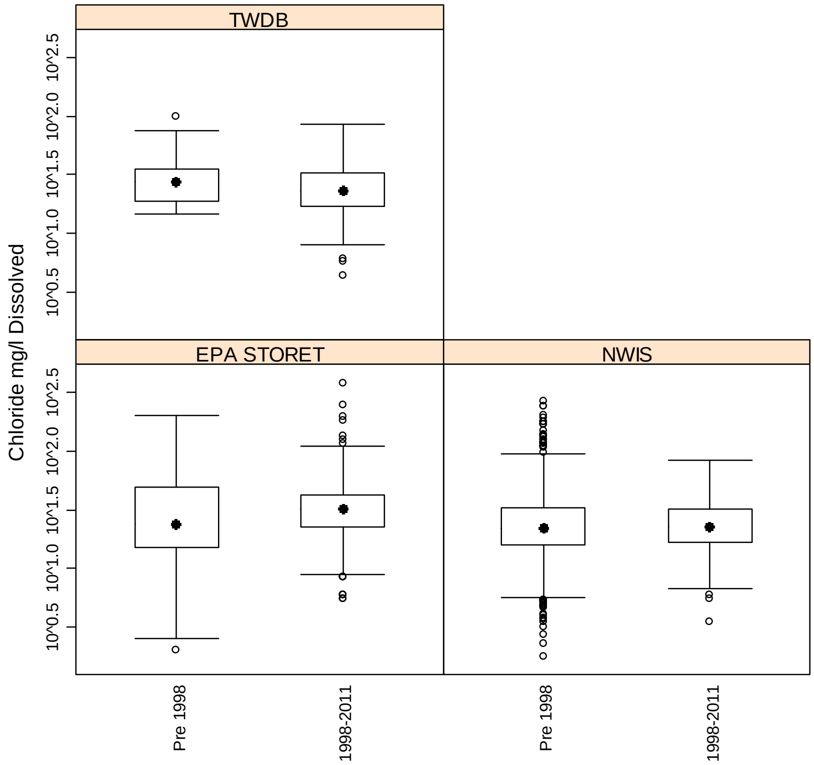


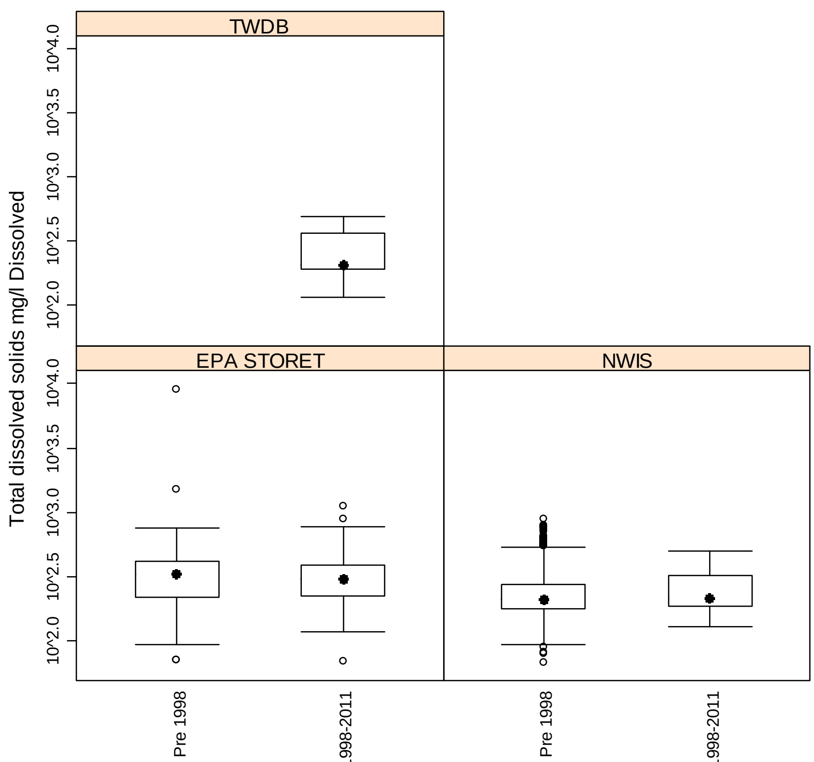
Wise Denton Surface Water Sulfate

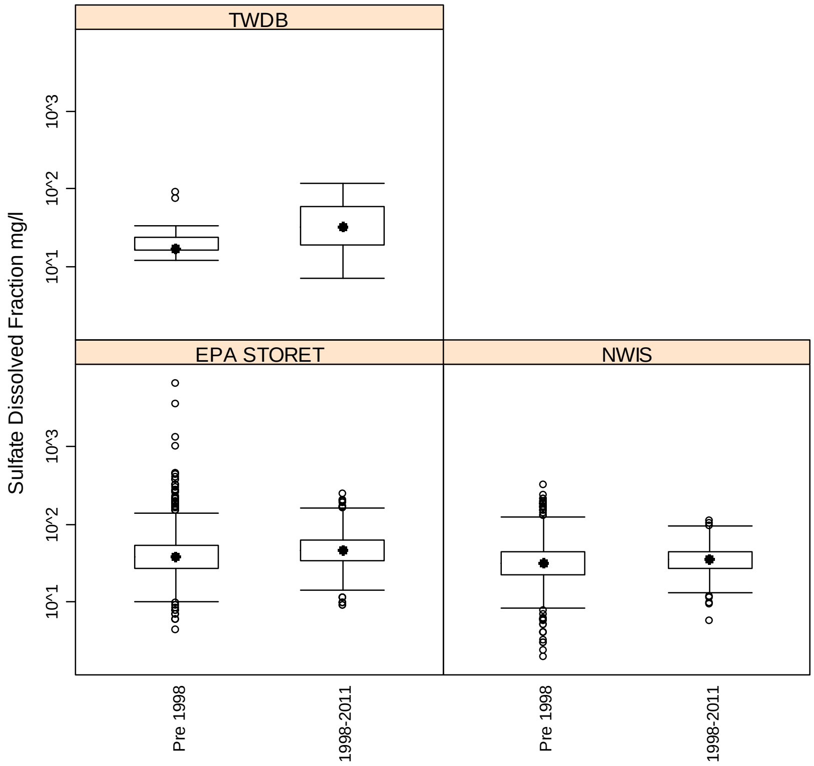



TWDB
EPA STORET
NWIS
Arsenic Dissolved Fraction ug/l
10^0.0
10^0.5
10^1.0
Pre 1998
1998-2011


TWDB
EPA STORET
NWIS
Selenium Dissolved Fraction ug/l
10^-0.5
10^0.0
10^0.5
10^1.0
Pre 1998
1998-2011


TWDB
EPA STORET
NWIS
Chloride mg/l Dissolved
10^0.5
10^1.0
10^1.5
10^2.0
10^2.5
Pre 1998
1998-2011


TWDB
EPA STORET
NWIS
Total dissolved solids mg/l Dissolved
10^2.0
10^2.5
10^3.0
10^3.5
10^4.0
Pre 1998
1998-2011



The total dissolved solids observation at TCEQMAIN-10860 on 8/28/1990 (sample name TCEQMAIN-61668) was suspiciously high: 9000 mg/l (the next highest value was 1510 mg/l). The regression analysis for TDS was repeated with and without this observation. The conclusions for significance were unchanged.

Appendix D

Groundwater Contamination Tables

Explanation of Tables

The tables presented here (Tables D-1 through D-3) are from the "Joint Groundwater Monitoring and Contamination Report – 2004," the Texas Groundwater Protection Committee's (TGPC's) annual report on current groundwater monitoring activities and documented contamination associated with all state-regulated activities. The tables summarize the report's groundwater quality information regarding Denton and Wise counties.

Each of the tables are laid out in columns (Figure D-1) with the heading above each column describing the data field below. The names of and descriptions of each data field as they are found in the "Joint Groundwater Monitoring and Contamination Report – 2010" are in the table below.

Data Field Name	Data Field Description
New Cases	An asterisk denotes each case that was not listed in the previous year's report.
File Name	Consists of: company names, cities, persons, or other entities considered potentially responsible parties or otherwise associated with the case. File names may also consist of geographic location names or well numbers.
File Number	Identification number assigned to the case by the numbering system used by the agency or program with jurisdiction for the case.[1]
Location	Location references. Most location descriptions refer to cities and addresses, others are geographic locations using distances from known points.
Contamination Description	Consists of a listing of contaminants or general group of contaminants (such as "gasoline" or "creosote constituents"). Abbreviations, explained at the beginning of each table, may also be used.
Date	The earliest date of contamination confirmation at the site by the jurisdictional agency or program. More detail on the significance of this field is given at the beginning of each table if the date represents something other than the above definition.
Enforcement Status	A two-to-four character code representing the status of the case with respect to agency enforcement action and contamination site activity.[2]
Data Quality	A code (up to 6 characters) describing the reliability of analytical data used by each regulatory agency to analyze the case. Addresses field and laboratory quality assurance procedures and data reliability and quality in determining conclusions for each case.
Section 5.236 (TCEQ Table Only)	Included in Table 1 only to distinguish cases subject to notification requirements under §5.236 TWC. A "Y" code identifies cases in which contamination has or may potentially affect a public drinking water supply.[3] The "Y" code appears only in the report for the year in which the case is listed as a new case (cases requiring such notification identified in previous reports are not duplicated in this report).

1 File numbers can be used to access the files of the regulating agency to obtain data on each groundwater contamination case listed in Tables 1 through 3. Cases without file numbers may be accessed in the regulating agencies' files with the case file name.

2 The regulatory agencies reporting the contamination cases have procedures and internal structures that differ from agency to agency. Definitions and descriptions for enforcement or activity status have been generalized to account for these differences. A more detailed explanation is given in the following section entitled Enforcement Status Matrix.

3 An entry in this field constitutes secondary notification from the TCEQ to local officials for cases reported since the publication of the previous report.

Figure D-1. Summary of Column Headings and Their Descriptions

Under the “Enforcement Status” of each table there are two sets of numbers. The first number is the enforcement status of the file and the second number provides the activity status (the status of the activity taken on a contaminated site). Each enforcement and activity status should be read (YA, XA) where Y corresponds to the number on the vertical Enforcement Status and X represents the number on the horizontal Activity Status in Figure D-2. The alphabetical code in YA or XA corresponds to a level of agency response or level of contaminated activity from a site. More information on the alphabetical coding of the enforcement and activity statuses can be found in Figures D-3 and D-4.

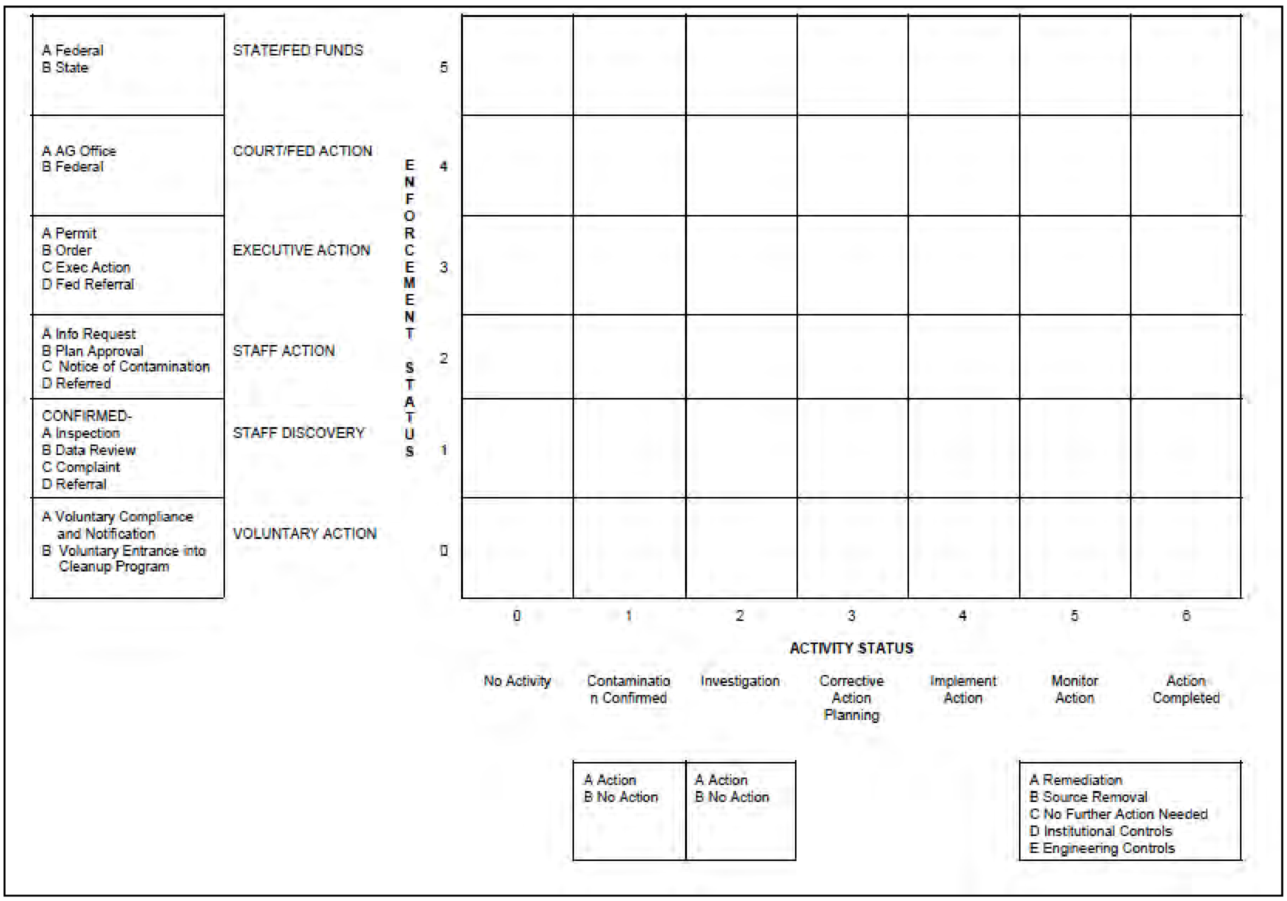


Figure D-2. Enforcement Status Matrix

Code	Enforcement	Description
0	Voluntary Action	An entity addresses the contamination incident, without being compelled to do so by enforcement action, and either A) reports its actions to the agency, or B) enters into an agency's voluntary cleanup program.
1	Staff Discovery	The agency confirms identification of a contamination incident through its activities, such as: A) inspections, B) reviews of self-reported data, C) complaints received, or D) referrals received from other agencies.
2	Staff Action	The agency initiates an action to address a contamination incident, such as: A) an information request of the entity, B) approval of a work plan (e.g., assessment, corrective action, etc.), C) sending a notice of contamination to affected parties, or D) referring the incident to another agency with jurisdiction.
3	Executive Action	Action at the highest level of the agency, such as: A) issuing a permit with corrective action provisions; B) issuing an administrative order; C) other executive level action such as letter of approval or revocation, or conditional or final release of liability; or, D) referral to federal authorities such as U.S. EPA.
4	Court or Federal Agency Action	When other options fail or do not apply, an agency can: A) seek legal representation by the Texas Attorney General before the courts, or B) let federal agencies seek resolution according to federal laws or programs.
5	State or Federal Funds	The agency, by utilizing special federal (option A) or state (option B) funds, finances the cost of addressing contamination incidents. Examples are the federal and state "superfunds" for abandoned waste sites, and the state fund for plugging oil and gas wells.

Figure D-3. Description of Enforcement Status

Code	Activity	Description
0	No Activity	No actions have been conducted at the incident site.
1	Contamination Confirmed	Contamination is being verified through resampling or data quality validation, etc. Options are to: A) take action and investigate further if validated or required, or B) not take action based on confirmation findings.
2	Investigation	The incident is being studied to determine the extent, composition, and/or other properties and circumstances of the contamination. Additional action A) may or B) may not be required based on investigation findings.
3	Corrective Action Planning	A remedy (corrective action plan) for the contamination is being developed (based on the investigation findings). General examples include plans to: remove the source of contamination, remediate impacted groundwater, disinfect or replace wells, etc.
4	Implement Action	The planned remedy (corrective action plan) is being carried out. Actions to address the contamination are being conducted.
5	Monitor Action	The effectiveness of the remedy is being monitored. This can be a long- or short-term action and can be performed during and after implementation.
6	Action Completed	The remedy is considered complete when the desired result has been achieved. Options include: A) remediation efforts were completed (contaminants reduced to health based levels); B) the contaminant source was removed and the impact addressed; C) no further regulatory action required; D) agency action final, however, contamination still exists under institutional controls (deed records noting contamination; use and exposure restrictions; required maintenance of engineering controls, etc.); or, E) agency action final, however, contamination still exists under required engineered controls.

Figure D-4. Description of Activity Status

It should also be noted that all of the agencies and divisions in the tables are acronyms. A list of the acronyms and their meanings are given in Figure 5.

Acronym	Agency/Devision
RMD/CA	Remediation Division/Corrective Action Section (TCEQ)
RMD/PST	Remediation Division/Petroleum Strage Tank Section (TCEQ)
RMD/VC	Remediation Division/Voluntary Cleanup (TCEQ)
RMD/VCBSA	Remediation Division/Voluntary Cleanup, Brownfeilds Site Assessment (TCEQ)
RMD/VCIO	Remediation Division/Voluntary Cleanup/Innocent Owner (TCEQ)
TNRCC	Texas Natural Resource Conservation Commission (see TCEQ)
TCEQ	Texas Commission on Environmental Quality
WPD/MSW	Waste Permits Division/Municipal

Figure D-5. Acronyms

Table D-1. Groundwater Contamination Case Description

County Data	New Cases	File Name	File Number	Location	Contamination Description	Date	Enforcement Status	Division Quality	Section 5.236
Denton RMD/CA									
		SAFETY KLEEN CORP	65124	1722 COOPER CREEK RD DENTON 76208	DIESEL	1/22/1988	1B 4, 5	E,Q	
RMD/DCRP									
		BAUMGART FAMILY CLEANERS	DC0047	2216 LONG PRAIRIE ROAD, FLOWER MOUND	CHLORINATED SOLVENTS, BTEX	8/25/2006	5B,2A 2A	E,Q	N
		COMET CLEANERS - DENTON	DC0152	507 WEST UNIVERSITY DRIVE	CHLORINATED SOLVENTS	4/17/2008	2B 0	E	N
		GARDEN RIDGE PLAZA - FORMER CALCON CLEANERS	DC0112	601 CROSS TIMBERS ROAD	CHLORINATED SOLVENTS	9/28/2001	2B, 5B 2A	E	N
		HI-TECH CLEANERS - NORTH COLONY	DC0006	6805 MAIN STREET, THE COLONY	CHLORINATED SOLVENTS	1/10/2005	2B, 5B 2A	E	N
RMD/PST									
		380 MARKET CHEVRON MCMAHAN OIL	108765	1205 E UNIVERSITY DR, DENTON	GASOLINE	11/16/1994	2 6	E,Q	
		7 ELEVEN IN/SHAW	118067	193 CORPORATE DR, LEWISVILLE	GASOLINE	6/10/2009	2 6	E,Q	
		7 ELEVEN INC	117152	1629 W UNIVERSITY, DENTON	GASOLINE	3/16/2007	2 6	E,Q	
		7 ELEVEN INC	117690	1610 TEASLEY LN, DENTON	GASOLINE	4/21/2008	2 6	E,Q	
		7 ELEVEN INC	116843	966 S MILL ST, LEWISVILLE	GASOLINE	5/5/2006	2 6	E,Q	
	*	BECK W C	118446	110 PAULINE ST, DENTON	GASOLINE	12/3/2010	2 6	E,Q	
		CHEVRON EMC	116149	1099 W MAIN ST, LEWISVILLE	GASOLINE	10/4/2004	2 6	E,Q	
		CHEVRON PRODUCTS CO	116139	1301 S HWY 121, LEWISVILLE	GASOLINE	9/27/2004	2 2A	E,Q	
	*	CIENA CAPITAL	118068	1829 W FRANKFORD RD, CARROLLTON	GASOLINE	6/10/2009	2 2A	E,Q	
		CONOCOPHILLIPS	116103	660 N STEMMONS, LAKE DALLAS	GASOLINE	9/14/2004	2 6	E,Q	
		DENTON TANK RENTAL INC	113776	220 STEMMONS FWY, DENTON	GASOLINE	12/9/1998	2 2A	E,Q	
		EXXONMOBIL	115965	102 W UNIVERSITY AVE, DENTON	GASOLINE	5/11/2004	2 6	E,Q	
		GIBSON RON	114694	331 N MILL ST, LEWISVILLE	GASOLINE, DIESEL	7/27/1999	2 2A	E,Q	
		GITA K SAMADI	110351	7616 N MAIN ST, THE COLONY	GASOLINE	3/8/1996	2 2A	E,Q	
		JESWOOD OIL CO	114011	1213 E UNIVERSITY, DENTON	GASOLINE, WASTE OIL	1/6/1999	2 4	E,Q	
		JESWOOD OIL CO	114189	801 N IH 35, DENTON	GASOLINE, WASTE OIL	1/7/1999	2 4	E,Q	
		KARL KLEMENT PROPERTIES	116571	923 S CARROLL ST, DENTON	UNKNOWN	7/28/2005	2 6	E,Q	
		KELSOE TRACTOR CO INC	113643	915 FORT WORTH DR, DENTON	GASOLINE, DIESEL	11/23/1998	2 6	E,Q	

County Data	New Cases	File Name	File Number	Location	Contamination Description	Date	Enforcement Status	Division Quality	Section 5.236
		KELSOE TRACTOR CO INC	113659	200 W WALCOTT, PILOT POINT	GASOLINE, DIESEL	11/17/1998	2 2A	E,Q	
		MARINAS INTERNATIONAL	117855	1481 E HILL RD, LEWISVILLE	GASOLINE	9/23/2008	2 2A	E,Q	
		MARTIN EAGLE OIL CO INC	117524	FM 407, ARGYLE	UNKNOWN	1/3/2008	1B 1A	E,Q	
		METRO PETRO RENTALS INC	113742	434 S MILL, LEWISVILLE	GASOLINE	12/2/1998	2 2A	E,Q	
		MILLENNIUM GASOLINE CORP	116240	3012 E UNIVERSITY DR, DENTON	UNKNOWN	11/5/2004	2 2A	E,Q	
		MOTIVA ENTERPRISES LLC	115706	1823 N ELM ST, DENTON	UNKNOWN	4/18/2003	2 6	E,Q	
		NORTH TEXAS TANK RENTAL INC	113741	1724 BERNARD, DENTON	GASOLINE	12/2/1998	2 6	E,Q	
		NORTHWEST ISD	114611	18501 HWY 114, JUSTIN	GASOLINE, DIESEL	5/27/1999	2 2A	E,Q	
		SHAMROCK ADVENTURES XXL LTD	114554	1903 N LOCUST ST, DENTON	UNKNOWN	4/20/1999	2 2A	E,Q	
		SPRUANCE OWEN	107133	515 IH 35, DENTON	GASOLINE	10/14/1993	2 6	E,Q	
		SUNPOWER INC	094606	6421 N IH 35 E, DENTON	DIESEL	1/5/1990	2 6	E,Q	
	*	TRIPLE A FUELS INC	118452	4916 FM 423, THE COLONY	GASOLINE	12/14/2010	2 2A	E,Q	
		TRIPLE A OIL CO	111264	120 N WASHINGTON, PILOT POINT	GASOLINE	8/28/1996	2 6	E,Q	
		TRIPLE A OIL CO INC	117504	1301 W FM 407, LEWISVILLE	GASOLINE	12/10/2007	2 6	E,Q	
		TRIPLE A OIL CO INC	116956	100 S HWY 377, KRUGERVILLE	UNKNOWN	8/29/2006	2 2A	E,Q	
		UAC OF GARLAND INC	100282	7228 N MAIN ST, THE COLONY	GASOLINE	9/26/1991	2 2A	E,Q	
		UNDERGROUND SOLUTIONS INC	113738	W HWY 380, PONDER	GASOLINE, DIESEL	12/2/1998	2 6	E,Q	
		VICTRON STORES	117942	3000 W UNIVERSITY DR, DENTON	GASOLINE	1/6/2009		E,Q	
RMD/VC							0B 5		
		ANDERSON GREENWOOD & CO. (SOUTH RICE)	845	5425 SOUTH RICE AVENUE, HOUSTON	CHLORINATED SOLVENTS,TPH, BTEX	10/8/1998	0B 2B	E	
	*	DALLAS HOUSING AUTHORITY CENTRAL MAINTENANCE	879	2075 WEST COMMERCE ST, DALLAS	METALS, SOLVENTS, HYDROCARBONS	11/25/1998	0B o	E	
		EAGLE PICHER AUTOMOTIVE GROUP	267	1500 IH 35W, DENTON	TPH, VOCS	6/3/1996	0B 1A	E	
		EAST END CORRIDOR III	2233	5504-5592 HARRISBURG BOULEVARD, HOUSTON	VOCS, HEAVY METALS, CHLORINATED SOLVENTS, TPH	11/12/2008	0B o	E	
		GARDEN RIDGE PLAZA CENTER	1391	601 CROSS TIMBERS ROAD	CHLORINATED SOLVENTS	9/24/2001	0B 4	E	

County Data	New Cases	File Name	File Number	Location	Contamination Description	Date	Enforcement Status	Division Quality	Section 5.236
		OAKITE PRODUCTS FACILITY	526	10100 HIRSCH ROAD, HOUSTON	VOCS, METALS	5/14/1997	0B o	E	
		OLD ORCHARD SHOPPING CENTER	403	1310 WEST MAIN STREET, LEWISVILLE	CHLORINATED SOLVENTS	11/18/1996	0B o	E	
		SNAZZY CLEANERS	171	OLD ORCHARD VILLAGE EAST, 1228 W. MAIN, LEWISVILLE	CHLORINATED SOLVENTS	1/23/1996	0B o	E	
		TEXACO SERVICE STATION - DENTON	560	906 WEST UNIVERSITY DRIVE, DENTON	BTEX, TPH	7/2/1997	0B o	E	
		TEXAS BLUE SADDLE, LTD.	2120	SWC US HIGHWAY 280 AND IH-35, DENTON	SVOCS, METALS, TPH	12/12/2007	0B o	E	
		THERECTORSEAL CORPORATION – SPENWICK ROAD	613	2601 SPENWICK ROAD, HOUSTON	TPH/SOLVENTS	9/19/1997		E	
RMD/VCIO							6		
		FORMER LITTLE ELM BAPTIST CHURCH	719	111 E ELDORADO PKWY, LITTLE ELM	VOCS	4/20/2009	1B	E	
		INDUSTRIAL DEVELOPMENT	699	143 ACRE TRACT SOUTH OF AIRPORT ROAD, DENTON	CHLORINATED SOLVENTS	9/2/2008		E	
WPD/MSW							2B 45		
		CITY OF DENTON LANDFILL	MSW01590A	0.35 MILE E OF EDWARDS ROAD AND MAYHILL ROAD INTERSECTION 0.35 MILE S OF WASTE WATER TREATMENT PLANT	MW-4L, 4U, 12LS: VOCS (1,1-DCA, CIS-1,2-DCE, PCE, TCE), SVOCS (ACETOPHENONE); MW-12LS: METALS (ARSENIC, COBALT, NICKEL)	9/15/2005	2B 45A	E,Q,V2	
		CITY OF FARMERS BRANCH CAMELOT LANDFILL	MSW01312A	.8 MILE S STATE HIGHWAY 121 N TRINITY RIVER 1.5 MILE W FM 2281	MW-10: ARSENIC; MW-13R: BARIUM; MW-1R, 4R, 9, 10, 11, 12: VOCS (1,1-DCA, CIS-1,2-DCE, TRANS-1,2-DICHLOROETHYLENE, TRICHLOROETHYLENE, VINYLCHLORIDE)	6/4/2003	2A 3	E,Q,V2	
		WASTE MANAGEMENT DFW RECYCLING AND DISPOSAL FACILITY	MSW01025B	2.25 MILE E SE OF INTERSECTION OF INTERSTATE HIGHWAY 35 E AND US HIGHWAY 121	MW-A, EE: VOCS (CIS-1,2-DCE); MWBB: VOCS (1,1-DCA, 1,2-DCA, 1,1-DCE); MW-M: VOCS (CIS-1,2-DCE; PCE); MW-N: ARSENIC; MW-P: VOCS (1,1-DCA)	12/31/2004	2A 3	E,Q,V2	
WISE RMD/PST							2 2A		
		CARUTHERS OIL COMPANY	113476	807 13TH ST, BRIDGEPORT	GASOLINE	9/25/1998	5B 2A	E,Q	
		CUNNINGHAM LAURA	115273	190 S MAIN, RHOME	UNKNOWN	11/7/2001	2 6	E,Q	
		DRY CREEK DISTRIBUTIN	101260	1504 CHICO, BRIDGEPORT	DIESEL	1/30/1992	2 2A	E,Q	

County Data	New Cases	File Name	File Number	Location	Contamination Description	Date	Enforcement Status	Division Quality	Section 5.236
		INC							
		FAIRMAN C E	112053	FM 455, SLIDELL	GASOLINE, DIESEL	1/15/1997	1B 1A	E,Q	
		S & J OIL COMPANY INC	116283	1000 S BUSINESS HWY 287, DECATUR	UNKNOWN	12/6/2004	2 6	E,Q	
		SAPPINGTON INC	113597	285 HWY 380, RUNAWAY BAY	GASOLINE	11/5/1998	2 2A	E,Q	
		SWARINGEN MARY	112703	1308 N LOOP 81, DECATUR	GASOLINE, DIESEL	10/22/1997	2 6	E,Q	
		TEXAS INDUSTRIES OPERATIONS LP	093371	HWY 101, BRIDGEPORT	GASOLINE	8/3/1989	2 6	E,Q	
		USR CO MARTIN EAGLE OIL	112190	600 HALE ST, DECATUR	UNKNOWN	3/18/1997		E,Q	

Table D-2. Groundwater Contamination Case Description by County Railroad Commission of Texas

County Division	New Cases	File Name	File Number	Location	Contamination Description	Enforcement Status	Data Quality
WISE OIL & GAS	*	MERIT ENERGY COMPANY	OCP# 3704	TANFIELD, KATE A. "B" LEASE LAT 33.1967 LONG-97.8092(NAD83) (030751)	CRUDE/CONDENSATE	0 4	E,Q,V,2
		MITCHELL GAS SERVICES	OCP# 1548	BRIDGEPORT GAS PL, 1 MI W OF LAT 33.21 LONG-97.7545(NAD83) BRIDGEPORT	CONDENSATE	0 3	E,Q,V,2
		REX KEESE WATER WELL		BOONSVILLE (BEND CONGL), GA, 5 WSW DECATUR	CONDENSATE	0 2B	E,Q,V,2
		TARGA	OCP# 1046	DECATUR COMPRESSOR STA,1 M NW LAT 33.2667 LONG-97.6208(NAD83) OF DECATUR	CONDENSATE	0 4	E,Q,V,2

Table D-3. Historic Groundwater Contamination Case Description by County All Agencies 1994-2009

County Agency	Division	Section	File Name	File Number	Location	Contamination Description	Enforcement Status	Year Deleted
DENTON TCEQ								
	RMD	CA	GNB TECHNOLOGIES INC	30516	7471 S 5TH ST FRISCO 75034	LEAD, CADMIUM, PH	3A 6E	2002
		VC/BSA	FREEDOM OIL PROPERTY	G045	NWC HENRIETTA CREEK RD AND HIGHWAY 377, ROANOKE	TPH, PCBS	6C	
		VC/IOP	WILLOW RIDGE APARTMENTS	112	797 SOUTH OLD ORCHARD, LEWISVILLE	CHLORINATED SOLVENTS, MTBE	0 6D	2000
			HENRIETTA CREEK ROAD SITE	519	5800-5900 BLOCK OF HENRIETTA CREEK ROAD,ROANOKE	VOCS	0 6C	2000
			SACK N SAVE	473	1500 IH 35E @ AVENUE C, DENTON	TPH, BTEX, METALS	0 6C	2002
			TEXAS NEW MEXICO POWER COMPANY	668	792 EAST MAIN STREET, LEWISVIL LE	TPH, VOCS, SVOCS, PHENOLS	6C	2004
			THE DENTON- RECORD CHRONICLE	1286	314 EAST HICKORY STREET, DENTON	VOCS, SVOCS, CHLORINATED SOLVENTS	0 6C	2001
			VALLEY SQUARE SHOPPING CENTER	803	724 WEST MAIN STREET, LEWISVILLE	CHLORINATED SOLVENTS	6C	
		DCRP	FORMER COTTAGE CLEANERS	DC0067	2636 FRANKFORD ROAD, DALLAS	CHLORINATED SOLVENTS	2B, 5B 6C	2009
	WPD	MSW	CAMELOT LANDFILL (CITY OF FARMERS BRANCH)	MSW01312A	0.8 MI S OF SH 121, N OF ELM FORK TRINITYRIVER, 1.5 MI W OF FM 2281, HEBRON	MW-10: VOCS (CIS- 1,2-DICHLOROETHYLENE; TRICHLORO ETHYLENE; VINYL CHLORIDE	2A 6C	1999
WISE RRC								
	OIL & GAS	9	MEC BUSEY UNIT	OCP# 1549	5 MILES E OF BRIDGEPORT	CONDENSATE	0 6C	2006
TCEQ								
	WSD	PDW	CITY OF CHICO EAST	G2490004L	4 - 42 ACRE	BENZENE	2D 6C	2003
			CITY OF CHICO EAST	G2490004M	5 - 42 ACRE	BENZENE	2D 6C	2003