El Paso County Groundwater Quality Study
Phase 1

PREPARED FOR:
El Paso County Groundwater
Quality Study Committee

For Presentation to
El Paso County Board of
County Commissioners

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Executive Summary

This report documents the work, findings, analysis, and recommendations of the Colorado Geological Survey (CGS) in executing the scope of work commissioned by El Paso County, through the Groundwater Study Committee, established in reference to Resolution No. 09-202. The subject of this report is the groundwater quality of the alluvial aquifer within the Upper Black Squirrel Creek (UBSC) basin (Figure 1.1). The Phase 1 study objectives are to characterize the current groundwater quality in the alluvial aquifer and determine whether there is a correlation between existing and future land uses and groundwater quality. The scope of work for Phase 1 was finalized in January 2010, and the County contracted with CGS to perform the work.

The current study is limited to evaluation of existing water quality data for groundwater in the alluvial aquifer system of the Upper Black Squirrel Creek Designated Groundwater basin (UBSC basin) of east-central El Paso County, Colorado. As part of the study a literature review identified 34 relevant publications and an annotated bibliography was prepared. Previous published studies indicated that the groundwater was of good quality, but identified nitrate as a contaminant of concern. Water quality data was acquired from a variety of public sources (county, state, and federal) and study cooperators. The data represent 150 samples collected from 72 different wells between 1954 and 2009. Samples collected for water quality analysis within the study area have a limited spatial and temporal distribution. Approximately 80% of the data were collected in the 1980s and 1990s, and the great majority of wells are within three miles of the Ellicott Highway. One of the most important characteristics of this data is the lack of multiple samples from individual locations. The northern and western portions of the UBSC basin where rapid development has occurred and is expected to continue are not represented in the data.

Groundwater chemical analysis data for inorganic compounds, total dissolved solids (TDS), nitrate, metals, organic compounds, and radionuclides were evaluated to characterize the UBSC basin alluvial aquifer's water quality. The groundwater sample data indicate that, where sampled, the water is generally acceptable with respect to drinking water standards; of moderate hardness; and free of pesticides, herbicides, and regulated organic contaminants. At certain times and locations, some water quality parameters were detected at concentrations in violation of primary and secondary drinking water standards including: arsenic, nitrate, pH, TDS, sulfate, and iron. Nitrate values greater than 5.0 mg/L are common in the basin, and suggest that the alluvial water quality has been influenced by sources of nutrient loading.

No clear relationship between land uses and groundwater quality was evident from the available data. Existing UBSC basin land uses evaluated include residential, agricultural, urban, commercial, industrial, military, and unregulated industrial waste disposal. Elevated nitrate concentrations are distributed over parcels associated with residential, dry land farming/grazing, and irrigated agriculture, suggesting localized sources rather than being impacted from categorical land use. Groundwater quality data are lacking in the northwest portion of the basin where the majority of the development is occurring. Consequently, information regarding nitrate concentrations in areas with higher density ISDSs is missing. Elevated TDS values are associated with both dryland farming/grazing land and rural residential land use. Potential contaminant sources associated with future land uses have been summarized in Table 5.1. Anticipated future land uses within the basin are a continuation and expansion of current land uses, primarily consisting of residential development in urban, rural residential and rural development densities with accompanying commercial development. Figure 5.2 summarizes activity nodes and transportation corridors where future development is expected to be concentrated.

Due to the spatial and temporal limitations of the compiled water quality data, this study was only partially successful in meeting the objectives established by the study committee. Unfortunately, there is no groundwater quality data available in the northwest portion of the basin, where urban land uses and ISDSs are concentrated and continued development is expected. Decision makers in El Paso County attempting to assess the vulnerability of the groundwater resource currently lack a complete understanding of the hydrogeology of the aquifer system and the associated anthropogenic effects controlling the source, transport, and fate of potential contaminants. To address this gap, we recommend implementing a Phase 2 investigation focusing on refining our understanding of the groundwater flow system and acquiring the water quality data needed to support and scientifically defend land use planning decisions.

1. Introduction

This report documents the work, findings, analysis, and recommendations of the Colorado Geological Survey in executing the Phase 1 scope of work commissioned by El Paso County, through the Board of County Commissioners, to study the groundwater quality of the alluvial aquifer within the Upper Black Squirrel Creek (UBSC) basin (Figure 1.1). The objectives of this initial phase were to document and characterize the historic and current groundwater quality in the alluvial aquifer and determine whether the water quality was influenced by existing land uses or may be influenced by future land uses. Depending upon the results of this phase of study, a Phase 2 may be necessary consisting of additional data collection and analysis. Phase 3, if warranted, would include additional land use analysis and development of land use regulations.

1.1. Background and Need

In early 2009, the El Paso County Board of County Commissioners held work sessions regarding potential changes to the El Paso County Land Development Code, including those related to groundwater protection. In May 2009, the Board adopted Resolution No. 09-202 which directed staff to initiate a groundwater contamination study, and provided for the formation of a groundwater quality study committee (Committee). A press release was issued on May 26, 2009, inviting participation on the Committee. The Committee consists of 14 voting members representing areas of the scientific community, developmental industry, building industry, agricultural community, and the community at-large. Additionally, the Committee includes 5 non-voting members from the El Paso County staff and the El Paso County Planning Commission. The study objective is to evaluate potential groundwater contamination issues to help participants make informed land use decisions.

Development Services Division staff were directed to report back to the Board with a stakeholder process and list of potential stakeholders. They also provided a study coordinator, Elaine Kleckner, to manage the process. Staff consulted with a number of individuals with technical knowledge of groundwater contamination issues including U.S. Geological Survey (USGS), Colorado Geological Survey (CGS), groundwater management districts, special districts, and governmental agencies and presented a preliminary work plan to the Board on July 9, 2009. The Committee met through the summer and fall of 2009 to refine the scope of work and identify funding partners. Pat Edelmann of the USGS Colorado Water Science Center and Ralf Topper of CGS participated in a technical advisory role.

1.2. Scope of Work

The scope of work for Phase 1 was finalized in January 2010 and the Committee voted to recommend to the Board contracting with the Colorado Geological Survey (CGS) to perform the study. USGS personnel would continue to participate in the committee meetings and assist in a technical advisory capacity. Recognizing the diversity of groundwater resources in El Paso County, the Board's desire to obtain results quickly, and the limited funds available, the Committee and the Board of County Commissioners decided to focus the study on the alluvial aquifer of the Upper Black Squirrel Creek (UBSC) basin (Figure 1.2). The approved scope of work was divided into five tasks:

1. Project management, committee coordination and public participation
2. Literature review and data compilation/analysis
3. Identification of potential contaminant sources based on land use
4. Summary of results of Phase 1
5. Report compilation and presentation

In consultation with CGS, the Committee modified the scope of work by addendum; largely to clarify the providers and contractor deliverable requirements. In May 2010, El Paso County entered into agreement with CGS to conduct the study and executed a Memorandum of Understanding to identify the funding commitments for the study. In addition to the county and CGS's match of in-kind services, funding was provided by Cherokee Metropolitan District, Meridian Service Metropolitan District, Sunset Metropolitan District, Upper Black Squirrel Creek Ground Water Management District, and Accretive Investments, Inc. The El Paso County Development Services and Information Technologies departments were instrumental in providing data related to land use and the presence of individual sewage disposal systems (ISDSs).

1.3. Study Limitations

The current study is limited to evaluation of existing water quality data for groundwater in the alluvial aquifer system of the Upper Black Squirrel Creek (UBSC) Designated Groundwater basin of east-central El Paso County, Colorado. The study is intended to document and evaluate the current groundwater quality in the UBSC basin alluvial aquifer and assess the potential for groundwater contamination from existing and future land use. To accomplish this, the CGS has collected existing groundwater quality data from publicly available sources and from study cooperators. The CGS then evaluated the data with respect to water quality and potential water quality impacts that current and future land uses have had, or are likely to have.

In addition to data provided by the study's utility cooperators, Cherokee Metropolitan District and Meridian Service Metropolitan District, CGS searched publicly available databases and reports for site-specific water quality information. Local, state, and U. S. government sources were queried for relevant data or information. Also, El Paso County issued a press release soliciting water quality data from private landowners and any other interested parties.

All public entities contacted agreed to share relevant groundwater quality data, if available, and the authors are not aware of any other sources of significant data relevant to the current study. No new water-quality sample collection and analysis was performed. CGS collected data from numerous sources, documenting some inconsistencies between data sources. Consequently, it is important to recognize that we discuss and evaluate the chemistry of common constituents in natural groundwater without the benefit of knowing or having documentation of the quality of the data presented. For example, original laboratory reports were seldom available. We complied the date collected into an internally consistent data set for the analyses presented herein.

1.4. Understanding Water Quality Data

Laboratory analysis of chemical constituents in natural waters is commonly conducted on both the suspended and dissolved solids in the fluid. Suspended solids being insoluble particles remaining dispersed in a liquid. Suspended solids are common in surface water but not in groundwater, as subsurface materials (soil and rock) act as good filters. Consequently, analysis of groundwater and the water quality standards upon which those standards are based focus on concentrations of dissolved constituents. Most of the dissolved constituents in native groundwater are the result of chemical interactions between the water and the geologic materials with which groundwater has been in contact.

Dissolved solids in water come from a variety of sources including the atmosphere and earth materials. The chemical processes occurring between water and its contact environment can also be strongly influenced by biologic activity. In natural systems, precipitation is the source of groundwater. Rain or snow fall may pick up and incorporate atmospheric particles and gases. As the rain or snowmelt flow over the land and percolate into the soil, some of the soil minerals and surface materials, such as decaying leaves or wood, dissolve into the water and become part of the water's chemistry. As the water percolates to the underlying water table, and moves through pores, within the soil or rock, the dissolved solids content will usually increase until, given enough time, the groundwater reaches a state of chemical equilibrium with the aquifer materials it flows through. The major dissolved constituents in groundwater include: calcium, magnesium, sodium, potassium, chloride, sulfate, bicarbonate, carbonate, and silica. Minor constituents may include: iron, manganese, fluoride, nitrate and other trace elements. Typically the dissolved solids content is relatively low in natural groundwater systems and the types and concentrations of dissolved solids reflect the dominant mineralogy of the aquifer through which the water has flowed. From a land use perspective, poor water quality is typically attributed to contamination from anthropogenic (man-made) sources such as road salt, excess fertilizer, storage tank leaks, or wastewater effluent.

Over the years, a wide variety of units have been used in reporting water analyses. Understanding the units and conventions used in the past is helpful when using the data available in the published literature. Because water is a liquid, concentrations are typically reported as the mass of a given solute per unit volume of water. For example, if one were to stir ten grams, or about 1 and 2/3 teaspoons, of table salt (sodium chloride), into one liter of pure water the mixture would have a salt concentration of "ten grams per liter." Since the concentration of dissolved constituents in most natural waters is generally low, the standard practice in water quality interpretation is to report units of one thousandths of a gram, or milligrams per liter (mg/L). These units can also be considered in terms of a weight basis to obtain "parts per million" values. Historically, the U.S. Geological Survey, and other labs throughout the U.S., reported concentrations in "parts per million (ppm)" (Hem, 1985). The assumption of equivalence between mg/L and ppm is based on unit density for water and is considered reasonable by hydrologists for waters with low dissolved mineral matter and ambient temperatures. For the purposes of this report, dissolved constituent concentrations are reported in the accepted convention of milligrams per liter.

Some metals or organic compounds, such as arsenic or benzene, respectively, have been shown to impact human health at much lower concentrations than one milligram per liter. Such constituents are often measured in concentrations of micrograms per liter (ug/L), or the approximation "parts per billion" (ppb).

1.5. Evaluating Contaminant Concentrations

The quality of public drinking water is regulated by the US Environmental Protection Agency (US EPA) and enforced by the Colorado Department of Environmental Health and Environment (CDPHE). These agencies have developed rules and regulations intended to ensure the safety of drinking water supplies by setting numerical standards for the amount of certain constituents (bacteria, dissolved metals, organic chemicals and other compounds) considered harmful. When these constituents are found in water, at concentrations greater than the regulatory Maximum Contaminant Levels (MCLs), they are considered contaminants. MCLs are enforceable health based standards. The MCL is established to be protective of human health as determined by toxicological research.

Some dissolved constituents found in drinking water are not concerns with respect to health but rather produce nuisance issues such as poor taste, offensive odor, skin or tooth discoloration, or staining of laundry and plumbing fixtures. The EPA has set non-enforceable aesthetic guidelines regulating concentration of these contaminants, known as the Secondary Maximum Contaminant Levels (SMCLs). While contaminants have also been defined as an unwanted substance or a substance occurring in concentrations above background levels, the data presented herein are compared with the regulatory limits for both MCLs and SMCLs.

1.6. Sample Location (well) Identification System

Data tables presented in this report use a site identification numbering system based on the U.S. Bureau of Land Management system of land subdivision. The system identifies the survey meridian and the quadrant of the principal meridian in which the well is located, and then identifies the township, range, section and the well's location within the 160-acre quarter section, the 40 acre quarter-quarter section, and the 10 acre quarter- quarter- quarter section. As an example, the location of well SC01306230ACC1 can be determined by reading the identification number from left to right, the (S) indicates the Sixth Principal Meridian Survey, in the southwest quadrant (C), in Township 13 South (013) and Range 62 West (062) , section 30 (30). The last three letters of the well identification indicate the well is located in the southwest quarter (C) of the southwest (C) quarter of the northeast quarter (A). The last three letters of the well identification ("ACC") represent, from left to right, the largest to the smallest area. If more than one well is present in the 10-acre quarter-quarter-quarter section each well is given a numbered suffix. The well in this example is designated as the Number 1 well in the 10-acre quarter-quarter-quarter section. A graphical depiction of the well identification system is shown in Appendix A.

2. Previous Studies and Literature Review

In the Committee's preliminary work plan a number of publications and data sources were identified for review. Task 2 of the scope of work included the compilation of an annotated bibliography. The annotation includes abstracts for publications, or a short paragraph summary if an abstract is not available. Our literature review identified 34 publications relevant to the current study and an annotated bibliography is presented in Appendix B. Table 2.1 presents a list of the publications and their relevance to this study. Both Table 2.1 and the annotated bibliography are presented in reverse chronological order, under the assumption that the more recent publications have greater relevancy to current land uses and water quality.

Documents reviewed were grouped into the following categories:

1) Studies containing data specifically from groundwater sampling performed in the UBSC basin,
2) Studies containing research relevant to physical, biological and chemical processes that may affect groundwater quality in the UBSC basin,
3) Studies containing research on the general relationship between land use and the potential for groundwater contamination, and
4) Studies containing data relevant to USBC basin groundwater quantity and supply.

Previous studies containing data, from groundwater sampling performed in the UBSC basin, were published between 1966 and 2009. These publications range from regional water- resource assessments, which include the UBSC basin, to research specifically focused on the water quality in the UBSC basin. To establish a foundation of previous work conducted specific to the UBSC basin, we provide a brief summary of the results and conclusions published by other investigators.

- The earliest study considered here was by McGovern and Jenkins (1966) who evaluated conditions in the alluvial aquifer in 1964 with respect to future groundwater development. Analyses from three groundwater samples were presented that included results for nitrate and other general chemistry parameters. McGovern and Jenkins predicted declines in water levels due to overdraft pumping of the aquifer and stated *the water quality as being generally good and of a mixed cation bicarbonate type*. The prediction of declining water levels has been validated historically and the water quality finding agrees with the current study.

- Bingham and Klein (1973) evaluated water level declines and groundwater quality in the UBSC basin and observed water level declines of 20 to 35 feet, in part of the UBSC basin, over a seven-year period between 1964 and 1971. They described *overall water quality as good and total dissolved solids (TDS) were observed to increase laterally from the main alluvial channel*. These results agree with what is known about the UBSC basin and what has been observed in the current study.

- Livingston, Klein and Bingham (1976) evaluated water resources of El Paso County including multiple watersheds and estimated the amount of available groundwater in the UBSC basin alluvial aquifer at 350,000 acre-feet. They found the TDS content of groundwater in the UBSC basin to be far lower than other alluvial aquifers in El Paso County. The storage estimate is conservative in comparison with a more recent study indicating approximately 475,000 acre-feet available in the alluvial aquifer (Topper, 2008). *Their conclusions with respect to water quality generally agree with the current study and other more recent studies*.

- Buckles and Watts (1988) evaluated water quality and performed preliminary groundwater flow modeling of the UBSC basin alluvial aquifer. They documented continuing decline of alluvial aquifer water levels and simulated the future effects of groundwater pumping. In 1984, they sampled 36 wells for water quality parameters including nitrate. The report documents that five wells, in the UBSC basin, had nitrate concentrations exceeding drinking water standards. However, at three of these wells, nitrate concentrations were interpreted to be anomalously high because the wells were located near local sources of nitrate loading. *The water quality results of Buckles and Watts (1988) are generally consistent with other studies and the current study*.

- Watts (1995) evaluated the hydraulic connection between the alluvial and bedrock aquifers, documented water level declines in the alluvial and underlying bedrock aquifers, and simulated the physical groundwater flow system. Watts (1995) considered water quality only as an indicator of flow between the two types of aquifers and did not focus on issues relevant to this study. His report, however, provides water quality data for a limited number of wells.

- Brendle (1997) compared nitrate concentrations from two time periods at specific wells to determine whether an observed increasing nitrate concentration trend was localized or typical of the UBSC basin alluvial aquifer in general. Brendle resampled 28 of the 36 wells sampled in 1984 by Buckles and Watts (1988) and performed statistical evaluation of changes in nitrate concentrations over the 12 years. *Brendle found nitrate concentrations to have decreased at eight wells and to have increased at 20 wells*. The average difference in nitrate concentrations over the 12-year period between the two sampling events was -0.18 mg/L. He documented anomalously high decreases in nitrate concentrations (-8 mg/L and -10 mg/L) in two wells. Removal of these two samples from the data set results in an average nitrate concentration difference among the remaining 26 wells of +0.55 mg/L over the 12-year period. *A statistical analysis using a paired t-test found there to be no significant difference in overall nitrate concentrations over the entire UBSC basin. However, if the geographic distribution is considered and the UBSC basin is divided into its northern one-third (10 wells in the north) and southern two-thirds (18 wells in the south), a statistically significant increase in the southern two-thirds of the UBSC Basin is indicated*.

- The Colorado Water Resources Research Institute (CWRRI, 2008) published generalized results of the Agricultural Chemicals and Groundwater Protection Program, a cooperative program between the Colorado Department of Agriculture (CDA), Colorado State University Extension Services (CSUES), and the Water Quality Control Division (WQCD). This program systematically monitored for the presence of agricultural related chemicals in vulnerable aquifers throughout Colorado. As part of the evaluation, the CDA sampled 49 wells in El Paso County, including seven alluvial wells in the UBSC basin, for a range of agricultural chemicals, metals, and general water quality parameters including nitrate. Data from the UBSC basin wells are not presented in the report; however, the data was provided to CGS for the current study by the CDA (Mauch, 2010). *A sample from one well yielded a nitrate concentration of 11.5 mg/L which exceeds the MCL for nitrate. Other than this single nitrate exceedance, sample results indicate generally good water quality for the aquifer at the locations sampled*. The analysis of the seven wells also reported concentrations below laboratory detection limits for 47 different pesticides and agricultural chemicals, and metals concentrations below primary (MCL) and secondary (SMCL) regulatory levels.

- The Colorado Geological Survey (Topper, 2008) performed a study of the UBSC basin alluvial aquifer to evaluate and refine the existing knowledge of the hydrogeology of the alluvial aquifer system for the purposes of assessing the potential for aquifer recharge and storage implementation. Water quality samples were obtained from new monitoring wells installed and hydrogeologic and geologic characterization was performed. The results indicate water from the alluvial aquifer in the UBSC basin is classified as either a sodium calcium-mixed anion or a sodium calcium bicarbonate type. *With few exceptions, the alluvial groundwater was determined to be of very good quality with total dissolved solids concentrations below 500 milligrams per liter*. In four samples cited from the literature, nitrogen compounds were observed to exceed the MCL. Subsequent reevaluation of the nitrate data indicates that data from the original source (McGovern and Jenkins 1966) were uncorrected with respect to reporting nitrate concentrations as nitrogen. This distinction is further discussed in Section 3.

- The Water Quality Control Division of the Colorado Department of Public Health and Environment publishes a status of water quality in Colorado (CDPHE, 2008) on a bi-annual basis. Groundwater monitoring results are collected through the Agricultural Chemicals and Groundwater Protection Program cited previously. The program collaborated with the CSU Cooperative Extension in eastern El Paso County to conduct a reconnaissance investigation of groundwater quality with respect to agricultural chemicals. CSU sampled forty-nine domestic, irrigation, stock watering, and municipal wells in El Paso County. These wells were completed in both the alluvial aquifer and the shallow portions of the Denver Basin bedrock aquifers. *The report concludes "that nitrate contamination does not appear to be a widespread problem based on the results of the reconnaissance investigation".* However, the report warns against drawing site-specific conclusions due to a lack of sample distribution. *The program did not recommend a follow-up investigation and gave El Paso County a low priority with respect to vulnerability to agricultural chemicals and nitrate.*

Table 2.1

Literature Review Summary

Reference (by date)[1]	UBSC Basin Groundwater Studies	Processes Relevant to Groundwater Quality	Relationship Between Land Use and Groundwater Quality	UBSC Basin Groundwater Quantity and Supply
Rupert and Plummer, 2009		X	X	
CDPHE, 2008	X			
Topper, 2008	X			X
Conn, Segrist and Barber, 2007		X		
Paul, 2007		X		
Paul, Poeter, and Lewis, 2007		X		
Topper, 2007				X
Miller and Ortiz, 2007		X		
CWRRI 2008	X		X	
Dano, Poeter, and Thyne, 2006		X		
Wakida and Lerner, 2006		X		
Gardner and Vogel, 2005			X	
Heatwold, McCray, and Lowe, 2005		X		
Brendle, 2004		X		
Poeter and Thyne, 2004		X		
Oritz, 2004		X		
Thyne, Guler and Poeter, 2004		X		
PPACG, 2003			X	
Poeter et al, 2003		X		
Trojan, et al., 2003			X	
Halapaska and Associates, 2002				X
Martin, Bassinger and Steele, 2002		X		
CWQCC, 2002		X		
Wakida and Lerner, 2002		X		
USGS, 2000		X		
Brendle, 1997	X			
Eckhardt and Strackleberg, 1995			X	
Watts, 1995	X			X
Buckles and Watts, 1988	X			X
Edlemann and Cain, 1985		X		
Livingston, Klein and Bingham, 1976	X			X
CDWR, 1974		X		
Bingham and Klein, 1973	X			X
McGovern and Jenkins, 1966	X			X

1. Full citations available in Reference Section

3. Existing Water Quality Data

CGS acquired data from a variety of public sources, in both electronic and “hard copy” formats, compiled the data into an internally consistent database, and processed it for use in the analyses presented herein.

3.1 Water Quality Data Sources, Format and Limitations

CGS obtained site-specific information from publicly available databases, published reports, individuals, special and metropolitan districts, and government agencies at the local, regional, state, and federal level. We compiled all relevant and available data. Entities queried or providing data include:

- U.S. Environmental Protection Agency (STORET, SDWIS, UCMR, NCOD)
- U.S. Geological Survey (NWIS, CWQDR)
- Colorado Department of Public Health & Environment, Water Quality Control Division
- Colorado Department of Public Health & Environment, Solid Waste Unit
- Colorado Department of Public Health & Environment, Hazardous Waste Enforcement Unit
- Colorado Department of Agriculture
- Colorado Department of Labor & Employment, Division of Oil & Public Safety
- Colorado Department of Wildlife, Riverwatch Program
- Colorado State University Extension Service
- Pikes Peak Area Council of Governments
- El Paso County
- Cherokee and Meridian Metropolitan Districts
- Waste Management Inc.
- Scheiver Air Force Base
- Schubert Sod Farms
- Mr. Charles Barber

Publications with relevant water quality data include:

- McGovern and Jenkins, 1966
- Bingham and Klein, 1973
- Buckles and Watts, 1988
- Watts, 1995
- Brendle, 1997

- Topper, 2008

El Paso County also issued a press release calling for any data held by private well owners; no responses were received. The authors are not aware of any other sources of groundwater quality data relevant to the current study.

All data presented herein is preexisting and collected by others; as new water quality sampling and analysis was not included in the current study's scope. CGS created a master water-quality database that included chemical constituents, common to natural waters, and relevant to the use of the alluvial aquifer as a drinking and irrigation water source. CGS staff converted reported data into common units, manually entered data from paper documents, and combined all data into a master database. All values reported as either "parts per million" or in mass per volume units were converted to milligrams per liter (mg/L). CGS staff, other than those performing data entry, checked the accuracy of data entered into the master data set. The water-quality master database, organized into seven tables, is attached as Appendix C.

In some cases, different published and/or electronically available sources reported different sets of analytes for the same well and sampling event. We combined different data sets and removed duplicate records. In other cases, two different analytical results were available for the same parameter from the same sample. In these cases, the project team used the most recently published value, presuming newer data to have undergone additional quality assurance evaluation since publication of the older value.

We did not include or analyze all available water-quality data in this study. First, we believe that surface water samples collected from streams and lakes were not relevant to the current study's groundwater priority. These data, while representative of a portion of the water that percolates to the water table and recharges the aquifer, are not representative of water quality within the aquifer due to chemical and biological reactions occurring in the unsaturated zone, and dilution of the water once it reaches the aquifer. Secondly, most water supply analyses come from municipal water distribution systems. These samples are generally not representative of native groundwater quality because water providers treat the water and may blend it other water sources. Therefore, we did not use these sampling data, often provided to the public in Consumer Confidence Reports, in the current study. Any "new source" water quality data made available are representative of the groundwater quality and are included in the current report.

In general, the details of the sampling methods, laboratory analytical procedures and case narratives, well construction information, or other factors often indicative of sample bias were not available to the current study. The majority of the data was provided as summary data sheets from consultant reports or other secondary sources such as published reports or electronic databases.

Concentrations reported for many parameters were below the laboratory detection limits, but the detection limits were not quantified. Older data reports often used terms such as “BDL” (“below detection limit”) or “ND” (“not detected”) to describe parameters analyzed but not detected. We qualify these entries as “detection limit not quantified” (“DLNQ”) in the data tables provided.

The respective studies and sampling events from which the data are derived produce inconsistencies with regard to issues such as sampling protocol, the selection of analytes, methodologies and laboratories used, reporting criteria, and the design, construction, or original purpose of the well sampled. The lack of original laboratory reports and a consistent set of analytes precluded the ability to perform rigorous quality assurance and control. Despite these differences, CGS compiled the data into an internally consistent data set for the analyses presented.

3.2 Spatial and Temporal Characteristics of the Data

Samples collected for water quality analysis within the alluvial aquifer of the Upper Black Squirrel Creek basin have a limited areal distribution. Most sample locations are concentrated along the main alluvial channel, which follows a general north-south alignment within about three miles on either side of the Ellicott Highway. The locations of all 72-sample sites used in this study are displayed in Figure 3.1. To facilitate cross-referencing of the well locations with the well site identification numbers used in the subsequent data tables, a simplified reference table is presented in Appendix C, Table 1. No alluvial aquifer samples are available in the northwest portion of the basin that contains the urban corridor along US Highway 24. The limited spatial distribution of the data is portrayed as a histogram of water quality data by township and range. Figure 3.2 presents the number of available data points by township from north to south in the basin. Only 12 individual data points are available north of Judge Orr Road (township 12 south). The greatest number of data points, in township 13 south, is deceiving as 48 of the 61 reported are from a single sampling location.

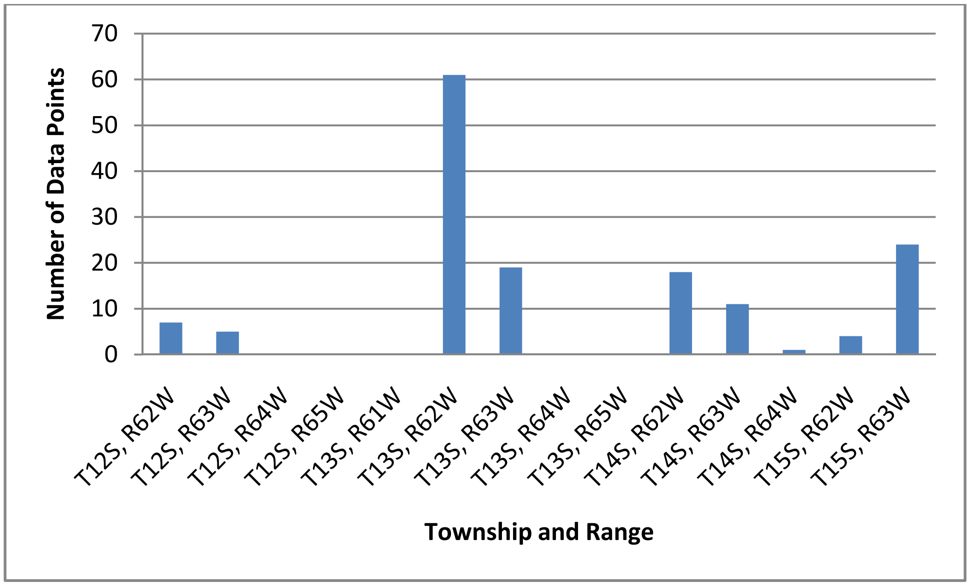


Figure 3.2 – Spatial distribution of water quality data

The groundwater quality data used in the current study consists of 150 samples collected from 72 wells between December 20, 1954 and Nov. 5, 2009. Table 3.1 present a summary of the data. The table provides statistics for the overall data set and in each of four periods: pre-1980, the 1980s, the 1990s, and the 2000s. Seventy-nine percent of the water quality data included in the current study was collected during the 1980s and 1990s. Data from prior to 1980 include only 11 samples and data from only 21 samples are available from the 2000s. One of the most important characteristics of this data is the lack of multiple samples from individual locations. Only four well sites have been sampled three or more times, with only one well reporting more than four sampling events. Consequently, the data's temporal irregularity limit the evaluation of groundwater constituent trends to "snapshot" maps showing distribution of respective constituents during different decadal periods.

CGS used data from 72 wells in the current study area. Of these 72 wells, 25 wells were sampled twice, three wells were sampled three times and one well (SC01306230ACC1) was sampled 48 times. The resulting data set contains analytical results from a total of 150 samples collected from the 72 different wells (Table 3.1). Well SC01306230ACC1 provides almost one third of the nitrate concentration data available to the current study.

Table 3.1

Water Quality Data Summary Information

	Overall Data Set	Pre_1980	1980s	1990s	2000s
Number Records with Laboratory Parameters	150	11	65	53	21
Number of Wells Sampled	72[1]	11	47	28	19
Earliest Record	12/21/1954				
Latest Record	11/5/2009				
Number of pH Data Values	121	10	63	27	21
Number of NO_3 Data Values	142	10	65	53	14
Number of TDS Data Values	77	10	45	2	20
Number Pesticide Analyses	21	0	6	2	13
Number of VOC Analyses	3	0	0	0	3
Number of Inorganic Analyses (Cations)[2]	51	9	22	2	18
Number of Inorganic Analyses (Anions)[3]	37	10	19	2	6
Number of Metals Analyses[4]	8	0	0	0	8
Number of Iron Analyses	43	7	22	2	12
Number of Radioactivity Analyses[5]	12	0	2	2	8

Notes:
1 – Number of wells sampled in overall data set may be less than the sum of individual time periods due to multiple sampling events in the same well
2 - Analyses include Mg, Na, K, and Ca
3 - Analyses include HCO_3, SO_4, and Cl
4 - Metals included are Ba, Cd, Cr, Cu, Pb, and Zn
5 - Gross Alpha and Gross Beta Emitter Analyses

3.3. Data Analysis

The data have limitations described above in Section 3.1. We can only assume that the data have been collected by trained personnel using valid methods, subjected to quality assurance evaluation, evaluated by the original data users, and deemed representative of the alluvial groundwater quality at the wells sampled.

CGS compiled the data into a MS Excel spreadsheet. This format allowed for statistical analysis of the data, the creation of tables, and allowed us to utilize the chemical analysis tools in Rockware's® Aq•QA software to convert units, check for internal consistency, and create graphs and diagrams. We then imported information derived from our data analysis into GIS (ESRI ArcMap 9.3) software to allow display and presentation with respect to other geospatially referenced information and land use layers provided by

El Paso County. Project staff mapped wells or sample locations, lacking precise location coordinate data, at the center of the most refined public land survey system (PLSS) subdivision available.

As a method of evaluating the data set, CGS attempted a charge balance calculation for water samples for which major ion data were available; however, for many samples, the calculation indicates a charge balance discrepancy exceeding the standard analysis reliability criterion of 5% for chemical data. This discrepancy indicates several possibilities (Hounslow 1995), the most likely of which include:

- Inaccurate laboratory analyses
- Presence of ions not indicated in laboratory data sheets

Despite the potential for a discrepancy in the charge balance, sufficient data are present to characterize the overall water quality within the UBSC basin alluvial aquifer.

The spatial, temporal, and technical limitations of the available groundwater-quality data influence the objectives of the current study. Spatially, the data are unevenly distributed across the UBSC basin. There are no groundwater data available where dense residential development is a significant land use, primarily in the northwestern portion of the basin. Temporally the data cluster around particular time periods even though the data set spans more than five decades. Due to the chemical and physical changes that may occur in the groundwater environment over time, the age of much of the data precludes its application for characterizing the current groundwater quality in the study area. A number of technical aspects limit the usefulness of the data in the current study. Investigators typically sampled wells only once or twice; only one well was the subject of more than four sampling events during the period of record. Consequently, evaluation of water quality trends over the period of record is limited.

4. Alluvial Groundwater Quality in the Upper Black Squirrel Creek Basin

Groundwater chemical analysis data for inorganic compounds, total dissolved solids, nitrates, metals, volatile organic compounds, and radionuclides were evaluated to characterize the UBSC basin alluvial aquifer water quality. Natural waters obtain a chemical signature as a result of weathering, a process whereby water in the form of precipitation dissolves atmospheric gases and reacts with minerals on the surface of the earth. The interaction of geologic materials with the atmosphere and hydrosphere determines the native chemical signature of the groundwater. This chemical signature can be further modified by human activities and the release of chemicals into the environment. Regulatory agencies such as the US EPA have established numerical standards for drinking water supplies that are protective of human health. We evaluate the water quality of the alluvial aquifer of the UBSC basin with respect to naturally occurring compounds and chemicals that may be introduced by various land uses. A copy of all the groundwater chemical analysis data utilized in this study is attached as Appendix C. Illustration of water quality analyses is used to plot the geographic distribution of the parameter of interest and evaluate the presence of chemical trends.

4.1 Total Dissolved Solids Concentrations

The most common indicator of water quality is the determination of the total dissolved solids (TDS) content. This analysis quantifies the amount of major ions in solution. Pure waters have very low TDS concentrations while brines have extremely high concentrations. The US EPA established a Secondary Maximum Contaminant Level (SMCL) of 500 milligrams/liter (mg/L) for drinking water. Seventy-seven TDS values were available to us from 72 wells. Concentrations ranged from a low of 165 mg/L to a high of 842 mg/L (Table 4.1). The distribution of TDS values by number of wells sampled is presented in Figure 4.1.

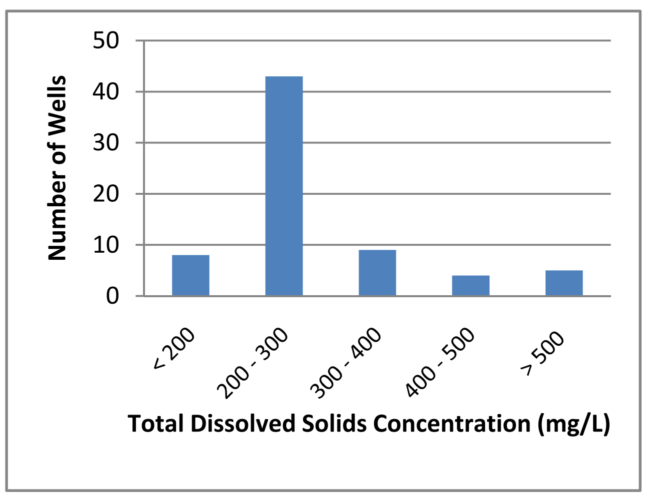


Figure 4.1 – Distribution of TDS

For presentation, we averaged values collected from the same well over the period of record. As can be seen in the TDS histogram (Fig. 4.1), 51 of the 72 wells sampled for TDS have values of less than

300 mg/L; indicating groundwater is generally of good quality. Six wells reported concentrations exceeding the SMCL of 500 mg/L.

The locations of the sampling points for these data are presented in Figure 4.2. Generally, lower TDS values are present along and to the west of the main alluvial channel of Black Squirrel and Brackett Creeks in areas of the thickest saturated alluvium. Samples with higher TDS values were collected from wells generally to the east of Black Squirrel and Brackett Creeks and in areas of thinner alluvium such as the northern and eastern portions of the UBSC basin alluvial aquifer. The TDS values compiled for this study indicate that in the majority of the areas where sample data are available, TDS values are typically less than 300 mg/L.

In some cases, higher TDS values are reported adjacent to wells with low values (e.g. southern portion of the basin). The reason for the increased TDS concentrations in areas of thinner saturated alluvium is unknown. Possible sources of higher TDS concentrations include runoff, irrigation return flow, and discharge of underlying bedrock aquifers.

4.2 Major Ion Ratios

The total dissolved solids concentration in a water sample can be divided into the individual constituents present. These constituents are usually referred to as the major ions and their ratios can be used to classify the water by general chemical type. These constituents usually include the positively charged ions (cations) calcium, magnesium, sodium and potassium, and the negatively charged ions (anions) chloride, sulfate, and bicarbonate. Commonly, in natural waters, the electrical charge associated with the combined cations will be equal to the combined charge of the anions resulting in a charge balance. As water migrates through an aquifer, the chemistry can evolve along the flow path from one water type to another due to dissolution of minerals within the aquifer, infiltration of water from other sources, upward migration of water from underlying aquifers (Watts, 1995) or reactions resulting from changes in the aquifer mineralogy (Hounslow, 1995).

The major ion ratios for all water samples, with sufficient data, are presented in Figure 4.3. Due to the weathering process, major ion chemistry may vary between different aquifers. Watts (1995) used major ion ratios as an indication of how water was flowing between the alluvial aquifer and underlying bedrock aquifers in the UBSC basin. The percentages of the different ions are plotted on triangular or

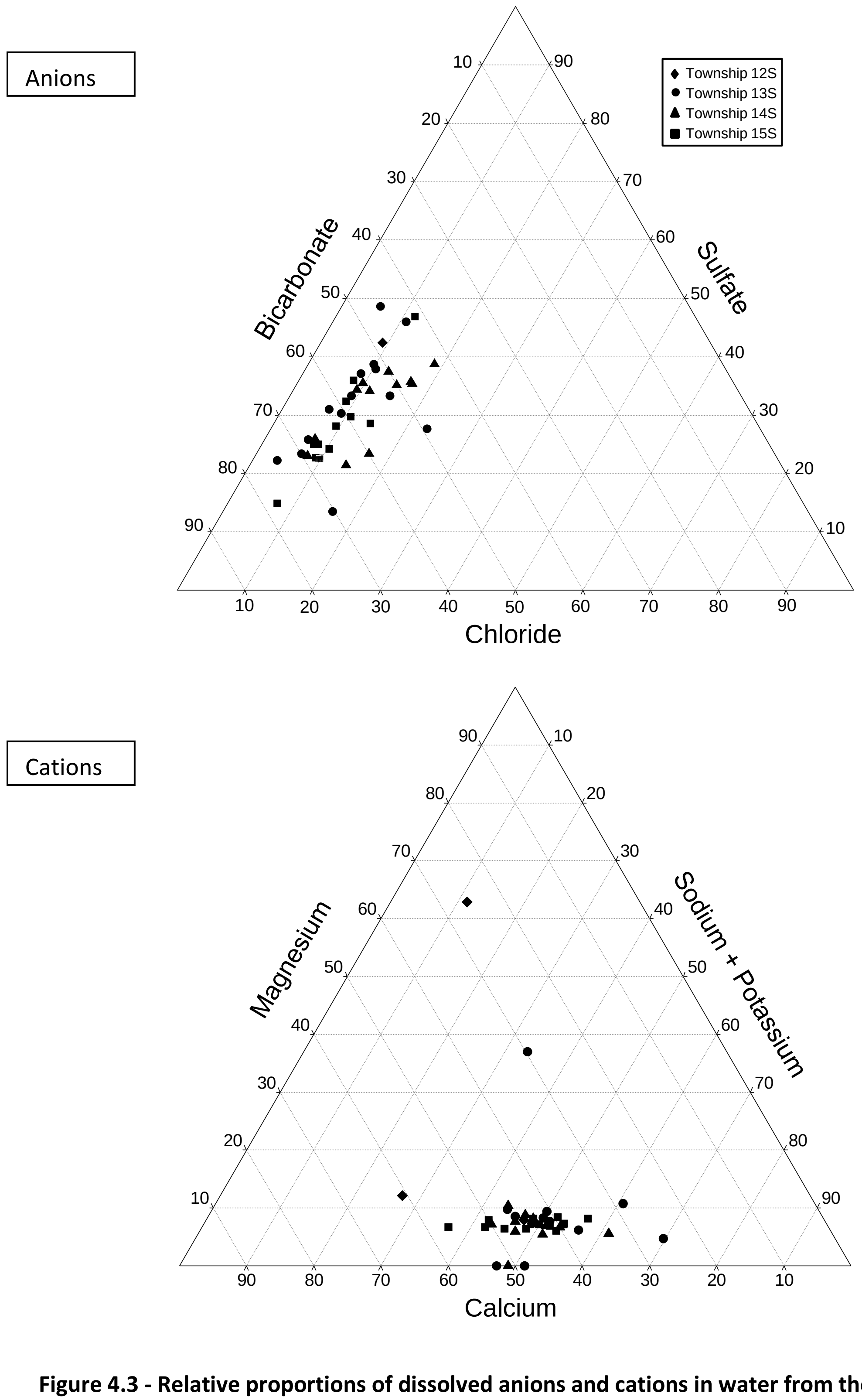


Figure 4.3 - Relative proportions of dissolved anions and cations in water from the alluvial aquifer in the Upper Black Squirrel Creek Basin.
(Units along axes are percentage of total milliequivalents per liter)

Ternary diagrams to evaluate water chemistry trends and sources. Overall, in charge balanced units of milliequivalents per liter, the proportions of cations generally range from approximately 35% - 55% calcium, 35% - 55% sodium and 5% - 10% magnesium, while anions generally fall within ranges of 20% - 50% sulfate, 55% to 70% bicarbonate and 5% - 15% chloride. These analyses indicate that the alluvial groundwater within the study area is a mixed cation bicarbonate water, containing a mixture of the cations calcium and sodium, with an anion content consisting predominantly of bicarbonate. The use of different symbols, in Figure 4.3, for each of the different townships in the study area allows for evaluation of geographic trends in the major ion proportions. No significant geographic zonation in water chemistry is evident from this analysis.

Two outliers are evident in the cation ratio ternary plot of Figure 4.3, samples SC01306230ACC3 and SC01306219CDB. These samples are skewed by relatively high magnesium concentrations of 12 and 54 mg/L, respectively. The water supply wells from which the samples were collected are within one mile of each other and both draw water from the bottom portion of the alluvial aquifer in a location underlain by the Denver aquifer which may contribute to water captured by the two wells and explain the different water chemistry.

4.3 Hardness

Water hardness is a measure of the dissolved metallic ions in water that can react with soaps to produce a residual scum (bath tub ring), result in plumbing fixture scaling, and hamper the efficiency of detergents. The calcium and magnesium constituents represented by hardness values also react with other dissolved constituents in water to form mineral scale in boilers and other appliances using hot water. Eventually, mineral scale is capable of rendering boilers inefficient and fouling appliances that heat water. Hardness data represent a combination of dissolved constituents and for simplicity are generally expressed as “mg/L as $CaCO_3$” or “mg/L equivalent calcium carbonate” (Freeze and Cherry, 1979). Soft water has concentrations less than 60 mg/L, while very hard water is classified by values greater than 150 mg/L.

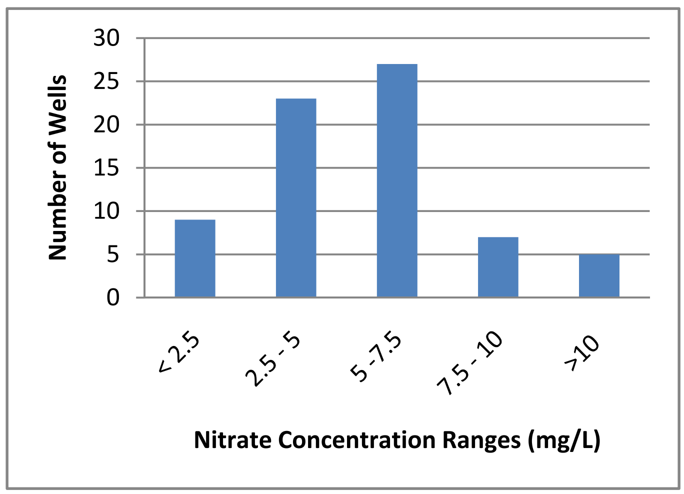
Available hardness data are mapped in Figure 4.4. The data indicate that groundwater in the UBSC basin alluvial aquifer is generally classified as “moderately hard” with isolated areas containing water classified as “hard” or “very hard.” Locations with hard and very hard water coincide with locations containing the highest TDS values, and are generally in the shallower portions of the aquifer outside of the main alluvial channel. This indicates that water hardness is associated with the TDS concentrations.

4.4 Flouride

Flouride is found naturally in low concentrations in groundwater. Flouride compounds are salts that form when the element fluorine combines with minerals in soils and rocks. Flourine is derived from the weathering of fluoride minerals, such as flourite. Many water suppliers add fluoride to their drinking water to promote dental health. The US EPA has established an SMCL for fluoride at 2.0 mg/L. Fourteen samples contained an analysis for fluoride. Flouride concentrations in groundwater, for the data available, ranged from 0.3-1.0 mg/L, with the majority of values ranging from 0.4-0.5 mg/L.

4.5 Nitrate Concentrations

The Committee has identified nitrate as a contaminant of concern in the UBSC basin. Common sources of nitrate in groundwater include: runoff from improper application of fertilizer or manure spreading, leaching from septic tanks, sewage and weathering of geologic units. Nitrate concentration values in the basin at individual sample locations were averaged and a histogram prepared to show a frequency distribution of nitrate values (Figure 4.5). The majority of nitrate concentrations range between 2.5-7.5 mg/L. The MCL for nitrate is 10 mg/L. For the current study, all nitrate values are expressed in terms of nitrate as nitrogen. For graphical presentation of nitrate data, we assumed concentration values were less than 2.5 mg/L for samples in which nitrate was not detected, regardless of the laboratory detection limits.



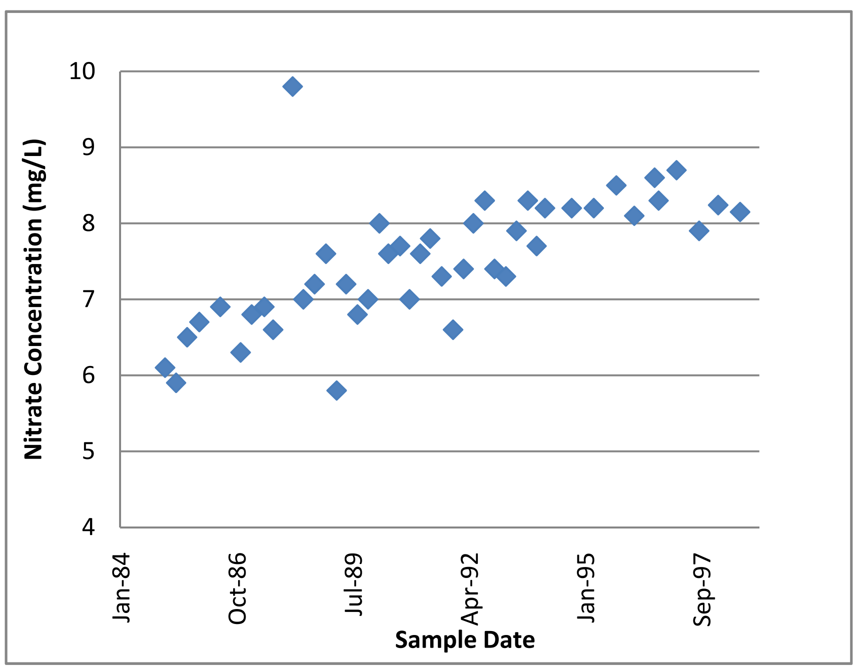
4.5 - Frequency Distribution of Nitrate Values

Nitrate values represent one of the largest data sets in our database, 142 samples with detectable values. The availability of this data allowed us to analyze the potential changes in nitrate concentrations over time. Four decadal time periods, pre-1980, the 1980s, the 1990s, and the 2000s were evaluated using average decadal nitrate concentrations at individual sampling sites and mapped to display potential changes over time (Figures 4.6 through 4.9). Information on nitrate concentrations in the alluvial aquifer pre-1980 is sparse.

Figure 4.6 shows two locations with elevated concentrations associated with irrigated agriculture along the mainstem of Black Squirrel Creek in the southern portion of the basin. The sampling data for nitrate increased significantly in the 1980s with five locations exceeding the MCL (Fig. 4.7). Four of these locations are in the upper reaches of Brackett Creek. Groundwater in the main alluvial channel was characterized by nitrate concentrations of 7.5 mg/L or less. Less sampling occurred in the 1990s, but available data indicate similar concentrations as observed in the 1980s with portions of Brackett Creek experiencing higher values (Fig. 4.8). The 2000s data suggest that the area around Brackett Creek continues to experience elevated nitrate concentrations in groundwater (Fig. 4.9). It should be recognized, however, that most of these data represent different well/sample locations for the periods evaluated. These conclusions generally support those of Brendle (1997) who resampled 28 wells throughout the UBSC Basin that had been sampled in August 1984 by Buckles and Watts (1988). However, as Brendle (1997) states, "…two samples from each of the 28 wells are not sufficient to definitively determine trends in nitrate concentrations…".

The geographic distribution of nitrate data in the UBSC Basin is greatly skewed toward the main alluvial paleochannel, which follows a general north-south alignment along the Ellicott Highway (Topper, 2008). Groundwater has historically been sampled from locations in the mainly agricultural portion of the UBSC Basin. Data are not available to determine whether ISDS's associated with large residential developments in the northwestern portion of the UBSC Basin have impacted groundwater quality.

We previously mentioned in Section 3 that few wells have multiple sampling events associated with them. The exception being well SC01306230ACC1, a monitoring well associated with Cherokee Metropolitan District production well #4. At that location, a series (from February 1985 through August 1998) of nitrate concentration data has been reported (Fig. 4.10). The well



4.10 - Nitrate Concentrations with Time at Well SC01306230ACC1 shows an increasing trend in nitrate concentrations, from the mid 1980s to the mid 1990s. This trend was the impetus for Brendle's (1997) study.

Elevated nitrate (>10 mg/L) in drinking water is a significant health issue for infants below the age of six months. The risk known as methemoglobinemia is commonly referred to as "blue baby syndrome" due to the afflicted baby's bluish skin color, particularly around the eyes and mouth (Jennings and Sneed, 1996).

Nitrate is often naturally present in groundwater at concentrations of less than 2-3 mg/L due to decomposition of proteins and other organic nitrogen compounds present in vegetation and animal wastes. Nitrate contamination from wastewater effluent has been observed to persist for decades in groundwater and can travel from its source for miles through an aquifer (LeBlanc, 2006).

4.6 Metals

Dissolved metals can be derived from weathering of natural deposits, from waste, or chemical spills. These include common elements like iron, lead, copper, and zinc, and less familiar elements like selenium, barium, arsenic, and beryllium. Drinking water containing high dissolved metal concentrations can be harmful to human health and the EPA has established various numeric standards for different metals. The data summary table 3.1 indicates that we acquired 43 samples with iron analysis and 8 samples with results of other metals. The dissolved metals concentrations indicate that only one detection of a regulated metal has been at, or greater than, that metal's respective MCL. During January of 1987, arsenic was detected at a concentration of 0.01 mg/L, equal to the recently established arsenic MCL, in a sample from well SC01306301DCB.

Iron has been detected in three samples at concentrations exceeding the SMCL (0.3 mg/L). In September 1980, iron was detected at a concentration of 1 mg/L in a sample from wellSC01306219CDB and in March 2006; iron was detected at concentrations of 2.8 and 0.48 mg/L in samples from well SC01206219CC and SC01206230BB, respectively. The limited and/or inconsistent values for dissolved metals do not lend itself to meaningful graphical presentation.

4.7 Organic Chemicals

Organic chemicals include a wide range of petroleum products, solvents, pesticides, herbicides, and other carbon containing compounds. These chemicals are often associated with internal organ damage and consequently have very low MCLs. We acquired data for 21 independent samples with pesticide analyses and 3 samples with analyses of volatile organic compounds. All reported concentrations of volatile organic compounds were below the laboratory detection limits. The pesticides and herbicides are common agricultural chemicals used on crops and pastures to control weeds and other threats to crops. The concentrations for these chemicals were also below the laboratory's detection limit.

4.8 Radioactivity

Water quality sampling requirements for municipal water providers includes analysis of radioactivity. This typically includes quantification of radioactive particle (gross alpha and beta) activity as a trigger for additional analysis of radioactive elements such as radon and uranium. The US EPA has established action levels of 15 picocuries per liter (pCi/L) for gross alpha emitters and a gross beta particle dose of 4 millirems per year. The beta emitter concentration, expressed in millirems per year, is calculated from a detailed laboratory analysis that is generally not performed on routine water samples and only required when gross beta radioactivity exceeds 50 pCi/L (U. S. EPA, 2001). Thirteen data points were acquired with gross alpha and beta analyses. Radioactivity, in the context of the UBSC basin alluvial aquifer, is an indicator of naturally occurring dissolved constituents that emit alpha and beta particles. Low levels of alpha and beta particle activity were detected in groundwater sample analysis presented in the current study. The highest detections of both alpha and beta particle activity were 3.6 and 6.0, respectively, well below the regulatory action levels.

4.9 Summary of Groundwater Quality Standard Exceedences

Exceedence of Maximum contaminant levels (MCL) or Secondary maximum contaminant levels (SMCL) are presented in bold text in data tables herein. Table 4.1 summarizes the samples from which the reported values exceed those standards. A total of 22 groundwater quality values reported concentrations that equal or exceed the regulatory standards. MCL or SMCL exceedences were observed for arsenic, nitrate, pH, sulfate, and iron:

- Only one sample, collected in 1987, reported an elevated arsenic concentration of 0.01 mg/L, which is the MCL.
- Nine samples, with collection dates from 1971 to 2006, reported nitrate concentrations in excess of the 10 mg/L MCL. Most of these samples reported concentrations of 11 mg/L, with three having significantly higher concentrations. The two well sites with the highest nitrate concentrations were documented as being near likely nitrate point source (Buckles and Watts, 1988).

- Two samples collected in 1984, reported pH values below (6.3) and above (9.2) the SMCL standard range of 6.5-8.5.
- The SMCL (500 mg/L) for total dissolved solids was exceeded in six samples, collected in 1971 and 1984, with a maximum concentration of 842 mg/L reported.
- One sample, collected in 1971, reported a sulfate concentration at the SMCL of 250 mg/L.
- Three samples, from municipal production wells, exceeded the SMCL (0.3 mg/L) for iron

The locations of these samples are illustrated in Figure 4.11. Three wells in particular, SC01206314DDC, SC01306209BBB and SC01506325ABA, provided samples where multiple parameters exceeded MCLs or SMCLs. A sample collected from well SC01206314DDC in August of 1984 was observed to have 72 mg/L nitrate and 650 mg/L TDS. The nitrate concentration reported is the highest groundwater nitrate concentration available to the current study and is consequently suspect. The water sample also contained relatively high concentrations of other dissolved solids and yielded the highest value for hardness (510 mg/L as $CaCO_3$) observed in the current study. More recent groundwater sample data are not available for this well, described by Buckles and Watts (1988) as being at a point source of nitrate contamination. This information, combined with a comparison of TDS, hardness, and all other nitrate concentration observed indicates the groundwater quality observed at well SC01206314DDC represents localized groundwater conditions and is not representative of the aquifer as a whole.

Table 4.1
Samples Exceeding Regulatory Standards

Site ID	Sample Date	Local Well Name	Reported Value	Data Source	Comments
Arsenic (As), MCL = 0.01 mg/L					
SC01306301DCB	1/1/1987	CMD-08	**0.01**	3	Reported as 0.01 in data summary sheet[3]
Nitrate (NO_3), MCL = 10 mg/L					
SC01206314DDC	8/9/1984		**72**	2	TDS exceedence also, well at nitrate point source[2]
SC01306209BBB	8/10/1984		**33**	5	Well at nitrate point source[2], TDS exceedence also
SC01306209BBB	8/22/1996		**25**	5	Well at nitrate point source[2]
SC01306229DAC	11/30/06	PP-D-039	**11.5**	4	Farm animals watered by well, turf farms in area
SC01206230CDC	8/8/1984		**11**	5	Resampled in 1996, nitrate below MCL
SC01206230BDB	8/9/1984		**11**	5	Resampled in 1996, nitrate below MCL
SC01306334ABB	8/10/1984		**11**	5	Resampled in 1996, well nitrate point source[2]
SC01306334ABB	8/21/1996		**11**	5	Sampled in 1984, well at nitrate point source[2]
SC01506325ABA	9/8/1971		**11**	5	Sulfate and TDS exceedences also
pH, SMCL defined as outside range between 6.5 and 8.5					
SC01306221BDD	8/10/1984		**9.2**	5	NA
SC01206336ACC	8/8/1984		**6.3**	5	NA
Total Dissolved Solids (TDS), SMCL = 500 mg/L					
SC01306209BBB	8/10/1984		**842**	5	Nitrate exceedence also, well at nitrate point source[2]
SC01506325ABA	9/8/1971		**767**	1	NA
SC01206314DDC	8/9/1984		**650**	2	Nitrate exceedence also
SC01406228CCB	9/8/1971		**596**	1	NA
SC01406220DBC	8/10/1984		**548**	2	NA
SC01406216CCC	8/10/1984		**546**	5	NA
Sulfate (SO_4), SMCL = 250 mg/L					
SC01506325ABA	9/8/1971		**250**	1	Nitrate exceedence also
Iron (Fe), SMCL = 0.3 mg/L					
SC01206219CC	March 2006	Guthrie Well #2	**2.8**	6	NA
SC01206230BB	March 2006	Guthrie Well #1	**0.48**	6	NA
SC01306219CDB	9/10/1980	CMD-05	**1.0**	3	NA

Notes: MCL= Maximum Contaminant Level; SMCL= Secondary Maximum Contaminant Level

Data Source: 1 – Bingham and Klein, 1973; 2 - Buckles and Watts, 1988; 3 – CMD, Curt Well's Reports; 4 – CO Dept. of Agriculture; 5 – USGS NWIS/WQR database; 6 – Woodman Hills Metro

5. Potential Land Use Impacts on Groundwater Quality

As discussed in Section 1, the objective of this study is to evaluate groundwater contamination issues to help participants make informed land use decisions. The El Paso County Board of County Commissioners is considering potential changes to the El Paso County Land Development Code, including those related to groundwater protection. The El Paso County Development Services Division and Information Technology Division have provided GIS analysis and mapping services to portray existing and future land uses within the study area. The County also provided parcel-based well and septic data derived from the Assessor's database. Existing land use was integrated with the groundwater quality data to identify potential sources of contamination associated with land uses that may negatively influence groundwater quality. Future land use scenarios were also considered to focus efforts of any proposed Phase 2 investigations.

The existing land uses within the study area are presented as Figure 5.1. Land uses are classified as industrial, commercial, urban residential, rural residential, vacant land, irrigated and dry land agricultural and other (forest land, parks, federal and institutional properties). The vast majority of land uses, within the UBSC basin, are agricultural and rural residential. Urban residential is concentrated within and north of Falcon, in Peyton, and at several isolated small developments throughout the basin. Only two industrial parcels exist within the study area and these are located north of Highway 24 in the Falcon area. A number of commercial land uses exist largely along the Highway 24 corridor near Ellicott.

5.1 Potential Contamination Sources Related to Land Use.

Groundwater quality can be degraded by a variety of naturally occurring and anthropogenic (man-made) processes. Groundwater quality changes can also result from materials in the aquifer matrix such as organic matter, minerals, salts or metals that leach into groundwater as it flows through the aquifer. Examples of anthropogenic groundwater contaminant sources include: fuel or chemical spills, stormwater runoff from roads and parking areas, road deicing, or improper application of pesticides, herbicides or fertilizers. Other potential sources include improper disposal of industrial wastes, landfill leakage, wastewater treatment plant effluent, feedlot waste, and improperly designed or maintained individual sewage disposal systems (ISDS).

The relationship between land use and groundwater quality has been documented in a variety of settings (Eckhard and Strackleberg, 1995, USGS, 1999, Gardner and Vogel, 2005, Dano and Poeter, 2004, Dano, et al., 2006, Brendle 1997). Land use has been referred to as the dominant factor affecting shallow groundwater quality by Trojan, et al. (2003). Since high-density urban and industrial land uses are limited in the UBSC basin; commercial, agricultural, and residential activities present the greatest potential to impact groundwater quality.

Table 5.1 provides a summary of common types of groundwater contaminants and land uses often associated with them. Land uses present in the UBSC Basin having the potential to contaminate groundwater include retail fuel distribution, agricultural operations, automotive salvage yards, residential ISDSs, feedlots, landfills, military facilities, and industrial waste/wastewater disposal. Potential sources of groundwater contamination related to existing and future land uses in the UBSC basin are discussed in detail below.

Table 5.1
Groundwater Contaminants Commonly Associated with Various Land Uses

Groundwater Quality Constituents	**Total Dissolved Solids**	**pH**	**Major Ions**	**Nutrients (nitrate / phosphate)**	**Pathogens**	**Pesticides / Herbicides**	**Semi-Volatile Organic Compounds**	**Volatile Organic Compounds**	**Petroleum Hydrocarbons**	**Heavy Metals**	**Radioactivity**
Land Use											
Agriculture / Cultivation	X	X	X	X	X	X					
Animal Feedlot	X	X	X	X	X						
Residential	X	X	X	X	X	X					
Industrial / Commercial	X	X	X	X		X	X	X	X	X	
Fuel Distribution	X	X	X				X	X	X	X	
Industrial Waste Disposal	X	X	X	X	X	X	X	X	X	X	X
Landfill	X	X	X	X		X	X	X	X	X	X
Military	X	X	X	X	X	X	X	X	X	X	X
Mining	X	X	X							X	X
Metal Plating	X	X	X					X		X	
Commercial Property	X	X	X	X		X					
Automotive Salvage	X	X	X				X	X	X	X	

After USGS (1997) and CDPHE (2006).

Residential: Typical groundwater contaminants from residential land use are primarily associated with ISDSs and lawn care chemicals such as pesticides, herbicides and fertilizers. Contaminants from ISDSs generally include nutrients such as nitrates and phosphorus, and bacteria such as fecal coliform (Fetter 1994, Brendle 1997). Other contaminants that may result from residential ISDSs are personal care products and medications that are not metabolized. Pesticides, herbicides and fertilizers, used in lawn and garden applications, can be a potential contaminant when improperly used or disposed. Excess irrigation can cause these products to leach to the water table and impact groundwater quality. Common brand name pesticides often contain organophosphates, carbamates, and organochlorines. Commonly available herbicides may contain metolachlor glyphosate, and atrazine. Fertilizers often contain concentrated nitrogen and phosphorous.

Agricultural Activities: Improper storage and/or application of agricultural pesticides and herbicides can result in groundwater being contaminated by organic chemicals and their breakdown products. Common agricultural pesticides contain lindane and endrin. Chemicals, such as toxaphane and methoxychlor, which have been banned, may persist in the environment. Agricultural herbicides include such chemicals as 2,4-Dichlorophenoxyacetic acid (2,4-D), glyphosate (Roundup ®), and atrazine. The herbicide 2 (2,4,5-Trichlorophenoxy) propionic acid (2,4,5-TP or Silvex) has been banned but may persist in the environment.

Improper storage and application of agricultural fertilizers can result in nutrient loading to the aquifer. Nutrient loading to groundwater can also result where manure is spread or is concentrated such as in fields, feedlots, and corrals, respectively (Brendle 1997).

Leaks from fuels or fluids used in agricultural machinery may pose a threat to groundwater resources depending upon the volume spilled and surface conditions. Typically, fuel storage tanks for agricultural activities are often smaller than those used in retail fueling facilities and installed aboveground where leakage can be observed and quickly mitigated.

Unregulated Industrial Waste Disposal: Improper disposal of industrial wastes can result in a wide variety of contaminants being introduced to the groundwater. Common groundwater contaminants include heavy metals, volatile and semi-volatile organic compounds, highly acidic or basic solutions, solvents and nutrients.

Urban and Commercial: As an area is urbanized, the amount of paved and impermeable surfaces increases and so does the volume of stormwater runoff. Stormwater can pick up chemicals from spills, leaks, or those inherent in the surface materials over which it passes. Stormwater runoff is often contained and conveyed from streets, parking lots, rooftops, and other impervious surfaces to detention basins or discharged to streams and other surface water bodies. These engineered features represent areas in which chemical contaminants may be concentrated. If stormwater is released to ephemeral drainages or allowed to infiltrate, the dissolved chemicals can impact groundwater quality. Runoff percolating into the subsurface from dry or low-flow stream channels can carry dissolved and microscopic contaminants to the water table. Contaminants present in stormwater runoff that degrade groundwater quality include pathogens, metals, nutrients, PCBs, pesticides, road de-icing solutions, and volatile- and semi-volatile organic compounds (US EPA, 1994).

In addition to potential contaminants in stormwater, urban and commercial land uses may involve industrial processes or other activities using chemicals that can directly contaminate groundwater if spilled or disposed of improperly. ISDSs associated with commercial, industrial and manufacturing facilities may impact groundwater with a variety of chemicals used at the facility that cannot be degraded by the septic system.

Older or improperly designed municipal solid waste landfills have been known as sources for a wide variety of groundwater contaminants including nutrients, volatile and semi-volatile organic compounds, heavy metals, pesticides, herbicides, and PCBs.

Retail fueling facilities (gas stations) carry petroleum fuels, oils, and lubricants that can migrate to the water table through leaks or spills. Gasoline contains volatile organic compounds such as benzene, ethylbenzene, toluene and xylenes, while diesel fuels contain naphthalene and a variety of semi-volatile hydrocarbons. These common groundwater contaminants are typically released to the environment by leaking underground storage tanks (USTs) and piping. Spills from fueling facilities can have a significant impact on groundwater quality in the immediate vicinity of the retail fueling facility.

Automotive salvage yards may also result in contamination of soil and groundwater. Commonly observed contaminants include petroleum fuels, oils, lubricants, heavy metals including mercury, antifreeze, lead, battery acid, plasticizers, and solvents (CDPHE, 2006).

Military: Facilities associated with military activities have been the source of a wide variety of groundwater contaminants due to the improper storage and disposal of wastes from diverse activities ranging from vehicle fueling and maintenance to ordnance training and chemical weapon storage. Groundwater contaminants historically associated with military bases include pathogens, petroleum fuels, heavy metals, radioactive materials, explosives, chemical weapons, and PCBs.

5.2 Anticipated Future Land Use

El Paso County Development Services Division provided GIS layers representing future land use or build out. The Falcon/Peyton Small Area Master Plan, Black Forest Preservation Plan, Highway 94 Comprehensive Plan, and Ellicott Valley Comprehensive Plan were the basis for future land uses. The result of that synthesis is presented in Figure 5.2. The future land uses anticipated within the UBSC basin are a continuation and expansion of current land uses, primarily consisting of residential development in urban, rural residential and rural development densities corresponding to lot sizes of less than 2.5 acres, 2.5 to 5 acres, and greater than 5 acres, respectively. Commercial development is expected to accompany residential development and is identified as activity nodes (Fig. 5.2).

Future development is expected to occur primarily in the northern and western portions of the UBSC basin along major transportation corridors and where infrastructure is expected to be concentrated. Specifically, these areas include corridors along Highway 24, Judge Orr Road, the Peyton Highway and Curtis Road. Additionally, activity node development is expected to occur at locations such as at the intersection of Highway 94 and the Ellicott Highway, Peyton Highway, Curtis Road, Enoch Road, and at locations where Enoch and Blue Roads enter Schriever Air Force Base. The future land use plans do not propose significant industrial development; however, some industrial uses are expected to develop in areas proposed for urban density. Conversion of agricultural land to urban use is expected to occur.

The potential impacts to groundwater quality associated with expected future land uses primarily consist of contaminants associated with stormwater runoff and wastewater disposal facilities. Currently only a small portion of urban and rural residential development in the UBSC basin is served by sanitary sewers and municipal wastewater facilities. If future development continues to rely on ISDSs then the potential contaminants associated with these systems could negatively impact groundwater quality. Impacts to groundwater are expected to be more pronounced in areas with higher density of ISDSs and in particular, where lot size is less than one acre (WQCD 2008). Currently, county regulations and development codes require central sewer service for urban development, commercial and industrial development, and residential lots less than 2.5 acres.

6. Results Summary

This section summarizes the results of the current study and addresses specific questions presented in the Scope of Work. The Colorado Geological Survey has attempted to compile all publicly available water quality data associated with the alluvial aquifer of the UBSC basin. These data were analyzed in conjunction with current land uses in the basin to meet the objectives for the groundwater quality study. Thirty-four relevant publications were identified and reviewed, some of which contained water quality data incorporated into this study. In addition to data compiled from the published literature, information was acquired from public water providers, regional and local government agencies, and state and federal regulatory and scientific agencies. A total of 150 records with laboratory analysis were collected from 72 wells.

Most of the sampling locations are concentrated along the Black Squirrel Creek and Brackett Creek alluvial valleys (Fig. 1.1). The data are limited in its spatial distribution with no groundwater quality data available in the northwest portion of the basin where the majority of development is occurring. The sampling frequency or temporal distribution of the data is also limited with the majority of samples collected in the 1980s and 1990s. Only four sampling locations have been sampled more than three times. Consequently, continuous water quality trends are discernible at only one location. The data could not be subjected to rigorous quality control or analysis reliability due to absence of comprehensive laboratory analyses, lack of sampling method details, laboratory analytical procedures and case narratives, well construction information, or other factors often indicative of potential sample bias.

Groundwater chemical analysis data for inorganic compounds, total dissolved solids, nitrate, metals, organic compounds, and radionuclides were evaluated to characterize the UBSC basin alluvial aquifer's water quality. Based on major ion ratios, the alluvial groundwater within the study area is a calcium/sodium bicarbonate water type. The groundwater is generally classified as moderately hard with isolated areas of harder water. Total dissolved solids concentrations, being an overall indicator of water quality, are generally at 300 mg/L or less indicating good water quality. Fluoride concentrations are well below the EPA's SMCL. Nitrate has been identified as a contaminant of concern in the UBSC basin due to the predominance of individual sewage disposal systems associated with residential development. Nitrate values greater than 5.0 mg/L are common in the basin, and suggest that the alluvial water quality has been influenced by sources of nutrient loading. Limited analyses of dissolved metals indicate concentrations below regulatory levels with three locations reporting higher iron values. Organic chemical analyses were available for a few source water supply wells. We focused on the more common compounds in this group of chemicals representing volatile and semi-volatile compounds, i.e. pesticides and herbicides. No concentrations above the laboratory's detection limit were reported for these chemicals. Available analysis of radioactivity indicated particle activity counts well below the regulatory action levels also.

The data were compared with regulatory drinking water standards established by the US EPA. A total of 22 groundwater quality exceedences were observed in data from 18 samples collected from 16 different wells. MCL or SMCL exceedences were reported for arsenic, nitrate, pH, sulfate, TDS and iron. Nine samples, with collection dates from 1971 to 2006, reported nitrate concentrations in excess of the 10 mg/L MCL, with most reporting concentrations of 11 mg/L.

6.1 Relationship between Land Use and Water Quality

To assess the relationship of current land uses to nitrate concentrations in the UBSC basin, we present nitrate analyses from the past two decades (1990-2009) on a map of current land use (Fig. 6.1). The resulting data set contains 47 groundwater nitrate data values. Analyses from wells at which nitrate was detected more than once during the evaluation period were averaged. As presented in Figure 6.1, the data are distributed along the central portion of the basin where rural residential, dry land farming/grazing, and irrigated agriculture are the dominant the land uses. Elevated nitrate concentrations are distributed over all three of these land uses. In general, however, where data are associated with parcels classified as irrigated agriculture, nitrate concentrations exceed 5.0 mg/L. Sample locations with the highest nitrate concentrations are not associated with irrigated agriculture and suggest a local source such as cattle pens. Additionally, some locations with elevated concentrations are in close proximity to locations with low concentrations. This may be an artifact of the longer period of evaluation, localized sources of nutrient loading or sampling bias. While it appears that the alluvial aquifer has historically been impacted by nitrate loading, the data is insufficient to determine whether the impact is regional.

To further assess the relationship between nitrate concentration in the basin and land use, we have plotted these same nitrate values (Fig. 6.1) with land parcels listed as having ISDSs in the El Paso County assessor's database. This relationship is presented as Figure 6.2 which portrays the locations of the 4,887 parcels listed as having ISDSs by El Paso County. This analysis does not indicate a direct correlation with elevated nitrate concentrations, where data are present. However, most of the locations where groundwater data are available have residential developments with lots greater than 35 acres and thus a low ISDS density. Elevated nitrate concentrations also occur in areas with no septic systems. It is unlikely that low-density residential septic systems are contributing significantly to the nitrate loading as the subsurface materials act as sand filters. Areas of higher density residential septic systems lack water quality monitoring information.

A similar analysis was conducted to assess total dissolved solids concentrations with respect to current land use. Twenty-one TDS values are available; 2 values from the 1990s and 19 values from between 2000 and 2010. This relationship is presented as Figure 6.3. TDS concentrations are classified into three categories. Of the 21 values presented in Figure 6.3, all but 5 are in the lowest category of 200-300 mg/L. Elevated TDS values are associated with both dryland farming/grazing land and rural residential land use. As with nitrate, the limited data indicate there is no regional trend in the aquifer that may be associated with particular land uses.

Table 5.1 listed common groundwater contaminants that were associated with certain land uses. During this investigation, we were made aware of operations and facilities within the UBSC basin that could pose a greater potential for impacts to groundwater quality. These include animal feedlots, retail fueling facilities, unpermitted industrial waste treatment/disposal, a permitted landfill and a military base. Where known, the locations of these facilities are shown on Figure 6.4.

- A former animal feedlot has been reported south of Judge Orr Road and west of the Ellicott Highway (Kleckner, 2010). Details regarding the exact location, size and period(s) of operation are unavailable to the current study.
- Five retail-fueling facilities with registered underground storage tanks (USTs) are present in the UBSC basin. According to the Colorado Division of Oil and Public Safety, there are currently no sites with documented groundwater contamination within the study area (Noel 2010). Fuel components have also not been observed in groundwater sample data evaluated for the current study.
- Improper industrial waste treatment has been documented in the UBSC basin. This unpermitted operation occurred at a location (the Cordova property) where metal wastes were discharged into an unregulated waste evaporation pond for the stated purpose of concentrating the waste for metals recovery. The primary contaminants identified in the waste are nickel, copper, cadmium and zinc. Currently, the Colorado Department of Public Health and Environment is overseeing assessment and cleanup activities and monitoring results have not been made available (Henderson, 2010). Indications of elevated metal concentrations have not been observed in groundwater sample data evaluated for the current study.

- The Colorado Springs Landfill is the only regulated landfill known to exist within the current study area and straddles the southwestern boundary of the UBSC basin. This facility accepts municipal solid waste and conducts regular groundwater monitoring for a wide range of groundwater contaminants including metals, organic compounds, and major ions. Groundwater monitoring at well MWG-15 does not indicate elevated concentrations of these constituents.
- The southwest boundary of the UBSC basin is straddled by Schriever Air Force Base (Schriever). This military facility was constructed in the 1980s and known operations at this facility have little potential impact to groundwater quality. Interviews with environmental management staff (Olsen et. al., 2010) and review of documents provided to the CGS by Schriever AFB environmental staff indicate that only minor spills have occurred and have been appropriately mitigated (Schriever AFB, 2007).

Due to the predominance of water supply wells, residents using groundwater may be the first to be influenced by impacts to groundwater quality associated with various land use activities and operations. El Paso County provided information on water supply wells in the basin from the assessor's database. Figure 6.5 presents the 4,955 parcels listed by El Paso County as containing water supply wells in comparison with the location of potential alluvial wells registered with the Office of the State Engineer as determined the CGS study (Topper, 2008). This figure indicates that groundwater is used extensively throughout the basin. The difference between these data is that the county assessor's database data does not differentiate the well depths or aquifer supply water to individual parcels. This information is presented so that stakeholders may assess specific parcel/well locations with respect to the water quality data presented herein.

6.2 Questions from Scope of Work

The Scope of Work for the current study includes a list of specific questions that the Committee wanted to address. These are answered below and expanded upon as needed.

Substantive Scope

- **What is the status of existing groundwater quality, focusing initially on the alluvium of the Upper Black Squirrel Creek Basin?** Overall the groundwater quality is good and the groundwater is suitable for existing beneficial uses. Historically, elevated nitrate concentrations have been observed with some samples exceeding drinking water standards. Water quality data is lacking in those portions of the basin experiencing the most development pressure. The Colorado Department of Public Health and Environment (CDPHE, 2008) gave El Paso County a low priority with respect to vulnerability to agricultural chemicals and nitrate.
- **What groundwater pathways exist? (Understanding how the groundwater system functions is important in determining groundwater contamination migration potential, impacts and solutions.)** The dominant surficial geologic deposits in the UBSC basin are unconsolidated aeolian and alluvial materials that are more vulnerable to contamination than the underlying Denver Basin bedrock aquifers. In general, the UBSC basin alluvial aquifer is characterized by ancient channels carved into the underlying bedrock into which clay, silt, sand and gravel have been deposited. These channels generally follow streambeds currently present in the UBSC basin, but may diverge from the main channels of modern-day streams. Figure 1.2 displays the thickness and distribution of the alluvial deposits and the locations of modern streams. Areas with thicker alluvium, indicated by the cooler colors on the map, are generally the main groundwater pathways. The direction of groundwater flow is from the edges of the basin towards the central main alluvial channel and from north to south. Groundwater flow velocity is estimated by Topper (2008) as 3.1 feet per day resulting in approximately two miles of travel per decade.
- **What is the groundwater age? (Groundwater age can help determine contamination potential according to published reports.)** No age-dating has been reported for the alluvial aquifer within the basin. Water table aquifers such as those present in the UBSC basin are influenced and replenished by precipitation, and the correlation of water levels with precipitation indicate the qualitative age of the water is more modern than “fossil” waters found in the Denver Basin bedrock aquifers.

- **What are potential sources of contamination now and in the future (per drinking water and agricultural standards), relating contaminants to land uses and land use patterns, specifically addressing septic systems and other nitrate sources?** Table 5.1 lists common groundwater contaminants that are associated with certain land uses. Land uses present in the UBSC Basin having the potential to contaminate groundwater include retail fuel distribution, agricultural operations, automotive salvage yards, residential ISDSs, feedlots, landfills, military facilities, and industrial waste/wastewater disposal. Analysis of the 4,887 parcels listed as having ISDSs by El Paso County does not indicate a direct correlation with elevated nitrate concentrations, where data are present. However, most of the locations where groundwater quality data are available have residential developments with lots greater than 35 acres and thus a low ISDS density. Elevated nitrate concentrations also occur in areas with no septic systems. The temporal and spatial limitations of the data available for this study precluded identification of potential sources for the elevated concentrations observed.

- **What is the probability of groundwater contamination (now and in the future)?** The water quality data collected for this study indicate that some parameters (arsenic, nitrate, pH, sulfate, TDS and iron) have exceeded regulatory drinking water standards at certain locations and times. The data available to this study are not sufficient to indicate whether regional impact to water quality from existing land uses or operations have occurred. However, over half of the samples analyzed for nitrate exceeded 5 mg/L suggesting that historic land uses or operations have likely increased nitrate concentrations in the alluvial aquifer. This also indicates groundwater quality is susceptible to future land use activities. An assessment of the vulnerability of the groundwater resource to contamination depends both on the physical and chemical factors influencing the aquifer as well as the associated anthropogenic effects.

  The probability of groundwater contamination in the future is dependent upon the type of development anticipated and occurrence of unpermitted or illegal activities. High density ISDS development, improper disposal of commercial and industrial wastes, focused discharge of stormwater runoff, and discharge of wastewater treatment plant effluent all have the potential to negatively impact groundwater quality in the future.

- **What and where are the data gaps?** Significant geographic and temporal limitations of existing water quality data have been identified. There has been no consistent basin-wide, long-term groundwater monitoring program and the available data are insufficient to reliably evaluate specific land use impacts on groundwater quality. There are no data indicative of groundwater age which could then be used to determine whether contamination is the result of historic, recent or ongoing activities. The most significant geographic data gap is in the northern and western portion of the UBSC basin where the more intensive current development is occurring. The most significant temporal data gap is the lack of regularly-acquired groundwater quality data from a consistent set of wells that would allow determination of trends throughout the UBSC basin.

- **What are appropriate constituents and locations for further testing in Phase 2 to support development of recommendations in Phase 3?** Recommendations for a Phase 2 study are presented in Section 7. The Committee should consider incorporating a vulnerability index assessment tool and defining clear water-resource management objectives before committing to more comprehensive and contaminant specific studies.

7. Phase 2 Study Recommendations

The Phase 1 study objectives were to characterize the current UBSC basin alluvial aquifer groundwater quality and determine whether there is a correlation between existing and future land uses and groundwater quality. This study was only partially successful in meeting those objectives. The data collected indicates that groundwater is generally of good quality. The study Committee identified nitrate as a contaminant of concern and concentrations exceeding the regulatory drinking water standards have been documented in the basin. Unfortunately, there is no groundwater quality data available in the northwest portion of the basin, where urban land uses and ISDSs are concentrated and continued development is expected. Therefore, we could not correlate groundwater quality with land use and land use patterns.

The vulnerability of the groundwater resource to contamination depends not only on the properties of the groundwater flow system but also on the locations and types of sources of naturally occurring and anthropogenic contaminants, physical and chemical characteristics of the contaminant, and locations of sensitive receptors. Decision makers in El Paso County attempting to assess the vulnerability of the groundwater resource currently lack a complete understanding of the hydrogeology of the aquifer system and the associated anthropogenic effects controlling the source, transport, and fate of potential contaminants. The lack of comprehensive knowledge founded on scientifically defensible data often leads to a choice of deciding whether to manage the groundwater resource based on existing knowledge of the groundwater flow system and the known associations of water quality and land use or to commission more comprehensive and contaminant specific assessments.

The path forward and components of a Phase 2 investigation are very dependent upon the water-resource/land use management objectives to be met. This Phase 1 investigation addressed the concerns about water quality impacts and land use by compiling and quantifying potential contaminants to provide an assessment of current and historic groundwater quality. It did not further our understanding of the groundwater flow system or the geochemical system that determines fate and transport of contaminants. A determination of land use impacts on water quality necessitates a scientific assessment of groundwater vulnerability that can assess both the groundwater flow system and geochemical system. To provide a balance between management and scientific objectives, in addressing the county's concerns, we recommend that a Phase 2 study be implemented focusing on the following primary goals:

1. Further refine our understanding of the groundwater flow system by mapping the geometry and extent of the alluvial aquifer, in the northern and western portions of the basin, and the shallow bedrock aquifers most vulnerable to contamination from surficial sources, investigate interactions with surface water, well pumping and other stresses that influence advective transport of contaminants; and
2. Acquire the data needed to support land-use planning decisions by establishing a long-term groundwater monitoring program throughout the basin.

Groundwater monitoring is a critical component of water-resource management. Specifics of the groundwater monitoring program will be dependent upon the objectives to be achieved and need to be determined in the scoping process of the Phase 2 program. With respect to addressing the county's concerns, the monitoring program should focus on assessing the impact from contaminant sources that are related to specific land uses.

7.1 Further Refine the Hydrogeology of Vulnerable Alluvial and Shallow Bedrock Aquifers

The water resources in the UBSC basin alluvial sediments and the shallow portions of the Denver Basin bedrock aquifers are both vulnerable to contamination from surface activities. The current study has documented the water quality of the alluvial aquifer in the UBSC basin based on limited data availability. Due to the distribution of the available data, our results are limited to the central and southern portions of the basin where the alluvium is thicker. Mapping by the Colorado Geological Survey (Topper, 2008) indicates that thinner alluvial deposits extend into the northern and western portions of the UBSC basin as tributary channels. The degree of saturation in these thinner exterior portions of alluvium is unknown as is their usefulness for water supply. However, these thinner portions of the alluvium are pathways for potential contaminant migration to the greater aquifer. In the northern portions of the basin the Denver Basin bedrock aquifers are also present either at the surface or overlain by relatively thin alluvial or aeolian deposits.

A Phase 2 investigation should include additional hydrogeologic characterization of the alluvial and aeolian sediments in the northern and western portions of the UBSC basin, as well as the shallow portions of Denver Basin bedrock aquifers. Characterization of these aquifers can be performed by evaluating both subsurface and surface geologic information through available geologic mapping, drill logs, and geotechnical reports. Incorporation of current geologic mapping of the Falcon Quadrangle by the CGS would benefit this effort. In addition to refining the geology, the Phase 2 investigation should also study hydraulic stresses that could influence groundwater flow and surface water interactions. This additional information would provide a better characterization of the hydrogeology in the areas of the basin where the majority of development is occurring or being planned. Details of the Phase 2 Investigation are expected to be refined in Phase 2 Scoping activities.

7.2 Basin-Wide Long-Term Groundwater Monitoring Program

The current data set is highly inconsistent and hampers any analysis to understand potential land use impacts on alluvial aquifer groundwater quality. A long-term groundwater monitoring program will help planners, developers and water suppliers better understand natural and anthropogenic factors affecting groundwater quality throughout the UBSC basin alluvial aquifer. The new data will also provide a scientific basis to support regulators and policy makers regarding potential policy and / or regulatory changes that may result from Phase 3 activities or provide input for statistical and process-based methods used in groundwater vulnerability assessments.

The proposed long-term, groundwater monitoring program will fill data gaps in the current study and help evaluate impacts related to specific land uses. Objectives and specific details (well locations, monitoring parameters, monitoring frequency, etc.) of the monitoring program should be determined as part of the Phase 2 scoping process. In designing a monitoring program or sampling strategy, it is important to have specific goals/objective in mind. Depending on the ultimate study objectives other alternate approaches to long-term monitoring may be appropriate.

For guidance, and assuming a long-term, groundwater monitoring program is the preferred approach, we provide a general framework and considerations for implementing such a program. The Phase 2 groundwater monitoring program should incorporate select sampling locations (wells) previously sampled by the USGS (e.g. Brendle, 1997) and CGS (e.g. Topper, 2008) to provide continuity and repeatability of long-term concentration trends. To assess trends and determine current water quality, wells from which samples have exceeded water quality standards should be resampled during the first two years for the respective parameter(s) that have exceeded standards. Existing wells considered for inclusion in a monitoring network should be assessed and construction details evaluated to determine the suitability for meeting the programs objective.

Based on the finding of the Phase 1 study, we offer suggested locations for groundwater quality monitoring that fill data gaps and provide for assessment of potential contaminant sources. The general locations of proposed monitoring wells are presented in Figure 7.1. While generalized, these proposed locations address spatial data gaps, consider surface water interactions and flow pathways, are downgradient of potential nitrate sources, and include areas where new development is anticipated. These locations are predominantly along stream channels and at the confluence of alluvial channels. Figure 7.1 also shows those wells that have been included in previous USGS and CGS monitoring well sampling programs with existing water quality data.

Design of the monitoring plan will be dependent upon the objectives and scope of the project. Considerations include: hydrogeologic units to be monitored; analytes of concern; well types and sampling intervals; land use; timeframe for the program; financial, personnel, and analytical considerations; and data management considerations. We suggest semi-annual monitoring for the first two years of the program with a focus on contaminants of concern and those commonly associated with existing and future land uses. The following general groups of indicator parameters should be considered for inclusion in the groundwater monitoring program:

- Field measurements (water level, pH, specific conductance, temperature, dissolved oxygen)
- Total dissolved solids (TDS)
- Major Inorganic Ions (calcium, magnesium, sodium, potassium, chloride, sulfate, and bicarbonate)
- Nitrate and Phosphate
- Coliform bacteria
- Total petroleum hydrocarbons (gasoline and diesel range)
- Total organic carbon (TOC)

The above parameters are either contaminants of concern previously identified in the UBSC basin alluvial aquifer or indicators of potential groundwater quality impacts associated with current and expected land uses in the UBSC basin. The use of indicator parameters establishes baseline water quality at each sample location and an early warning system of potential contamination can guide the selection of additional, more specific sampling parameters to monitor for potential contaminants. Following establishment of baseline conditions, the monitoring program may be revised as needed to change sampling frequency and/or list of parameters either for the entire program or at individual wells.

The Committee may desire to design a specific stratified network based on land use and other important variables that could impact groundwater quality, and sample that network for specific constituents needed for data analysis. It may also consider adding emerging contaminants such as pharmaceuticals and personal care products. Conn, Siegrist and Barber (2007) have identified such compounds in residential and commercial wastewater and describe negligible removal of these compounds by ISDS treatment alone. Should more quantitative groundwater age data than the estimates provided herein be desired, Rupert and Plummer (2009) provide a template for age determination sampling and analysis. Details of the Phase 2 program are dependent upon the ultimate study objectives, which are expected to be clarified in the Phase 2 scoping activities.

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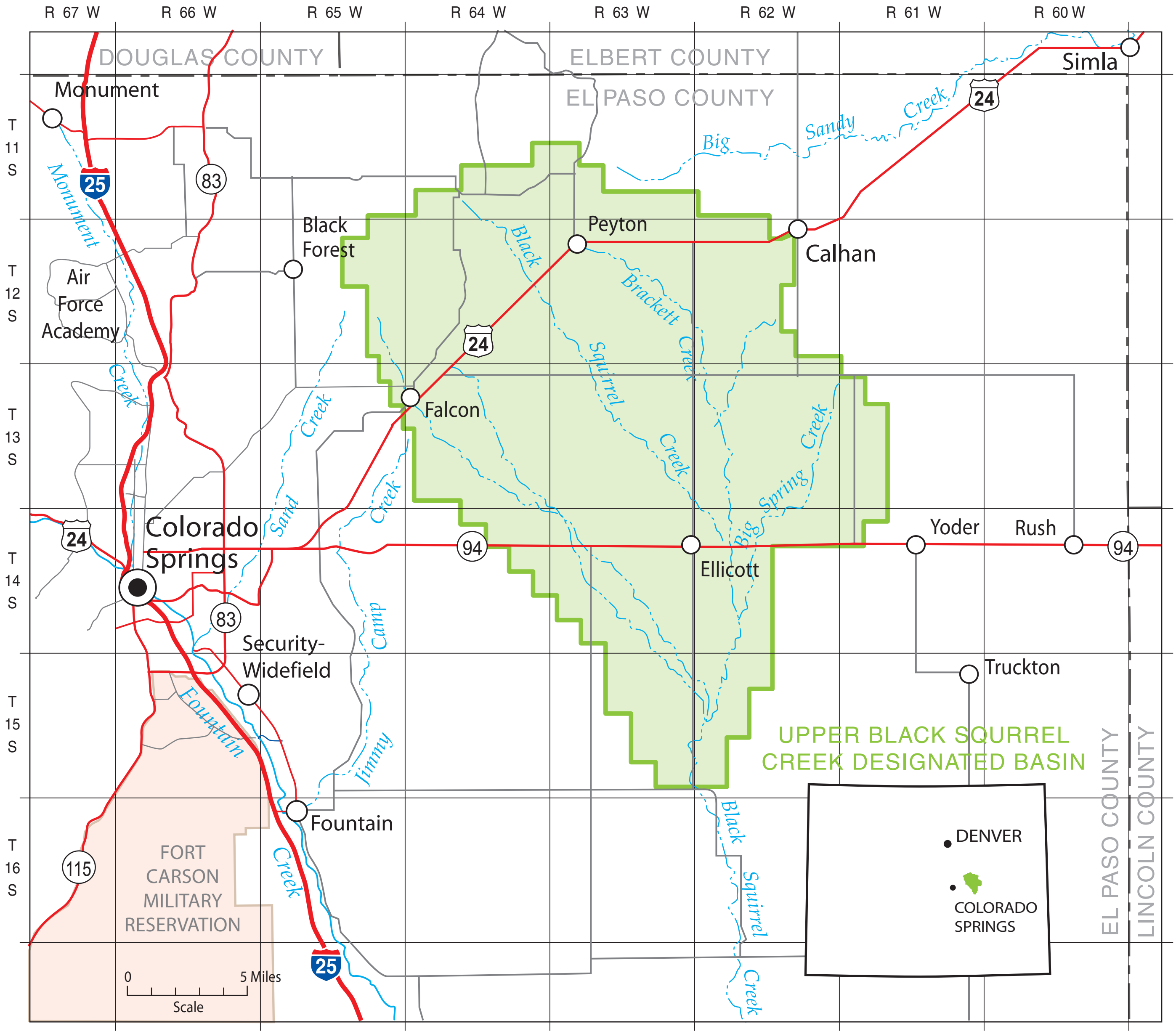

Figure 1.1 Location of the Upper Black Squirrel Creek Basin and Study Area

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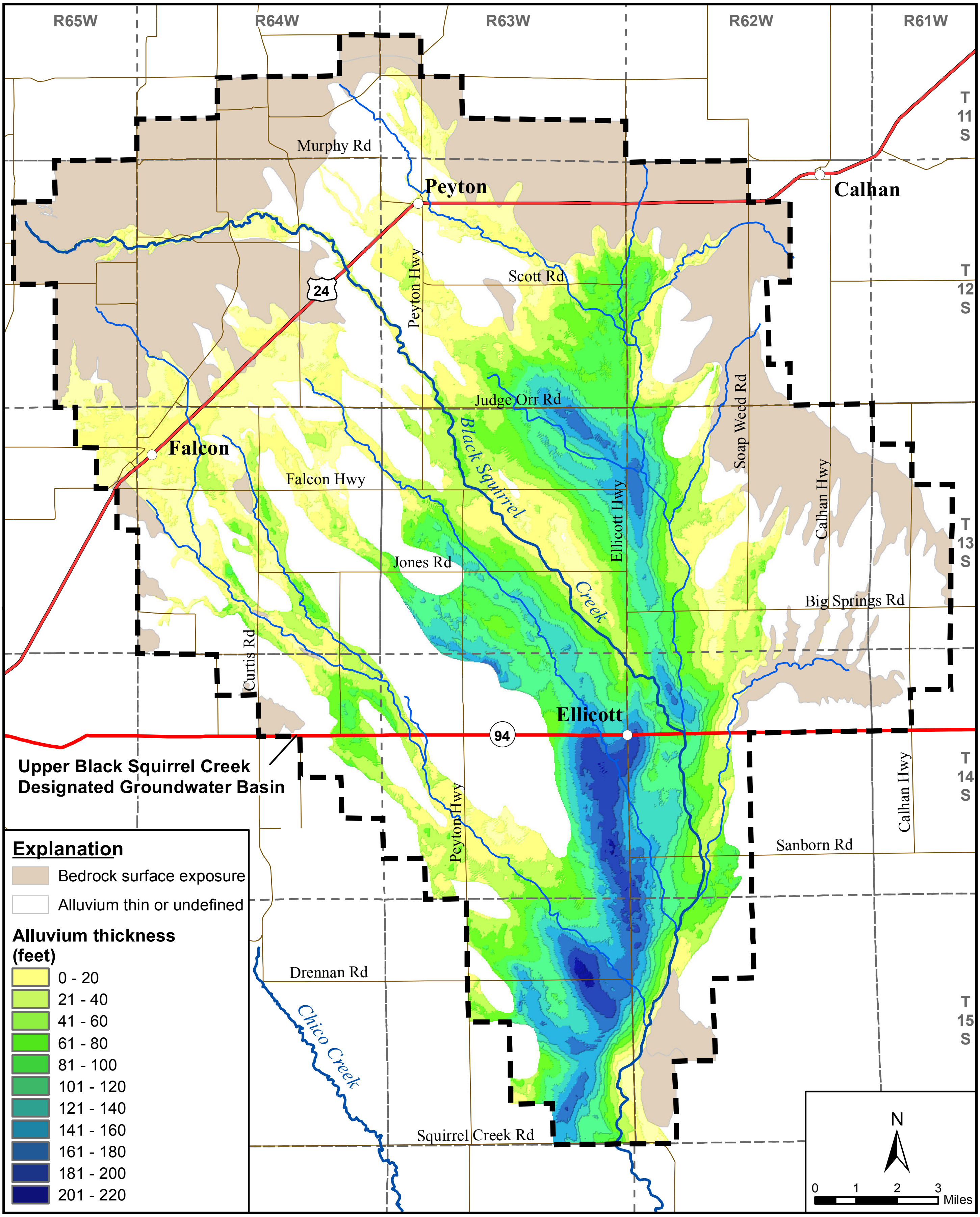

Figure 1.2 Extent and Thickness of the Alluvial Aquifer System in the Upper Black Squirrel Creek Basin

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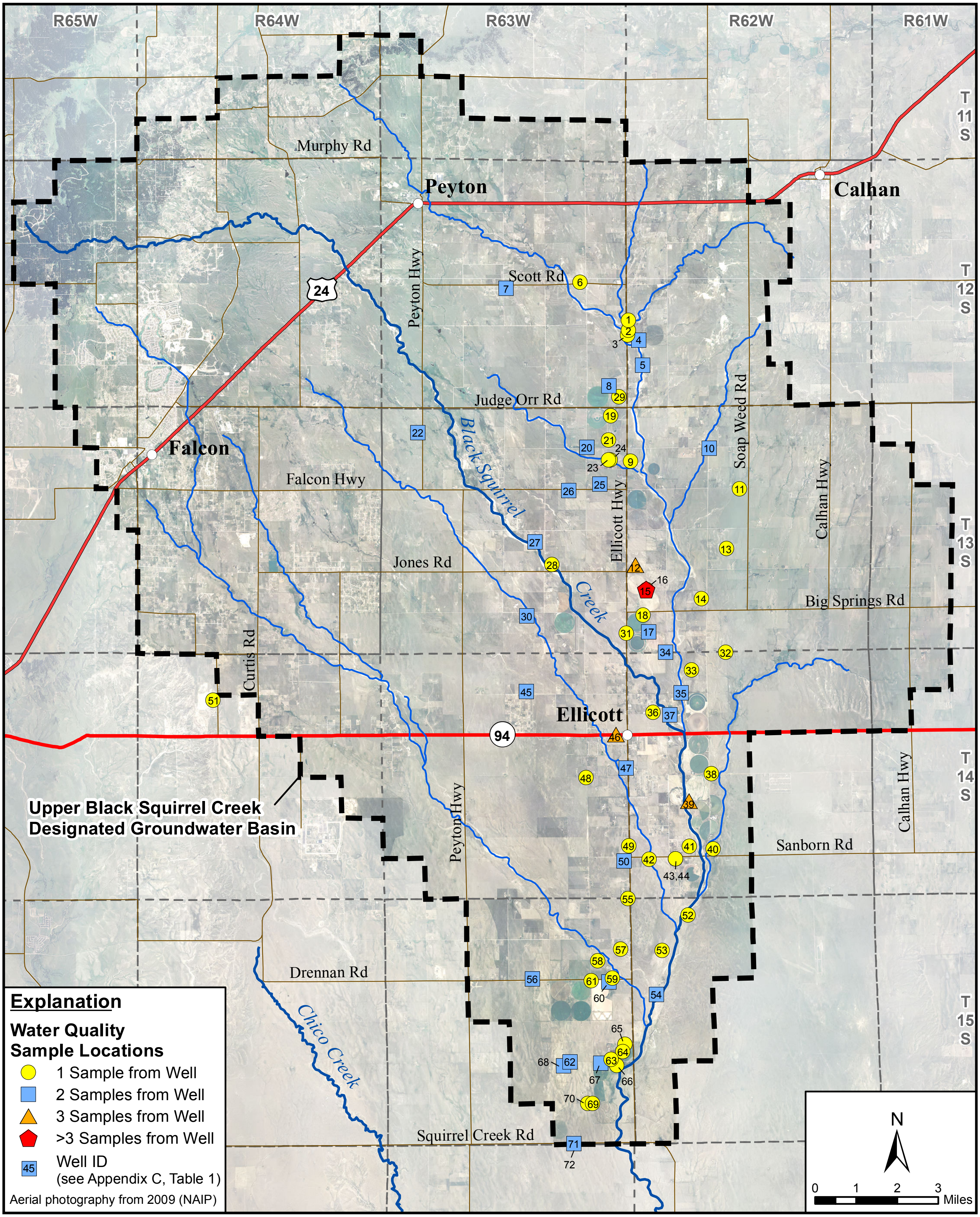

Figure 3.1 Water Quality Sample Location Map

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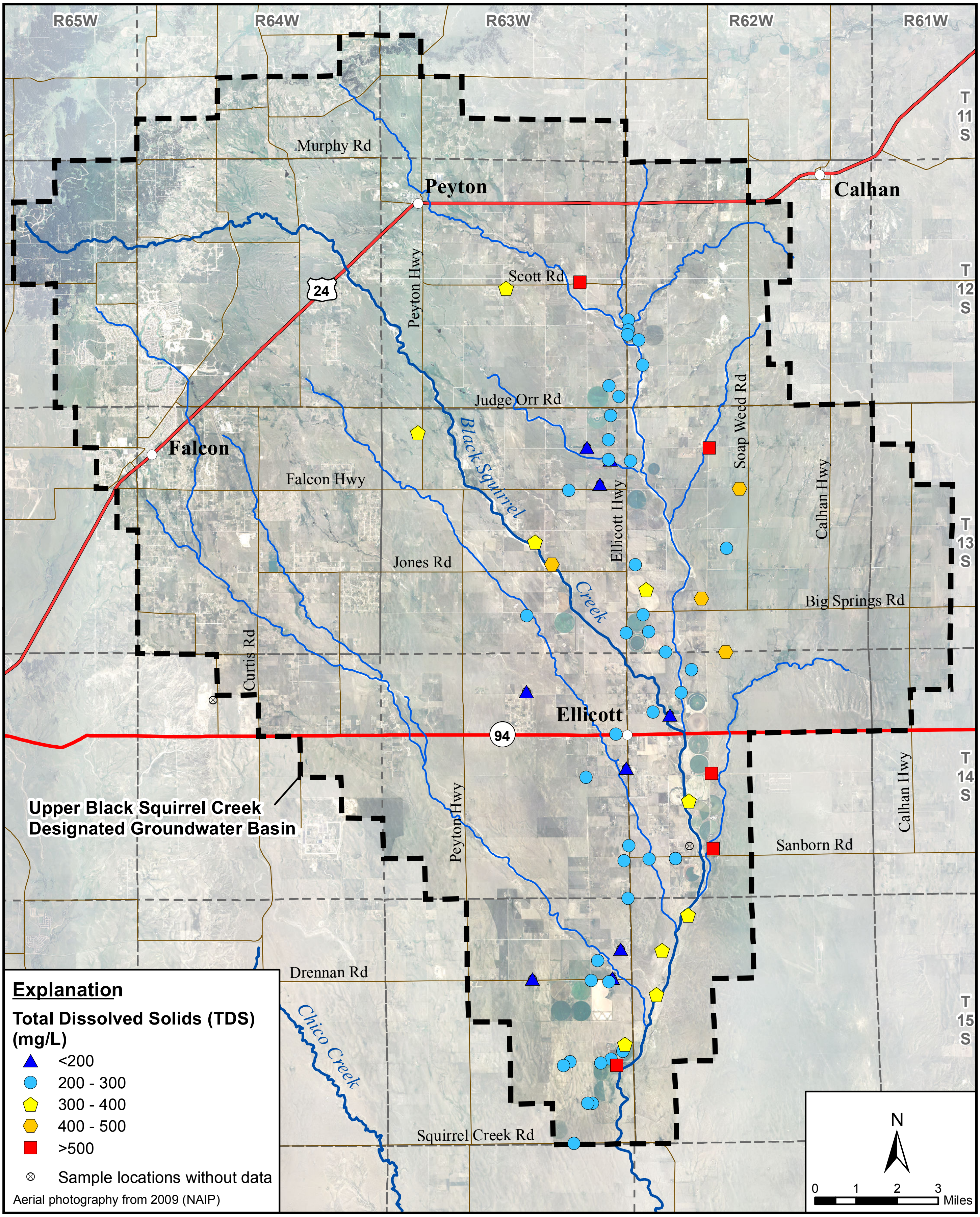

Figure 4.2 Total Dissolved Solids Distribution, 1954-2009

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February 2011

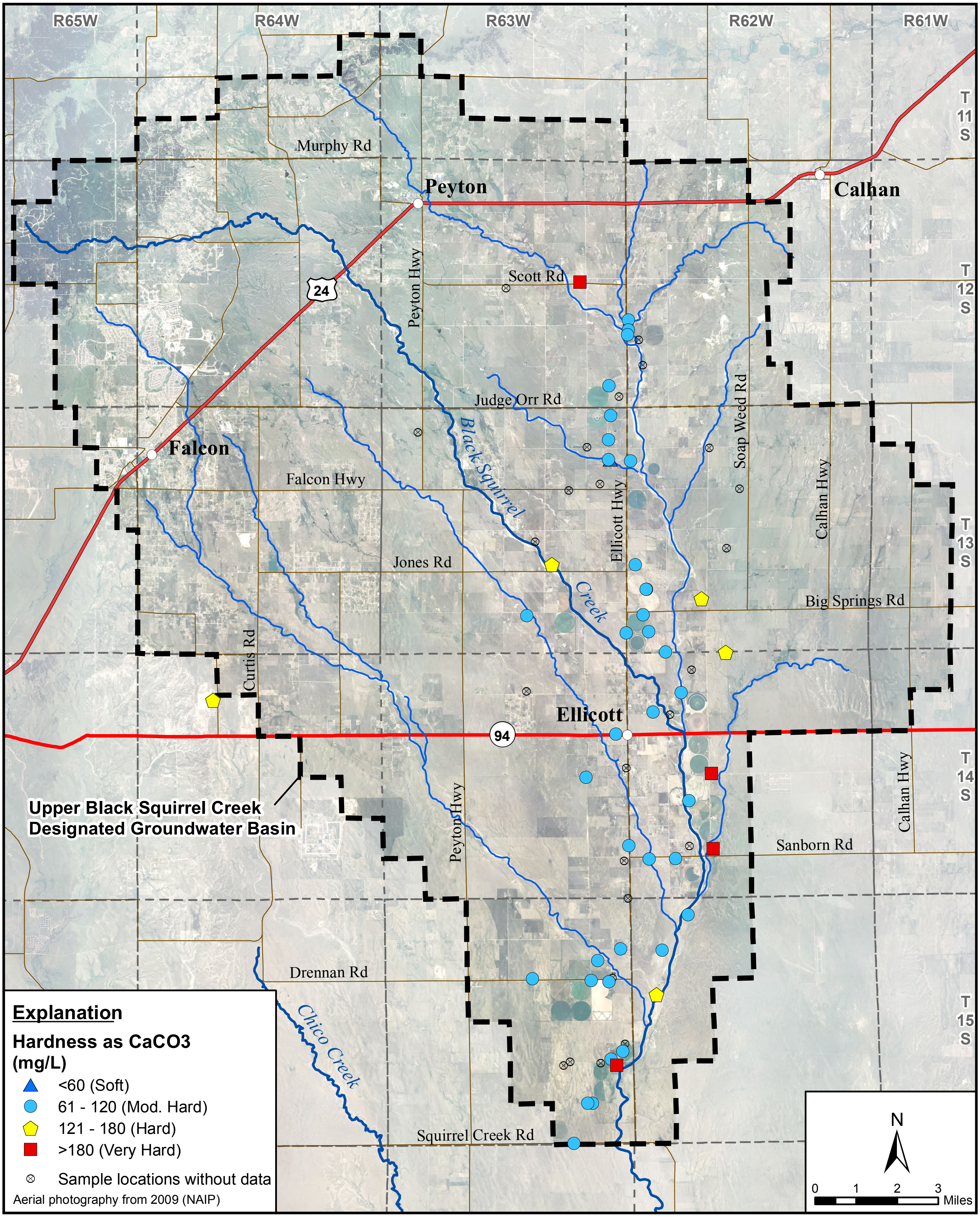

Figure 4.4 Hardness Value Distribution, 1954-2009

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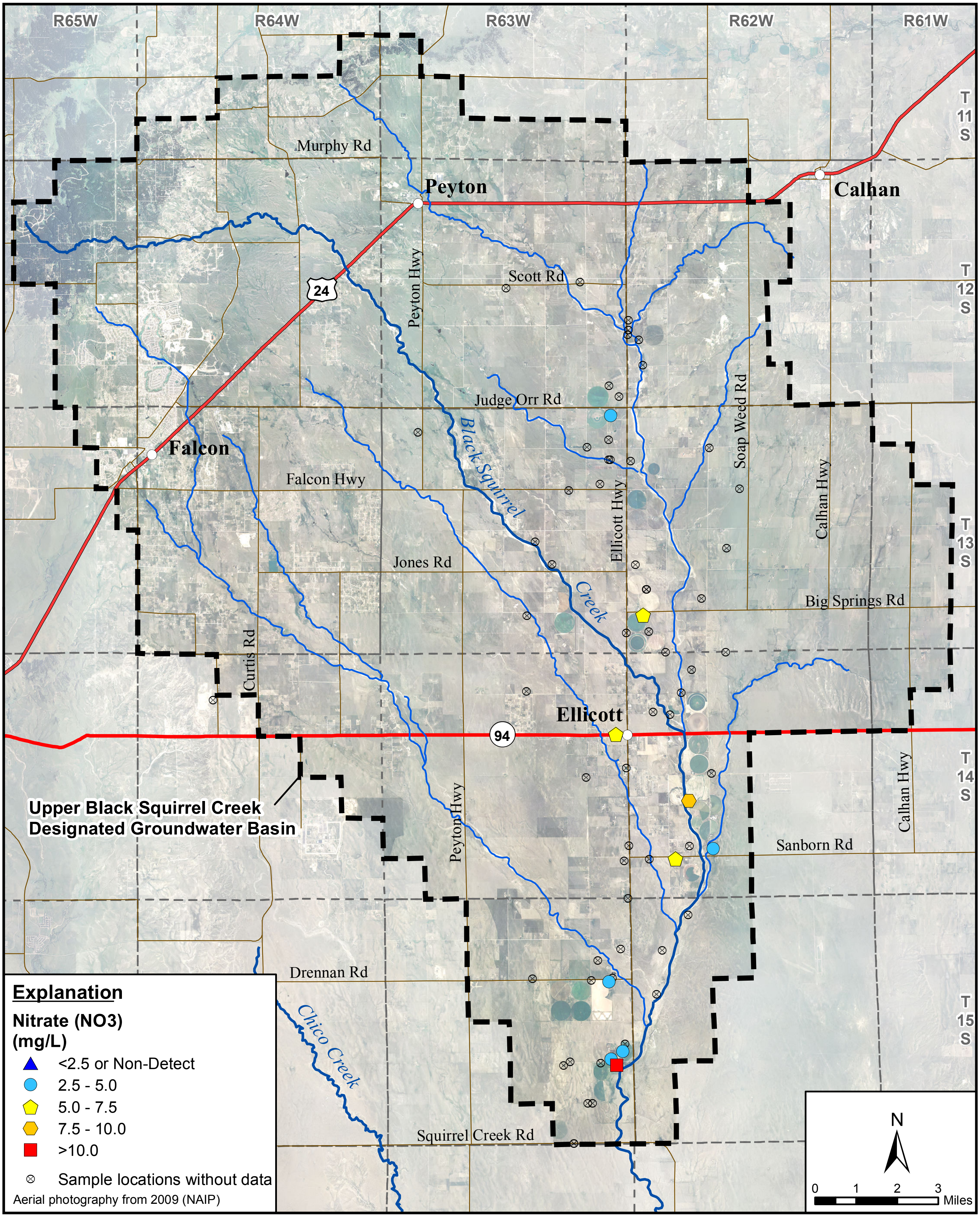

Figure 4.6 Nitrate Distribution, Pre-1980

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February 2011

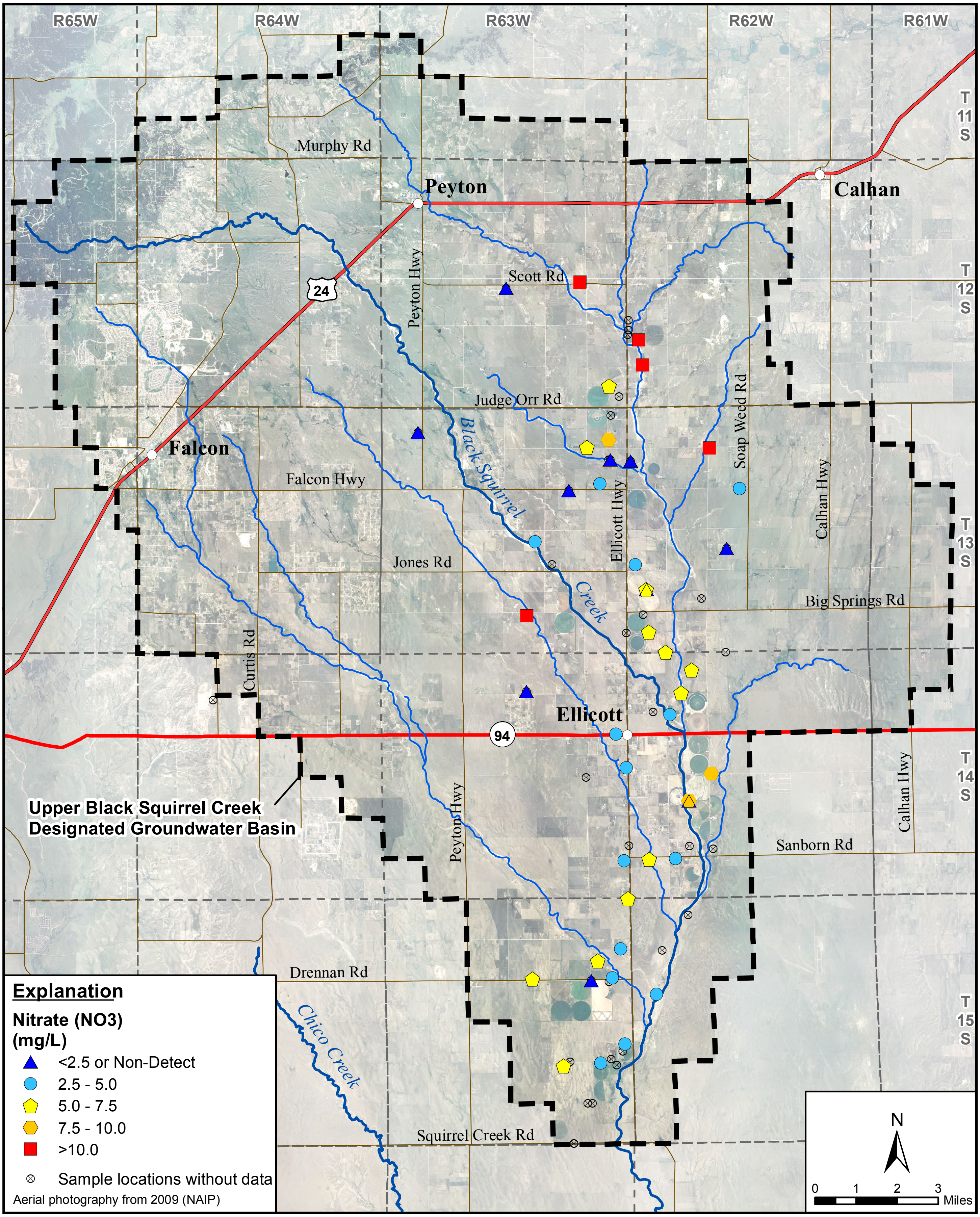

Figure 4.7 Nitrate Distribution, 1980s

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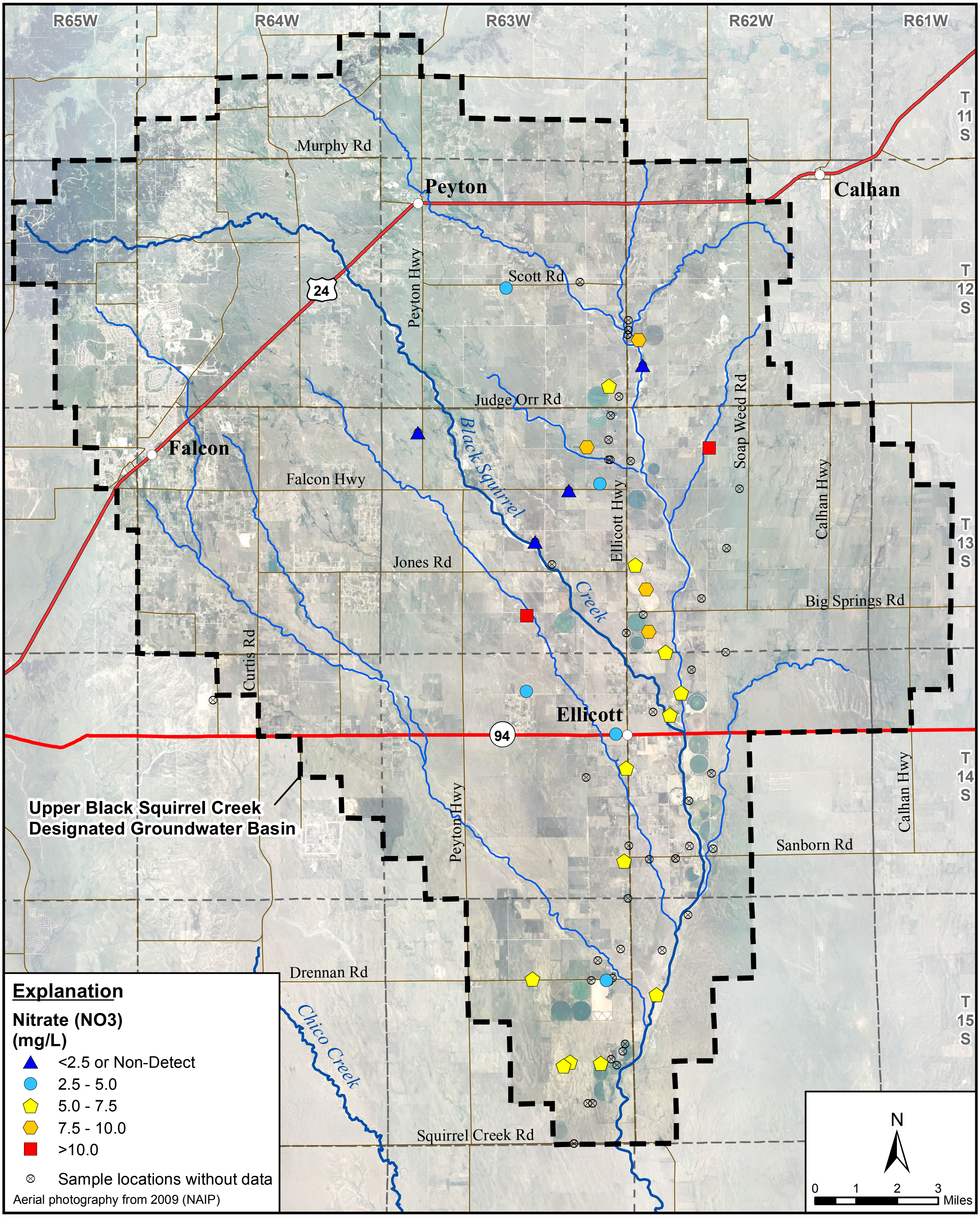

Figure 4.8 Nitrate Distribution, 1990s

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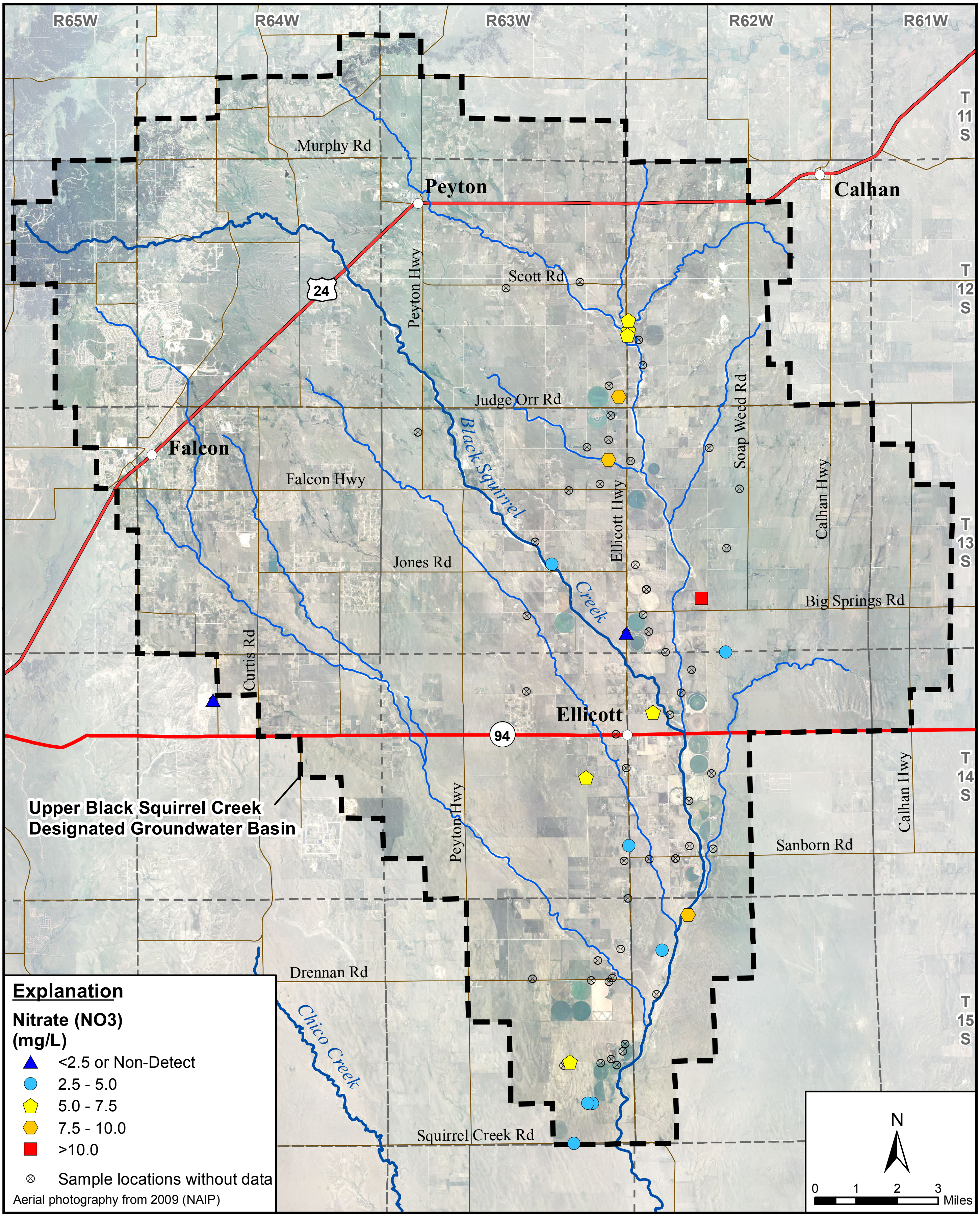

Figure 4.9 Nitrate Distribution, 2000s

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COLORADO GEOLOGICAL SURVEY

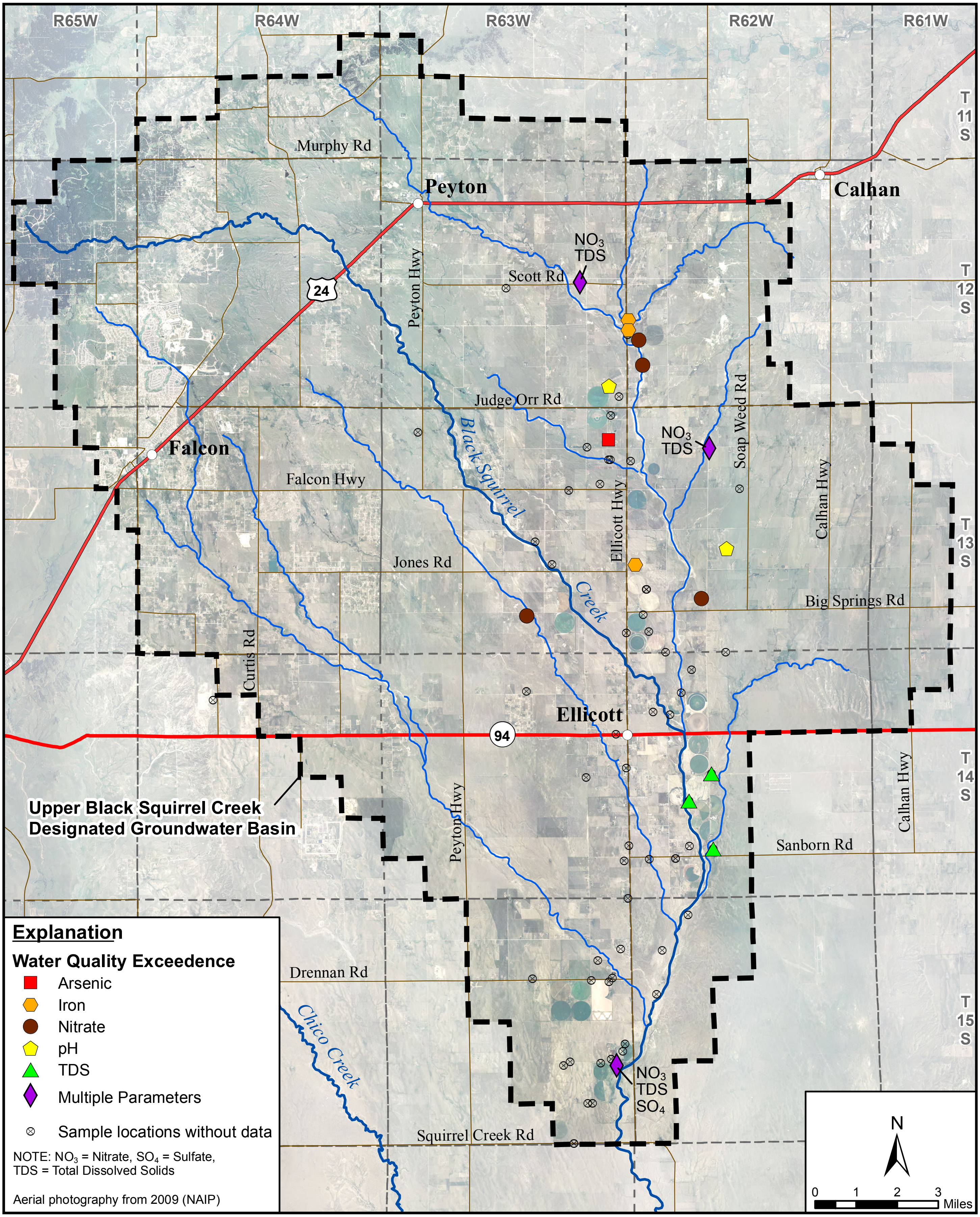

Figure 4.11 Groundwater Quality MCL and SMCL Exceedences, 1954-2009

El Paso County Groundwater Quality Study

February 2011

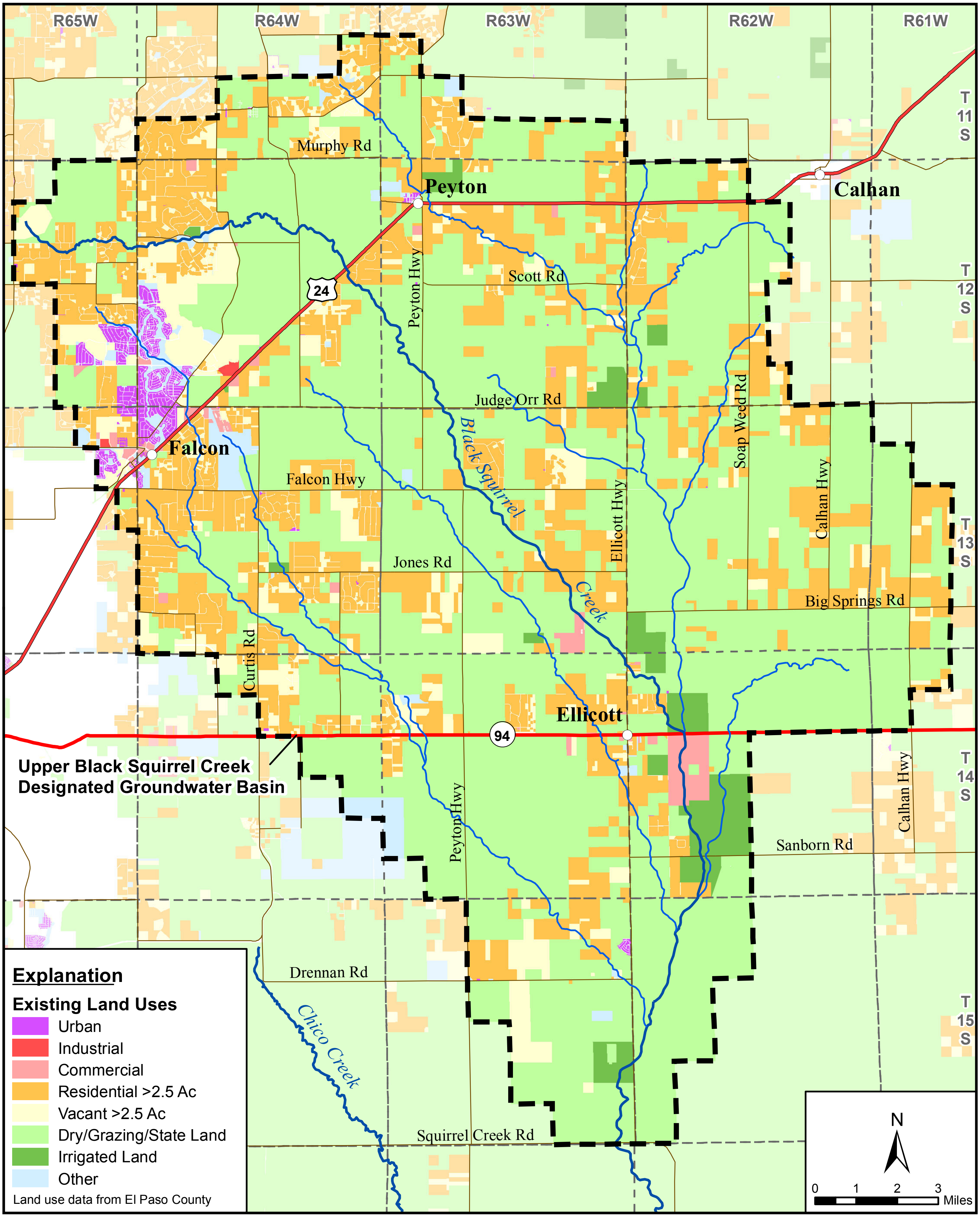

Figure 5.1 Existing Land Use

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COLORADO GEOLOGICAL SURVEY

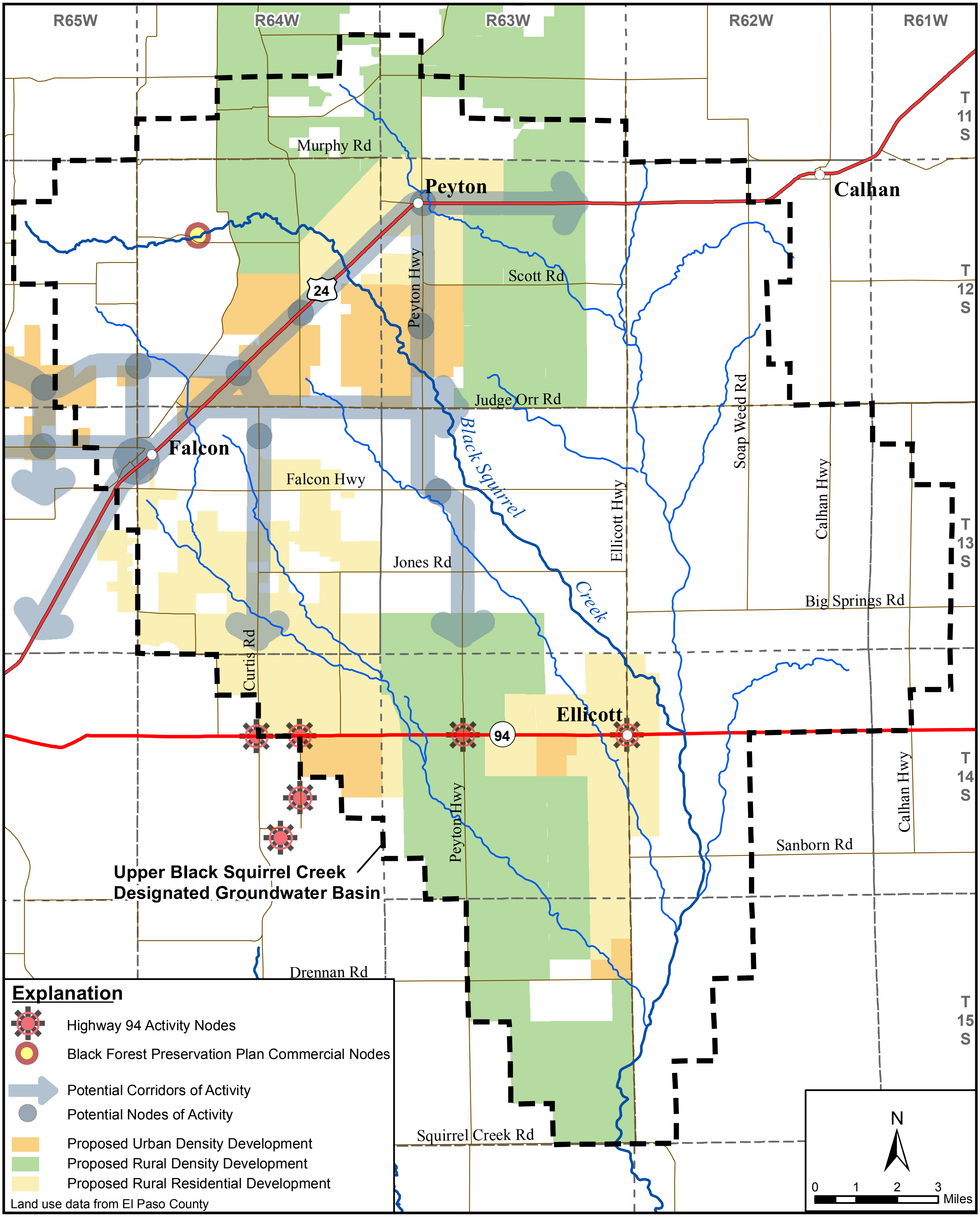

Figure 5.2 Anticipated Future Land Use

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Colorado Geological Survey

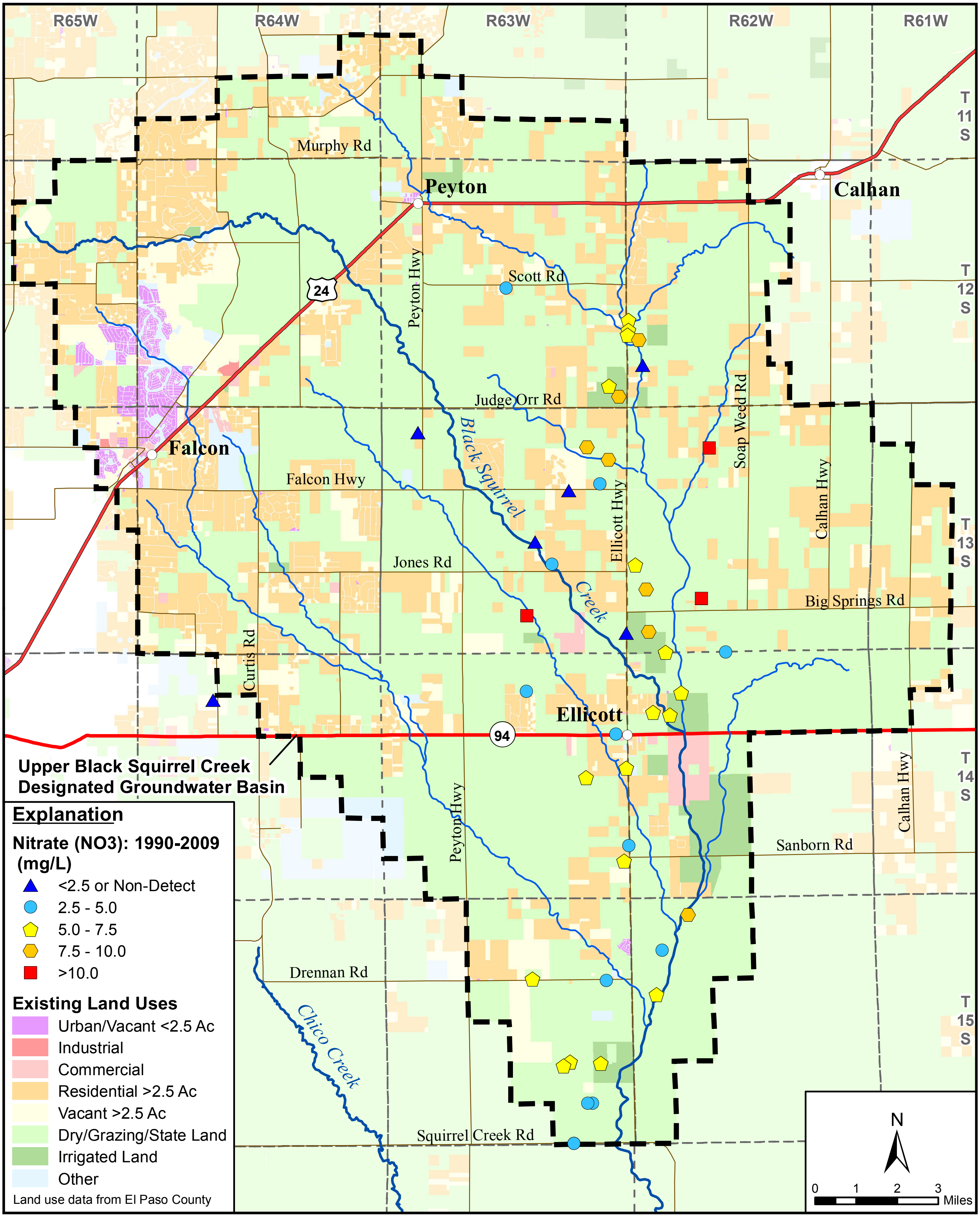

Figure 6.1 Relationship of Nitrate Concentrations to Existing Land Use

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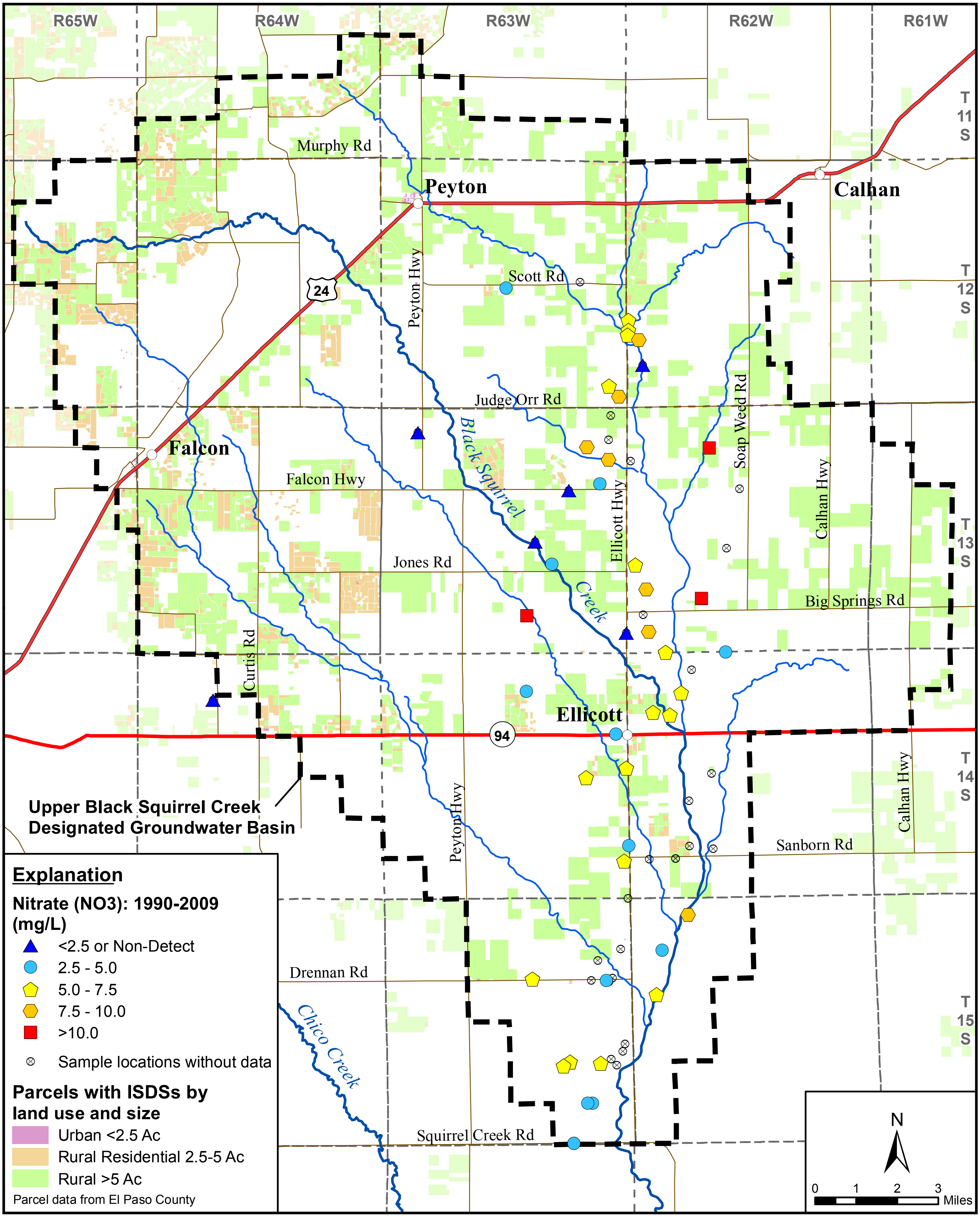

Figure 6.2 Relationship of Nitrate Concentrations with Parcels Containing ISDSs

El Paso County Groundwater Quality Study

February 2011

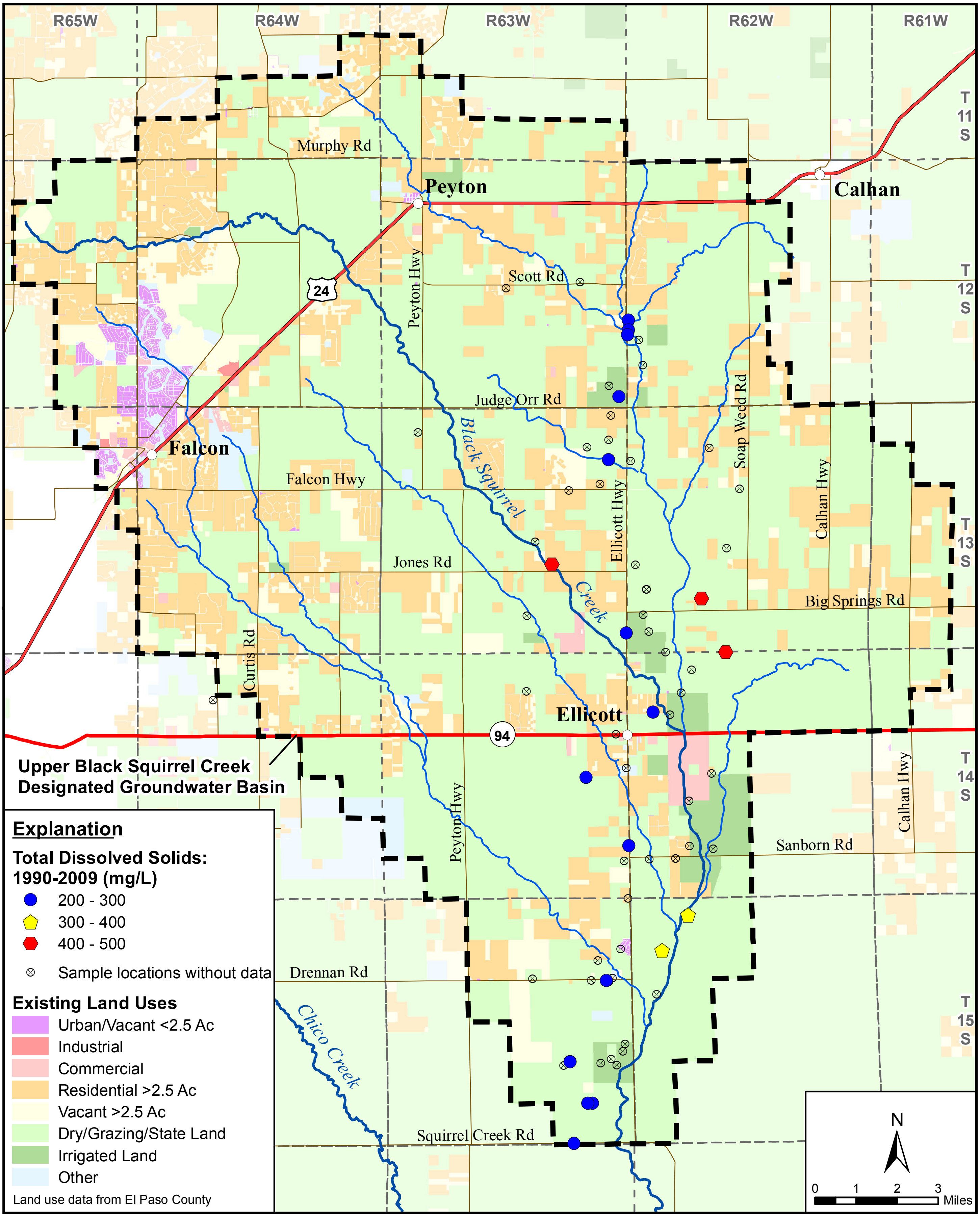

Figure 6.3 Relationship of Total Dissolved Solids Concentrations to Existing Land Use

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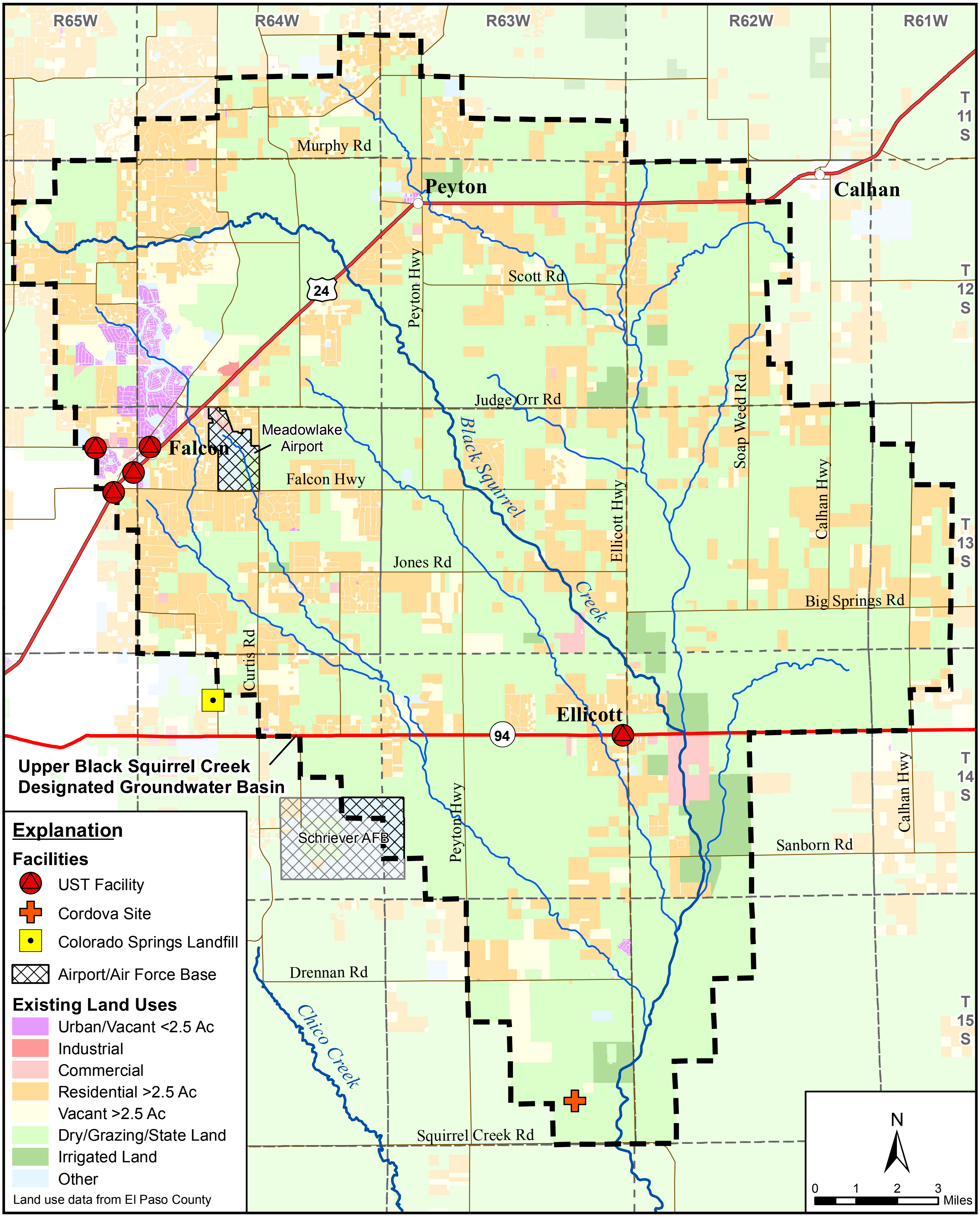

Figure 6.4 Select Facilities in the Upper Black Squirrel Creek Basin

El Paso County Groundwater Quality Study

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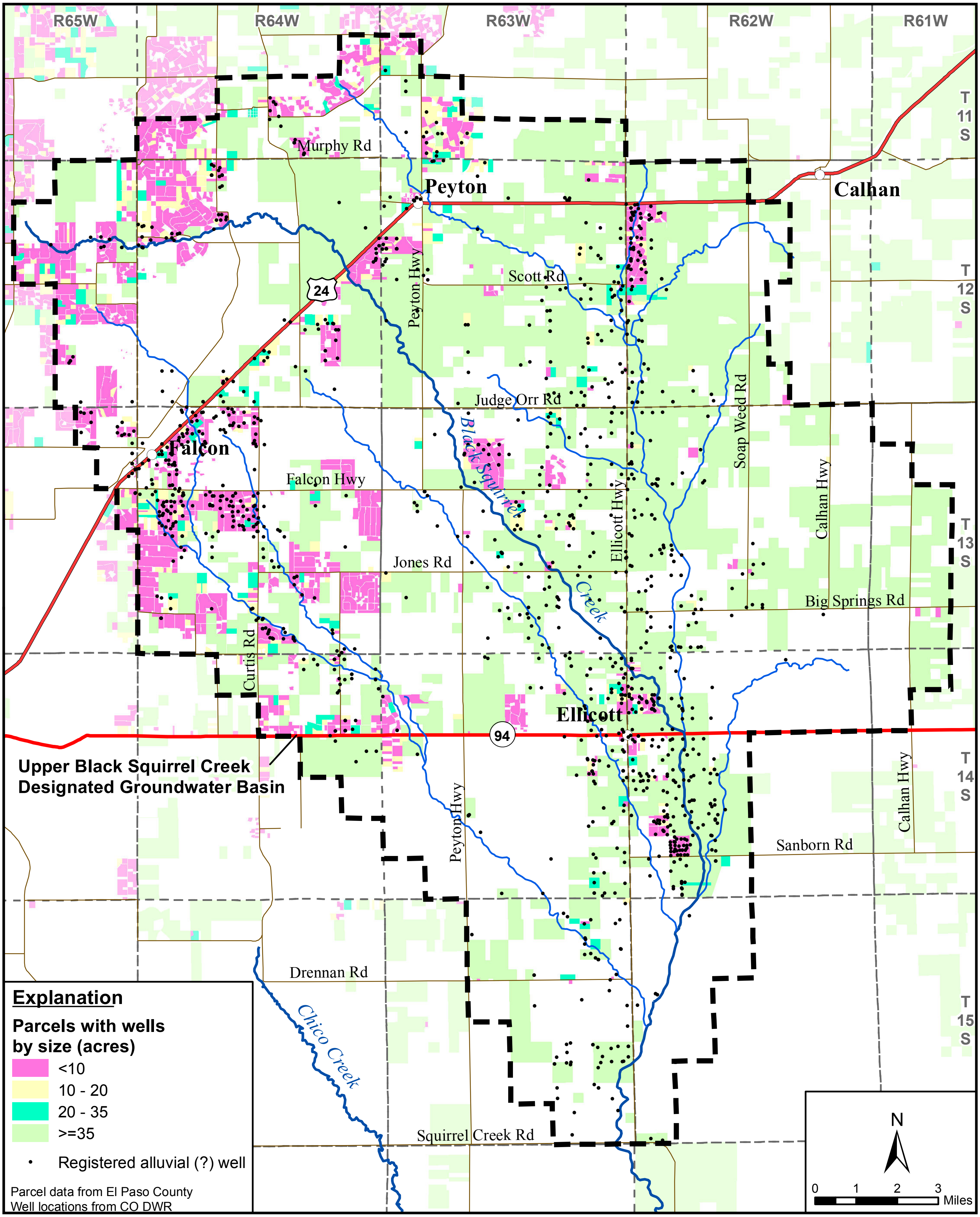

Figure 6.5 DWR Well Locations and Parcels Listed with Wells

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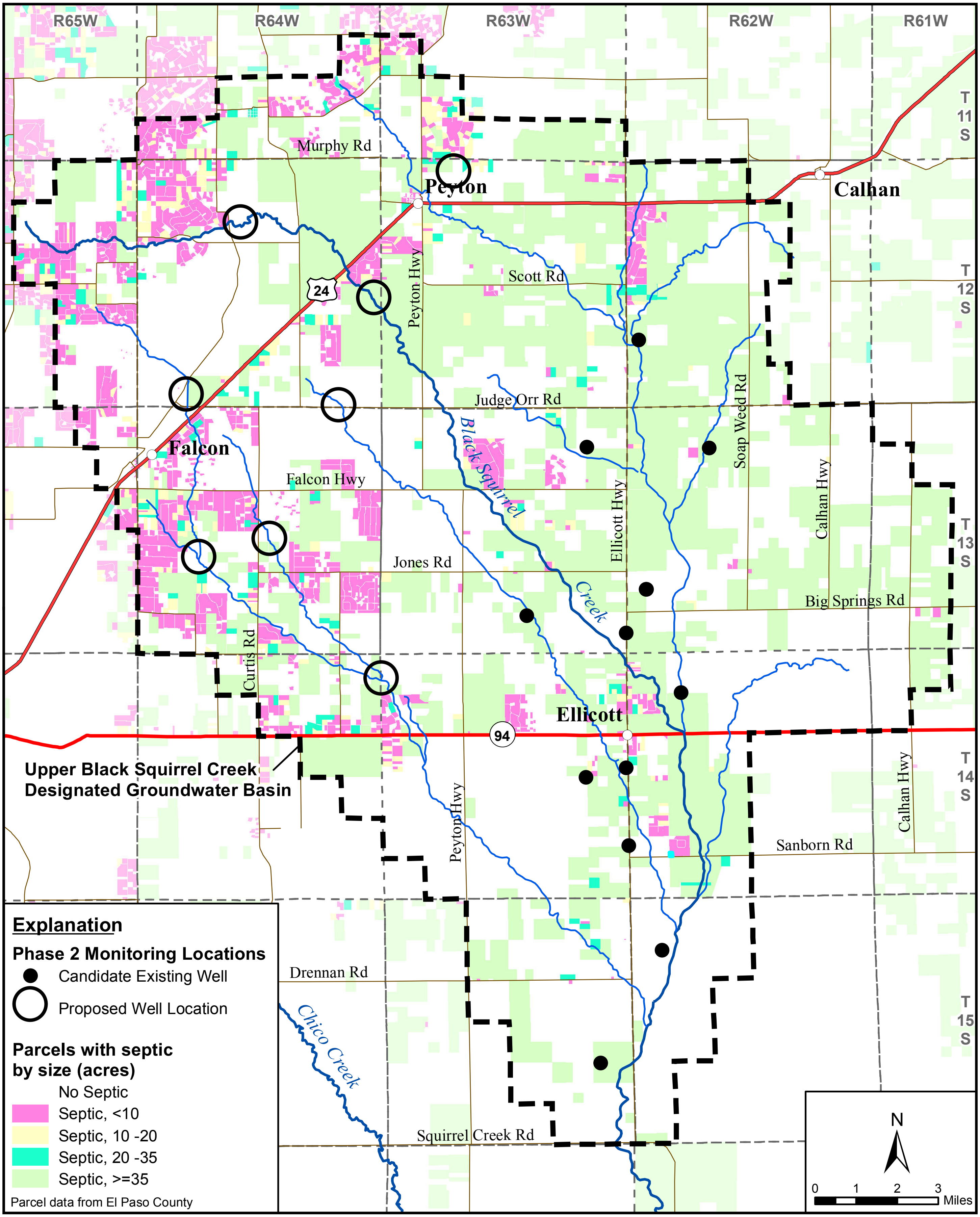

Figure 7.1 Proposed Phase 2 Monitoring Locations

El Paso County Groundwater Quality Study

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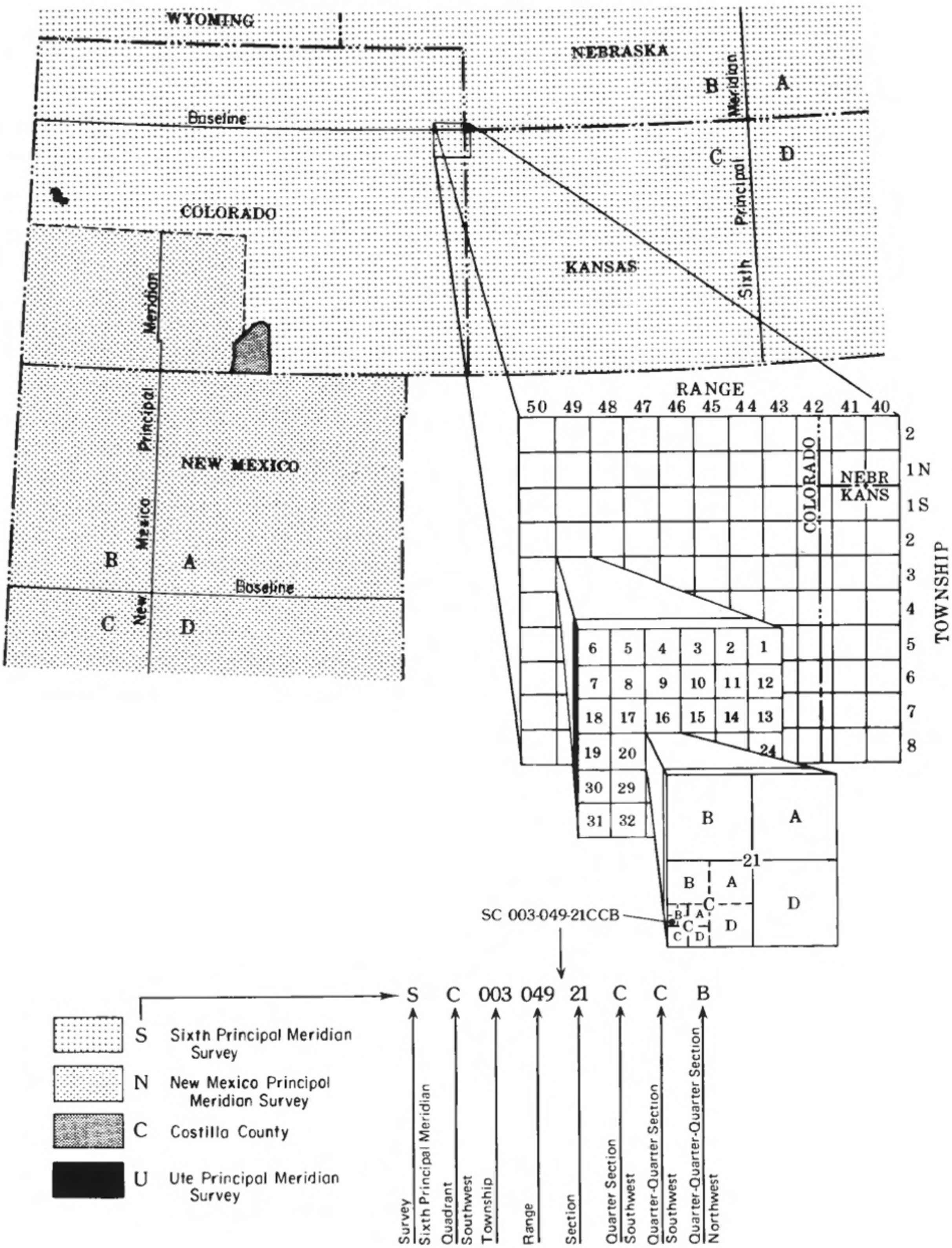
Appendix A

Bureau of Land Management Well Identification System
El Paso County Groundwater Quality Study

Appendix A
Bureau of Land Management Well Identification System
El Paso County Groundwater Quality Study



Appendix B

Annotated Bibliography
El Paso County Groundwater Quality Study

2009

Rupert, M.G., and Plummer, L.N., 2009, Groundwater Quality, Age, and Probability of Contamination, Eagle River Watershed Valley-Fill Aquifer, North- Central Colorado, 2006-2007: U.S. Geological Survey Scientific Investigations Report 2009-5082, 59 p.

The Eagle River watershed is located near the destination resort town of Vail, Colorado. The area has a fast growing permanent population, and the resort industry is rapidly expanding. A large percentage of the land undergoing development to support that growth overlies the Eagle River watershed valley-fill aquifer (ERWVFA), which likely has a high predisposition to groundwater contamination. As development continues, local organizations need tools to evaluate potential land-development effects on ground- and surface-water resources so that informed land-use and water management decisions can be made. To help develop these tools, the U.S. Geological Survey (USGS), in cooperation with Eagle County, the Eagle River Water and Sanitation District, the Town of Eagle, the Town of Gypsum, and the Upper Eagle Regional Water Authority, conducted a study in 2006-2007 of the groundwater quality, age, and probability of contamination in the ERWVFA, north-central Colorado.

Ground- and surface-water quality samples were analyzed for major ions, nutrients, stable isotopes of hydrogen and oxygen in water, tritium, dissolved gases, chlorofluorocarbons (CFCs), and volatile organic compounds (VOCs) determined with very low-level laboratory methods. The major-ion data indicate that ground waters in the ERWVFA can be classified into two major groups: groundwater that was recharged by infiltration of surface water, and groundwater that had less immediate recharge from surface water and had elevated sulfate concentrations. Sulfate concentrations exceeded the USEPA National Secondary Drinking Water Regulations (250 milligrams per liter) in many wells near Eagle, Gypsum, and Dotsero. The predominant source of sulfate to groundwater in the Eagle River watershed is the Eagle Valley Evaporite, which is a gypsum deposit of Pennsylvanian age located predominantly in the western one-half of Eagle County.

Nitrite plus nitrate as nitrogen (nitrate) concentrations in groundwater in the ERWVFA were generally low, with the median nitrate concentration about 0.74 milligram per liter (mg/L) and a maximum concentration of 5.4 mg/L. More than 50 percent of the nitrate concentrations in the ERWVFA were less than 1 mg/L, indicating that more than 50 percent of the wells tested in the ERWVFA had nitrate concentrations similar to precipitation. Most groundwater in the ERWVFA was under oxidized geochemical conditions, indicating that nitrate from anthropogenic sources (caused or produced by humans) could persist for several decades in groundwater of the ERWVFA.

The groundwater age-dating data indicated that most groundwater in the ERWVFA was recently recharged water and had a high probability of contamination if anthropogenic compounds were released to the environment. Based upon the CFC concentrations and tritium activities in groundwater, the median groundwater recharge date was 1989 and the standard deviation was about 9 years, indicating that most groundwater in the ERWVFA that was sampled was young water.

VOCs were detected in all water samples at or above the low-level laboratory reporting limit concentrations, but VOC concentrations in all samples were at least one order of magnitude less than their USEPA Maximum Contaminant Level.

Logistic regression statistical modeling techniques were used to develop statistical models that predict the probability of elevated nitrate concentrations, the probability of unmixed young water (using chlorofluorocarbon-11 concentrations and tritium activities), and the probability of elevated VOC concentrations. These three models used different compounds such as nitrate and VOCs to provide an indication of the probability of groundwater contamination under a variety of conditions and contaminant inputs. Although the groundwater age dating indicates that most areas of the ERWVFA have a high probability of contamination, the probability maps help to show areas with a particularly high probability of contamination if compounds of concern are released to the environment.

2008

Colorado Department of Public Health and Environment, Status of Water Quality in Colorado – 2008 (Update to the 2002, 2004, and 2006 305(b) Reports), Water Quality Control Division, 2008

Section 305(b)(1) of the Clean Water Act (CWA) requires that each state submit a biennial report to the United States Congress through the United States Environmental Protection Agency (EPA). The 305(b) Report is required to include the following:

- *an assessment of water quality of the State*
- *an analysis of the extent to which the waters of the State provide protection for the propagation of aquatic life and recreation in and on the water*
- *a report of the water pollution control programs*
- *a description of the nonpoint source pollution control programs, ground water and drinking water programs*

In 2007, the Water Quality Control Commission (WQCC) conducted a triennial review hearing to address Colorado's Basic Standards for Ground Water (Regulation 41). During the hearing the WQCC updated and revised the numeric ground water standards for toluene, ethylene dibromide (1,2-dibromoethane), and fecal coliform. The WQCC also adopted new standards for four pesticides; acetochlor, dicamba, metribuzin, and prometon. The WQCC also elected to implement the ground water narrative standards on a statewide basis.

The Agricultural Chemicals and Groundwater Protection Program (Program), a cooperative program between the Colorado Department of Agriculture (CDA), Colorado State University Extension Services (CSUCE), and the Water Quality Control Division (WQCD), has been systematically monitoring for the presence of agricultural related chemicals in vulnerable aquifers throughout Colorado. Forty-nine wells were selected for sampling in the reconnaissance survey of El Paso County in 2006. Most samples were located in alluvial aquifers or in the shallow bedrock aquifers of the Denver Basin in the northern portion of the county. Tables and figures provide site-specific information.

In El Paso County in 2006, the average nitrate concentration was 2.74 ppm, and 50% of all samples had a nitrate concentration less than approximately 4 ppm. Seven wells had nitrate concentrations above 5.0 ppm, with only four of those exceeding 7.5 ppm. Six samples were below detection limit. One sample had a nitrate concentration of 11.5 ppm, and was the only sample greater than the ground water standard of 10 ppm. No pesticides were detected in any of the samples from El Paso County. The majority of the wells with nitrate concentrations greater than 5.0 ppm were located in alluvial aquifers. Of the six wells located in alluvial aquifers, with concentrations greater than 5.0 ppm, all were located in *areas that have numerous potential non-point sources for nitrate contamination including septic leach field discharge, agricultural runoff and leaching, or urban runoff. Nitrate contamination does not appear to be a widespread problem based on the results of the reconnaissance investigation. Given the results of the sampling, the Program has not found anything that would necessitate a follow up investigation. El Paso County therefore, is a low priority, with respect to additional monitoring for potential agricultural chemical impacts to ground water.*

Colorado Water Resources Research Institute, 2008. Agricultural Chemicals & Groundwater Protection in Colorado 1990 – 2006. Special Report No. 16.

This document describes the activities of the Colorado Department of Agriculture (CDA) and other entities in helping ensure compliance with Colorado's Agricultural Chemicals and Groundwater Protection Act which took effect in 1990. The CDA is the lead agency and is accompanied by Colorado State University Extension and the Colorado Department of Public Health and Environment. The purpose of the Agricultural Chemicals and Groundwater Protection Act is to reduce agricultural chemicals' negative impacts on groundwater and the environment. Agricultural chemicals covered under this legislation include commercial fertilizers and all pesticides. The goal is to prevent groundwater contamination before it occurs by improving agricultural chemical management. This report summarizes the first 15 years of
the Agricultural Chemicals and Groundwater Protection Act and provides an overview of activities and monitoring data. The report describes pesticide facility inspections, waste agricultural chemical collection, and education and training efforts to reduce the impacts of agricultural chemicals on the environment. Also described are the program's groundwater monitoring efforts which have sampled 1,096 wells and analyzed 1,956 samples statewide as of December 2006. The program has included sampling in the UBSC Basin and detailed results were made available to CGS by the CDA.

Topper, Ralf, 2008, Upper Black Squirrel Creek Basin Aquifer Recharge and Storage Evaluation, Colorado Geological Survey report prepared for El Paso County Water Authority.

The objective of this project is to evaluate and refine the existing knowledge of the hydrogeology of the alluvial aquifer system in the Upper Black Squirrel Creek basin for the purposes of assessing the potential for aquifer recharge and storage implementation. Geographic, geologic, hydrologic and water quality data were collected and analyzed to evaluate the recharge potential, storage capacity, and ambient water quality in the study area. The study area encompasses the entire Upper Black Squirrel Creek drainage basin and coincides with the designated ground water basin boundary.

The report contains a section on water quality. Water quality data from 123 wells was compiled from five different literature sources. Based on the analytical data, water from the alluvial aquifer in the basin is classified as either a sodium calcium-mixed anion or a sodium calcium bicarbonate type. With few exceptions, the alluvial groundwater is of very good quality with total dissolved solids concentrations below 500 milligrams per liter. In four wells, nitrogen compounds exceeded the state drinking water standard.

2007

Conn, K., Siegrist, R.L., and Barber, L.B., 2007, Colorado School of Mines (CSM) Research Regarding Occurrence and Fate of Organic Wastewater Contaminants During Onsite Wastewater Treatment: pg. 12-14.

Organic wastewater contaminants (OWCs) such as pharmaceuticals and personal care products have received increasing attention in the last decade due to their possible adverse effects on ecosystems and human health. Several studies have identified wastewater as a primary contributing source of OWCs to the environment, but few have quantified their occurrence and fate in onsite wastewater treatment systems and associated receiving environments. A substantial portion of the wastewater generated in the United States is processed by onsite wastewater treatment systems before discharge to the environment.

Between 2002 and 2005, the CSM/USGS research team quantified the occurrence and OWCs in 30 Colorado onsite wastewater treatment systems serving different homes, businesses, institutions, and varied types of confined treatment systems. Concentrations of OWCs in effluents before and after septic tank treatment were usually similar, suggesting low to negligible removal of OWCs during septic tank treatment alone. **.** *Results from the reconnaissance survey of 30 onsite wastewater treatment systems suggest that OWCs are being applied to onsite system soil treatment units at environmentally relevant concentrations. To help understand the fate of OWCs in wastewater effluents during soil treatment, a tracer test was conducted at the CSM Mines Park Test Site using a conservative tracer (potassium bromide) and a pharmaceutical surrogate (rhodamine WT). The results suggest that OWCs with similar properties as the pharmaceutical surrogate may be retarded and/or removed during onsite system soil treatment depending on the site-specific soil characteristics. Understanding the additional treatment that occurs during soil infiltration and percolation through the vadose zone and within the groundwater and surface water receiving environments is critical to aid in defining potential adverse effects to ecosystem and human health due to OWCs being discharged from onsite wastewater treatment systems.*

Paul, W., 2007. Water budget of a mountain residence, Jefferson County, Colorado. Thesis (M.Sc.) -- Colorado School of Mines, 65 pg.

A water budget for an individual sewage disposal system (ISDS) located at a mountain residence near Evergreen, Colorado, was calculated using field data as inputs to a continuity equation. Water pumped from the fractured, unconfined aquifer was metered. A pressure transducer in the dosing chamber of the septic tank monitored waste water flow from the home into the ISDS system. A tipping-bucket rain gauge measured precipitation. Actual evapotranspiration (AET) was measured at various times of year during the study using a plastic, hemisphere-shaped chamber that monitored humidity. Potential evapotranspiration (PET) was continuously calculated by an on-site meteorological station with a half hour frequency. Using multiple, linear regression, a model of continuous PET based on meteorological data was calibrated with the intermittent AET data to estimate continuous AET throughout the study period. Lateral flow was negligible during the majority of the year. Vertical flow to the fractured bedrock was estimated using two methods. The first method based on measurements of vertical hydraulic conductivity and gradient yielded unreasonable results with large uncertainty and are not presented. The second method determined vertical *flow as the unknown in the continuity equation and resulted in reasonable values. Calculated water loss in the residence and AET of ISDS effluent were combined to estimate the percent of pumped water available to recharge the underlying fractured bedrock. At this residence, an average of 84.4 % (with an uncertainty ranging from 83.5 to 85.2 %) of water pumped into the residence was estimated to be available to recharge the underlying aquifer.*

Paul, W., Poeter, E., and Laws, R., 2007, Consumptive Loss from an Individual Sewage Disposal System in a Semi-Arid Mountain Environment: in Colorado Water, v.24, issue 4, pg. 4-9

Consumptive loss from an individual sewage disposal system (ISDS) located at a residence in the foothills of the Rocky Mountains near Evergreen, Colorado, was calculated using field data. Water pumped from the fractured crystalline bedrock unconfined aquifer was metered, and the volume of effluent dosed to the infiltration area was monitored. Actual evapotranspiration (AET) was measured intermittently using a plastic, hemisphere-shaped chamber that monitored humidity. Potential evapotranspiration (PET) was calculated using data from an on-site meteorological station. A model of continuous PET based on meteorological data was calibrated with the intermittent AET data to estimate continuous AET throughout the study period. Calculated water loss in the residence and AET of ISDS effluent were combined to estimate the percent of pumped water available to recharge the underlying fractured bedrock. At this site, an average of 84.4% of water pumped to the residence was estimated to be available to recharge the underlying aquifer. This is comparable to the potential amount of return flow (87.7%) inferred from the 12.3% consumptive loss of water estimated by the Colorado Division of Water Resources in 1974 (Van Slyke and Simpson, 1974). This loss may not be representative of loss from ISDS sites throughout the foothills. Future study is recommended to characterize the average amount of water lost in and around the ISDS infiltration area throughout the foothills.

Topper, R., 2007, Consumptive Use Estimates for Return Flows from Individual Sewage Disposal Systems: in Colorado Water, v.24, issue 4, pg. 10-11

Article summarizes the historical and current knowledge of the consumptive use of water related to Individual Sewage Disposal Systems in Colorado. Compares the consumptive use value of 12.3% given by the State Engineer in the mid 1970's to more recent studies on the subject of ISDS consumptive use. The conclusion is that recent studies have found similar values (±5%) to that determined by the State Engineers Office. However, few Colorado site-specific studies have been done on the matter of ISDS consumptive use so additional investigations are warranted to better understand the issue.

Miller, L.D., and Ortiz, R.F., 2007, Ground-Water Quality and Potential Effects of Individual Sewage Disposal Effluent on Ground-Water Quality in Park County, Colorado, 2001-2004: U.S. Geological Survey Scientific Investigations Report 2007-5220, 48 p.

In 2000, the U.S. Geological Survey, in cooperation with Park County, Colorado, began a study to evaluate ground-water quality in the various aquifers in Park County that supply water to domestic wells. The focus of this study was to identify and describe the principal natural and human factors that affect ground-water quality. In addition, the potential effects of individual sewage disposal system (ISDS) effluent on ground-water quality were evaluated.

Ground-water samples were collected from domestic water-supply wells from July 2001 through October 2004 in the alluvial, crystalline-rock, sedimentary-rock, and volcanic-rock aquifers to assess general ground-water quality and effects of ISDS's on ground-water quality throughout Park County. Samples were analyzed for physical properties, major ions, nutrients, bacteria, and boron; and selected samples also were analyzed for dissolved organic carbon, human-related (wastewater) compounds, trace elements, radionuclides, and age-dating constituents (tritium and chlorofluorocarbons).

Drinking-water quality is adequate for domestic use throughout Park County with a few exceptions. Only about 3 percent of wells had concentrations of fluoride, nitrate, and (or) uranium that exceeded U.S. Environmental Protection Agency national, primary drinking-water standards. These primary drinking-water standards were exceeded only in wells completed in the crystalline-rock aquifers in eastern Park County. Escherichia coli bacteria were detected in one well near Guffey, and total coliform bacteria were detected in about 11 percent of wells sampled throughout the county. The highest total coliform concentrations were measured southeast of the city of Jefferson and west of Tarryall Reservoir. Secondary drinking-water standards were exceeded more frequently. About 19 percent of wells had concentrations of one or more constituents (pH, chloride, fluoride, sulfate, and dissolved solids) that exceeded secondary drinking-water standards. Radon concentrations in about 91 percent of ground-water samples were greater than or equal to 300 pCi/L, and about 25 percent had radon concentrations greater than or equal to 4,000 pCi/L. Generally, the highest radon concentrations were measured in samples collected from wells completed in the crystalline-rock aquifers.

Analyses of ground-water-quality data indicate that recharge from ISDS effluent has affected some local ground-water systems in Park County. Because roughly 90 percent of domestic water used is assumed to be recharged by ISDS's, detections of human-related (wastewater) compounds in ground water in Park County are not surprising; however, concentrations of constituents associated with ISDS effluent generally are low (concentrations near the laboratory reporting levels).

ISDS density (average subdivision lot size used to estimate ISDS density) was related to ground-water quality in Park County. Chloride and boron concentrations were significantly higher in ground-water samples collected from wells located in areas that had average subdivision lot sizes of less than 1 acre than in areas that had average subdivision lot sizes greater than or equal to 1 acre. No significant increases in constituent concentrations were observed in wells completed in the sedimentary-rock aquifers for any lot-size category, and *too few samples were collected from wells completed in the alluvial aquifers to do statistical tests.*

The year of ISDS installation also was related to ground-water quality in Park County. For example, significantly higher nitrite-plus-nitrate concentrations were measured between wells with ISDS's installed in the 1970's and those installed in the 1980's. Significantly higher nitrite-plus-nitrate concentrations were not measured between wells with ISDS's installed in the 1980's and those installed in the 1990's. However, significantly higher nitrite-plus-nitrate concentrations were measured between wells with ISDS's installed in the 1990's and those installed after 1999. The lowest overall nitrite-plus-nitrate concentrations were measured in wells that had ISDS's installed after 1999, and the highest concentrations were measured in wells with ISDS's installed before 1980. Nitrate concentrations may be less in samples collected from wells with ISDS's installed after 1980 because effluent has not had enough time to move through the unsaturated zone to the ground-water table in sufficient quantities to significantly affect ground-water quality.

2006

Dano, K., Poeter, E., Thyne, G., 2006, Fate of individual sewage disposal system wastewater in mountainous terrain: in Colorado Ground-Water Association Newsletter, Colorado Groundwater Association, March 2006 pg. 1, 4-9

While the fate of individual sewage disposal system (ISDS) effluent is relatively well understood in soils, less is known about its fate in regolith overlying fractured-rock aquifers. Effluent from an ISDS was tracked via geophysical, geochemical, and hydrological methods. Under typical precipitation conditions, the effluent entered the fractured bedrock within 5 meters of the boundary of the constructed infiltration area. Mass balance models of the surface water chemistry near the mouth of the basin require an anthropogenic component very similar to effluent to account for the decline in water quality suggesting a causative relationship.

Wakida, F.T., and Lerner, D.N, 2006, Potential nitrate leaching to groundwater from house building: in Hydrological Processes, 2006, Vol. 20 pg. 2077-2081 http://www3.interscience.wiley.com/journal/112556371/abstract?CRETRY=1&SRETRY=0).

Nitrate pollution has been identified as a major water quality issue in the UK. This study aimed to determine the potential additional loading of nitrate that could arise from the disturbance caused by house construction. The study is centered around the towns of Nottingham and Mansfield, UK, which are situated on a Triassic Sandstone aquifer. Soil samples up to a depth of 2·70 m were taken from seven sites under construction and other land uses. The average nitrogen load was 59 kg ha-1, which is slightly higher than the nitrate leaching observed when temporary grassland is ploughed in temperate climates. The most important factors involved in nitrogen loss from house building are expected to be previous land use, quantity of total nitrogen after topsoil stripping, and seasonal timing of construction.

2005

Gardner, K. K., and Vogel, R. M., 2005. Predicting ground water nitrate concentration from land use. Ground Water, Vol. 43, No. 3, pg. 343 – 352.

Ground water nitrate concentrations on Nantucket Island, Massachusetts, were analyzed to assess the effects of land use on ground water quality. Exploratory data analysis was applied to historic ground water nitrate concentrations to determine spatial and temporal trends. Maximum likelihood Tobit and logistic regression analyses of explanatory variables that characterize land use within a 1000-foot radius of each well were used to develop predictive equations for nitrate concentration at 69 wells. The results demonstrate that historic nitrate concentrations downgradient from agricultural land are significantly higher than nitrate concentrations elsewhere. Tobit regression results demonstrate that the number of septic tanks and the percentages of forest, undeveloped, and high-density residential land within a 1000-foot radius of a well are reliable predictors of nitrate concentration in ground water. Similarly, logistic regression revealed that the percentages of forest, undeveloped, and low-density residential land are good indicators of ground water nitrate concentration >2 mg/L. The methodology and results outlined here provide a useful tool for land managers in communities with shallow water tables overlain with highly permeable materials to evaluate potential effects of development on ground water quality.

Heatwole, K.K., McCray, J., and Lowe, K., 2005, Predicting Nitrogen Transport From Individual Sewage Disposal Systems for a Proposed Development in Adams County, Colorado: Eos Trans. AGU, 86(52), Fall Meet. Suppl., Abstract, January 21, 2010 10

Individual sewage disposal systems (ISDS) have demonstrated the capability to be an effective method of treatment for domestic wastewater. They also are advantageous from a water resources standpoint because there is little water leaving the local hydrologic system. However, if unfavorable settings exist, ISDS can have a detrimental effect on local water-quality. This presentation focuses on assessing the potential impacts of a large housing development to area water quality. The residential development plans to utilize ISDS to accommodate all domestic wastewater generated within the development. The area of interest is located just west of Brighton, Colorado, on the northwestern margin of the Denver Basin. Efforts of this research will focus on impacts of ISDS to local groundwater and surface water systems. The Arapahoe Aquifer, which exists at relatively shallow depths in the area of proposed development, is suspected to be vulnerable to contamination from ISDS. Additionally, the local water quality of the Arapahoe Aquifer was not well known at the start of the study. As a result, nitrate was selected as a focus water quality parameter because it is easily produced through nitrification of septic tank effluent and because of the previous agricultural practices that could be another potential source of nitrate. Several different predictive tools were used to attempt to predict the potential impacts of ISDS to water quality in the Arapahoe Aquifer. The objectives of these tools were to 1) assess the vulnerability of the Arapahoe Aquifer to nitrate contamination, 2) predict the nitrate load to the aquifer, and 3) determine the sensitivity of different parameter inputs and the overall prediction uncertainty. These predictive tools began with very simple mass-loading calculations and progressed to more complex, vadose-zone numerical contaminant transport modeling.

2004

Brendle, D.L., 2004, Potential Effects of Individual Sewage Disposal System Density on Ground-Water Quality in the Fractured-Rock Aquifer in the Vicinity of Bailey, Park County, Colorado, 2001-2002: U.S. Geological Survey Fact Sheet 2004-3009, 5 p.

This fact sheet discusses the relationship between the number of individual sewage disposal systems (ISDS) and the potential to affect groundwater quality in the fast growing community of Bailey in Park County. The report provides a preliminary assessment of water-quality data collected in 2001 from domestic wells completed in the fractured-rock aquifer. Water samples were collected from 57 domestic wells during 2001, once in July and once in September. Samples were analyzed for chemicals and bacteria that might indicate whether ISDS effluent has caused degradation of ground-water quality.

Because the rate of recharge and flow in the vicinity of each well can vary, it is not known whether ISDS effluent can reach the ground water before chemical and biological contaminants are removed from the effluent or reduced in concentration. Samples collected from wells were analyzed for chemicals and bacteria that can originate from an ISDS. Candidate wells were classified into one of the three density categories that represent areas of 1 acre, 3 acres, or 5 acres.

- *Bacteria were present in samples from wells in the low-, medium-, and high-density categories. Detections of bacteria did not appear to be correlated with ISDS density.*
- *Samples from four wells in the low-density and background categories contained organic chemicals that can originate only from an ISDS.*
- *nitrate concentrations tended to be higher in the high- and medium-density categories than in the low-density or background categories. The comparisons also indicate a higher probability of transport of nitrate to the ground water in areas with a higher density of houses and their associated ISDSs. However, in the high-density category only 7 percent (two samples) of the samples had nitrate concentrations greater than the primary drinking-water standard.*
- *chloride concentrations tended to be higher in the high- and medium-density categories than in the low-density or background categories. The comparisons also indicate that there may be a higher probability of transport of chloride to the ground water in areas with higher density of houses and their associated ISDSs. However, in the high-density category only 7 percent (two samples) of the samples had chloride concentrations greater than the USEPA secondary drinking-water standard.*
- *Significant differences as determined by the Wilcoxon rank-sum test for the boron data were found only between the high- and low-density categories for September 2001 data.*
- *Five tritium samples indicate that recharge to the groundwater system occurred after 1954*

Dano, K, Poeter, E., and Thyne, G, 2004, Investigation of the Fate of Individual Sewage Disposal system Effluent in Turkey Creek Basin, Colorado: Colorado Water Resources Research Institute, May 2004 Completion Report No. 200, 150 p.

With rapid development and population growth in the Turkey Creek Basin (TCB) of Jefferson County, Colorado, the degradation of water quality has become a pressing issue. Residents of TCB are served by a fractured, crystalline-rock-aquifer, typical of those in the western US that provide water to residential users through individual domestic wells and treat wastewater with individual sewage disposal systems (ISDSs). Comparison of basin-scale geochemical data from the 1970s and recent geochemical data from TCB reveals that Specific Conductivity (an indicator of water quality) in the surface water has increased by a factor of 3.3 over the past 30 years. Specific Conductivity in the majority of the ground water has increased by a factor of only 1.2 over the same time period. However, Specific Conductivity of ground water in localized areas has increased by a larger factor. This study investigates the role of ISDS effluent in the degradation of the basin's water quality by investigating the flow path and chemical evolution of ISDS effluent after it leaves the infiltration area of one individual sewage treatment system.

Geophysical methods located the ISDS effluent plume of a single home at the regolith-bedrock interface beneath and adjacent to an ISDS infiltration area. Shallow piezometers were installed to measure hydraulic properties and monitor water level and quality. A water budget was calculated for the ISDS system, to estimate the bedrock infiltration rate. The home had a typical household pumpage of 644 L/day (170 gallons/day) of which ~72%, an average of 466L/day (123 gallons/day), was dosed into the infiltration area from the septic tank. The low return rate is unexpected; an ongoing study is evaluating this finding.

Under typical conditions, the effluent infiltrates the fractured bedrock within 5 meters of the infiltration area, rather than migrating laterally through the regolith to the closest surface water, North Turkey Creek, which is 500 m away. During an unusually high spring runoff the plume migrated 50 to 100 m within the regolith before infiltrating the fractured bedrock. The chemical fingerprint of the effluent is similar to the anthropogenic component required to account for the ground water quality decline as indicated by other studies. The chemical fingerprint of the effluent has a chemical signature similar to surface water near the mouth of the basin suggesting that it contributes to the decreased surface water quality.

Ortiz, R.F., 2004, Ground-Water Quality of Alluvial and Sedimentary-Rock Aquifers in the Vicinity of Fairplay and Alma, Park County, Colorado, September-October 2002: U.S. Geological Survey Fact Sheet 2004-3065, 6 p.

This report summarizes the ground-water quality of samples collected in September or October 2002 from domestic wells completed in alluvial and sedimentary-rock aquifers in the vicinity of Fairplay and Alma, Colorado. Additionally, this report provides an initial assessment of the potential effects of ISDSs on ground-water quality in sedimentary-rock aquifers in the vicinity of Fairplay and Alma, Colorado.

Water samples were collected from 53 domestic wells during September and October of 2002; 13 of the wells were completed in alluvial aquifers, and 40 were completed in sedimentary-rock aquifers. Water samples were analyzed for various chemical groups *including major ions, nitrogen species, phosphorus species, selected trace metals, and radiochemical constituents. Additionally, water samples at selected wells were analyzed for an extensive list of organic chemicals that are indicative of contamination from ISDS effluent.*

This report provides a general assessment of ground-water quality and an initial assessment of whether contamination of ground water has occurred. The water quality was similar in samples collected from the alluvial and sedimentary-rock aquifers. Generally, most chemicals associated with ISDS contamination were not detected in the water samples collected during this study. However, quantification of even small concentrations of bacteria and chemicals associated with ISDS effluent can indicate a potential for contamination. Only one sample had detectable concentrations of total coliform bacteria, and none of the 43 ground-water samples analyzed had detectable concentrations of E. coli. Boron was detected in 23 percent of the samples collected from wells completed in the alluvial aquifer and in 27 percent of the samples collected from wells completed in the sedimentary-rock aquifer. Only one of the seven samples analyzed for selected organic chemicals associated with contamination from human activities had detectable concentrations of an organic chemical.

Comparisons using Wilcoxon rank-sum tests did not identify significant differences between ISDS density categories for any constituent with the exception of phosphorus. Significant differences for phosphorus were observed between the high-density category and both the low-density category and the background wells. Overall, the data did not indicate major effects of ISDS on ground-water quality.

Thyne, G., Guler, C., and Poeter, E., 2004. Sequential analysis of hydrochemical data for watershed characterization. Ground Water, Vol. 42 (5), p. 711- 723.

A methodology for characterizing the hydrogeology of watersheds using hydrochemical data that combine statistical, geochemical, and spatial techniques is presented. Surface water and ground water base flow and spring runoff samples (180 total) from a single watershed are first classified using hierarchical cluster analysis. The statistical clusters are analyzed for spatial coherence confirming that the clusters have a geological basis corresponding to topographic flowpaths and showing that the fractured rock aquifer behaves as an equivalent porous medium on the watershed scale. Then principal component analysis (PCA) is used to determine the sources of variation between parameters. PCA analysis shows that the variations within the dataset are related to variations in calcium, magnesium, SO4, and HCO3, which are derived from natural weathering reactions, and pH, NO3, and chlorine, which indicate anthropogenic impact. PHREEQC modeling is used to quantitatively describe the natural hydrochemical evolution for the watershed and aid in discrimination of samples that have an anthropogenic component. Finally, the seasonal changes in the water chemistry of individual sites were analyzed to better characterize the spatial variability of vertical hydraulic conductivity. The integrated result provides a method to characterize the hydrogeology of the watershed that fully utilizes traditional data. The integrated statistical/spatial/geochemical analysis showed that some locations (groups 1 and 2) have water chemistry due to natural water-rock interactions, while other locations (group 3) were impacted by an anthropogenic source or sources. In this case, the source of degradation of water quality is strongly associated with increasing populations that employ ISDS.

2003

Pikes Peak Area Council of Governments, 2003. Water Quality Management Plan 2003 Update, 314 p.

The Pikes Peak Area Council of Governments (PPACG) was designated by the Governor of the State of Colorado and the EPA in 1974 as the regional water quality management planning agency for the Pikes Peak Region (Figure 1-1). This is referred to as Colorado State Management Region IV and is a three-county region containing El Paso, Teller and Park Counties. The Pikes Peak Region is unique because it includes portions of two different drainage Basins – South Platte and Arkansas River Basins. As the designated planning agency, PPACG is required to prepare and update a Regional Water Quality Management Plan to address regional water quality issues under Section 208 of the Federal Clean Water Act. This Plan is commonly referred to as the 208 Plan and, as defined in State and Federal law, it is a planning and not a regulatory document. The 2003 208 Plan update supersedes the 1999 update and reflects the dynamic nature and changing conditions in the region.

The 2003 update of the 208 Plan follows the watershed approach. Five watersheds are in the Pikes Peak Region including the Chico Creek watershed. The 208 Plan provides guidance on water quality goals and objectives, and social, economic, and environmental costs and benefits. The 208 Plan is used to assist local, state, and federal decision makers focus on priority water quality issues and provide local input and guidance to Colorado's overall water quality program.

Because most of the stream segments in the Chico Creek watershed are ephemeral, there are currently no monitoring stations located in the watershed. The USGS in cooperation with Cherokee Metropolitan District collected samples from 36 wells in August 1984 for nitrate analysis. Twenty-eight of those wells were re-sampled in 1996.No significant differences were found for the 28 wells sampled in 1984 and 1996. Results indicate that nitrate concentrations increased in the southern two-thirds of the basin.

Poeter, E., Thyne, G., Vanderbeek, G., and Guler, C., 2003, Ground Water in Turkey Creek Basin of the Rocky Mountain Front Range in Colorado: in Engineering Geology in Colorado-Contributions, Trends, and Case Histories. Denver, Colorado: Association of Engineering Geologists, 26 p.

Evaluation of front-range fractured aquifers is difficult because the expense of characterization is not deemed warranted for development decisions. Data integration in Turkey Creek Basin, a well-studied area, reduces uncertainty and eventually will identify the key data required for characterization. Current analysis of the available data reveals the basin can be represented with an equivalent porous media model to facilitate management decisions at the watershed scale. However, impacts on individual wells cannot be predicted accurately. Water levels are declining and water quality is impacted by anthropogenic activity in Turkey Creek Basin, but the available data only provide an estimate of whether the basin can sustain the current population. Using one approach, annual recharge is estimated to be on the order of an inch per year (25.4mm/yr), with 75% of that volume pumped, but only 7% consumed. However, the estimates are uncertain due to the short period of record and limited spatial distribution. Ground-water chemistry has been impacted by anthropogenic effects that include high nitrate and chloride and lower pH, primarily in areas of high population density.

Trojan, M. D., Maloney, J. S., Stocklinger, J. M., Eid, E. P., and Lahtinen, M. J., 2003. Effects of Land Use on Ground Water Quality in the Anoka Sand Plain Aquifer of Minnesota. Ground Water Vol. 41, No. 4, pg. 482 – 492.

We began a study, in 1996, to compare ground water quality under irrigated and nonirrigated agriculture, sewered and nonsewered residential developments, industrial, and nondeveloped land uses. Twenty-three monitoring wells were completed in the upper meter of an unconfined sand aquifer. Between 1997 and 2000, sampling occurred quarterly for major ions, trace inorganic chemicals, volatile organic compounds (VOCs), herbicides, and herbicide degradates. On single occasions, we collected samples for polynuclear aromatic hydrocarbons (PAHs), perchlorate, and coliform bacteria. We observed significant differences in water chemistry beneath different land uses. Concentrations of several trace inorganic chemicals were greatest under sewered urban areas. VOC detection frequencies were 100% in commercial areas, 52% in sewered residential areas, and <10% for other land uses. Median nitrate concentrations were greatest under irrigated agriculture (15,350 µg/L) and nonsewered residential areas (6080 µg/L). Herbicides and degradates of acetanilide and triazine herbicides were detected in 86% of samples from irrigated agricultural areas, 68% of samples from nonirrigated areas, and <10% of samples from other land uses. Degradates accounted for 96% of the reported herbicide mass. We did not observe seasonal differences in water chemistry, but observed trends in water chemistry when land use changes occurred. Our results show land use is the dominant factor affecting shallow ground water quality. Trend monitoring programs should focus on areas where land use is changing, while resource managers and planners must consider potential impacts of land use changes on ground water quality.

2002

Halepaska and Associates, Inc., 2002, El Paso County Water Report: El Paso County Water Authority, 2002, 125 p.

The El Paso County Water Authority (EPCWA) has prepared this Water Report to assist in evaluating how water demands of the EPCWA members can be met to the year 2020. Current annual water demands in El Paso County (County) are estimated to be approximately 89,600 acre-feet (ac-ft). These values include Colorado Springs Utilities (CSU), which is not a member of EPCWA. The estimated current annual water demand, without CSU, is approximately 19,600 ac-ft. The future water demand for year 2020 is estimated to be 163,300 ac-ft with CSU and approximately 30,000 without CSU. Therefore, this Water Report looks at not only continuing to provide the current water demands of approximately 20,000 ac-ft per year (ac-ft/yr), but also expand that water supply to provide up to 30,000 ac-ft/yr by the year 2020. This report does not address water quality.

Martin, P., Bassinger, S., and Steele, T., 2002, A Case Study: Teller County, Colorado, in Fractured-Rock Aquifers 2002, March 13-15, 2002, Denver, Proceedings, National Groundwater Association, pg. 62-65

Teller County, like many of the counties in the mountainous portions of Colorado where fractured rock aquifers comprise the bulk of the overall water supply, is experiencing the effects on local ground water of older, poorly maintained and designed ISDS. ISDS-derived contamination has been detected in some water supply wells in Teller County and the *potential for much more serious impacts on the drinking water supply is being brought to the forefront by the more recent increase in population growth within parts of the County. In addition, the County also has numerous existing and platted subdivisions wherein the existence of many very small lots concentrated in local areas are raising questions over the ability of lot owners to develop adequate water supply and sewage treatment and the means by which this will be done without further greatly exacerbating the problems of ground-water quality protections and adequacy of supply. All of the foregoing is made more critical due to the relatively limited nature of the underlying fractured crystalline rock aquifers and to the mountainous and general colder alpine nature of the county.*

In light of these growing problems, the County authorized a multiphase study to assess the potential magnitude and important parameters of the problem in light of expected levels of growth, to examine three selected subdivisions in detail relative to water supply, water quality and ISDS usage as a function of time and buildout levels, to identify alternatives that might assist the County in developing regulatory guidelines to protect the County water supply, and to identify areas where further data collection and study would be of significant value.

For the subdivision studies, a mass-balance model incorporating past levels of growth and predicted future levels of buildout was constructed and utilized to make gross predictions of estimated nitrate concentration buildup in the underlying ground water with time and assuming that use of conventional ISDS technology continued. In each case, the model runs indicated that ambient nitrate contamination above the maximum permissible limit would be expected to occur throughout the subdivisions within relatively short periods of time, but in every case by the year 2020.

Water rights considerations and increased downstream scrutiny of any activities in the headwaters of the South Platte River and the Arkansas River that could impact water supply and water quality will require increased awareness by Teller County water authorities and will have potentially large future impacts on the methodologies considered as appropriate options for treatment of residential sewage.

Colorado Water Quality Control Commission, 2002. Recommendations of the Individual Sewage Disposal System Steering Committee, February 14, 2002, 30 p.

The ISDS Steering Committee was established in early 2001 by Jane Norton, Executive Director of the Colorado Department of Public Health and Environment. The Steering Committee members represent a wide range of expertise and interests related to onsite wastewater systems. The Steering Committee members agreed that an important first step in their efforts would be to arrive at a consensus regarding the current status quo with respect to the potential water quality impacts of onsite wastewater systems. This effort led to the development of a Summary Characterization of Onsite Wastewater System Impacts, which is set forth in Appendix B and includes:

1. *Water quality impacts are occurring from onsite wastewater systems in a number of specific areas in Colorado. However, the presence and nature of these problems often has not been verified or rigorously documented.*
2. *The overall scope and extent of water quality impacts from onsite wastewater systems in most areas of Colorado is unknown.*

3. There are areas of known nitrate contamination and increased nitrate levels in ground water in areas of high density (lots less than one acre) and a significant number of homes. In some surface water basins, phosphorus loadings from onsite wastewater systems are a potentially significant water quality factor.
4. ISDS systems pose a greater risk when they are present in high numbers and high density, they are present in areas served by private drinking water wells that are shallow or poorly constructed, they are improperly sited, particularly in sensitive environments, they were installed prior to 1973, when uniform design and siting standards were first established, and/or when they are not properly designed, installed, operated and/or maintained.
5. Growth trends in Colorado are likely to result in the installation of substantially greater numbers of onsite wastewater systems in the years to come. In some areas of Colorado, it will continue to be necessary and appropriate to serve homes and/or businesses with onsite wastewater systems, rather than centralized wastewater systems.
6. Properly sited, designed, installed, operated and maintained onsite wastewater systems can function without resulting in adverse water quality impacts.

Based on its assessment of options to address the principal risk factors identified in the Summary Characterization, the Steering Committee developed 13 recommendations.

Wakida, F.T., and Lerner, D.N, 2002, Nitrate leaching from construction sites to groundwater in the Nottingham, UK, urban area, Groundwater Protection & Restoration Group, Department of Civil & Structural Engineering, University of Sheffield, Mappin Street, Sheffield S1 3JD: in Water Science and Technology, 2002, Vol. 45 (9) pg. 243-248 http://cat.inist.fr/?aModele=afficheN&cpsidt=14180567)

Nitrate pollution has been identified as a major water quality issue in the UK. The aim of this project is to research the rate of nitrate leaching to groundwater that arises from construction works. The study area is situated in Nottingham UK, which is situated on the Triassic Sandstone aquifer. Soil samples up to a depth of 2.50 m were taken from three sites under construction and other land use. The results have shown a high variability in the concentrations of soil-nitrate. The reasons for this variability include soil type, past land use, soil treatment and type of vegetation prior to construction works. The average nitrogen load was 65 kg N ha(-1) which is higher than the nitrate leaching observed when temporary grassland is ploughed during autumn. The highest nitrate concentrations were observed in an allotment site (133 kg N ha(-1)) due to the high amount of manure applied at this location. The construction practice of top soil stripping can produce a reduction of nitrate leaching because it removes the part of the soil that contains most of the potentially mineralizable nitrogen.

2000

U.S. Geological Survey, 2000, Quality of Ground Water and Surface Water in an Area of Individual Sewage Disposal System Use Near Barker Reservoir, Nederland, Colorado, August - September 1998: U.S. Geological Survey Open-File Report 00-214, 7 p.

Analyses of ground water north of Barker Reservoir do not indicate widespread contamination, although isolated areas have concentrations of septic indicators such as boron, nitrate, and TOC that are larger than at other areas. The sites that show the greatest concentrations of indicator constituents (for example, S5, W3, W7, and W13) are at *residences that are older than the other residences north of Barker Reservoir in this study, and contaminants may have had more time to reach the ground water. Surface-water site D3 had greater concentrations of nitrate, phosphorus, fecal coliform, and TOC than upgradient site S7.*

South of Barker Reservoir, downgradient surface-water sites (D1, D2, S3, and S4) had greater concentrations of some constituents than upgradient surface-water sites (S1 and S2). The contamination could be from runoff in the area or from wildlife and domestic animals but also could indicate ISDS contamination. Ground-water data are limited south of the reservoir, with only one relatively shallow well to sample (well W1). Concentrations of nitrate, boron, fecal coliform, and TOC at this site were suggestive of possible ISDS effects.

1997 and older

Brendle, 1997, U. S. Geological Survey Fact Sheet FS-072-97, Have Nitrate Concentrations Changed in the Upper Black Squirrel Creek Basin Since 1984?

The alluvial aquifer of the upper Black Squirrel Creek Basin, about 25 miles east of Colorado Springs, supplies most of the water for irrigation and domestic use in the basin and, since 1964, supplies water for export to the Colorado Springs area. Most wells in the basin tap the alluvial aquifer and have high yields, ranging from about 10 gallons per minutes (gal/min) for stock wells to more than 1,000 gal/min for high-capacity irrigation wells. Because of increasing demand for ground water in the basin, the U.S. Geological Survey, in cooperation with the Cherokee Metropolitan District (CMD), collected samples from 36 wells in the upper Black Squirrel Creek alluvial aquifer in August 1984 to determine distribution of concentrations of nitrite plus nitrate as nitrogen (referred to as nitrate). Twenty-eight of the 36 wells sampled in August 1984 were resampled in August 1996 to determine whether nitrate concentrations in the alluvial aquifer changed since 1984. Findings show that the proportion of samples with nitrate concentrations in the 5.1 to 10 mg/L range increased 36-54% from 1984 to 1996. The proportion of samples with concentrations from 1.0 to 5.0 mg/L decreased 43-25% from 1984 to 1996. 57% of the wells sampled had small to no differences in nitrate concentrations, 29% indicated moderate increases, and 14% indicated moderate to large decreases. A statistical test showed that average nitrate concentrations did not change significantly. However, wells in the southern two-thirds of the basin did show a significant increase in nitrate concentrations.

Watts, K.R., 1995, Hydrogeology and simulation of flow between the alluvial and bedrock aquifers in the upper Black Squirrel Creek basin, El Paso County, Colorado: U.S. Geological Survey Water-Resources Investigations Report 94-4238, 82 p.

Anticipated increases in pumping from the bedrock aquifers in El Paso County potentially could affect the direction and rate of flow between the alluvial and bedrock aquifers and lower water levels in the overlying alluvial aquifer. The alluvial aquifer underlies about 90 square miles in the upper Black Squirrel Creek Basin of eastern El Paso County. The alluvial aquifer consists of unconsolidated alluvial deposits that unconformably overlie siltstones, sandstones, and conglomerate (bedrock aquifers) and claystone, shale, and coal (bedrock confining units) of the Denver Basin. The bedrock aquifers (Dawson, Denver, Arapahoe, and Laramie-Fox Hills aquifers) are separated by confining units (upper and lower Denver and the

Laramie confining units) and overlie a relatively thick and impermeable Pierre confining unit. The Pierre confining unit is assumed to be a no-flow boundary at the base of the alluvial/ bedrock aquifer system.

During 1949-90, substantial water-level declines, as large as 50 feet, in the alluvial aquifer resulted from withdrawals from the alluvial aquifer for irrigation and municipal supplies. Average recharge to the alluvial aquifer from infiltration of precipitation and surface water was an estimated 11.97 cubic feet per second and from the underlying bedrock aquifers was an estimated 0.87 cubic foot per second.

Water-level data from eight bedrock observation wells and eight nearby alluvial wells indicate that, locally, the alluvial and bedrock aquifers probably are hydraulically connected and that the alluvial aquifer in the upper Black Squirrel Creek Basin receives recharge from the Denver and Arapahoe aquifers but-locally recharges the Laramie-Fox Hills aquifer.

Physical and chemical characteristics of water from the bedrock aquifers in the study area generally differ from the physical and chemical characteristics of water from the alluvial aquifer, except for the physical and chemical characteristics of water from one bedrock well, which is completed in the Laramie-Fox Hills aquifer. In the southern part of the study area, physical and chemical characteristics of ground water indicate downward flow of water from the alluvial aquifer to the Laramie-Fox Hills aquifer.

A three-dimensional numerical model was used to evaluate flow of water between the alluvial aquifer and underlying bedrock. Simulation of steady-state conditions indicates that flow from the bedrock aquifers to the alluvial aquifer was about 7 percent of recharge to the alluvial aquifer, about 0.87 cubic foot per second. The potential effects of withdrawal from the alluvial and bedrock aquifers at estimated (October 1989 to September 1990) rates and from the bedrock aquifers at two larger hypothetical rates were simulated for a 50-year projection period. The model simulations indicate that water levels in the alluvial aquifer will decline an average of 8.6 feet after 50 years of pumping at estimated October 1989 to September 1990 rates. Increases in withdrawals from the bedrock aquifers in El Paso County were simulated to: (1) capture flow that currently discharges from the bedrock aquifers to springs and streams in upland areas and to the alluvial aquifer, (2) induce flow downward from the alluvial aquifer, and (3) accelerate the rate of water level decline in the alluvial aquifer.

Eckhardt, D. and Strackleberg, P., 1995. Relation of Ground-Water Quality to Land Use on Long Island, New York. Ground Water, Vol. 33, No. 6, pg. 1019 – 1033.

Water-quality data from 90 monitoring wells screened within 50 feet of the water table in the unconfined upper glacial aquifer beneath five areas of differing land use in Nassau and Suffolk Counties, Long Island, were compared to assess the effects of land use on ground-water quality. The areas, which range from 22 to 44 square miles, represent suburban land sewered more than 22 years at the time of the study (long-term sewered), suburban land sewered less than 8 years (recently sewered), suburban land without a regional sewer system, agricultural land, and undeveloped (forested) land. Comparison of water-quality data from the 90 wells indicated that samples from the undeveloped area had the lowest and smallest range in concentrations of several human-derived constituents, such as nitrate, alkalinity, boron, synthetic solvents, and pesticides. Concentrations of *these constituents in samples from the three suburban areas and the agricultural area generally were intermediate to high and had the widest variation.*

Maximum-likelihood logistic regression analysis of explanatory variables that characterize the type of land use and population density within a 1/2-mile radius of each of the 90 wells was used to develop predictive equations for contaminant occurrence in ground water within 50 feet of the water table. Two logistic regression equations for the 90 monitoring wells were compared with equations developed independently from ground-water quality data at more than 240 other wells throughout Nassau and Suffolk Counties to evaluate the predictive value of the land-use variables at the larger two-county scale. The results demonstrate that the population density and amount of agricultural, commercial, and high- and medium-density residential land within specified areas around wells can be reliable predictors of contaminant presence. The strength of the correlations supports the premise that land use affects the quality of water in water-table aquifers overlain by highly permeable material because land use commonly determines the types and amounts of chemicals introduced at land surface. When coupled with GIS technology and accurate, detailed land-use and water-quality information, the methods and results of this study can be useful to local planning boards in evaluation of potential effects of development on ground-water quality. The methods can also be useful to hydrologists in the analysis and design of ground-water-monitoring networks.

Buckles, D.R., and Watts, K.R., 1988, Geohydrology, water quality, and preliminary simulations of ground-water flow of the alluvial aquifer in the upper Black Squirrel Creek basin, El Paso County, Colorado: U.S. Geological Survey Water-Resources Investigations Report 88-4017, 49 p.

The upper Black Squirrel Creek basin in eastern El Paso County, Colorado, is underlain by an alluvial aquifer and four bedrock aquifers. Groundwater pumpage from the alluvial aquifer has increased since the mid-1950's, and water level declines have been substantial; the bedrock aquifers virtually are undeveloped. Groundwater pumpage for domestic, stock, agricultural, and municipal uses have exceeded recharge for the past 25 years. The present extent of the effect of pumpage on the alluvial aquifer was evaluated, and a groundwater flow model was used to simulate the future effect of continued pumpage on the aquifer.

Measured water level declines from 1974 through 1984 were as much as 30 ft in an area north of Ellicott, Colorado. On the basis of the simulations, water level declines from October 1984 to April 1999 north of Ellicott might be as much as 20 to 30 ft and as much as 1 to 10 ft in most of the aquifer. Flow from the bedrock aquifers to the alluvial aquifer may account for a substantial volume of the recharge to the alluvial aquifer.

The groundwater flow models provided a means of evaluating the importance of groundwater evapotranspiration at various stages of aquifer development. Simulated groundwater evapotranspiration was about 43% of the outflow from the aquifer during predevelopment stages but was less than 3% of the outflow from the aquifer during late-development stages.

Analyses of 36 groundwater samples collected during 1984 indicated that concentrations of dissolved nitrite plus nitrate as nitrogen generally were large. Samples from 5 of the 36 wells had concentrations of dissolved nitrite plus nitrate as nitrogen that exceeded drinking water standards. Water from the alluvial aquifer generally is of suitable quality for most uses.

Edelmann and Cain, 1985, Sources of Water and Nitrogen to the Widefield Aquifer, Southwestern El Paso County, Colorado, U. S. Geological Survey Water-Resources Investigations Report 85-4162, 81 p.

The Widefield aquifer near Colorado Springs, Colorado, is recharged primarily by Fountain Creek and, to a lesser extent, by infiltration and percolation of water from the land surface and from groundwater inflow. During the past 20 to 30 years, concentrations of nitrate (as nitrogen) in the Widefield aquifer have increased from 0.5 to 3.0 milligrams/L to nearly 10 milligrams/L, and occasionally exceed the drinking-water standard.

During the summer of 1982, the concentrations of nitrite plus nitrate as nitrogen in water in the aquifer ranged from 3.2 to 15 milligrams/L with a mean concentration of 6.9 milligrams/L. In general, the nitrite-plus-nitrate concentrations are greatest near the north end of the aquifer, probably resulting from effluent from Colorado Springs Sewage Treatment Plant being discharged to Fountain Creek. During 1982, 93% of the total estimated 160 tons of nitrogen available to enter the Widefield aquifer was from the Colorado Springs Sewage Treatment Plant. Nitrogen also enters the aquifer as a result of seepage from Canal No. 4, artificial recharge ponds, and irrigation at the Pinello Ranch.

Livingston, R.K., Klein, J.M., and Bingham, D.L., 1976, Water Resources of El Paso, County, Colorado: Colorado Water Conservation Board, Colorado Water Resources Circular No. 32, 85 p.

El Paso County is an area of 2,157 square miles located along the Front Range in Central Colorado. The purpose of this study is to appraise and describe the surface water, the groundwater, and the water quality in the county. This report was prepared under a cooperative agreement with the city of Colorado Springs, El Paso County board of Commissioners, Pikes Peak Area Council of Governments, and the U.S. Air Force Academy.

Alluvial deposits, widespread throughout El Paso County, are important sources of water supply. The principal alluvial aquifers are in Fountain Creek and Jimmy Camp Creek valleys, which contain an estimated 100,000 acre-feet of water in storage, and in the upper Black Squirrel Creek basin, which contains an estimated 350,000 acre-feet of water in storage. The Widefield aquifer, an alluvial aquifer located in Fountain Creek valley, contains about 8,000 acre-feet of water in storage.

The dissolved solids concentration of water from the alluvium of Fountain and Jimmy Camp valleys generally increases in a downstream direction and ranges from 364 to 3,690 milligrams per liter. The dissolved solids concentration of water from the alluvial aquifer in the upper Black Squirrel Creek basin is generally less than 250 milligrams per liter.

Colorado Division of Water Resources Memorandum, February 13, 1974, Consumptive Use of Water by Homes Utilizing Leach Fields for Sewage Disposal: unpublished.

In February 1974, then State Engineer C.J. Kuiper asked staff to investigate the consumptive use of water by homes using leach fields for sewage disposal. In preparing a plan of augmentation, developers relying on leach fields for effluent disposal were submitting the figure of 10% consumptive use within the system. The State Engineer had accepted this value without knowing whether or not the figure is accurate. Division of Water Resources

staff spent considerable time reviewing the published literature but found no direct studies pertaining to consumptive use of residential septic systems.

Literature with ancillary information useful to their investigation was obtained. In addition, a number of persons and agencies were contacted to solicit additional information and input. Based on their findings, staff concluded that 80% of the water entering a house was used by toilets and in bathing. Applying estimates for in-house consumption and evaporation, they determined that 8.4% of the water would be consumptively used before entering the septic tank. Staff determined that during the growing season approximately 9.6% of the water was consumed within the leach field. On an annual basis, this amounted to only 3.9%. Thus, on an annual basis, the total consumptive use (in-house + leach field) was estimated at 12.3% (8.4% + 3.9%).

Bingham, D.L., and Klein, J.M., 1973, Water-level declines and ground-water quality, upper Black Squirrel Creek basin, Colorado: Colorado Water Conservation Board Water Resources Circular 23, 21 p.

Ground-water-level declines of 10 feet or more in a 15-square-mile area and declines of 20 to 35 feet over a 5-square mile area have been observed in the alluvial aquifer during 1964-71. The saturated thickness of the aquifer exceeds 40 feet in about 40 square miles of the 350-square-mile basin. Present trends indicate a continued lowering of the water table. Water of a good chemical quality, dissolved-solids concentrations less than 250 milligrams per liter, underlies the central part of the basin. The dissolved-solids concentration increases laterally from the central part of the basin.

McGovern, H.E., and Jenkins, E.D., 1966, Ground water in Black Squirrel Creek valley El Paso County, Colorado: U.S. Geological Survey Hydrologic Investigations Atlas HA-236, 1 sheet.

The purpose of this study is to determine ground-water conditions in the alluvium in 1964 and to point out possible effects of further ground-water development. Three wells were sampled for chemical constituents and to determine aquifer properties. This study concluded that ground water can be pumped for short periods of time at rates exceeding underflow without significantly depleting the aquifer and that the chemical quality of the water is very good. The water is described as mixed cation bicarbonate with TDS less than 250 mg/L; sodium and bicarbonate were observed to increase slightly to the south. The results of increased pumping would have both detrimental and beneficial affects to the aquifer. A general decline in water levels would cause an increase in pumping lifts, reduction in well yields, and the elimination of subirrigation in some areas. Benefits would include a reduction in non-beneficial evapotranspiration, creation of additional storage space for salvage of excess surface runoff, a decrease of underflow out of the valley and utilization of the large quantity of water in storage.

Appendix C

Data Tables
El Paso County Groundwater Quality Study

Appendix C, Table 1

El Paso County Groundwater Quality Study

Well Number Reference Table (for use with Figure 3.1)

Map Number	Site ID
1	SC01206219CC
2	SC01206230BB
3	SC01206230BBC
4	SC01206230BDB
5	SC01206230CDC
6	SC01206314DDC
7	SC01206322BBB
8	SC01206336ACC
9	SC01306207BCB
10	SC01306209BBB
11	SC01306216AAB
12	SC01306219CDB
13	SC01306221BDD
14	SC01306229DAC
15	SC01306230ACC1
16	SC01306230ACC3
17	SC01306231ACC
18	SC01306231BAA
19	SC01306301A
20	SC01306301CCC
21	SC01306301DCB
22	SC01306306DAA
23	SC01306312ACB
24	SC01306312ACB2
25	SC01306312CDB
26	SC01306314ABB
27	SC01306322ADB
28	SC01306323CCA
29	SC01306324ABB2
30	SC01306334ABB
31	SC01306336CA
32	SC01406204AB
33	SC01406205ACD
34	SC01406205BBB
35	SC01406205CAA
36	SC01406207ACD
37	SC01406208CCB
38	SC01406216CCC
39	SC01406220DBC

Map Number	Site ID
40	SC01406228CCB
41	SC01406229DCB
42	SC01406231BAA
43	SC01406232B
44	SC01406232BBA
45	SC01406303DCC
46	SC01406312DCD
47	SC01406313DAA2
48	SC01406323AA
49	SC01406325AD
50	SC01406336AAB
51	SC01406408AA
52	SC01506205BDD
53	SC01506207DA
54	SC01506218ACB
55	SC01506301AAA
56	SC01506310DCC
57	SC01506312ACA
58	SC01506312CBA
59	SC01506312DCC
60	SC01506313BAA
61	SC01506313BBB
62	SC01506323CDB
63	SC01506324CDD
64	SC01506324D
65	SC01506324DAB
66	SC01506325ABA
67	SC01506325BBA
68	SC01506326BAB
69	SC01506335AAA
70	SC01506335AAB
71	SC01506335DCC1
72	SC01506335DCC2

Please see Appendix A for explanation of Site ID numbering system

Appendix C, Table 2
El Paso County Groundwater Quality Study

Groundwater Quality Data Summary

Parameter	Number of Data Points	Detections	Minimum	Maximum	Average of Detected Values	US EPA Drinking Water MCL	Values Exceeding MCL or SMCL
WELL AND SAMPLING INFORMATION							
Well Permit No.	22	NA	NA	NA	NA	NA	NA
Local Well Name	34	NA	NA	NA	NA	NA	NA
Depth to Water (ft)	9	9	26.0	180.0	76	NA	NA
Sample Collection Depth	9	9	102.0	186.0	139	NA	NA
PHYSICAL PARAMETERS							
Water Temperature (C)	103	103	9.4	20.0	13.1	NA	NA
pH	120	120	6.3	9.2	7.3	6.5 - 8.5[1]	2[2]
Specific Cond. (mhos/cm)	101	101	270	1430	446	NA	NA
GENERAL CHEMISTRY							
Total Dissolved Solids (mg/L)	77	77	165	842	287	500[1]	6
Alkalinity	43	43	48	197	109	NA	NA
Hardness (ppm)	50	50	7	510	111	NA	NA
Turbidity (NTU)	15	13	0	3.56	1.1	NA	NA
Sodium Adsorption Ratio	42	42	0.63	19.00	3.2	NA	NA
Langlier Index	3	1	NA	0.44	0.4	NA	NA
Calcium Carbonate	2	2	62	65	64	NA	NA
Carbonate	23	1	DLNQ	10.0	10.0	NA	NA
Bicarbonate	44	44	58	289	128	NA	NA
Chloride	74	74	3.5	76	13.7	250[1]	0
Nitrate (as N)	148	141	<0.05	72	6.8	10	9
Sulfate	53	53	17	250	57	250[1]	1
Phosphate	63	50	DLNQ	2.0	0.1	NA	NA
Bromide	9	8	<0.1	0.2	0.1	NA	NA
Calcium	53	53	16	170.0	39.0	NA	NA
Magnesium	52	48	<5.2	54	5.6	NA	NA
Sodium	55	55	18	140	46.2	NA	NA
Potassium	51	49	<1	27	2.7	NA	NA
Silicate (as SiO_2)	30	30	16	33	27.3	NA	NA
METALS							
Antimony	3	0	NA	NA	NA	0.006	NA
Iron	43	35	<0.03	2.8	0.178	0.3[1]	3
Cadmium	22	2	DLNQ	0.0037	0.002	0.005	0
Chromium	24	8	DLNQ	0.014	0.25	0.1	0
Lead	21	2	DLNQ	0.00087	0.0007	0.015	0
Mercury	17	2	DLNQ	0.0050	0.003	0.002	0
Seleniuum	18	12	DLNQ	0.0180	0.007	0.05	0
Silver	15	5	DLNQ	0.0012	0.0009	0.1[1]	0
Manganese	38	9	DLNQ	0.024	0.007	0.05[1]	0
Barium	19	13	DLNQ	0.36	0.066	2	0
Arsenic	18	2	DLNQ	0.01	0.006	0.01	1
Beryllium	4	0	NA	NA	NA	0.004	NA
Cobalt	1	0	NA	NA	NA	NA	NA
Copper	7	0	NA	NA	NA	1[1]	NA
Vanadium	1	0	NA	NA	NA	NA	NA
Zinc	7	4	<0.02	0.0152	0.0102	1[1]	0
Thallium	4	0	NA	NA	NA	0.002	NA

Groundwater Quality Data Summary

Parameter	Number of Data Points	Detections	Minimum	Maximum	Average of Detected Values	US EPA Drinking Water MCL	Values Exceeding MCL or SMCL
Endrin	21	0	NA	NA	NA	0.002	NA
Lindane	20	0	NA	NA	NA	0.0002	NA
Methoxychlor	20	0	NA	NA	NA	0.04	NA
Toxaphane	14	0	NA	NA	NA	0.003	NA
2, 4-D[3]	20	0	NA	NA	NA	0.07	NA
Fenoprop (2, 4-5 TP)	14	0	NA	NA	NA	0.05	NA
RADIOACTIVITY							
Gross Alpha	13	13	0.3	3.6	1.5	15[4]	0
Gross Beta	13	13	1.1	6.0	2.8	50[4]	0
ORGANIC CONSTITUENTS							
Benzene	3	0	NA	NA	NA	0.005	NA
Ethylbenzene	3	0	NA	NA	NA	0.7	NA
Total Xylenes	3	0	NA	NA	NA	10	NA
Toluene	3	0	NA	NA	NA	1	NA
Tetrachloroethene	3	0	NA	NA	NA	0.005	NA
Trichloroethene	3	0	NA	NA	NA	0.005	NA
cis-1,2-Dichloroethene	3	0	NA	NA	NA	0.07	NA
Vinyl Chloride	3	0	NA	NA	NA	0.002	NA
1,1,1-Trichloroethane	3	0	NA	NA	NA	0.2	NA
Carbon Tetrachloride	3	0	NA	NA	NA	NA	NA
Napthalene	2	0	NA	NA	NA	0.005	NA

NOTES:
MCL - US EPA Drinking Water Maximum Contaminant Level
SMCL - US EPA Drinking Water Secondary Maximum Contaminant Level
All non-radioactivity concentration data in mg/L, Radioactivity in pCi/L
NA - Not applicable for parameter
DLNQ - Detection Limit not quantified in source data
1. Constituent has no MCL, Secondary Drinking Water Standard provided
2. Two pH values were outside SMCL range of 6.5 - 8.5
3. 2,4-Dichlorophenoxyacetic acid
4. US EPA 2001

Well Information and Physical Parameters

Site ID	Sample Date	Well Permit No.	Local Name	Temperature (C)	pH	Specific Conductance (mhos/cm)
SC01206219CC	3/1/2006	27554-RFP	Guthrie Alluvial Well #2		6.95	
SC01206230BB	3/1/2006	612-RFP	Guthrie Alluvial Well #1		7.44	
SC01206230BBC	11/7/2006		PP-D-027	11.5	7.70	484
SC01206230BDB	8/9/1984			14.5	6.80	370
SC01206230BDB	8/21/1996					
SC01206230CDC	8/8/1984			18.0	6.60	375
SC01206230CDC	8/21/1996					
SC01206314DDC	8/9/1984			11.0	7.00	1430
SC01206322BBB	8/9/1984			13.0	6.90	400
SC01206322BBB	8/21/1996					
SC01206336ACC	8/8/1984			11.5	6.30	400
SC01206336ACC	8/21/1996					
SC01306207BCB	1/20/1986	29089-F	CMD-06		7.10	
SC01306209BBB	8/10/1984			13.0	7.20	1380
SC01306209BBB	8/22/1996					
SC01306216AAB	8/10/1984			13.5	7.50	630
SC01306219CDB	9/10/1980	24680-F	CMD-05		7.30	
SC01306219CDB	8/7/1984			13.5	7.70	390
SC01306219CDB	8/22/1996					
SC01306221BDD	8/10/1984			13.5	9.20	350
SC01306229DAC	11/30/2006		PP-D-039	9.4	8.10	948
SC01306230ACC1	8/8/1984		CMD-I	13.0	7.30	358
SC01306230ACC1	1/21/1994		CMD-I	11.0	7.10	391
SC01306230ACC1	2/8/1985		CMD-I	12.0	7.10	410
SC01306230ACC1	2/11/1988		CMD-I	11.0	7.30	417
SC01306230ACC1	2/13/1991		CMD-I	12.0	7.30	412
SC01306230ACC1	2/19/1993		CMD-I	11.0	7.20	402
SC01306230ACC1	2/20/1998		CMD-I	11.5	7.30	394
SC01306230ACC1	2/21/1992		CMD-I	12.0	7.20	404
SC01306230ACC1	2/23/1987		CMD-I	12.5		400
SC01306230ACC1	2/24/1989		CMD-I	13.0	7.30	370
SC01306230ACC1	2/26/1997		CMD-I	12.0	7.30	399
SC01306230ACC1	2/27/1990		CMD-I	11.5	7.40	416
SC01306230ACC1	2/29/1996		CMD-I	12.0	7.20	407
SC01306230ACC1	8/22/1996		CMD-I			
SC01306230ACC1	3/17/1995		CMD-I	12.5	7.20	404

Well Information and Physical Parameters

Site ID	Sample Date	Well Permit No.	Local Name	Temperature (C)	pH	Specific Conductance (mhos/cm)
SC01306230ACC1	5/9/1991		CMD-I	12.5	7.20	402
SC01306230ACC1	5/13/1985		CMD-I	12.0	7.50	410
SC01306230ACC1	5/13/1988		CMD-I	12.5	7.30	410
SC01306230ACC1	5/15/1990		CMD-I	12.5	7.40	412
SC01306230ACC1	5/15/1992		CMD-I	12.5	7.10	400
SC01306230ACC1	5/16/1989		CMD-I		7.30	379
SC01306230ACC1	5/21/1993		CMD-I	12.0	7.20	399
SC01306230ACC1	5/29/1986		CMD-I	13.0	7.70	390
SC01306230ACC1	6/12/1987		CMD-I	13.0	6.70	400
SC01306230ACC1	8/7/1984		CMD-I	12.5	7.20	425
SC01306230ACC1	8/7/1986		CMD-I	13.0	7.30	358
SC01306230ACC1	8/16/1985		CMD-I	12.5		375
SC01306230ACC1	8/16/1991		CMD-I	12.5	7.20	402
SC01306230ACC1	8/18/1988		CMD-I	12.5	7.20	404
SC01306230ACC1	8/21/1992		CMD-I	13.0	7.20	393
SC01306230ACC1	8/22/1989		CMD-I	11.5	7.20	418
SC01306230ACC1	8/23/1990		CMD-I	13.0	7.60	410
SC01306230ACC1	8/27/1987		CMD-I	12.0	7.20	412
SC01306230ACC1	8/27/1993		CMD-I	12.0	7.20	400
SC01306230ACC1	8/28/1998		CMD-I	15.0	7.20	396
SC01306230ACC1	9/8/1994		CMD-I	13.6	7.20	396
SC01306230ACC1	9/9/1997		CMD-I	12.0	7.20	400
SC01306230ACC1	9/25/1996		CMD-I	13.0	7.10	401
SC01306230ACC1	9/28/1995		CMD-I	12.0		395
SC01306230ACC1	11/10/1993		CMD-I	12.0	7.30	396
SC01306230ACC1	11/13/1990		CMD-I	12.5	7.40	408
SC01306230ACC1	11/13/1992		CMD-I	10.5	7.20	403
SC01306230ACC1	11/20/1986		CMD-I	12.0	7.20	411
SC01306230ACC1	11/20/1987		CMD-I	12.0	7.10	413
SC01306230ACC1	11/21/1989		CMD-I	11.5	7.30	405
SC01306230ACC1	11/22/1991		CMD-I	11.5	7.20	409
SC01306230ACC1	11/23/1988		CMD-I	13.0	7.20	395
SC01306230ACC1	11/29/1985		CMD-I	12.0		280
SC01306230ACC3	9/8/1980	24976-F	CMD-04		7.30	
SC01306231ACC	8/7/1984			13.5	7.20	385
SC01306231ACC	8/22/1996					
SC01306231BAA	9/8/1971			12.5	7.20	324
SC01306301A	1/1/1954		A	11.7	7.40	311
SC01306301CCC	8/16/1984			15.0	6.60	270
SC01306301CCC	8/19/1996					

Site ID	Sample Date	Well Permit No.	Local Name	Temperature (C)	pH	Specific Conductance (mhos/cm)
SC01306301DCB	1/1/1987		CMD-08		7.10	
SC01306306DAA	8/9/1984			11.0	7.80	520
SC01306306DAA	8/21/1996					
SC01306312ACB	9/27/2006		PP-D-014	13.1	7.70	392
SC01306312ACB2	1/1/1986	29088-F	CMD-07		7.40	
SC01306312CDB	8/9/1984			12.5	7.50	320
SC01306312CDB	8/19/1996					
SC01306314ABB	8/13/1984			11.5	8.10	451
SC01306314ABB	8/21/1996					
SC01306322ADB	8/10/1984			13.0	7.70	555
SC01306322ADB	8/21/1996					
SC01306323CCA	9/27/2006		PP-D-013	13.5	7.50	749
SC01306324ABB2	11/28/2006		CMD-18	20.0	7.00	
SC01306334ABB	8/10/1984			13.5	7.30	410
SC01306334ABB	8/21/1996					
SC01306336CA	5/7/2008	277307	SLB-2A		6.60	
SC01406204AB	5/7/2008	277314	SLB-3		6.90	
SC01406205ACD	8/16/1984			14.5	6.70	385
SC01406205BBB	8/7/1984			13.0	6.70	380
SC01406205BBB	8/22/1996					
SC01406205CAA	8/7/1984			13.5	6.70	410
SC01406205CAA	8/22/1996					
SC01406207ACD	11/30/2006		PP-D-040	9.8	8.40	496
SC01406208CCB	8/10/1984			14.5	7.00	290
SC01406208CCB	8/19/1996					
SC01406216CCC	8/10/1984			13.0	7.50	870
SC01406220DBC	8/12/1986			13.0	7.30	535
SC01406220DBC	9/8/1971			12.5	7.10	488
SC01406220DBC	8/10/1984			17.5	7.30	825
SC01406228CCB	9/8/1971			11.5	7.60	935
SC01406229DCB	12/1/1955			12.1		440
SC01406231BAA	8/7/1984			14.5	6.80	310
SC01406232B	1/1/1955		B	12.2	7.50	335
SC01406232BBA	8/7/1984			15.5	6.60	330
SC01406303DCC	8/9/1984			16.0	8.20	305
SC01406303DCC	8/19/1996					
SC01406312DCD	9/8/1971			18.5	7.20	297
SC01406312DCD	8/10/1984			16.0	7.40	295
SC01406312DCD	8/21/1996					
SC01406313DAA2	8/10/1984			13.5	7.10	290

Well Information and Physical Parameters

Site ID	Sample Date	Well Permit No.	Local Name	Temperature (C)	pH	Specific Conductance (mhos/cm)
SC01406313DAA2	8/19/1996					
SC01406323AA	5/7/2008	277315	SLB-4		6.80	
SC01406325AD	5/8/2008	277316	SLB-5		6.60	
SC01406336AAB	8/7/1984			14.5	7.10	338
SC01406336AAB	8/20/1996					
SC01406408AA	11/5/2009	033357-M	MWG-15	13.3	6.92	545
SC01506205BDD	12/1/2006		PP-D-042	12.9	8.30	594
SC01506207DA	5/8/2008	277318	SLB06		6.70	
SC01506218ACB	8/8/1984			13.5	7.10	525
SC01506218ACB	8/20/1996					
SC01506301AAA	8/7/1984			15.0	7.10	310
SC01506310DCC	8/7/1984			14.5	7.20	280
SC01506310DCC	8/20/1996					
SC01506312ACA	11/1/1987	14145-FP	CMD-09		7.60	
SC01506312CBA	11/1/1987	14146-FP	CMD-10		7.60	
SC01506312DCC	8/7/1984			16.5	6.90	305
SC01506313BAA	1/1/1992	11198-FP	CMD-12		7.55	
SC01506313BAA	9/8/1971			14.0	7.40	286
SC01506313BBB	11/1/1987	6821-FP	CMD-11		7.60	
SC01506323CDB	4/12/2001	52429-F	CMD-14	15.5	6.99	
SC01506323CDB	7/27/1999	52429-F	CMD-14		7.60	
SC01506324CDD	9/8/1971			13.5	7.20	384
SC01506324D	1/1/1955		C	12.8	7.50	343
SC01506324DAB	7/24/1984			14.0	7.90	554
SC01506325ABA	9/8/1971			15.0	7.40	1150
SC01506325BBA	7/24/1984			14.0	8.40	325
SC01506325BBA	8/20/1996					
SC01506326BAB	8/8/1984			14.5	6.90	375
SC01506326BAB	8/20/1996					
SC01506335AAA	5/30/2000	54070-F	CMD-15		7.35	
SC01506335AAB	8/7/2000	54069-F	CMD-16		7.47	
SC01506335DCC1	9/25/2000	63094-F	CMD-17		7.67	
SC01506335DCC1	6/9/2005	63094-F	CMD-17	20.0	7.57	
SC01506335DCC2	9/27/2006		PP-D-015	14.9	7.30	414

								Anions								Cations					SiO2)
Site ID	**Sample Date**	**Total Dissolved Solids (mg/L)**	**Alkalinity**	**Hardness (ppm)**	**Turbidity (NTU)**	**Sodium Adsorption Ratio**	**Langlier Index**	**Calcium Carbonate**	**Carbonate**	**Bicarbonate**	**Chloride**	**Nitrate (as N)**	**Sulfate**	**Phosphate**	**Flouride**	**Bromide**	**Calcium**	**Magnesium**	**Sodium**	**Potassium**	**Silicate (as SiO_2)**
SC01206219CC	3/1/2006	228	71	87	0.47	1.92			DLNQ	71.2	8.7	6.2	41	2.00	DLNQ		29.00	3.50	29.00	2.50	
SC01206230BB	3/1/2006	243	76	84	1.20	1.74			DLNQ	76.1	10.3	6.4	45	0.29	DLNQ		35.00	4.20	29.00	2.50	
SC01206230BBC	11/7/2006	260	82	103					<0.1	99.5	13.4	6.7	47				33.98	4.55	25.56	2.80	
SC01206230BDB	8/9/1984	244										**11.0**									
SC01206230BDB	8/21/1996											8.3									
SC01206230CDC	8/8/1984	237										**11.0**									
SC01206230CDC	8/21/1996											0.7									
SC01206314DDC	8/9/1984	**650**		510		1.64				307.0	76.0	**72.0**	110	0.02	0.50		170.00	21.00	85.00	4.20	31.00
SC01206322BBB	8/9/1984	316										1.7									
SC01206322BBB	8/21/1996											2.8									
SC01206336ACC	8/8/1984	262	79	104		1.66				96.0	10.0	6.3	65	0.07	0.40		35.00	4.10	39.00	2.40	28.00
SC01206336ACC	8/21/1996											6.8									
SC01306207BCB	1/20/1986	210	85	98	0				<0.1	100.0	7.7	2.4	84	<0.1	0.40	0.20	39.00	<1	39.00	1.30	16.00
SC01306209BBB	8/10/1984	**842**										**33.0**									
SC01306209BBB	8/22/1996											**25.0**									
SC01306216AAB	8/10/1984	401										3.6									
SC01306219CDB	9/10/1980			88		1.37			<0.1	83.0	14.0	2.4	45	<0.1	1.00		16.00	12.00	21.00	<1	28.00
SC01306219CDB	8/7/1984	261	101	95		1.97				123.0	8.9	6.5	50	0.04	0.40		32.00	3.60	44.00	2.40	30.00
SC01306219CDB	8/22/1996											**6.3**									
SC01306221BDD	8/10/1984	210										0.2									
SC01306229DAC	11/30/2006	454	165	134					<0.1	201.0	18.9	**11.5**	105				44.68	5.37	76.27	0.91	
SC01306230ACC1	8/7/1984	272	96	113		1.59				117.0	12.0	6.0	62	0.05	0.40		38.00	4.50	39.00	2.30	30.00
SC01306230ACC1	8/8/1984	328	97								12.0	<6.8	60				35.00	<4.4	40.00	2.40	
SC01306230ACC1	2/8/1985										11.0	6.1									
SC01306230ACC1	5/13/1985										11.0	5.9									
SC01306230ACC1	8/16/1985										11.0	6.5									
SC01306230ACC1	11/29/1985										10.0	6.7									
SC01306230ACC1	5/29/1986										12.0	6.9									
SC01306230ACC1	8/7/1986	328	97	8		19.00					12.0	<6.8	60								30.00
SC01306230ACC1	11/20/1986										11.0	6.3									
SC01306230ACC1	2/23/1987										14.0	6.8									
SC01306230ACC1	6/12/1987										13.0	6.9									
SC01306230ACC1	8/27/1987										11.0	6.6									
SC01306230ACC1	11/20/1987										13.0										
SC01306230ACC1	2/11/1988										13.0	9.8									
SC01306230ACC1	5/13/1988										12.0	7.0									
SC01306230ACC1	8/18/1988										11.0	7.2									
SC01306230ACC1	11/23/1988										11.0	7.6									
SC01306230ACC1	2/24/1989										9.9	5.8									
SC01306230ACC1	5/16/1989										11.0	7.2									
SC01306230ACC1	8/22/1989										11.0	6.8									
SC01306230ACC1	11/21/1989										10.0	7.0									

								Anions								Cations					SiO2)
Site ID	Sample Date	Total Dissolved Solids (mg/L)	Alkalinity	Hardness (ppm)	Turbidity (NTU)	Sodium Adsorption Ratio	Langlier Index	Calcium Carbonate	Carbonate	Bicarbonate	Chloride	Nitrate (as N)	Sulfate	Phosphate	Flouride	Bromide	Calcium	Magnesium	Sodium	Potassium	Silicate (as SiO_2)
SC01306230ACC1	2/27/1990										10.0	8.0									
SC01306230ACC1	5/15/1990										9.9	7.6									
SC01306230ACC1	8/23/1990										10.0	7.7									
SC01306230ACC1	11/13/1990											7.0		0.03							
SC01306230ACC1	2/13/1991											7.6		0.04							
SC01306230ACC1	5/9/1991											7.8		0.04							
SC01306230ACC1	8/16/1991											7.3		0.04							
SC01306230ACC1	11/22/1991											6.6		0.04							
SC01306230ACC1	2/21/1992											7.4		0.04							
SC01306230ACC1	5/15/1992											8.0		0.05							
SC01306230ACC1	8/21/1992											8.3		0.04							
SC01306230ACC1	11/13/1992											7.4		0.04							
SC01306230ACC1	2/19/1993											7.3		0.04							
SC01306230ACC1	5/21/1993											7.9		0.05							
SC01306230ACC1	8/27/1993											8.3		0.04							
SC01306230ACC1	11/10/1993											7.7		0.04							
SC01306230ACC1	1/21/1994											8.2		0.04							
SC01306230ACC1	9/8/1994											8.2		0.04							
SC01306230ACC1	3/17/1995											8.2		0.03							
SC01306230ACC1	9/28/1995											8.5		0.04							
SC01306230ACC1	2/29/1996											8.1		0.04							
SC01306230ACC1	8/22/1996											8.6									
SC01306230ACC1	9/25/1996											8.3		0.04							
SC01306230ACC1	2/26/1997											8.7		0.04							
SC01306230ACC1	9/9/1997											7.9		0.02							
SC01306230ACC1	2/20/1998											8.2		0.04							
SC01306230ACC1	8/28/1998											8.2		0.04							
SC01306230ACC3	9/8/1980			112		0.63			<0.1	127.0	8.4	2.5	37	<0.1	0.30		36.00	54.00	18.00	<1	30.00
SC01306231ACC	8/7/1984	251	95	93		1.85				116.0	9.7	6.0	51	0.05	0.40		31.00	3.70	41.00	2.00	29.00
SC01306231ACC	8/22/1996											8.4									
SC01306231BAA	9/8/1971	233		72		2.90				108.0	7.6	6.5	43	0.09	0.30		24.00	2.90	40.00	2.00	31.00
SC01306301A	1/1/1954	225		80		2.40				91.0	11.0	5.0	51				27.00	3.20	35.00	2.20	
SC01306301CCC	8/16/1984	171										6.5									
SC01306301CCC	8/19/1996											7.8									
SC01306301DCB	1/1/1987	265	80	88	0.4				<0.3	96.0	13.0	9.5	80	0.10	0.40	0.10	36.00	<1	42.00	1.20	27.00
SC01306306DAA	8/9/1984	321										<0.1									
SC01306306DAA	8/21/1996											<0.05									
SC01306312ACB	9/27/2006	223	48	72					<0.1	58.2	13.2	8.8	31				23.01	3.46	30.69	0.75	
SC01306312ACB2	1/1/1986	165	105	56	0.7	3.23			<0.1	125.0	3.5	1.0	29	<0.1	0.60	0.10	16.00	3.70	39.00	1.30	17.00
SC01306312CDB	8/9/1984	195										2.8									
SC01306312CDB	8/19/1996											3.1									
SC01306314ABB	8/13/1984	257										1.7									

Site ID	Sample Date	Total Dissolved Solids (mg/L)	Alkalinity	Hardness (ppm)	Turbidity (NTU)	Sodium Adsorption Ratio	Langlier Index	Anions								Cations					SiO2)
								Calcium Carbonate	Carbonate	Bicarbonate	Chloride	Nitrate (as N)	Sulfate	Phosphate	Flouride	Bromide	Calcium	Magnesium	Sodium	Potassium	Silicate (as SiO_2)
SC01306314ABB	8/21/1996											0.3									
SC01306322ADB	8/10/1984	353										2.9									
SC01306322ADB	8/21/1996											2.5									
SC01306323CCA	9/27/2006	438	149	153					<0.1	182.0	27.5	4.4	79				50.14	6.83	62.11	0.85	
SC01306324ABB2	11/28/2006	278	86				<0.75					8.3					38.00		39.00		
SC01306334ABB	8/10/1984	267	107	103		1.97				130.0	6.1	**11.0**	33	0.04	0.40		36.00	3.30	46.00	1.90	27.00
SC01306334ABB	8/21/1996											**11.0**									
SC01306336CA	5/7/2008	268	157	65		5.22					20.5	1.7	23	0.08			22.60	1.96	68.10	1.24	
SC01406204AB	5/7/2008	443	193	138		5.30					51.9	3.0	86	<0.065			47.20	4.83	101.00	1.19	
SC01406205ACD	8/16/1984	233										6.0									
SC01406205BBB	8/7/1984	255	89	99		1.75				109.0	10.0	6.5	53	0.05	0.40		33.00	3.90	40.00	2.10	30.00
SC01406205BBB	8/22/1996											5.9									
SC01406205CAA	8/7/1984	266	82	106		1.73				100.0	14.0	7.0	58	0.05	0.40		36.00	4.00	41.00	2.30	30.00
SC01406205CAA	8/22/1996											7.1									
SC01406207ACD	11/30/2006	243	107	104					<0.1	130.0	7.4	7.1	39				35.13	4.09	24.66	1.70	
SC01406208CCB	8/10/1984	193										4.8									
SC01406208CCB	8/19/1996											7.4									
SC01406216CCC	8/10/1984	**546**	197	212		2.99				240.0	48.0	8.1	140	0.04	0.70		73.00	7.20	100.00	2.80	20.00
SC01406220DBC	9/8/1971	329		130		2.44				145.0	16.0	8.7	73	0.15			45.00	5.50	46.00	2.60	31.00
SC01406220DBC	8/10/1984	**548**										8.4									
SC01406220DBC	8/12/1986	284	125	7		17.00					24.0	<10	72		0.30		47.00	<5.2	50.00	2.60	27.00
SC01406228CCB	9/8/1971	**596**		260		3.83				289.0	48.0	4.3	160	0.40	0.30		87.00	9.80	100.00		26.00
SC01406231BAA	8/7/1984	206	90	74		1.83				110.0	6.8	5.1	27	0.08	0.50		25.00	2.70	36.00	1.90	
SC01406232B	1/1/1955	239		90		2.34				103.0	12.0	5.4	51				30.00	3.60	36.00	2.50	30.00
SC01406232BBA	8/7/1984	220										4.1									
SC01406303DCC	8/9/1984	179										0.7									
SC01406303DCC	8/19/1996											5.0									
SC01406312DCD	9/8/1971	217		84		1.74				110.0	6.5	6.8	32	0.06	0.30		29.00	2.90	26.00	3.00	33.00
SC01406312DCD	8/10/1984	200										4.2									
SC01406312DCD	8/21/1996											4.4									
SC01406313DAA2	8/10/1984	196										4.4									
SC01406313DAA2	8/19/1996											5.3									
SC01406323AA	5/7/2008	262	110	91		2.79					16.8	5.3	35	<0.065			31.80	2.85	43.30	2.17	
SC01406325AD	5/8/2008	234	109	91		2.22					12.5	4.9	28	<0.065			31.70	2.91	34.50	2.34	
SC01406336AAB	8/7/1984	222										4.4									
SC01406336AAB	8/20/1996											5.8									
SC01406408AA	11/5/2009		190	170	3.56	2.36			10.00	190.0	19.0	<0.5	54				59.00	5.40	50.00	5.00	
SC01506205BDD	12/1/2006	312	119	78					<0.1	145.0	13.2	7.9	44				27.24	2.35	54.48	1.23	
SC01506207DA	5/8/2008	320	146	115		3.31					19.5	4.5	56	0.08			39.70	3.81	57.70	1.65	
SC01506218ACB	8/8/1984	326	176	129		2.56				215.0	13.0	4.4	61	0.15	1.00		44.00	4.70	67.00	2.40	22.00
SC01506218ACB	8/20/1996											5.8									
SC01506301AAA	8/7/1984	204										5.1									

Site ID	Sample Date	Total Dissolved Solids (mg/L)	Alkalinity	Hardness (ppm)	Turbidity (NTU)	Sodium Adsorption Ratio	Langlier Index	Anions								Cations					SiO2)
								Calcium Carbonate	Carbonate	Bicarbonate	Chloride	Nitrate (as N)	Sulfate	Phosphate	Flouride	Bromide	Calcium	Magnesium	Sodium	Potassium	Silicate (as SiO_2)
SC01506310DCC	8/7/1984	200	104	86		1.50				127.0	7.0	5.5	17	0.06	0.40		30.00	2.80	32.00	1.90	22.00
SC01506310DCC	8/20/1996											5.6									
SC01506312ACA	11/1/1987	185	96	100	2.00	1.50			<0.1	115.0	9.8	4.2	32	0.04	0.47	0.20	34.00	2.80	24.00	2.40	27.00
SC01506312CBA	11/1/1987	225	100	96	0	1.52			<0.1	120.0	10.0	5.3	45	0.03	0.42	<0.1	46.00	3.40	28.00	27.00	24.00
SC01506312DCC	8/7/1984	199										3.5									
SC01506313BAA	9/8/1971	198		70		2.28				128.0	5.9	3.7	20	0.18	0.40		24.00	2.50	31.00	2.30	32.00
SC01506313BAA	1/1/1992	210	93	83	1.46	2.26			DLNQ	93.0	7.5	4.2	24	DLNQ	0.40	0.02	29.00	2.54	33.40	1.90	17.40
SC01506313BBB	11/1/1987	260	105	115	0.90	2.09			<0.01	130.0	9.1	<0.5	32	0.05	0.40	0.20	39.00	3.60	36.00	2.70	27.00
SC01506323CDB	7/27/1999	257	86		0.16				DLNQ	85.7	12.3	6.0	57	DLNQ	0.45		29.00	3.10	46.00	2.20	
SC01506323CDB	4/12/2001	250	90				<1.29	65.00				6.6			0.54				43.00		
SC01506324CDD	9/8/1971	262		94		2.60				134.0	13.0	4.1	53	0.25	0.40		32.00	3.50	41.00	1.60	33.00
SC01506324D	1/1/1955	241		75		3.26				124.0	11.0	2.9	51				26.00	3.40	47.00	1.70	
SC01506324DAB	7/24/1984	349										4.3									
SC01506325ABA	9/8/1971	**767**		290		5.09				281.0	46.0	**11.0**	**250**	0.09	0.70		95.00	12.00	140.00	3.00	33.00
SC01506325BBA	7/24/1984	223										4.6									
SC01506325BBA	8/20/1996											5.6									
SC01506326BAB	8/8/1984	235										5.5									
SC01506326BAB	8/20/1996											5.8									
SC01506335AAA	5/30/2000	232	83	95	0.37	3.03			DLNQ	83.2	8.4	4.8	44	DLNQ	0.46	0.04	32.00	3.70	48.00	2.60	
SC01506335AAB	8/7/2000	209	95	71	1.20	2.48			DLNQ	95.4	5.8	3.7	28	DLNQ	0.65	0.02	24.00	2.70	34.00	2.10	
SC01506335DCC1	9/25/2000	197	99		0.34				DLNQ	99.3	5.6	3.5	25	DLNQ	0.48		24.00	2.90	39.00	2.20	
SC01506335DCC1	6/9/2005	204	97				0.44	62.00				3.6			0.49				32.00		
SC01506335DCC2	9/27/2006	244	77	97					-0.10	94.3	13.5	3.6	44				31.54	4.37	28.28	1.02	

NOTES:
All concentration data in mg/L
NA - Not applicable for parameter
DLNQ - Detection Limit not quantified in source data
Bold text indicated MCL / SMCL exceedence

Dissolved Metals Data

Site ID	Sample Date	Antimony	Iron	Cadmium	Chromium	Lead	Mercury	Seleniuum	Silver	Manganese	Barium	Aresnic	Beryllium	Cobalt	Copper	Vanadium	Zinc	Thallium
SC01206219CC	3/1/2006		**2.80**	DLNQ	DLNQ	DLNQ	DLNQ	0.0074	DLNQ	0.024	0.088	DLNQ						
SC01206230BB	3/1/2006		**0.48**	DLNQ	DLNQ	DLNQ	DLNQ	0.0074	DLNQ	0.016	0.110	DLNQ						
SC01206230BBC	11/07/06		<0.01	<0.005	<0.01	<0.005				<0.01	0.019				<0.01		0.01	
SC01206314DDC	8/9/1984		0.045							0.003								
SC01206336ACC	8/8/1984		0.006															
SC01306207BCB	1/20/1986		0.060		<0.005	<0.005	<0.005	0.006	0.0009			<0.01						
SC01306219CDB	9/10/1980		**1.0**															
SC01306219CDB	8/7/1984		0.008							0.002								
SC01306229DAC	11/30/06		<0.01	<0.005	<0.01	<0.005				<0.01	0.010				<0.01		<0.01	
SC01306230ACC1	8/7/1984		0.030							0.001								
SC01306230ACC1	8/7/1986		0.004							<1								
SC01306230ACC3	9/8/1980		0.030															
SC01306231ACC	8/7/1984		0.014							<0.001								
SC01306231BAA	9/8/1971		0.005							DLNQ								
SC01306301DCB	1/1/1987		0.060		0.005	<0.005	0.005	0.018	0.0008	<0.05		**0.01**						
SC01306312ACB	09/27/06		<0.01	<0.005	<0.01	<0.005				<0.01	<0.01				<0.01		<0.01	
SC01306312ACB2	1/1/1986		0.260	0.0037	<0.005	<0.005	<0.0005	0.003	0.0005			<0.01						
SC01306323CCA	09/27/06		<0.01	<0.005	<0.01	<0.005				<0.01	0.022				<0.01		0.01	
SC01306324ABB2	11/28/2006	<0.0004		<0.0005	0.0016		<0.0001	0.006			0.120	<0.0014	<0.0003					<0.0003
SC01306334ABB	8/10/1984		0.004							<0.001								
SC01406205BBB	8/7/1984		0.010							<0.001								
SC01406205CAA	8/7/1984		0.010							0.003								
SC01406207ACD	11/30/06		<0.01	<0.005	<0.01	<0.005				<0.01	0.011				<0.01		0.0152	
SC01406216CCC	8/10/1984		0.016							<0.001								
SC01406220DBC	9/8/1971		0.005							DLNQ								
SC01406220DBC	8/12/1986		0.005							<0.001								
SC01406228CCB	9/8/1971		0.005							DLNQ								
SC01406231BAA	8/7/1984		0.014							0.002								
SC01406312DCD	9/8/1971		0.020							DLNQ								
SC01406408AA	11/5/2009			<0.005	<0.01	<0.005		<0.005	<0.025		<0.2	<0.01	<0.005	<0.05	<0.025	<0.05	<0.02	<0.002
SC01506205BDD	12/01/06		<0.01	<0.005	<0.01	<0.005				<0.01	<0.01				<0.01		0.0057	
SC01506218ACB	8/8/1984		0.019							<0.001								
SC01506301AAA	8/7/1984																	
SC01506310DCC	8/7/1984		0.022							0.003								
SC01506312ACA	Nov-87		0.120	<0.01	<0.01	<0.01	<0.0005	<0.01	<0.001	<0.01		<0.01						
SC01506312CBA	Nov-87		<0.03	<0.01	<0.01	<0.01	<0.0005	<0.01	<0.001	0.01		<0.01						
SC01506313BAA	9/8/1971		0.005							DLNQ								
SC01506313BAA	1/1/1992		0.068	DLNQ	DLNQ	DLNQ	0.0009	DLNQ	DLNQ	DLNQ	0.016	DLNQ						
SC01506313BBB	Nov-87		0.080	<0.01	<0.01	<0.01	<0.005	<0.01	0.0010	<0.01		<0.01						
SC01506323CDB	7/27/1999		0.260	0.0002	0.0140	0.0009	DLNQ	0.010	0.0012	DLNQ	DLNQ	0.0014						
SC01506323CDB	4/12/2001	<0.005		<0.0001	0.0020		<0.0001	0.006			0.021	<0.001	<0.001					<0.001
SC01506324CDD	9/8/1971		0.020							DLNQ								
SC01506325ABA	9/8/1971		0.020							DLNQ								
SC01506335AAA	5/30/2000		0.250	DLNQ	0.0033	0.0006	DLNQ	0.0059	DLNQ	DLNQ	0.040	DLNQ						
SC01506335AAB	8/7/2000		0.210	DLNQ	0.0032	DLNQ	DLNQ	0.0071	DLNQ	DLNQ	0.021	DLNQ						
SC01506335DCC1	9/25/2000		0.270	DLNQ	0.0061	DLNQ	DLNQ	0.0051	DLNQ	DLNQ	0.360	DLNQ						
SC01506335DCC1	6/9/2005	<0.002		<0.0005	<0.006		<0.0001	0.0061			0.024	<0.002	<0.001					<0.001
SC01506335DCC2	09/27/06		<0.01	<0.005	<0.01	<0.005				<0.01	<0.01				<0.01		<0.01	

NOTES:
Bold text indicated MCL / SMCL exceedence
All concentration data in mg/L
DLNQ - Detection Limit not quantified in source data

Pesticides / Herbicides and Radionuclide Data

Site ID	Sample Date	Pesticides and Herbicides						Radioactivity	
		Endrin	Lindane	Methoxychlor	Toxaphene	2, 4-D	2, 4-5 TP	Gross Alpha	Gross Beta
SC01206219CC	3/1/2006	DLNQ	DLNQ	DLNQ	DLNQ	DLNQ	DLNQ	1.40	2.10
SC01206230BB	3/1/2006	DLNQ	DLNQ	DLNQ	DLNQ	DLNQ	DLNQ	2.80	2.20
SC01206230BBC	11/7/2006	<0.00014	<0.000069	<0.000004		<0.000084			
SC01306207BCB	1/20/1986	<0.0001	<0.001	<0.001	<0.002	<0.01	<0.005		
SC01306229DAC	11/30/2006	<0.00014	<0.000069	<0.000004		<0.000084			
SC01306301DCB	1/1/1987	<0.0001	<0.001	<0.001	<0.002	<0.01	<0.005		
SC01306312ACB	9/27/2006	<0.00016	<0.000075	<0.000004		<0.000041			
SC01306312ACB2	1/1/1986	<0.0001	<0.001	<0.001	<0.002	<0.01	<0.005		
SC01306323CCA	9/27/2006	<0.00016	<0.000075	<0.000004		<0.000041			
SC01306324ABB2	11/28/2006	<0.00001	<0.00001	<0.00005	<0.0005	<0.0001	<0.0002	1.00	2.70
SC01306334ABB	8/21/1996	DLNQ							
SC01406207ACD	11/30/2006	<0.00014	<0.000069	<0.000004		<0.000084			
SC01506205BDD	12/1/2006	<0.00014	<0.000069	<0.000004		<0.000084			
SC01506312ACA	11/1/1987	<0.0001	<0.001	<0.001	<0.002	<0.01	<0.005	1.50	6.00
SC01506312CBA	11/1/1987	<0.0001	<0.001	<0.001	<0.002	<0.01	<0.005	2.10	1.10
SC01506313BAA	1/1/1992	DLNQ	DLNQ	DLNQ	DLNQ	DLNQ	DLNQ	3.60	3.40
SC01506313BBB	11/1/1987	<0.0001	<0.001	<0.001	<0.002	<0.01	<0.005		
SC01506323CDB	7/27/1999							2.50	2.70
SC01506323CDB	4/12/2001							1.38	3.59
SC01506335AAA	5/30/2000	DLNQ	DLNQ	DLNQ	DLNQ	DLNQ	DLNQ	0.40	2.20
SC01506335AAB	8/7/2000	DLNQ	DLNQ	DLNQ	DLNQ	DLNQ	DLNQ	0.90	2.90
SC01506335DCC1	9/25/2000							0.30	2.60
SC01506335DCC1	6/9/2005	<0.00001	<0.00002	<0.0001	<0.001	<0.0001	<0.0002	0.50	1.50
SC01506335DCC2	9/27/2006	<0.00016	<0.000075	<0.000004		<0.000041			

NOTES:

All Pesticide and Herbicide concentration data in mg/L; Radioactivity data in pCi/L

DLNQ - Detection limit not quantified in source data

2,4,5-TP - 2 (2,4,5-Trichlorophenoxy) propionic acid

2, 4-D - 2,4-Dichlorophenoxyacetic Acid

Organic Compound Data

Site ID	Sample Date	Benzene	Ethylbenzene	Total Xylenes	Toluene	Napthalene
SC01306324ABB2	11/28/2006	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
SC01406408AA	11/5/2009	<0.0016	<0.0012	<0.0056	<0.002	
SC01506335DCC1	6/9/2005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005

Site ID	Sample Date	Tetrachloroethene	Trichloroethene	cis-1,2-Dichloroethene	Vinyl chloride	1,1,1-Trichloroethane	Carbon Tetrachloride
SC01306324ABB2	11/28/2006	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
SC01406408AA	11/5/2009	<0.0012	<0.0016	<0.0016	<0.002	<0.0012	<0.0016
SC01506335DCC1	6/9/2005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005

NOTE:
All concentration data in mg/L