WATER-QUALITY ASSESSMENT OF THE PRINCIPAL VALLEY-FILL AQUIFERS IN THE SOUTHERN SANPETE AND CENTRAL SEVIER VALLEYS, SANPETE COUNTY, UTAH

by Janae Wallace

UTAH DNR GEOLOGICAL SURVEY

SPECIAL STUDY 132
UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES
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Cover photo: *View to the southeast of a typical agricultural scene in southern Sanpete Valley with Gunnison Reservoir and the White Hills in the foreground and the snow-capped Valley Mountains on the horizon along the western margin of central Sevier Valley.*

ISBN 978-1-55791-828-4

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WATER-QUALITY ASSESSMENT OF THE PRINCIPAL VALLEY-FILL AQUIFERS IN THE SOUTHERN SANPETE AND CENTRAL SEVIER VALLEYS, SANPETE COUNTY, UTAH

ABSTRACT

Southern Sanpete and central Sevier Valleys are rural areas characterized by extensive agricultural activity and increasing population. The unconsolidated valley-fill aquifers in both valleys are an important source of drinking water. In cooperation with the Utah Division of Drinking Water and the U.S. Environmental Protection Agency (EPA), I assessed water quality in the valley-fill aquifers to determine (1) the relationship of ground-water quality to geologic units in the San Pitch and Sevier River drainage basins, (2) likely sources of nitrate pollution documented in previous reports, and (3) the relative age of high-nitrate water from selected water wells. I mapped water quality in the valley-fill aquifers with emphasis on nitrate and total-dissolved-solids (TDS) concentrations. Water-well samples from domestic, municipal, and irrigation sources were collected and analyzed by the Utah Geological Survey (UGS) during spring/summer 2007. I selected 77 water-sampling sites including wells, springs, and streams, without bias to land-use practice, to represent a widespread distribution of water-quality data. Most of the sampled water wells are less than 200 feet deep. Water samples from all wells were analyzed for nutrients (nitrate, nitrite, ammonia, and phosphate), general ion chemistry, and dissolved metals. Of these 77 samples, those having relatively high (greater than 5 mg/L) nitrate concentrations were also analyzed for environmental tracers including nitrogen and oxygen isotopes in nitrate, tritium, chlorofluorocarbons (CFC), and carbon isotopes. I used TDS and nitrate data from nine wells and nine springs from the Utah Division of Drinking Water and four wells from the Utah Department of Agriculture and Food (UDAF) to augment the study, for a total of 99 samples analyzed. During summer and autumn of 2008, UDAF re-sampled 21 of the wells sampled by UGS; the majority of the TDS and nitrate concentrations from re-sampled wells are similar to those from wells sampled during 2007.

Nitrate concentrations for 81 water wells, 15 springs, and 3 streams in the study area range from less than 0.1 mg/L to 39 mg/L, with an average concentration of 6.5 mg/L, and a median of 5.2 mg/L. Fifty-one percent of the wells and springs yielded values greater than 5 mg/L, and 20% showed nitrate values that exceed the Utah and EPA primary drinking water-quality standard of 10 mg/L. These data indicate that high-nitrate-concentration areas are widespread. Possible sources of nitrate include fertilizer, feed lots, septic-tank systems, and natural sources. TDS concentrations for water wells and springs in the valley range from 202 to 3530 mg/L (average 915 mg/L and a 688 mg/L median). TDS concentrations for 33% of the wells and springs are greater than 1000 mg/L (a concentration regulated by the Utah Division of Drinking Water for public-supply wells in accordance with rule R309-200-5). Elevated TDS concentrations are likely caused by dissolution of minerals from the evaporite-rich Arapien Shale and Green River Formation, and by return irrigation water.

Field observation of possible nitrate sources upgradient of high-nitrate wells suggests animal and human waste (from feed lots, corrals, and septic tanks) may be the nitrate source in most cases. Tritium analysis of ground water from 23 high-nitrate wells indicates that contaminated ground water was recharged pre-, post-, and during above-ground nuclear testing when tritium concentrations in the atmosphere were at their low, medium, and peak levels, respectively. CFC data show most high-nitrate wells have an average recharge year of 1976 (for CFC-11, CFC-12, and CFC-113), with an overall date range from 1943 to 2000. Ground-water dates derived from carbon isotope data range from modern to 19,000 years old, and show the high-nitrate ground water is derived from both old and young ground-water sources. Overall, most ground water in the area likely reflects mixed or combined sources of water.

INTRODUCTION

Background

Southern Sanpete Valley (which, for the purposes of this study, includes the communities of Sterling and Mayfield in Arapien Valley) and central Sevier Valley (figure 1) are rural areas where most residential development and agricultural activities are located on unconsolidated valley-fill deposits, which are the principal drinking-water aquifers for the area. Septic-tank effluent, agricultural fertilizers, and animal waste from feed lots and farms are potential sources of nitrate, which is the principal ground-water contaminant identified during previous ground-water studies in the area (Lowe and others, 2002; Sunrise Engineering, 2002) and a review of data for public water-supply wells and springs (Rachael Cassidy, Utah Division of Drinking Water, written communication, 2006). High

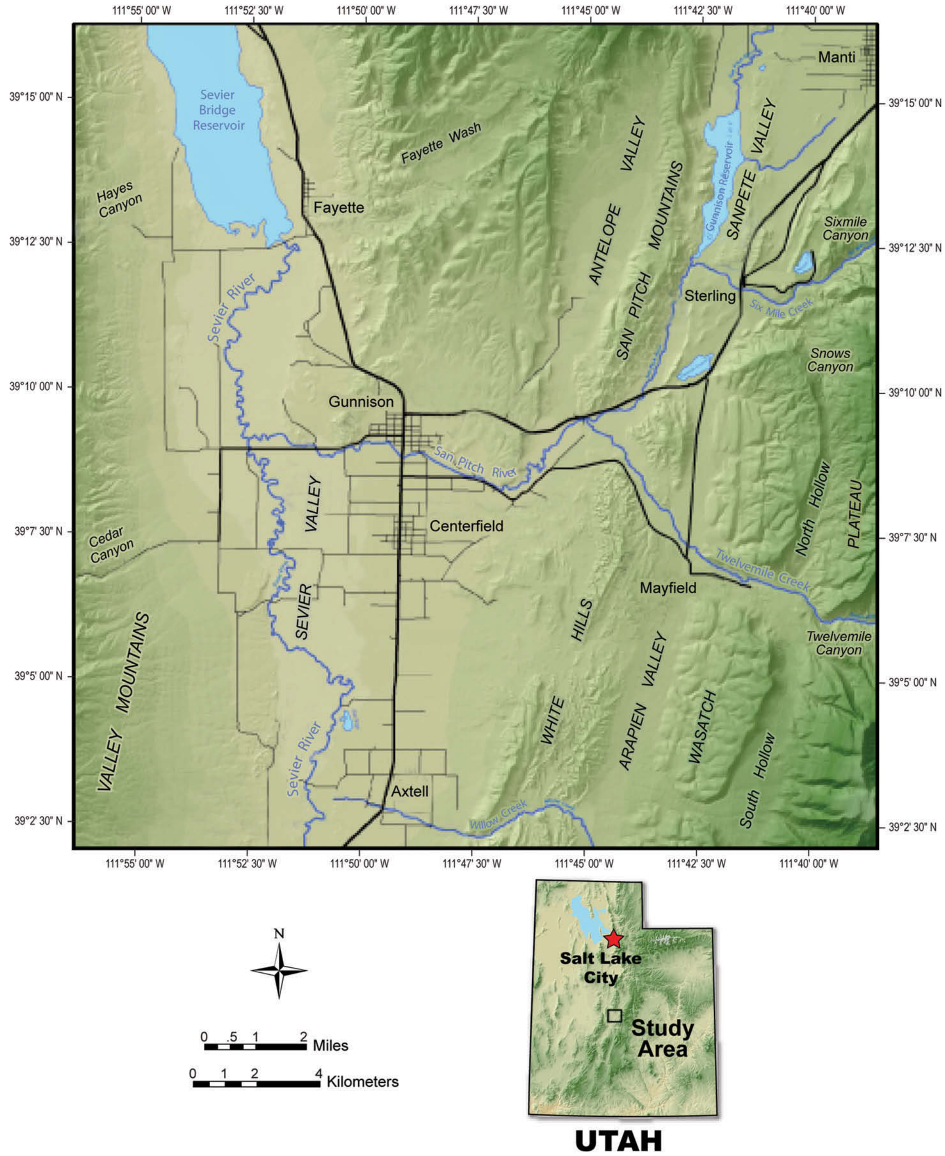


Figure 1. Location of the study area in Sanpete County, Utah.

nitrate levels in ground water have also been documented in northern and central Sanpete Valley, where many wells have historically yielded ground water having greater than 40 mg/L nitrate as nitrogen (Robinson, 1968; Horns, 1995; Lowe and others, 2002). A recent investigation by Sunrise Engineering in the southern Sanpete and central Sevier Valleys shows water from a large number of wells (including two potential public-supply wells they sited and engineered) as having high nitrate concentrations, possibly sourced by natural nitrate in the aquifer (John Iverson, Sunrise Engineering, verbal communication, 2006). One public-supply well drilled for the town of Centerfield in Hayes Canyon yielded water having a nitrate concentration of 16 mg/L but no apparent upgradient nitrate source. Similarly, a public-supply spring for Centerfield that issues from the Green River Formation near a mapped fault zone has a relatively high nitrate concentration of 7 mg/L (this study); this spring has had a persistent nitrate concentration ranging from 6.65 mg/L in 1984 to 6.8 mg/L in 2006 (Bob Hart, Utah Division of Drinking Water, written communication, November 2006). In addition, the Arapien Shale is prevalent throughout both valleys and has been associated with poor water quality with total-dissolved-solids (TDS) concentrations from wells reported as high as 2752 mg/L (unsuitable for a public water-supply well) (Lowe and others, 2002). These incidents of relatively high TDS and nitrate concentrations reported in domestic and public-supply wells and springs prompted this study to evaluate water quality in southern Sanpete and central Sevier Valleys.

The valley-fill aquifers are the principal source of drinking water for residents of southern Sanpete and central Sevier Valleys, although some springs along the valley margins are also used for drinking water. The availability of good quality ground water is a critical issue for land-use planning and resource management in Sanpete County. Local government officials in Sanpete County have expressed concern about the impact of nitrate contamination on ground-water resources, especially for public water-supply wells. Additionally, protecting ground-water resources is a priority in the Utah State Comprehensive Ground Water Management Plan (Utah Division of Water Resources, 1999). Utah Division of Drinking Water regulators would like to understand the relationship between geology and water quality so that they can assist the community in siting a new public-supply well that will have nitrate concentrations well below the drinking water-quality standard of 10 mg/L.

Purpose and Scope

State and local government officials and water users in southern Sanpete and central Sevier Valleys need ground-water quality information to help them make informed decisions on land use to protect ground-water resources. The purpose of this study, a cooperative effort among the Utah Geological Survey (UGS), the Utah Division of Drinking Water, and the U.S. Environmental Protection Agency (EPA), is to provide local government officials, state agencies, and private water users with (1) maps showing TDS concentrations and nitrate concentrations for the principal valley-fill aquifers, (2) a determination of the relationship between basin geology and ground-water quality, (3) an identification of all likely sources of nitrate contamination, and (4) an evaluation of the significance of individual nitrate sources and ground-water ages using isotope data in southern Sanpete and central Sevier Valleys.

The scope of work included:

(1) conducting a water-well inventory to identify wells for valley-wide sampling,

(2) collecting water samples for water-chemistry analysis (nutrients, general chemistry, metals, and isotopes),

(3) mapping TDS and nitrate concentrations,

(4) examining some wells containing water exceeding 5 mg/L nitrate concentration by analyzing well characteristics and evaluating nitrogen and oxygen isotopes to help determine the source(s) of nitrate,

(5) sampling ground water from selected high-nitrate wells and analyzing for chlorofluorocarbons (CFCs), tritium, and carbon isotopes to constrain the age of contaminated water,

(6) compiling drillers' well logs to produce an isopach map to help identify a suitable site for a public water-supply source, and

(7) preparing this report summarizing the findings.

This study focuses on water quality, and does not provide a ground-water flow model; existing literature and information regarding the hydrogeology of the area is sparse. No attempt is made to identify a specific location to install a well for public-water supply based on economics or the water quantity available to supply these communities' future demands.

Methods

Water-Well Sampling

I selected 68 wells (plate 1) for sampling. Six springs and three streams were also sampled. The wells, springs, and streams were sampled during spring/summer of 2007, and the water was analyzed for nutrients (nitrate, nitrite, ammonia, and phosphorous) and general chemistry by the Utah Division of Epidemiology and Laboratory Services, and for dissolved metals by the U.S. EPA. The constituents sampled for, the EPA analysis method used, and ground-water quality standard (if the constituent has been assigned one) are provided in appendix A (table A1). I followed requirements for sampling methods, equipment used, sample containers, and preservation outlined in Utah Division of Water Quality's QAPP for Water Monitoring Programs (Utah Division of Water Quality, 2006, section 17). Steve Deacon of UDAF collected samples from wells and springs during summer and autumn of 2008; samples were analyzed by UDAF's laboratory for the same chemical constituents as sampled by the UGS, but also for organics and pesticides. Various agents sampled public supply wells and springs over various years and seasons for the Utah Division of Drinking Water; all samples were analyzed by an EPA certified lab.

Stable Isotopes/Environmental Tracers

Stable isotopes can be useful tracers of ground-water flow paths (Kendall and Caldwell, 1998) and ground-water recharge ages, and hence are indicators of the source(s) of waters bearing similar isotopic signatures. To gain a better understanding of the ground-water hydrology in southern Sanpete and central Sevier Valleys, water samples were collected and analyzed for the following isotopes: nitrogen-15 and oxygen-18 (expressed as $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$, for isotopes in nitrate), tritium (^{3}H), CFCs, carbon-14 (^{14}C), and carbon-13 ($\delta^{13}C$). Twenty-four samples were tested for $\delta^{15}N_{NO3}$ and 22 for $\delta^{18}O_{NO3}$, 23 for ^{3}H, 17 for CFCs, and 21 wells for ^{14}C and $\delta^{13}C$. Nitrogen and oxygen isotopes in nitrate will help determine the source of nitrate. Data from samples tested for tritium, CFCs, and carbon isotopes will help determine the age of the ground water.

Nitrogen and oxygen: Nitrogen and oxygen isotopes have been used to help determine sources of nitrate, can be useful tracers of ground-water flow paths (Kendall and Caldwell, 1998), and hence are indicators of source(s) of waters bearing similar isotopic signatures. By measuring the ratio of isotopes taken from different sources and environments and comparing them to ratios of the same ground-water isotopes (e.g., comparing nitrogen isotope ratios from a known source to nitrogen isotope ratios of nitrate in ground water) the source of potential contamination to aquifers can be determined (Canter, 1997). In general, stable isotopes are reported as a ratio of the relative abundance of the isotope in the sample to the relative abundance of the isotope in a standard and expressed as:

$$\delta \text{ Isotope (in ‰)} = [(R_{sample}/R_{Standard})-1]*1000 \quad (1)$$

where R is the ratio of the “heavy” isotope to the “light” isotope in the sample or standard. Isotopes are reported as parts per thousand, commonly termed as parts per mil, or symbolically as ‰, and can be expressed as positive or negative numbers depending on the relationship to the given standard. For nitrate, the standard is atmospheric nitrogen (N_2) and nitrogen isotopes are commonly represented as $\delta^{15}N$ (where $\delta^{15}N$=0 ‰ for N in air); the standard for oxygen is Vienna Standard Mean Ocean Water (VSMOW) (Gonfiantini, 1978), with the oxygen isotope reported as $\delta^{18}O$. Nitrogen has two common stable isotopes: ^{15}N and ^{14}N. Oxygen has three common stable isotopes: ^{16}O, ^{17}O, and ^{18}O.

Figure 2 shows the relationship between nitrogen/oxygen isotopes of nitrate and selected nitrate source types (Kendall, 1998); figure 3 shows the common ranges for nitrogen isotope composition for septic waste, animal waste, fertilized soil, and natural soil (Kendall, 1998). Fertilizer typically has a $\delta^{15}N$ value range from –2 to +2‰, non-cultivated fertilized soils typically have a $\delta^{15}N$ value range from 0 to +8‰ (Canter, 1997; Kendall, 1998), values that range between -5 and 5‰ are typically associated with rain and ammonia-rich fertilizer, and animal and human waste are generally isotopically indistinguishable and have higher ranges between +10 and +20‰ (Kendall, 1998), but have been reported as low as 0‰; Canter (1997) reports decomposed animal waste having a range from +10 to +22‰. Animal waste is common to barnyard and feed lots, human waste is associated with effluent from septic-tank systems. Nitrate derived from nitrate in precipitation, desert nitrate deposits, and nitrate fertilizer typically has $\delta^{18}O_{NO3}$ values greater than 15‰ and lower $\delta^{15}N_{N03}$ values (less than 10‰) (figure 2). Processes such as denitrification and mixing of ground water can affect isotopic signature, and thus mask the actual source(s) of nitrate. Isotopic analysis for $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ was performed by the University of Waterloo, Ontario, Canada.

Tritium: Tritium (^3H) provides a qualitative age of ground water for determining the relative time when water entered the ground-water system (Clark and Fritz, 1997). Tritium is an unstable isotope of hydrogen having a half-life of 12.3 years; tritium concentration in ground water isolated from other water will decrease by one-half after 12.3 years. Tritium occurs naturally in the atmosphere, but above-ground nuclear fusion testing from 1952 to 1969 added tritium to the atmosphere in amounts that far exceed the natural production rates, and, as a result, tritium concentrations in precipitation also increased. The amount of tritium in the atmosphere from weapons testing probably peaked in the early to mid-1960s, and has been declining since atmospheric nuclear testing ceased. Modern concentrations are typically between 20 and 50 tritium units (one tritium unit [TU] equals 1 tritium atom in 10^{18} hydrogen atoms). Tritium in the atmosphere incorporates into water molecules and enters the ground-water system as recharge from precipitation. Because tritium is part of the water molecule, it is not affected by reactions other than radioactive decay, and thus can be used as a tracer of ground water on a time scale of less than 10 to about 55 years before present.

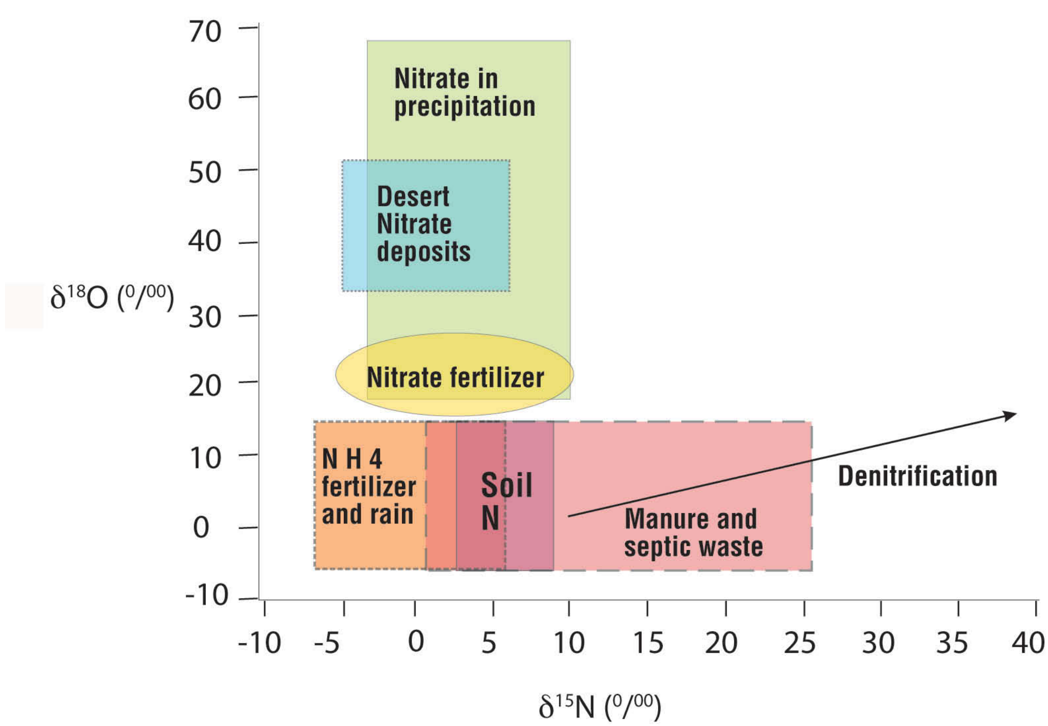


Figure 2. *Plot of nitrogen and oxygen isotopes characterizing sources of nitrate, (from Kendall, 1998).*

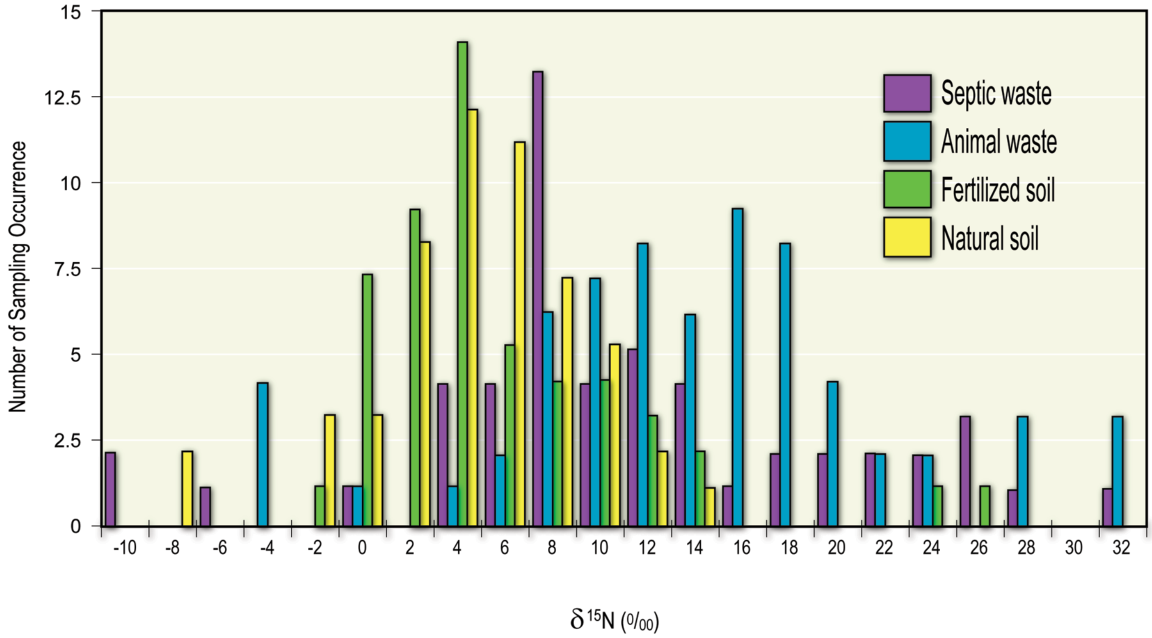


Figure 3. *Summary of the range of δ^{15}N values for septic waste, animal waste, fertilized soil, and natural soil, compiled from global sources, (modified from figure 16.4, Kendall, 1998).*

Water that entered the ground-water system before 1952 and has remained isolated from younger water contains no detectable tritium, and is interpreted to have recharged before 1952. Therefore, tritium can be used to distinguish between water that entered an aquifer before 1952 and water that entered the aquifer after 1952. Tritium analysis was performed by the U.S. Geological Survey (USGS) in Menlo Park, California.

Chlorofluorocarbons: Chlorofluorocarbons (CFCs) are stable synthetic compounds used in the production of refrigerants, propellants, and manufactured products associated with the electronics industry, and were introduced into the environment during the 1930s (Plummer and Busenberg, 1999). The compounds CFC-11 and CFC-12 are more commonly associated with coolants in air-conditioning and refrigeration, blowing agents in foams, insulation, propellants in aerosol cans, and solvents. The CFC-113 compound is typically used by the electronics industry in semiconductor chips, vapor degreasing and cold immersion cleaning of microelectronic components, and as solvents (Plummer and Busenberg, 1999).

When a ground-water sample is collected and analyzed for CFC concentrations, the concentration in the water is related to the concentration of CFC in the atmosphere at the time the water entered the subsurface (University of Utah Dissolved & Noble Gas Lab, 2008). The conditions for CFC analysis described herein were obtained from the lab-analysis sampling sheet by the University of Utah Dissolved & Noble Gas Lab (undated, unpublished sample form). For each sample analyzed for CFC content in ground water, current local physical and chemical parameters must be considered, such as the salinity of the water (at the time of recharge), the recharge temperature, and the recharge elevation. Chlorofluorocarbon raw data are calculated as the concentration of CFCs in air that would be in equilibrium with the sample at the temperature and elevation given; the calculation compares the equivalent air concentration with the atmospheric mixing ratios to estimate the recharge year. The atmospheric mixing ratio for CFC-11 began declining in 1994. As of 2001 it had dropped to about the same value it was in 1989. Thus, the CFC-11 dates are not unique for the period 1989 to 2001 (as of 2001). That is, there are two possible years that correspond to the same concentration; the results are typically reported as the older of the two possible dates. The same issue exists for CFC-113 starting in 1991. Chlorofluorocarbon analysis was performed by the University of Utah Dissolved & Noble Gas Lab, Salt Lake City, Utah.

Carbon: Carbon-14 (^{14}C) is a naturally occurring radioactive isotope of carbon that has a half-life of about 5730 years (Clark and Fritz, 1997). Carbon-14 data can provide information on ground water of greater ages than can the other environmental tracers, which only provide relative ground-water ages for the 20th century. Carbon-14 data are expressed as percent modern carbon (PMC) based on the National Bureau of Standards oxalic acid standard. Atmospheric testing of nuclear weapons also produced ^{14}C, so in some instances values greater than 100 PMC can occur in ground water that contains tritium, because the water was recharged when the atmosphere had above natural levels of ^{14}C. Carbon-14 is not part of the water molecule, so ^{14}C activities are affected by chemical reactions between the aquifer material and the dissolved constituents in the water. Chemical reactions can either add or remove carbon; therefore, knowledge of chemical reactions that occur during recharge and transport through the aquifer is necessary for estimating the initial activity of ^{14}C.

This is the most difficult aspect of using carbon-14 for dating ground water. The methods for dating carbon in ground water are complex and beyond the scope of this report; only a brief description is provided. Age calculations require estimates of some chemical parameters during recharge and model calculations of reactions during ground-water transport; calculation of ground-water age (expressed in years before present [yr B.P.], where "present" is A.D. 1950) from raw carbon isotope data was performed by Dr. Alan Mayo of Brigham Young University (written communication, May 25, 2008). Clark and Fritz (1997) provide a more detailed description of carbon isotope dating and the various required parameters to calculate carbon-based ages.

Carbon-13 is a naturally occurring stable isotope of carbon that is used to evaluate chemical reactions involving carbon (Clark and Fritz, 1997). Carbon-13 is expressed using the delta notation as a ratio with carbon-12, similar to $\delta^{18}O_{H20}$ and δD_{H20}, but with the Vienna Pee Dee Belemnite (VPDB) as the reference standard. The $\delta^{13}C$ concentration in ground water depends upon numerous factors, which include the type of vegetation in the recharge area, whether carbonates are dissolved or precipitated during recharge, and whether the system is open or closed. Carbon isotope analysis was performed by Brigham Young University, Provo, Utah.

Location and Geography

Southern Sanpete Valley and central Sevier Valley are in central and south-central Sanpete County (figure 1), central Utah, about 100 miles (160 km) south of Salt Lake City. Southern Sanpete Valley (figure 1; plate 1) ranges in elevation from about 5600 feet (1700 m) in the east to about 5400 feet (1650 m) in the west. The southernmost part of southern Sanpete Valley (Arapien Valley) is 8 miles (13 km) long and 1 mile (1.6 km) wide, and is separated from the main northern Sanpete Valley by a low divide located about 1 mile (1.6 km) south of Ninemile Reservoir. Arapien Valley is bounded by the Wasatch Plateau on the east and the White Hills on the west, and is separated from the central Sevier River basin at its southernmost point by a low divide about 4 miles (6.4 km) south of Mayfield. The Mayfield area includes the drainage of Twelvemile Creek, which flows west from the Wasatch Plateau and into the San Pitch River about 2 miles (3.2 km) southwest of Ninemile Reservoir (figure 1); the San Pitch River flows from Gunnison Reservoir south, then west toward central Sevier Valley.

Central Sevier Valley (figure 1; plate 1) ranges in elevation from a low near the base of the Sevier Bridge Dam at 4954 feet (1510 m) to a high of 8436 feet (2571 m) in the Valley Mountains (unnamed peak). The Sevier River flows from south to north toward Sevier Bridge Reservoir; the San Pitch River joins the Sevier River in central Sevier Valley, just southwest of the southern tip of the San Pitch Mountains.

Population and Land Use

Sanpete County is a rural area experiencing moderate population growth resulting in increased residential development; much of the existing and future development uses septic tank soil-absorption systems for wastewater disposal, though some areas are connected to sewer systems and maintain sewage lagoons (see waste-water disposal on plate 2). Sanpete County had an estimated July 2007 population of 26,464 (Utah Demographic and Economic Analysis Section, 2008); its 2000 census population was 22,763 (Utah Demographic and Economic Analysis Section, 2008). Population is projected to grow another 1% annually over the next 12 years; by 2020 the population of Sanpete County is expected to approximately reach 29,000 (Utah Demographic and Economic Analysis Section, 2000).

Government and non-farm proprietors (private business owners) have provided the most employment in Sanpete County throughout the last decade (Utah Governor's Office of Planning and Budget, unpublished data reported in Utah Division of Water Resources, 1999). Trade replaced agriculture as the third-largest employment provider in the county between 1994 and 1997; agriculture is expected to fall below the service industry in terms of number of people employed by 2020 (Utah Governor's Office of Planning and Budget, unpublished data reported in Utah Division of Water Resources, 1999). In 2003, Sanpete County ranked first in Utah in the production of turkeys, had the largest inventory of sheep in Utah, and ranked fifth in the state for milk cows (Utah State University Extension Economics Department, 2008). Although employment in agriculture and the number of farms are decreasing, agricultural commodity production is expected to remain an important part of Sanpete County's economy.

Most farming occurs on the unconsolidated valley-fill deposits that also serve as the principal source of drinking water for the residents of Sanpete County. There are 101,760 acres (41,182 hm^2) of irrigated cropland in Sanpete County (Utah Division of Water Resources, 1999); most irrigated cropland is in the central portions of southern Sanpete and central Sevier Valleys. Alfalfa is an important crop in Sanpete County. The eastern and western margins of both valleys are mostly rangeland for sheep and cattle.

Sanpete County may experience unexpected growth from current oil exploration. South of Mayfield, oil exploration and development is ongoing in the vicinity of the recently discovered Providence oil field along a northern extension of the structural trend of the Covenant field, discovered in 2003. The petroleum community has requested a permit from Sanpete County to construct a temporary storage/treatment facility (Wes Wilson, U.S. Environmental Protection Agency, personal communication, May 2008).

Climate

Climate in the San Pitch River drainage basin ranges from semiarid in Sanpete Valley to subhumid in the surrounding uplands (Robinson, 1971; U.S. Department of Agriculture, 2005). The area is characterized by large seasonal and daily temperature variations, especially during the summer (Robinson, 1971; U.S. Department of Agriculture, 2005). The closest weather station to southern Sanpete Valley is the Manti station, north of the study area. Temperatures reach a normal maximum of 86.7°F (30.4°C) and a normal minimum of 13.9°F (-10°C) recorded at the Manti station (Ashcroft and others, 1992). Normal annual precipitation ranges from 9.85 inches (25 cm) to 13.74 inches (35 cm). The average number of frost-free days in Sanpete County at Manti is 127 (Ashcroft and others, 1992). The local weather station for central Sevier Valley is located in Gunnison. Normal annual precipitation in the valley measured at Gunnison is 9.18 inches (23.3 cm) (Ashcroft and others, 1992). Temperatures reach a normal maximum of 91.5°F (33°C) and a normal minimum of 11.4°F (-11.4°C) recorded at the Gunnison station (Ashcroft and others, 1992). The average number of frost-free days in Sanpete County at the Gunnison station is 104 (Ashcroft and others, 1992).

Most of the precipitation in the San Pitch River drainage basin falls as snow in the mountains, particularly the Wasatch Plateau, from November to April (Robinson, 1971). The months of June through August are generally the driest, although brief, intense thunderstorms can locally produce large precipitation totals (Robinson, 1971). At elevations above 8000 feet (2500 m), the Wasatch Plateau receives an average of 24 inches (60 cm) of precipitation annually (normal climatic information is not available) (Ashcroft and others, 1992). Normal annual precipitation ranges from 8 inches (20 cm) in Sevier Valley to 20 inches (50 cm) in higher mountain elevations (Covington and Williams, 1972).

Normal annual evapotranspiration in Sanpete Valley at Manti is 45.81 inches (116.4 cm) (Ashcroft and others, 1992). Robinson (1971) noted that average annual evaporation in the San Pitch River drainage basin is 3.5 times greater than average annual precipitation; based on data from the Manti station for a recording period from 1893 to 2007, average annual evaporation is 3.3 times greater than the average annual precipitation ((Moller and Gillies, 2008). Normal annual evapotranspiration in central Sevier Valley at Gunnison is 51.22 inches (130 cm) (Ashcroft and others, 1992).

PREVIOUS HYDROGEOLOGIC INVESTIGATIONS

Lambert and others (1995) examined the hydrology of the Sevier-Sigurd ground-water basin and other ground-water basins that include central Sevier Valley and part of southern Sanpete Valley. Sandberg and Smith (1995) reported on a 1988 seepage study above the Sevier Bridge Reservoir, including areas in southern Sanpete and central Sevier Valleys. Wilberg and Heilweil (1995) conducted a hydrogeologic study, which included ground-water chemistry analysis and digital ground-water flow modeling for northern Sanpete Valley. Lowe and Snyder (1996) and Snyder and Lowe (1998) mapped recharge and discharge areas for the principal valley-fill aquifers in Sanpete and Arapien Valleys. Wallace and Lowe (1997) mapped ground-water quality in Sanpete and Arapien Valleys. Lowe and others (2002) evaluated the relationship of ground-water quality to geology and other sources of nitrate contamination for the valley-fill aquifer of Sanpete and Arapien Valleys. Bishop and others (2007) mapped recommended maximum densities of septic tank soil-absorption systems used for wastewater disposal. Lowe and others (2007) mapped ground-water sensitivity and vulnerability to pesticides. Wallace and others (2007) analyzed water-quality data and compiled water-quality, recharge-area, and septic-tank density maps as science-based land-use planning tools to help protect ground-water quality in Sanpete County.

GEOLOGIC SETTING

Most of the following summary of Sanpete County geology is from the original work of Spieker (1946, 1949a, 1949b), Witkind and others (1987), Witkind and Weiss (1991), and modified from Lowe and others (2002). Plate 3 shows a simplified geologic map for southern Sanpete and central Sevier Valleys.

The San Pitch and Sevier River drainage basins are in the Basin and Range-Colorado Plateau transition zone (Stokes, 1977), which contains features characteristic of both the Basin and Range and Colorado Plateau physiographic provinces. Stratigraphic units exposed in the Sanpete Valley area range from Jurassic to Quaternary in age. The San Pitch Mountains and Wasatch Plateau both consist of Jurassic to Tertiary sedimentary rocks, capped by Tertiary limestone. The Cretaceous section consists mostly of Upper Cretaceous clastic sedimentary rocks. Underlying the Cretaceous units are the Jurassic Twist Gulch Formation and evaporite-bearing Arapien Shale.

Structurally, Sanpete Valley is bounded on the east by the 50-mile-long (80 km) Wasatch monocline, along which Upper Cretaceous and Tertiary strata dip steeply to the west below Sanpete Valley from their near-horizontal dip atop the Wasatch Plateau (Spieker, 1946, 1949a, 1949b). Some of these tilted beds have been cut by westward-flowing consequent streams to form deep, sinuous canyons extending eastward into the Wasatch Plateau (Witkind and others, 1987). The westward dip becomes less steep beneath Sanpete Valley alluvium (Spieker, 1946, 1949a, 1949b).

Unconsolidated valley-fill deposits are at least 300 feet (100 m) thick in the center of southern Sanpete Valley (plate 3).

The valley fill is predominantly fluvial and alluvial-fan deposits consisting mainly of poorly sorted gravel, gravelly sand, and, locally, sand and sandy silt, interlayered with silt and clay. The valley-fill deposits generally become more fine grained toward the valley center.

West of Sanpete Valley and northeast of central Sevier Valley, the north-south-trending San Pitch Mountains consist of sedimentary rocks that have been folded to form a southward-plunging syncline (Witkind and others, 1987; Witkind and Weiss, 1991). Local diapirism has modified structures in several places in Sanpete County (Weiss and Sprinkel, 2002), especially in the south where the Arapien Shale is exposed along Sevier Valley's western margin. The Arapien Shale is the dominant rock type exposed in the White Hills, which separate southern Sanpete Valley from central Sevier Valley. Hylland and Machette (2008) mapped the southernmost extension of the Wasatch fault zone (the Fayette Segment) at the base of the western slope of the San Pitch Mountains north of the town of Fayette. The Fayette segment forms the eastern margin of northern Sevier Valley (Hylland and Machette, 2008).

The Valley Mountains bound Sevier Valley on the west. Structurally, the Valley Mountains exhibit faulted and tilted strata, typically dipping eastward at 15 to 35 degrees (Willis, 1991). Deeply dissected pediment surfaces flank the Valley Mountains and conceal faulted and folded, dominantly Tertiary-age bedrock (Willis, 1991). Faults are typically high-angle normal faults that trend northward or eastward and have up to 2500 feet (760 m) of vertical displacement. A north-south-trending zone of mostly east-facing fault scarps located near Hayes Canyon and named the Dover fault zone by Hylland and Machette (2008) is on-trend with the Levan segment of the Wasatch fault zone to the north. A west-facing fault scarp north of Hayes Canyon is part of the Dover fault zone, which extends 2 kilometers (1.2 miles) south of Hayes Canyon. The down-to-the-east fault is mapped south of Hayes Canyon (concealed) and has an estimated vertical offset of 4000 feet (1220 m) in undifferentiated Quaternary and Tertiary deposits (Petersen, 1997). Unconsolidated sediments of central Sevier Valley are up to 575 feet (175 m) thick based on drillers' logs (Petersen, 1997). Unconsolidated sediments consist of clay, silt, sand, and gravel that formed in alluvial-fan, fluvial, and lacustrine environments. Mesozoic and Tertiary strata likely underlie these sediments and form the east-dipping, west flank of a large, faulted syncline, similar to folded strata composing the San Pitch Mountains (Willis, 1991).

GROUND-WATER CONDITIONS

Aquifer Characteristics

Ground water in the southern Sanpete and central Sevier Valley areas (also referred to as the Redmond-Gunnison/Gunnison-Sevier Bridge Reservoir basins in Lambert and others, 1995) is obtained principally from unconsolidated deposits of the valley-fill aquifers (Wilberg and Heilweil, 1995; Lambert and others, 1995), where it occurs under confined and unconfined conditions (Robinson, 1971). Where the principal valley-fill aquifers are under confined conditions, they are generally overlain by a shallow unconfined aquifer (figure 4). The apparent potentiometric surface in the valley-fill aquifer is irregular and depends on the well depth, season, and the year water-level measurements are made (Robinson, 1971;

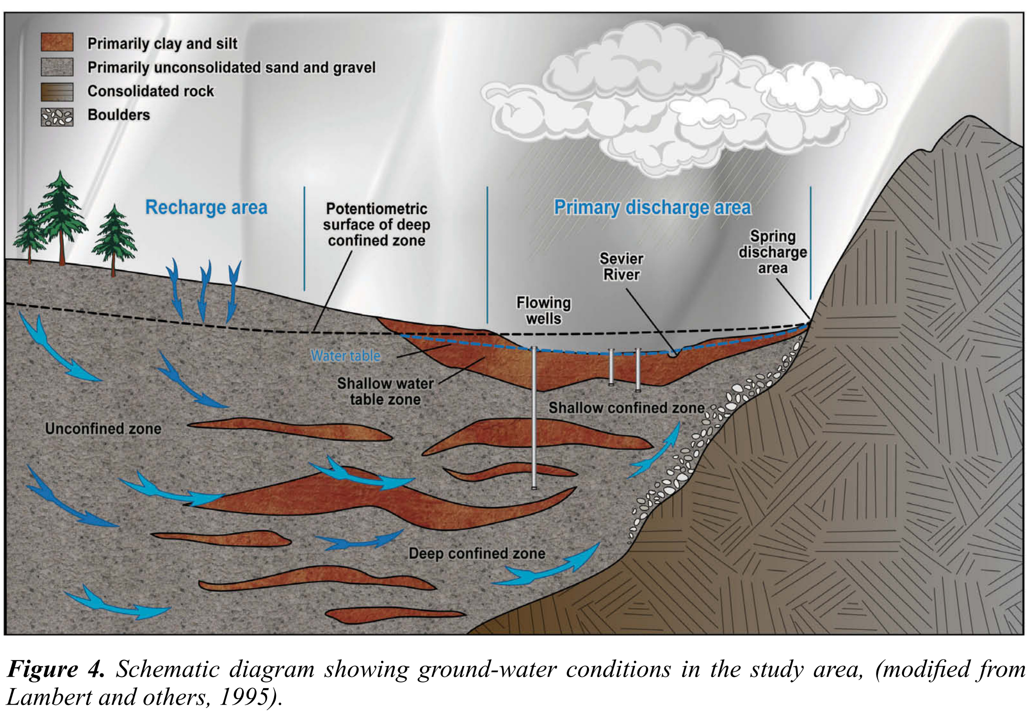


Figure 4. *Schematic diagram showing ground-water conditions in the study area, (modified from Lambert and others, 1995).*

Lambert and others, 1995). In unconfined parts of the aquifer, the potentiometric surface corresponds to the water table. In Sanpete Valley, ground water generally flows westward from the Wasatch Plateau and eastward from the San Pitch Mountains toward the San Pitch River, and then southward toward Gunnison Reservoir.

The central Sevier Valley is the northernmost extension of the larger Sevier-Sigurd hydrologic basin. In central Sevier Valley, ground water flows from south to north toward Sevier Bridge Reservoir and in the same general direction as the north-flowing Sevier River (figure 5). Valley-fill thickness ranges from 50 feet (15 m) near the San Pitch River to 320 feet (96 m) west of Gunnison (Young and Carpenter, 1965). In general, alluvial-fan deposits and pediment surfaces are common on valley margins. Fluvial deposits of the Sevier River floodplain and lacustrine deposits of highstand Lake Bonneville sediments (Hylland and Machette, 2008) are more common in the valley center. Basin-fill deposits near Fayette are 500 feet (150 m) thick and consist of fine-grained material (Young and Carpenter, 1965). The thickness of deposits near Sevier Bridge Reservoir is unknown due to the presence of the reservoir, and is assumed to be relatively thin in some locations (Young and Carpenter, 1965).

Based on the above descriptions of basin-fill deposits and examination of drillers' logs for the area, the aquifers of southern Sanpete and central Sevier Valleys are composed of heterogeneous units. Both valleys are characterized by coarse-grained alluvial-fan marginal deposits that grade into fluvial and/or fluvial-lacustrine finer grained deposits. Confining (or clay) layers are discontinuous; the degree of interconnectedness between coarser grained material is unknown. The use of drillers' logs requires interpretation because of the variable quality of the logs. Correlation of geology from well logs is difficult because lithologic descriptions prepared by various drillers are generalized and commonly inconsistent. Use of water level data from well logs is also problematic because levels in the shallow unconfined aquifer are commonly not recorded and because water levels were measured during different seasons and years. A detailed report on ground-water conditions in the study area is not available. Ground-water

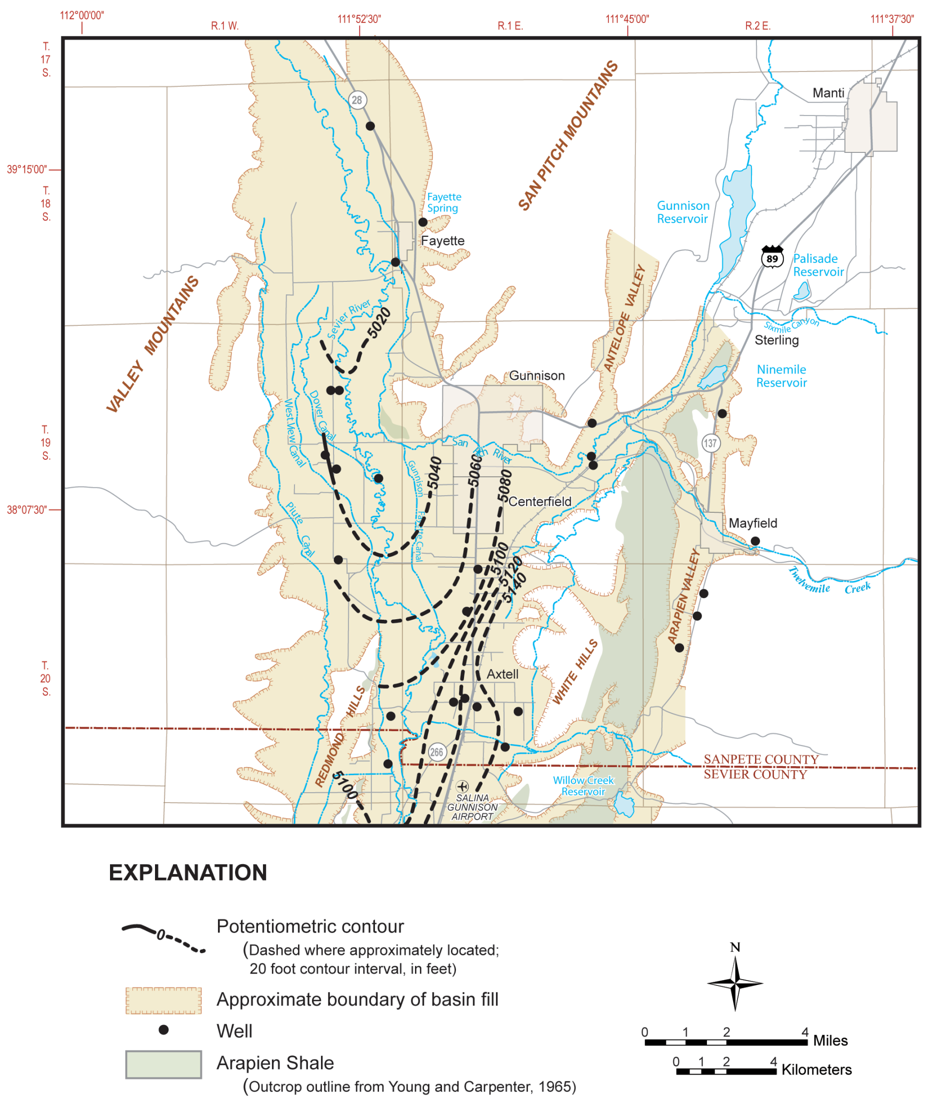


Figure 5. *Potentiometric surface of the principal ground-water reservoir for the shallow confined zone for September 1988, central Sevier Valley, Utah, (modified from Lambert and others, 1995).*

flow, in general, is higher in more permeable material having greater hydraulic conductivity; no hydraulic conductivity data exist for the study area.

Plate 3 illustrates the relative thickness of unconsolidated valley-fill deposits in southern Sanpete and central Sevier Valleys. Plate 3 represents a compiled isopach map based on information from 77 drillers' well logs (appendix B) and previously published cross sections, and is superimposed on a compiled geologic map. The majority of densely spaced wells are in the Sterling and Mayfield areas; I determined the bedrock depth based on some of those well logs. The actual thickness in the middle part of the valley may be greater than the illustrated thickness (plate 3) because wells in the middle part of the valley do not penetrate bedrock. The thickness of valley-fill material generally increases toward the center, and thins toward valley margins.

Water Quality

Water quality from fractured-rock aquifers in the San Pitch River drainage varies. Robinson (1971) attributed high specific conductance in water in fractured-rock wells along the east-central margin of Sanpete Valley to dissolution of minerals in the Green River Formation and Arapien Shale. Robinson (1971) indicated some of these wells were too saline for culinary use; for example, a specific conductance of 4800 micromhos per centimeter at 25°C (a TDS of about 3200 mg/L) was measured from a 1500-foot- (457 m) deep well in northern Sanpete Valley. Evaporites from the Arapien Shale beneath the San Pitch Mountains likely increase ground-water salinity in southwestern Sanpete Valley (Richardson, 1907; Robinson, 1971) and east-central Sevier Valley. The Flagstaff Limestone, composed of limestone, siltstone, and sandstone, yields water to springs in the central Sevier Valley and is an important water resource where it contains solution fractures (Lambert and others, 1995).

Away from areas of high nitrate concentrations, water quality in southern Sanpete and central Sevier Valleys' principal valley-fill aquifers is commonly good and suitable for most uses. Ground water in the valley-fill aquifers is generally a mixed type containing calcium, sodium, magnesium, sulfate, bicarbonate, and chloride ions (Wilberg and Heilweil, 1995; Lambert and others, 1995, figure 38). Nitrate, typically associated with human activities, has been identified in ground water in Sanpete Valley in previous studies (common anthropogenic sources include septic tanks, agricultural fertilizer, and manure from feeding operations). A nitrate concentration exceeding the EPA maximum contaminant level (MCL) (10 mg/L nitrate as nitrogen) was identified in a Sanpete County public-supply well in the 1990s (Horns, 1995); the well was replaced and taken off line. Nitrate concentrations for ground water in the principal valley-fill aquifer in Sanpete Valley range from 0.02 to 40.2 mg/L (Lowe and others, 2002; Wallace and Lowe, 2005). Nitrate data from a public-supply spring for the town of Centerfield maintains a 7 mg/L concentration (Keith James, town of Centerfield, personal communication, November 2006); a test well sited by Sunrise Engineering and drilled by Wright Drilling, Inc., for Centerfield in Hayes Canyon yielded a nitrate concentration of 16 mg/L and has since been filled in and sealed (John Iverson, Sunrise Engineering, personal communication, 2006).

SOURCES OF GROUND-WATER QUALITY DEGRADATION

Background

A detailed discussion of potential sources of ground-water quality degradation in Sanpete Valley is given in Lowe and others (2002) and attached as appendix C. Degradation in ground-water quality may be due to either natural sources or contamination associated with human activities. Many constituents dissolved in water are derived from geologic materials such as rock or sediment. Common sources of water-quality degradation in rural areas include natural agents (atmospheric, biologic, and geologic), agricultural activities (irrigation, pesticide and fertilizer application, nitrogen-fixing crops, livestock grazing, and feed-lot operations), and septic-tank systems (pathogens, household and industrial chemicals, phosphate, and nitrate). Changes in land-use practices in arid regions in the western U.S. have also affected trends of water quality with emphasis on nitrate contamination (Xu and others, 2007).

Potential Contaminant Mapping

I mapped potential ground-water contaminant sources including facilities related to mining, manufacturing, agricultural practices, and wastewater treatment (plate 2; appendix D). Approximately 365 potential contaminant sources were identified in the following categories in Sanpete Valley:

(1) Mining, which includes abandoned and active gravel mining operations and borrow pits that potentially contribute metals, solvents, and petroleum products.

(2) Agricultural practices, which consist of irrigated and non-irrigated farms, active and abandoned animal feed lots, corrals, and stables/barnyards, that potentially contribute nitrate.

(3) Animal wastes that are dominantly produced from feeding facilities, waste transported by runoff, and excrement on grazing or pasture land that potentially contribute nitrate.

(4) Industrial wastes that potentially contribute pesticides, metals, solvents, petroleum products, and polychlorinated biphenyls from a variety of sources such as salt production/storage facilities, transportation facilities, transformer (power) stations, and excavating facilities.

(5) Small businesses, such as laundromats, beauty parlors, and dry cleaners, some of which may contribute pollutants, such as solvents, into the ground-water system.

(6) Large lawns, including parks, cemeteries, and nurseries, that may contribute fertilizer and pesticides.

(7) Service stations, including auto shops and gas stations, that may contribute fuel, oil, antifreeze, and solvents; junkyard/salvage operations that may contribute pollutants such as metals and solvents.

(8) Waste-disposal sites that may contribute pollutants such as solvents, metals, and nitrate.

(9) Storage tanks that may contribute pollutants such as fuel and oil.

(10) Medical facilities, including dental and health clinics, and pharmaceutical and veterinarian services, that may contribute pollutants such as metals and solvents.

In addition to the above-described potential contaminants, septic tank soil-absorption systems are also prevalent in southern Sanpete and central Sevier Valleys. Between 1981 and 2000, about 150 wastewater permits were issued each year in Sanpete County (George Johansen, Central Utah Public Health Department, verbal communication, 2000). This is an indication that more than 4000 septic tanks may have been installed since 1981. Outside of towns and cities, septic-tank systems in Sanpete County, until recently, have been widely spaced. Septic-tank systems may contribute contaminants such as nitrate and solvents.

WATER-QUALITY RESULTS

Ground-water quality in southern Sanpete and central Sevier Valleys is generally good; TDS concentrations are primarily below 1000 mg/L, although elevated TDS and nitrate concentrations exist in the valley-fill aquifers. A tri-linear Piper diagram showing general chemistry for 74 water samples indicates that ground-water chemistry is variable throughout both valleys (figure 6). Appendix B summarizes the general chemistry, nutrients, and metals; table 1 summarizes environmental tracer data.

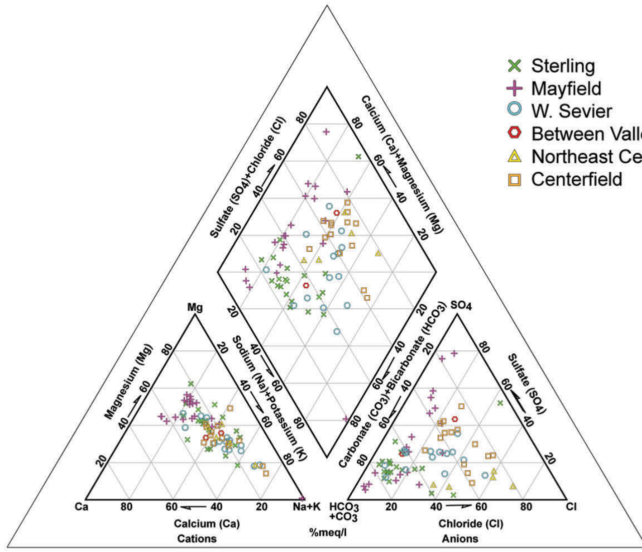
Total-Dissolved-Solids Concentrations

Measured TDS concentrations range from 202 to 3530 mg/L (plates 1 and 4); the average TDS concentration from the valley-fill aquifers is 915 mg/L. Total-dissolved-solids concentrations for ground-water samples from 67% of the wells tested for general chemistry are below 1000 mg/L. A concentration of 1000 mg/L is a threshold value deemed by Utah Division of Drinking Water regulations that require public-water suppliers to document that no better water quality is available, otherwise, the maximum contaminant level for TDS in water from public-supply wells is 2000 mg/L. In this study, the highest quality water, in terms of low measured TDS, exists along the western margin of central Sevier Valley and northeast of Fayette along the southwestern margins of the San Pitch Mountains; in southern Sanpete Valley, highest water quality exists east of Sterling and south and east of Mayfield in the canyon and tributary areas (plates 1 and 4).

Ground water having TDS concentrations less than 1000 mg/L in central Sevier Valley ranges from 360 to 688 mg/L. In the central part of the central Sevier Valley, TDS concentrations are generally between 1000 and 3000 mg/L, but values range from 904 to 2632 mg/L (plates 1 and 4). Ground water having TDS concentrations less than 1000 mg/L in the Mayfield area ranges from 202 to 978 mg/L, but some wells have TDS concentrations up to 1418 mg/L. Ground-water TDS concentration in the Sterling area ranges from 522 to 1018 mg/L; the highest TDS value in the Sterling area is 1650 mg/L. Water having TDS greater than 3000 mg/L exists in only two wells, one completed in red shale and located southwest of Mayfield near the Arapien Shale of the White Hills and the other completed in the Flagstaff Limestone north of Gunnison (plates 1, 3, and 4). As mentioned above, previous investigators have attributed elevated TDS concentrations to the Jurassic Arapien Shale and the Tertiary Green River and Crazy Hollow Formations. Comparison of plates 3 and 4 supports this conclusion. Return irrigation water also likely contributes to higher TDS values.

Nitrate Concentrations

Nitrate values range from less than 0.1 mg/L to 39 mg/L (plates 5 and 6; appendix B), average nitrate concentration in the valley-fill aquifer is about 6.5 mg/L, 51% of the ground water from wells analyzed for nitrate yielded values greater than 5 mg/L, and 59% yielded values greater than 3 mg/L. Twenty samples (20%) of the water from water wells, springs, and streams analyzed for this study exceeded the EPA standard of 10 mg/L. The average nitrate concentration of 6.5 mg/L and large percentage of wells having relatively high nitrate concentration (greater than 5 mg/L) are atypical compared to other rural areas in Utah (Lowe and Wallace, 1999a, 1999b; Lowe and others, 2002, 2003). The highest nitrate concentrations (>10 mg/L) exist (1) in the northwestern margin of central Sevier Valley south of Sevier Bridge Reservoir, (2) in the valley center of central Sevier Valley between Centerfield and Axtell, (3) along the east side of the hills bounding the east side of Gunnison Reservoir near Sterling, and (4) south of Mayfield along the valley margin (plates 5 and 6). A well sampled by the UDAF east of Sevier-Bridge Reservoir in the northwestern part of the Sevier Valley located on a dairy farm has a nitrate concentration of 23 mg/L. This well has a depth similar to the surrounding wells on the farm, which have nitrate concentrations less than 1 mg/L. The high nitrate concentration is considered to be an anomaly caused by conditions unique to that particular well, possibly local ground subsidence (Steve Deacon, UDAF, written communication, Febru-



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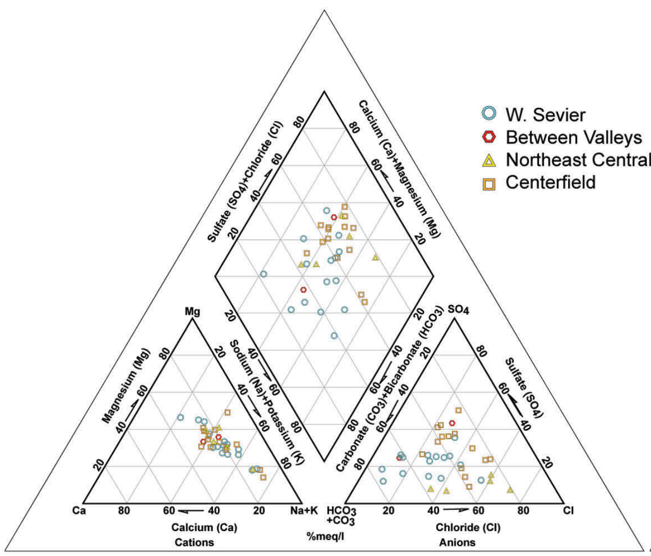

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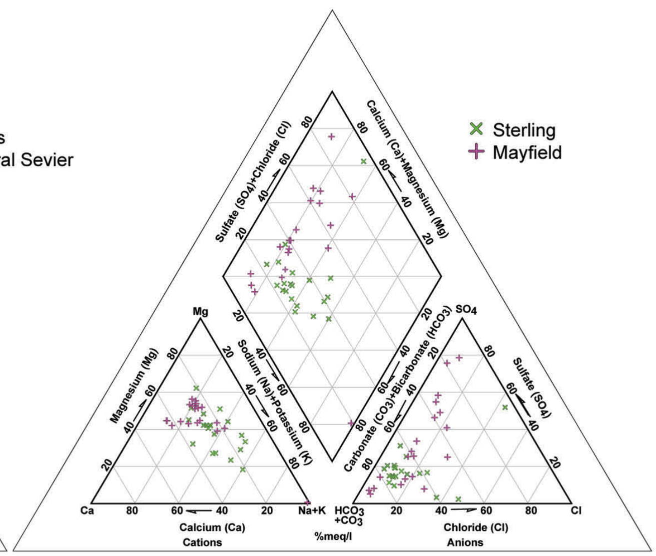

6c.

Figure 6. *Piper diagrams showing chemistry type for all ground-water samples from southern Sanpete County. 6a) shows chemistry type for all water samples; 6b) shows chemistry for 36 wells in central Sevier Valley; 6c) shows chemistry for 40 samples in southern Sanpete Valley near Sterling and Mayfield.*

ary 2009). This well is not included in plate 5 and will not be discussed further. Sources of nitrate in other sampled wells are discussed in subsequent sections. In general, the areas shown on plate 5 where the highest nitrate concentration wells exist coincide with the TDS contour interval of 1000 to 3000 mg/L (plate 4).

Other Chemical Constituents

EPA drinking-water standards were exceeded for arsenic in ground water from six wells and for selenium in one (appendix B). Secondary drinking-water standards were exceeded in 25 wells for sulfate, 19 for chloride, and 3 for iron; these constituents are not deleterious to human health, but may impart an unpleasant taste, odor, or color to the water (appendices A and B). All samples tested for iron had concentrations that were less than the detection limit (<100 µg/L), except the three wells mentioned above.

NITRATE SOURCES

Background

Nitrogen in the natural environment is abundant and is derived from a multitude of sources. Whole-earth abundance of nitrogen is 0.03%, with 97.76% of the total nitrogen present

Table 1. *Environmental tracer data for ground-water samples.*

Site ID[1]	$\delta^{15}N$ 0/00	$\delta^{18}O_{NO3}$ 0/00	^{3}H T.U.	^{3}H +/-	$\delta^{13}C$ 0/00	^{14}C (PMC)	^{14}C Age[2] (yr B.P.)	CFC-11 Rech. year	CFC-12 Rech. year	CFC-113 Rech. year	^{3}H Age[4]	Interpreted age	Well depth (feet)
Northern Central Sevier Valley													
229	3.60	13.60	0.0	0.26	-8.03	5.09	19,000	1966.5	1968	1970	pre1952	mixed	265
232	3.28	-0.84	0.0	0.23	-8.22	26.42	5,750	1985.5	1987.5	1983	pre1952	mixed	75
189	-	-	4.4	0.23	-	-	-	-	-	-	mixed/ modern	mixed	98
184	3.46	1.00	5.9	0.4	-8.03	33.46	3,750	1974.5	1980	1975.5	modern	mixed	160
211	6.73	1.25	-	-	-	-	-	-	-	-	-	-	200
188	7.98	-3.54	5.6	0.3	-7.46	13.93	10,500	1972	1971.5	1972.5	modern	mixed	199
193	13.82	5.72	6.0	0.27	-12.53	101.17	modern	1974.5	1984.5	1976.5	modern	<1974	55
194	11.14	4.71	7.5	0.4	-10.63	85.39	modern	1974	1985	1975.5	modern	<1974	158
240	4.44	0.84	1.6	0.27	-8.39	16.62	9,250	1959	1963.5	1943	mixed	mixed	220
242	8.01	2.01	7.0	0.4	-10.05	90.16	modern	1976	1996	1977	modern	<1977	78
183	6.78	7.11	8.5	0.3	-6.96	46.74	500	-	-	-	modern	mixed	274
182	6.23	-0.64	9.8	0.4	-10.92	95.65	modern	Contam[3]	Contam[3]	1981	modern	modern	135
Southern Central Sevier Valley													
190	5.26	0.10	9.3	0.4	-11.16	95.61	modern	-	-	-	modern	modern	84
201	4.08	-2.63	10.0	0.4	-	-	-	-	-	-	"bomb age"	"bomb age"	87
236	7.92	-0.22	7.4	0.3	-7.46	76.18	modern	Contam[3]	1981.5	1971	modern	<1971	57
Mayfield area													
209	7.43	-0.94	10.2	0.5	-11.66	81.24	modern	1989.5	1986	-	"bomb age"	<1952	56
203	7.21	-0.39	10.2	0.4	-10.39	74.92	modern	1989	2000	1943	"bomb age"	<1952	120
206	8.66	1.04	-	-	-	-	-	1989	1978	1943	-	<1943	160
200	8.65	2.39	2.7	0.2	-9.43	38.01	2,500	1977.5	1980	1977	mixed	mixed	185
233	7.77	-	9.5	0.4	-10.87	82.1	modern	-	-	-	modern	modern	spring
204	7.77	-	11.1	0.4	-10.14	64.21	modern	-	-	-	"bomb age"	<1952	spring
Sterling area													
213	9.75	0.41	10.8	0.4	-12.89	110.81	modern	-	-	-	"bomb age"	<1952	75
221	7.27	0.22	8.0	0.4	-10.71	73.32	modern	Contam[3]	1986.5	1943	modern	<1943	40
224	10.51	-1.41	9.5	0.4	-11.32	93.41	modern	1982.5	1975.5	1943	modern	<1943	98
228	6.37	-2.69	13.4	0.5	-10.70	81.73	modern	1981.5	1989.5	1978	"bomb age"	<1952	103

[1]Site ID in appendix B. [2]Carbon age calculations by A. Mayo, BYU, written communication, 5/25/08. [3]Contaminated. [4]Tritium ages from Clark and Fritz (1997), modern refers to <10 years.

in rocks, 2.01% in the atmosphere, and the remainder in the hydrosphere and biosphere (Kendall, 1998). Nitrogen oxides are present in the environment and can undergo various chemical reactions that produce H^+, eventually converting the nitrogen (N) to nitrate (NO_3^-) or ammonia (NH_3). Nitrogen that is present as NH_4^+ can transform to ammonia in basic environments and subsequently can be released as NH_3 gas to the atmosphere (Canter, 1997). With increasing oxygen content, nitrification of ammonium occurs (NH_4^+ to NO_3^-). When anoxic conditions prevail, denitrification of nitrate can occur with the production of N_2 gas (Canter, 1997). Identifying nitrogen derived from single or multiple sources is difficult to determine due to complex chemical, biological, and physical interactions that occur in the environment. Figure 7 shows the complex nature of the nitrogen cycle and the types of chemical, physical, and biological processes involved with nitrification and denitrification of septic-tank effluent. The cycle is similar for other nitrate sources. Under ideal circumstances,

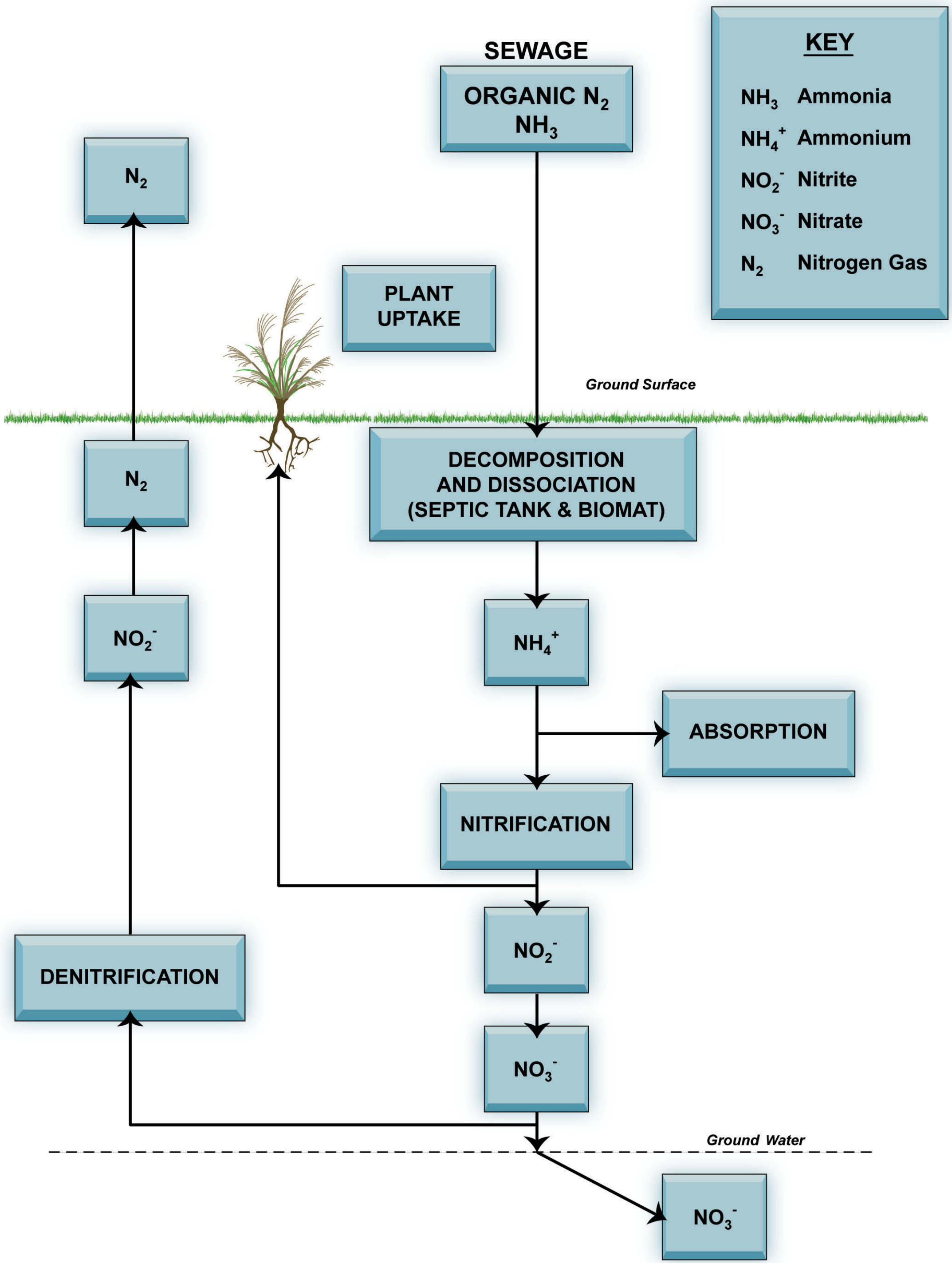

Figure 7. *Diagram of the nitrogen cycle in the environment, (modified from Hansen, Allen, and Luce, Inc., 1994).*

the analysis of nitrogen and oxygen isotopes can help determine the source of nitrogen; more commonly, the interaction of nitrogen and oxygen with other chemical and biological species obscures the true origin of the nitrate species.

Both natural and anthropogenic sources of nitrate are common (appendix C). Natural sources of nitrogen can contribute, to some extent, nitrate concentrations in ground water; natural sources include atmospheric, biologic, and geologic components. Common anthropogenic sources include septic-tank systems, fertilizer, agricultural practice (current and historical), animal-feeding operations, and improperly sealed/constructed wells. Ground water having less than 0.2 mg/L nitrate is assumed to represent natural background concentrations; ground water having nitrate concentrations between 0.21 and 3.0 mg/L is considered transitional, and may or may not represent human influence (Madison and Brunett, 1985). Ground water having concentrations exceeding 3 mg/L is typically associated with human- or animal-derived sources, but higher concentrations have also been identified with natural sources (Green and others, 2008), albeit less commonly.

Nitrate Source Analysis

Herein, I attempt to identify the sources of nitrate in ground water in southern Sanpete and central Sevier Valleys based on the data presented in this report with the caveat that processes such as mixing of different sources of water in aquifers, ammonia volatilization, denitrification, and nitrification complicate the analysis for determining a source or sources of nitrate contamination for each high-nitrate well. In addition, this report utilizes data from only one sampling event; numerous sampling events examining temporal and spatial trends in water chemistry is desired in order to document and understand long-term sustainability of the ground-water resource.

I determined statistical correlations between some of the data included in appendix B and various land-use parameters, and provide the correlation coefficient (and the statistical "R-squared") for each set of graphs. Correlation coefficients range between 1 and -1, and are used for analyzing the relationship between selected data sets. A value near 1 or -1 indicates a predictable relationship between data sets, whereas a value approaching zero reflects a non-predictable relationship between selected parameters. As discussed below, most of the results correspond to non-predictable relationships, which indicate most of the compared data sets correlate poorly and are not interrelated.

"Geologic nitrogen" was first recognized by Boyce and others (1976) as nitrogen associated with certain geologic formations, sedimentary and inorganic in origin. The weathering of nitrogen from rock can potentially affect the chemistry of water and soil (Holloway and others, 1998). The term "geologic nitrogen" was used to describe the source of high-nitrogen soils on alluvial fans in the San Joaquin Valley of California (Sullivan and others, 1979; Strathouse and others, 1980). The contribution of weathered rock from the Diablo Range to soil nitrogen in the western San Joaquin Valley was explored by Sullivan and others (1979). The chemical state of this nitrogen includes fixed and exchangeable ammonium sorbed to clay and organic surfaces, organic matter, and natronite, a sodium nitrate salt (Sullivan and others, 1979). The revegetation of coal mine spoils in the Canadian Rockies is facilitated by high nitrogen concentrations in the soils (Fyles and others, 1985). Holloway and others (1998) specifically analyzed rocks in the Mokelumne River watershed in California to determine if bedrock could be a source of stream-water nitrate and reported that metasedimentary rocks containing appreciable concentrations of nitrogen contributed a significant amount of nitrate to surface waters. They concluded that nitrogen-rich rocks in the watershed, though occupying a small areal extent, had a greater influence on water quality than the areally extensive nitrogen-poor metavolcanic and plutonic rocks in the watershed.

Coal deposits are one potential contributor of geologic nitrogen (see appendix C) in the San Pitch and Sevier River drainage basins. Alluvial-fan sediments deposited by streams draining the Wasatch Plateau in the Sixmile Canyon area would be the most likely units to contain coal debris in the valley fill of Sanpete Valley; less extensive coal deposits are also found in a few canyons in the San Pitch Mountains. However, nitrate concentrations from Sixmile Creek up Sixmile Canyon (0.32 mg/L) and from water obtained from a public-supply source via an inactive coal mine (<0.1 mg/L) along the east side of Sanpete Valley are generally low (plate 5, appendix B). Therefore, I do not attribute high nitrate concentrations in ground water from any wells to geologic nitrogen from coal.

Elevated nitrate concentrations near fault zones are another potential geologic source. Hydrothermal alteration may produce ammonium-rich minerals by replacing potassium in micas and feldspar with ammonium (Altaner and others, 1988). Ammonium-bearing alunite, a mineral indicative of acidic solutions at certain temperatures, coupled with high ammonium and low potassium in solution, is associated with hydrothermal systems in Nevada, California, Colorado, and Utah (Altaner and others, 1988). Nitrogen from these minerals, if present, could then be dissolved in ground water flowing along faults (Lowe and Wallace, 2001). Many wells having high nitrate concentration are located on or near fault zones in both southern Sanpete and central Sevier Valleys (plates 3 and 5); the Hayes Canyon-Centerfield well having a nitrate concentration of 16 mg/L is mapped within the Dover fault zone of Hylland and Machette (2008), and several wells and springs in the Mayfield area having nitrate concentrations ranging from 7 to 25 mg/L are located on or near mapped normal faults. Additional sampling and analysis of rocks, minerals, and ground water along and near fault zones may help determine whether nitrogen or nitrate exists through isotopic and nutrient analysis of soil, rock, and water when/if new wells are drilled in these areas.

Another potential source of geologic nitrogen is from residual nitrate attached to soil in the vadose zone, especially on alluvial-fan and pediment surfaces (Graham and others, 2008) and in areas having high evapotranspiration rates (Green and others, 2008). Desert pavement on alluvial-fan and pediment surfaces is also a source of high soil nitrate concentrations (Graham and others, 2008). In the southern Sanpete and central Sevier Valleys, 31% of the valley-fill material consists of gravelly soils and 21% of sampled wells exist within gravelly soil deposits, compared to northern-central Sanpete Valley which has 15% valley-fill material and 7% of wells sampled within gravelly deposits (National Soil Survey Center, 2005). The average nitrate concentration of 6.5 mg/L for ground water in the southern Sanpete and central Sevier Valleys is nearly double the average concentration for ground water in northern-central Sanpete Valley (3.3 mg/L) (Lowe and others, 2002). Many of the wells having high nitrate are located in gravelly soils or downgradient from gravelly soils and potentially may yield ground water that contains vadose-zone nitrate. Nitrate analyses of well cuttings from the Hayes Canyon well at variable depths showed that the sediments from intervals above and below the water table had negligible concentrations of nitrate (Jack Sheets, EPA lab analyst, personal communication, 2007). I examined the drill cuttings microscopically and described the lithology for 45 samples taken approximately every 10 feet from the surface to a total depth of 440 feet. The dominant lithology for the Hayes Canyon well cuttings consisted of yellow-tan, gray, and pink angular to rounded gravel clasts dominated by different types of limestone (some oolitic and some fossiliferous) with minor sandstone, siltstone, and chert (see Centerfield well log, appendix E). The well was drilled in 2004; samples remained in storage until 2007, so the original nitrogen content, if present, may have been transformed by subsequent physical, chemical, or biological processes. Data from the EPA nitrate sediment-extraction analysis is not conclusive with respect to the source of nitrate due to potential nitrate loss from extended storage (Jack Sheets, EPA lab analyst, personal communication, 2007).

The study area, especially along the alluvial-fan dominated eastern margin of the Valley Mountains, shares similar geomorphic, climatic, and ecological conditions to areas in the desert southwest where studies have determined the mechanism (advective transport) by which the nitrate travels vertically downward (Green and others, 2008). These studies showed that areas having high evapotranspiration rates and low water-table fluxes (low flushing) result in deeper water-table zones having relative high nitrate concentrations, versus areas having lower evapotranspiration rates and high water-table fluxes (Green and others, 2008). Scanlon and others (2007) reported conversion of natural ecosystems to rain-fed agriculture impacted water quantity and quality. In semiarid shrublands, conversion to rain-fed agriculture decreased evapotranspiration by 10% and increased downward water fluxes well below the root zone by 1 to 2 orders of magnitude. They attributed the increase in recharge to replacement of deep-rooted perennial crops by shallow-rooted annual vegetation. Similar conditions of high evapotranspiration and low flux may exist for some wells in the study area and could explain pervasive high nitrate concentrations in areas where a decreased chance of dilution of high nitrate in the vadose zone coupled with advective transport of nitrate well below the root zone depth could occur.

Non-geologic sources of residual nitrate also exist in the vadose zone. In semiarid regions, build-up of vadose-zone nitrogen results from millennia of precipitation and evapotranspirative concentration of nitrate in the unsaturated zone (Scanlon and others, 2007). A primary source of natural nitrate in some semiarid regions is related to unsaturated zones beneath native vegetation (unfertilized). Increased recharge due to changes in land-use practice (e.g., cultivation of formerly fallow fields) increases nutrient loading by flushing nutrients into underlying aquifers (Scanlon and others, 2007). Median nitrate concentrations in soil water beneath fertilized cropland compared to non-fertilized forests were considerably higher (18 mg/L versus 1.5 mg/L) based on a European study (Scanlon and others, 2007). Fertilizer may also be a source of residual nitrate in the vadose zone. Future sampling of soils in the vadose zone and below the water table may verify whether residual nitrate is a potential source contributing to groundwater chemistry as new wells are drilled.

Nitrogen concentrations that exceed the EPA contaminant level of 10 mg/L in ground water below agricultural lands in the U.S occur in 19% of sampled wells (Green and others, 2008). Agricultural chemical application rates are generally highest on irrigated lands (Lowe and others, 2007). Differences in irrigation practices, such as conventional furrow irrigated versus center-pivot irrigated, can affect nitrate concentrations in the soil profile (Spalding and others, 2001) as can differences in fertilizer type. For example, applications of poultry manure greater than 13 mg/ha can result in nitrate concentrations in ground water that greatly exceed the EPA standard of 10 mg/L (Liebhardt and others, 1979). Some studies have shown that nitrogen from applied NH_4 fertilizer may undergo oxidation to nitrate before transport to the water table (Green and others, 2008); this process may affect nitrate concentration in wells in the study area.

Plate 6 shows nitrate concentration data from sampled wells superimposed on a land-use map (Barbara K. Perry, Utah Division of Water Resources, written communication, 2006) of the study area. Nitrogen-fixing crops, principally alfalfa, are grown in southern Sanpete and central Sevier Valleys (plate 6), and are also irrigated. Of 77 samples analyzed for nitrate as part of this study, 41 are within 100 feet of the boundaries of irrigated lands, and 24 are within 100 feet (30 m) of alfalfa fields. The average nitrate concentration for all wells is 6.5 mg/L; the average nitrate concentration for wells located on irrigated lands is 9.0 mg/L, and the average nitrate concentration for wells located near alfalfa fields is 9.4 mg/L. These values suggest that irrigation and agricultural fertilizer application within irrigated lands in southern Sanpete and central Sevier Valleys impact water quality with respect to nitrate. However, I did not verify fertilizer application practices in the study area, which would be needed to determine specific effects from fertilizer.

Animal feed-lot operations and other concentrations of domestic animals are common in southern Sanpete and central Sevier Valleys (plate 2, appendix D). Figure 8 shows that all of the high-nitrate areas are in the general vicinity of current or former domestic farm animal operations. Figure 8 and plate 2 are based on field mapping of potential contaminants performed during October 2007 and represent a snapshot in time; thus, the maps do not necessarily show continual point sources of nitrate of pollution, but potential sources that may contribute nitrate to ground water. The maps do not account for ground-water flow direction or well depth, and they show some areas where low-nitrate-concentration wells exist near animal feeding operations. Some of these low concentrations can be explained by local conditions. For example, a well having a nitrate concentration of 1.94 mg/L and situated near an animal feeding operation in southwestern Sanpete Valley near the gap in the White Hills (figure 8) penetrates bedrock that provides water. Another well with a nitrate concentration of 0.09 mg/L and situated near an animal feeding operation near the southwesternmost point of the San Pitch Mountains and south of the San Pitch River (figure 8) obtains water from a perforated interval below two protective confining clay layers (15 and 25 feet [4.6 and 7.6 m] thick). The average nitrate concentration for all wells and springs that are within 1640 feet (500 m) of current or former animal feeding operations is 7.68 mg/L; the average nitrate concentration for wells that are located more than 1640 feet (500 m) from former or current animal feeding operations is 5.31 mg/L. The majority of wells having nitrate concentrations greater than the EPA standard are located within 1640 feet (500 m) of former or current animal feeding operations, and all 19 wells having nitrate concentrations that exceed 10 mg/L are located within 3280 feet (1000 m) from animal feeding operations.

Septic-tank systems are known sources of nitrate contamination, but because they are below ground, I was not able to map their locations on plate 2 and I did not attempt to digitize home/barn structures from aerial maps to estimate septic locations. Between 1981 and 2000, about 150 wastewater permits have been issued each year in Sanpete Valley (George Johansen, Central Utah Health Department, verbal communication, 2000). Outside of towns and cities, septic-tank systems in Sanpete Valley, until recently, have been widely spaced. However, the towns initially used septic-tank systems, cesspools, or privies for wastewater disposal, and in some situations, old abandoned wells were used as cesspools (Richardson, 1907). These domestic wastewater facilities could have contributed to high nitrate concentrations in ground water in the vicinity of the towns and cities. If so, high-nitrate-concentration ground water in the vicinity of towns and cities could be areally extensive. I sampled one well immediately downgradient from the community sewage lagoons near Gunnison. The ground water did not yield high nitrate concentrations; the well was sampled two times and each sample had a nitrate concentration of 0.09 mg/L and an ammonia concentration of 0.96 mg/L (only one of two wells throughout both valleys having detectable ammonia). Septic tanks also can produce relatively high concentrations of TDS, but this is likely not the case in southern Sanpete and central Sevier Valleys; wells having high nitrate concentrations potentially associated with septic tanks (table 2) have an average TDS concentration of 1175 mg/L. Figure 9 shows the relationship between nitrate and TDS concentration, where R-squared is 0.11 and the correlation coefficient is 0.32, indicating a poor correlation. Although some wells having high nitrate concentration also have elevated TDS concentrations, wells having low nitrate concentrations (less than 2 mg/L) and elevated TDS concentrations (greater than 1000 mg/L) are common, especially in the southern and east-central parts of the study area.

Studies in other rural areas have shown a positive correlation between high (or increased) nitrate concentration in water from wells that are shallow (<50 feet [15 m]) and/or older in age (Spalding and Exner, 1993; Goss and others, 1998; Lowe and others, 2002). Figure 10 shows the relationship between nitrate concentration and well depth for 73 wells in the data set; the correlation coefficient is -0.1 and R-squared is 0.002 indicating very poor correlation. The average depth for the high-nitrate wells is 148 feet (45 m). The average year of installation (age) of the wells having nitrate concentration above 10 mg/L is 1986 (~23 years old), and the majority were drilled in the late 1990s and early 2000s (appendix B). The correlation coefficient for nitrate concentration and well-installation year is -0.004, indicating very poor correlation.

EXTENT OF AREAS HAVING HIGH NITRATE CONCENTRATION

Four different locations in the valley have wells with high nitrate concentrations (generally areas having one well with NO_3>10 mg/L or two or more wells having >7 mg/L NO_3) (plate 5); two are in areas that have been sampled more than once. Data indicate some of the high-nitrate wells are impacted by diffuse non-point sources, and some areas are possibly affected by point-source contamination. A comparison of nitrate concentration data and general chemistry, nitrogen and oxygen isotopes, tritium, CFC, and carbon isotope data is presented below.

Nitrate and General Chemistry

The areas where wells have elevated nitrate concentrations share similar general chemistry, which may help determine the nature of the ground-water conditions. These conclusions are based on the results of Piper plots used to analyze and compare chemistry and well characteristics (appendix E) of

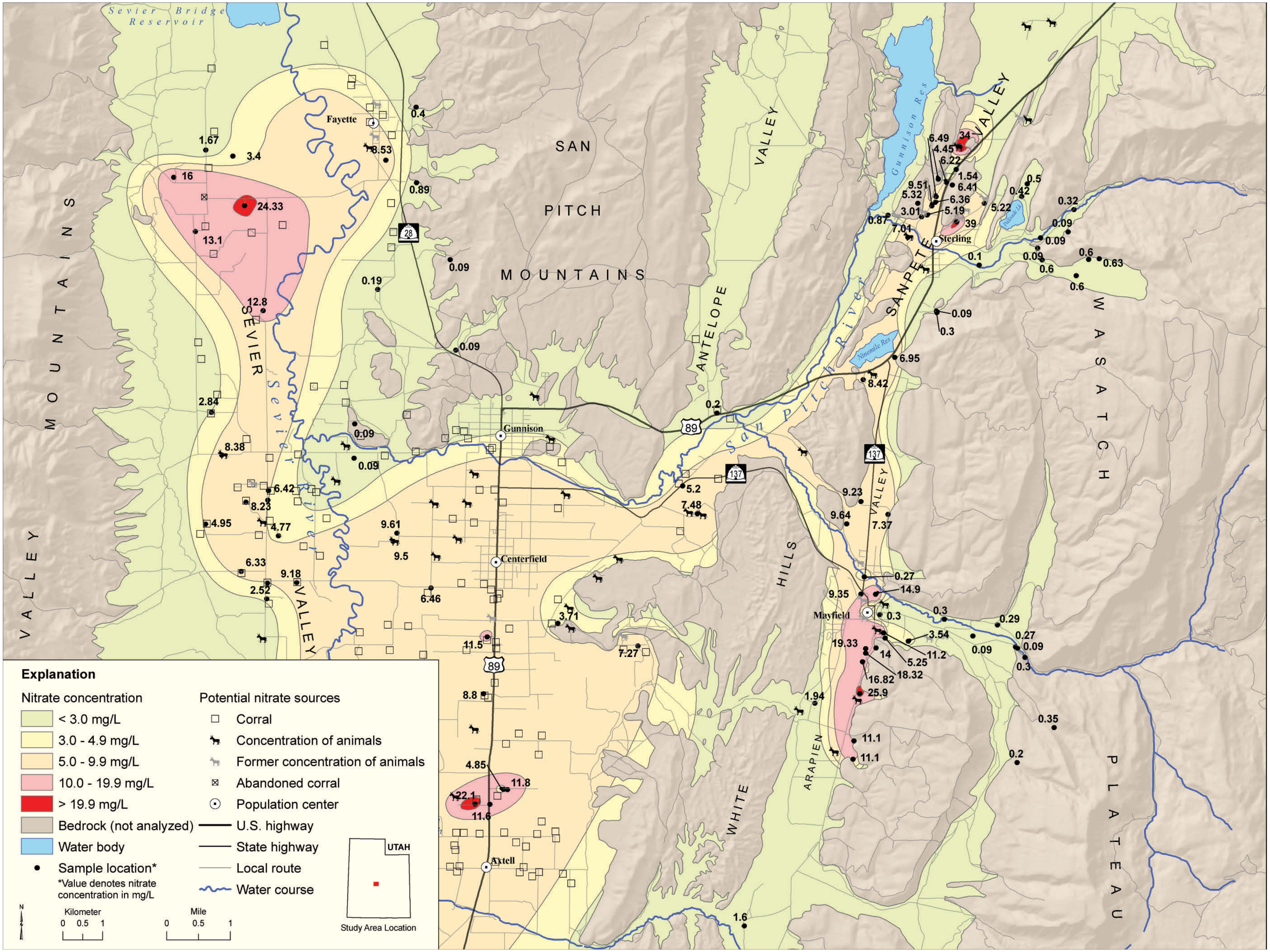

***Figure 8.** Location of current and former animal operation units and nitrate concentration in southern Sanpete and central Sevier Valleys.*

Table 2. *Possible sources of nitrate in ground water obtained from wells having nitrate concentrations that exceed the EPA drinking-water quality standard of 10 mg/L in southern Sanpete and central Sevier Valleys, Sanpete County, Utah, based on field observation.*

Well ID[1]	NO_3 (mg/L)	Depth (feet)	Possible sources of nitrate
184[2]	24.2	81	septic tank; downgradient from cultivated field (fertilizer)
185	13.1	160	agriculture; near fault zone
190[2]	11.5	84	corral; septic tank; downgradient from cultivated field (fertilizer)
198	11.10	185	corral; septic tank; near fault zone
199	25.90	160	dairy farm; septic tank; near fault zone
200[2]	11.10	185	corral, septic tank; near fault zone
206[2]	19.30	160	corral, septic tank
211	12.80	200	waste disposal on a campground; downgradient from cultivated field (fertilizer) and small feed lots
213[2,3]	34.10	75	small dairy; septic tank
224[2]	39.10	98	corral; septic tank; near agriculture activity
236[2]	11.60	57	septic tank; downgradient from cattle/dairy operation; downgradient from cultivated field (fertilizer)
237	22.20	107	septic tank; nearby cattle/dairy operation; downgradient from cultivated field (fertilizer)
238	11.80	52	septic tank; nearby cattle/dairy operation; downgradient from cultivated field (fertilizer)
257	14.00	160	septic tank; near fault zone
258	18.30	160	septic tank; downgradient from cultivated field (fertilizer)
259	16.80	100	septic tank; downgradient from cultivated field (fertilizer)
261	11.20	167	elk/corral; septic tank; near fault zone
283[3]	14.90	400	septic tank; downgradient from agricultural development
284[3]	16.0	440	near fault zone; natural soil; antecedent agriculture (grazing)

[1]See appendix B and plate 5.
[2]Site has isotopic data.
[3]Sampled more than once.

individual high-nitrate wells.

I generated individual Piper plots for areas in the valley having elevated nitrate concentration to assess whether a correlation between general chemistry type and nitrate concentration exists. Plate 5 shows the locations of these high-nitrate concentration areas (in red). A positive correlation between conservative constituents (relatively non-reactive cations) and relatively mobile nitrate may indicate that the high-nitrate ground water in two or more wells
is from a common source.

In the northwest part of central Sevier Valley, southeast of Sevier Bridge Reservoir on the eastern bench of the Valley Mountains near Hayes Canyon (plate 5), several wells have yielded ground water with elevated nitrate concentrations (appendices B and E, table 2). A Piper plot of data from five wells (figure 11) indicates similar water quality. Well depths range between 129 and 440 feet (39–134 m) (figure 12). Total-dissolved-solids concentrations range from 478 to 1348 mg/L, with an average of 662 mg/L. Three of the wells (site ID 184, 185, and 284) yielded nitrate concentrations that exceed the EPA drinking-water standard. These wells are generally upgradient from the other wells having similar water quality but lower nitrate concentrations (site ID 208 and 210). Characteristics of the wells show they penetrate mostly unconsolidated alluvial material (except site ID 208, which I believe was misinterpreted by the driller based on local geology [figure 12, plate 3]). Both upgradient and downgradient wells likely penetrate the same aquifer, so the lower nitrate values for the wells downgradient may be due to dilution or because the high-nitrate ground water has not reached them. I interpret this area as having a common source of ground water, based on elevated nitrate concentration in three water wells coupled with established land-use practice (appendix F) and similar general chemistry (table 2). South of this area, some high-nitrate wells (site ID 187 and 188) are located near low-nitrate wells (site ID 183 and 186) (plate 5), and probably represent single-well contaminations.

A Piper plot of data from eight wells south of Centerfield (figure 13) indicates similar water quality and the potential for ground-water mixing. Depths for four high-nitrate wells, clustered in the valley center and in closest proximity, are between 49 and 107 feet (15–33 m). All but one of these four wells at this southern location are less than 100 feet (30 m) deep, drilled between 1941 and 1979, older than the average year of installation of 1986 in both valleys. Total-dissolved-solids concentrations for these same wells range from 994 to 2488 mg/L (figure 14), with an average concentration of 1647 mg/L. These four wells have elevated nitrate concentrations and are located both upgradient and downgradient from the low-nitrate wells (figure 13). Well characteristics show these four wells penetrate alluvial material consisting of sand, silt, and clay, and have a 20-foot or greater confining layer present near the surface in all wells (figure 14). The shallow nature of the wells, similar water quality, and nitrate concentrations support the possibility of a high-nitrate ground-water source mixing with one or more lower nitrate sources, each having similar general chemistry.

A Piper plot of data from nine wells southeast of the town of Mayfield indicates more variable water quality and possible ground-water mixing for some of the wells (figure 15). Well depths range between 100 and 185 feet (30–56 m) (figure 16), and average 159 feet (48 m). Total-dissolved-solids concentrations range from 432 to 1348 mg/L, with an average concentration of 950 mg/L. All of the wells have nitrate concentrations that exceed 10 mg/L. For this area, wells penetrating bedrock (site ID 198, 200, 257), in general, share common

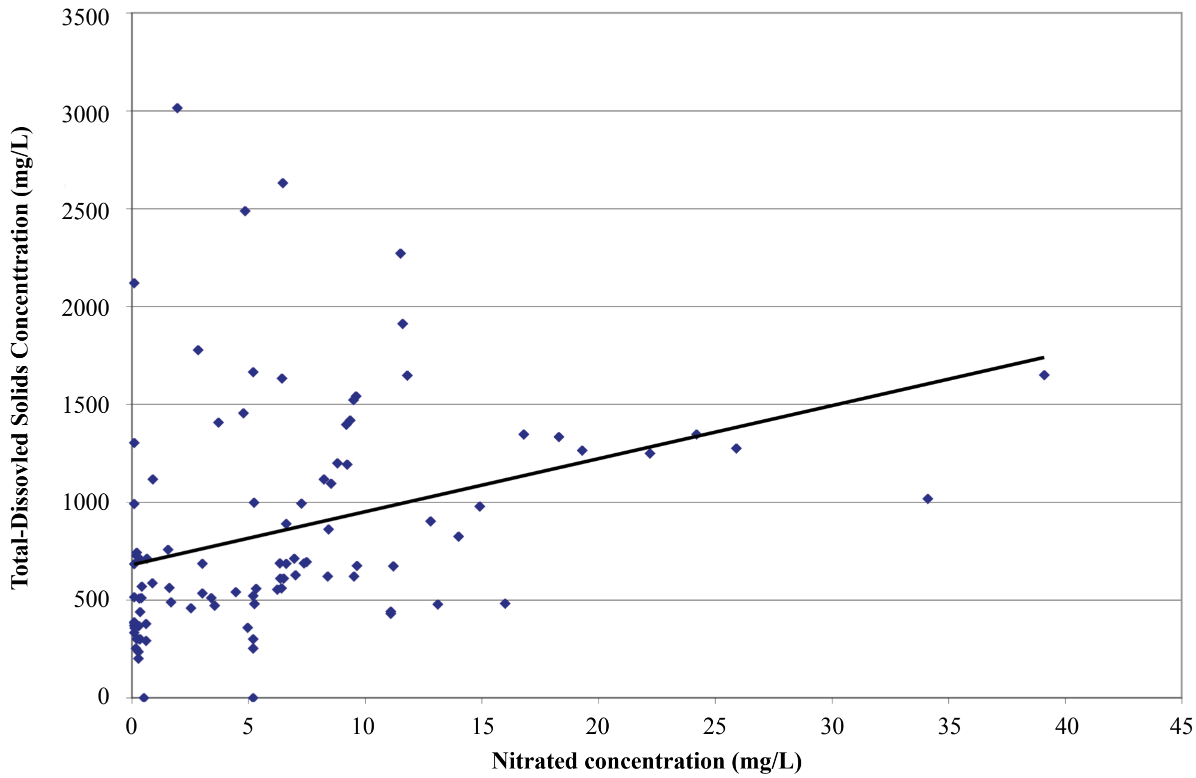

Figure 9. Nitrate concentration versus TDS concentration for 76 wells and springs in southern Sanpete and central Sevier Valleys, Sanpete County, Utah. R-squared is 0.11, indicating a poor correlation.

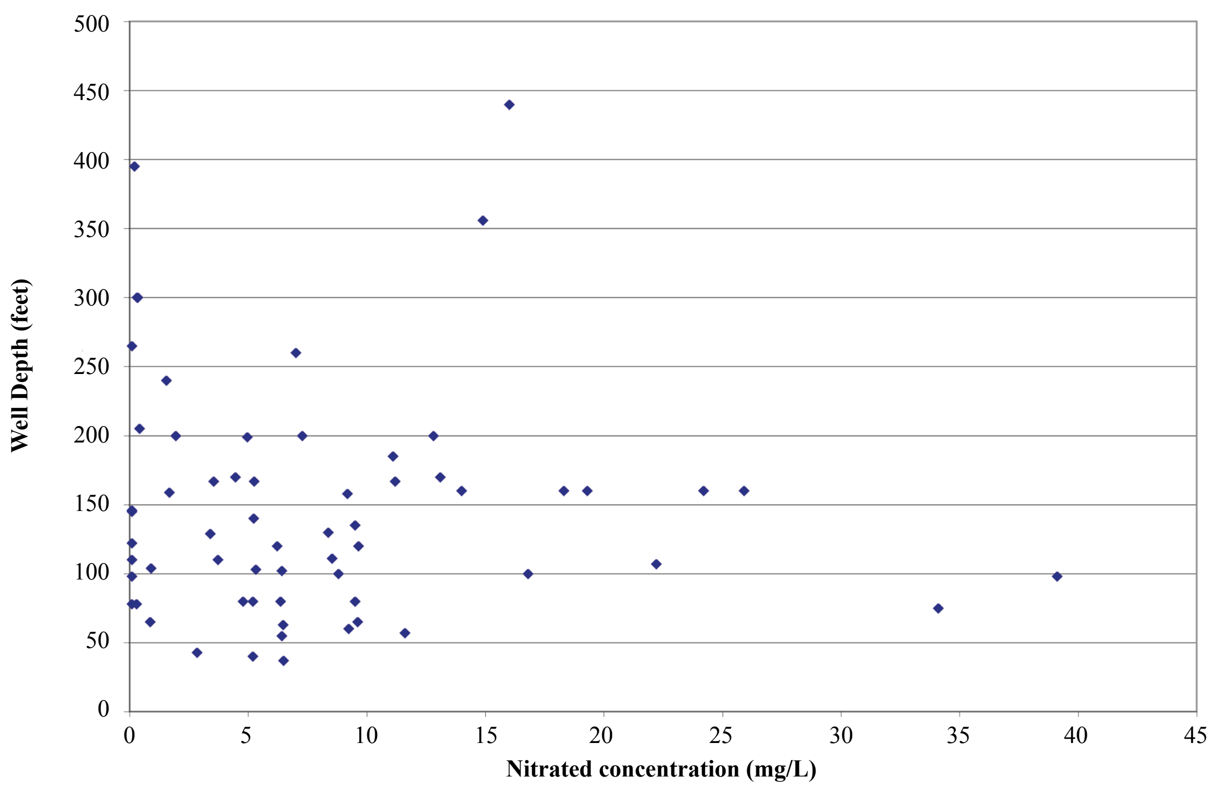

***Figure 10.** Nitrate concentration versus well depth in southern Sanpete and central Sevier Valleys, Sanpete County, Utah. R-squared is 0.002, indicating a very poor correlation.*

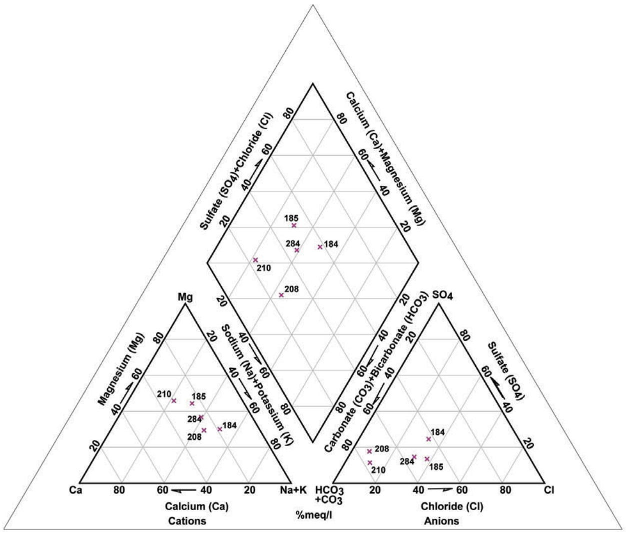

Figure 11. Piper diagram showing chemistry type for five ground-water samples in the northwestern part of the study area near Hayes Canyon. Number corresponds to site ID in appendix B.

characteristics, including lower TDS values and similar water quality, common well depths, and relatively high nitrate concentrations; these support the possibility of ground-water mixing. I believe the drillers' well logs for site IDs 206 and 259 are incorrect, and the wells likely penetrate alluvium, based on local geology (plate 3). For wells that are completed in alluvium (site ID 199, 258, and possibly 259), TDS values exceed 1000 mg/L and share overall similar water chemistry and well depths and may derive water from a similar source. For wells penetrating clay (site ID 261 and 256), similar water quality may be indicative of a common source. Overall, the wells that penetrate bedrock may share a common source of water isolated from the other ground-water samples obtained from the unconsolidated aquifer (figure 16). Vagaries in drillers' logs preclude determining whether or not mixing of ground water is occurring.

Data for 11 wells in the vicinity of Sterling generally show similar major ion water chemistry except well site 213 (figure 17). Two of the highest nitrate concentrations throughout the

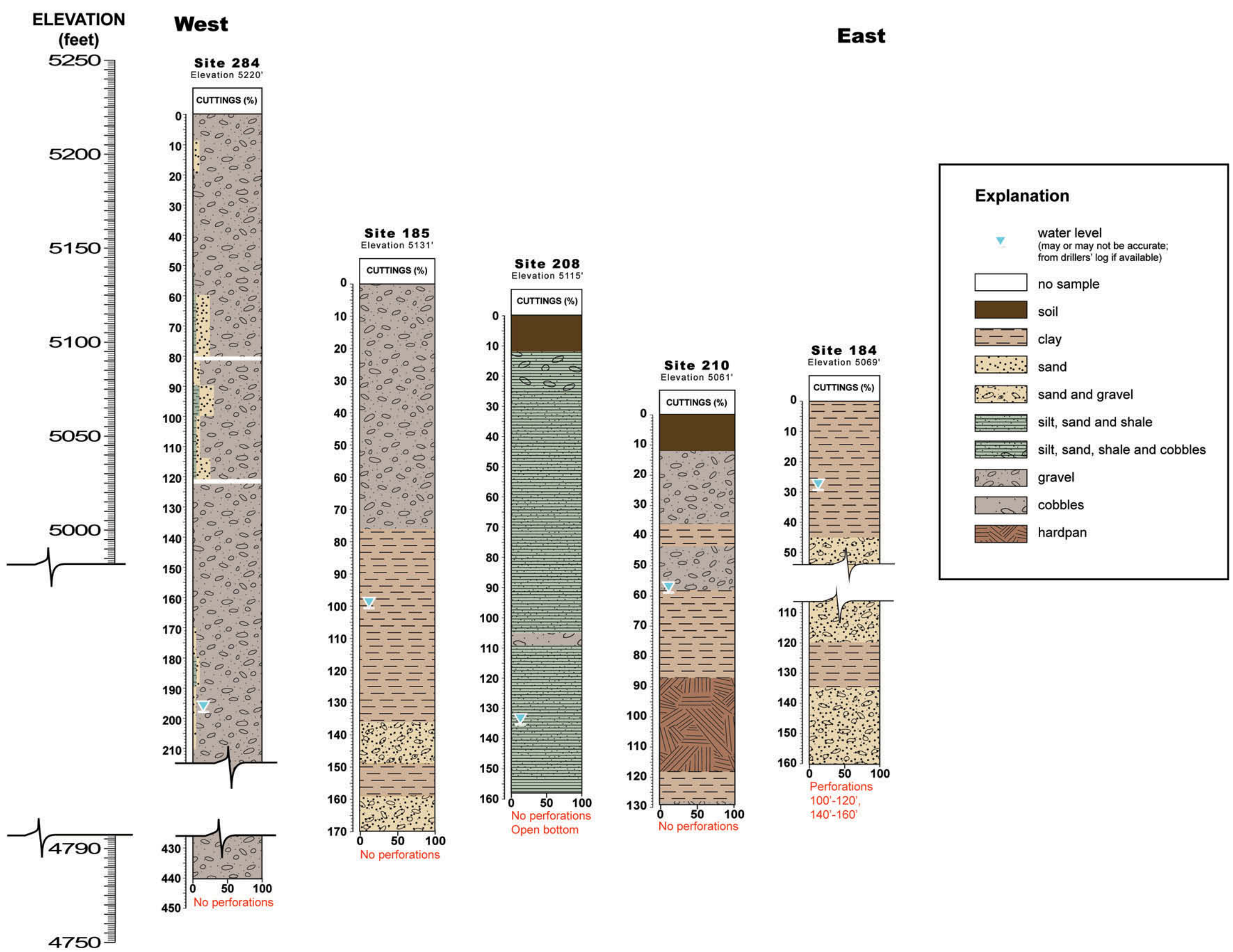

Figure 12. Compilation of drillers' well logs in the Hayes Canyon area. Not to scale horizontally. Site ID refers to well location (appendix B; plates 4 and 5).

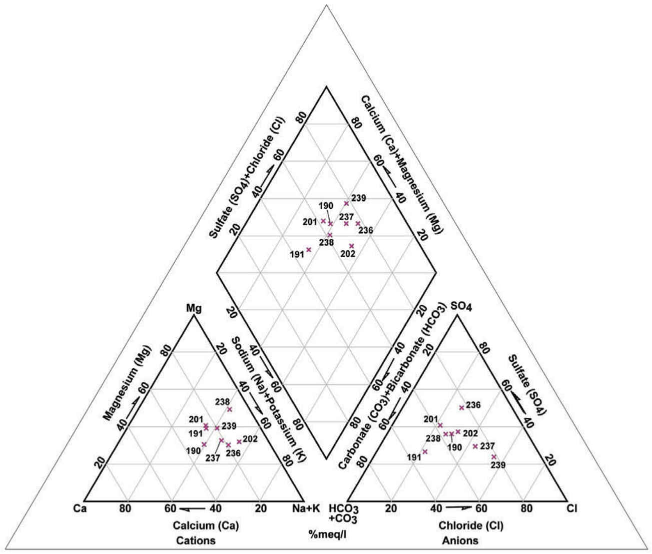

Figure 13. Piper diagram showing chemistry type for eight ground-water samples in the south-central part of the study area south of Centerfield. Number corresponds to site ID in appendix B.

study area are located north of the town (site 213) and east of the town (site 224). These wells also have TDS concentration values that are greater than TDS concentration values of all the other wells shown in the Piper plot. The two wells with elevated nitrate concentrations (35 mg/L and 39 mg/L) have respective TDS concentrations of 1018 and 1650 mg/L and are near current or former small-scale animal-based occupation (plate 2). Depths for wells plotted in figure 17 range from 37 to 170 feet (11–52 m), and have an average depth of 89 feet (27 m) for these 11 wells (not all wells are shown of figure 18). Three of the wells are less than 100 feet (30 m) deep. The variable depth of these wells may indicate they penetrate different aquifers (figure 18), although mixing of ground water from the shallow wells in the central Sterling area is likely. Sites 213 and 224 are isolated geographically and geologically and likely not part of the same aquifer; determining whether mixing is occurring is not possible for these two wells.

Environmental Tracer Analysis

To determine the influences of other processes, such as mixing

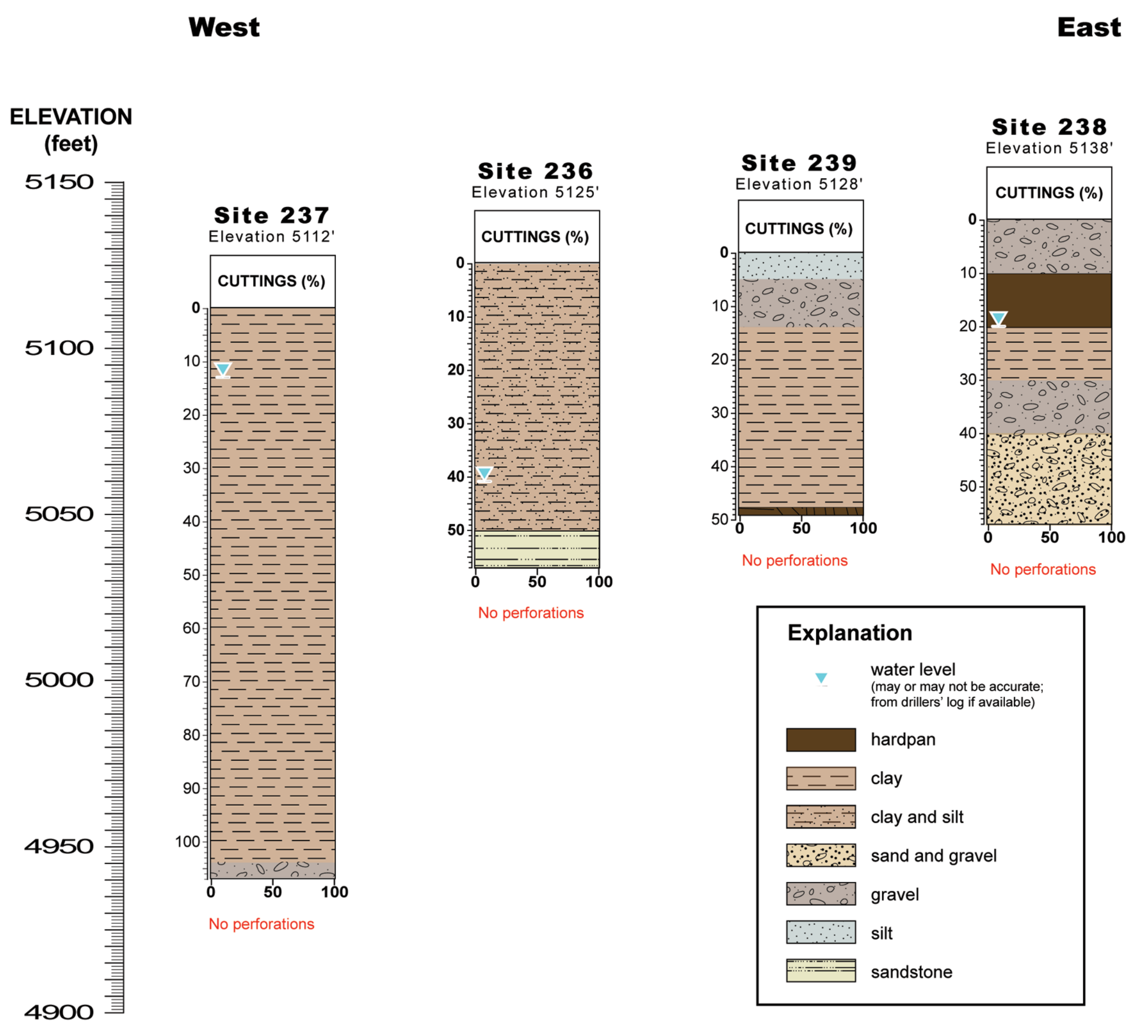

Figure 14. Compilation of drillers' well logs in the south-central part of the study area south of Centerfield. Not to scale horizontally. Site ID refers to well location (appendix B; plates 4 and 5).

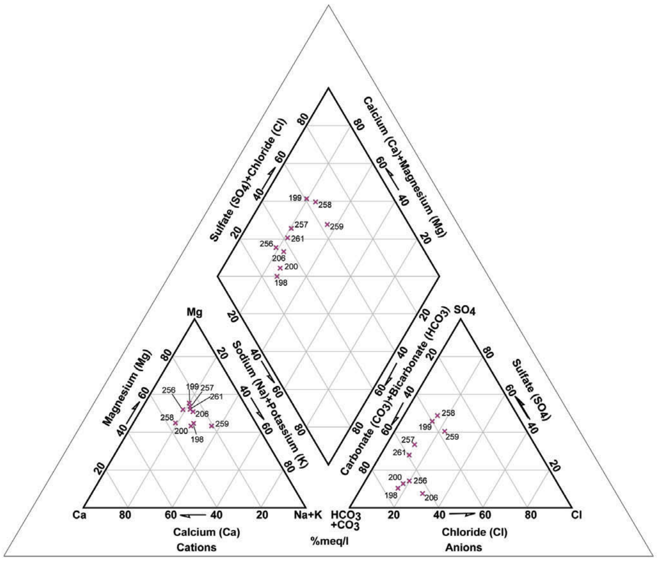

Figure 15. *Piper diagram showing chemistry type for nine ground-water samples in the Mayfield area. Number corresponds to site ID in appendix B.*

of ground water contaminated by different sources of nitrate, I evaluated environmental tracer data collected as part of this study. Environmental tracers can help determine the source of recharge water. The different types of tracers can be used in tandem to help characterize ground-water flow.

Nitrogen and Oxygen Isotopes

I sampled 24 wells for $\delta^{15}N_{NO3}$ and 22 wells for $\delta^{18}O_{NO3}$ in southern Sanpete and central Sevier Valleys. All but one of the wells has relatively high nitrate concentrations (average nitrate concentration of 11 mg/L and median concentration of 8.5 mg/L) (table 1, appendix B). Figure 19 shows a plot of $\delta^{18}O_{NO3}$ versus $\delta^{15}N_{NO3}$. The values and distribution of nitrogen isotopes range from +3.28 to +13.82‰, with a median of 7.34‰; $\delta^{18}O$ values range from –3.54 to +13.60‰, with a median of 0.32‰ (table 1). All of the data fall in the manure/septic-tank nitrogen field, and many plot in the area of overlap between the soil nitrogen, manure/septic-tank nitrogen, and ammonia fertilizer/rain fields (figure 19). The nitrogen in samples having values for $\delta^{15}N$ falling between 5 and

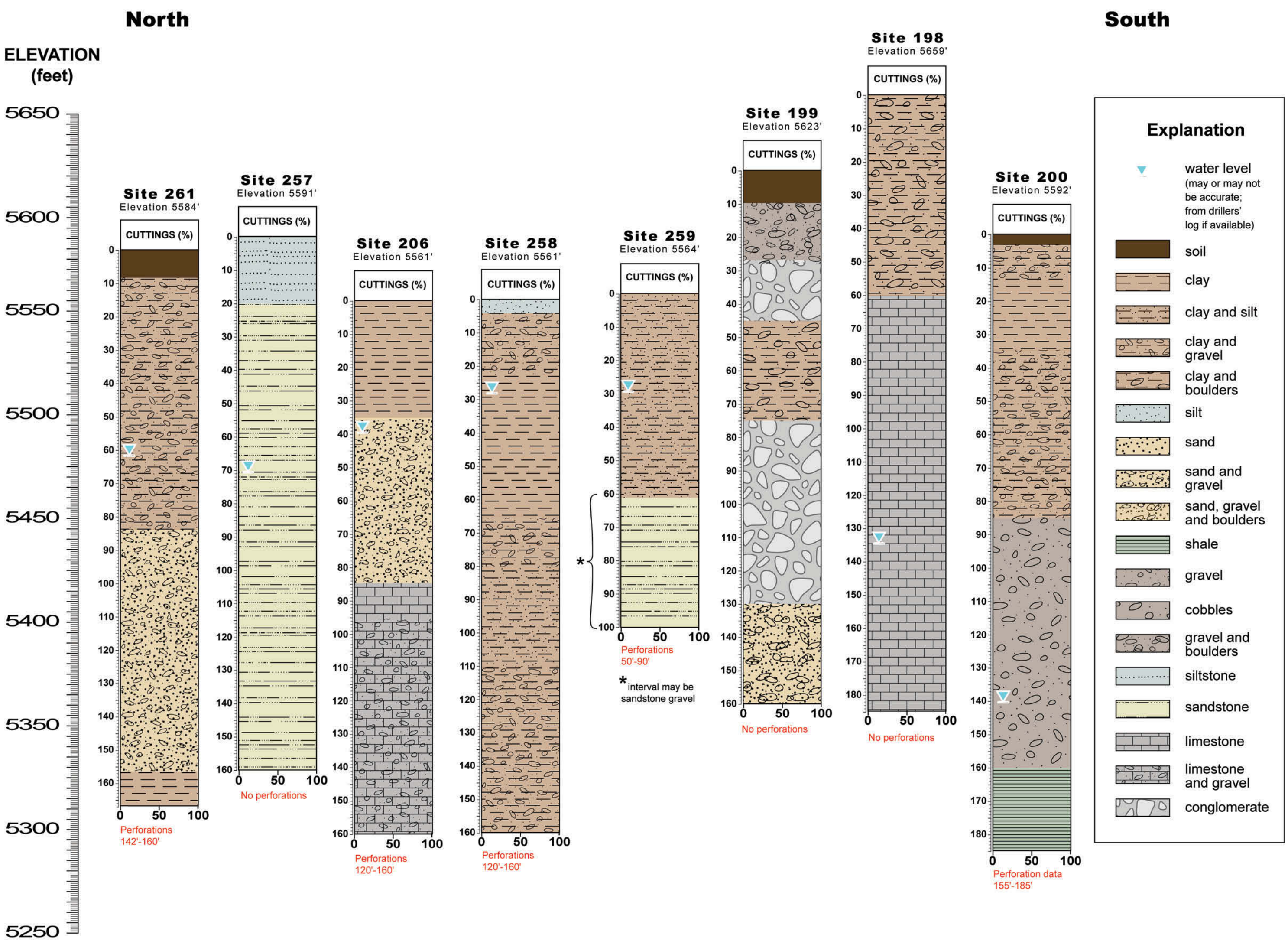

Figure 16. *Compilation of drillers' well logs in the Mayfield area located along the southeast margin of Arapien Valley. Not to scale horizontally. Site ID refers to well location (appendix B; plates 4 and 5).*

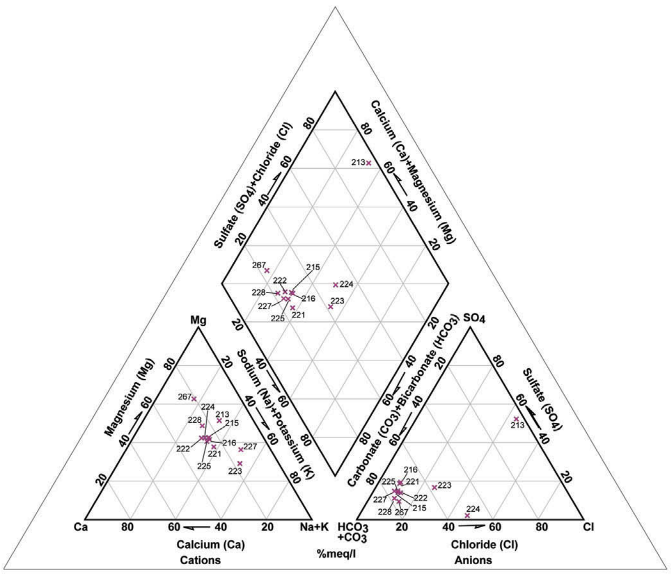

Figure 17. Piper diagram showing chemistry type for 11 ground-water samples in the entire Sterling area. Number corresponds to site ID in appendix B.

8.5‰ may have been derived from nitrate in soil cultivated without fertilizer (figure 19) as well as manure/septic tanks. Three samples had values for $\delta^{15}N$ greater than 10‰ (table 1); these likely have been derived from nitrate from animal manure and/or septic-tank sources, which typically range between 10 and 25‰ (Canter, 1997). The five data points having values less than 5.00‰ may be associated with ammonia fertilizer and rain, as well as soil nitrogen and manure/septic tanks. The overlapping nature may be indicative of mixing of ground-water sources and thus nitrate sources. Field investigation confirmed the validity of an animal-manure nitrate source interpretation and agricultural source (possibly from fertilizer) (table 2). Due to the overlap between the fields, determination of a sole source is difficult, but field observations of potential sources are listed in table 2. Since none of the data plot in the sediment nitrate field (0 to -10‰), a source of nitrate from sedimentary rock is unlikely.

Septic systems in residential developments may be the source of nitrate contamination in some areas (table 2). Most new residential development has occurred in Sterling and May-

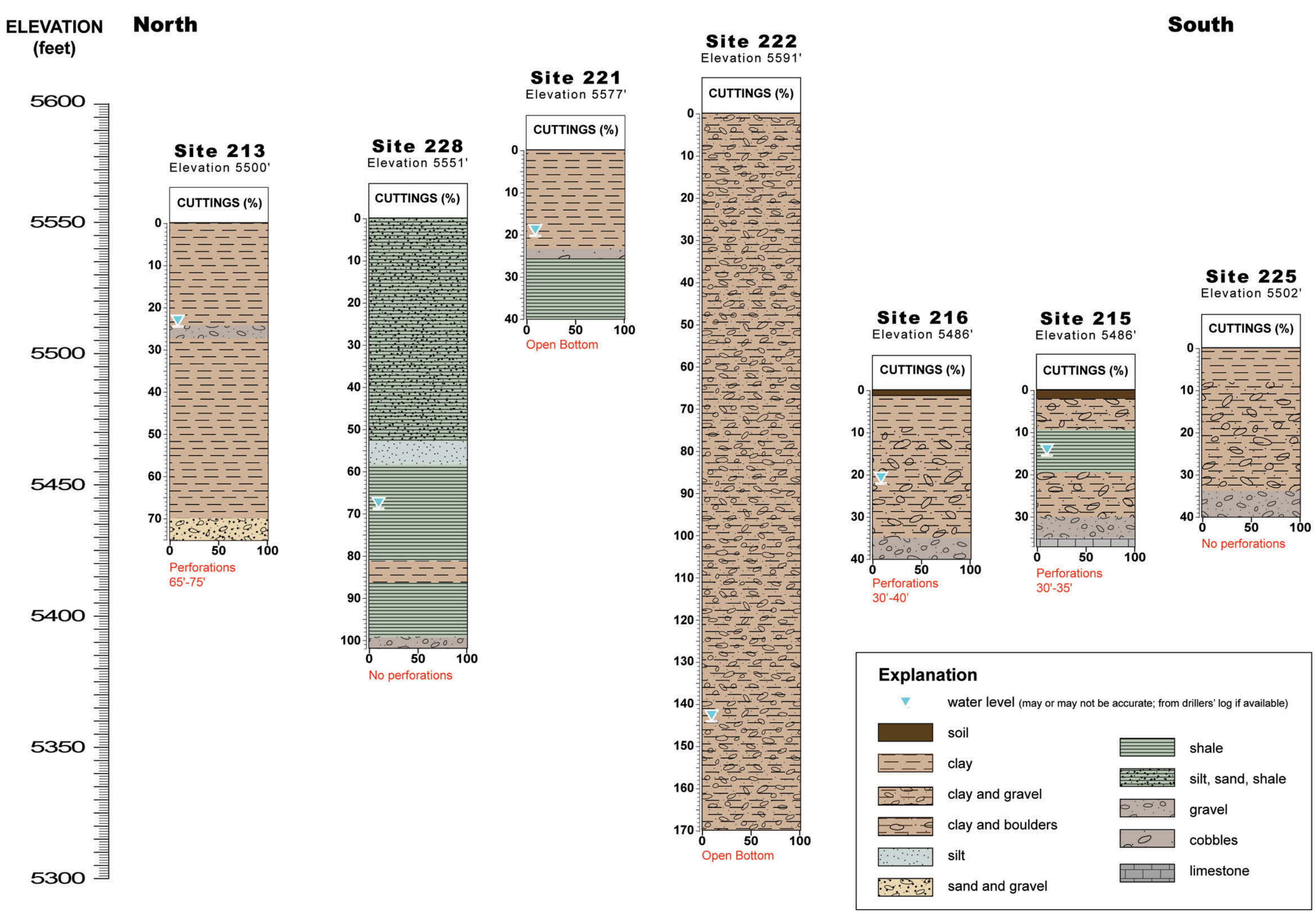

Figure 18. Compilation of drillers' well logs in the central Sterling area roughly trending north to south. Not to scale horizontally. Site ID refers to well location (appendix B; plates 4 and 5).

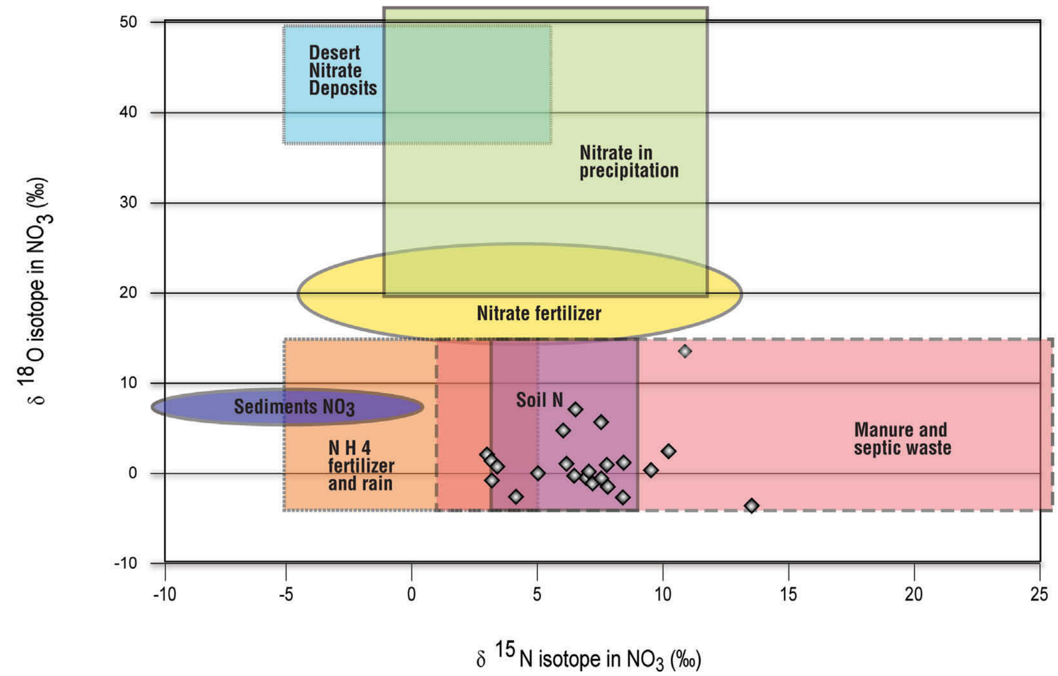

Figure 19. *Nitrogen and oxygen stable isotope data for wells and springs in central Sevier and southern Sanpete Valleys. Labeled fields of nitrogen sources taken from Kendall (1998). "Sediments NO_3" (modified from Clark and Fritz, 1997) field has no corresponding $\delta^{18}O$ range.*

field, and some of these newer homes use septic systems as a method of wastewater disposal. In central Sevier Valley, however, the areas with high nitrate concentrations are sporadic and typically coincide with older, more sparsely developed regions along the eastern margin of the Valley Mountains and in a clustered, older development south of Centerfield (plate 5). Because most of the isotopic data for these clustered developments are not the high $\delta^{15}N$ and low $\delta^{18}O$ values more typical of septic tanks, the expected septic-related isotopic signatures could be obscured by dilution/mixing from recharge by lighter $\delta^{15}N$ water that is more typical of recharge/precipitation and/or soil $\delta^{15}N$ and $\delta^{18}O$ values (figure 19). These areas are located where irrigation is a potential source of recharge water.

Many of the data points for $\delta^{15}N$ and $\delta^{18}O$ isotopes fall within the soil N category, but determining whether nitrate from soil is a source of ground-water nitrate in wells is complicated. An interpretation that ground-water nitrate derives from soil nitrogen deserves caution due to the complexities of the processes and the mechanism by which the nitrate moves from the root zone/soil profile vertically to the water table. Concentrations of nitrogen in soil vary widely and depend on local conditions, including climate, soil type, vegetation, presence (or absence) of animal burrowing, and land use. Recent investigations in arid/desert environments indicate residual vadose zone nitrate as a source of elevated nitrate concentrations in ground water (Stonestrom and others, 2003; Walvoord and others, 2003; Osenbrüch and others, 2006). In areas where native vegetation is sparse and rainfall is low, nitrate can leach into subsoil horizons and accumulate in a subsoil reservoir; subsequent nitrate migration can be from a change in recharge through a change in land use (e.g., from natural recharge on native vegetation to irrigation). The process of nitrate accumulation and migration typically spans thousands to tens of thousands of years (Stonestrom and others, 2003; Walvoord and others, 2003; Osenbrück, 2006; Scanlon and others, 2007). Other recent studies show that variability in nutrient enrichment is based on microecological changes in desert environments where nutrient concentrations and types are affected by differences in shrub coverage, burrowing intensity, amounts of original organic matter, and vegetation spacing/density (Titus and others, 2002), as well as differences in water fluctuations, leaching rates, fertilizer application amounts, and evapotranspiration (Green and others, 2008). Green and others (2008) examined nitrogen fluxes through unsaturated zones in agricultural settings and determined that soil nitrate moves by advective transport below the root zone under conditions conducive to this process: high evapotranspiration and low water-table flux in areas having sandier sediments in unsaturated zones. Under these conditions, Green and others (2008) show soil nitrate can reach deeper parts of the aquifer and contribute to elevated nitrate concentrations in ground water. The Hayes Canyon-Centerfield high-nitrate well (site ID 284) is the only well located on an alluvial-fan pediment surface having no apparent upgradient source of nitrate (table 2, plate 2); no isotope data are available for this well because it has been sealed and cemented.

The data points for $\delta^{15}N$ and $\delta^{18}O$ isotopes that fall into the ammonia fertilizer/rain field may derive from recharge water from return irrigation of fertilized fields. Although I did not investigate the fertilizer application rate or type in this study, variations in nitrate concentrations in wells along the eastern margin of the Valley Mountains and in the high-nitrate wells located south of Centerfield may be explained by differences in fertilizer application rates and irrigation practices by individual farmers.

Using $\delta^{15}N$ to determine the source/relative contributions of fertilizer and animal waste to ground water is complicated by reactions including ammonia volatilization, nitrification, denitrification, ion exchange, plant uptake, and ground-water mixing (figure 7). These processes can modify the $\delta^{15}N$ values of nitrogen sources prior to mixing and in the resultant mixtures, causing estimations of the relative contributions of the sources of nitrate to be inaccurate (Kendall, 1998). Denitrification is likely negligible in the study area, based on the combination of high-nitrate concentration data, low δ15N values, and low iron concentrations (appendix B; figure 19). With future analyses of seasonally collected samples for chemical species (e.g., chloride, manganese, and dissolved oxygen, as well as seasonal $\delta^{15}N$ and $\delta^{18}O$ isotopes), I may be able to better assess the source(s) and whether other processes, such as denitrification, occur with time. The overlapping nature of the data points likely reflects ground-water mixing, which is discussed below based on ground-water age data.

Tritium

I collected water samples for tritium analysis from 23 wells having high nitrate concentrations in southern Sanpete and central Sevier Valleys (appendix B, figure 20, table 1). Tritium concentrations measured in ground water from these wells range from 0.0 to 13.4 TU with an average of 7.3 TU and a median of 8.0 TU. Tritium concentrations that have values less than 0.8 TU are categorized as pre-1952 (pre-bomb [atmospheric nuclear testing] water), values between 0.8 and 4 TU are categorized as mixed water (pre- and post-1952), values from 5 to 10 are categorized as modern water (last 10 to 20 years), and values exceeding 10 TU are categorized as "bomb-age" water (Clark and Fritz; 1997). The tritium values in this report have two samples that are characterized as pre-bomb water, three that are characterized as mixed water, 12 that are characterized as modern water, and 6 that are characterized as "bomb" water (table 1). Two of those categorized as modern water have standard deviations that could characterize them as "bomb" water, and two of those characterized as "bomb" water have standard deviations that could categorize them as modern water (table 1, appendix B). The values reported indicate that at least some of the water must have been recharged when the tritium levels were greater than 1000 TU in the recharge water. Tritium concentrations in the wells suggest that some water in the wells was recharged on the order of 40 years ago (post-atmospheric testing) when tritium concentrations in the atmosphere were near peak levels. While some ground water in an area can be older than the estimated minimum age, but younger than pre-1952 water due to mixing with younger, lower tritium ground water, these data represent a pre- and post-atmospheric testing age as well as a mixture of the two, for ground water entering the aquifer system before traveling to the well.

I use tritium as the basis for a qualitative estimate of ground-water age, or time since ground water was recharged. This is because quantitative determination of ground water ages using tritium requires multiple samples collected over a certain time period, or multiple samples collected from different depths in the same well, or estimation of the initial tritium concentration prior to recharge. Additionally, mixing of recent ground water with old ground water can cause complications

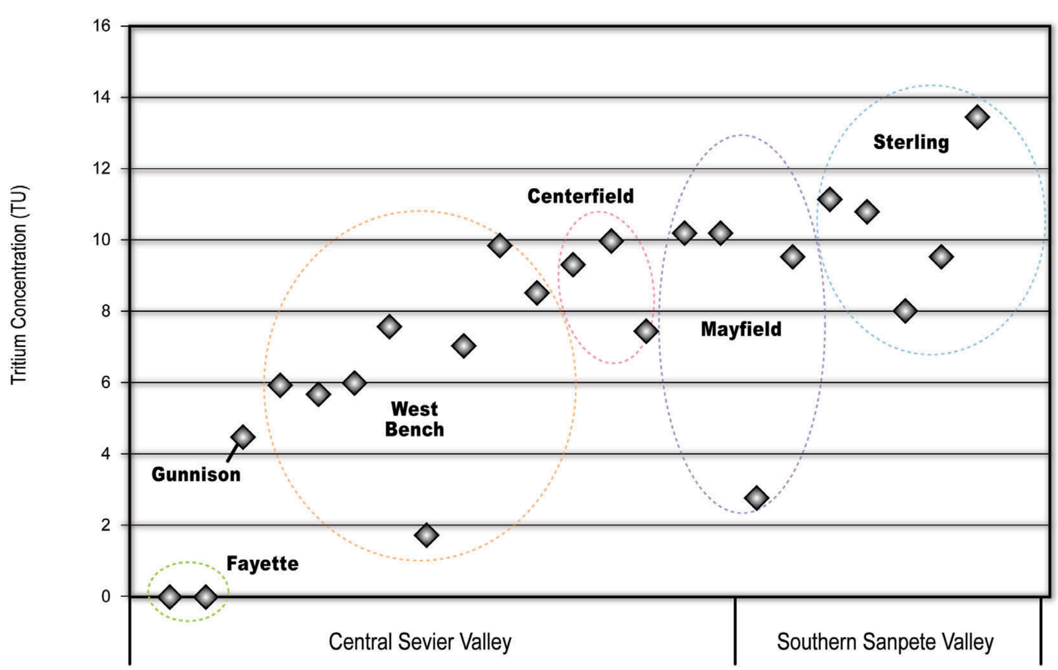

Figure 20. *Tritium concentrations for 23 wells sampled in southern Sanpete and central Sevier Valleys.*

using quantitative methods, so a qualitative age estimate is probably the most appropriate for this study. The variations in tritium values indicate high-nitrate wells were recharged at different times, from relatively recent recharge events to pre-atmospheric nuclear testing.

Chlorofluorocarbons

I collected water samples for CFC analysis from 17 high-nitrate wells in southern Sanpete and central Sevier Valleys (table 1, appendix B). CFC concentrations measured in ground water from these wells yield dates ranging from 1943 to 2000 (table 1). CFC-12 and CFC-11 were first produced in the United States during 1931 and 1936, respectively, with CFC-113 more commonly produced subsequently. The values reported indicate that at least some of the water must have been recharged recently (the year 2000) (table 1). Other CFC concentrations in the wells suggest that some water in the wells was recharged at least 65 years ago (table 1). These data coupled with other environmental tracer and isotope data show overall mixing of ground water in both southern Sanpete and central Sevier Valleys. Most all of the CFC data fall within the range of estimated tritium ages (between 1952 and modern), except wells 229 and 232 (the only wells having tritium ages of pre-1952), which incidentally are two of six wells having the greatest carbon-based ages as discussed below (greater than 2500 years old).

Carbon Isotopes

Carbon-14 is an unstable isotope with a half-life of 5730 years that allows determining a numerical age for older recharge water compared to the other environmental tracers, which provide relative ages. I collected water samples for carbon-14 and $\delta^{13}C$ analysis from 21 high- nitrate wells in southern Sanpete and central Sevier Valleys (table 1, appendix B). Carbon-14 concentrations measured in ground water from these wells range from 5.1 to 110.8 PMC, and -6.96 to -12.89‰ for $\delta^{13}C$ (table 1, appendix B). These values correspond to ground-water ages ranging from modern to 19,000 yr B.P. based on computation of the raw carbon isotope values according to the methods of Fontes and Garnier (1979) and Pearson and Hanshaw (1970) (Alan Mayo, BYU, written communication, May 25, 2008). Of the 21 water samples analyzed for carbon isotopes, two-thirds have modern carbon-based ages; the remaining have ages ranging from 500 to 19,000 yr B.P.

In the northern central Sevier Valley, ^{14}C ground-water ages range from modern to 19,000 yr B.P. (table 1). Sites 229 and 232 (plate 1, appendix E) are located on the southwestern margin of the San Pitch Mountains and both penetrate limestone bedrock. The older aged water (table 1) likely derives from bedrock that received recharge in the mountains and flowed via faults and fractures. Sites 184, 188, 193, 194, 240, 242, and 183 (plate 1) are located along the eastern margin of the Valley Mountains in western central Sevier Valley mostly along alluvial-fan deposits in an agricultural and sparsely populated area; most wells penetrate alluvial material (appendix E). Carbon-based ages here range from modern to 10,500 yr B.P. (table 1). Modern-age ground water here is likely from return agricultural irrigation water, whereas the older ages are from deeper wells (> 199 feet) located upgradient from most irrigation and situated closer to the fault zone mapped along the margin of the Valley Mountains (plate 1 and plate 3). Water from these wells may have also been recharged with older water flowing along faults and fractures or from wells penetrating a bedrock aquifer (appendix E).

In southern central Sevier Valley, ^{14}C ground-water ages are modern for sites 190 and 236 (table 1, plate 1). Both of these wells are shallow and are located downgradient/adjacent to agricultural areas that likely receive return irrigation water as a major source of recharge. They are all domestic wells near homes using septic-tank systems for wastewater disposal.

In the Mayfield area, ^{14}C ground-water ages for all sites are modern except well site 200, which has an age of 2500 yr B.P. (table 1). Site 209 is a shallow well (table 1) located on farmland in an agricultural area and likely receives recharge water from return irrigation. Site 203 is also situated near agricultural areas possibly receiving recharge water from return irrigation. Sites 233 and 204 are springs situated along/near mapped faults (plate 3). The ^{14}C modern age may be fault related with recharge occurring along the fault zone recharged from the Wasatch Plateau to the east. The springs' relatively high nitrate concentrations of 7.37 and 6.95 mg/L (appendix B) are more enigmatic, but may be explained by their proximity to historical grazing lands (Elden Olson, former resident and Utah Division of Drinking Water, personal communication, August 2007) or from nitrate-rich fluids from the fault zone. Site 200, the deepest well in the area and located in the most southeastern part of the study area, penetrates bedrock (table 1, figure 16) and is situated along a mapped fault zone (plates 1 and 3). The ^{14}C ground-water age of 2500 yr B.P. may indicate that the recharge water is derived from the bedrock or fault zone.

In the Sterling area, all four water wells have ^{14}C ground-water ages calculated as modern. All wells are shallow (40-103 feet; table 1) and likely penetrate the same aquifer, except well site 213, located in an isolated area of the valley on a small family-operated dairy farm (plate 1 and 2). The modern ground-water ages for all wells are likely derived from return irrigation water from agriculture and domestic lawn watering from a shallow aquifer (figure 18).

SUMMARY AND CONCLUSIONS

This study evaluated ground-water quality in the aquifers of southern Sanpete and central Sevier Valleys in Sanpete County. High nitrate levels in ground water have been documented locally in Sanpete County, where many wells have historically yielded ground water having greater than 10 mg/L nitrate concentration, including two wells drilled by the town of Centerfield, and a public-supply spring that has had persistent nitrate concentration of about 7 mg/L. This study was prompted by these incidents and by the concern of potential water-quality degradation in the growing communities of southern Sanpete County.

I analyzed water samples from 68 wells, six springs, and three streams for nutrients, general chemistry, and dissolved metals. Of these 77 samples, those having relatively high (generally greater than 5 mg/L) nitrate concentration were also analyzed for environmental tracers (isotopes); 24 were tested for nitrogen and 22 for oxygen isotopes in nitrate, 23 for tritium, 17 for chlorofluorocarbons (CFC), and 21 for carbon isotopes. I used TDS and nitrate data from nine wells and nine springs from the Utah Division of Drinking Water and four wells from the Utah Department of Agriculture and Food to augment the study, for a total of 99 samples analyzed.

Total-dissolved-solids concentrations for wells tested for general chemistry range from 202 to 3014 mg/L. Elevated TDS concentrations in ground water are largely attributed to proximity to outcrops of the Green River Formation and the Arapien Shale and return irrigation water. There is no correlation between high-TDS wells and high-nitrate wells.

Average nitrate concentration for ground water in the valley-fill aquifer is about 6.5 mg/L. Of the water wells analyzed for nitrate, 51% yielded values greater than 5 mg/L, and 20% exceeded EPA drinking-water standards for nitrate. Most of the high-nitrate wells are less than 150 feet (46 m) deep and contamination sources are likely within a short distance (3200 feet [1000 meters]) of the high-nitrate wells.

Overall water quality in southern Sanpete and central Sevier Valleys is fair. The highest quality of water in terms of low TDS and nitrate concentration occurs primarily along the margins in both valleys: along Sixmile and Twelvemile Creeks in southern Sanpete Valley, and along the western margin of the San Pitch Mountains and the southeastern margin of the Valley Mountains in central Sevier Valley. A correlation is apparent between high nitrate concentration in wells and proximity to current or pre-existing animal feed-lot operations and irrigated agricultural areas, as supported by field observation of potential sources of nitrate upgradient of wells yielding high-nitrate ground water. However, nitrogen isotope data indicate multiple sources could be responsible for the high nitrate concentration in wells and that multiple nitrogen sources exist, including septic-tank systems, agricultural fertilizer, animal-waste products, and natural soil nitrate. Well log information indicates some high-nitrate wells may be isolated single-well contaminations, and some high-nitrate wells occur in relatively large areas of high- nitrate ground water. Water chemistry data indicate high-nitrate wells may have a common source of ground-water recharge on a local scale. I recommend installing monitoring wells downgradient from the impacted wells in order to make this determination since the drillers' logs are inconsistent and may not represent accurate ground-water conditions.

Data from nitrogen and oxygen isotopes in nitrate indicate most high-nitrate wells contain water derived possibly from human and/or animal sources, soil nitrate, ammonia in fertilizer and rain, and mixed sources. No isotope data plot as nitrate from sediment, and many wells penetrating bedrock (possibly the Green River Formation) have negligible nitrate concentration. Therefore, I conclude bedrock is not a source of high nitrate, however field investigation confirmed fertilizer and animal manure as possible sources of nitrate. Septic-tank systems likely contribute nitrate to many of the wells, but due to the overlapping nature of the data, determination of a sole source is difficult, except in areas lacking development and thus free of septic systems. Determining whether nitrate in ground water is derived from soil or from fault zones is more complex. Future work to attempt to determine the spatially variable vadose-zone flow conditions is necessary to better estimate the potential for ground-water nitrate loading from soil. Because this study did not include a ground-water flow model and does not address subsurface conditions, determining the transport mechanism by which nitrogen from soil reaches ground water as nitrate is precluded.

Tritium analysis of ground water from 23 high-nitrate wells indicates that contaminated ground water was recharged pre-, post- and during the bomb years when tritium concentrations in the atmosphere were at their low, medium, and peak levels, respectively. CFC data show most high-nitrate wells have an average recharge year of 1976 (for CFC-11, CFC-12, and CFC-113), with an overall date range from 1943 to 2000. Carbon-14/$\delta^{13}C$ data indicate ground-water ages range from modern to 19,000 yr B.P., and show the high-nitrate ground water is derived from both modern and very old recharge waters that likely has mixed with younger recharge water. Based on all environmental tracer data for high-nitrate wells, most ground water reflects mixed or combined sources of water, with one spring and two shallow wells containing water that is distinguished as modern, seven wells containing water greater than 500 years old but also having a modern-age component, and 14 samples having mixed-age ground water recharged during the 20th century. Because all samples analyzed for environmental tracer data (mostly tritium and CFC) have water with a recharge-age component indicative of historical time, I believe the dominant sources of nitrate in ground water in the area are from human-related activity.

To control potential degradation of ground-water quality in southern Sanpete and central Sevier Valleys, I recommend (1) applying agricultural fertilizer to the surface at rates not exceeding nitrogen uptake by crops, (2) storing feed-lot waste on facilities designed to prevent leakage of contaminants associated with manure to ground water, and (3) avoiding septic-tank system installation in areas where implementation of a public-sewer system is feasible. Due to the pervasive nature of relatively high nitrate concentration in wells, I recommend temporal and spatial analyses of nitrate contamination to help Sanpete County's southernmost communities understand the trends in potential changes in ground-water quality in order to provide an affordable and sustainable long-term water supply. This study focused on water quality, and I did not attempt to determine a specific location for siting a public-water supply well based on economics or the water quantity available to supply these communities' future demands. The thickest alluvial deposits in the study area are located in areas that may not yield the highest quality water. The best places in the valleys in terms of highest water quality to consider future water-resource development are located in Sixmile Canyon, Twelvemile Canyon, the southwestern margin of the San Pitch Mountains, and along the southeastern margin of the Valley Mountains.

ACKNOWLEDGMENTS

This project was funded by the Utah Division of Drinking Water, the U.S. Environmental Protection Agency, and the Utah Geological Survey. Critical review and comments were provided by Mike Lowe, Lucy Jordan, Toby Hooker, Mike Hylland, and Robert Ressetar, Utah Geological Survey; Bob Hart and Jim Martin, Utah Division of Drinking Water Quality; Mike Wireman and Wes Wilson, U.S. Environmental Protection Agency; and Dan Aubrey and Ed Fall, Utah Division of Water Resources. I thank Steve Deacon, Utah Department of Agriculture and Food and John Iverson of Sunrise Engineering for providing additional data. I thank Richard Emerson and Kim Nay, Utah Geological Survey, for preparing the figures and maps for this publication. I thank Keith James and Stewart Jensen for their field assistance and help in contacting well owners in central Sevier Valley, and Mayor Bringhurst of Sterling and Elden Olson for their field assistance in contacting well owners in southern Sanpete Valley. I especially thank Sanpete County well owners who allowed access to sample their wells.

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APPENDICES

APPENDIX A
UTAH AND EPA WATER-QUALITY STANDARDS AND ANALYTICAL METHODS

Table A1. *Utah and EPA primary and secondary drinking water-quality standards and analytical methods for some chemical constituents sampled in Sanpete County, Utah.*

CHEMICAL CONSTITUENT	EPA ANALYTICAL METHOD[1]	WATER-QUALITY STANDARD (mg/L)
Nutrients:		
total nitrate/nitrite	353.2	10.0
ammonia as nitrogen	350.3	-
total phosphorous and dissolved total phosphate	365.1	-
Dissolved metals (as listed in State of Utah Public Health Laboratory online manual):		
arsenic	200.9	0.01
barium	200.7	2.0
cadmium	200.9	0.005
chromium	200.9	0.1
copper	200.7	1.3
lead	200.9	0.015
mercury	245.1	0.002
selenium	200.9	0.05
silver*	200.9	0.1
zinc*	200.7	5.0
General Chemistry :(as listed in State of Utah Public Health Laboratory online manual):		
total dissolved solids (TDS)	160.1	2000+** or (500*++)
pH*	150.1	between 6.5 and 8.5
aluminum*	200.7	0.05 to 0.2
calcium	200.7	-
sodium	200.7	-
boron	200.7	-
bicarbonate	406C	-
carbon dioxide	406C	-
carbonate	406C	-
chloride*	407A	250
total alkalinity	310.1	-
total hardness	314A	-
specific conductance	120.1	-
iron*	200.7	0.3
potassium	200.7	-
hydroxide	406C	-
sulfate *++	375.2	250
magnesium	200.7	-
manganese	200.7	0.5

- no drinking-water quality standard exists for the chemical constituent

*for secondary standards (exceeding these concentrations does not pose a health threat)

+ maximum contaminant level is reported from the Utah Administrative Code R309-200 (Utah Division of Drinking Water)

**For public water-supply wells, if TDS is greater than 1000 mg/L, the supplier shall satisfactorily demonstrate to the Utah Water Quality Board that no better water is available. The Board shall not allow the use of an inferior source of water if a better source of water is available.

++TDS and sulfate levels are given in the Primary Drinking Water Standards, R309-200. They are listed as secondary standards, excess of recommended levels cause consumer complaint.

[1] http://www.epa.gov/safewater/methods/analyticalmethods_ogwdw.html#one

APPENDIX B
WATER-QUALITY DATA

Table B1. *Water-quality chemistry for wells, springs, and streams in southern Sanpete and central Sevier Valleys.*

Site ID	Well Depth (feet)	Completion date	Sample Date	Nitrogen NO2 + NO3 (mg/L)	Solids, residue @180°C, dissolved (mg/L)	Field Tempera-ture, (°C)	Field, Specific Conductance (µmhos)	Lab, Specific Conduc tance (µmhos)	pH, Field	pH, Lab	Field, Dissolv-ed Oxygen	Aluminum, dissolved (µg/L)
181	65	01/06/95	04/03/07	9.61	1542	17.1	2359	2350	7.3	8.28	3.7	<100
182	135	04/21/86	04/03/07	9.50	1522	11.8	2359	2380	7.5	8.03	5.9	<100
183	274	03/25/40	04/03/07	2.52	460	8.8	788	791	8.4	8.57	8.9	<100
184	160	01/14/99	04/03/07	24.20	1348	13.0	2209	2200	7.7	8.20	5.3	<100
185	170	08/22/43	04/03/07	13.10	478	11.1	885.3	889	8.1	8.35	9.8	<100
186	43	06/01/64	04/03/07	2.84	1778	15.0	2917	2900	7.3	8.22	5.1	<100
187	130	11/20/94	04/03/07	8.38	622	16.0	1070	1059	8.1	8.29	7.8	<100
188	199	01/29/42	04/03/07	4.95	360	10.5	660	661	8.5	8.39	8.6	<100
189	98	02/25/97	04/03/07	0.09	2120	10.4	3786	3800	7.9	8.30	5.2	<100
190	84	12/24/42	04/04/07	11.50	2272	9.6	3269	3270	7.2	8.00	6.1	<100
191	200	06/16/02	04/04/07	7.27	994	11.4	1689	1675	7.9	8.37	6.2	<100
192	80	10/15/90	04/04/07	5.20	1666	13.8	2525	2500	7.5	8.29	5.3	<100
193	55	05/04/88	04/04/07	6.42	1632	14.0	2694	2700	7.6	8.34	3.0	<100
194	158	01/17/67	04/04/07	9.18	1398	11.0	2337	2320	7.6	8.31	4.4	<100
195	146	03/18/03	04/04/07	0.09	992	16.1	1938	1909	8.0	8.62	2.5	<100
196	395	05/15/91	04/04/07	0.19	728	17.2	1486	1470	7.9	8.41	4.5	<100
197	300	09/30/01	04/04/07	0.35	440	12.5	874	873	8.0	8.55	5.1	<100
198	185	11/11/04	04/04/07	11.10	432	12.9	841	818	7.9	8.60	7.8	<100
199	160	10/12/74	04/04/07	25.90	1276	14.0	1895	1847	7.5	8.42	4.5	<100
200	185	06/13/95	04/04/07	11.10	442	12.8	813	802	7.8	8.61	6.1	<100
201	87	10/19/79	04/05/07	8.80	1200	14.0	1947	1910	7.5	8.10	7.2	<100
202	110	02/10/76	04/05/07	3.71	1408	28.0	2580	2370	7.6	8.27	2.7	<100
203	120	05/25/99	04/05/07	9.64	676	14.0	1140	1109	7.4	8.26	5.4	<100
204	spring	-	04/05/07	6.95	712	13.5	1204	1090	7.8	8.63	6.3	<100
205	63	11/30/43	04/06/07	6.46	2632	11.8	4334	4250	7.2	8.22	6.2	<100
206	160	03/11/00	04/06/07	19.30	1264	11.3	1914	1869	7.6	8.35	4.9	<100

- Indicates no data; UGS is Utah Geological Survey; UDDW is Utah Div. of Drinking Water; UDAF is Utah Department of Agriculture and Food; Sunrise is Sunrise Engineering; shaded intervals indicate sample was analyzed for isotopes (see table 1).

Table B1. continued

Site ID	Well Depth (feet)	Completion date	Sample Date	Nitrogen NO2 + NO3 (mg/L)	Solids, residue @180°C, dissolved (mg/L)	Field Tempera-ture, (°C)	Field, Specific Conductance (µmhos)	Lab, Specific Conduc tance (µmhos)	pH, Field	pH, Lab	Field, Dissolv-ed Oxygen	Aluminum, dissolved (µg/L)
207	140	08/08/03	04/06/07	3.54	472	10.6	882	871	8.0	8.41	7.5	<100
208	159	04/01/06	04/16/07	1.67	490	-	-	835	-	8.48	-	<100
209	56	-	04/16/07	7.48	696	-	-	1047	-	8.32	-	<100
210	129	07/31/43	04/16/07	3.40	512	-	-	872	-	8.40	-	<100
211	200	01/08/96	04/16/07	12.80	904	12.4	1630	1602	7.6	8.26	3.3	<100
212	260	05/18/89	04/17/07	7.01	628	11.2	-	1019	7.6	8.26	-	<100
213	75	03/21/77	04/17/07	34.10	1018	13.9	-	1652	7.5	8.32	-	<100
214	240	04/28/01	04/17/07	1.54	758	11.1	-	1338	8.0	8.46	-	<100
215	37	12/03/00	04/17/07	6.49	610	16.2	-	1055	7.5	8.36	-	<100
216	80	11/03/00	04/17/07	6.36	610	13.3	-	1059	7.6	8.35	-	<100
217	205	06/25/69	04/17/07	0.42	570	15.3	-	934	8.0	8.48	-	<100
218	78	08/17/95	04/17/07	0.09	516	17.0	-	870	8.0	8.44	-	<100
219	122	09/18/06	04/17/07	0.09	388	12.0	-	681	7.9	8.43	-	<100
220	65	05/14/98	04/17/07	0.87	586	12.8	-	1028	7.6	8.40	-	<100
221	40	11/05/01	04/17/07	5.32	558	11.6	983	955	7.8	8.49	3.3	<100
222	170	04/10/01	04/17/07	4.45	542	13.0	-	963	7.6	8.48	-	<100
223	140	09/28/01	04/18/07	5.22	998	15.2	-	1707	7.6	8.49	-	<100
224	98	10/07/05	04/18/07	39.10	1650	12.7	2590	2720	7.6	8.47	1.2	<100
225	40	11/03/00	04/18/07	5.19	522	11.8	-	906	7.7	8.49	-	<100
227	80	04/25/98	04/18/07	9.51	622	11.0	-	1052	7.7	8.01	-	<100
228	103	08/27/96	04/18/07	6.41	562	12.2	972	948	7.7	8.01	3.4	<100
229	265	07/12/01	05/15/07	0.09	1304	17.0	-	2500	7.8	8.36	-	<100
230	104	09/27/70	05/15/07	0.89	1118	18.0	-	1979	7.6	8.40	-	<100
231	spring	-	05/15/07	0.40	512	19.2	-	1004	7.6	8.41	-	<100
232	75	03/23/36	05/15/07	8.53	1096	17.0	-	2000	7.6	8.30	-	<100
233	spring	-	05/15/07	7.37	688	15.5	1203	1125	7.3	8.22	-	<100

- Indicates no data; UGS is Utah Geological Survey; UDDW is Utah Div. of Drinking Water; UDAF is Utah Department of Agriculture and Food; Sunrise is Sunrise Engineering; shaded intervals indicate sample was analyzed for isotopes (see table 1).

Table B1. continued

Site ID	Well Depth (feet)	Completion date	Sample Date	Nitrogen NO2 + NO3 (mg/L)	Solids, residue @180°C, dissolved (mg/L)	Field Tempera-ture, (°C)	Field, Specific Conductance (µmhos)	Lab, Specific Conduc tance (µmhos)	pH, Field	pH, Lab	Field, Dissolv-ed Oxygen	Aluminum, dissolved (µg/L)
234	spring	04/06/04	05/15/07	0.09	384	25.0	-	719	7.9	8.40	-	<100
235	spring	-	05/15/07	8.42	862	15.5	-	1482	7.5	8.45	-	<100
236	57	11/28/80	05/15/07	11.60	1912	18.0	2830	2810	7.8	8.37	2.2	<100
237	107	12/14/69	05/15/07	22.20	1250	17.8	-	2000	7.6	8.32	-	<100
238	52	02/15/41	05/15/07	11.80	1648	16.5	-	2640	7.5	8.48	-	<100
239	49	04/11/79	05/15/07	4.85	2488	16.7	-	3940	7.2	8.35	-	<100
240	220	04/25/90	05/15/07	6.33	688	17.9	-	1129	7.9	8.13	-	<100
241	80	06/03/02	05/15/07	4.77	1456	16.0	-	2450	7.1	7.96	-	<100
242	78	05/02/35	05/15/07	8.23	1118	15.5	-	1845	7.5	7.98	-	<100
243	spring	-	05/16/07	0.09	370	17.6	-	679	7.6	8.28	-	<100
244	200	06/13/78	05/16/07	1.94	3014	13.9	3520	3440	7.2	7.63	3.2	<100
256	98	06/23/79	07/10/07	5.25	480	13.4	856	846	7.9	8.48	5.8	<100
257	160	07/14/90	07/10/07	14.00	826	15.2	1281	1260	7.4	8.38	4.5	<100
258	160	06/02/98	07/10/07	18.30	1334	12.5	1920	1893	7.4	8.47	3.8	<100
259	100	06/18/07	07/10/07	16.80	1348	13.1	2060	1942	7.3	7.78	3.2	118
260	130	07/17/74	07/10/07	9.35	1418	13.6	1930	1892	7.3	8.28	3.2	<100
261	167	07/10/98	07/10/07	11.20	674	16.4	1104	1088	7.5	8.47	4.1	<100
262	145	07/27/96	07/10/07	0.09	684	18.5	1165	1161	9.1	9.11	1.3	<100
263	78	07/27/96	07/10/07	0.29	368	16.9	683	670	7.4	8.50	4.5	<100
264	stream	-	07/10/07	0.27	202	18.9	393	370	8.8	8.80	5.1	245
265	60	06/06/99	07/10/07	9.23	1194	12.3	1980	1943	7.3	8.57	2.3	<100
266	stream	-	07/10/07	0.27	235	21.5	392	392	8.8	-	4.9	<100
267	120	08/27/96	07/11/07	6.22	554	16.3	964	952	7.5	8.62	6.1	<100
268	110	06/18/07	10/16/07	0.09	334	12.6	680	622	7.2	8.15	2.3	<100
269	stream	-	04/15/08	0.32	-	-	-	-	-	-	-	-
270	spring	-	01/10/07	0.30	712	-	-	-	-	-	-	-

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Table B1. continued

Site ID	Well Depth (feet)	Completion date	Sample Date	Nitrogen NO2 + NO3 (mg/L)	Solids, residue @180°C, dissolved (mg/L)	Field Tempera-ture, (°C)	Field, Specific Conductance (µmhos)	Lab, Specific Conduc tance (µmhos)	pH, Field	pH, Lab	Field, Dissolv-ed Oxygen	Aluminum, dissolved (µg/L)
271	spring	-	06/28/05	0.30	300	-	-	-	-	-	-	-
272	spring	-	09/14/05	0.60	292	-	-	-	-	-	-	-
273	spring	-	07/29/05	1.60	564	-	-	-	-	-	-	-
274	spring	-	07/27/06	0.30	300	-	-	-	-	-	-	-
275	spring	-	12/30/04	0.60	292	-	-	-	-	-	-	-
276	345	03/07/78	12/04/94	0.20	742	-	-	-	-	-	-	-
277	300	06/13/78	06/28/05	0.30	508	-	-	-	-	-	-	-
278	spring	-	05/22/96	0.63	712	-	-	-	-	-	-	-
279	well	-	08/07/92	0.10	358	-	-	-	-	-	-	-
280	spring	-	07/27/06	0.35	300	-	-	-	-	-	-	-
281	well	-	09/14/05	0.60	380	-	-	-	-	-	-	-
282	spring	-	07/27/06	0.20	300	-	-	-	-	-	-	-
283	400	10/04/04	12/02/03	14.90	978	-	-	-	-	-	-	-
284	440	11/09/04	11/09/04	16.00	484	-	-	840		7.40		<100
285	-	12/26/00	08/31/06	0.50	-	-	-	-	-	-	-	-
286	well	-	06/27/05	3.01	536	-	-	-	-	-	-	-
287	960	07/10/08	07/10/08	0.09	3530	18.9	5000	-	7.5	-	2.0	-
288	150	-	06/17/08	0.20	416	-	-	-	-	-	-	-
289	150	-	06/17/08	23.00	773	-	-	-	-	-	-	-
290	150	-	06/17/08	0.63	517	-	-	-	-	-	-	-
291	80	-	06/17/08	7.42	1698	-	-	-	-	-	-	-
292	-	-	06/17/08	7.55	766	-	-	-	-	-	-	-

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Table B1. continued

Site ID	Ammonia (mg/L)	Arsenic, dissolved (µg/L)	Barium, dissolved (µg/L)	Boron (µg/L)	Bicarbon-ate (mg/L)	Cadmium, dissolved (µg/L)	Calcium, dissolved (mg/L)	Carbon dioxide (mg/L)	Carbonate (mg/L)	Chloride (mg/L)	Chromium, dissolved (µg/L)	Carbonate (CO3) Solids (mg/L)
181	<0.05	<25.0	24	431	564	<1.0	129.0	5	0	212.0	<2	277
182	<0.05	<25.0	23	422	620	<1.0	140.0	9	0	225.0	<2	305
183	<0.05	<25.0	25	569	296	<1.0	18.7	1	0	35.3	<2	154
184	<0.05	<25.0	41	570	528	<1.0	93.6	5	0	238.0	<2	260
185	<0.05	<25.0	55	281	235	<1.0	44.4	2	2	105.0	<2	117
186	<0.05	<50.0	25	597	690	<2.0	114.0	7	0	465.0	<2	339
187	<0.05	<25.0	27	482	326	<1.0	44.8	3	0	102.0	2	159
188	<0.05	<25.0	41	267	254	<1.0	25.1	2	3	41.6	<2	128
189	0.96	<75.0	42	515	674	<3.0	77.2	5	0	454.0	<2	332
190	<0.05	<50.0	12	818	580	<2.0	230.0	9	0	283.0	<2	285
191	<0.05	<25.0	88	321	564	<1.0	93.6	4	7	145.0	<2	284
192	<0.05	<25.0	22	382	480	<1.0	158.0	4	0	259.0	<2	236
193	<0.05	<50.0	27	846	741	<2.0	83.4	5	5	279.0	<2	370
194	<0.05	<50.0	26	852	718	<2.0	67.0	6	1	209.0	<2	354
195	<0.05	<50.0	78	208	374	<2.0	37.3	1	15	294.0	<2	199
196	<0.05	<25.0	80	<100	313	<1.0	56.9	2	5	254.0	<2	158
197	<0.05	<25.0	85	<100	298	<1.0	43.7	1	8	113.0	<2	154
198	<0.05	<25.0	108	153	336	<1.0	50.7	1	15	48.5	<2	180
199	<0.05	<25.0	29	376	488	<1.0	108.0	3	12	108.0	<2	252
200	<0.05	<25.0	82	182	311	<1.0	51.5	1	14	49.6	<2	167
201	<0.05	<25.0	15	527	518	<1.0	105.0	7	0	175.0	<2	255
202	<0.05	<50.0	15	1270	478	<2.0	70.8	4	0	282.0	<2	235
203	<0.05	<25.0	39	176	472	<1.0	84.1	4	0	54.2	<2	232
204	<0.05	<25.0	53	393	420	<1.0	59.4	2	20	74.3	<2	227
205	<0.05	<50.0	37	439	694	<2.0	233.0	7	0	881.0	<2	341
206	<0.05	<25.0	25	376	446	<1.0	109.0	3	4	119.0	<2	223

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Table B1. continued

Site ID	Ammonia (mg/L)	Arsenic, dissolved (µg/L)	Barium, dissolved (µg/L)	Boron (µg/L)	Bicarbon-ate (mg/L)	Cadmium, dissolved (µg/L)	Calcium, dissolved (mg/L)	Carbon dioxide (mg/L)	Carbonate (mg/L)	Chloride (mg/L)	Chromium, dissolved (µg/L)	Carbonate (CO3) Solids (mg/L)
207	<0.05	<25.0	131	181	384	<1.0	48.9	2	7	68.2	<2	196
208	<0.05	<20.0	72	<100	400	<1.0	79.4	2	8	24.7	<2	205
209	<0.05	<20.0	72	479	488	<1.0	37.1	4	2	56.5	<2	242
210	<0.05	<20.0	94	154	445	<1.0	80.4	3	6	39.0	<2	225
211	<0.05	<20.0	65	274	262	<1.0	43.4	2	0	274.0	<2	129
212	<0.05	<20.0	77	<100	510	<1.0	77.4	4	0	36.6	<2	251
213	<0.05	130	79	389	8	<1.0	56.4	6	3	83.5	<2	366
214	<0.05	<20.0	25	351	428	<1.0	35.0	2	10	159.0	<2	220
215	<0.05	<20.0	65	211	523	<1.0	57.3	4	5	41.5	<2	263
216	<0.05	<20.0	62	211	542	<1.0	58.3	4	4	42.0	<2	271
217	<0.05	<20.0	37	158	385	<1.0	58.7	2	9	22.3	<2	199
218	0.23	<20.0	33	155	340	<1.0	38.0	2	6	38.4	<2	173
219	<0.05	<20.0	39	<100	333	<1.0	43.8	2	5	13.1	<2	169
220	<0.05	<20.0	102	<100	456	<1.0	82.6	3	6	68.0	<2	230
221	<0.05	<20.0	35	203	455	<1.0	51.8	2	11	41.2	<2	235
222	<0.05	<20.0	45	163	447	<1.0	57.0	2	10	43.9	<2	230
223	0.08	<20.0	31	444	603	<1.0	62.2	3	16	163.0	<2	313
224	<0.05	<20.0	49	799	572	<1.0	72.0	3	16	327.0	<2	297
225	<0.05	<20.0	40	180	414	<1.0	49.0	2	10	35.7	<2	214
227	<0.05	<20.0	54	199	544	<1.0	60.8	9	0	38.1	<2	268
228	<0.05	<20.0	49	177	500	<1.0	50.8	8	0	41.0	<2	246
229	<0.05	<8.0	39	145	334	<0.4	60.7	2	3	670.0	<2	167
230	<0.05	<4.0	42	131	314	<0.2	68.4	2	5	438.0	<2	159
231	<0.05	<4.0	80	<100	313	<0.2	47.1	2	5	160.0	<2	158
232	<0.05	<4.0	33	119	340	<0.2	72.9	3	0	429.0	<2	167
233	<0.05	5.0	93	163	472	<0.2	86.2	5	0	68.8	<2	232

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Table B1. continued

Site ID	Ammonia (mg/L)	Arsenic, dissolved (µg/L)	Barium, dissolved (µg/L)	Boron (µg/L)	Bicarbon-ate (mg/L)	Cadmium, dissolved (µg/L)	Calcium, dissolved (mg/L)	Carbon dioxide (mg/L)	Carbonate (mg/L)	Chloride (mg/L)	Chromium, dissolved (µg/L)	Carbonate (CO3) Solids (mg/L)
234	<0.05	<4.0	86	138	325	<0.2	37.1	2	2	37.1	<2	162
235	<0.05	40.7	68	445	596	<0.2	49.5	3	13	133.0	<2	306
236	<0.05	8.5	18	1460	438	<0.4	118.0	3	5	304.0	<2	220
237	<0.05	5.0	17	155	310	<0.2	86.8	2	1	290.0	2	154
238	<0.05	29.1	23	1050	653	<0.2	54.5	3	17	279.0	<2	338
239	<0.05	11.6	24	1040	566	<0.4	161.0	4	7	850.0	<2	285
240	<0.05	4.2	17	530	226	<0.2	51.8	3	0	132.0	<2	111
241	<0.05	14.2	22	547	612	<0.2	115.0	11	0	314.0	<2	301
242	<0.05	5.3	25	786	784	<0.2	64.7	13	0	102.0	2	386
243	<0.05	<4.0	40	<100	342	<0.2	46.4	3	0	14.0	<2	168
244	0.63	10.9	10	664	352	0.2	404.0	13	0	157.0	<2	173
256	<0.05	7.7	142	142	345	<0.2	51.2	2	7	62.2	<2	177
257	<0.05	8.3	66	242	430	<0.2	70.2	3	6	59.8	<2	217
258	<0.05	8.9	25	362	444	<0.2	98.9	2	14	116.0	<2	232
259	<0.05	9.3	32	333	504	<0.2	92.4	13	0	180.0	<2	248
260	<0.05	7.3	24	355	450	<0.2	121.0	4	0	77.7	<2	221
261	<0.05	8.4	67	229	402	<0.2	62.7	2	11	53.3	<2	209
262	0.13	4.4	23	664	540	<0.2	1.3	1	46	23.4	<2	312
263	<0.05	<4.0	143	<100	400	<0.2	63.6	2	10	10.4	<2	207
264	<0.05	<4.0	149	<100	222	<0.2	38.9	1	15	<10	<2	124
265	<0.05	7.3	31	319	516	<0.2	78.1	2	22	228.0	<2	276
266	-	<4.0	140	<100	-	<0.2	35.6	-	-	-	<2	-
267	<0.05	56.0	126	255	438	<0.2	43.9	2	21	50.2	<2	236
268	0.09	<4.0	92	<100	410	<0.2	60.3	5	0	13.8	<2	202
269	-	-	-	-	-	-	-	-	-	-	-	-
270	-	-	-	-	-	-	-	-	-	-	-	-

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Table B1. continued

Site ID	Ammonia (mg/L)	Arsenic, dissolved (µg/L)	Barium, dissolved (µg/L)	Boron (µg/L)	Bicarbon-ate (mg/L)	Cadmium, dissolved (µg/L)	Calcium, dissolved (mg/L)	Carbon dioxide (mg/L)	Carbonate (mg/L)	Chloride (mg/L)	Chromium, dissolved (µg/L)	Carbonate (CO3) Solids (mg/L)
271	-	-	-	-	-	-	-	-	-	-	-	-
272	-	-	-	-	-	-	-	-	-	-	-	-
273	-	-	-	-	-	-	-	-	-	-	-	-
274	-	-	-	-	-	-	-	-	-	-	-	-
275	-	-	-	-	-	-	-	-	-	-	-	-
276	-	-	-	-	-	-	-	-	-	-	-	-
277	-	-	-	-	-	-	-	-	-	-	-	-
278	-	-	-	-	-	-	-	-	-	-	-	-
279	-	-	-	-	-	-	-	-	-	-	-	-
280	-	-	-	-	-	-	-	-	-	-	-	-
281	-	-	-	-	-	-	-	-	-	-	-	-
282	-	-	-	-	-	-	-	-	-	-	-	-
283	-	-	-	-	-	-	-	-	-	-	-	-
284	<0.2	<4.0	150	250	260	<0.5	41.0	200	0	85.0	<2	260
285	-	-	-	-	-	-	-	-	-	-	-	-
286	-	-	-	-	-	-	-	-	-	-	-	-
287	-	-	-	-	-	-	-	-	-	-	-	-
288	-	-	-	-	-	-	-	-	-	-	-	-
289	-	-	-	-	-	-	-	-	-	-	-	-
290	-	-	-	-	-	-	-	-	-	-	-	-
291	-	-	-	-	-	-	-	-	-	-	-	-
292	-	-	-	-	-	-	-	-	-	-	-	-

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Table B1. continued

Site ID	Copper, dissolved (µg/L)	Hydroxide (mg/L)	Iron, dissolved (µg/L)	Lead, dissolved (µg/L)	Magnesium, dissolved (mg/L)	Manganese, dissolved (µg/L)	Mercury, dissolved (µg/L)	Nitrite (mg/L)	Phosphate, total (mg/L)	Potassium, dissolved (mg/L)	Selenium, dissolved (µg/L)
181	23	0	<100	<5.0	116.0	<2	-	<0.1	<0.02	5.5	5.8
182	19	0	<100	<5.0	113.0	<2	-	<0.1	<0.02	4.5	5.5
183	<10	0	<100	<5.0	18.6	<2	<0.10	<0.1	<0.02	3.3	<5.0
184	<10	0	<100	<5.0	88.7	<2	-	<0.1	0.026	5.0	12.6
185	<10	0	<100	<5.0	49.1	<2	-	<0.1	<0.02	3.1	<5.0
186	<10	0	<100	<10.0	120.0	<2	-	<0.1	0.036	3.9	11.3
187	<10	0	<100	<5.0	34.4	<2	-	<0.1	<0.02	3.4	<5.0
188	<10	0	<100	<5.0	27.1	2	-	<0.1	<0.02	3.2	<5.0
189	<10	0	8630	<15.0	82.7	210	-	<0.1	<0.02	5.6	<15.0
190	<10	0	<100	<10.0	140.0	<2	-	<0.1	<0.02	5.8	<10.0
191	38	0	<100	<5.0	88.2	<2	-	<0.1	<0.02	8.8	6.9
192	<10	0	<100	<5.0	113.0	<2	-	<0.1	<0.02	4.0	5.1
193	11	0	<100	<10.0	103.0	<2	<0.10	<0.1	0.023	4.3	<10.0
194	10	0	<100	<10.0	52.8	<2	-	<0.1	.044	3.5	13.9
195	<10	0	<100	<10.0	31.2	<2	-	<0.1	<0.02	2.7	<10.0
196	<10	0	<100	<5.0	50.7	<2	-	<0.1	<0.02	3.2	<5.0
197	<10	0	<100	<5.0	42.8	<2	-	<0.1	<0.02	2.2	<5.0
198	<10	0	<100	<5.0	49.1	<2	-	<0.1	<0.02	2.3	<5.0
199	24	0	<100	<5.0	148.0	<2	-	<0.1	<0.02	2.5	6.2
200	<10	0	<100	<5.0	45.9	<2	-	<0.1	<0.02	1.9	<5.0
201	<10	0	<100	<5.0	105.0	2	<0.10	-	<0.02	6.5	5.0
202	17	0	<100	<10.0	98.7	<2	-	-	<0.02	4.3	10.8
203	<10	0	<100	<5.0	65.1	<2	<0.10	-	<0.02	2.0	<5.0
204	<10	0	<100	<5.0	61.6	<2	<0.10	-	<0.02	2.0	<5.0
205	13	0	<100	<10.0	161.0	<2	-	-	<0.02	6.1	<10.0
206	<10	0	<100	<5.0	135.0	<2	-	-	<0.02	2.5	8.0

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Table B1. continued

Site ID	Copper, dissolved (µg/L)	Hydroxide (mg/L)	Iron, dissolved (µg/L)	Lead, dissolved (µg/L)	Magnesium, dissolved (mg/L)	Manganese, dissolved (µg/L)	Mercury, dissolved (µg/L)	Nitrite (mg/L)	Phosphate, total (mg/L)	Potassium, dissolved (mg/L)	Selenium, dissolved (µg/L)
207	30	0	<100	<5.0	65.1	<2	-	-	<0.02	2.0	5.3
208	<10	0	<100	<5.0	55.6	<2	-	<0.1	<0.02	3.9	12.5
209	10	0	<100	<5.0	39.8	14	-	<0.1	<0.02	3.7	<5.0
210	<10	0	<100	<5.0	69.7	<2	<0.10	<0.1	<0.02	1.8	10.0
211	10	0	<100	<5.0	51.5	<2	-	<0.1	<0.02	4.3	5.1
212	<10	0	<100	<5.0	64.8	<2	-	<0.1	<0.02	1.3	<5.0
213	74	0	<100	<5.0	112.0	<2	<0.10	<0.1	0.12	33.0	11.2
214	<10	0	<100	<5.0	55.3	<2	-	<0.1	<0.02	6.0	33.3
215	32	0	<100	<5.0	60.0	<2	-	<0.1	<0.02	2.1	8.0
216	26	0	<100	<5.0	59.2	<2	-	<0.1	<0.02	2.1	7.6
217	20	0	<100	<5.0	64.2	<2	-	<0.1	<0.02	2.7	8.1
218	<10	0	<100	<5.0	20.0	4	-	<0.1	<0.02	3.1	<5.0
219	<10	0	<100	<5.0	24.2	4	-	<0.1	<0.02	2.7	<5.0
220	63	0	<100	<5.0	43.1	<2	-	<0.1	<0.02	2.1	<5.0
221	<10	0	<100	<5.0	48.2	<2	<0.10	<0.1	<0.02	1.9	7.2
222	<10	0	<100	<5.0	53.1	<2	-	<0.1	<0.02	1.8	9.1
223	12	0	<100	<5.0	63.7	6	-	<0.1	<0.02	6.0	11.1
224	15	0	<100	<5.0	123.0	<2	-	<0.1	<0.02	5.2	57.7
225	15	0	<100	<5.0	46.1	<2	-	<0.1	<0.02	2.0	6.3
227	17	0	<100	<5.0	60.0	<2	-	<0.1	<0.02	2.4	7.1
228	12	0	<100	<5.0	61.2	<2	-	<0.1	<0.02	1.9	8.5
229	10	0	<100	<2.0	52.3	<2	<0.10	<0.1	<0.02	6.3	<2.0
230	<10	0	<100	<1.0	94.3	<2	-	<0.1	<0.02	5.1	8.1
231	<10	0	<100	<1.0	40.5	<2	-	<0.1	<0.02	2.1	1.8
232	15	0	<100	<1.0	70.2	<2	<0.10	<0.1	<0.02	2.9	4.0
233	<10	0	<100	<1.0	72.5	<2	<0.10	<0.1	<0.02	1.8	4.7

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Table B1. continued

Site ID	Copper, dissolved (µg/L)	Hydroxide (mg/L)	Iron, dissolved (µg/L)	Lead, dissolved (µg/L)	Magnesium, dissolved (mg/L)	Manganese, dissolved (µg/L)	Mercury, dissolved (µg/L)	Nitrite (mg/L)	Phosphate, total (mg/L)	Potassium, dissolved (mg/L)	Selenium, dissolved (µg/L)
234	<10	0	<100	<1.0	21.5	<2	-	<0.1	<0.02	2.2	2.5
235	<10	0	<100	<1.0	86.0	<2	-	<0.1	0.031	3.3	9.2
236	<10	0	<100	<2.0	112.0	<2	-	<0.1	<0.02	5.0	10.0
237	<10	0	<100	<1.0	80.5	<2	-	<0.1	<0.02	5.9	6.3
238	49	0	<100	<1.0	175.0	<2	-	<0.1	<0.02	4.1	12.8
239	23	0	<100	<2.0	196.0	29	-	<0.1	<0.02	<2	12.0
240	<10	0	<100	<1.0	42.0	3	<0.10	<0.1	<0.02	3.6	3.7
241	<10	0	<100	<1.0	84.3	<2	-	<0.1	<0.02	4.3	6.2
242	<10	0	<100	<1.0	65.9	3	<0.10	<0.1	0.039	3.3	12.4
243	<10	0	<100	<1.0	24.6	7	-	<0.1	<0.02	2.6	<1.0
244	<10	0	333	<1.0	254.0	148	-	0.30	3.44	8.0	30.0
256	<10	0	<100	5.2	57.8	<2	-	-	<0.02	2.7	5.0
257	<10	0	<100	2.1	91.0	<2	-	<0.1	<0.02	2.2	5.3
258	<10	0	<100	1.1	135.0	<2	-	<0.1	<0.02	2.4	9.1
259	<10	0	<100	1.4	118.0	<2	<0.10	<0.1	0.036	2.3	9.9
260	<10	0	<100	<1.0	139.0	<2	-	<0.1	<0.02	5.1	10.2
261	<10	0	<100	<1.0	76.1	<2	<0.10	<0.1	<0.02	2.3	4.9
262	<10	0	<100	<1.0	1.3	<2	<0.10	<0.1	0.032	1.1	<1.0
263	17	0	<100	1.1	38.6	<2	-	<0.1	<0.02	1.1	1.5
264	<10	0	107	2.2	24.4	10	-	<0.1	0.021	<1.0	<1.0
265	<10	0	<100	1.3	102.0	<2	-	<0.1	<0.02	2.4	6.1
266	<10	-	<100	<1.0	24.6	<2	-	-	-	<1.0	<1.0
267	85	0	<100	1.1	79.7	<2	<0.10	<0.1	<0.02	1.6	5.5
268	<10	0	595	<1.0	43.8	11	-	<0.1	<0.02	32.5	1.1
269	-	-	-	-	-	-	-	-	-	-	-
270	-	-	-	-	-	-	-	-	-	-	-

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Table B1. continued

Site ID	Copper, dissolved (µg/L)	Hydroxide (mg/L)	Iron, dissolved (µg/L)	Lead, dissolved (µg/L)	Magnesium, dissolved (mg/L)	Manganese, dissolved (µg/L)	Mercury, dissolved (µg/L)	Nitrite (mg/L)	Phosphate, total (mg/L)	Potassium, dissolved (mg/L)	Selenium, dissolved (µg/L)
271	-	-	-	-	-	-	-	-	-	-	-
272	-	-	-	-	-	-	-	-	-	-	-
273	-	-	-	-	-	-	-	-	-	-	-
274	-	-	-	-	-	-	-	-	-	-	-
275	-	-	-	-	-	-	-	-	-	-	-
276	-	-	-	-	-	-	-	-	-	-	-
277	-	-	-	-	-	-	-	-	-	-	-
278	-	-	-	-	-	-	-	-	-	-	-
279	-	-	-	-	-	-	-	-	-	-	-
280	-	-	-	-	-	-	-	-	-	-	-
281	-	-	-	-	-	-	-	-	-	-	-
282	-	-	-	-	-	-	-	-	-	-	-
283	-	-	-	-	-	-	-	-	-	-	-
284	20	0	20	4	39.0	<2	<0.2	<0.1	<0.01	2.2	3.7
285	-	-	-	-	-	-	-	-	-	-	-
286	-	-	-	-	-	-	-	-	-	-	-
287	-	-	-	-	-	-	-	-	-	-	-
288	-	-	-	-	-	-	-	-	-	-	-
289	-	-	-	-	-	-	-	-	-	-	-
290	-	-	-	-	-	-	-	-	-	-	-
291	-	-	-	-	-	-	-	-	-	-	-
292	-	-	-	-	-	-	-	-	-	-	-

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Table B1. continued

Site ID	Silver, dissolved (µg/L)	Sodium, dissolved (mg/L)	Sulfate (mg/L)	Total Alkalinity (mg/L)	Total Suspended Solids (mg/L)	Turbidity, (NTU)	Zinc, dissolved (µg/L)	Data source **
181	<2.5	235	534	462	<4.0	0.104	<40	UGS
182	<2.5	247	391	508	<4.0	0.122	<40	UGS
183	<2.5	133	100	256	<4.0	0.107	<40	UGS
184	<2.5	260	244	433	<4.0	1.65	41	UGS
185	<2.5	60.9	53	195	<4.0	0.586	<40	UGS
186	<5.0	356	317	566	<4.0	0.179	<40	UGS
187	<2.5	127	118	266	<4.0	0.202	<40	UGS
188	<2.5	71.9	50	213	<4.0	0.242	127	UGS
189	<7.5	624	262	553	19.2	120.0	<40	UGS
190	<5.0	334	476	476	<4.0	0.826	67	UGS
191	<2.5	149	232	474	4.8	1.450	<40	UGS
192	<2.5	244	553	394	<4.0	0.329	54	UGS
193	<5.0	377	330	617	<4.0	<0.1	<40	UGS
194	<5.0	378	297	590	<4.0	0.150	<40	UGS
195	<5.0	315	120	331	<4.0	<0.1	<40	UGS
196	<2.5	165	58	264	<4.0	0.153	<40	UGS
197	<2.5	73.9	33	257	<4.0	<0.1	<40	UGS
198	<2.5	54.8	41	300	<4.0	0.140	<40	UGS
199	<2.5	97.5	474	420	<4.0	<0.1	<40	UGS
200	<2.5	51.9	51	279	<4.0	0.166	43	UGS
201	<2.5	166	443	425	<4.0	0.013	<40	UGS
202	<5.0	318	454	392	8.0	0.359	<40	UGS
203	<2.5	64	151	387	<4.0	0.125	100	UGS
204	<2.5	112	1455	379	<4.0	<0.1	<40	UGS
205	<5.0	434	525	569	<4.0	<0.1	45	UGS
206	<2.5	115	44	372	<4.0	<0.1	55	UGS

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Table B1. *continued*

Site ID	Silver, dissolved (µg/L)	Sodium, dissolved (mg/L)	Sulfate (mg/L)	Total Alkalinity (mg/L)	Total Suspended Solids (mg/L)	Turbidity, (NTU)	Zinc, dissolved (µg/L)	Data source **
207	<2.5	37.5	497	326	<4.0	0.703	290	UGS
208	<2.5	151	81	341	<4.0	1.97	<40	UGS
209	<2.5	90.7	152	403	<4.0	0.171	<40	UGS
210	<2.5	60.5	55	376	<4.0	<0.1	50	UGS
211	<2.5	71.1	86	215	<4.0	0.277	82	UGS
212	<2.5	58.4	116	418	<4.0	<0.1	<40	UGS
213	<2.5	119	134	610	<4.0	0.135	40	UGS
214	<2.5	164	19	367	<4.0	<0.1	<40	UGS
215	<2.5	87.9	114	438	<4.0	0.173	54	UGS
216	<2.5	89.6	117	451	<4.0	3.23	1110	UGS
217	<2.5	45.8	158	331	<4.0	0.114	42	UGS
218	<2.5	122	113	289	<4.0	0.175	<40	UGS
219	<2.5	71	66	282	5.2	4.820	<40	UGS
220	<2.5	76	86	384	<4.0	0.393	<40	UGS
221	<2.5	89.5	71	392	<4.0	0.243	290	UGS
222	<2.5	70.7	71	384	<4.0	3.450	<40	UGS
223	<2.5	219	144	522	<4.0	0.673	260	UGS
224	<2.5	316	19	495	<4.0	0.205	44	UGS
225	<2.5	70	68	356	<4.0	2.11	<40	UGS
227	<2.5	83.1	83	446	<4.0	0.273	122	UGS
228	<2.5	63.6	57	410	<4.0	0.609	<40	UGS
229	<1.0	361	89	279	14.0	89.0	<40	UGS
230	<0.5	182	150	266	<4.0	0.682	63	UGS
231	<0.5	97.6	35	264	<4.0	<0.1	<40	UGS
232	<0.5	223	115	279	<4.0	2.200	99	UGS
233	<0.5	61.7	160	387	<4.0	<0.1	<40	UGS

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Table B1. continued

Site ID	Silver, dissolved (µg/L)	Sodium, dissolved (mg/L)	Sulfate (mg/L)	Total Alkalinity (mg/L)	Total Suspended Solids (mg/L)	Turbidity, (NTU)	Zinc, dissolved (µg/L)	Data source **
234	<0.5	89.9	65	271	<4.0	0.947	<40	UGS
235	<0.5	148	129	510	4.8	0.415	<40	UGS
236	<1.0	351	760	367	<4.0	0.147	<40	UGS
237	<0.5	212	267	256	8.8	6.19	45	UGS
238	<0.5	278	514	564	<4.0	0.528	58	UGS
239	<1.0	382	504	476	<4.0	0.147	53	UGS
240	<0.5	115	197	185	<4.0	0.928	352	UGS
241	<0.5	291	311	502	<4.0	<0.1	111	UGS
242	<0.5	272	255	643	<4.0	<0.1	<40	UGS
243	<0.5	69.9	75	280	<4.0	0.944	<40	UGS
244	<0.5	126	1810	289	2560.0	6206.0	46	UGS
256	<0.5	36.0	63	295	<4.0	0.356	<40	UGS
257	<0.5	65.6	217	362	<4.0	0.339	<40	UGS
258	<0.5	119.0	510	387	<4.0	0.241	<40	UGS
259	<0.5	181.0	439	413	79.3	23.700	<40	UGS
260	<0.5	109.0	645	369	<4.0	0.749	<40	UGS
261	<0.5	56.7	158	348	<4.0	0.264	<40	UGS
262	<0.5	272.0	88	520	<4.0	0.765	<40	UGS
263	<0.5	26.2	26	344	<4.0	0.197	60	UGS
264	<0.5	11.8	19	207	107.0	70.700	<40	UGS
265	<0.5	192.0	251	459	11.2	32.600	<40	UGS
266	<0.5	12.4	-	-	-	-	<40	UGS
267	<0.5	39.4	48	394	<4.0	0.492	177	UGS
268	<0.5	15.7	<20	336	<4.0	8.500	<40	UGS
269	-	-	-	-	-	-	-	UGS
270	-	-	-	-	-	-	-	UDDW

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Table B1. continued

Site ID	Silver, dissolved (µg/L)	Sodium, dissolved (mg/L)	Sulfate (mg/L)	Total Alkalinity (mg/L)	Total Suspended Solids (mg/L)	Turbidity, (NTU)	Zinc, dissolved (µg/L)	Data source **
271	-	-	-	-	-	-	-	UDDW
272	-	-	-	-	-	-	-	UDDW
273	-	-	-	-	-	-	-	UDDW
274	-	-	-	-	-	-	-	UDDW
275	-	-	-	-	-	-	-	UDDW
276	-	-	-	-	-	-	-	UDDW
277	-	-	-	-	-	-	-	UDDW
278	-	-	-	-	-	-	-	UDDW
279	-	-	-	-	-	-	-	UDDW
280	-	-	-	-	-	-	-	UDDW
281	-	-	-	-	-	-	-	UDDW
282	-	-	-	-	-	-	-	UDDW
283	-	-	-	-	-	-	-	UDDW
284	<0.5	75	57	220	-	0.100	<10	Sunrise
285	-	-	-	-	-	-	-	UDDW
286	-	-	-	-	-	-	-	UDDW
287	-	-	-	-	-	-	-	Sunrise
288	-	-	-	-	-	-	-	UDAF
289	-	-	-	-	-	-	-	UDAF
290	-	-	-	-	-	-	-	UDAF
291	-	-	-	-	-	-	-	UDAF
292	-	-	-	-	-	-	-	UDAF

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APPENDIX C
POTENTIAL SOURCES OF GROUND-WATER QUALITY DEGRADATION

POTENTIAL SOURCES OF GROUND-WATER QUALITY DEGRADATION

Introduction

This discussion is taken directly from Lowe and others (2002). The type and amount of dissolved constituents determine the beneficial use of water. Ground-water quality standards for drinking water are provided in table A1. Degradation in ground-water quality may be due to either natural sources or contamination associated with human activities. Many constituents dissolved in water are derived from geologic materials such as rock or sediment. As discussed below, natural sources of nitrogen which may be oxidized to nitrate do occur, but are not considered common. Thomas and Taylor (1946) noted that nitrate concentrations more than a few mg/L in shallow ground water is considered an indication of water-quality degradation typically associated with human-related activities; water-quality data collected from 124,000 water wells nationwide support the designation of 3 mg/L as a division between human- and natural-nitrate influences (Madison and Brunett, 1985). In general, elevated nitrate levels in ground water are primarily obtained from wells less than 100 feet (30 m) deep (Madison and Brunett, 1985), and an inverse relationship exists between well depth and nitrate concentration (Spruill, 1983).

Natural Sources of Water-Quality Degradation

Dissolved Solids

The ultimate source of most chemical constituents dissolved in water is the mineral assemblage in rocks at or near the land surface; other important factors determining the composition of water passing over or through rock masses and unconsolidated deposits include, but are not limited to, the purity and crystal size of minerals, rock and soil texture and porosity, regional structure, the degree of fracturing, the length of previous exposure time, and rock temperatures (Hem, 1985). The mineral assemblage in the rock unit determines the type of dissolved constituents. In mining areas, dissolved metals, arsenic, and sulfide (which readily oxidizes to sulfate) can contribute to water-quality degradation. Rock units rich in evaporite deposits, sulfates, and chlorides can degrade water quality. Water from carbonate rock units can be hard from dissolved calcium and magnesium. Silica-rich rock units, such as volcanic rocks, contribute negligible dissolved material to ground water. In general, total-dissolved-solids concentrations increase with increased residence time and longer ground-water flow paths. Climate and biochemical factors play secondary roles in determining the nature and distribution of dissolved solids in ground water (Hem, 1985).

Nitrate

Natural sources of nitrogen contribute, to some extent, nitrate concentrations in ground water; these natural sources include atmospheric, biologic, and geologic components. Ground water with less than 0.2 mg/L nitrate is assumed to represent natural background concentrations; ground water with nitrate concentrations between 0.21 and 3.0 mg/L is considered transitional, and may or may not represent human influence (Madison and Brunett, 1985).

Atmospheric nitrogen: Nitrogen oxides are present in the atmosphere and can undergo various chemical reactions that produce hydrogen ions, eventually converting the nitrogen to nitrate or ammonia, reducing the pH of precipitation (Hem, 1985). Concentrations of nitrate in rainfall typically range from 0.1 to 0.7 mg/L (National Academy of Sciences, 1978). In Smith Valley, Colorado, during 1986-93, the mean annual average-precipitation-weighted concentration of ammonia was 0.30 mg/L and of nitrate was 0.76 mg/L (Colorado State University at Fort Collins, National Atmospheric Deposition Program/National Trends Network Coordination Office, written communication, in Seiler, 1996). Seiler (1996) estimated the total-nitrogen contribution from precipitation per year in Lemmon Valley, Nevada, is 0.91 kilogram (2 lbs). Data collected from rainfall in the United States indicate, in general, that nitrogen concentrations are lower in coastal areas than inland (Junge, 1958, in Feth, 1966). Not all nitrogen introduced by rainfall is natural in origin. Human activities contribute approximately 50 percent of the fixed nitrogen from rainfall, the combustion of fossil fuels being the largest source of this anthropogenic nitrogen (National Academy of Sciences, 1978).

Some portion of nitrogen in rainfall is removed through volatilization, used by plants, or denitrified in saturated soils rich in organic matter (Seiler, 1996); Walker and others (1973) estimated 12.5 to 25 percent of the nitrogen in precipitation reaches ground water.

Biologic nitrogen: Natural sources of biologic nitrogen include decay of organic material (primarily from plant remains) and animal excrement. The accumulation of natural nitrogen in caves from bat guano or in coastal breeding grounds from seabirds is well known, and these deposits are sources of commercial nitrogen fertilizer; however, the extent to which these sources contribute to nitrate in ground water has not been well documented (Madison and Brunett, 1985). Water pools in Carlsbad Caverns, New Mexico, near cave areas frequented by bats have yielded water samples having more than 1,000 mg/L of nitrate (Hem, 1985).

Decay of natural organic material in the subsurface also can contribute nitrogen to ground water (Seiler, 1996). Native vegetation that had been destroyed by dryland farming was shown by Kreitler and Jones (1975) to have contributed high concentrations of nitrate to ground water in west-central Texas; the average nitrate concentration (nitrate reported as nitrate) for 230 sampled wells was 250 mg/L, and the highest nitrate concentration exceeded 3,000 mg/L. Patt and Hess (1976) identified naturally occurring, buried plant material as a possible source of nitrate-related water-quality degradation in domestic wells near Las Vegas, Nevada.

Geologic nitrogen: Many investigators have recognized the contribution of bedrock nitrogen to nitrate concentrations in water (Mansfield and Boardman, 1932; Gulbrandsen, 1974; Boyce and others, 1976; Holloway and others, 1998; Holloway and Dahlgren, 1999). The following is a summary of types of rocks that have contributed nitrogen to nitrate concentrations in ground and surface water. Many of the rock types described below are also present in Sanpete Valley including volcanic and sedimentary rocks (for example, sandstone, limestone, shale, coal-rich deposits, evaporites, and playa-type deposits), and alluvial sediments. A more detailed discussion regarding natural sources of nitrate is presented in a special evaluation of potential sources of nitrate contamination in ground water in Cedar Valley, Iron County, Utah, by Lowe and Wallace (2001).

Release of nitrogen through weathering of nitrogen-bearing rock can potentially affect the quality of water and soil (Holloway and others, 1998). The term "geologic nitrogen" has been used to describe the source of high-nitrogen soils on alluvial fans in the San Joaquin Valley of California (Sullivan and others, 1979; Strathouse and others, 1980), and sedimentary rocks in Nebraska (Boyce and others, 1976). Holloway and others (1998) analyzed rocks in the Mokelumne River watershed, California, to determine if bedrock could be a source of stream-water nitrate and showed that metasedimentary rocks containing appreciable concentrations of nitrogen contributed a large amount of nitrate to surface waters.

Sedimentary rocks that form in an organic-rich depositional environment can include nitrogen as residual organic matter or as ammonium minerals (Holloway and others, 1998). Ammonium concentrations in rock associated with hydrocarbons are a function of fluid migration and hydrocarbon maturation (Williams and others, 1989; Williams and others, 1993). The accumulation of ammonium in illite above and below coal seams in the Cumnock Formation of North Carolina indicates that nitrogen is transported from the organic matter in the coal seam to mineral sites where ammonium substitutes for potassium (Krohn and others, 1988).

Natural nitrate is also associated with sediments typical of arid environments such as playa-lake, alluvial-fan, and braided-stream deposits, primarily associated with atmospheric nitrogen. Rock-salt crusts in Chilean playas contain soda niter (Stoertz and Ericksen, 1974) associated with oxidized ammonium salts that were subsequently leached and mobilized as nitrate in ground water. High nitrate concentrations in ground water from wells in Paradise Valley, Arizona, are partly attributed to natural sources of nitrate, possibly from ammonium chloride that was produced and trapped in volcanic rocks, and with subsequent weathering, leaching, and oxidization, eventually was transported as nitrate by ancient streams (Silver and Fielden, 1980). Nitrate exists as water-soluble salts in zones below leached soils in evaporative playa environments in southeastern California, and is associated with Tertiary playa deposits and beds of saline and gypsiferous shale, sandstone, and limestone (Noble, 1931).

Ground-Water Contamination from Agricultural Activities

Many agricultural activities can potentially degrade water-quality, including irrigation (especially flood irrigation), pesticide application, fertilizer application, raising of nitrogen-fixing crops, livestock grazing, and feed-lot operations. Increased total-dissolved-solids concentrations in ground water is the principal concern related to irrigation practices. Ground-water contamination associated with pesticides is relatively uncommon in Utah; during calendar year 2000, no pesticides were detected in ground water in 318 samples collected from wells and springs in Utah and analyzed by the Utah Department of Agriculture and Food (Ivan Sanderson, Utah Department of Agriculture and Food, verbal communication, November 30, 2000). Nitrate and other forms of nitrogen are the principal contaminants of concern with respect to fertilizer application, some crop types, grazing, and feed-lot operations.

Irrigation Practices

The role of irrigation for crop-production expansion increased during the last century in the United States (Feth, 1966). Shallow wells in areas where flood irrigation is common typically have high total-dissolved-solids concentrations. The dissolved solids are derived from naturally occurring shallow ground water and from irrigation. Excess irrigation and return-irrigation water leach soil in valley lowlands where ground water is within the zone of capillary action and the accompanying "alkali" salt-rich soil (Richardson, 1907). These dissolved salts in the soil are concentrated by flood-irrigation processes as near-land-surface water evaporates (Pipkin, 1994). Reducing rates of flood irrigation, in some areas, can produce additional salts in irrigation return flows as the quantity of salts removed by periodic leaching decreases (National Academy of Sciences, 1978). To leach out these unwanted salts and maintain soil salinity within crop tolerance, the amount of water applied must exceed plant requirements (Feth, 1966).

Leaching of soil by sprinkler irrigation water occurs at a much lower rate. In Panguitch Valley, Sevier County, Utah, Thiros and Brothers (1993) demonstrated that sprinkler irrigation increased moisture content only in the upper 1 to 3 feet (0.3-0.9 m) of the soil zone. Between 1975 and 1989, the percentage of irrigated land in Sanpete Valley using sprinkler irrigation methods increased from 10 to 50 percent (Wilberg and Heilweil, 1995).

Agricultural Fertilizer

Nationwide, the largest single source of anthropogenic nitrogen is fertilizer, due to an increase in chemical fertilizer application occurring since the end of World War II (National Academy of Sciences, 1978). In Utah, 88,000 tons of fertilizers were used during the 1969-70 period (Geraghty and others, 1973, plate 54). The amount of fertilizer typically applied varies with crop type. The amount of nitrogen from fertilizers depends on: (1) the amount and type of fertilizer applied, (2) the pH of the soil to which it is applied, (3) the air temperature at the time of application, and (4) the amount of water applied after the fertilizer application (Seiler, 1996). Fertilizer-use efficiency depends more on crop-production management than on fertilizer-application rates; farms using large quantities of fertilizer to optimize crop yield may be using the nutrients more efficiently and producing less leachable nitrogen than farms applying less fertilizer to produce average yields (1971 Illinois Pollution Control Board in National Academy of Sciences, 1978). However, excess fertilizer application is generally avoided, based on economics alone. The 1971 Illinois Pollution Control Board reported crop-price increases from 1971 to 1975 (2.2 times for corn) accompanied by nitrogen fertilizer increases of a factor of 3.4, and concluded that economics alone would demand that farmers carefully monitor nitrogen fertilizer application rates.

The role of air temperature and soil pH varies in nitrification/denitrification processes associated with fertilizers. Both parameters are inherent properties, independent of external control by fertilizer users. Certain pH and temperature conditions can facilitate nutrient uptake, but can also impede nutrient uptake of nitrogen, and ultimately contribute to water-quality degradation. For example, both nitrification and denitrification rates are higher during warm temperatures than cold temperatures because cold temperatures slow the functioning of biologic organisms important to both processes (National Academy of Sciences, 1978). Prevailing basic or acidic conditions also can impact the nitrification/denitrification process. Under certain soil/liquid pH conditions, ammonia gas is released into the atmosphere. For example, under neutral or acidic conditions, nitrogen is present as NH_4^+, and with increasingly basic conditions is transformed to ammonia which can be released as N_2 gas to the atmosphere (Canter, 1997). When the redox potential of the ground water declines, denitrification of nitrate can also occur (Canter, 1997). Biologic denitrification can occur in the presence of organic carbon in ground water. In this process, microorganisms utilize nitrate as an electron acceptor, and can eventually be reduced to nitrogen gas (Canter, 1997). Fertilizing intensity can also affect the pH of the soil in terms of oxidation potential. If the amount of fertilizer applied exceeds that required by the crops, nitrate concentrations may increase in ground water. As nitrate becomes available through oxidation, it can be leached from the root zone (Canter, 1997).

Nitrogen fertilizer is either used by plants, lost through denitrification (biological reduction of nitrate to nitrogen gas), leached into the ground-water system, or immobilized in soil materials (National Academy of Sciences, 1978, p. 239). Westerman and others (1972) estimated 22 to 25 percent of fertilizer applied to test plots in Iowa during the spring of 1966 was unaccounted for at the end of the crop cycle and attributed this loss primarily to denitrification. Although denitrification of fertilizer may account for nitrogen not used by crops, leaching of nitrogen-based fertilizer to ground water does occur, and the extent to which this contributes to ground-water quality degradation depends partly on irrigation practices.

In non-irrigated lands (dry farms), leaching of nitrate in the upper soil zones generally occurs during spring snowmelt. Nitrogen fertilizers within the upper few feet of soil are incorporated into organic matter, stabilize, and become less susceptible to leaching (Allen and others, 1973). Additionally, nitrate in soils in non-irrigated areas migrate through the soil profile at rates ideal for denitrification (Pratt and others, 1972). In general, nitrogen from fertilizers does not pollute ground water beneath non-irrigated farms, whereas poor farm-irrigation management promotes nitrogen leaching into the ground-water system (Sommerfeldt and Smith, 1973).

Muir and others (1973) reported that the intensity of irrigation, particularly in areas underlain by coarse-grained materials, controls nitrogen contamination of ground water. Irrigation water leaches nitrate from soil and into the ground-water system through the same processes discussed for leaching of "alkali" salts discussed above. Ground water under heavily fertilized, irrigated crop lands can contain high concentrations of nitrate (National Academy of Sciences, 1978). Adriano and others (1972) report nitrate-as-nitrogen concentrations 10 to 50 feet (3-15 m) below row crops in the Santa Ana Basin of California range from 36 to 122 mg/L; water from wells completed in deeper aquifers below these sites currently average only 5.8 mg/L nitrate as nitrogen, but some wells in the basin exceed 20 mg/L nitrate as nitrogen. Most data based on ground-water studies below California crop lands indicate nitrate levels are typically about 25 to 30 mg/L nitrate as nitrogen (National Academy of Sciences, 1978). However, more efficient water use through decreasing irrigation rates is a viable method to reduce the amount of nitrate leached into the ground water and thus lost as fertilizer nitrogen (National Academy of Sciences, 1978).

Nitrogen-Fixing Crops

Some plants, principally legumes, have the ability to fix nitrogen into the soil; this nitrogen could subsequently be leached into the ground-water system. Alfalfa is the most efficient of the legumes with respect to nitrogen fixation. The actual fixation of atmospheric nitrogen is by bacteria of the genus Rhizobium, symbiotic with the legumes. Although it is prudent to provide some nitrogen fertilizer to young legumes to keep them supplied with nutrients until the Rhizobia are stabilized on their roots (Tisdale and Nelson, 1975), additional fertilization application is ineffectual. Nitrogen fixation by legumes is at a maximum only when the level of nitrogen available in the soil is at a minimum, and large or continued applications of nitrogen cause a reduction in the activity of the Rhizobia (Tisdale and Nelson, 1975).

Animal Grazing and Feed-Lot Operations

Water-quality degradation associated with livestock operations is related to the intensity of operation in terms of animal density. Dispersed grazing on rangelands presents no obvious environmental problems, but a trend of increasing animal-production efficiency by high-density confinement of poultry, hogs, and cattle exists, along with the concentrated accumulation of animal wastes (National Academy of Sciences, 1978). Egg-laying facilities may house up to one million confined birds, and pork operations which house animals from birth to finishing are becoming common (Nye, 1973).

From a water-quality standpoint, manure is probably the most important component of animal waste produced from feed-lot operations. Manure is a combination of feces, urine, bedding litter, and feed wastage (Brady, 1974). The chemical composition of manure varies depending on: (1) animal species, (2) age and condition of the animals, (3) nature and amount of litter, and (4) handling and storage of the litter before it is spread on the land or otherwise disposed (Brady, 1974). The average cow, horse, and pig excretes 156, 128, and 150 pounds of nitrogen per year, respectively (Van Vuren, 1949); the waste produced by one horse over a year contains as much nitrogen as the domestic sewage produced by a family of four for the same period (Hantzsche and Finnemore, 1992).

Besides manual waste removal (from cleaning processes) and natural removal by storm runoff, four other possible fates exists for nitrogen in manure: (1) accumulation in the soil, (2) percolation into unconsolidated deposits below the soil zone as ammonium, nitrate, and soluble organic compounds, (3) denitrification, and/or (4) atmospheric loss as ammonia and volatile bases (National Academy of Sciences, 1978). Under warm, moist conditions, urea hydrolyzes rapidly to form NH_3 and CO_2; this process can account for 25 to 90 percent of the nitrogen in urine (Stewart, 1970), or approach 50 percent of the nitrogen in urine and feces combined (Adriano and others, 1974). Snow cover prevents volatilization of nitrogen as ammonia (Lauer and others, 1976), and only 30 percent of nitrogen in manure applied to the land surface is lost to the atmosphere when the air temperature is 50°F (10°C) (Vinten and Smith, 1993). Low infiltration rates of active feed lots from hydrophilic substances in manure, and soil compaction caused by hoof action also tends to promote volatilization (Mielke and others, 1974). Nitrogen transferred into the atmosphere due to volatilization as ammonia is commonly transferred by wind away from the immediate vicinity of the feed lot, sometimes creating unpleasant odors, but ultimately contributing to nitrogen loading of nearby areas, especially lakes (Hutchinson and Viets, 1969).

Major controls on ground-water contamination from animal feed lots and their associated treatment and disposal facilities include: (1) runoff and infiltration from the feed lots themselves, (2) runoff and infiltration from waste products collected and disposed on land, and (3) seepage and infiltration through the bottoms of waste lagoons (Miller, 1980). Based on analysis of water from more than 5,000 wells and springs in Missouri, Keller and Smith (1967) reported 42 percent of the ground-water sources yielded samples containing more than 5 mg/L nitrate as nitrogen and reported the dominant source as nitrogenous waste from livestock feed lots. More than 20 percent of samples from 800 wells in Sussex County, Delaware, where millions of chickens are raised annually, exceeded the drinking-water standard of 10 mg/L nitrate as nitrogen; the average nitrate as nitrogen concentration in ground water sampled at chicken farms was 14 mg/L (Robertson, 1979).

Ground-Water Contamination from Septic-Tank Systems

Though commonly treated as non-point sources of ground-water quality degradation, septic-tank systems are potential point sources of pollution, because each septic-tank system has an associated discrete plume of wastewater (Harman and others, 1996; Canter, 1997). Localized contamination, such as effluent from a disposal system entering a nearby well, can occur in almost any hydrogeologic setting (Madison and Brunett, 1985).

Harman and others (1996) delineated a plume of effluent in an unconfined sand aquifer below a septic system servicing a school in Ontario, Canada. The septic system produced a 50-foot-wide (15 m) plume core 360 feet (110 m) downgradient from the septic-system tile bed with nitrate-as-nitrogen concentrations ranging from 20 to 120 mg/L (Harman and others, 1996). Harman and others (1996) estimated the ground-water flow velocity at the site to be about 330 feet (100 m) per year; thus the delineated plume represents only about 1 year of effluent loading. This case study shows that the placement of septic-tank systems with respect to water wells and springs, for example, should be considered in addition to overall density and lot size.

In urban or suburban areas where high densities of individual septic-tank systems are used, they contribute large quantities of wastes and have the potential to contaminate large parts of water-supply aquifers (Madison and Brunett, 1985). Wastewater from septic-tank systems contains many constituents which can cause water-quality degradation.

Pathogens

As the effluent from a septic tank soil-absorption system leaves the drain field and percolates into the underlying soil, it can have high concentrations of pathogens, such as viruses and bacteria. Organisms such as bacteria can be mechanically filtered by fine-grained soils and are typically removed after traveling a relatively short distance in the unsaturated zone. However, in coarse-grained soils, or soils containing preferential flow paths such as cracks, worm burrows, or root holes, these pathogens can reach the water table. Pathogens can travel up to 40 feet (12 m) in the unsaturated zone in some soils (Franks, 1972). Some viruses can survive up to 250 days (U.S. Environmental Protection Agency, 1987), which is the minimum ground-water travel time for public water-supply wells or springs to be separated from potential biological contamination sources.

Household and Industrial Chemicals

Many household and industrial chemicals are commonly disposed of through septic systems and, unless they volatilize easily, are not remediated by percolation through soils in the unsaturated zone. Contamination from these chemicals can be minimized by reducing their disposal via septic-tank systems, maximizing the potential for dilution of household and industrial chemicals that do reach ground water (Lowe and Wallace, 1999a).

Phosphate

Phosphate, typically derived from organic material and some detergents, is discharged from septic-tank systems (Fetter, 1988). While phosphate (and phosphorus) causes eutrophication (increases in nutrient content and consequent oxygen deficiency) of surface waters (Fetter, 1988), it is generally not associated with water-quality degradation from septic-tank systems (Lowe and Wallace, 1999a). Phosphates are removed from septic-tank system effluent by adsorption onto fine-grained soil particles and by precipitation with calcium and iron (Fetter, 1988). In most soils, complete removal of phosphate from septic-tank effluent is common (Franks, 1972).

Nitrate

Ammonia and organic nitrogen are commonly present in effluent from septic-tank systems, mostly from urine. Unlike animal wastes in feed-lot operations, waste in septic-tank systems is generally not exposed to the atmosphere, temperature is low, moisture is high, and air movement is inhibited; these conditions minimize ammonia volatilization in some septic tanks and drain fields (Wells and Krothe, 1989; Aravena and others, 1993). Although individual humans produce less nitrogen than individual farm animals, more of the nitrogen produced by animals is lost to the atmosphere before reaching ground water (Seiler, 1996).

Typically, almost all ammonia is converted into nitrate before leaving the septic tank soil-absorption system drain field. Once nitrate passes below the zone of aerobic bacteria and the roots of plants, negligible attenuation takes place as it travels farther through the soil (Franks, 1972). Once in ground water, nitrate becomes mobile and can persist in the environment for long periods. Areas having high densities of septic-tank systems risk elevated nitrate concentrations reaching unacceptable levels. In the early phases of ground-water quality degradation associated with septic-tank systems, nitrate is likely to be the only pollutant detected (Deese, 1986). Regional nitrate contamination from septic-tank discharge has been documented on Long Island, New York, where many densely populated areas without sewer systems exist (Fetter, 1988).

A typical single-family septic-tank system discharges about 400 gallons (1,500 L) of effluent per day containing nitrate concentrations ranging from 30 to 80 mg/L (Hansen, Allen, and Luce, Inc., 1994). The U.S. Environmental Protection Agency maximum contaminant level for drinking water (Utah ground-water quality standard) for nitrate is 10 mg/L. Therefore, distances between septic tank soil-absorption system drain fields and sources of culinary water must be sufficient for dilution of nitrate in the effluent to levels below the ground-water quality standard.

Other Sources

Dynamite and other explosives contain nitrogen which can contribute to the degradation of ground-water quality. Van Denburgh and others (1993) documented nitrogen contamination at a Nevada facility which processed munitions. Mining activities can cause concentrations of sulfide, dissolved metals, and, if cyanide or nitric acids are used in ore processing, nitrogen. Industrial manufacturing can produce various potential ground-water contaminants; the production of ammonia, ammonium nitrate fertilizers, and nitric acid are sources of potential nitrogen contamination (Davis, 1973). We did not identify any of these activities in Sanpete Valley. Landfills and community sanitary sewage treatment plants are also potential sources of water-quality degradation, including nitrogen compounds.

APPENDIX D
POTENTIAL CONTAMINANT INVENTORY

Table D1. *Inventory of potential ground-water contaminants in southern Sanpete and central Sevier Valleys (inventory performed October 2007).*

SITE #[1]	POTENTIAL CONTAMINANT	LOCATION/SOURCE DESCRIPTION	POLLUTANT
1	AFO[2]	small scale animal feeding operation	fertilizers, manure, nitrate
2	AFO	small scale animal feeding operation	fertilizers, manure, nitrate
3	AFO	small scale animal feeding operation	fertilizers, manure, nitrate
4	Junk Yard/Salvage	junk site	metals, solvents, petroleum
5	Mining	quarry	metals, solvents, petroleum
6	AFO	elk ranch	fertilizers, manure, nitrate
7	Large Lawn	cemetery	pesticides, fertilizer
8	Storage Tank	gravity driven gas tank	petroleum
9	FCAF[3]	abandoned animal feeding operation	fertilizers, manure, nitrate
10	Storage Tank	gravity driven gas tank	petroleum
11	Storage Tank	2 gravity driven gas tank, gas pump	petroleum
12	Storage Tank	gravity driven gas tank	petroleum
13	Storage Tank	gravity driven gas tank	petroleum
14	Storage Tank	2 gravity driven gas tank	petroleum
15	Business	beauty salon	metals, solvents
16	FCAF, Junk/salvage	abandoned animal feeding operation, junk yard/salvage	fertilizers, manure, nitrate, metals, solvents
17	FCAF	corral, abandoned animal feeding operation	fertilizers, manure, nitrate
18	Business	RV dumping	metals, solvents
19	AFO	animal feeding operation	fertilizers, manure, nitrate
20	Service Station	gas station	metals, petroleum, solvents
21	FCAF	abandoned animal feeding operation	fertilizers, manure, nitrate
22	Large Lawn	ball park	pesticides, fertilizer
23	Storage Tank	gravity driven gas tank	petroleum
24	Mining	abandoned gravel pit/gravity driven gas tank/lumber junk	metals, solvents, petroleum
25	Storage Tank	gravity driven gas tank	petroleum
26	AFO	barns, animal feeding operation	fertilizers, manure, nitrate
27	FCAF	abandoned animal feeding operation	fertilizers, manure, nitrate
28	Storage Tank	2 gravity driven gas tank	petroleum
29	Storage Tank	gravity driven gas tank	petroleum
30	Storage Tank	gravity driven gas tank	petroleum
31	AFO	animal feeding operation	fertilizers, manure, nitrate

[1]Site # corresponds to ID on plate 2; [2]AFO-concentration of animals and/or feed lot (no specified number of animals); [3]FCAF-former concentration of animals and/or feed lot

Table D1. continued

SITE #[1]	POTENTIAL CONTAMINANT	LOCATION/SOURCE DESCRIPTION	POLLUTANT
32	Mining	gravel pit	metals, solvents, petroleum
33	Service Station	service station	solvents, petroleum
34	Large Lawn	cemetery	pesticides, fertilizer
35	Large Lawn	ball park	pesticides, fertilizer
36	AFO	animal feeding operation	fertilizers, manure, nitrate
37	AFO	animal feeding operation, large scale	fertilizers, manure, nitrate
38	Service Station	service station	petroleum, solvents
39	FCAF	abandoned animal feeding operation	fertilizers, manure, nitrate
40	Storage Tank	gravity driven gas tank	petroleum
41	Storage Tank	gravity driven gas tank	petroleum
42	FCAF	abandoned animal feeding operation	fertilizers, manure, nitrate
43	FCAF	abandoned animal feeding operation	fertilizers, manure, nitrate
44	AFO	dairy farm	fertilizer, manure, nitrate
45	Service Station	car repair	metals, solvents, petroleum
46	AFO	ostrich farm	fertilizers, manure, nitrate
47	FCAF	abandoned animal feeding operation	fertilizers, manure, nitrate
48	Storage Tank	gravity driven gas tank	petroleum
49	FCAF	abandoned poultry	fertilizers, manure, nitrate
50	FCAF	abandoned animal feeding operation	fertilizers, manure, nitrate
51	Large Lawn	golf course	pesticides, fertilizer
52	Business	taxidermy, kennels	manure, nitrate, metals, solvents
53	FCAF	abandoned swine farm	fertilizers, manure, nitrate
54	AFO	corrals	fertilizers, manure, nitrate
55	AFO	corrals	fertilizers, manure, nitrate
56	Mining	quarries	metals, solvents, petroleum
57	Mining	quarries	metals, solvents, petroleum
58	Mining	quarries	metals, solvents, petroleum
59	Mining	quarries	metals, solvents, petroleum
60	Mining	quarries	metals, solvents, petroleum
61	Mining	gravel pit	metals, solvents, petroleum
62	AFO	large dairy cattle operation	fertilizer, manure, nitrate
63	Large Lawn	cemetery	pesticides, fertilizer
64	Industry	transformer substation, local power supply	PCBs, metals, solvents
65	Grazing	sheep grazing	manure, nitrate
66	Corral	horses	manure, nitrate

[1]Site # corresponds to ID on plate 2; [2]AFO-concentration of animals and/or feed lot (no specified number of animals); [3]FCAF-former concentration of animals and/or feed lot

Table D1. continued

SITE #[1]	POTENTIAL CONTAMINANT	LOCATION/SOURCE DESCRIPTION	POLLUTANT
67	Storage Tank	gravity driven gas tank	petroleum
68	Storage Tank	gravity driven gas tank	petroleum
69	Corral	abandoned corral	manure, nitrate
70	FCAF	abandoned farm operation, manure, silage, old barn structure	fertilizers, manure, nitrate
71	Storage Tank	gravity driven gas tank	metals, solvents, petroleum
72	Corral	abandoned corral	manure, nitrate
73	Corral	abandoned corral, silage	manure, nitrate
74	Grazing	cows grazing, unconfined area	manure, nitrate
75	Corral	corral	manure, nitrate
76	Corral	former corral, some farm equipment, silage, tractors	manure, nitrate, metals
77	Corral	abandoned corral	manure, nitrate
78	Corral	abandoned corral	manure, nitrate
79	FCAF	abandoned chicken coops	fertilizers, manure, nitrate
80	Large Lawn	greenhouse	pesticides, fertilizer
81	Junk/Salvage	personal junk yard, cars, bus, boat, equipment	nitrate, metals, solvents
82	AFO	less than 10 horses, fenced in	manure, nitrate
83	AFO	small animal feeding operation	manure, nitrate
84	Business	abandoned restaurant	metals, solvents
85	Corral	abandoned corral	manure, nitrate
86	Corral	abandoned corral	manure, nitrate
87	Mining	gravel pit	metals, solvents, petroleum
88	Corral	corral,silage,cows grazing	fertilizers, manure, nitrate
89	Large Lawn	large lawn and swimming pool	pesticides, fertilizer
90	Cemetery	cemetery	pesticides, fertilizer
91	Business	Corrections Facility	pesticides, fertilizer
92	AFO	Equestrian Park	pesticides, fertilizer
93	Business	log homes, lumber	pesticides, fertilizer
94	Business	storage shed, metals scraps	nitrate, metals, solvents
95	Government	UDOT site, government	nitrate, metals, solvents
96	Junk/Salvage	junk yard, abandoned pipes, metals scraps, cars, trucks, stoves	nitrate, metals, solvents
97	Corral	abandoned corral	manure, nitrate
98	Grazing	sheep grazing	manure, nitrate

[1]Site # corresponds to ID on plate 2; [2]AFO-concentration of animals and/or feed lot (no specified number of animals); [3]FCAF-former concentration of animals and/or feed lot

Table D1. continued

SITE #[1]	POTENTIAL CONTAMINANT	LOCATION/SOURCE DESCRIPTION	POLLUTANT
99	Storage Tank	gravity driven gas tank, stacks of hay	petroleum
100	Storage Tank	gravity driven gas tank	petroleum
101	Corral	corral, silage, cow grazing	fertilizers, manure, nitrate
102	Storage Tank	gravity driven gas tank	petroleum
103	Corral	abandoned corral	manure, nitrate
104	Corral	abandoned corral, haystacks	manure, nitrate
105	Grazing	grazing elk	manure, nitrate
106	Corral	abandoned corral	manure, nitrate
107	Storage Tank	gravity driven gas tank	petroleum
108	farm equipment	farm equipment	nitrate, metals, solvents
109	Corral	abandoned corral	manure, nitrate
110	Junk/Salvage	abandoned home with farm equipment, hay stacks	nitrate, metals, solvents
111	AFO	shed, unknown animals	manure, nitrate
112	AFO	confined elk about 50 animals	manure, nitrate
113	Corral	sheds	manure, nitrate
114	Grazing	grazing horses	manure, nitrate
115	AFO	dairy	manure, nitrate
116	Large Lawn	large lawn high school	fertilizers, manure, nitrate
117	Medical	veterinarian animal clinic	fertilizers, manure, nitrate
118	Corral	grazing sheep and horses	manure, nitrate
119	Corral	abandoned corral, horses	manure, nitrate
120	AFO	veal sheds, dairy farm	fertilizers, manure, nitrate
121	Grazing	sheep grazing, in alfalfa	manure, nitrate
122	Business	feed Company and abandoned corral	manure, nitrate
123	Corral	abandoned corral	manure, nitrate
124	Junk/Salvage	personal junk yard	metal, solvents
125	Corral	corral	manure, nitrate
126	AFO	dairy operation	manure, nitrate
127	Corral	abandoned corral	manure, nitrate
128	Storage Tank	gravity driven gas tank	petroleum
129	Storage Tank	gravity driven gas tank	petroleum
130	Corral	corral with horses	manure, nitrate

[1]Site # corresponds to ID on plate 2; [2]AFO-concentration of animals and/or feed lot (no specified number of animals); [3]FCAF-former concentration of animals and/or feed lot

Table D1. continued

SITE #[1]	POTENTIAL CONTAMINANT	LOCATION/SOURCE DESCRIPTION	POLLUTANT
131	Business	mini storage sheds	metals, petroleum, solvents
132	Storage Tank	gas station	metals, petroleum, solvents
133	Corral	corrals	manure, nitrate
134	Corral	corrals	manure, nitrate
135	Business	car dealership	metals, petroleum, solvents
136	Business	hardware store	metals, petroleum, solvents
137	Storage Tank	gas station	metals, petroleum, solvents
138	Storage Tank	gravity driven gas tank	petroleum
139	Farm equipment	silage stored, some farm equipment	manure, metals, solvents
140	Business	furniture store	metals, solvents
141	Business	hardware store	metals, solvents
142	Corral	horses in yard	manure, nitrate
143	Corral	horses in a shed/ shelter	manure, nitrate
144	Corral	silage and horses in a corral	manure, nitrate
145	Wastewater	sewage lagoon, treatment center	metals, petroleum, solvents
146	Corral	abandoned barns	manure, nitrate
147	AFO	barns and shed	manure, nitrate
148	Corral	abandoned corral	manure, nitrate
149	Corral	abandoned corral	manure, nitrate
150	Wastewater	sewage treatment	metals, petroleum, solvents
151	Junk/Salvage	junkyard	metals, solvents
152	AFO	dairy farm operation	fertilizers, manure, nitrate
153	Wastewater	sewage	fertilizers, manure, nitrate
154	AFO	confined animal feeding operation, corral area	manure, nitrate
155	AFO	small chicken coop	manure, nitrate
156	Corral	abandoned barn and abandoned corral	manure, nitrate
157	Storage Tank	gravity driven gas tank	petroleum
158	AFO	dairy farm	manure, nitrate
159	Corral	abandoned barn, house and corral	manure, nitrate
160	AFO	active dairy	manure, nitrate
161	Grazing	grazing cows	manure, nitrate
162	Storage Tank	gravity driven gas tank	petroleum
163	Junk/Salvage	personal junkyard	metals, solvents
164	Junk/Salvage	personal junkyard trailers, camper tops, cars, vans, trucks	metals, solvents, petroleum

[1]Site # corresponds to ID on plate 2; [2]AFO-concentration of animals and/or feed lot (no specified number of animals); [3]FCAF-former concentration of animals and/or feed lot

Table D1. continued

SITE #[1]	POTENTIAL CONTAMINANT	LOCATION/SOURCE DESCRIPTION	POLLUTANT
165	Business	abandoned taxidermy	metal, solvents
166	Mining	gravel pit	metals, solvents, petroleum
167	Mining	gravel pit	metals, solvents, petroleum
168	Mining	gravel pit	metals, solvents, petroleum
169	AFO	dairy operation, silage, silos and barn, shed, corrals, gravity driven gas tank	fertilizers, manure, nitrate, petroleum
170	Mining	gravel pit	metals, solvents, petroleum
171	Corral	corral with cows	manure, nitrate
172	Mining	gravel pit	metals, solvents, petroleum
173	Industry	gravel operation tires	metals, solvents, petroleum
174	Corral	silage and abandoned corrals	manure, nitrate
175	Storage Tank	gas station	metals, petroleum, solvents
176	Business	car wash	metals, solvents, petroleum
177	Large lawn	large lawn	fertilizers, nitrate
178	Business	refrigerator and appliance store	metals, solvents
179	Business	car batteries sold	metals, solvents
180	Business	upholstery place	metals, solvents
181	Industry	mill factory	metals, solvents
182	Business	cleaners	metals, solvents
183	Medical	family clinic, medical	metals, solvents
184	Medical	medical clinic	metals, solvents
185	Business	car dealership	metals, solvents
186	Business	Tire Shop, Gas Station, car wash	metals, petroleum, solvents
187	Business	hardware store, equipment for rent, tractors, cranes	metals, petroleum, solvents
188	Business	photo studio	metals, solvents
189	Storage Tank	garage shed, diesel trucks, possible storage business	metals, petroleum, solvents
190	Business	heating & air conditioning storage	metals, solvents
191	Business	storage sheds	metals, solvents
192	Business	motors	fuels, metals, petroleum
193	Large lawn	landscape nursery plants & supplies	fertilizer, manure, nitrate
194	Business	glass	metals, solvents
195	Business	hair care	metals, solvents
196	Business	TV electronics repair shop	metals, solvents

[1]Site # corresponds to ID on plate 2; [2]AFO-concentration of animals and/or feed lot (no specified number of animals); [3]FCAF-former concentration of animals and/or feed lot

Table D1. continued

SITE #[1]	POTENTIAL CONTAMINANT	LOCATION/SOURCE DESCRIPTION	POLLUTANT
197	Farm equipment	dairy farm, silage, barn, tractors, trucks, feed trucks, grain trucks, haystacks	fertilizers, manure, nitrate, metals, solvents
198	Corral	corral, animals	manure, nitrate
199	Corral	trailer and corrals	fertilizers, manure, nitrate, metals, solvents
200	Corral	corral	manure, nitrate
201	Corral	corral, hay stacks	manure, nitrate
202	Corral	abandoned corral	manure, nitrate
203	Corral	corral with haystack, cows, farm equipment	manure, nitrate
204	Corral	cows	manure, nitrate
205	Grazing	alfalfa field with sheep grazing	manure, nitrate
206	Corral	corral	manure, nitrate
207	Corral	corral	manure, nitrate
208	Corral	corral with haystacks	manure, nitrate
209	Grazing	grazing cattle (100s)	manure, nitrate
210	Corral	ranch, barn and haystack, corral	manure, nitrate
211	Corral	corral	manure, nitrate
212	Grazing	grazing	manure, nitrate
213	AFO	cattle ranch, lot of silage	manure, nitrate
214	Grazing	grazing	manure, nitrate
215	Grazing	grazing, broadly fenced in, open range grazing	manure, nitrate
216	Corral	abandoned corral	manure, nitrate
217	Business	campground	metals, solvents, petroleum
218	Storage Tank	gravity driven gas tank	petroleum
219	Grazing	grazing	manure, nitrate
220	Corral	corral	manure, nitrate
221	Corral	abandoned corral	manure, nitrate
222	Cemetery	cemetery	pesticides, fertilizer
223	Junk/Salvage	personal junkyard, trailer, trucks, campers, hay, horse trailer and barn shed, and corral	metals, solvents, petroleum
224	Grazing	grazing sheep on open land	manure, nitrate
225	Corral	corrals (5 or 6), cows, silage and farm equipment	fertilizers, manure, nitrate, metals, solvents
226	Mining	gravel pit	metals, solvents, petroleum
227	Corral	corral	manure, nitrate

[1]Site # corresponds to ID on plate 2; [2]AFO-concentration of animals and/or feed lot (no specified number of animals); [3]FCAF-former concentration of animals and/or feed lot

Table D1. continued

SITE #[1]	POTENTIAL CONTAMINANT	LOCATION/SOURCE DESCRIPTION	POLLUTANT
228	Farm equipment	farm equipment, some silos	fertilizers, manure, nitrate
229	Storage Tank	2 gravity driven gas tank	petroleum
230	Corral	abandoned corral	manure, nitrate
231	Corral	abandoned barn	manure, nitrate
232	Grazing	grazing cows	manure, nitrate
233	Grazing	cattle in alfalfa field	fertilizers, manure, nitrate
234	Grazing	animals, hay and silos	fertilizers, manure, nitrate
235	Grazing	cattle grazing on alfalfa	manure, nitrate
236	Corral	abandoned corral	manure, nitrate
237	Grazing	alfalfa fields with cattle grazing	fertilizers, manure, nitrate
238	Storage Tank	gravity driven gas tank	petroleum
239	Corral	abandoned corral	manure, nitrate
240	Grazing	hay barn with cattle grazing	manure, nitrate
241	Corral	abandoned corral	manure, nitrate
242	Corral	abandoned corral	manure, nitrate
243	Corral	corral	manure, nitrate
244	Grazing	grazing	manure, nitrate
245	Grazing	grazing sheep in alfalfa field	manure, nitrate
246	Corral	fish and game club, abandoned corral	manure, nitrate
247	Corral	corral	manure, nitrate
248	Corral	corral	manure, nitrate
249	Corral	corral	manure, nitrate
250	Corral	corral	manure, nitrate
251	FCAF	abandoned dairy	manure, nitrate
252	Storage Tank	gravity driven gas tank	petroleum
253	Corral	corral	manure, nitrate
254	Storage Tank	gravity driven gas tank	petroleum
255	Corral	horses in a corral	manure, nitrate
256	Corral	corral, cows, hay	manure, nitrate
257	Corral	corral	manure, nitrate
258	Grazing	grazing	manure, nitrate
259	AFO	hay, cows	manure, nitrate
260	Corral	corral	manure, nitrate
261	Corral	abandoned corral	manure, nitrate
262	Corral	horses on property	manure, nitrate
263	Grazing	cattle grazing in the field on alfalfa crops	fertilizer, manure, nitrate

[1]Site # corresponds to ID on plate 2; [2]AFO-concentration of animals and/or feed lot (no specified number of animals); [3]FCAF-former concentration of animals and/or feed lot

Table D1. continued

SITE #[1]	POTENTIAL CONTAMINANT	LOCATION/SOURCE DESCRIPTION	POLLUTANT
264	Grazing	cattle grazing in the field on alfalfa crops	fertilizer, manure, nitrate
265	Corral	barns and sheds, corral, windmill, haystack	manure, nitrate
266	Corral	corrals and abandoned home	manure, nitrate
267	Storage Tank	2 gravity driven gas tank's	petroleum
268	Corral	barn sheds, some hay stored and with horses and silo and corral	manure, nitrate
269	Corral	corrals	manure, nitrate
270	AFO	big cattle operation	manure, nitrate
271	Mining	gravel pit	metals, solvents, petroleum
272	Mining	mine	metals, solvents, petroleum
273	Mining	gravel pit	metals, solvents, petroleum
274	Corral	abandoned corral, hay stacked	manure, nitrate
275	Mining	salt mine	metals, solvents, petroleum
276	Industry	salt mine, mining industry plant	metals, solvents, petroleum
277	Grazing	Cattle and sheep grazing on alfalfa field	manure, nitrate
278	Grazing	Cattle and sheep grazing	manure, nitrate
279	AFO	ranch, bunch of hay, silos and tractors	manure, nitrate, metals
280	Storage Tank	2 gravity driven gas tank	petroleum
281	Corral	corral, 100s of cattle grazing	manure, nitrate
282	Corral	corral	manure, nitrate
283	Corral	abandoned corral	manure, nitrate
284	Grazing	cattle grazing	manure, nitrate
285	Grazing	cattle grazing	manure, nitrate
286	Corral	corral, sheep, horses	manure, nitrate
287	Corral	horses	manure, nitrate
288	Corral	horses in corral	manure, nitrate
289	Storage Tank	gravity driven gas tank	petroleum
290	Corral	cows	manure, nitrate
291	Storage Tank	2 gravity driven gas tank	petroleum
292	Corral	horses in corral	manure, nitrate
293	Corral	silage and some cows	manure, nitrate
294	Corral	barn and stored hay, corral	manure, nitrate
295	Corral	cows, hay stack, cattle	manure, nitrate
296	Corral	hay, corral, tractors, trailers	manure, nitrate, petroleum
297	Corral	corral	manure, nitrate
298	Corral	barn, hay, silos	manure, nitrate

[1]Site # corresponds to ID on plate 2; [2]AFO-concentration of animals and/or feed lot (no specified number of animals); [3]FCAF-former concentration of animals and/or feed lot

Table D1. continued

SITE #[1]	POTENTIAL CONTAMINANT	LOCATION/SOURCE DESCRIPTION	POLLUTANT
299	Cemetery	cemetery	pesticides, fertilizer
300	Industry	industrial waste pond, sugar factory	metals, solvents, petroleum
301	Mining	gravel pit	metals, solvents, petroleum
302	Mining	gravel pit	metals, solvents, petroleum
303	Grazing	grazing	manure, nitrate
304	Business	equipment sales, for sale truck and tractors	metals, solvents, petroleum
305	Corral	horses, corral	manure, nitrate
306	Corral	horses in yard	manure, nitrate
307	Corral	corral, hay, horses	manure, nitrate
308	Corral	horses, corral	manure, nitrate
309	Grazing	grazing cattle	manure, nitrate
310	Corral	barn and corral	manure, nitrate
311	Grazing	cattle,unconfined, alfalfa field	manure, nitrate
312	Cemetery	cemetery	pesticides, fertilizer
313	Corral	corral with some cows	manure, nitrate
314	Corral	corral has horses, hay, sheds, cattle	manure, nitrate
315	Corral	confined cows in a corral	manure, nitrate
316	Corral	cows	manure, nitrate
317	AFO	cattle operation, veal sheds, cattle, sheds, silage	manure, nitrate
318	AFO	confined cows	manure, nitrate
319	Corral	confined cattle in a corral	manure, nitrate
320	FCAF	abandoned turkey sheds	manure, nitrate
321	Corral	haystacks/ alfalfa farm, cattle confined in small corral	manure, nitrate
322	Storage Tank	2 gravity driven gas tank	petroleum
323	Corral	corral	manure, nitrate
324	AFO	small dairy operation, silage, barns, gravity driven gas tank	petroleum, manure, nitrate
325	Grazing	sheep grazing unconfined	manure, nitrate
326	Business	welding shop	metals, solvents, petroleum
327	FCAF	abandoned chicken coops	manure, nitrate
328	Corral	corral, horses	manure, nitrate
329	Corral	haystack, corral and shed	manure, nitrate
330	Corral	corral	manure, nitrate
331	Storage Tank	gravity driven gas tank	petroleum

[1]Site # corresponds to ID on plate 2; [2]AFO-concentration of animals and/or feed lot (no specified number of animals); [3]FCAF-former concentration of animals and/or feed lot

Table D1. continued

SITE #[1]	POTENTIAL CONTAMINANT	LOCATION/SOURCE DESCRIPTION	POLLUTANT
332	Corral	old barn shed and corral	manure, nitrate
333	Corral	home with a small corral	manure, nitrate
334	Corral	abandoned corral	manure, nitrate
335	Corral	corral	manure, nitrate
336	Storage Tank	gravity driven gas tank	petroleum
337	Farm equipment	hay and farm equipment, tractors, trailers, semi trucks	manure, nitrate, metals, solvents
338	Corral	Corral, haystacks	manure, nitrate
339	Corral	Corral with few horses	manure, nitrate
340	Corral	corral with horses and horse trailers	manure, nitrate
341	Grazing	cattle grazing, unconfined	manure, nitrate
342	Corral	corral with few horses	manure, nitrate
343	AFO	cattle	manure, nitrate
344	Corral	active corrals	manure, nitrate
345	Corral	some abandoned corrals	manure, nitrate
346	Corral	abandoned corrals, trailer home	manure, nitrate
347	Corral	home and barn, corral	manure, nitrate
348	Corral	corral with horses grazing, cattle grazing in alfalfa field	manure, nitrate
349	Corral	barn, sheds, irrigated alfalfa fields, cattle grazing	manure, nitrate
350	Corral	angus cattle and horses, bulls, corral	manure, nitrate
351	AFO	livestock	manure, nitrate
352	Storage Tank	gravity driven gas tank	petroleum
353	Corral	small corral with horses	manure, nitrate
354	Corral	small corral with few horses	manure, nitrate
355	Corral	small corral with few horses	manure, nitrate
356	Corral	corral with horses in yard	manure, nitrate
357	Corral	corral, sheds, wooden shack sheds 3 or 4 horses and pastures	manure, nitrate
358	Corral	corral	manure, nitrate
359	Storage Tank	gravity driven gas tank	petroleum
360	Corral	corral	manure, nitrate
361	Corral	corral	manure, nitrate
362	Corral	corral	manure, nitrate
363	Corral	corral with horses	manure, nitrate

[1]Site # corresponds to ID on plate 2; [2]AFO-concentration of animals and/or feed lot (no specified number of animals); [3]FCAF-former concentration of animals and/or feed lot

Table D1. continued

SITE #[1]	POTENTIAL CONTAMINANT	LOCATION/SOURCE DESCRIPTION	POLLUTANT
364	Large lawn	large lawn	pesticides, fertilizer
365	Cemetery	cemetery	pesticides, fertilizer
366	Corral	corral	manure, nitrate
367	Corral	llamas	manure, nitrate

[1]Site # corresponds to ID on plate 2; [2]AFO-concentration of animals and/or feed lot (no specified number of animals); [3]FCAF-former concentration of animals and/or feed lot

APPENDIX E
DRILLERS' WELL LOGS FOR HIGH-NITRATE-CONCENTRATION WELLS

WL1

WELL DRILLER'S REPORT
State of Utah
Division of Water Rights

MBG

WP 184

For additional space, use "Additional Well Data Form" and attach

Well Identification

WATER RIGHT APPLICATION: 63-178(A20824)

RECEIVED FEB 05 1999 WATER RIGHTS SALT LAKE

Owner *Note any changes*

Hammond, Loni D. and Julie
P.O. Box 300504
Fayette, UT 84630

should we be publishing their address?

Contact Person/Engineer:

Well Location *Note any changes*

COUNTY: Sanpete
SOUTH 520 feet EAST 745 feet from the NW Corner of
SECTION 35, TOWNSHIP 18S, RANGE 1W, SLB&M.

Location Description: (address, proximity to buildings, landmarks, ground elevation, local well #)

Drillers Activity Start Date: 1/13/99 Completion Date: 1/14/99

Check all that apply: ☐ New ☐ Repair ☐ Deepen ☐ Abandon ☑ Replace ☐ Public Nature of Use STK

DEPTH (feet) FROM	TO	BOREHOLE DIAMETER (in)	DRILLING METHOD	DRILLING FLUID
0	160	8	Mud Rotary	Bentonite

Well Log

DEPTH (feet) FROM	TO	WATER	PERMEABLE high	PERMEABLE low	CLAY	SILT	SAND	GRAVEL	COBBLES	BOULDERS	OTHER	ROCK TYPE	COLOR	DESCRIPTIONS AND REMARKS (include comments on *water quality* if known.)
0	45				X									
45	120	X					X	X						
120	135				X									
135	160	X					X	X						

Unconsolidated: Clay, Silt, Sand, Gravel, Cobbles, Boulders, Other. Consolidated: Rock Type.

Static Water Level

Date 1/18/99 Water Level 29 feet Flowing? ☐ Yes ☐ No

Method of Water Level Measurement ______ If Flowing, Capped Pressure ______ PSI

Point to Which Water Level Measurement was Referenced Ground

Height of Water Level reference point above ground surface ______ feet Temperature ______ ☐ °C ☐ °F

Well Log

Construction Information

DEPTH (feet) FROM	DEPTH (feet) TO	CASING: CASING TYPE AND MATERIAL/GRADE	WALL THICK (in)	NOMINAL DIAM. (in)	DEPTH (feet) FROM	DEPTH (feet) TO	SCREEN ☐ PERFORATIONS ☐: SLOT SIZE OR PERF SIZE (in)	SCREEN DIAM. OR PERF LENGTH (in)	SCREEN TYPE OR NUMBER PERF (per round/interval)
0	160	PVC		5	100	120	1/8	3	3 X 18"
					140	160	1/8	3	" "

Well Head Configuration: cap Access Port Provided? ☐ Yes ☐ No

Casing Joint Type: glue Perforator Used: saw

DEPTH (feet) FROM	DEPTH (feet) TO	FILTER PACK / GROUT / PACKER / ABANDONMENT MATERIAL: ANNULAR MATERIAL, ABANDONMENT MATERIAL and/or PACKER DESCRIPTION	Quantity of Material Used (if applicable)	GROUT DENSITY (lbs./gal.,# bag mix, gal./sack etc.)
0	25	Cement		
25	160	Garvel pack		

Well Development / Pump or Bail Tests

Date	Method	Yield	Units Check One: GPM	Units Check One: CFS	DRAWDOWN (ft)	TIME PUMPED (hrs & min)
	AiR	50	✓		80	

Pump (Permanent)

Pump Description: ____ Horsepower: ____ Pump Intake Depth: ____ feet

Approximate maximum pumping rate: ____ Well disinfected upon completion? ☐ Yes ☐ No

Comments: Description of construction activity, additional materials used, problems encountered, extraordinary circumstances, abandonment / procedures. *Use additional well data form for more space.*

abandond old Well With 10 Cubic ft. of Neet cement pumped with Trimy pipe

Well Driller Statement: This well was drilled or abandoned under my supervision, according to applicable rules and regulations, and this report is complete and correct to the best of my knowledge and belief.

Name: Unzicker & Wells (Person, Firm, or Corporation – Print or Type) License No. 328

Signature: [illegible signature] (Licensed Well Driller) Date: 2/1/99

Page 1 of 2

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Site 184

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UTAH DIVISION OF WATER RIGHTS

WELLPRT Well Log Information Listing

(D-63-178) 61 5131

Version: 2003.09.18.00 Rundate: 10/11/2003 09:56 PM

Utah Division of Water Rights

Water Well Log

(C-18-1) 35bba Hammond House

LOCATION:

S 520 ft E 745 ft from NW CORNER of SECTION 35 T 18S R 1W BASE SL

DRILLER ACTIVITIES:

ACTIVITY # 1 WELL REPLACEMENT
DRILLER: UNZICKER & WELLS DRILLING CO INC LICENSE #
START DATE: 01/13/1999 COMPLETION DATE: 01/14/1999

BOREHOLE INFORMATION:

Depth(ft) From	Depth(ft) To	Diameter(in)	Drilling Method	Drilling Fluid
0	160	8	MUD ROTARY	BENTONITE

LITHOLOGY:

Depth(ft) From	Depth(ft) To	Lithologic Description
0	45	CLAY
45	120	WATER-BEARING,SAND,GRAVEL
120	135	CLAY
135	160	WATER-BEARING,SAND,GRAVEL

WATER LEVEL DATA:

Date	Time	Water Level (feet) (-)above ground	Status
01/18/1999		29.00	

CONSTRUCTION - CASING:

Depth(ft) From	Depth(ft) To	Material	Gage(in)	Diameter(in)
0	160	PVC		5

CONSTRUCTION - SCREENS/PERFORATIONS:

Depth(ft) From	Depth(ft) To	Screen(S) or Perforation(P)	Slot/Perf. siz	Screen Diam/Le
100	120	PERFORATION	.125	3
140	160	PERFORATION	.125	3

CONSTRUCTION - FILTER PACK/ANNULAR SEALS

Depth(ft)	Material	Amount	Density(pcf)

#81

From	To	
0	25	CEMENT
25	160	GRAVEL PACK

WELL TESTS:

Date	Test Method	Yield (CFS)	Drawdown (ft)	Time Pumped (hr
/ /	AIR	.111	80	

GENERAL COMMENTS:

CONSTRUCTION INFORMATION:
Well Head Configuration: cap
Casing type: glue
Perforator: saw
Comments: abandoned old well with 10 cubic ft. of Neet Cement pumped with Trimy pipe.
ADDITIONAL DATA NOT AVAILABLE

#63

WP 185

PAGE..........
(Leave Blank)

Report No. 3049
Filed Sept. 3 1943
Rec. By Mail
Ret'd.

63-90

E.V. 9-7-43
M.V. 10-22-43
V. 9-7-43

Report of Well and Tunnel Driller

STATE OF UTAH

(Separate report shall be filed for each well or tunnel)

(D-18-1)34cbc-1

GENERAL INFORMATION:

Report of well or tunnel driller is hereby made and filed with the State Engineer, in accordance with Sections 100-3-22, Revised Statutes of Utah 1933, as amended by Session Laws of 1935. (This report shall be filed with the State Engineer within 30 days after the completion or abandonment of well or tunnel. Failure to file such report constitutes a misdemeanor.)

1. Name and address of person, company ~~or corporation boring~~ or drilling well ~~or tunnel~~ (Strike words not needed)
C. W. Anderson, Manti, Utah

2. Name and address of owner of well ~~or tunnel~~ (Strike words not needed) Milt Hammond
(Fayette) Utah, Gunnison

3. Source if supply is in Sanpete County;
.... drainage area; .... artesian basin
(Leave blank) (Leave blank)

4. The number of approved application to appropriate water is 14612

5. Location of well or ~~mouth of tunnel~~ is situated at a point E. 1020 ft. and S. 50 ft. from W¼ Cor. Sec. 34, T. 18 S., R. 1 W., SLB&M

(Describe by course and distance with reference to U. S. Government Survey Corner—Copy description from well owner's approved application)

6. Date on which work on well ~~or tunnel~~ was begun Aug. 22, 1943
(Strike words not needed)

7. Date on which work on well ~~or tunnel~~ was completed ~~or abandoned.~~ Aug. 27, 1943
(Strike words not needed)

8. Maximum quantity of water ~~flowing, pumped or~~ dipped on completion of well ~~or tunnel in sec.~~ (Strike words not needed)
ft. ....; or in gals. per minute 5; Date Aug. 27, 1943

DETAIL OF COLLECTING WORKS:

9. WELL: It is a drilled, ~~dug, flowing~~ or pump well. Temperature of water 58½ °F.
(Strike words not needed)

(a) Total depth of well is 170 ft. below ground surface.

(b) If flowing well, give water pressure (hydrostatic head) above ground surface..........ft.

(c) If pump well, give depth from ground surface to water surface before pumping 101; during pumping 105

(d) Size and kind of casing 6" Standard
(If only partially cased, give details)

(e) Depth to water bearing stratum 149 to 170
(If more than one stratum, give depth to each)

(f) If casing is perforated, give depth from ground surface to perforations..........

(g) Log of well 0-10 gravel hard pan, 10-20 gravel hard pan, 20-30 gravel hard pan, 30-40 gravel hard pan, 40-50 gravel hard pan, 50-60 gravel hard pan, 60-70 gravel hard pan, 70-76 gravel hard pan, 76-86 brown clay, 86-96 brown clay, 96-106 brown clay, 106-126 brown clay, 126-136 brown clay, 136-149 gravel and sand, 149-159 brown clay, 159-169 brown clay, 169-170 gravel & sand

(h) Well was equipped with cap, ~~valve, or~~ .... to control flow.
(Strike words not needed)

(Over)

...counties
M.V. 1-23-43
Recorded 7/14 1-11-43
or filing J.A.W. 1-26-43
checked M.V. 1-23-43
& No. Assigned
M.V. 1-23-43
...ed well
...t DI...

PAGE .... (Leave Blank) Munk

Report No. 2830
Filed 1 - 4 194 3
Rec. By Mail
Ret'd

WP-190

Report of Well and Tunnel Driller

STATE OF UTAH

(Separate report shall be filed for each well or tunnel)

Wtypf 190 Near (Vern Munk)

GENERAL INFORMATION:

Report of well or tunnel driller is hereby made and filed with the State Engineer, in accordance with Sections 100-3-22, Revised Statutes of Utah 1933, as amended by Session Laws of 1935. (This report shall be filed with the State Engineer within 30 days after the completion or abandonment of well or tunnel. Failure to file such report constitutes a misdemeanor.)

1. Name and address of person, ~~company or corporation boring~~ or drilling well ~~or tunnel~~ (Strike words not needed) C. W. Anderson, Manti, Utah

2. Name and address of owner of well ~~or tunnel~~ (Strike words not needed) Ira Overfelt, Gunnison, Utah

3. Source if supply is in Sanpete County; .... (Leave blank) drainage area; .... (Leave blank) artesian basin

4. The number of approved application to appropriate water is 15057

5. Location of well ~~or mouth of tunnel~~ is situated at a point N. 30.50 chs. & W. 17.23 chs. from SE Cor. Sec. 32, T. 19 S., R. 1 E., SLB&M. 2013' 1131.18'
(Describe by course and distance with reference to U. S. Government Survey Corner—Copy description from well owner's approved application)

6. Date on which work on well ~~or tunnel~~ was begun (Strike words not needed) Dec. 16, 1942

7. Date on which work on well ~~or tunnel~~ was completed ~~or abandoned~~ (Strike words not needed) Dec. 24, 1942

8. Maximum quantity of water ~~flowing, pumped~~ or dipped on completion of well ~~or tunnel~~ in sec. (Strike words not needed) ft. ....; or in gals. per minute 9; Date Dec. 24, 1942

DETAIL OF COLLECTING WORKS:

9. WELL: It is a drilled, ~~dug, flowing or~~ pump well. (Strike words not needed) Temperature of water 59½ °F.
   (a) Total depth of well is 84 ft. below ground surface.
   (b) If flowing well, give water pressure (hydrostatic head) above ground surface .... ft.
   (c) If pump well, give depth from ground surface to water surface before pumping 38'; during pumping 38'
   (d) Size and kind of casing 4" standard (If only partially cased, give details)
   (e) Depth to water bearing stratum 84' (If more than one stratum, give depth to each)
   (f) If casing is perforated, give depth from ground surface to perforations ....
   (g) Log of well 0-10 clay, 10-20 clay, 20-27 clay, 27-37 hard pan, 37-42 conglomerate, 42-52 conglomerate, 52-57 sand gravel, 57-67 conglomerate, 67-77 conglomerate, 77-83 conglomerate, 83-84 sand gravel.
   (h) Well was equipped with cap, ~~valve, or~~ (Strike words not needed) .... to control flow.

(Over)

WELL DRILLER'S REPORT
State of Utah
Division of Water Rights

El 5659 B.S. WP 198
12-9-04
OK

For additional space, use "Additional Well Data Form" and attach

Well Identification

Change Application: a27405 (63-4395) WIN: 29348

Owner *Note any changes*

Horse Brand Ranch
P.O. Box 534
Mayfield UT 84643

Is this ~~Need~~ ace sampled

Crane on my map

Contact Person/Engineer:

Well Location *Note any changes*

S 2340 E 330 from the N4 corner of section 08, Township 20S, Range 2E, SL B&M

acc Horse Brand Ranch WP-196

Location Description: (address, proximity to buildings, landmarks, ground elevation,local well #)

Drillers Activity Start Date: Oct 21, 2004 Completion Date: 11-11-04

Check all that apply: ☒ New ☐ Repair ☐ Deepen ☐ Clean ☐ Replace ☐ Public Nature of Use:

If a replacement well, provide location of new well. ________ feet north/south and ________ feet east/west of the existing well.

DEPTH (feet) FROM	TO	BOREHOLE DIAMETER (in)	DRILLING METHOD	DRILLING FLUID
0	185	8 3/4"	Air Rotary	Water

Well Log

DEPTH (feet) FROM	TO	WATER	PERMEABLE High	PERMEABLE Low	UNCONSOLIDATED CLAY	SILT	SAND	GRAVEL	COBBLES	BOULDER	OTHER	CONSOLIDATED ROCK TYPE	COLOR	DESCRIPTION AND REMARKS (e.g., relative %, grain size, sorting, angularity, bedding, grain composition density, plasticity, shape, cementation, consistancy, water bearing, ordor, fracturing, minerology, texture,degree of weathering, hardness, water quality, etc.)
0	60				X					X			TAN	
60	185	X	X									Limestone	White	180'-185 Fracturing
														Trace @ 140'-150'

RECEIVED DEC [illegible] WR

Static Water Level

Date 11-11-04 Water Level 135' feet Flowing? ☐ Yes ☒ No

Method of Water Level Measurement TAPE If Flowing, Capped Pressure ________ PSI

Point to Which Water Level Measurement was Referenced Top of Casing Elevation ________

Height of Water Level reference point above ground surface 2' feet Temperature ________ degrees ☐C ☐F a 27405 WP 198

Construction Information

DEPTH (feet)		CASING			DEPTH (feet)		☐SCREEN ☒PERFORATIONS ☒OPEN BOTTOM		
FROM	TO	CASING TYPE AND MATERIAL/GRADE	WALL THICK (in)	NOMINAL DIAM. (in)	FROM	TO	SCREEN SLOT SIZE OR PERF SIZE (in)	SCREEN DIAM. OR PERF LENGTH (in)	SCREEN TYPE OR NUMBER PERF (per round/interval)
0	185	A53B	.250	6.625	165	185	1/8"	6"	40

Well Head Configuration: Welded Lip Access Port Provided? ☐Yes ☒No

Casing Joint Type: Welded Perforator Used: Plasma Cutter

Was a Surface Seal Installed? ☒Yes ☐No Depth of Surface Seal: 30 feet Drive Shoe? ☐Yes ☒No

Surface Seal Material Placement Method: UNHYDRATED BENTONITE WAS POURED INTO ANNULUS AND FILLED FROM BOTTOM TO THE TOP

DEPTH (feet)		SURFACE SEAL / INTERVAL SEAL / FILTER PACK / PACKER INFORMATION		
FROM	TO	SEAL MATERIAL, FILTER PACK and PACKER TYPE and DESCRIPTION	Quantity of Material Used (if applicable)	GROUT DENSITY (lbs./gal., # bag mix, gal./sack etc.)
0	30	UNHYDRATED BENTONITE	500 lbs	
		SHALE TRAP SET @ 30'		

Well Development and Well Yield Test Information

DATE	METHOD	YIELD	Units Check One GPM	CFS	DRAWDOWN (ft)	TIME PUMPED (hrs & min)
	AIRLIFT		40		N/A	2 HRS

Pump (Permanent)

Pump Description:_____ Horsepower:_____ Pump Intake Depth:_____ feet

Approximate Maximum Pumping Rate:_____ Well Disinfected upon Completion? ☐Yes ☐No

Comments

Description of construction activity, additional materials used, problems encountered, extraordinary Circumstances, abandonment procedures. *Use additional well data form for more space.*

Well Driller Statement

This well was drilled and constructed under my supervision, according to applicable rules and regulations, and this report is complete and correct to the best of my knowledge and belief.

Name FAIRVIEW DRILLING & PUMP SERVICE License No. 728

(Person, Firm, or Corporation - Print or Type)

Signature Kenneth Paulson Date 11-11-04

(Licensed Well Driller)

Form 113—5M—12-60

Examined 3/31/75 (WD)

Recorded: B. C. 3/31/75 T. B. (WD)

Inspection Sheet

Copied 4-8-75 WD

63-1975

Doug

63-1925

WP-199

REPORT OF WELL DRILLER

STATE OF UTAH

No Card

Application No. 43 669

Claim No.

Coordinate No. (D-20-2)5 dbc

GENERAL STATEMENT: Report of well driller is hereby made and filed with the State Engineer, in accordance with the laws of Utah. (This report shall be filed with the State Engineer within 30 days after the completion or abandonment of the well. Failure to file such reports constitutes a misdemeanor.)

1/4 of Sec 5 T. 20 S. R. 2 E. SLBM

(1) WELL OWNER:

Name Neil H. Sorensen

Address Sterling, Utah

(2) LOCATION OF WELL:

County ______ Ground Water Basin ______ (leave blank)

North/South ______ feet, East/West 440 ft. E. of 1/4 Cor. feet from NE Corner

of Section 1/4 of Sec 5 T. 20 S., R. 2 E SLBM (strike out words not needed)

(3) NATURE OF WORK (check):

New Well ☑ Replacement Well ☐ Deepening ☐ Repair ☐ Abandon ☐

If abandonment, describe material and procedure:

(4) NATURE OF USE (check):

Domestic ☑ Industrial ☐ Municipal ☐ Stockwater ☐
Irrigation ☐ Mining ☐ Other ☐ Test Well ☐

(5) TYPE OF CONSTRUCTION (check):

Rotary ☑ Dug ☐ Jetted ☐
Cable ☐ Driven ☐ Bored ☐

(6) CASING SCHEDULE:

Threaded ☑ Welded ☐

______" Diam. from ______ feet to ______ feet Gage ______
______" Diam. from ______ feet to ______ feet Gage ______
______" Diam. from ______ feet to ______ feet Gage ______

New ☐ Reject ☐ Used ☐

(7) PERFORATIONS:

Perforated? Yes ☑ No ☐

Type of perforator used Slotted

Size of perforations 3/4 inches by 4 inches

______ perforations from ______ feet to ______ feet
______ perforations from ______ feet to ______ feet
______ perforations from ______ feet to ______ feet
______ perforations from ______ feet to ______ feet
______ perforations from ______ feet to ______ feet

(8) SCREENS:

Well screen installed? Yes ☐ No ☑

Manufacturer's Name

Type ______ Model No. ______

Diam. ______ Slot size ______ Set from ______ ft. to ______

Diam. ______ Slot size ______ Set from ______ ft. to ______

(9) CONSTRUCTION:

Was well gravel packed? Yes ☑ No ☐ Size of gravel: 1"

Gravel placed from 0 feet to 160 feet

Was a surface seal provided? Yes ☐ No ☑

To what depth? ______ feet

Material used in seal:

Did any strata contain unusable water? Yes ☐ No ☐

Type of water: ______ Depth of strata ______

Method of sealing strata off:

Was surface casing used? Yes ☐ No ☐

Was it cemented in place? Yes ☐ No ☐

(10) WATER LEVELS:

Static level ______ feet below land surface Date ______

Artesian pressure ______ feet above land surface Date ______

LOG RECEIVED:

(11) FLOWING WELL:

Controlled by (check) Valve ☐ Cap ☐ Plug ☐ No Control ☐

Does well leak around casing? Yes ☐ No ☐

(12) WELL TESTS:

Drawdown is the distance in feet the water level is lowered below static level.

Was a pump test made? Yes ☐ No ☑ If so, by whom?

Yield: ______ gal./min. with ______ feet drawdown after ______ hours

Bailer test ______ gal./min. with ______ feet drawdown after ______ hours

Artesian flow ______ g.p.m. Date ______

Temperature of water ______ Was a chemical analysis made? No ☐ Yes ☐

(13) WELL LOG:

Diameter of well 6 inches

Depth drilled 160 feet. Depth of completed well 160 feet.

NOTE: Place an "X" in the space or combination of spaces needed to designate the material or combination of materials encountered in each depth interval. Under REMARKS make any desirable notes as to occurrence of water and the color, size, nature, etc., of material encountered in each depth interval. Use additional sheet if needed.

DEPTH From	DEPTH To	Clay	Silt	Sand	Gravel	Cobbles	Boulders	Hardpan	Conglomerate	Bedrock	Other	REMARKS
0	10											Top Soil
10	28				✓		✓					
28	45								✓			
45	75	✓					✓					
75	130								✓			
130	160			✓	✓		✓					

Work started 10-20-74, 19__ Completed 11-11, 1974

(14) PUMP:

Manufacturer's Name

Type: ______ H. P. ______

Depth to pump or bowls ______ feet

Well Driller's Statement:

This well was drilled under my supervision, and this report is true to the best of my knowledge and belief.

Name B + B Drilling Co. Inc. (Person, firm, or corporation) (Type or print)

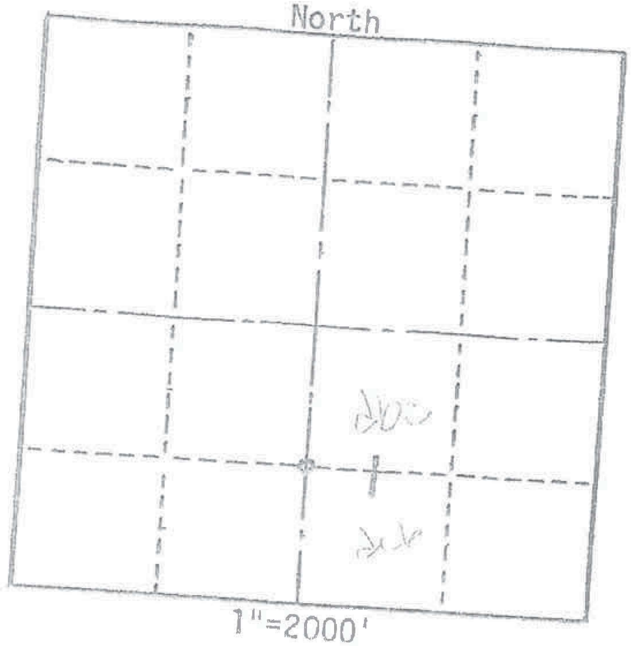
Address Delta, Utah

(Signed) ______ (Well Driller)

License No. 126 Date 12-12, 1974

USE OTHER SIDE FOR ADDITIONAL REMARKS

Sec____, ____, R____, SLB&M



N 1320' E 440'
from S1/4 Cor. Sec 5
T20S, R2E

63-475

plots

WE-200 156

State of Utah
Division of Water Rights

For additional space, use "Additional Well Data Form" and attach

Well Identification WATER RIGHT APPLICATION: 63-4113(A68849)

Owner *Note any changes*
Crane, James M. and Teri
1820 North 6900 East
Croydon, UT 84018
Needham

Contact Person/Engineer:

Well Location *Note any changes* COUNTY: Sanpete
SOUTH 775 feet EAST 2640 feet from the W¼ Corner of
SECTION 8, TOWNSHIP 20S, RANGE 2E, SLB&M.

Location Description: (address, proximity to buildings, landmarks, ground elevation, local well #) 2 miles South of Mayfield

Drillers Activity Start Date: June 6 95 Completion Date: June 13 95

Check all that apply: ☑ New ☐ Repair ☐ Deepen ☐ Abandon ☐ Replace ☐ Public Nature of Use: IRR, STK, DOM

DEPTH (feet) FROM	TO	BOREHOLE DIAMETER (in)	DRILLING METHOD	DRILLING FLUID
0	185	6"	Rotary air	Nova Foam

Well Log

DEPTH (feet) FROM	TO	WATER	PERMEABLE high	PERMEABLE low	CLAY	SILT	SAND	GRAVEL	COBBLES	BOULDER	OTHER	ROCK TYPE	COLOR	DESCRIPTIONS AND REMARKS (include comments on water quality if known.)
0	4													Top Soil
4	15				✓		✓	✓					Brown	
15	35				✓								"	
35	45				✓		✓	✓					"	
45	65				✓		✓	✓					"	
65	85				✓					✓			"	Casing Froze 84'
85	105									✓			"	
105	110									✓			"	
110	160									✓			"	
160	185	✓		✓							✓	Shale	White	Fracture Water

Static Water Level

Date June 14 Water Level 140 feet Flowing? ☐ Yes ☑ No

Method of Water Level Measurement Tape If Flowing, Capped Pressure ______ PSI

Point to Which Water Level Measurement was Referenced Ground

Height of Water Level reference point above ground surface ______ feet Temperature ______ ☐ °C ☐ °F

Well Log

63-4113 #1180

Construction Information

DEPTH (feet) FROM	DEPTH (feet) TO	CASING TYPE AND MATERIAL/GRADE	WALL THICK (in)	NOMINAL DIAM. (in)	DEPTH (feet) FROM	DEPTH (feet) TO	SLOT SIZE OR PERF SIZE (in)	SCREEN DIAM. OR PERF LENGTH (in)	SCREEN TYPE OR NUMBER PERF (per round/interval)
0	84	new	250	6	185	155	1/4 x 3		
60	185	"	237	4					

CASING — SCREEN [ ] PERFORATIONS [X]

Well Head Configuration: welded lid

Access Port Provided? ☐ Yes ☒ No

Casing Joint Type: welded Perforator Used: torch

DEPTH (feet) FROM	DEPTH (feet) TO	FILTER PACK / GROUT / PACKER / ABANDONMENT MATERIAL: ANNULAR MATERIAL, ABANDONMENT MATERIAL and/or PACKER DESCRIPTION	Quantity of Material Used (if applicable)	GROUT DENSITY (lbs./gal.,# bag mix, gal./sack etc.)
0	20	Bentonite		

Well Development / Pump or Bail Tests

Date	Method	Yield	Units Check One GPM	CFS	DRAWDOWN (ft)	TIME PUMPED (hrs & min)

Pump (Permanent)

Pump Description:____ Horsepower:____ Pump Intake Depth:____ feet

Approximate maximum pumping rate:____ Well disinfected upon completion? ☐ Yes ☐ No

Comments | Description of construction activity, additional materials used, problems encountered, extraordinary circumstances, abandonment / procedures. *Use additional well data form for more space.*

Well Driller Statement | This well was drilled or abandoned under my supervision, according to applicable rules and regulations, and this report is complete and correct to the best of my knowledge and belief.

Name FAIRVIEW DRILLING License No. 0504

(Person, Firm, or Corporation – Print or Type)

Signature RW Ponson Date June 12 95

(Licensed Well Driller)

UTAH DIVISION OF WATER RIGHTS

WELLPRT Well Log Information Listing

Version: 2003.09.18.00 Rundate: 10/10/2003 10:04 AM

WNP - 200

same pou as Needham

CRANE 159

Utah Division of Water Rights

Water Well Log

LOCATION:

S 775 ft E 2640 ft from W4 CORNER of SECTION 8 T 20S R 2E BASE SL Elevation:

DRILLER ACTIVITIES:

ACTIVITY # 1 NEW WELL
DRILLER: FAIRVIEW DRILLING LICENSE #: 679
START DATE: 06/06/1995 COMPLETION DATE: 06/13/1995

BOREHOLE INFORMATION:

Depth(ft) From	To	Diameter(in)	Drilling Method	Drilling Fluid
0	185	6.00	ROTARY AIR	NOVA FOAM

LITHOLOGY:

Depth(ft) From	To	Lithologic Description	C
0	4	TOP SOIL	
4	15	CLAY,SAND,GRAVEL	B
15	35	CLAY	B
35	45	CLAY,SAND,GRAVEL	B
45	65	CLAY,SAND,GRAVEL	B
65	85	CLAY,BOULDERS CASIGN FROZE 84'	B
85	105	BOULDERS	B
105	110	BOULDERS	B
110	160	BOULDERS	B
160	185	WATER-BEARING,LOW-PERMEABILITY,OTHER FRACTURES WATER	W

WATER LEVEL DATA:

Date	Time	Water Level (feet) (-)above ground	Status
06/14/1995		140.00	STATIC

CONSTRUCTION - CASING:

Depth(ft) From	To	Material	Gage(in)	Diameter(in)
0	84	NEW	.250	6.00
60	185	NEW	.237	4.00

CONSTRUCTION - SCREENS/PERFORATIONS:

Depth(ft) From	To	Screen(S) or Perforation(P)	Slot/Perf. siz	Screen Diam/Length Perf(in
155	185	PERFORATION	.250	3.00

CONSTRUCTION - FILTER PACK/ANNULAR SEALS

Depth(ft) From	To	Material	Amount	Density(pcf)
0	20	BENTONITE		

GENERAL COMMENTS:

CONSTRUCTION INFORMATION:
well head configuration: welded lid
Casing Joint type: welded
Perforator used: Torch
Additional data not available

UTAH DIVISION OF WATER RIGHTS

WELLPRT Well Log Information Listing

Version: 2003.09.18.00 Rundate: 10/12/2003 10:15 AM

Belnap WP 206

Utah Division of Water Rights

Water Well Log

Sunrise # 52

LOCATION:
S 135 ft E 590 ft from N4 CORNER of SECTION 5 T 20S R 2E BASE SL Elevation:

DRILLER ACTIVITIES:
ACTIVITY # 1 NEW WELL
DRILLER: UNZICKER & WELLS DRILLING CO INC LICENSE #: 398
START DATE: 03/10/2000 COMPLETION DATE: 03/11/2000

BOREHOLE INFORMATION:

Depth(ft) From	To	Diameter(in)	Drilling Method	Drilling Fluid
0	160	9	MUD ROTARY	BENTONITE

LITHOLOGY:

Depth(ft) From	To	Lithologic Description	Col
0	35	CLAY	
35	85	WATER-BEARING,SAND,GRAVEL	
85	95	OTHER Limestone ?	
95	120	WATER-BEARING,GRAVEL,OTHER	
120	135	OTHER Limestone ?	
135	160	WATER-BEARING,GRAVEL,OTHER ? not sure if this is gravel or this LST	

WATER LEVEL DATA:

Date	Time	Water Level (feet) (-)above ground	Status
03/11/2000		39.00	

CONSTRUCTION - CASING:

Depth(ft) From	To	Material	Gage(in)	Diameter(in)
0	160	200 PSI PVC		6

CONSTRUCTION - SCREENS/PERFORATIONS:

Depth(ft) From	To	Screen(S) or Perforation(P)	Slot/Perf. siz	Screen Diam/Length	Perf(in)
120	160	PERFORATION	.125	3	

CONSTRUCTION - FILTER PACK/ANNULAR SEALS

Depth(ft) From	To	Material	Amount	Density(pcf)
0	50	CEMENT	8 CU.FT.	

50 160 GRAVEL

WELL TESTS:

Date	Test Method	Yield (CFS)	Drawdown (ft)	Time Pumped (hrs)
03/10/2000	AIR	.223	150	1

GENERAL COMMENTS:

CONSTRUCTION INFORMATION
Well Head Configuration: Cap
Casing joint type: Glue
Perforator used: Saw
PUMP
Well disinfected on completion: yes
Additional data not available.

WP-211

utah gov | Online Services | Agency List | Business | Google | Search Ut

UTAH DIVISION OF WATER RIGHTS

WELLPRT Well Log Information Listing

Version: 2003.09.18.00 Rundate: 10/10/2003 04:43 PM

EI 5039

Utah Division of Water Rights

63-4098

KOA?

Water Well Log

(C-19-1)2cad

(or 16?

LOCATION:

N 1972 ft E 2059 ft from SW CORNER of SECTION 2 T 19S R 1W BASE SL

DRILLER ACTIVITIES:

ACTIVITY # 1 NEW WELL
DRILLER: LAKE HURON LLC LICENSE #
START DATE: 12/12/1995 COMPLETION DATE: 01/08/1996

BOREHOLE INFORMATION:

Depth(ft) From	To	Diameter(in)	Drilling Method	Drilling Fluid
0	20	8.00	CABLE TOOL	WATER
20	200	6.00	CABLE TOOL	WATER

LITHOLOGY:

Depth(ft) From	To	Lithologic Description
0	4	OTHER SOIL/BROWN
4	16	CLAY GRAY
16	196	CLAY, SAND, GRAVEL BROWN/SMALL GRAVEL ZONES MOSTLY FINE SANDS PRODUCED WATER FROM 17' SMALL CLAY ZONES
196	200	SAND, GRAVEL SAND 40%/GRAVEL 60%

WATER LEVEL DATA:

Date	Time	Water Level (feet) (-)above ground	Status
01/08/1996		-3.46	FLOWING

CONSTRUCTION - CASING:

Depth(ft) From	To	Material	Gage(in)	Diameter(in)
+1	200	A53B	.250	6.00

CONSTRUCTION - FILTER PACK/ANNULAR SEALS

73-4298

Depth(ft) From	To	Material	Amount	Density(pcf)
0	20	BENTONITE GRANULAR	5	

WELL TESTS:

Date	Test Method	Yield (CFS)	Drawdown (ft)	Time Pumped (hr
01/08/1996	BAIL	.089	22	5.5

GENERAL COMMENTS:

CONSTRUCTION INFORMATION:
Well head configuration: No data
Casing Joint Type: Welded
Perforator used: No
Additional data not available

PAGE..................
(Leave Blank)

Report No. 2975
Filed June 15 1943
Rec. By Mail
Ret'd.

WP-213
Water 65-66
i d c
70' deep 1/4 3/21/77

well record,
business,
A.K. 6-22-43
Recorded MH 6-15-43
Typed JAP 6-24-43
Checked Ad. 6-22-43
No Action
M.V. 6-22-43

Report of Well and Tunnel Driller
STATE OF UTAH

(Separate report shall be filed for each well or tunnel)

GENERAL INFORMATION:

Report of well or tunnel driller is hereby made and filed with the State Engineer, in accordance with Sections 100-3-22, Revised Statutes of Utah 1933, as amended by Session Laws of 1935. (This report shall be filed with the State Engineer within 30 days after the completion or abandonment of well or tunnel. Failure to file such report constitutes a misdemeanor.)

1. Name and address of person, ~~company or corporation boring or~~ drilling well ~~or tunnel~~
(Strike words not needed)
C. W. Anderson Manti, Utah Boiler

2. Name and address of owner of well ~~or tunnel~~ Royal Bown, Box 123, Manti, Utah
(Strike words not needed)

3. Source if supply is in Sanpete County;
drainage area; artesian basin
(Leave blank) (Leave blank)

4. The number of approved application to appropriate water is 15137

5. Location of well ~~or mouth of tunnel~~ is situated at a point N. 45½ ch. (3003') and E. 22 ch. (1452') from SW Cor. Sec. 27, T. 18 S., R. 2 E., SLB&M.
(Describe by course and distance with reference to U. S. Government Survey Corner — Copy description from well owner's approved application)

6. Date on which work on well ~~or tunnel~~ was begun March 29, 1943
(Strike words not needed)

7. Date on which work on well ~~or tunnel~~ was completed ~~or abandoned~~ March 30, 1943
(Strike words not needed)

8. Maximum quantity of water ~~flowing, pumped or~~ dipped on completion of well ~~or tunnel in sec.-ft.~~ ; or in gals. per minute 5 gal. ; Date March 30, 1943
(Strike words not needed)

DETAIL OF COLLECTING WORKS:

9. WELL: It is a drilled, ~~dug, flowing~~ or pump well. Temperature of water 58 °F.
(Strike words not needed)

(a) Total depth of well is 75 ft. below ground surface.

(b) If flowing well, give water pressure (hydrostatic head) above ground surface .... ft.

(c) If pump well, give depth from ground surface to water surface before pumping 24' ; during pumping 24'

(d) Size and kind of casing 75' of 5" welded tubing.
(If only partially cased, give details)

(e) Depth to water bearing stratum 70 - 75
(If more than one stratum, give depth to each)

(f) If casing is perforated, give depth from ground surface to perforations
65 to 75

(g) Log of well 0-26 clay red, 26-28 gravel & clay, 28-30 brown clay, 30-40 brown clay, 40-50 brown clay, 50-60 brown clay, 60-70 brown clay, 70-75 sand & gravel.

(h) Well was equipped with cap, ~~valve, or~~ .... to control flow.
(Strike words not needed)

(Over)

10. TUNNEL: It is timbered, tiled, piped, open, bulkheaded, covered or........................
(Strike words not needed)

(a) Dimensions..................; total length........................; temperature of water..................°F.

(b) Position of water bearing stratum or strata with reference to mouth of tunnel....................

(c) Log of tunnel....................

11. GENERAL REMARKS: (Note any general or detailed information not covered above.)

STATE OF UTAH,
COUNTY OF Sanpete } ss.

I, C. W. Anderson, being first duly sworn, do hereby certify that I am the driller of the aforesaid well or tunnel who furnished the foregoing statement of facts; that I have read said statement and each and all of the items therein contained are true to the best of my knowledge and belief.

/s/ C. W. Anderson
Driller

Subscribed and sworn to before me this 12th day of June, 1943
(SEAL) /s/ C. H. Beal
Notary Public

(SEAL) RES: Manti, Utah

My Commission Expires:
Sept. 19, 1946

#488

WELL DRILLER'S REPORT
State of Utah
Division of Water Rights

For additional space, use "Additional Well Data Form" and attach

RECEIVED
NOV - 9 2005
WATER RIGHTS
SALT LAKE

WP-224

Well Identification

Water Right: 65-2772 WIN: 34823

Owner *Note any changes*

Glen M. and Shane M. Goodrich
20630 Muddy Hollow Square
Sterling VA 20165

Boden OK

Contact Person/Engineer:

Well Location *Note any changes*

N 470 E 340 from the W4 corner of section 34, Township 18S, Range 2E, SL B&M

Location Description: (address, proximity to buildings, landmarks, ground elevation, local well #)

Drillers Activity Start Date: October 4, 2005 Completion Date: October 7, 2005

Check all that apply: [X] New [ ] Repair [ ] Deepen [ ] Clean [ ] Replace [ ] Public Nature of Use:

If a replacement well, provide location of new well. ______ feet north/south and ______ feet east/west of the existing well.

DEPTH (feet) FROM	TO	BOREHOLE DIAMETER (in)	DRILLING METHOD	DRILLING FLUID
0	30	10"	Air Rotary	Water + foam
30	98	8 3/4	" "	

Well Log

DEPTH (feet) FROM	TO	WATER	PERMEABLE High	PERMEABLE Low	UNCONSOLIDATED CLAY	SILT	SAND	GRAVEL	COBBLES	BOULDER	OTHER	CONSOLIDATED ROCK TYPE	COLOR	DESCRIPTION AND REMARKS (e.g., relative %, grain size, sorting, angularity, bedding, grain composition density, plasticity, shape, cementation, consistancy, water bearing, ordor, fracturing, minerology, texture, degree of weathering, hardness, water quality, etc.)
0	10					X							brown	
10	49						X					Shale	White/Gray	Some fractures in Shale - No water
49	69											soft shale	yellow	
69	82											soft shale	Green	
82	87	X	N									Shale	white, gray and green	Smells good - tastes good
87	98						X					soft shale		

Static Water Level

Date October 7 2005 Water Level 47 feet Flowing? [ ] Yes [X] No

Method of Water Level Measurement Wire String If Flowing, Capped Pressure ______ PSI

Point to Which Water Level Measurement was Referenced Ground surface Elevation ______

Height of Water Level reference point above ground surface 0 feet Temperature 53 degrees [ ] C [X] F

Construction Information

DEPTH (feet) FROM	TO	CASING TYPE AND MATERIAL/GRADE	WALL THICK (in)	NOMINAL DIAM. (in)	DEPTH (feet) FROM	TO	SCREEN SLOT SIZE OR PERF SIZE (in)	SCREEN DIAM. OR PERF LENGTH (in)	SCREEN TYPE OR NUMBER PERF (per round/interval)
+2	98	6" A53B	.250	6 5/8 OD	78	98	.125"	2½"	12/ft

☐SCREEN ☒PERFORATIONS ☐OPEN BOTTOM

Well Head Configuration: 6" steel pipe @ 2' above surface   Access Port Provided? ☒Yes ☐No

Casing Joint Type: Welded   Perforator Used: factory

Was a Surface Seal Installed? ☒Yes ☐No   Depth of Surface Seal: 30 feet   Drive Shoe? ☒Yes ☐No

Surface Seal Material Placement Method: tremie pipe

Was a temporary surface casing used? ☐Yes ☒No If yes, depth of casing: ____ feet diameter: ____ inches

DEPTH (feet) FROM	TO	SURFACE SEAL / INTERVAL SEAL / FILTER PACK / PACKER INFORMATION: SEAL MATERIAL, FILTER PACK and PACKER TYPE and DESCRIPTION	Quantity of Material Used (if applicable)	GROUT DENSITY (lbs./gal., # bag mix, gal./sack etc.)
0	30	Benseal - Baroid	200 lb.	50 lb/24 gal
30	98	gravel pack - ¼"	125 gal	

Well Development and Well Yield Test Information

DATE	METHOD	YIELD	GPM	CFS	DRAWDOWN (ft)	TIME PUMPED (hrs & min)
Oct 7, 05	air lift	20-25	✓			2 hrs

Pump (Permanent)

Pump Description: ____ Horsepower: ____ Pump Intake Depth: ____ feet

Approximate Maximum Pumping Rate: ____ Well Disinfected upon Completion? ☒Yes ☐No

Comments Description of construction activity, additional materials used, problems encountered, extraordinary Circumstances, abandonment procedures. *Use additional well data form for more space.*

Well Driller Statement This well was drilled and constructed under my supervision, according to applicable rules and regulations, and this report is complete and correct to the best of my knowledge and belief.

Name BROTHERSEN DRILLING (Person, Firm, or Corporation; Print or Type)   License No. 657

Signature Joseph McKean Brothersen (Licensed Well Driller)   Date 10-25-05

Form 113—516—12-60

Examined: DEC 10 1980 KET
Recorded: E. C. ______ T. B. ______
Inspection Sheet ______
Copied ______

REPORT OF WELL DRILLER
STATE OF UTAH

63-2349 WR# 256

Application No. 53838
Claim No. ______
Coordinate No. 63-2340
(A20S-1W) 17 adb

Cejudo

GENERAL STATEMENT: Report of well driller is hereby made and filed with the State Engineer, in accordance with the laws of Utah. (This report shall be filed with the State Engineer within 30 days after the completion or abandonment of the well. Failure to file such reports constitutes a misdemeanor.)

(1) WELL OWNER:
Name Jeffrey Lind
Address Flagstaff Ariz.

(2) LOCATION OF WELL:
County San Pete Ground Water Basin ______ (leave blank)
North 800 feet, East 1250 feet from E 1/4 Corner of Section 17, T. 20 S, R. 1 E SLBM (strike out words not needed)

(3) NATURE OF WORK (check): New Well ☑ Replacement Well ☐ Deepening ☐ Repair ☐ Abandon ☐
If abandonment, describe material and procedure: ______

(4) NATURE OF USE (check):
Domestic ☑ Industrial ☐ Municipal ☐ Stockwater ☐
Irrigation ☐ Mining ☐ Other ☐ Test Well ☐

(5) TYPE OF CONSTRUCTION (check):
Rotary ☑ Dug ☐ Jetted ☐
Cable ☐ Driven ☐ Bored ☐

(6) CASING SCHEDULE: Threaded ☐ Welded ☑
6" Diam. from 0 feet to 57 feet Gage .250
______" Diam. from ______ feet to ______ feet Gage ______
______" Diam. from ______ feet to ______ feet Gage ______
New ☑ Reject ☐ Used ☐

(7) PERFORATIONS: Perforated? Yes ☐ No ☑
Type of perforator used ______
Size of perforations ______ inches by ______ inches
______ perforations from ______ feet to ______ feet
______ perforations from ______ feet to ______ feet
______ perforations from ______ feet to ______ feet
______ perforations from ______ feet to ______ feet
______ perforations from ______ feet to ______ feet

(8) SCREENS: Well screen installed? Yes ☐ No ☑
Manufacturer's Name ______
Type ______ Model No. ______
Diam. ______ Slot size ______ Set from ______ ft. to ______
Diam. ______ Slot size ______ Set from ______ ft. to ______

(9) CONSTRUCTION:
Was well gravel packed? Yes ☐ No ☑ Size of gravel: ______
Gravel placed from ______ feet to ______ feet
Was a surface seal provided? Yes ☑ No ☐
To what depth? 20 feet
Material used in seal: Clay
Did any strata contain unusable water? Yes ☐ No ☑
Type of water: ______ Depth of strata ______
Method of sealing strata off: ______

Was surface casing used? Yes ☐ No ☑
Was it cemented in place? Yes ☐ No ☐

(10) WATER LEVELS:
Static level 12 feet below land surface Date Oct 28 80
Artesian pressure ______ feet above land surface Date ______

LOG RECEIVED: RECEIVED DEC 02 1980

(11) FLOWING WELL:
Controlled by (check) Valve ☐
Cap ☐ Plug ☐ No Control ☐
Does well leak around casing? Yes ☐ No ☐

(12) WELL TESTS: Drawdown is the distance in feet the water level is lowered below static level.
Was a pump test made? Yes ☑ No ☐ If so, by whom? Driller
Yield: 20 gal./min. with 20 feet drawdown after 2 hours
Bailer test ______ gal./min. with ______ feet drawdown after ______ hours
Artesian flow ______ g.p.m. Date ______
Temperature of water 52° Was a chemical analysis made? No ☐ Yes ☑

(13) WELL LOG: Diameter of well 6 inches
Depth drilled 57 feet. Depth of completed well 57 feet.

NOTE: Place an "X" in the space or combination of spaces needed to designate the material or combination of materials encountered in each depth interval. Under REMARKS make any desirable notes as to occurrence of water and the color, size, nature, etc., of material encountered in each depth interval. Use additional sheet if needed.

From	To	Clay	Silt	Sand	Gravel	Cobbles	Boulders	Hardpan	Conglomerate	Bedrock	Other	REMARKS
0	50	X	X									
50	57			X								sandstone

Work started Oct 27, 1980 Completed Oct 29, 1980

(14) PUMP:
Manufacturer's Name Gould
Type: Jet H. P. 1
Depth to pump or bowles 28 feet

Well Driller's Statement:
This well was drilled under my supervision, and this report is true to the best of my knowledge and belief.
Name Shank Well Drilling Co. (Person, firm, or corporation) (Type or print)
Address 375 N 5 E Richfield Utah
(Signed) Bennett Shank (Well Driller)
License No. 130 Date Nov 25, 1980

USE OTHER SIDE FOR ADDITIONAL REMARKS

Form 113—5M—12-60

Examined 12-17-69 V.F.O.
Recorded: B. 12-17-69 V.F.O. T. B. V.F.O.
Inspection Sheet 12-19-69 R. M.
Copied

REPORT OF WELL DRILLER
STATE OF UTAH

Application No. 14086
Claim No. (25-76)
Coordinate No. (D-20-1)17 dcc

237

GENERAL STATEMENT: Report of well driller is hereby made and filed with the State Engineer, in accordance with the laws of Utah. (This report shall be filed with the State Engineer within 30 days after the completion or abandonment of the well. Failure to file such reports constitutes a misdemeanor.)

(1) WELL OWNER:
Name Mike Jensen
Address Axtell Utah

(2) LOCATION OF WELL:
County Sanpete Ground Water Basin (leave blank)
North 1121.7 feet, East 445 feet from S¼ Corner of Section 17, T 20 S, R 1 E SLBM (strike out words not needed)

(3) NATURE OF WORK (check): New Well ☐ Replacement Well ☑ Deepening ☐ Repair ☐ Abandon ☐
If abandonment, describe material and procedure:

(4) NATURE OF USE (check):
Domestic ☑ Industrial ☐ Municipal ☐ Stockwater ☑ Irrigation ☐ Mining ☐ Other ☐ Test Well ☐

(5) TYPE OF CONSTRUCTION (check):
Rotary ☐ Dug ☐ Jetted ☐ Cable ☑ Driven ☐ Bored ☐

(6) CASING SCHEDULE: Threaded ☑ Welded ☐
4" Diam. from 0 feet to 105 feet Gage STD
" Diam. from feet to feet Gage
" Diam. from feet to feet Gage
New ☑ Reject ☐ Used ☐

(7) PERFORATIONS: Perforated? Yes ☐ No ☑
Type of perforator used
Size of perforations inches by inches
perforations from feet to feet
perforations from feet to feet
perforations from feet to feet
perforations from feet to feet
perforations from feet to feet

(8) SCREENS: Well screen installed? Yes ☐ No ☑
Manufacturer's Name
Type Model No.
Diam. Slot size Set from ft. to
Diam. Slot size Set from ft. to

(9) CONSTRUCTION:
Was well gravel packed? Yes ☐ No ☑ Size of gravel:
Gravel placed from feet to feet
Was a surface seal provided? Yes ☐ No ☑
To what depth? feet
Material used in seal:
Did any strata contain unusable water? Yes ☐ No ☑
Type of water: Depth of strata
Method of sealing strata off:

Was surface casing used? Yes ☐ No ☑
Was it cemented in place? Yes ☐ No ☐

(10) WATER LEVELS:
Static level 13 feet below land surface Date Dec 12, 69
Artesian pressure feet above land surface Date

LOG RECEIVED:

(11) FLOWING WELL:
Controlled by (check) Valve ☐ Cap ☐ Plug ☐ No Control ☐
Does well leak around casing? Yes ☐ No ☐

(12) WELL TESTS: Drawdown is the distance in feet the water level is lowered below static level.
Was a pump test made? Yes ☑ No ☐ If so, by whom? driller
Yield: 10 gal./min. with 2 feet drawdown after 2 hours
Bailer test gal./min. with feet drawdown after hours
Artesian flow g.p.m. Date
Temperature of water 52 Was a chemical analysis made? No ☑ Yes ☐

(13) WELL LOG: Diameter of well 4 inches
Depth drilled 107 feet. Depth of completed well 105 feet.

NOTE: Place an "X" in the space or combination of spaces needed to designate the material or combination of materials encountered in each depth interval. Under REMARKS make any desirable notes as to occurrence of water and the color, size, nature, etc., of material encountered in each depth interval. Use additional sheet if needed.

From	To	Clay	Silt	Sand	Gravel	Cobbles	Boulders	Hardpan	Conglomerate	Bedrock	Other	REMARKS
0	104	X										
104	107				X							

Use for Despain 2372

Work started Dec 6, 1969 Completed Dec 10, 1969

(14) PUMP:
Manufacturer's Name Myers
Type: jet H. P. ½
Depth to pump or bowls 90 feet

Well Driller's Statement:
This well was drilled under my supervision, and this report is true to the best of my knowledge and belief.
Name Sharp Well Drilling Co. (Person, firm, or corporation) (Type or print)
Address 275 N 5 E Richfield Utah
(Signed) Bennett Sharp (Well Driller)
License No. 130 Date Dec 14, 1969

USE OTHER SIDE FOR ADDITIONAL REMARKS

Form 168

Redmond Q

237

WELL INSPECTION REPORT

Water Right Application No. 14086 (63-76) Date Sept 16, 1970

Owner's Name Miles Jensen

Owner's Address Axtel, Utah

Well location (from application or claim) North 112.17 ft. and East 445 ft. from S¼ Cor.
Sec. 17, T 20S., R 1E., SLB&M County Sanpete

New Well ___ Repair ___ Clean ___ Deepen ___ Replace X

Diameter of Casing 4" New X Used ___

If "used" casing, was it inspected before being used? ___

Replacement Well

New well is located 3 feet ~~east or~~ west ~~and ___ feet north or south~~ from old well.

Has old well been plugged? Yes By whom? Naturally sanded up

Date plugged ___ Method of plugging Naturally sanded up

Flowing Well

Type of control: Valve ( ) Cap ( ) Other ( )

If other than commercial valve or cap, describe the type of control ___

Is the control effective? ___

If not, explain why: ___

Does water leak around casing when control is closed? ___

If so, what is the rate of leakage? ___

Was the well in use at time of inspection? ___

Does the well yield sand? ___ Are there signs of caving? ___

Non-Flowing Well

Was the well equipped with pump at time of inspection? Yes

Does well pump sand? No Are there signs of caving? No

Comments: Meyers HC 50 Pump

Nature of Use

Domestic X Stock X Irrigation ___ Municipal ___ Mining ___ Other ___

If "other" describe use ___

Rate of Discharge

Estimated ___ Measured ___ Method of Measurement: ___

(State whether g.p.m. or c.f.s.)

Tag placed on well X Tag already on well ___ Tag needs to be prepared ___

Comments: ___

Inspection made by K.H. McKinney

Listed on well record
Listed by counties
Copied
Exam. & returned 2-27-41
Exam. for filing 2-28-41
File Copy checked
Plotted & No. Assigned
Indexed 3-1-41
Engr. tied well
Engr. set BM
Well No.

PAGE 3
(Leave Blank)

Report No. 1840
Filed Feb. 26, 1941
Rec. By Counter
Ret'd
Rec. #4532

WP-238

Report of Well and Tunnel Driller
STATE OF UTAH

(Separate report shall be filed for each well or tunnel)

GENERAL INFORMATION:

Report of well or tunnel driller is hereby made and filed with the State Engineer, in accordance with Sections 100-3-22, Revised Statutes of Utah 1933, as amended by Session Laws of 1935. (This report shall be filed with the State Engineer within 30 days after the completion or abandonment of well or tunnel. Failure to file such report constitutes a misdemeanor.)

1. Name and address of person, ~~company or corporation boring or~~ drilling well ~~or tunnel~~ (Strike words not needed)
Cameron L. Thorpe, Axtell, Utah

2. Name and address of owner of well ~~or tunnel~~ (Strike words not needed) Cameron P. Jensen
Axtell, Utah

3. Source of supply is in Sanpete County;
(Leave blank) drainage area; (Leave blank) artesian basin

4. The number of approved application to appropriate water is 13863

5. Location of well ~~or mouth of tunnel~~ is situated at a point 1174 feet E. and 193 ft. S. of the S.W. corner of the N.W. 1/4 of Sec. 16, T. 20, S, R. 1 E. SLB&M. Sanpete County
(Describe by course and distance with reference to U. S. Government Survey Corner — Copy description from well owners' approved application)

6. Date on which work on well ~~or tunnel~~ was begun Jan. 4th '41
(Strike words not needed)

7. Date on which work on well ~~or tunnel~~ was completed ~~or abandoned~~ Feb. 15th '41
(Strike words not needed)

8. Maximum quantity of water ~~flowing~~, pumped ~~or dipped~~ on completion of well ~~or tunnel~~ in ~~sec-ft.~~ 750 gal. per hour; or in gals. per minute 12½; Date Feb. 15th '41
(Strike words not needed)

DETAIL OF COLLECTING WORKS:

9. WELL: It is a drilled, ~~dug, flowing or~~ pump well. Temperature of water About 54 °F.
(Strike words not needed)

(a) Total depth of well is 53 ft. below ground surface.

(b) If flowing well, give water pressure (hydrostatic head) above ground surface ft.

(c) If pump well, give depth from ground surface to water surface before pumping 20 ft.; during pumping Draw down 10 ft.

(d) Size and kind of casing 5 in. galvanized
(If only partially cased, give details)

(e) Depth to water bearing stratum 40 ft.
(If more than one stratum, give depth to each)

(f) If casing is perforated, give depth from ground surface to perforations

(g) Log of well 1st 10 feet top soil and gravel 2nd 10 feet sand few [illegible] soil, 3rd 10 feet and clay, 4th 10 feet gravel, 5th water bearing sand and gravel

RECEIVED
FEB 26 1941
STATE ENGINEER
COUNTER

(h) Well was equipped with cap, valve, or pump to control flow.
(Strike words not needed)

(Over)

14866

Use Jackson
Use This one for Jensen

10. TUNNEL: It is timbered, tiled, piped, open, bulkheaded, covered or..........
(Strike words not needed)

(a) Dimensions..........; total length..........; temperature of water..........°F.

(b) Position of water bearing stratum or strata with reference to mouth of tunnel..........

(c) Log of tunnel..........

11. GENERAL REMARKS: (Note any general or detail information not covered above.)

STATE OF UTAH,
COUNTY OF Salt Lake } ss.

I, Cannon L. Thorpe, being first duly sworn, do hereby certify that I am the driller of the aforesaid well or tunnel who furnished the foregoing statement of facts; that I have read said statement and each and all of the items therein contained are true to the best of my knowledge and belief.

Cannon L. Thorpe
Driller

Subscribed and sworn to before me this 26 day of February, 1941

[illegible]
Notary Public

(SEAL)

My Commission Expires:
April 28, 1944

REPORT OF WELL DRILLER
STATE OF UTAH

Application No. (A40961) WP #257
Claim No.
Coordinate No. 63 1815

GENERAL STATEMENT: Report of well driller is hereby made and filed with the State Engineer, in accordance with the laws of Utah. This report shall be filed with the State Engineer within 30 days after the completion or abandonment of the well. Failure to file such reports constitutes a misdemeanor.)

(1) WELL OWNER:
Name Marion Young
Address

(2) LOCATION OF WELL:
County Sanpete Ground Water Basin (leave blank)
South 60 feet, West 1025 feet from NE Corner of Section 5, T. 20 S, R. 2 E SLBM (strike out words not needed)

(3) NATURE OF WORK (check): New Well ☐ Replacement Well ☐ Deepening ☐ Repair ☐ Abandon ☐
If abandonment, describe material and procedure:

(4) NATURE OF USE (check): Domestic ☑ Industrial ☐ Municipal ☐ Stockwater ☐ Irrigation ☐ Mining ☐ Other ☐ Test Well ☐

(5) TYPE OF CONSTRUCTION (check): Rotary ☑ Dug ☐ Jetted ☐ Cable ☐ Driven ☐ Bored ☐

(6) CASING SCHEDULE: Threaded ☐ Welded ☑
6" Diam. from 0 feet to 23 feet Gage .250
" Diam. from feet to feet Gage
" Diam. from feet to feet Gage
New ☑ Reject ☐ Used ☐

(7) PERFORATIONS: Perforated? Yes ☐ No ☑
Type of perforator used
Size of perforations inches by inches
perforations from feet to feet
perforations from feet to feet
perforations from feet to feet
perforations from feet to feet
perforations from feet to feet

(8) SCREENS: Well screen installed? Yes ☐ No ☑
Manufacturer's Name
Type Model No.
Diam. Slot size Set from ft. to
Diam. Slot size Set from ft. to

(9) CONSTRUCTION:
Was well gravel packed? Yes ☐ No ☑ Size of gravel:
Gravel placed from feet to feet
Was a surface seal provided? Yes ☑ No ☐
To what depth? 10 feet
Material used in seal: Solid Clay
Did any strata contain unusable water? Yes ☐ No ☐
Type of water: Depth of strata
Method of sealing strata off:

Was surface casing used? Yes ☐ No ☑
Was it cemented in place? Yes ☐ No ☑

(10) WATER LEVELS:
Static level 70 feet below land surface Date Jul 14
Artesian pressure feet above land surface Date

LOG RECEIVED: SEP 1

(11) FLOWING WELL:
Controlled by (check) Valve ☐ Cap ☐ Plug ☐ No Control ☐
Does well leak around casing? Yes ☐ No ☐

(12) WELL TESTS: Drawdown is the distance in feet the water level is lowered below static level.
Was a pump test made? Yes ☐ No ☐ If so, by whom?
Yield: gal./min. with feet drawdown after hours
Bailer test gal./min. with feet drawdown after hours
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? No ☐ Yes ☐

(13) WELL LOG: Diameter of well 6 inches
Depth drilled 160 feet. Depth of completed well 160 feet.

NOTE: Place an "X" in the space or combination of spaces needed to designate the material or combination of materials encountered in each depth interval. Under REMARKS make any desirable notes as to occurrence of water and the color, size, nature, etc., of material encountered in each depth interval. Use additional sheet if needed.

From	To	Clay	Silt	Sand	Gravel	Cobbles	Boulders	Hardpan	Conglomerate	Bedrock	Other	REMARKS
0	20	X					X					Siltstone boulders
20	130									X		yellow sandstone 10 gpm water
130	140											White Sandstone 15 gpm water
140	160											white sandstone 25 gpm water

Work started Jul 3 1990 Completed Jul 14 1990

(14) PUMP:
Manufacturer's Name
Type: H. P.
Depth to pump or bowles feet

Well Driller's Statement:
This well was drilled under my supervision, and this report is true to the best of my knowledge and belief.
Name Sharp Well Drilling Co (Person, firm, or corporation) (Type or print)
Address 235 N 500 E Richfield Ut 84701
(Signed) Dale Sharp (Well Driller)
License No. 130 Date Sep 6 1990

USE OTHER SIDE FOR ADDITIONAL REMARKS

WL1

WELL DRILLER'S REPORT
State of Utah
Division of Water Rights

For additional space, use "Additional Well Data Form" and attach

WP T858

RECEIVED
JUL 13 1998
WATER RIGHTS
SALT LAKE

Well Identification CHANGE APPLICATION: t22200(63-4233)

Owner *Note any changes*
Reeves, David & Lucy
2785 South 1300 East
Salt Lake City, UT 84106

Contact Person/Engineer:

Well Location *Note any changes*
COUNTY: Sanpete
SOUTH 380 feet EAST 775 feet from the N¼ Corner of
SECTION 5, TOWNSHIP 20S, RANGE 2E, SLB&M.

Location Description: (address, proximity to buildings, landmarks, ground elevation, local well #) 0.5 mile south of Mayfield

Drillers Activity Start Date: 6/2/98 Completion Date: 6/2/98

Check all that apply: [x] New [ ] Repair [ ] Deepen [ ] Abandon [ ] Replace [ ] Public Nature of Use:

DEPTH (feet) FROM	TO	BOREHOLE DIAMETER (in)	DRILLING METHOD	DRILLING FLUID
0	160	9	Mud Rotary	Bentonite

Well Log

DEPTH (feet) FROM	TO	WATER	PERMEABLE high	PERMEABLE low	CLAY	SILT	SAND	GRAVEL	COBBLES	BOULDERS	OTHER	ROCK TYPE	COLOR	DESCRIPTIONS AND REMARKS (include comments on *water quality* if known.)
0	4					X								
4	22				X			X						
22	65				X									
65	80				X			X						
81	110				X	X								
110	160	X			X			X						

SCANNED

Static Water Level

Date 6/2/98 Water Level 28 feet Flowing? [ ] Yes [ ] No

Method of Water Level Measurement ______ If Flowing, Capped Pressure ______ PSI

Point to Which Water Level Measurement was Referenced ______

Height of Water Level reference point above ground surface ______ feet Temperature ______ [ ] °C [ ] °F

Well Log

Construction Information

DEPTH (feet) FROM	TO	CASING TYPE AND MATERIAL/GRADE	WALL THICK (in)	NOMINAL DIAM. (in)	DEPTH (feet) FROM	TO	SLOT SIZE OR PERF SIZE (in)	SCREEN DIAM. OR PERF LENGTH (in)	SCREEN TYPE OR NUMBER PERF (per round/interval)
0	160	PVC		6	120	160	1/8	3	4 x 18"

SCREEN ☐ PERFORATIONS ☐

Well Head Configuration: Cap Access Port Provided? ☐ Yes ☐ No

Casing Joint Type: Glue Perforator Used: Saw

FILTER PACK / GROUT / PACKER / ABANDONMENT MATERIAL

DEPTH (feet) FROM	TO	ANNULAR MATERIAL, ABANDONMENT MATERIAL and/or PACKER DESCRIPTION	Quantity of Material Used (if applicable)	GROUT DENSITY (lbs./gal.,# bag mix, gal./sack etc.)
0	30	Cement	6 Cu ft	
30	160	Gravel pack		

Well Development / Pump or Bail Tests

Date	Method	Yield	Units Check One GPM	CFS	DRAWDOWN (ft)	TIME PUMPED (hrs & min)
6/2/98	Air	65	✓		50	2

Pump (Permanent)

Pump Description: Grundfos Submersible Horsepower: 1 1/2 Pump Intake Depth: 44 feet

Approximate maximum pumping rate: 25 Well disinfected upon completion? ☒ Yes ☐ No

Comments Description of construction activity, additional materials used, problems encountered, extraordinary circumstances, abandonment procedures. *Use additional well data form for more space.*

SCANNED

Well Driller Statement This well was drilled or abandoned under my supervision, according to applicable rules and regulations, and this report is complete and correct to the best of my knowledge and belief.

Name Unricker & Wells (Person, Firm, or Corporation – Print or Type) License No. 388

Signature [signature] (Licensed Well Driller) Date 6/30/98

WP#259

UTAH DIVISION OF WATER RIGHTS

WELLPRT Well Log Information Listing

65 A233

Version: 2003.09.18.00 Rundate: 10/11/2003 05:59 PM

a 22199

Utah Division of Water Rights

Water Well Log

Sunrise #52

LOCATION:

S 380 ft E 775 ft from N4 CORNER of SECTION 5 T 20S R 2E BASE SL

DRILLER ACTIVITIES:

ACTIVITY # 1 NEW WELL

DRILLER: UNZICKER & WELLS DRILLING CO INC LICENSE #

START DATE: 06/02/1998 COMPLETION DATE: 06/02/1998

BOREHOLE INFORMATION:

Depth(ft) From	Depth(ft) To	Diameter(in)	Drilling Method	Drilling Fluid
0	160	9	MUD ROTARY	BENDONITE

LITHOLOGY:

Depth(ft) From	Depth(ft) To	Lithologic Description
0	4	SILT
4	22	CLAY,GRAVEL
22	65	CLAY
65	80	CLAY,GRAVEL
80	110	CLAY,SILT
110	160	WATER-BEARING,CLAY,GRAVEL

20-100 perf

WATER LEVEL DATA:

Date	Time	Water Level (feet) (-)above ground	Status
06/02/1998		28.00	

CONSTRUCTION - CASING:

Depth(ft) From	Depth(ft) To	Material	Gage(in)	Diameter(in)
0	160	PVC		6

CONSTRUCTION - FILTER PACK/ANNULAR SEALS

Depth(ft) From	Depth(ft) To	Material	Amount	Density(pcf)
0	30	CEMENT (CU FT)	6	
30	160	GRAVEL PACK		

a22199 #259

WELL TESTS:

Date	Test Method	Yield (CFS)	Drawdown (ft)	Time Pumped (hr
06/02/1998	AIR	.145	50	2

GENERAL COMMENTS:
CONSTRUCTION INFORMATION:
Well head configuration: cap
Casing Joint Type: glue
Perforator used: saw
Pump: Groundfos subbmersebel
Horsepower: 1.50
Depth: 44 feet
rate: 25
disinfected: yes
ADDITIONAL DATA NOT AVAILABLE

RECEIVED
JUN 25 2007
WATER RIGHTS
SALT LAKE
Waypoint -259

WELL DRILLER'S REPORT
State of Utah
Division of Water Rights

For additional space, use "Additional Well Data Form" and attach

Well Identification

Change Application: a32580 (63-4524) WIN: 430137

Owner *Note any changes*

Robert M. Johnson 1998 Living Trust
Robert M. and Carma F. Johnson, Co-Trustees
P.O. Box 1200
Washington UT 84780

Contact Person/Engineer:

Well Location *Note any changes*

S 1050 E 3050 from the NW corner of section 05, Township 20S, Range 2E, SL B&M

Location Description: (address, proximity to buildings, landmarks, ground elevation,local well #)

Drillers Activity Start Date: 6-13-07 Completion Date: 6-18-07

Check all that apply: ☒ New ☐ Repair ☐ Deepen ☐ Clean ☐ Replace ☐ Public Nature of Use:

If a replacement well, provide location of new well. NA feet north/south and NA feet east/west of the existing well.

DEPTH (feet) FROM	TO	BOREHOLE DIAMETER (in)	DRILLING METHOD	DRILLING FLUID
0	30	10"	Air Rotary	Air + Water
30'	100'	8"	" "	" "

Well Log

DEPTH (feet) FROM	TO	WATER	PERMEABLE High	PERMEABLE Low	UNCONSOLIDATED CLAY	SILT	SAND	GRAVEL	COBBLES	BOULDER	OTHER	CONSOLIDATED ROCK TYPE	COLOR	DESCRIPTION AND REMARKS (e.g., relative %, grain size, sorting, angularity, bedding, grain composition density, plasticity, shape, cementation, consistancy, water bearing, odor, fracturing, minerology, texture,degree of weathering, hardness, water quality, etc.)
0'	61'				X	X							Brown	
61	100'	X									X	Sandstone	TAN	

Static Water Level

Date 6-18-07 Water Level 28 feet Flowing? ☐ Yes ☒ No

Method of Water Level Measurement TAPE If Flowing, Capped Pressure NA PSI

Point to Which Water Level Measurement was Referenced Ground Elevation NK

Height of Water Level reference point above ground surface 0 feet Temperature 55.4 degrees ☐ C ☒ F

I III

259

Construction Information

DEPTH (feet) FROM	TO	CASING TYPE AND MATERIAL/GRADE	WALL THICK (in)	NOMINAL DIAM. (in)	DEPTH (feet) FROM	TO	☒SCREEN ☐PERFORATIONS ☐OPEN BOTTOM: SCREEN SLOT SIZE OR PERF SIZE (in)	SCREEN DIAM. OR PERF LENGTH (in)	SCREEN TYPE OR NUMBER PERF (per round/interval)
+2	13'	Steel	.250	6"	50'	90'	.010	5"	4 Rows
10'	100'	PVC-SDR-17	.327	5"					

Well Head Configuration: Pitless Adaptor 1 1/4" Access Port Provided? ☒Yes ☐No

Casing Joint Type: Sur-lock Perforator Used: Factory Perforations

Was a Surface Seal Installed? ☒Yes ☐No Depth of Surface Seal: 30' feet Drive Shoe? ☐Yes ☒No

Surface Seal Material Placement Method: Dumped IN

Was a temporary surface casing used? ☒Yes ☐No If yes, depth of casing: 21 feet diameter: 8" inches

DEPTH (feet) FROM	TO	SURFACE SEAL / INTERVAL SEAL / FILTER PACK / PACKER INFORMATION: SEAL MATERIAL, FILTER PACK and PACKER TYPE and DESCRIPTION	Quantity of Material Used (if applicable)	GROUT DENSITY (lbs./gal., # bag mix, gal./sack etc.)
0'	30'	Bentonite chips	14 Bags	Dry

Well Development and Well Yield Test Information

DATE	METHOD	YIELD	Units Check One: GPM	CFS	DRAWDOWN (ft)	TIME PUMPED (hrs & min)
6-14-07	Air Lift	80+	X		Total	2 Hrs
6-18-07	Pump	37	X		0'	1 1/2 Hrs

Pump (Permanent)

Pump Description: Sub- Grundfos Horsepower: 2 Pump Intake Depth: 85 feet

Approximate Maximum Pumping Rate: 25 GPM. Well Disinfected upon Completion? ☒Yes ☐No

Comments

Description of construction activity, additional materials used, problems encountered, extraordinary Circumstances, abandonment procedures. *Use additional well data form for more space.*

Well Driller Statement

This well was drilled and constructed under my supervision, according to applicable rules and regulations, and this report is complete and correct to the best of my knowledge and belief.

Name MILLER DRILLING License No. 292

Person, Firm, or Corporation - Print or Type

Signature Everett Miller Date 6-23-07

Licensed Well Driller

WL1

WELL DRILLER'S REPORT

State of Utah
Division of Water Rights

For additional space, use "Additional Well Data Form" and attach

WP-261

Well Identification
CHANGE APPLICATION: a21475(63-4235) WIN: 017765

Owner *Note any changes*

Hopkins, T. Mark and Kathy
P.O. Box 642
Gunnison, UT 84634

RECEIVED
NOV 30 1998
WATER RIGHTS
SALT LAKE

Contact Person/Engineer:

Well Location *Note any changes*

COUNTY: Sanpete
NORTH 1107 feet WEST 620 feet from the SE Corner of
SECTION 32, TOWNSHIP 19S, RANGE 2E, SLB&M.

Location Description: (address, proximity to buildings, landmarks, ground elevation, local well #) ~~1/2 mile south of Mayfield~~

Drillers Activity Start Date: 6-29-98 Completion Date: 7-10-98

Check all that apply: [X] New [ ] Repair [ ] Deepen [ ] Abandon [ ] Replace [ ] Public Nature of Use:

DEPTH (feet) FROM	TO	BOREHOLE DIAMETER (in)	DRILLING METHOD	DRILLING FLUID
0	167	8"	Cable Tool	Water

Well Log

DEPTH (feet) FROM	TO	WATER	PERMEABLE high	PERMEABLE low	CLAY	SILT	SAND	GRAVEL	COBBLES	BOULDER	OTHER	ROCK TYPE	COLOR	DESCRIPTIONS AND REMARKS (include comments on water quality if known.)
0	9													Top Soil
9	25				X		X	X					Brown	
25	72				X		X	X					White	
72	80	X					X	X					Brown	hit water @ 72'
80	117	X					X	X					Lt Brown	some water
117	120	X					X	X					" "	good water
120	142						X	X					Brown	more sand
142	158	X					X	X					"	good water
158	167				X								"	

Static Water Level

Date 7-10-98 Water Level 62 feet Flowing? [ ] Yes [X] No

Method of Water Level Measurement Baler If Flowing, Capped Pressure ______ PSI

Point to Which Water Level Measurement was Referenced Tip of Casing

Height of Water Level reference point above ground surface 1.5 feet Temperature ______ [ ] °C [ ] °F

261

Construction Information

DEPTH (feet) FROM	TO	CASING TYPE AND MATERIAL/GRADE	WALL THICK (in)	NOMINAL DIAM. (in)	DEPTH (feet) FROM	TO	SCREEN ☐ PERFORATIONS ☒ SLOT SIZE OR PERF SIZE (in)	SCREEN DIAM. OR PERF LENGTH (in)	SCREEN TYPE OR NUMBER PERF (per round/interval)
0	167	A52B Steel	.250	8"	142	158	2" x 1/4		8/round/every 8"

Well Head Configuration: ____ Access Port Provided? ☐ Yes ☐ No

Casing Joint Type: Welded Perforator Used: Mills

DEPTH (feet) FROM	TO	FILTER PACK / GROUT / PACKER / ABANDONMENT MATERIAL: ANNULAR MATERIAL, ABANDONMENT MATERIAL and/or PACKER DESCRIPTION	Quantity of Material Used (if applicable)	GROUT DENSITY (lbs./gal.,# bag mix, gal./sack etc.)
0	20	Grout Neat Cement	1 yard	1 bag cement / 8 gal water

Well Development / Pump or Bail Tests

Date	Method	Yield	Units GPM	Units CFS	DRAWDOWN (ft)	TIME PUMPED (hrs & min)
7-10-98	Bailer	30	X		0	4 hrs

Pump (Permanent)

Pump Description: ____ Horsepower: ____ Pump Intake Depth: ____ feet

Approximate maximum pumping rate: ____ Well disinfected upon completion? ☐ Yes ☐ No

Comments Description of construction activity, additional materials used, problems encountered, extraordinary circumstances, abandonment / procedures. *Use additional well data form for more space.*

Well Driller Statement This well was drilled or abandoned under my supervision, according to applicable rules and regulations, and this report is complete and correct to the best of my knowledge and belief.

Name Rhodes Well Service (Person, Firm, or Corporation – Print or Type) License No. 0257

Signature James Rhodes (Licensed Well Driller) Date 8-15-98

283 Well Site 1+ Test well B ?

WELL DRILLER'S REPORT
State of Utah
Division of Water Rights

For additional space, use "Additional Well Data Form" and attach

B.S. 1-10-05

Well Identification

Non-Production Well: 0463002M00 WIN: 30367

Owner *Note any changes*

Centerfield City and Mayfield town
P.O. Box 220200
130 S Main Street
Centerfield, UT 84622

North Mayfield

Contact Person/Engineer: ____

Well Location *Note any changes*

N 1160 W 1168 from the SE corner of section 20, Township 19S, Range 2E, SL B&M

This well is capped ?

Location Description: (address, proximity to buildings, landmarks, ground elevation, local well #)

Drillers Activity Start Date: 9-6-04 Completion Date: 10-4-04

Check all that apply: ☒ New ☐ Repair ☐ Deepen ☐ Clean ☐ Replace ☐ Public Nature of Use: Test Well

If a replacement well, provide location of new well. ____ feet north/south and ____ feet east/west of the existing well.

DEPTH (feet) FROM	TO	BOREHOLE DIAMETER (in)	DRILLING METHOD	DRILLING FLUID
0	78	9 7/8"	Air Rotary	water
78	400	7 7/8"	Air Rotary	water

Well Log

DEPTH (feet) FROM	TO	WATER	PERMEABLE High	PERMEABLE Low	CLAY	SILT	SAND	GRAVEL	COBBLES	BOULDERS	OTHER	ROCK TYPE	COLOR	DESCRIPTION AND REMARKS (e.g., relative %, grain size, sorting, angularity, bedding, grain composition density, plasticity, shape, cementation, consistancy, water bearing, ordor, fracturing, minerology, texture, degree of weathering, hardness, water quality, etc.)
0	5				X	X							Grey	
5	18	X		X	X								Tan	
18	53	X		X	X			X					Tan	
53	134	X	X				X	X						
134	170	X		X	X		X	X					Tan	160-170' Sand/H2O
170		X	X								X	Limestone	Dark Grey	Fractured limestone
														not much H2O

casing 100'

RECEIVED
JAN 10 2005
WATER RIGHTS
SALT LAKE

Static Water Level

Date 10-4-04 Water Level ____ feet Flowing? ☐ Yes ☒ No

Method of Water Level Measurement ____ If Flowing, Capped Pressure ____ PSI

Point to Which Water Level Measurement was Referenced ____ Elevation ____

Height of Water Level reference point above ground surface ____ feet Temperature ____ degrees ☐C ☐F

w/ John Wilson Summer 05

Well Log

Cased off to 100' Irrigation Water

283

Construction Information

DEPTH (feet) FROM	DEPTH (feet) TO	CASING TYPE AND MATERIAL/GRADE	WALL THICK (in)	NOMINAL DIAM (in)	DEPTH (feet) FROM	DEPTH (feet) TO	☐SCREEN ☐PERFORATIONS ☐OPEN BOTTOM SCREEN SLOT SIZE OR PERF SIZE (in)	SCREEN DIAM. OR PERF LENGTH (in)	SCREEN TYPE OR NUMBER PERF (per round/interval)
+1.5	178'	Steel A53-B	.250	8"					

Well Head Configuration: Steel plate welded to casing Access Port Provided? ☐Yes ☒No

Casing Joint Type: welded Perforator Used: ____

Was a Surface Seal Installed? ☒Yes ☐No Depth of Surface Seal: 42 feet Drive Shoe? ☐Yes ☒No

Surface Seal Material Placement Method: poured from surface

DEPTH (feet) FROM	DEPTH (feet) TO	SEAL MATERIAL, FILTER PACK and PACKER TYPE and DESCRIPTION	Quantity of Material Used (if applicable)	GROUT DENSITY (lbs./gal., # bag mix, gal./sack etc.)
0	42'	Bentonite Hole Plug	350#	Dry

most H_2O from 160

Well Development and Well Yield Test Information

DATE	METHOD	YIELD	Units GPM	Units CFS	DRAWDOWN (ft)	TIME PUMPED (hrs & min)
10-4-04	compressed Air	150 approx	X			

Pump (Permanent)

Pump Description: ____ Horsepower: ____ Pump Intake Depth: ____ feet

Approximate Maximum Pumping Rate: ____ Well Disinfected upon Completion? ☐Yes ☐No

Comments

Description of construction activity, additional materials used, problems encountered, extraordinary Circumstances, abandonment procedures. *Use additional well data form for more space.*

water Tested / excessive Nitrates, pump test has not been done as of yet. Owner considering using well for secondary water.

Airlifted in — may not represent a valid sample from the well

Well Driller Statement

This well was drilled and constructed under my supervision, according to applicable rules and regulations, and this report is complete and correct to the best of my knowledge and belief.

Name WRIGHT DRILLING License No. 333

Person, Firm, or Corporation - Print or Type

Signature [signature] Date 10-16-04

Licensed Well Driller

Well S-TE ID 2841

WELL DRILLER'S REPORT
State of Utah
Division of Water Rights

For additional space, use "Additional Well Data Form" and attach

Well Identification

Non-Production Well: 0463001M00 WIN: 31036

Owner *Note any changes*

Centerfield City and Mayfield Town
P.O.B ox 220200
130 S. Main Street
Centerfield, UT 84622

Contact Person/Engineer: John Iverson, Sunrise Engineering

Well Location *Note any changes*

N 1950 W 150 from the SE corner of section 28, Township 18S, Range 1W, SL B&M

(C-18-1)28 dca

Location Description: (address, proximity to buildings, landmarks, ground elevation, local well #)

Drillers Activity Start Date: 10-19-04 Completion Date: 11-09-04

Check all that apply: ☒ New ☐ Repair ☐ Deepen ☐ Clean ☐ Replace ☐ Public Nature of Use: Test Well

If a replacement well, provide location of new well. ______ feet north/south and ______ feet east/west of the existing well.

DEPTH (feet) FROM	TO	BOREHOLE DIAMETER (in)	DRILLING METHOD	DRILLING FLUID
0	40	12 1/4"	Air Rotary	air & water
40	440	7 7/8"	Air Rotary	air & water

Well Log

DEPTH (feet) FROM	TO	WATER	PERMEABLE High	PERMEABLE Low	CLAY	SILT	SAND	GRAVEL	COBBLES	BOULDER	OTHER	ROCK TYPE	COLOR	DESCRIPTION AND REMARKS (e.g., relative %, grain size, sorting, angularity, bedding, grain composition density, plasticity, shape, cementation, consistancy, water bearing, ordor, fracturing, minerology, texture, degree of weathering, hardness, water quality, etc.)
0	23						X	X						
23	53				X			X					Grey	
53	82				X			X					Tan	
82	114						X	X						
114	138							X						
138	140				X								Tan	
140	210				X			X					Tan	
210		X	X								X	Limestone		Fractured

Geologists Log attached

RECEIVED
NOV 23 2004
WATER RIGHTS
SALT LAKE

Static Water Level

Date 11-09-04 Water Level 198 feet Flowing? ☐ Yes ☒ No

Method of Water Level Measurement electric Sounder If Flowing, Capped Pressure ______ PSI

Point to Which Water Level Measurement was Referenced ground Surface Elevation ______

Height of Water Level reference point above ground surface 0 feet Temperature ______ degrees ☐C ☐F

284

Construction Information

Hayes Canyon

DEPTH (feet) FROM	TO	CASING TYPE AND MATERIAL/GRADE	WALL THICK (in)	NOMINAL DIAM. (in)	DEPTH (feet) FROM	TO	SCREEN SLOT SIZE OR PERF SIZE (in)	SCREEN DIAM. OR PERF LENGTH (in)	SCREEN TYPE OR NUMBER PERF (per round/interval)
+1.5'	220'	Steel A53-B	.250	8"					

☐SCREEN ☐PERFORATIONS ☒OPEN BOTTOM

Well Head Configuration: steel cap welded to casing Access Port Provided? ☐Yes ☒No

Casing Joint Type: welded Perforator Used: none

Was a Surface Seal Installed? ☒Yes ☐No Depth of Surface Seal: 40 feet Drive Shoe? ☒Yes ☐No

Surface Seal Material Placement Method: dry pour Bentonite Pellets

SURFACE SEAL / INTERVAL SEAL / FILTER PACK / PACKER INFORMATION

DEPTH (feet) FROM	TO	SEAL MATERIAL, FILTER PACK and PACKER TYPE and DESCRIPTION	Quantity of Material Used (if applicable)	GROUT DENSITY (lbs./gal., # bag mix, gal./sack etc.)
0	40	Bentonite hole plug	1½ cubicfeet	Dry

Well Development and Well Yield Test Information

DATE	METHOD	YIELD	Units Check One: GPM	CFS	DRAWDOWN (ft)	TIME PUMPED (hrs & min)
11-09-04	Test Pump	400	X		48	34

Pump (Permanent)

Pump Description: ______ Horsepower: ______ Pump Intake Depth: ______ feet

Approximate Maximum Pumping Rate: ______ Well Disinfected upon Completion? ☐Yes ☐No

Comments

Description of construction activity, additional materials used, problems encountered, extraordinary Circumstances, abandonment procedures. *Use additional well data form for more space.*

Well Driller Statement

This well was drilled and constructed under my supervision, according to applicable rules and regulations, and this report is complete and correct to the best of my knowledge and belief.

Name WRIGHT DRILLING (Person, Firm, or Corporation - Print or Type) License No. 333

Signature [signature] (Licensed Well Driller) Date 11-18-04

SITE ID
284[1]

PERCENTAGE LOG OF WATER-WELL CUTTINGS
UTAH GEOLOGICAL SURVEY

DWRi Appropriation #: 04-63-001-M00
Location: (C-18-1)28dad, Sanpete County, Utah
Driller: Wright Drilling Inc.

Well Owner: Centerfield/Mayfield
Win #: 31036
Geologist: Janae Wallace, 2/12/07

DEPTH RANGE (FEET)		PERCENTAGES unconsolidated			COMMENTS
		clay	sand	gravel+	
0	10	0	0	100	yellow-tan and minor pink gravel; gravel is angular to rounded and consists of dominantly of limestone (some oolitic and some fossiliferous) with minor sandstone, siltstone, and chert; maximum clast size (MCS) is 2.5 cm, average clast size (ACS) is 1 cm; calcareous
10	20	tr	10	90	yellow-tan and pink silt and sand with gravel; sand is fine to coarse and consists of lithic fragments with minor quartz, and feldspar; gravel is angular to rounded and consists of dominantly of limestone (some oolitic and some fossiliferous) with minor sandstone, siltstone, and chert; MCS is 3 cm, ACS is 1 cm; trace clay; calcareous
20	30	0	0	100	yellow-tan, gray, and pink gravel; gravel is angular to rounded and consists of dominantly of limestone (some oolitic and some fossiliferous) with minor sandstone, siltstone, and chert; MCS is 3 cm, ACS is 1 cm; calcareous
30	40	0	0	100	" MCS is 2.5 cm, ACS is 1 cm
40	53	0	0	100	" MCS is 3 cm, ACS is 2 cm

+angular nature of gravel is not necessarily a clast characteristic and may result from drill-bit action; estimated clast size may not be the actual size encountered by the driller

284

2

DEPTH RANGE (FEET)		PERCENTAGES unconsolidated			COMMENTS
		clay	sand	gravel+	
53	60	2	tr	98	tan with minor pink and gray clay and gravel with trace sand; gravel is angular to rounded and consists dominantly of limestone (some oolitic and some fossiliferous) with minor sandstone, siltstone, and chert; MCS is 2 cm, ACS is 0.3 cm; calcareous
60	70	5	20	75	yellow-tan with minor gray and pink clay, silt, sand, and gravel; sand is fine to coarse and consists of lithic fragments with minor quartz, and feldspar; gravel is angular to rounded and consists of dominantly of limestone (some oolitic and some fossiliferous) with minor sandstone, siltstone, and chert; MCS is 1.5 cm, ACS is 0.5 cm; calcareous
70	80	5	20	75	" MCS is 3 cm, ACS is 1 cm
80	82	0	0	0	no sample
82	90	tr	10	90	yellow-tan with minor gray and pink sand and gravel; sand is fine to coarse and consists of lithic fragments with minor quartz, feldspar, and calcite; gravel is angular to rounded and consists of dominantly of limestone (some oolitic and some fossiliferous) with minor sandstone, siltstone, and chert; MCS is 3 cm, ACS is 1 cm; trace clay; calcareous
90	100	10	20	70	tan, gray, and pink clay, silt, sand, and gravel; sand is fine to coarse and consists of lithic fragments with minor quartz, feldspar, and calcite; gravel is angular to rounded and consists of dominantly of limestone (some oolitic and some fossiliferous) with minor sandstone, siltstone, and chert; MCS is 3 cm, ACS is 1 cm; calcareous
100	114	5	5	90	" MCS is 2 cm, ACS is 1 cm
114	120	5	20	75	" MCS is 1 cm, ACS 0.3 cm

+angular nature of gravel is not necessarily a clast characteristic and may result from drill-bit action; estimated clast size may not be the actual size encountered by the driller

284

3

DEPTH RANGE (FEET)		PERCENTAGES unconsolidated			COMMENTS
		clay	sand	gravel+	
120	123	0	0	0	no sample
123	130	0	0	100	yellow-tan, gray, and pink gravel; gravel is angular to rounded and consists of dominantly of limestone (some oolitic and some fossiliferous) with minor sandstone, siltstone, and chert; MCS is 3 cm, ACS is 1.5 cm; calcareous
130	140	0	0	100	" MCS is 3 cm, ACS is 2 cm
140	150	0	0	100	yellow-tan, gray, and pink gravel; gravel is angular to rounded and consists of dominantly of limestone (some oolitic and some fossiliferous) with minor sandstone, siltstone, and chert; MCS is 3.5 cm, ACS is 2 cm; calcareous
150	160	0	0	100	" MCS is 3 cm, ACS is 2 cm
160	170	0	0	100	" MCS is 3.5 cm, ACS is 2 cm
170	180	tr	5	95	yellow-tan with minor gray and pink sand and gravel; sand is fine to coarse and consists of lithic fragments with minor quartz, feldspar, and calcite; gravel is angular to rounded and consists of dominantly of limestone (some oolitic and some fossiliferous) with minor sandstone, siltstone, and chert; MCS is 3 cm, ACS is 1 cm; trace clay; calcareous
180	190	5	5	95	tan-yellow, gray, and pink clay, silt, sand, and gravel; sand is fine to coarse and consists of lithic fragments with minor quartz, feldspar, and calcite; gravel is angular to rounded and consists of dominantly of limestone (some oolitic and some fossiliferous) with minor sandstone, siltstone, and chert; MCS is 2.5 cm, ACS is 1.5 cm; calcareous

+angular nature of gravel is not necessarily a clast characteristic and may result from drill-bit action; estimated clast size may not be the actual size encountered by the driller

234

4

DEPTH RANGE (FEET)		PERCENTAGES unconsolidated			COMMENTS
		clay	sand	gravel[+]	
190	200	tr	5	95	yellow-tan with minor gray and pink sand and gravel; sand is fine to coarse and consists of lithic fragments with minor quartz, feldspar, and calcite; gravel is angular to rounded and consists of dominantly of limestone (some oolitic and some fossiliferous) with minor sandstone, siltstone, and chert; MCS is 3 cm, ACS is 1 cm; trace clay; calcareous
200	210	tr	5	95	" MCS is 3.5 cm, ACS is 2 cm
210	220	0	0	100	yellow-tan, gray, and pink gravel; gravel is angular to rounded and consists of dominantly of limestone (some oolitic and some fossiliferous) with minor sandstone, siltstone, and chert; MCS is 3.5 cm, ACS is 2 cm; calcareous (*note–per driller's log, from 210-440', well consists of fractured limestone; however, cuttings available for this analysis consist of gravel-sized clasts that are angular to rounded and have a cement rind on some clasts, the composition is dominantly of heterolithic types of limestone (some oolitic and some fossiliferous) of different colors and textures with minor sandstone, chert, and siltstone [these may represent clasts that collapsed into the hole from above? or they represent the actual interval as labeled on the cuttings' sample bags])
220	230	0	0	100	" MCS is 1 cm, ACS is 0.5 cm
230	240	0	0	100	" MCS is 1 cm, ACS is 0.5 cm
240	250	0	0	100	" MCS is 1 cm, ACS is 0.5 cm
250	260	0	0	100	" MCS is 1 cm, ACS is 0.5 cm
260	270	0	0	100	" MCS is 1 cm, ACS is 0.5 cm

[+]angular nature of gravel is not necessarily a clast characteristic and may result from drill-bit action; estimated clast size may not be the actual size encountered by the driller

784

5

DEPTH RANGE (FEET)		PERCENTAGES unconsolidated			COMMENTS
		clay	sand	gravel+	
270	280	0	0	100	" MCS is 1 cm, ACS is 0.5 cm
280	290	0	0	100	" MCS is 1 cm, ACS is 0.5 cm
290	300	0	0	100	" MCS is 1 cm, ACS is 0.5 cm
300	310	0	0	100	" MCS is 1 cm, ACS is 0.5 cm
310	320	0	0	100	" MCS is 1 cm, ACS is 0.5 cm
320	330	0	0	100	" MCS is 1 cm, ACS is 0.5 cm
330	340	0	0	100	" MCS is 1 cm, ACS is 0.5 cm
340	350	0	0	100	yellow-tan, gray, and pink gravel; gravel is angular to rounded and consists of dominantly of limestone (some oolitic and some fossiliferous) with minor sandstone, siltstone, and chert; MCS is 1 cm, ACS is 0.5 cm; calcareous
350	360	0	0	100	" MCS is 1.5 cm, ACS is 0.5 cm
360	370	0	0	100	" MCS is 1 cm, ACS is 0.3 cm
370	380	0	0	100	" MCS is 1.5 cm, ACS is 0.3 cm
380	390	0	0	100	" MCS is 1.5 cm, ACS is 0.5 cm
390	400	0	0	100	" MCS is 1 cm, ACS is 0.5 cm
400	410	0	0	100	" MCS is 2 cm, ACS is 0.5 cm
410	420	tr	0	100	" MCS is 1.5 cm, ACS is 0.5 cm; trace pink clay
420	430	0	0	100	" MCS is 1.5 cm, ACS is 0.5 cm; no clay
430	440	0	0	100	" MCS is 1.5 cm, ACS is 0.5 cm

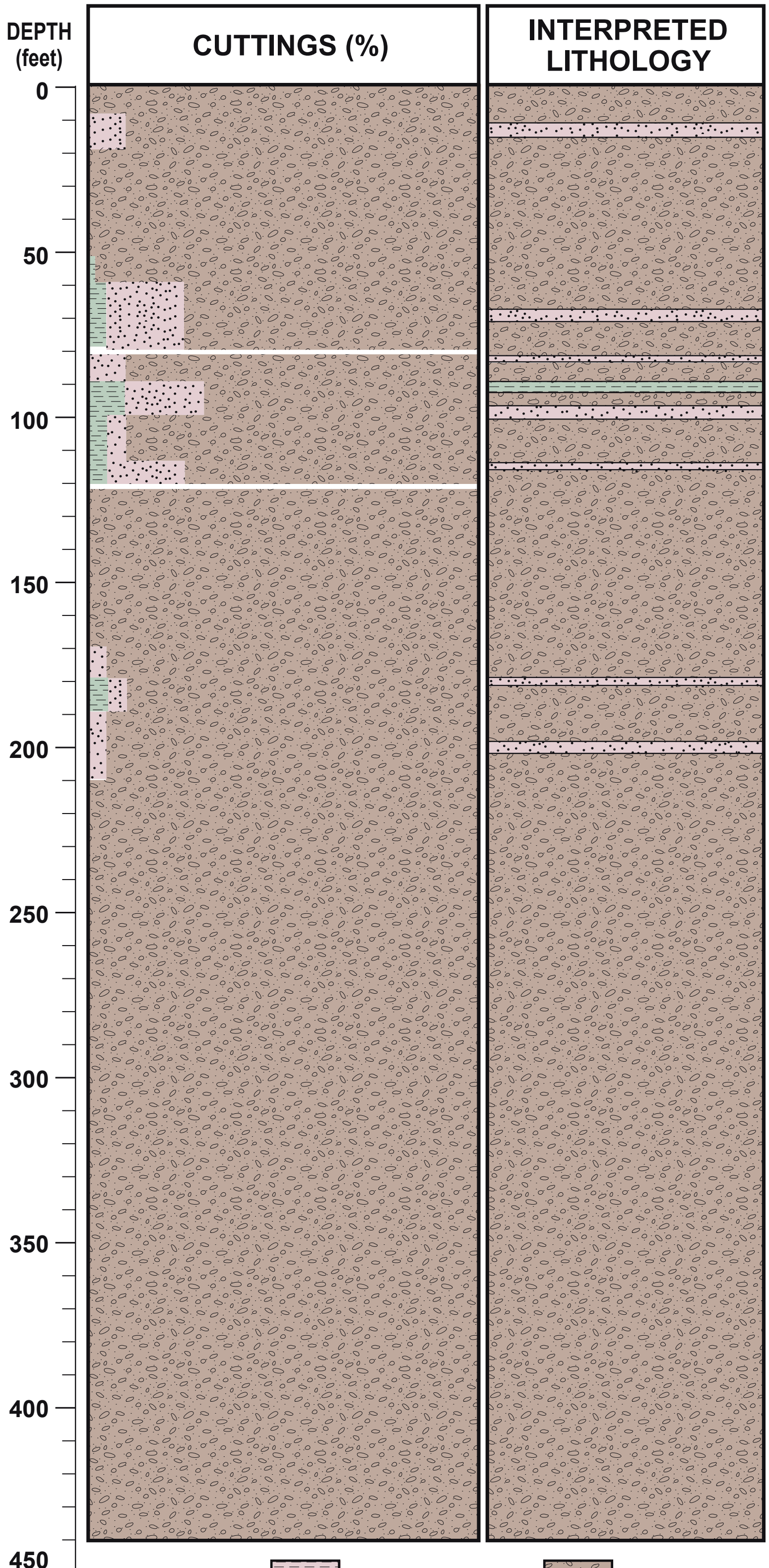
+angular nature of gravel is not necessarily a clast characteristic and may result from drill-bit action; estimated clast size may not be the actual size encountered by the driller

GEOLOGIC LOG OF WATER-WELL CUTTINGS

UTAH GEOLOGICAL SURVEY

DWRi Appropriation #: 04-63-001-M00
Location: (C-18-1)28dad, Sanpete County, Utah
Driller: Wright Drilling Inc.

Well Owner: Centerfield/Mayfield
Win #: 31036
Geologist: Janae Wallace, 02/12/07



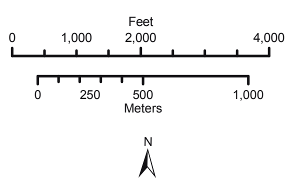
DESCRIPTION

Yellow-tan, gray, and pink gravel with minor clay, silt, and sand; gravel is angular to rounded and consists dominantly of limestone (some oolitic and some fossiliferous) with minor sandstone, siltstone, and chert; calcareous.

*Note - At 210 feet, driller's log indicates that the cuttings consist of fractured limestone; however, cuttings available for this analysis consist of gravel-sized clasts (alluvium) that are angular to rounded and have a cement rind on some clasts, the composition is dominantly of heterolithic types of limestone (some oolitic and some fossiliferous) of different colors and textures with minor sandstone, chert, and siltstone (these may represent clasts that collapsed into the hole from above? or they represent the actual interval as labeled on the cuttings' sample bags.

APPENDIX F
1963 AERIAL PHOTO OF THE HAYES CANYON AREA IN SANPETE COUNTY

1963 photo courtesy of U.S. Geological Survey, The National Map,
EROS Data Center USGS Medium Resolution Digitized Imagery (10/4/04)



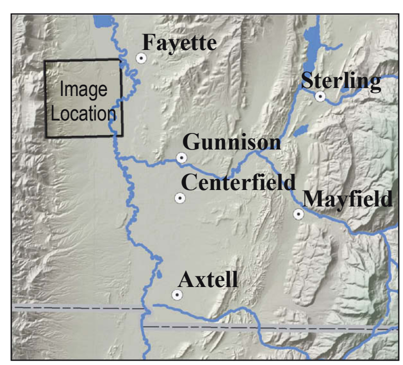
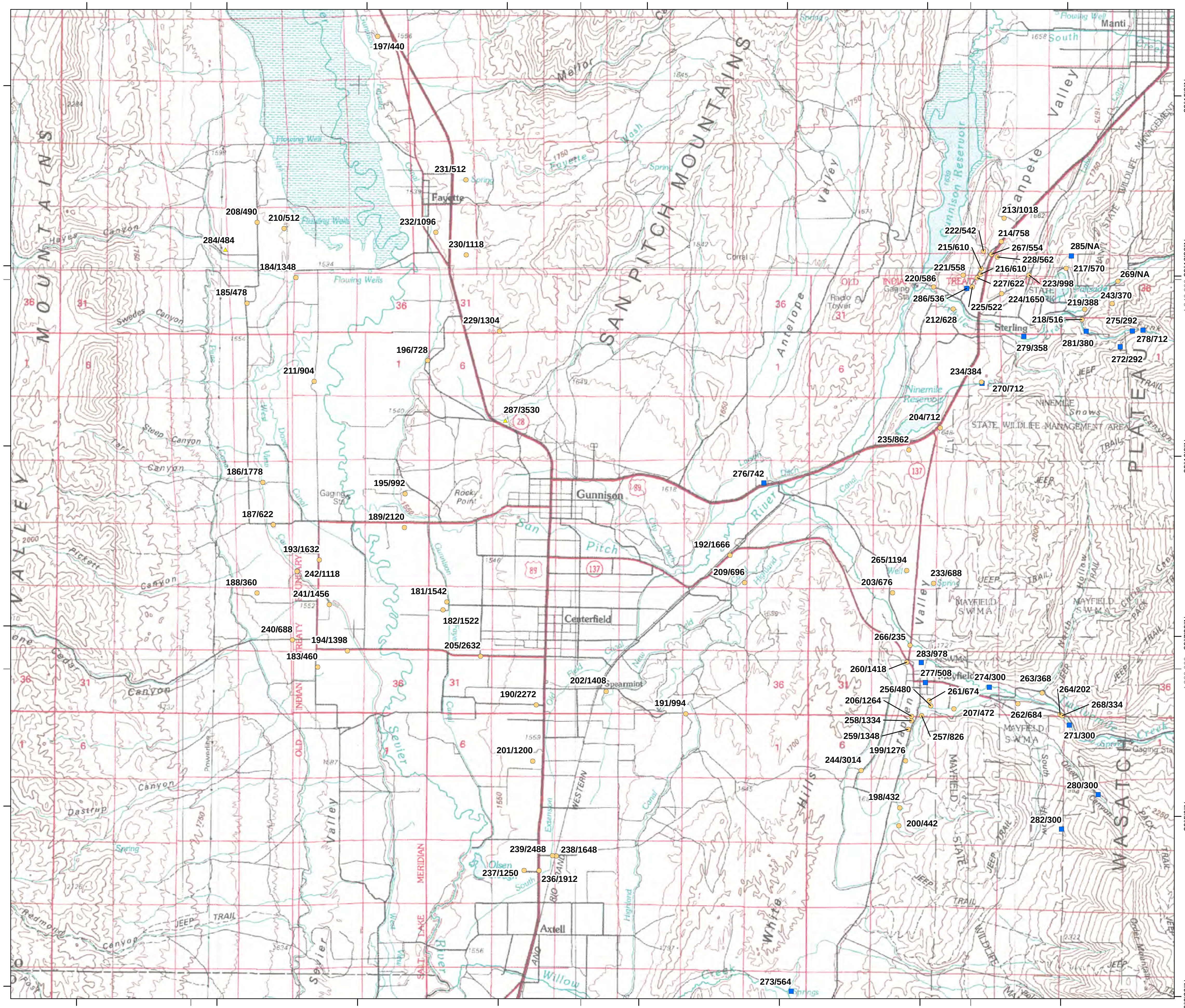


Figure F1. *1963 land-use practice near Hayes Canyon is similar to current land-use practices (compare to plates 2 and 6).*



UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources

Plate 1
Utah Geological Survey Special Study 132
Water-quality assessment of the principal valley-fill aquifers in southern Sanpete and central Sevier Valleys, Sanpete County, Utah

Explanation

Sampled wells by data source

- Utah Geological Survey
- Sunrise Engineering Inc.
- Utah Division of Drinking Water

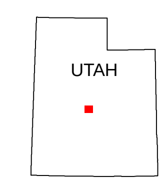
236/1912 Site ID/TDS concentration in mg/L. See Appendix B for complete water chemistry by site ID.

1 0.5 0 1 2 3 4 MILES

1 0.5 0 1 2 3 4 5 KILOMETERS

1:100,000

N



Study Area

This map was created from Geographic Information System (GIS) files.
Projection: Universal Transverse Mercator
Datum: North American 1983 Zone 12 N
Spheroid: Clarke 1866
Basemap: USGS 100K Topographic
Cartography by Richard Emerson

Plate 1.
Sample Locations and Total-Dissolved-Solids Concentration, Southern Sanpete and Central Sevier Valleys, Sanpete County, Utah

by Janae Wallace

2010

UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources

Plate 2
Utah Geological Survey Special Study 132
Water-quality assessment of the principal valley-fill aquifers in southern Sanpete and central Sevier Valleys, Sanpete County, Utah

1 0.5 0 1 MILE

1 0.5 0 1 KILOMETER

Scale 1:30,000

Explanation

Potential Contaminants

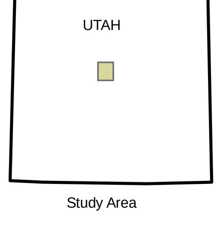
See appendix D for description of numbered contaminant

- Cemetery
- Business
- Concentration of animals and/or feed lot
- Former concentration of animals and/or feed lot
- Government
- Industry
- Farm equipment
- Junk yard/salvage
- Corral
- Grazing
- Large lawn
- Medical
- Mining
- Service station
- Storage tank (above ground)
- Waste-water disposal

Plate 2.
Potential Contaminant Sources, Southern Sanpete and Central Sevier Valleys, Sanpete County, Utah

By Janae Wallace

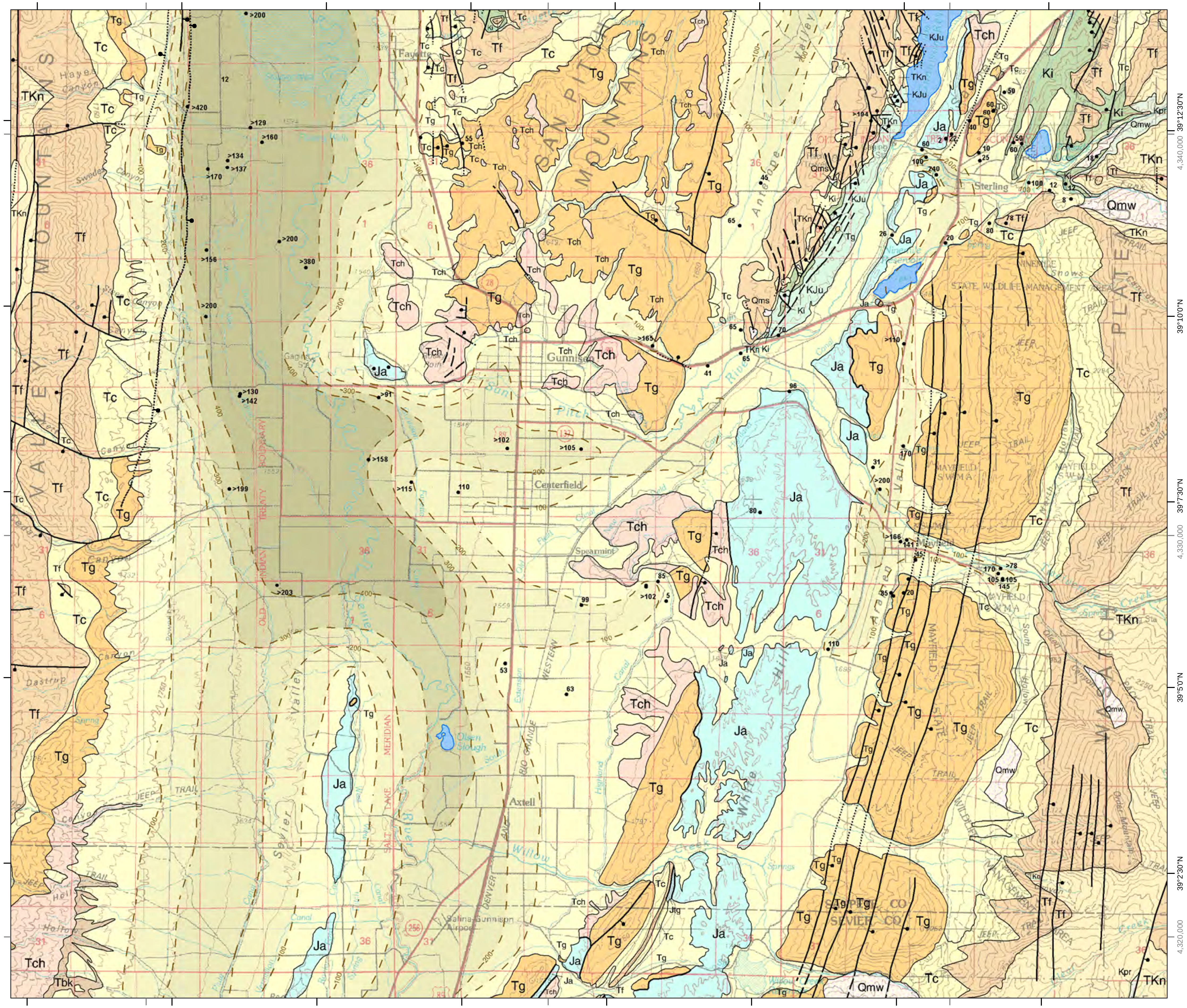
2010



This map was created from Geographic Information System (GIS) files.
Basemap from USGS 1:24,000 topographic
Projection: Universal Transverse Mercator
Datum: North American 1983 Zone 12 N
Spheroid: Clarke 1866
Basemap: USGS 100K Topographic
Cartography by Kim Nay

Plate 3
Utah Geological Survey Special Study 132
Water-quality assessment of the principal valley-fill aquifers in southern Sanpete and central Sevier Valleys, Sanpete County, Utah

UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources



Explanation

Geologic units

Qmw	Mass wasting deposit - Quaternary
Tbk	Bald Knoll Formation - Oligocene
Tch	Crazy Hollow Formation - Oligocene
Tg	Green River Formation - Eocene
Tc	Colton Formation - Eocene
Tf	Flagstaff Formation - Eocene and Paleocene
TKn	North Horn Formation - Paleocene and upper Cretaceous
Kpr	Price River Formation - Upper Cretaceous
Kc	Castlegate Sandstone - Upper Cretaceous
Ki	Indianola Group - Undivided Upper Cretaceous
Kbh	Blackhawk Formation - Upper Cretaceous
KJu	Morrison? Formation - Cretaceous and Jurassic strata undivided
Jtg	Twist Gulch Formation - Middle Jurassic
Ja	Arapien Shale - Jurassic
	Water body

Geologic symbols

Contact, well located
Fault, well located
Fault, concealed
Fault, approximately located
Normal fault, well located
Normal fault, concealed
Normal fault, approximately located

Valley fill
(depth in feet)

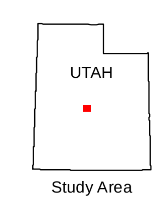
< 100
100 - 200
200 - 300
300 - 400
> 400

63 Wells used to determine isopach number denotes depth to bedrock in feet

1 0.5 0 1 2 3 4 MILES

1 0.5 0 1 2 3 4 5 KILOMETERS

1:100,000



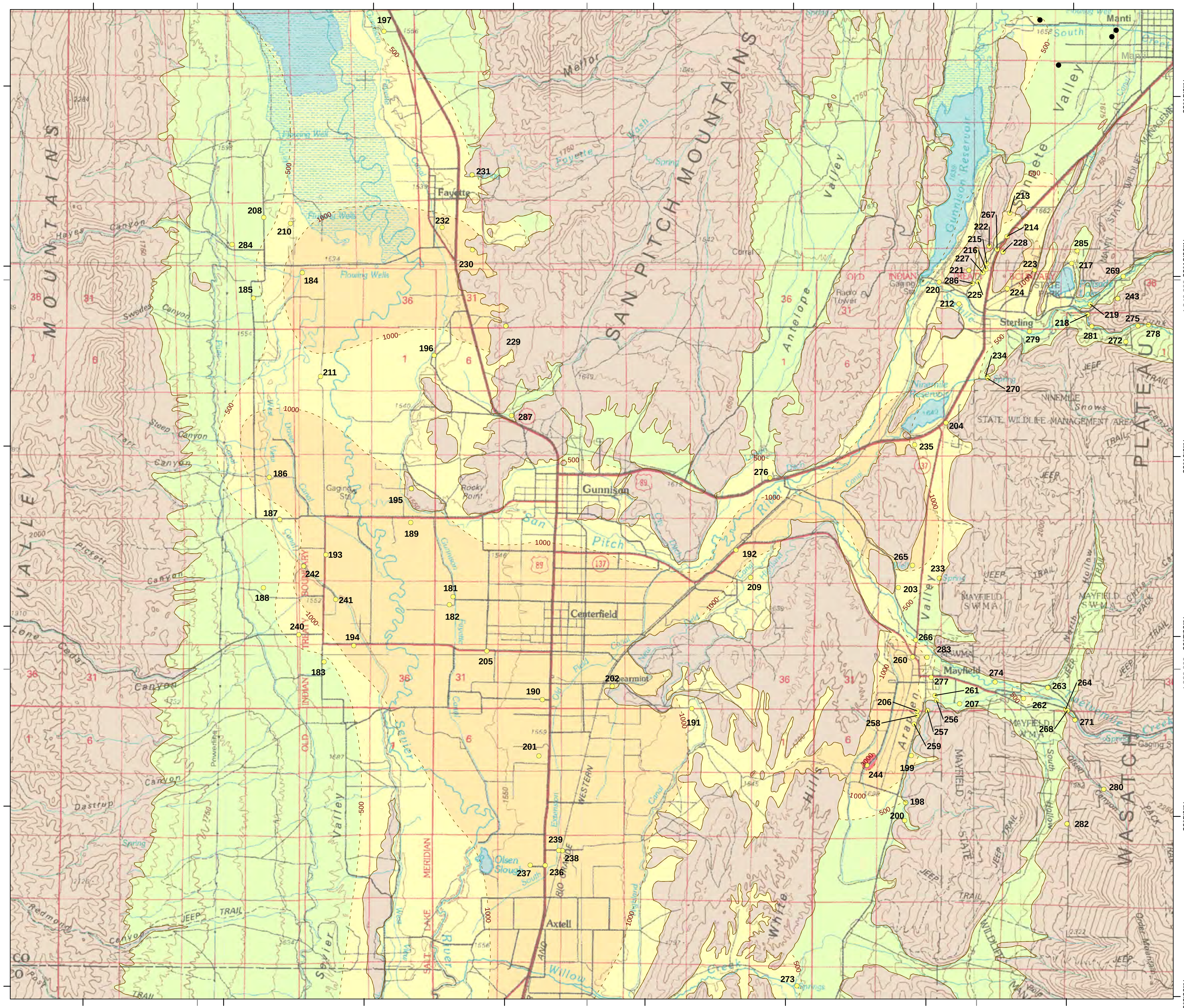
N

Geology modified from Witkind and others (1987), Hintze and Davis (2002), and Hylland and Machette (2008).
Isopachs developed from well log data and geologic cross sections.
This map was created from Geographic Information System (GIS) files.
Projection: Universal Transverse Mercator
Datum: North American 1983 Zone 12 N
Spheroid: Clarke 1866
Basemap: USGS 100K Topographic
Cartography by Richard Emerson

Plate 3.
Compiled Geology and Valley-fill Isopach Map, Southern Sanpete and Central Sevier Valleys, Sanpete County, Utah

By Janae Wallace

2010



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Explanation

- < 500 mg/L
- 500 - 1000 mg/L
- 1000-3000 mg/L
- > 3000 mg/L
- Bedrock (not analyzed)
- Water body
- Sample location*
- Sanpete Valley sample locations**

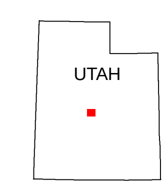
*Value denotes site ID. See appendix B.
**Sample from Lowe and others, 2002.

1 0.5 0 1 2 3 4 MILES

1 0.5 0 1 2 3 4 5 KILOMETERS

1:100,000

N



This map was created from Geographic Information System (GIS) files.
Projection: Universal Transverse Mercator
Datum: North American 1983 Zone 12 N
Spheroid: Clarke 1866
Basemap: USGS 100K Topographic
Cartography by Richard Emerson

Plate 4.
Total-Dissolved-Solids Concentrations, Southern Sanpete and Central Sevier Valleys, Sanpete County, Utah

by Janae Wallace

2010

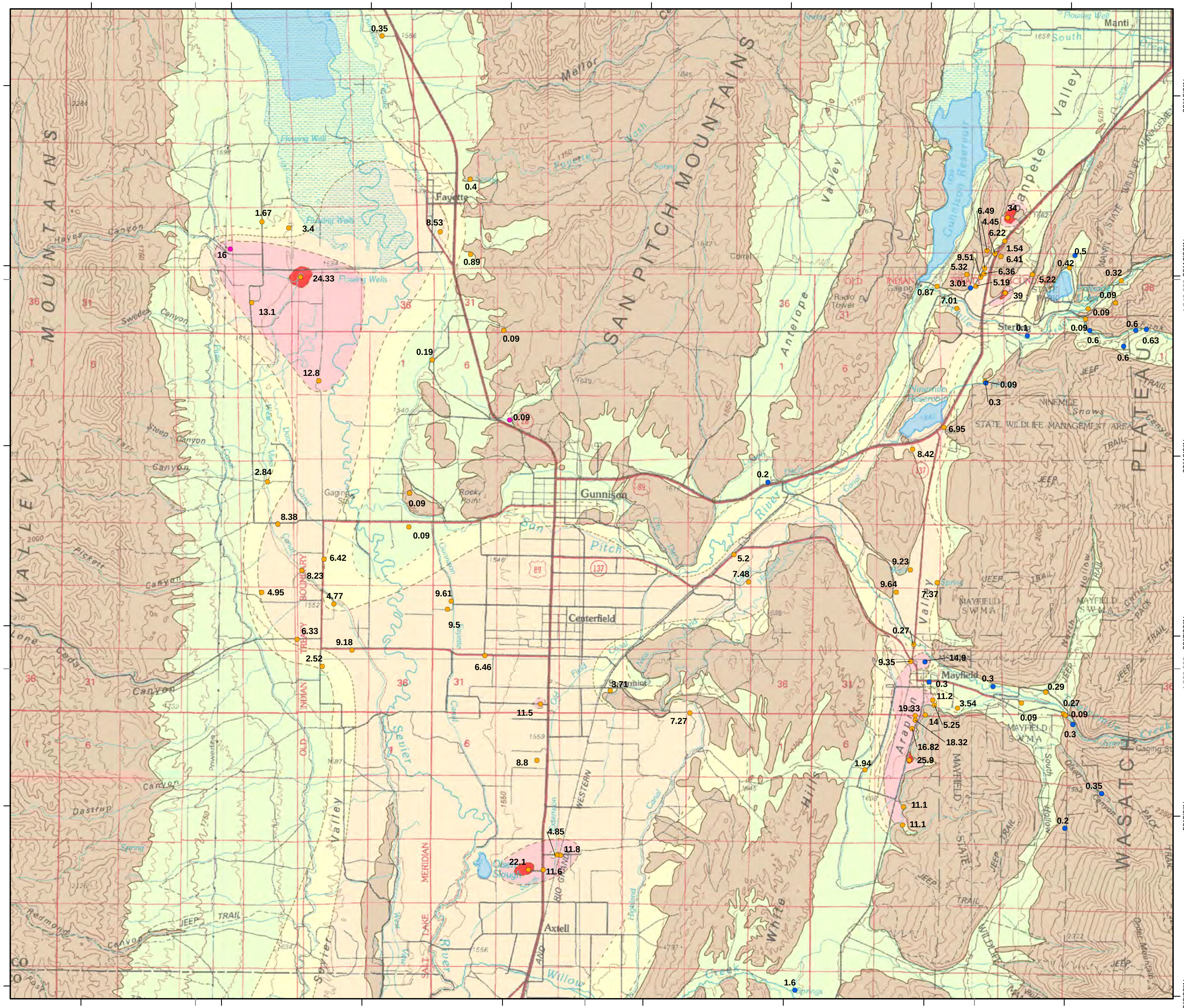


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Plate 5
Utah Geological Survey Special Study 132
Water-quality assessment of the principal valley-fill aquifers in southern Sanpete and central Sevier Valleys, Sanpete County, Utah

Explanation

Nitrate Concentration:

- < 3.0 mg/L
- 3.0 - 4.9 mg/L
- 5.0 - 9.9 mg/L
- 10.0 - 19.9 mg/L
- > 19.9 mg/L
- Bedrock (Not analyzed)
- Water body
- 5.22 Utah Geological Survey
- 1.2 Utah Division of Drinking Water
- 16 Sunrise Engineering

*Value denotes nitrate concentration (mg/L). See appendix B.

1 0.5 0 1 2 3 4 MILES

1 0.5 0 1 2 3 4 5 KILOMETERS

UTAH

Study Area

1:100,000

N

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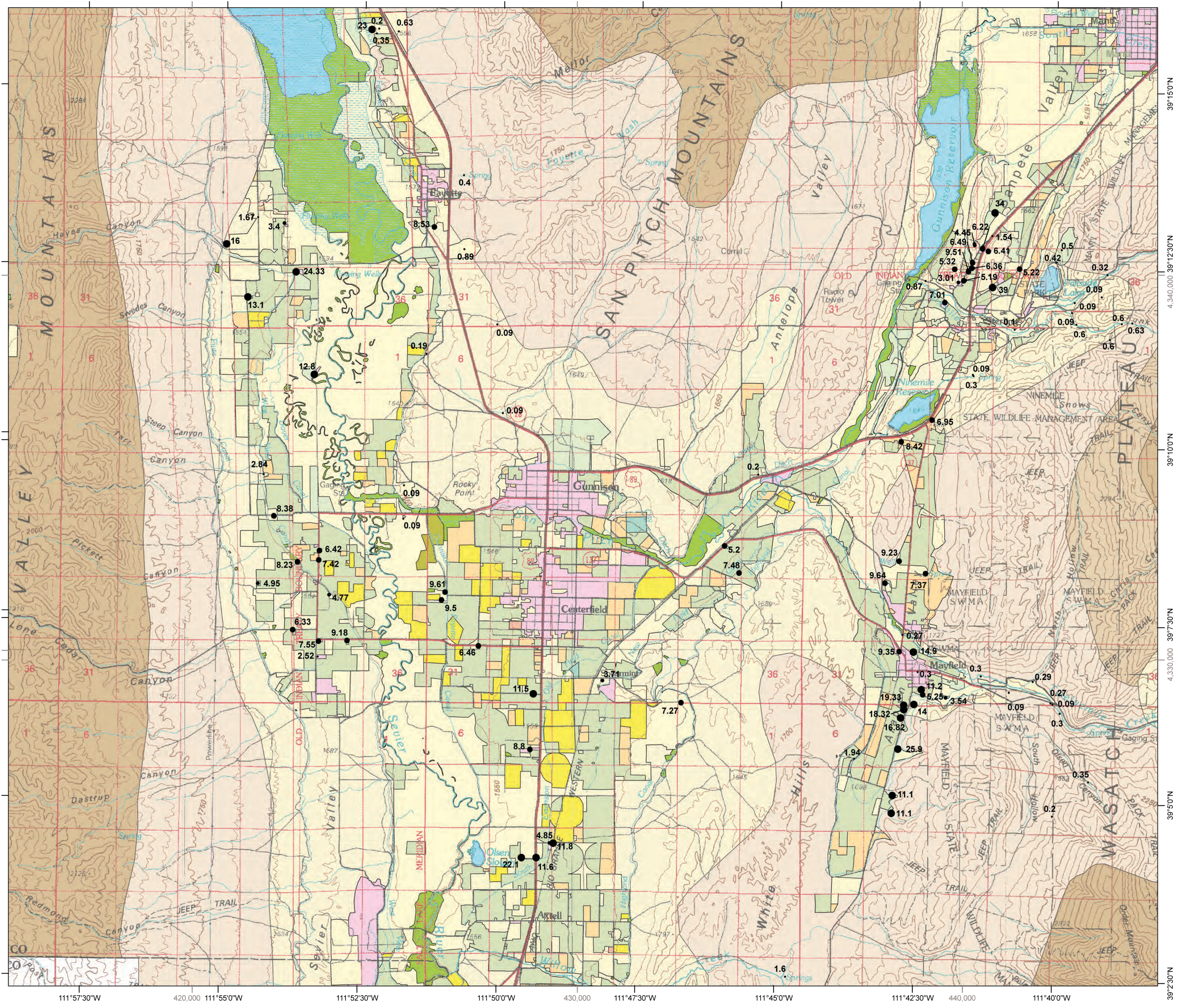
Projection: Universal Transverse Mercator
Datum: North American 1983 Zone 12 N
Spheroid: Clarke 1866
Basemap: USGS 100K Topographic
Cartography by Richard Emerson

Plate 5.
Nitrate Concentrations of the Valley-fill Aquifer, Southern Sanpete and Central Sevier Valleys, Sanpete County, Utah

by Janae Wallace

2010



UTAH GEOLOGICAL SURVEY
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Utah Department of Natural Resources

Plate 6
Utah Geological Survey Special Study 132
Water-quality assessment of the principal valley-fill aquifers in southern Sanpete and central Sevier Valleys, Sanpete County, Utah

Explanation

Land use*
- Sewage lagoon
- Alfalfa
- Grass/hay
- Range/pasture
- Sorghum
- Corn
- Dry grain/seeds
- Fruit/vegetables
- Urban
- Riparian

*Utah Division of Water Resources (2004)

Land cover**(not in use)
- Grasses/sedges
- Herbs/shrubs
- Mountain scrub
- Conifer
- Water body

**Utah Division of Wildlife Resources (2008)

Sample location
Nitrate value (mg/L)
- < 3.00
- 3.00 - 4.99
- 5.00 - 9.99
- > 10

UTAH
Study Area

1 0.5 0 1 2 3 4 MILES
1 0.5 0 1 2 3 4 5 KILOMETERS

1:100,000

This map was created from Geographic Information System (GIS) files.
Projection: Universal Transverse Mercator
Datum: North American 1983 Zone 12 N
Spheroid: Clarke 1866
Basemap: USGS 100K Topographic
Cartography by Richard Emerson

N

Plate 6.
Graduated Symbol Nitrate Concentration and Land Use, Southern Sanpete and Central Sevier Valleys, Sanpete County, Utah

by Janae Wallace

2010