Groundwater Quality in the Central Ahtanum Valley, Yakima County, March 2001 - December 2002

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Groundwater Quality in the Central Ahtanum Valley, Yakima County, March 2001 - December 2002

by
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July 2003

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Conversion Factors and Vertical Datum

Multiply	By	To obtain
inch (in)	25.4	millimeter
foot (ft)	0.3048	meter
foot per mile (ft/mi)	0.1894	meter per kilometer
square ft (ft^2)	0.0929	square meter
acre	0.4047 4,047	hectare square meter
acre-foot (acre-ft)	1,233	cubic meter
cubic foot (ft^3)	0.02832	cubic meter
cubic foot per second per mile (ft^3/sec/mi)	0.0176	cubic meter per second per kilometer
cubic foot per second per square mile ($ft^3/sec/mi^2$)	0.01093	cubic meter per second per square kilometer
cubic foot (ft^3)	28.32	liter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.59	square kilometer
gallon (gal)	3.785	liter
million gallons per day (Mgal/d)	0.04381	cubic meter per second

Temperature

To convert degrees Celsius (°C) to degrees Fahrenheit (°F), use the following equation:
°F= (9/5 x °C) + 32.

To convert degrees Fahrenheit (°F) to degrees Celsius (°C), use the following equation:
°C= 5/9(°F - 32).

Sea Level

In this report, sea level refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929).

Altitude

In this report, altitude is measured in feet above mean sea level.

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Abstract

Thirteen wells in the central Ahtanum Valley of Yakima County were monitored quarterly from March 2001 through December 2002 for traditional field parameters and a small suite of laboratory analyzed constituents, to determine if groundwater quality has changed appreciably since area wells were first broadly sampled in June 1973.

Nitrate+nitrite-N concentrations ranged from 0.04 to 7.1 mg/L. Concentrations of total persulfate nitrogen were similar, ranging from 0.1 to 8.0 mg/L. Fecal coliform bacteria were detected in samples from two wells at concentrations ranging from 4 to 35 CFU/100 ml, while total coliform bacteria were detected in samples from eight wells at concentrations ranging from 1 to 73 CFU/100 ml. Chloride concentrations ranged from 0.57 to 34.3 mg/L, while total iron and manganese concentrations ranged from less than 10 to 3030 μg/L, and less than 1 to 29.6 μg/L, respectively.

Trends in nitrate+nitrite-N concentration were evaluated using data from sampling events conducted in June 1973 (99 wells), September 1992 (16 wells), and September 2002 (13 wells). Apparent increases in nitrate+nitrite-N concentrations were noted between 1973 and 1992, and between 1973 and 2002. There was an apparent decrease in nitrate+nitrite-N concentrations between 1992 and 2002.

Acknowledgements

This study was made possible by the assistance and cooperation of the Ahtanum Valley landowners who provided access to their property and wells. Assistance with field sampling was provided by Nigel Blakley, Howard Christenson, Tom Gibbons, Pam Marti, and Morgan Roose. I thank Bob Raforth and Barb Carey for their helpful reviews of the report draft, and Joan LeTourneau for editing and formatting the final report. Lastly, I thank the staff at Manchester Environmental Laboratory who provided courier and analytical laboratory services throughout this project.

Introduction

The Ahtanum Valley in northeastern Yakima County has experienced rapid population growth in recent years, due to its proximity to the city of Yakima. During the 1990s the population of Yakima proper increased by about 31 percent, from a full-time resident population of 54,843 to 71,845. Much of this growth occurred within the lower Ahtanum Valley which abuts the western city limit of Yakima.

Most Ahtanum Valley residents who reside outside the city of Yakima service area depend on individual or small public supply wells to meet their potable water needs, and use individual or small community on-site septic systems to dispose of domestic wastewater. A one-time sampling of 99 Ahtanum Valley wells in June 1973 revealed that 23 percent of sampled wells contained coliform bacteria (DSHS, 1973). Nitrate+nitrite-N concentrations for these wells ranged from 0.01 to 1.2 mg/L, averaging 0.34 mg/L. A follow-up sampling of 16 Ahtanum Valley wells by Ecology in September 1992 found nitrate+nitrite-N concentrations ranging from 0.41 to 5.19 mg/L, averaging 2.03 mg/L (Larson, 1993). The apparent increase in nitrate+nitrite-N values between 1973 and 1992 suggested that concentrations of these compounds may have increased in area groundwater over time.

This investigation was undertaken in September 2000 to establish an ambient groundwater monitoring network for the central Ahtanum Valley, with the intent of providing current information for use in assessing groundwater quality conditions and trends within the high-growth area west of Yakima.

Study Purpose and Scope

This report summarizes a two-year sampling effort to evaluate groundwater quality conditions in the central Ahtanum Valley, of Yakima County. The major objectives of this study were:

1. To establish an ambient groundwater monitoring network for the Ahtanum Valley. The network will be used to update past monitoring results and to provide a means of assessing groundwater quality changes resulting from on-going urbanization or agricultural activities.

2. To determine if nitrate+nitrite-N concentrations vary seasonally and whether they have increased, decreased, or remained the same since area wells were last systematically sampled in September 1992.

The preliminary work for this project began in September 2000, when historic groundwater data were compiled, an initial project scoping meeting was held, and work on the study quality assurance project plan (QAPP) began. Field sampling activities began in March 2001 and continued through December 2002. Fourteen wells were monitored quarterly during this period for traditional field parameters: temperature, specific conductivity, pH, dissolved oxygen, and groundwater level. Water samples were also collected during each site visit for later laboratory analysis of total persulfate nitrogen, nitrate+nitrite-N, total and fecal coliform bacteria, chloride, total iron, and total manganese.

Study Area Description

The greater Ahtanum Valley encompasses an area of approximately 160 square miles and includes a portion of the City of Yakima and the outlying communities of Tampico, Wiley City, and Ahtanum (Figure 1). The Ahtanum Valley is one of several east-west trending structurally-controlled valleys within the Yakima area. The valley rises steadily, toward the west, from an altitude of approximately 940 feet at the Yakima River to 4,100 feet at the crest of Cowiche Mountain. Near the Yakima River the valley bottom is approximately three miles wide and characterized by relatively flat terrain. Approximately 1.5 miles east of the community of Ahtanum, the valley is bisected by a remnant terrace that raises as much as 100 feet above the valley floor (Foxworthy, 1962). This terrace effectively separates the Ahtanum Creek drainage from Wide Hollow Creek to the north. The valley floor of the Ahtanum Creek drainage continues to narrow and ascend toward the west, until it becomes narrowly constricted by resistant outcroppings of volcanic rock approximately four miles east of Tampico.

The Ahtanum Valley has a semi-arid continental climate with hot, dry summers and relatively cool, wet winters. Average annual precipitation ranges from greater than 40 inches near the eastern Cascade Foothills to less than 10 inches near the City of Yakima (Figure 1). Approximately 50 percent of the annual precipitation falls from November to February, with relatively little precipitation during the summer growing season. Land use on the upland terraces is dominated by orchards, while the valley bottoms are used primarily for pasture lands and residential/commercial development. The primary surface drainages include Ahtanum, Hatton, Bachelor, Spring, and Wide Hollow creeks.

Previous Investigations

Many of the early geologic investigations of the Ahtanum Valley and vicinity were driven by the need to identify reliable water supplies to meet the increasing demands of irrigated agriculture (Russell, 1893; Smith, 1901 and 1903; Twiss, 1943; Foxworthy, 1953 and 1962; and Clearlock et al, 1975). Other largely academic investigations were undertaken to refine the geologic framework and structural evolution of the greater Columbia River flood-basalt province of which the Ahtanum sub-basin is a part (Mackin, 1961; Robinson, 1966; Reidel and Hooper, 1989). More recently, area investigations have focused on the water quality impacts associated with urbanization and agricultural practices (DSHS, 1973; Fretwell, 1973; Molenaar, 1985; Larson, 1993).

Well Numbering and Location System

The locations of all wells referenced in this report are described using the township, range, section, and quarter-quarter section convention. Range designations include an "E" and township designations include an "N" to indicate the well lies east and north of the Willamette meridian and baseline respectively. Quarter-quarter sections are represented by a single capital letter. For example, an inventoried well located in the northeast quarter of the southeast quarter of Section 24, Township 13N, Range 17 E, is recorded as 13N/17E-24J (Figure 2).

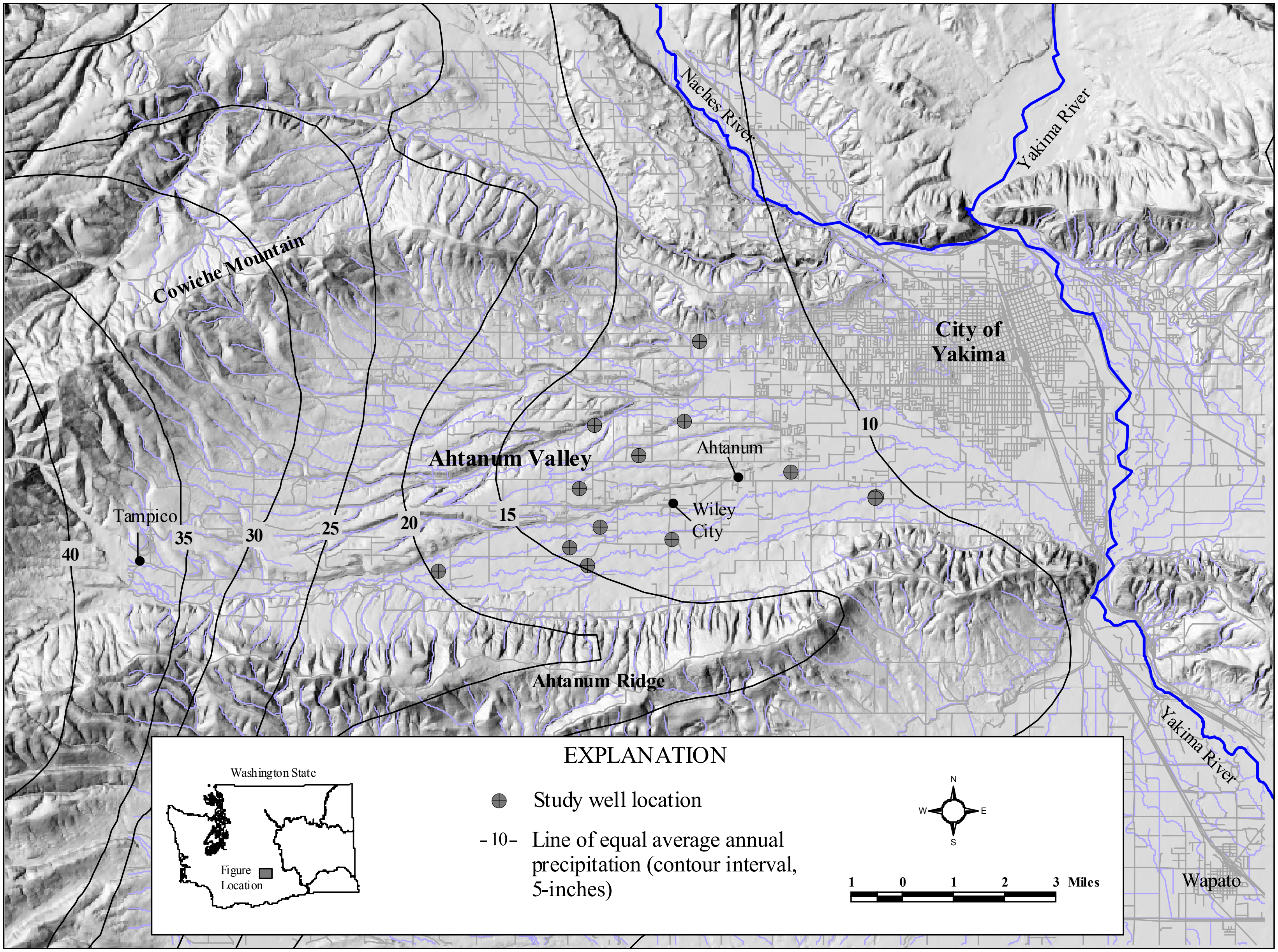

Figure 1. Map showing study area location, mean annual precipitation, and location of study wells (precipitation isohyets after Miller et al, 1973).

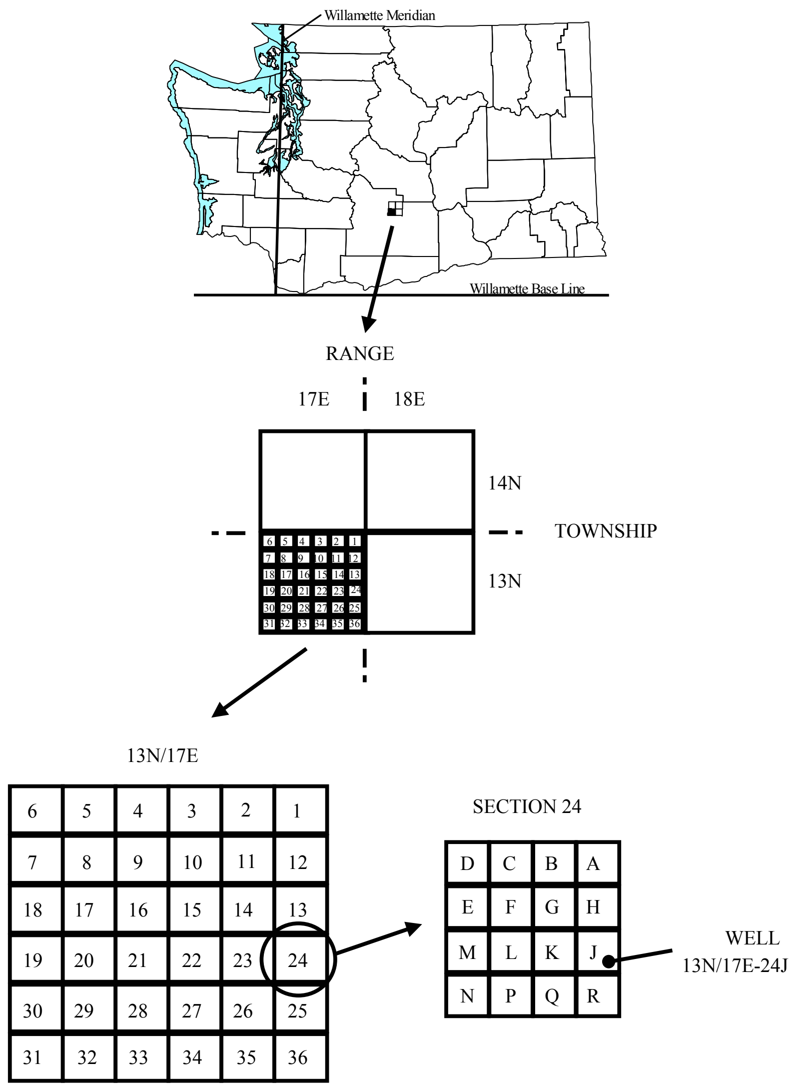

Figure 2 - Well numbering and location system

This site location and numbering convention has been used for many years by Ecology, the U.S Geological Survey (USGS), and others, and sometimes results in numbering conflicts between reports or agencies. Readers wishing to cross-reference this report with prior publications should verify well identity via the construction details and descriptions provided in Table A-1 (see Appendix A).

To aid subsequent investigators, all wells monitored during this study were assigned Department of Ecology unique well identification numbers consisting of three letters followed by three numbers (i.e. AAB827). The identification number is contained on an aluminum tag that was securely attached to the well casing or another permanent fixture of the water system.

Hydrogeologic Setting

The Ahtanum Valley lies within an east-west trending synclinal[1] trough and is bounded by steep sided anticlinal[2] ridges to the south (Ahtanum ridge) and west/northwest (Cowiche Mountain/ Sedge ridge). The present Ahtanum Valley was once part of an extensive, flat plain that formed during Miocene time, when huge volumes of basalt were repeatedly extruded from fissures centered southeast of the study area (Foxworthy, 1962). During this period andesite rich sediments were also being deposited along and upon the western portion of this plain by eastward flowing streams that eminated from a volcanically active upland to the west. These geologic processes continued through numerous flow events, resulting in inter-bedded deposits of basalt and sedimentary rock along the western margin of the basalt plain. When the basalt flows ceased in early Pliocene time, uplift of the Cascade Range to the west provided a heavy sediment load to eastward flowing streams which deposited sediments along and upon the western portion of the basalt plain.

Beginning in early Pliocene time, this assemblage of basalt flows and andesite-rich sediments was slowly folded to form the broad anticlines and synclines of the Yakima fold belt (of which the Ahtanum Valley is part). As folding progressed, the unconsolidated sediments were eroded from the up-folded ridges and deposited in the adjacent valley bottoms. With continued erosion, basalt in the anticline cores was exposed to weathering, and basaltic debris was carried down slope and deposited upon the valley-fill sediments. Although active folding is thought to have ceased by the late Pliocene, gravel continued to accumulate in the valley interior during Pleistocene time to depths of 200 feet or more (Foxworthy, 1962). The gravel was subsequently eroded and/or reworked through alluvial processes to form the terrace complex of the present valley bottom.

The geologic materials underlying the Ahtanum Valley may be aggregated, based on lithology and age, into four principal groups: Miocene age basalts, Miocene continental sediments, Pliocene continental sediments, and Quaternary age sediments/recent alluvium (Figures 3 and 4). The upper surface of the basalt, which comprises area bedrock, dips downward from west to east. Basalt lies at or near ground surface in the vicinity of Tampico, and is found at depths of approximately 800 feet below ground surface in the central Ahtanum Valley near Wiley City (Foxworthy, 1962). The basalt is dark gray to black on fresh surfaces and weathers to a gray reddish-brown color. It is typically fine-grained and often has a jointed or blocky appearance in surface exposures.

Within the eastern study area, the basalt is overlain by and, in some cases, inter-bedded with Miocene age continental sediments of the Ellensburg Formation (unit Mc in Figure 3).
The Ellensburg Formation sediments consist mostly of semi-consolidated clay, andesitic and pumiceous sandstone, and conglomerate comprised of weathered andesite pebbles (Foxworthy, 1962) (Figure 4). These sediments tend to increase in thickness from west to east and are several hundred feet thick in the valley bottom east of Wiley City.

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[1] Syncline - A large fold whose limbs are higher than its center; a fold with the youngest strata in the center (Press and Siever, 1978).
[2] Anticline - A large fold that is convex upward with the oldest strata at the center (Press and Siever, 1978)

Ellensburg Formation sediments are overlain throughout much of the valley bottom by a thick (up to 200 foot) layer of cemented gravel of Pliocene age (unit Plc in Figure 3). The cemented gravel unit consists mostly of rounded, basaltic pebbles and cobbles in a sand-and-silt matrix but may contain discontinuous layers of sand, silt, or clay. The cemented gravel is overlain by extensive but relatively thin deposits of recent alluvium within the Ahtanum and Wide Hollow creek bottoms and by alluvial fan and loess deposits along the flanks of Ahtanum Ridge and Cowiche Mountain (Figure 3). The alluvium (unit Qa in Figure 3) consists mostly of unconsolidated deposits of well-rounded cobbles, gravel, sand, and silt that vary in thickness from a few feet to more than 30 feet.

Each of these principal rock types contains aquifers that are capable of supplying groundwater to wells. Most domestic wells within the valley interior are completed in either the thicker sections of recent alluvium, the cemented gravel unit, or in the more permeable zones of the Ellensburg Formation. These aquifers are recharged through several mechanisms including downward percolation of local precipitation, leakage from unlined irrigation ditches or streams, percolation of unconsumed irrigation water, and by upward discharge from the underlying basalt units. Area groundwater generally moves from upland recharge zones along the ridge tops and flanks toward the valley interior, and laterally toward natural points of discharge along area streams and the Yakima River (Figure 3).

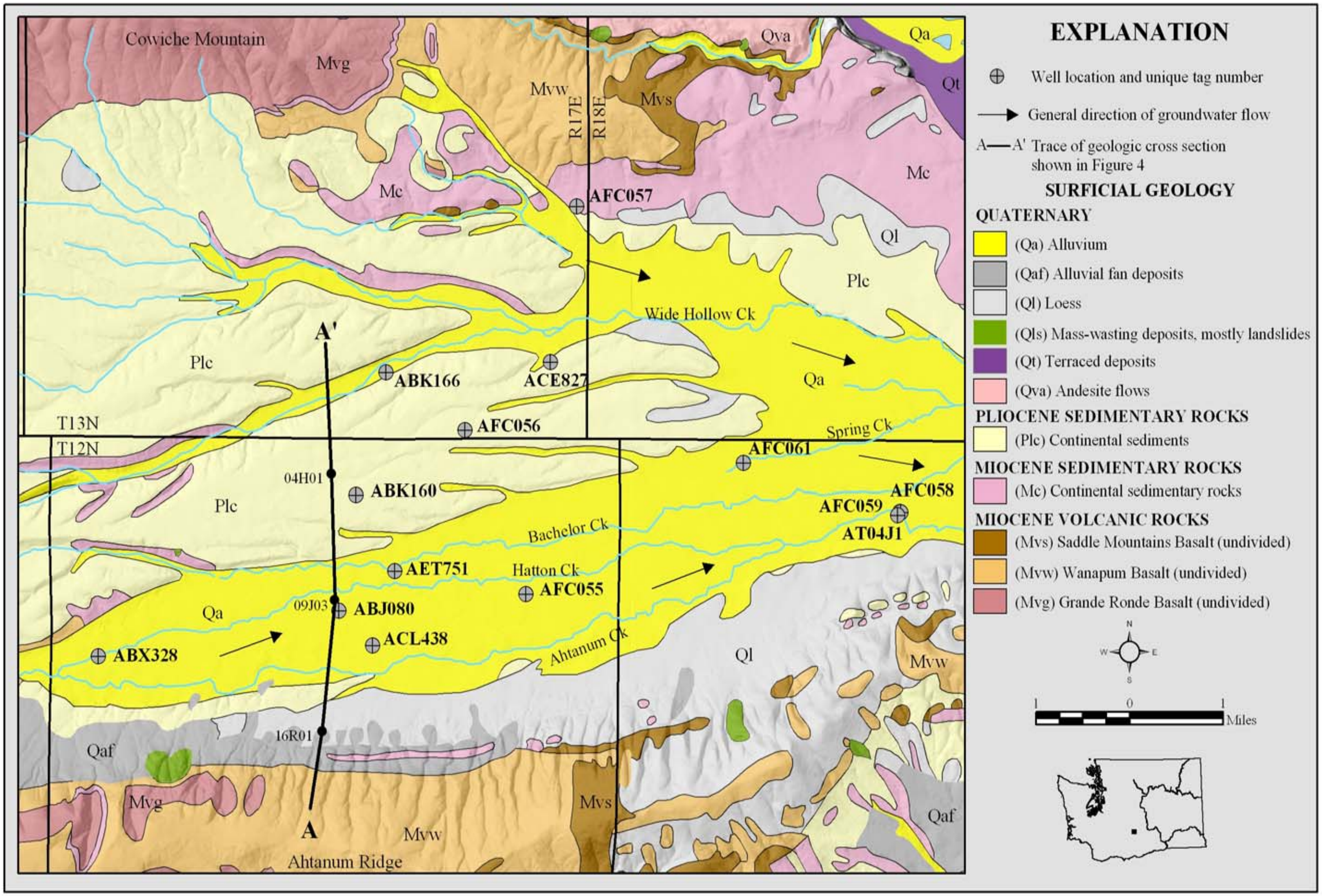


Figure 3. Map of surficial geology, study-well locations, geologic cross-section trace, and general direction of groundwater flow (surficial geology after Walsh et al, 1987; groundwater flow directions after Clearlock et al, 1975)

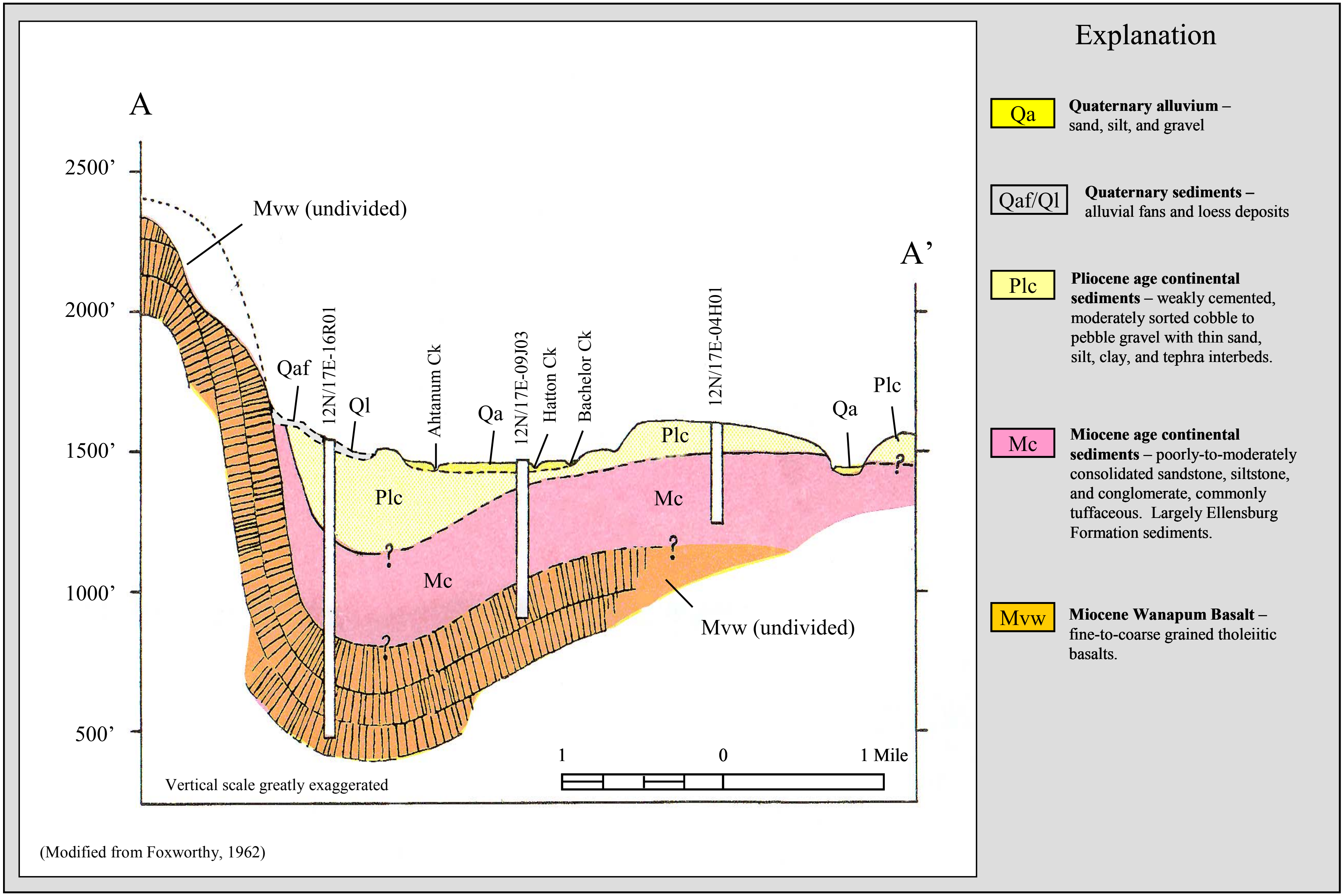


Figure 4. Geologic cross section A-A’ (see Figure 3 for section location).

Data Collection and Analysis Methods

Field sampling for this study began in March 2001 and continued through December 2002. Sampling techniques followed the procedures specified in the quality assurance project plan (Sinclair, 2000). Thirteen wells were sampled quarterly during this period for common field parameters (groundwater level, temperature, specific conductivity, pH, and dissolved oxygen) and a small suite of laboratory analyzed constituents (total persulfate nitrogen, nitrate+nitrite-N, total and fecal coliform bacteria, chloride, total iron, and total manganese) (Table 1).

Table 1. Target analytes, test methods, and method detection limits.

Parameter	Field or Laboratory[1] Test Method	Detection Limit
Field Measurements		
Temperature	WTW multiline P4 meter with Sentix 41-3 probe	0.1°C
Specific conductivity	WTW multiline P4 meter with Tetracon 325 probe	1 µs/cm
pH	WTW multiline P4 meter with Sentix 41-3 probe	0.1 SU
Dissolved oxygen	WTW multiline P4 meter with Cellox 325 probe	0.1 mg/L
Laboratory Parameters		
Total persulfate nitrogen	SM4500NB	0.10 mg/L
Nitrate+nitrite-N	SM4500NO3I	0.01 mg/l
Coliform, total (MF)	SM16-909B	1 CFU/100mL
Coliform, fecal (MF)	SM16-909C	1 CFU/100mL
Chloride	EPA 300.0	0.1 mg/L
Iron, total	EPA 200.7	10 ug/L
Manganese, total	EPA 200.7	1 ug/L

MF: Membrane filter method
SU: Standard units
CFU: Colony-forming units
[1] SM - Standard Method (see Eaton et al, 1995)
EPA - (see http://www.epa.gov/epahome/Standards.html)

These parameters were selected for evaluation because they provide an indication of overall water quality and are typically present in a number of contaminant sources. Where possible shallow wells were selected for sampling, since they are the most likely to be impacted by increased septic discharges, changing agricultural practices, or other land use activities. Physical descriptions and drillers logs for each of the study wells are provided in Appendix A: Tables A1 and A2.

Prior to sampling, wells were purged at approximately five gallons per minute, using a commercial flow cell. Field parameter values were recorded at three-minute intervals during purging. Purging continued until the values for two successive measurement intervals differed by no more than five percent. After the wells were purged, samples were collected in pre-cleaned bottles supplied by the Manchester Environmental Laboratory. All samples were stored on ice pending their arrival at the laboratory.

Groundwater levels were measured during each site visit prior to well purging. Water levels were measured with a calibrated electric well probe (E-tape) in accordance with standard USGS methodology (Stallman, 1983). Duplicate water-level measurements were made at each site to evaluate measurement precision and to ensure that the well-water level was not recovering from recent pumping. Individual water-level measurements were made to the nearest 0.01 foot and were then rounded to the nearest 0.1 foot for reporting purposes.

Evaluation of Water Quality Trends

Trends in groundwater nitrate concentrations were evaluated via hypothesis testing; a null hypothesis (H_O) of no trend was tested against the alternative hypothesis (H_A) of an increasing trend in nitrate concentration over the period 1973 to 2002. In similar fashion, a null hypothesis was formulated and tested to assess declining trends in nitrate concentration over this period. In both cases, the evaluation was performed using a significance level (or "p-value") of 0.05.

Study Findings

Groundwater Levels

During this investigation quarterly groundwater level measurements were made in 13 wells, for a total of seven to eight measurements per well (Appendix A: Table A-3). Area groundwater levels were generally highest (nearest land surface) in March and lowest in September (Figure 5 and Table A-3). The groundwater levels in individual wells fluctuated from 1.4 to 28.2 feet and averaged 13.3 feet for the wells as a whole. The measured water-level fluctuations tended to increase with increasing well depth, and were generally largest near the valley center where groundwater is used extensively for irrigation and significant stream-aquifer interactions occur.

Water Quality

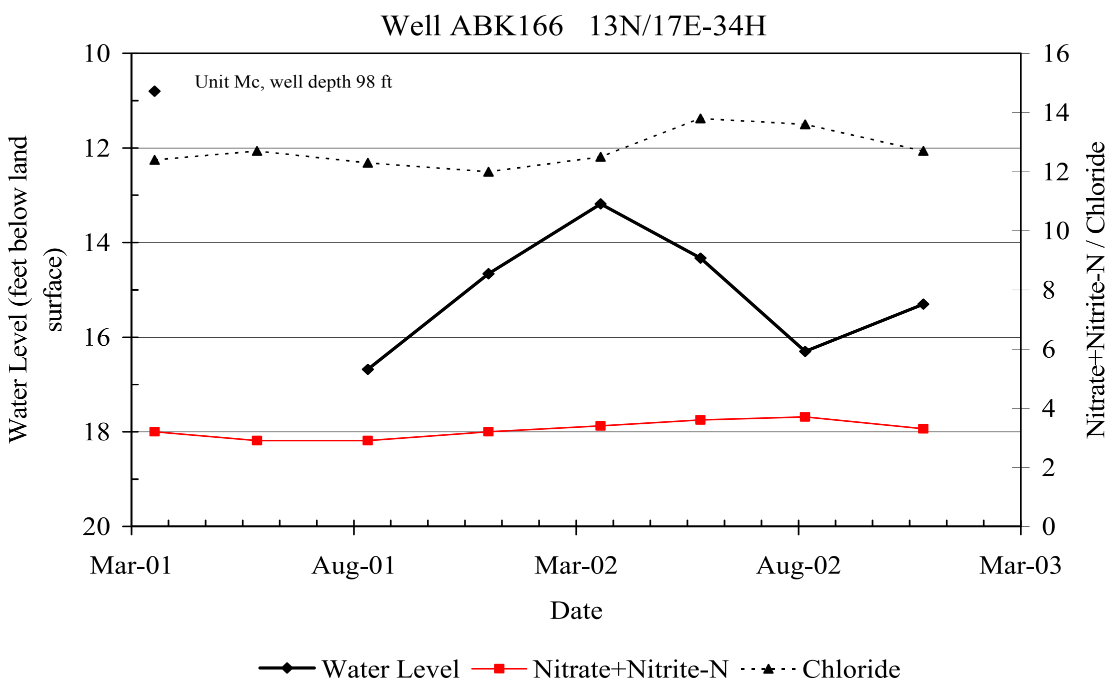
Temperature, Specific Conductivity, pH, and Dissolved Oxygen

Groundwater temperature was measured during this study to help define an appropriate purge volume prior to collecting samples for laboratory analysis. Measured groundwater temperatures ranged from 9.5 to 16.4°C and averaged 12.41°C (Table 2 and Table A3). Groundwater temperatures generally mirrored seasonal air temperatures and were warmest in June (average 12.6°C) and September (average 13.12°C) and coolest in December (average 12.12°C) and March (average 11.57°C). There is no formal groundwater quality standard for temperature (Table 3).

Specific conductivity is a measure of water's ability to conduct an electrical current and is related to the concentration and charge of dissolved ions in water. Specific conductivity is regulated as a secondary (aesthetic) contaminant in drinking water at concentrations greater than 700 µS/cm. During this study, measured specific conductivity values ranged from 116 to 840 µS/cm and averaged 296.5 µS/cm @ 25°C. One well (AFC057) consistently exceeded the drinking water standard for specific conductivity.

pH plays many important roles in the chemical and biological systems of natural waters, and can control the solubility of metal compounds and the rate or magnitude of chemical reactions. pH is regulated as a secondary (aesthetic) contaminant in drinking water at values less than 6.5 or greater than 8.5, since values outside this range may corrode plumbing fixtures or reduce the effectiveness of water treatment such as chlorination (U.S. EPA, 1986). The pH values measured during this study ranged from 6.64 to 7.8 and averaged 7.13.

The concentration of dissolved oxygen (DO) in groundwater can significantly affect many geochemical or biological processes, such as the solubility of iron or manganese and the oxidation or reduction of nutrients. The DO concentrations measured during this study ranged from 1.6 to 19.6 mg/L and averaged 7.87 mg/L, suggesting that oxidizing conditions prevailed at all wells monitored during this study. The highest average DO values (10-13.7 mg/L) were observed in wells completed within the upland terrace that separates the Ahtanum Creek drainage from the Wide Hollow Creek drainage. Wells located in the Ahtanum Creek valley bottom generally had average DO values between 3 and 8 mg/L. There is no groundwater quality standard for oxygen.



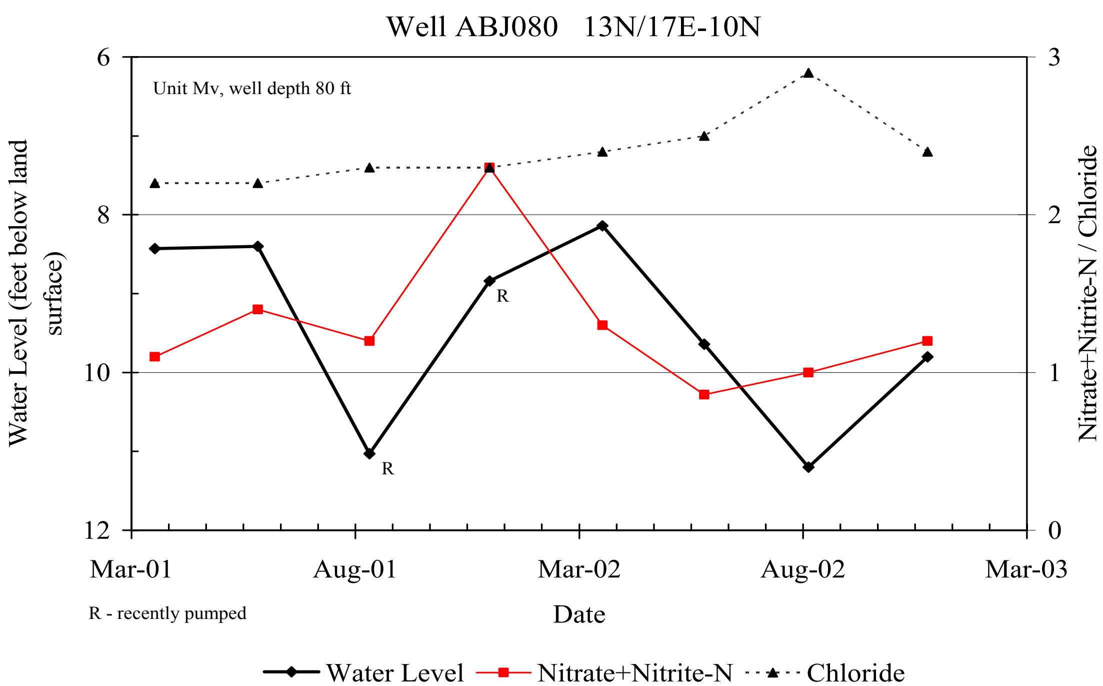
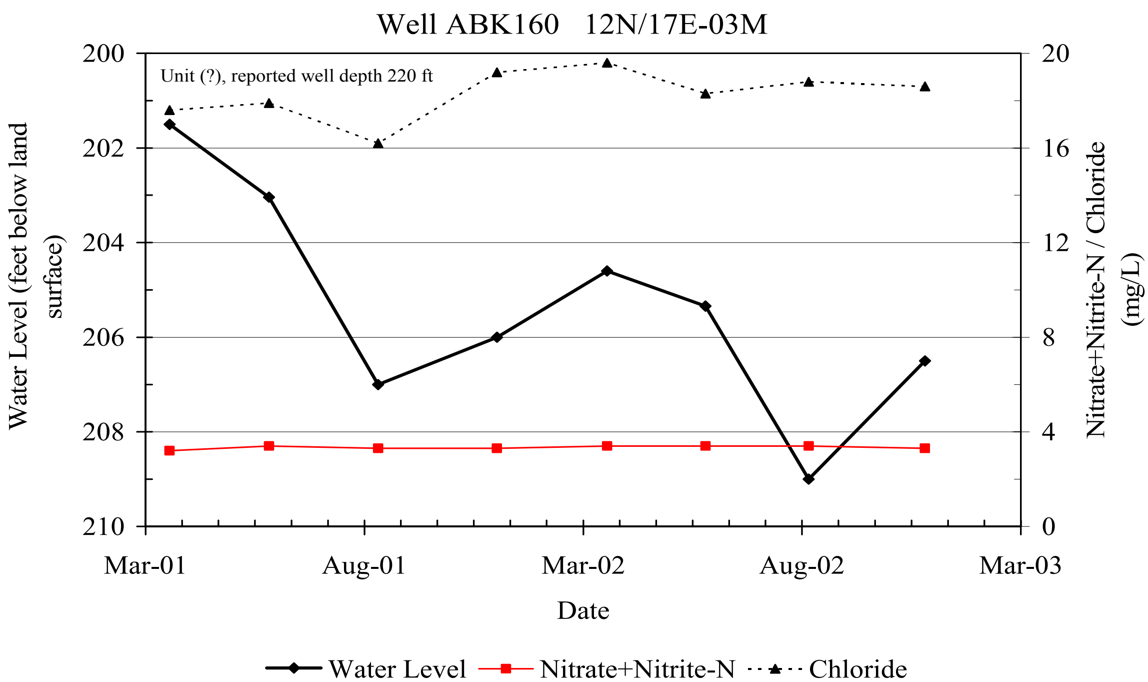


Figure 5. Water level, nitrate+nitrite-N, and chloride measurements for study wells, March 2001-December 2002.



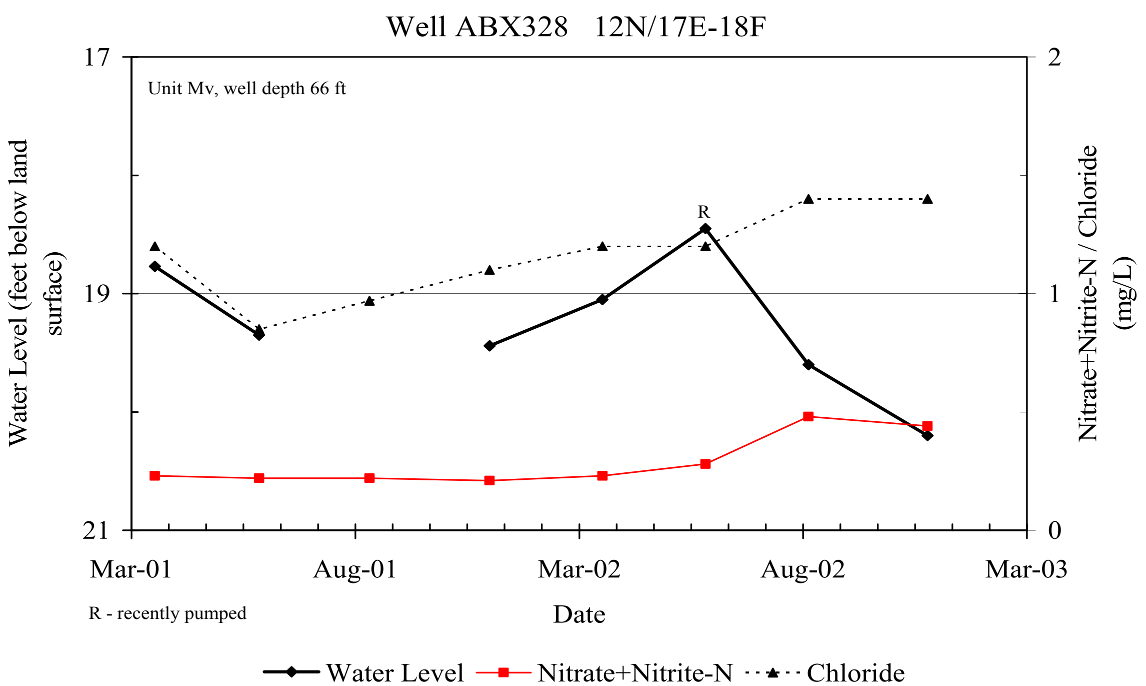
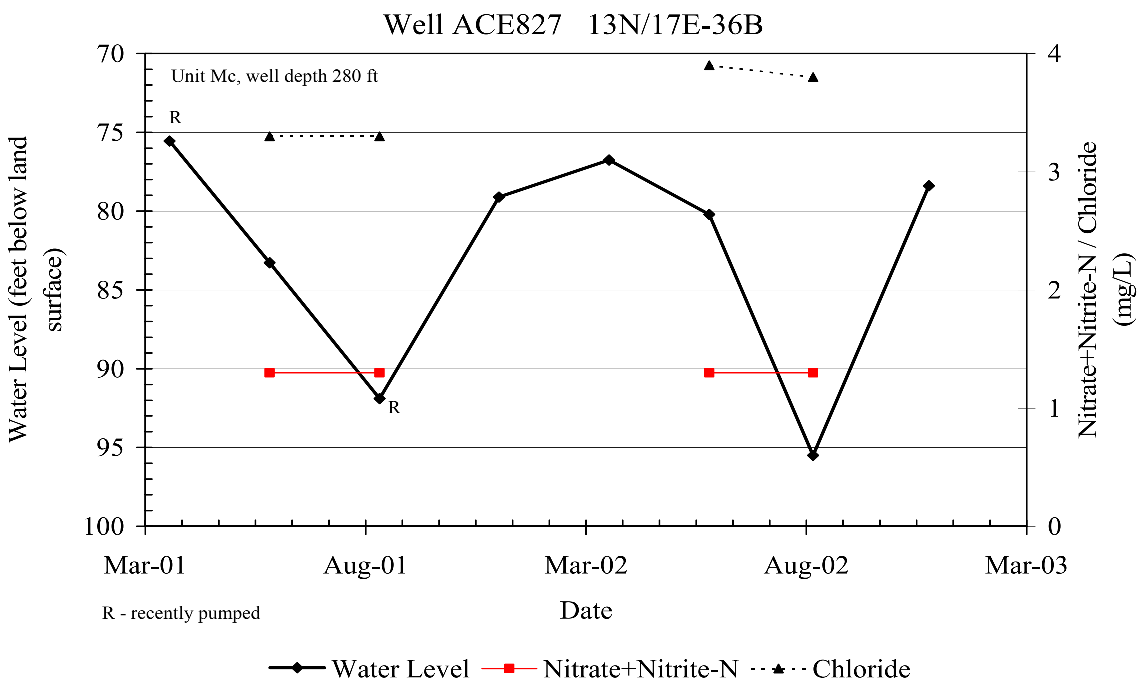


Figure 5 (continued). Water level, nitrate+nitrite-N, and chloride measurements for study wells, March 2001-December 2002.



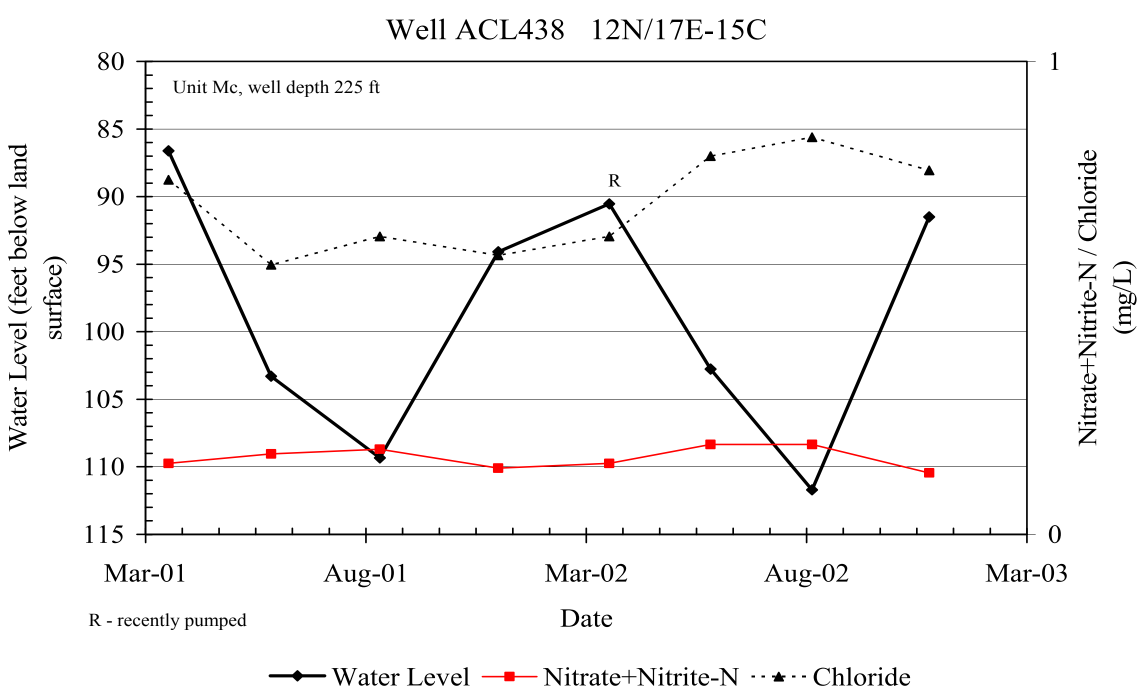
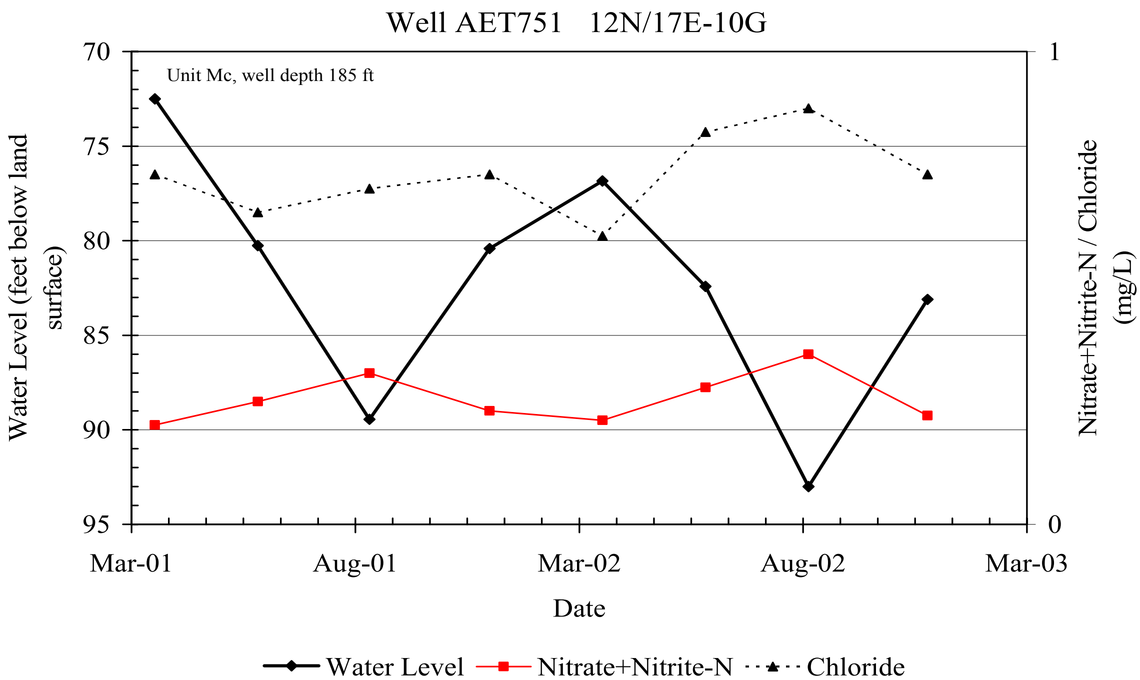


Figure 5 (continued). Water level, nitrate+nitrite-N, and chloride measurements for study wells, March 2001-December 2002.



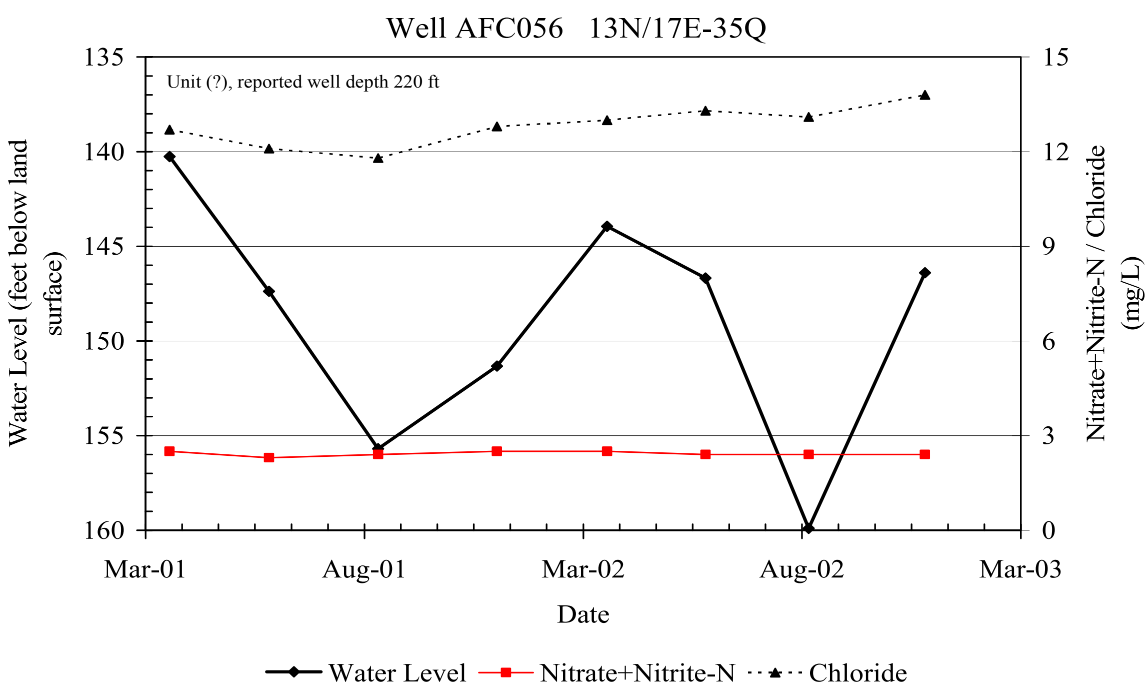
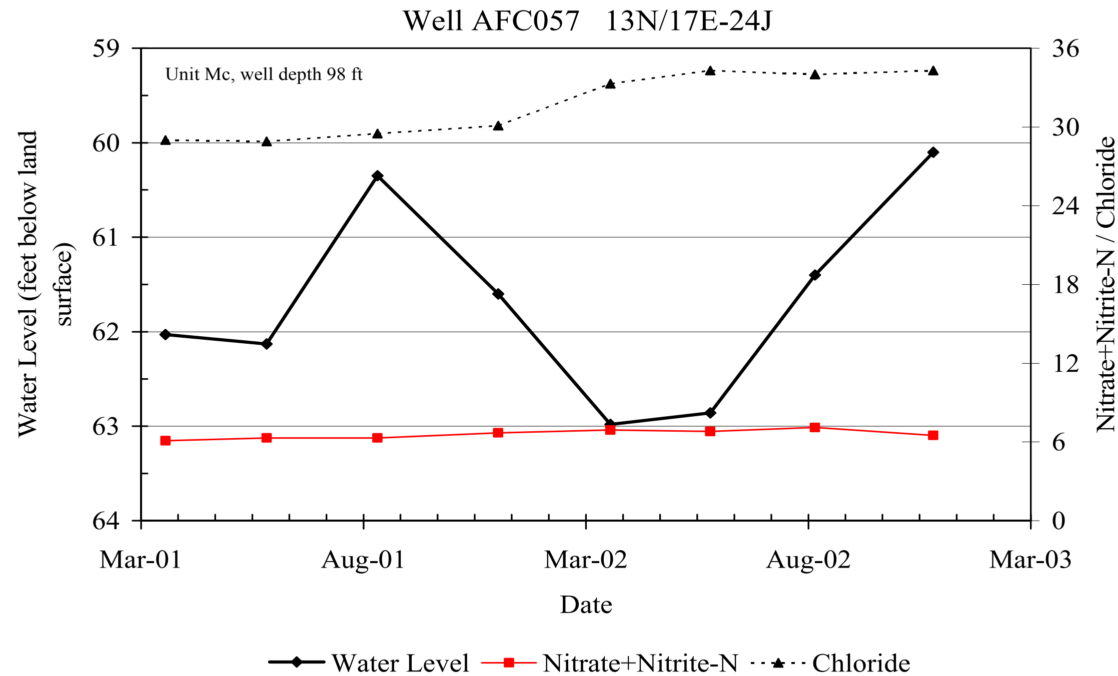


Figure 5 (continued). Water level, nitrate+nitrite-N, and chloride measurements for study wells, March 2001-December 2002.



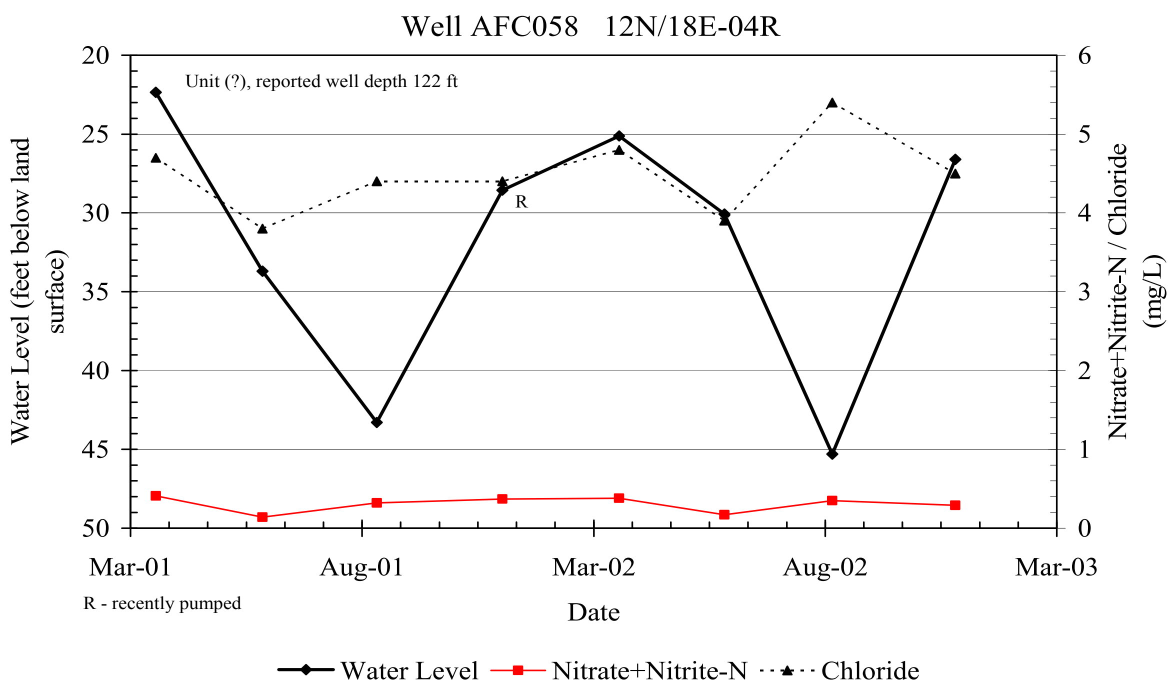
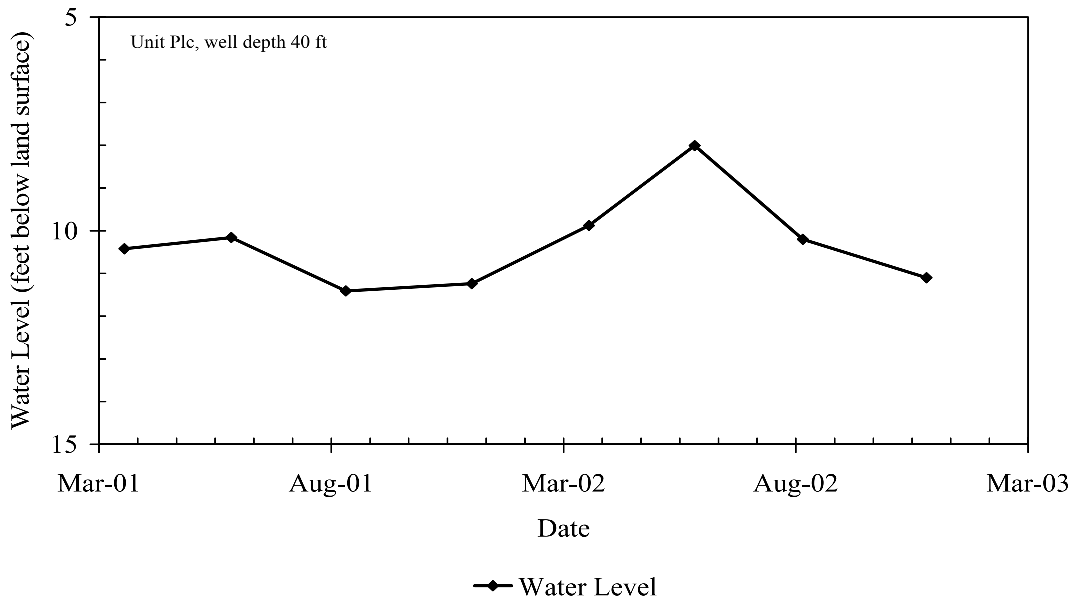


Figure 5 (continued). Water level, nitrate+nitrite-N, and chloride measurements for study wells, March 2001-December 2002.

Well AFC059 12N/18E-04R



Well AT04J1 12N/18E-04R

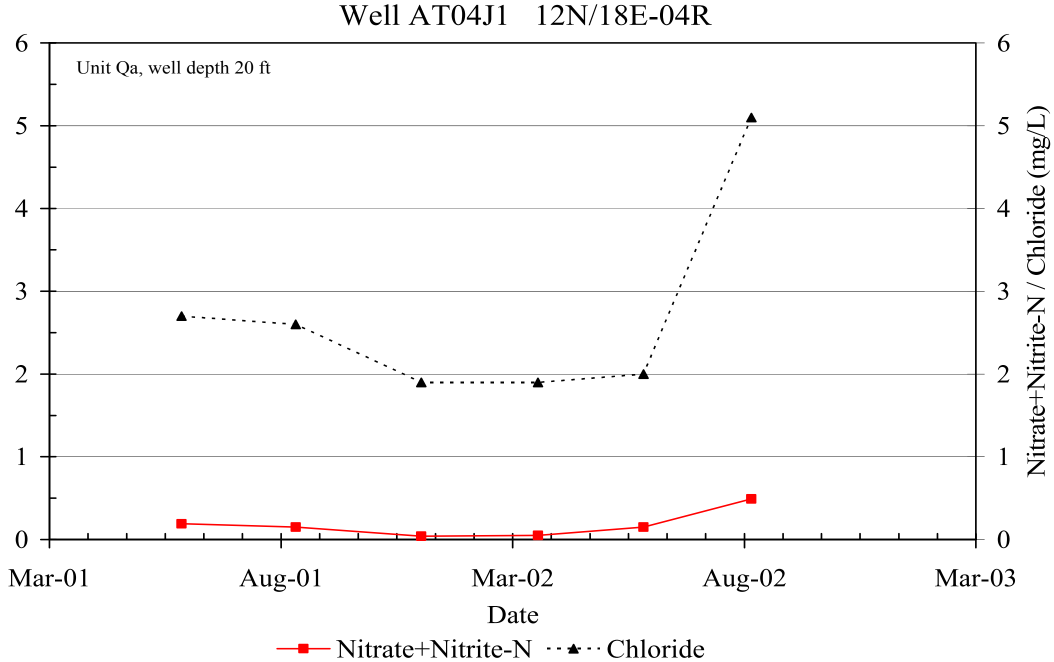
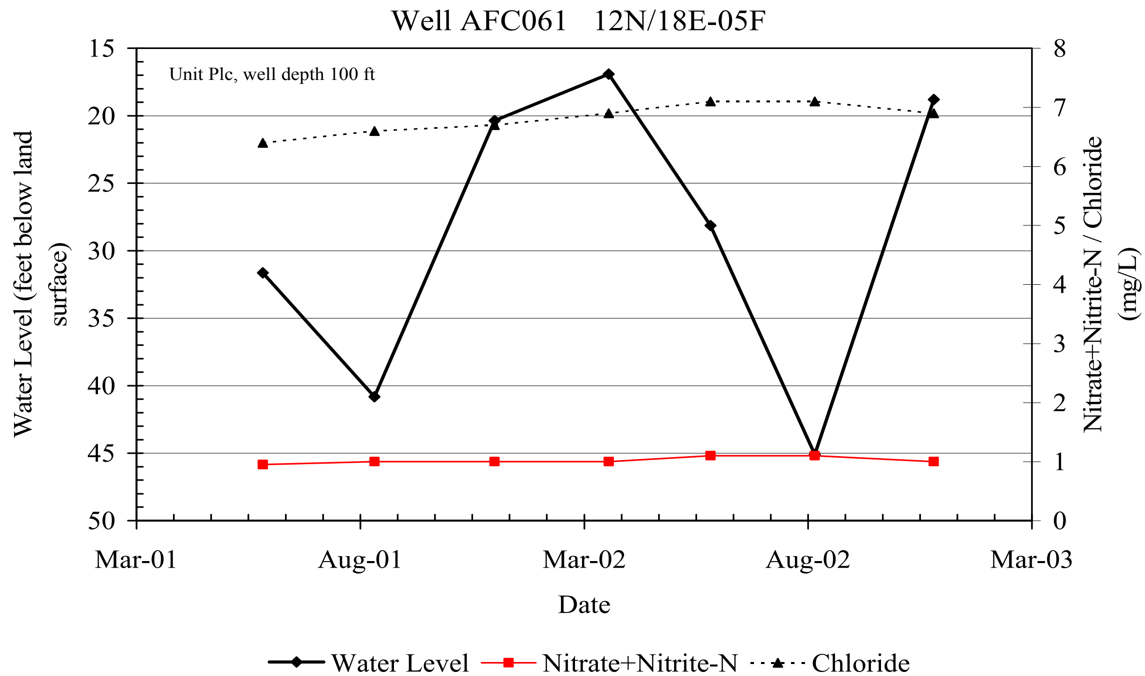


Figure 5 (continued). Water level, nitrate+nitrite-N, and chloride measurements for study wells, March 2001-December 2002.



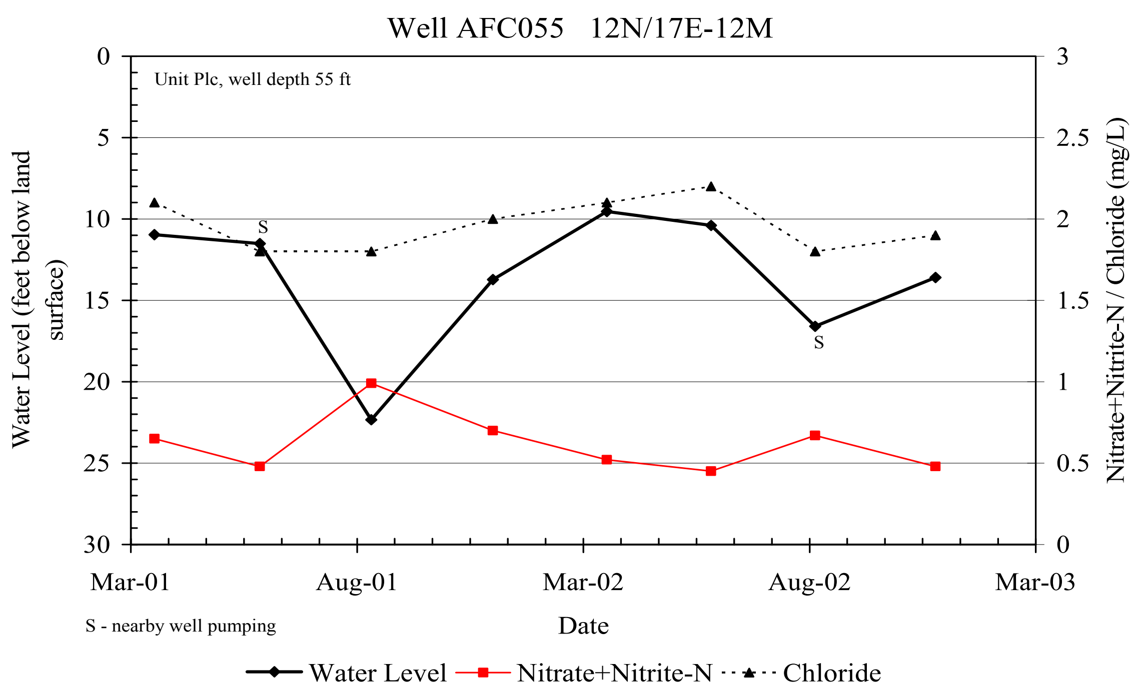


Figure 5 (continued). Water level, nitrate+nitrite-N, and chloride measurements for study wells, March 2001-December 2002.

Table 2. Summary of field measurements and laboratory analytical results for groundwater samples collected from March 2001 through December 2002.

Parameter	Number of samples	Minimum	25th Percentile	Median	75th percentile	Maximum
Field Measurements						
Temperature (C°)	93	9.5	11.4	12.3	13.3	16.4
Specific conductivity (µs/cm@ 25 C°)	94	116	184	253	328	840
pH (standard units)	71	6.64	6.88	7.14	7.34	7.8
Dissolved oxygen (mg/L)	92	1.6	4.9	6.9	10.3	19.6
Laboratory Parameters						
Total persulfate nitrogen (mg/L)	97	0.1	0.29	1.01	2.99	8
Nitrate+nitrite-N (mg/L)	97	0.04	0.26	1	2.5	7.1
Coliform, total (#/100 mL)	97	<1	<1	<1	<1	73 J
Coliform, fecal (#/100mL)	97	<1	<1	<1	<1	35 J
Chloride (mg/L)	97	0.57	1.77	3.83	12.7	34.3
Iron, total (µg/L)	97	<10	<25	<50	81	3030
Manganese, total (µg/L)	97	<1	1.6	2.7	5.1	29.6

mg/L - milligram per liter
µS - microsiemens per centimeter
#/100mL - number of colonies per hundred milliliter
< - less than
µg/L - microgram per liter
J - the reported value is an estimate

Table 3. Maximum contaminant level and groundwater quality criteria.

Parameter	Primary MCL[1]	Secondary MCL[1]	Groundwater Quality Criteria[2]
Field Measurements			
Temperature	None	None	None
Specific conductivity	None	700 umhos/cm	None
pH	None	None	6.5 - 8.5 standard units
Dissolved oxygen	None	None	None
Laboratory Parameters			
Total persulfate nitrogen	None	None	None
Nitrate+nitrite-N	10 mg/L	None	10 mg/L
Coliform, total (MF)	1 CFU/100 mL	None	1 CFU/100mL
Coliform, fecal (MF)	None	None	None
Chloride	None	250 mg/L	250 mg/L
Iron, total	None	0.3 mg/L	0.3 mg/L
Manganese, total	None	0.05 mg/L	0.05 mg/L

[1] - Maximum Contaminant Level: Primary MCL values are based on human health criteria; secondary MCL values are based on aesthetic considerations such as taste, smell, or color (Chapter 248-54 WAC).
[2] - Chapter 173-200 WAC (Water quality standards for ground waters of the State of Washington).

Nitrogen Compounds

Nitrogen compounds such as ammonium ($NH4^+$) and nitrate (NO_3^-) are important nutrients for plant and bacterial growth. Nitrate is generally the dominant form of nitrogen in groundwater, since ammonium and nitrite (NO_2^-) are typically converted to nitrate through bacterial processes. High nutrient concentrations in groundwater may indicate contamination by animal waste or sewage, nitrogen-rich fertilizers, or industrial discharges. Nitrate-N is regulated as a primary contaminant in drinking water at concentrations greater than 10 mg/L, where it can inhibit the oxygen-carrying capacity of blood and cause methemoglobinemia (blue-baby syndrome) in infants. For the purposes of this evaluation, nitrate-N and nitrate+nitrite-N were treated as equivalent analyses since concentrations of nitrite-N in groundwater are typically quite small in comparison to nitrate-N (Matthess, 1982).

The nitrate+nitrite-N values measured during this study ranged from 0.04 to 7.1 mg/L and averaged 1.67 mg/L (Figures 5 and 6). Of the 13 wells sampled, six had average nitrate+nitrite-N concentrations less than 1.0 mg/L, six had average concentrations between 1 and 4 mg/L, and one had an average concentration of approximately 6.6 mg/L. None of the sampled wells exceeded the drinking water standard for nitrate-N during this evaluation (Tables 2 and 3).

Values for total persulfate nitrogen closely followed those of nitrate+nitrite-N and ranged from 0.1 to 8 mg/L and averaged 1.76 mg/L. The good correspondence between nitrate+nitrite-N and total persulfate nitrogen indicates that concentrations of ammonia and organic nitrogen in the study area groundwater are low.

Bacteria

Two classes of bacteria, total coliform and fecal coliform, were evaluated during this study. Total coliform bacteria represent a broad class of microorganisms that occur in untreated surface water, soil, or decaying vegetation. They are also found in the intestines of both warm- and cold-blooded animals, where they aid in food digestion. Fecal coliform is a subgroup of total coliform that is found only in the intestines and fecal matter of warm-blooded animals.

Collectively, coliform bacteria generally pose no direct health risk to humans. However, their presence in groundwater may indicate that a well or aquifer has been contaminated by human or animal fecal matter, surface water, or other coliform-rich waste products. Fecal coliform bacteria were detected in 3 of 97 water samples at concentrations ranging from 4 to 35 CFU/100 ml. Total coliform bacteria were detected in 21 of 97 samples at values ranging from 1 to 73 CFU/100 ml.

Eight wells exceeded (violated) the federal drinking water standard for total coliform (≥1 CFU/100 mL) during at least one sampling event, while four wells exceeded the standard during two or more events (Table 3 and Appendix A: Table-A3).

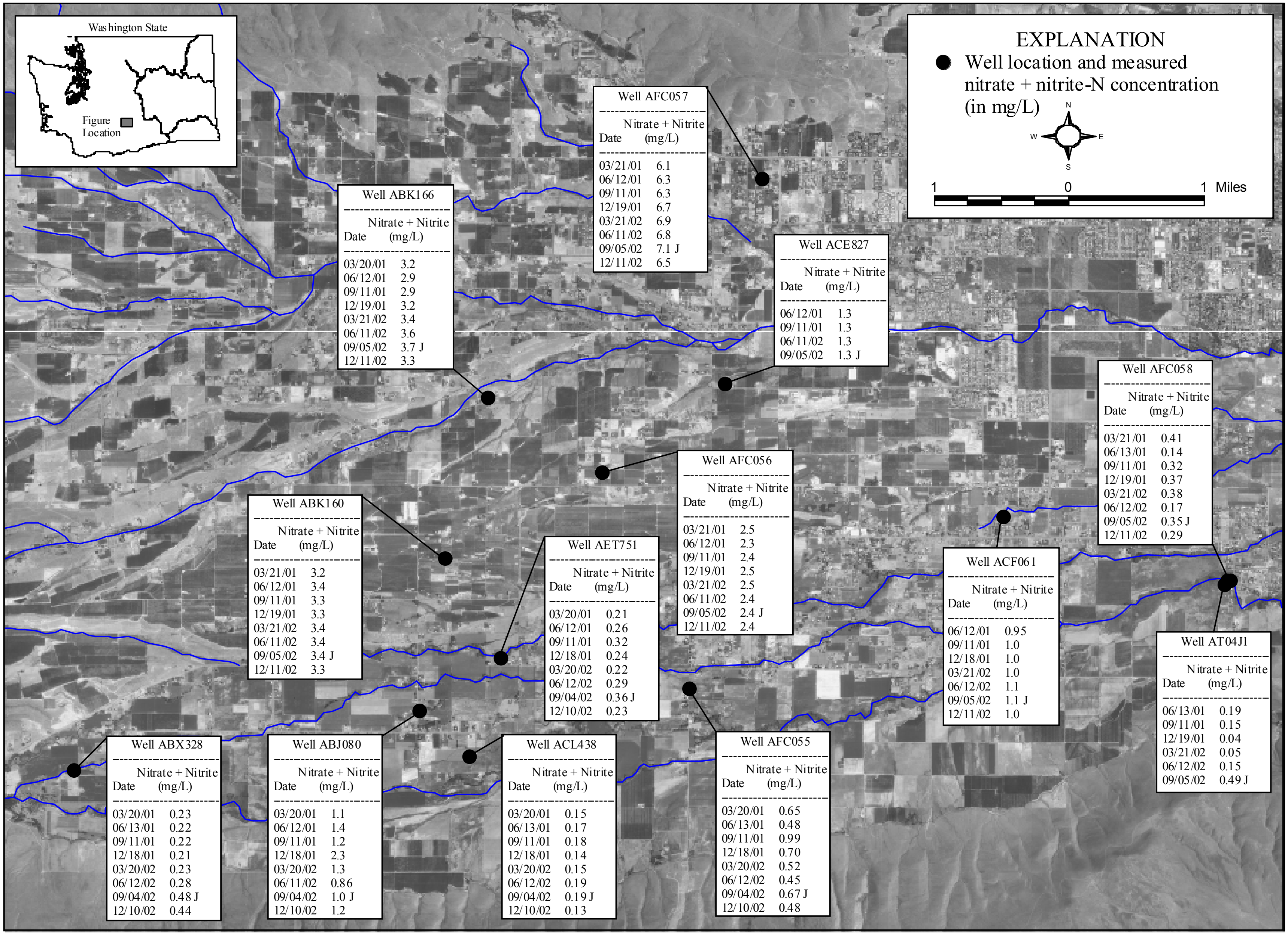


Figure 6. Map showing concentrations of nitrate+nitrite-N for study wells, March 2001 to December 2002

Chloride

Chloride is considered a secondary (aesthetic) contaminant in drinking water at concentrations greater than 250 mg/L (Table 3). None of the wells sampled during this study exceeded the drinking water standard for chloride. Chloride concentrations were generally low, ranging from 0.57 to 34.3 mg/L and averaging 7.98 mg/L.

Total Iron and Manganese

Iron plays many important biochemical roles in plant and animal life cycles, and serves as an oxygen transporter in blood. In oxygenated groundwater, iron is typically present only in trace amounts. It may be more prevalent under reducing conditions and can reach concentrations of 1-10 mg/L as Fe^{2+}. Iron is regulated as a secondary (aesthetic) contaminant in drinking water at concentrations greater than 0.30 mg/L (300 µg/L), where it can encrust plumbing fixtures or stain laundry. The total iron concentrations measured during this study ranged from less than 10 to 3,030 µg/L and averaged 139.6 µg/L. Five wells exceeded the drinking water standard for iron at least once during the investigation, while two wells, ACL438 and AFC058, exceeded the standard during two or more sampling events.

Manganese, like iron, is a vital micro-nutrient and is required in small amounts to maintain plant and animal health. Manganese is regulated as a secondary (aesthetic) contaminant in drinking water at concentrations greater than 0.05 mg/L (50 µg/L) due to its objectionable taste and propensity to stain laundry and plumbing fixtures. Total manganese concentrations during this study ranged from less than 1 to 29.6 µg/L and averaged 3.26 µg/L.

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Discussion

Water Quality Results and Drinking Water MCL Criteria

Most residents of the upper and central Ahtanum Valley obtain their household water from individual wells or small public water systems located near their homes, and use on-site septic systems to treat and dispose of household wastewater. A primary objective of this investigation was to broadly determine whether on-site wastewater disposal and other land-use practices have negatively impacted groundwater quality since area wells were last sampled in 1992 (Larson, 1993). One means of evaluating potential impacts from land-use practices is to compare water quality results against federal and state maximum contaminant level (MCL) criteria for drinking water (Table 3).

With a few exceptions, groundwater within the study area generally met both state and federal drinking water standards for the constituents evaluated. Primary MCL criteria for nitrate-N were met in all cases. Total coliform bacteria were detected in approximately 22 percent of samples and were found on one or more occasions in 8 of 13 wells sampled during this study. Five wells exceeded secondary (aesthetic) drinking water quality criteria for total iron during one or more sampling events.

Evaluation of Nitrate+Nitrite-N Trends (1973-2002)

Trends in nitrate+nitrite-N concentration were evaluated via the Wilcoxon-rank-sum test procedure using data from sampling events conducted in June 1973 (99 wells), September 1992 (16 wells), and September 2002 (13 wells) (Gilbert, 1987). Based on this evaluation, there was an apparent increase in nitrate+nitrite-N concentrations between 1973 and 1992, and between 1973 and 2002. There was an apparent decrease in nitrate+nitrite-N concentrations between 1992 and 2002. The mean nitrate concentrations observed during these events were 0.34 mg/L (1973), 2.08 mg/L (1992), and 1.73 mg/L (2002).

While these trends may be statistically significant, the data used to perform the analyses were derived from independent observation networks whose wells were completed at different locations and depths within the study area. The lack of uniformity in well locations and sampling depths across these data sets likely introduces considerable variability that was not accounted for through this simplistic analysis. Continued monitoring of the well network established during this study will help to mitigate such problems, should they exist.

The highest nitrate+nitrite-N concentrations were observed in well AFC057 which is located in a non-sewered, rapidly urbanizing area west of the city of Yakima. This well is likely influenced by nearby septic systems. Nitrate+nitrite-N concentrations were generally higher in wells located on the upland terraces than those located in the Ahtanum Creek or Wide Hollow Creek valley bottoms (Figure 6). This pattern appears to hold true for total persulfate nitrogen, chloride, specific conductivity, and dissolved oxygen as well (Table A3). Foxworthy (1962) noted a similar pattern for chloride and hardness which he attributed to natural geo-chemical differences in the study area geologic units. Many of the upland terrace wells are completed in the consolidated gravel (unit Plc) or Ellensburg Formation (unit Mc) sediments which tend to contain larger concentrations of chloride and other ions relative to the recent alluvial deposits of the valley bottom.

Data Seasonality

Detecting long-term trends in environmental data is often complicated by inconsistent sampling procedures (over time or among sampling staff) or seasonal differences between sampling events. The influence of these factors can be minimized by establishing and adhering to a consistent sampling methodology carried out on a fixed schedule. Table 4 summarizes the nitrate+nitrite-N concentrations measured during the quarterly sampling conducted for this investigation. These data suggest that seasonal differences between sampling events were minor.

Table 4. Summary of nitrate+nitrite-N concentrations (in mg/L) by sampling month.

	March	June	September	December
Min	0.51	0.14	0.20	0.04
Max	6.92	6.84	7.1	6.69
Mean	1.72	1.58	1.7	1.74
Median	0.84	0.9	1	1.04
N*	22	26	26	23

* Total number of samples. Non-detect values were used to calculate the above statistics by assuming the sample concentration equaled one half the method detection limit.

Summary and Conclusions

Thirteen wells in the central Ahtanum Valley in Yakima County were sampled quarterly from March 2001 through December 2002 to assess the distribution and concentration of nitrate+nitrite-N, total persulfate nitrogen, total iron, total manganese, chloride, and total and fecal coliform bacteria in area groundwater. With a few exceptions, groundwater within the study area generally meets state and federal drinking water standards for the constituents evaluated.

Twenty-two percent of collected samples, and 8 of 13 wells evaluated, exceeded primary maximum contaminant level (MCL) criteria for total coliform bacteria. Five wells exceeded the secondary (aesthetic) MCL criteria for total iron during at least one sampling event. The highest nitrate+nitrite-N concentration (7.1 mg/L) was observed in the non-sewered, rapidly urbanizing area west of the city of Yakima. This suggests that on-site wastewater disposal and/or other activities, such as the use of nitrogen fertilizers, have locally impacted groundwater quality.

Trends in groundwater nitrate+nitrite-N concentration were evaluated using data from three independent sampling events: June 1973 (99 wells), September 1992 (16 wells), and September 2002 (13 wells). Based on this evaluation, there was an apparent increase in nitrate+nitrite-N concentrations between 1973 and 1992, and between 1973 and 2002. There was an apparent decrease in nitrate+nitrite-N concentrations between 1992 and 2002. The lack of uniformity in well locations and sampling depths across these data sets may introduce considerable variability that was not accounted for through this simplistic analysis. To confirm these apparent trends, it will be necessary to periodically monitor the well network established during this study on an ongoing basis.

Recommendations

This study provides a useful benchmark for assessing long-term water quality conditions and trends within the central Ahtanum Valley. Periodic monitoring of the network established during this study should continue on a twice yearly basis (May-June and September-October) to better enable area residents and local public health officials to evaluate the effects of land-use changes on area groundwater quality over time.

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Appendices

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Appendix A

Data Tables

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Table A1- Physical Description of Monitored Wells Within the Ahtanum Valley

Well ID tag number	Local Number	Site Latitude (dms)	Site Longitude (dms)	Water use	Land surface altitude (feet)	Completed well depth (feet)	Casing diameter (inches)	Completion type and open interval (feet)	Well yield (gpm)	Draw-down (feet)	Drawdown test method and duration (hours)	Interpreted source aquifer	Remarks
ABK160	12N/17E-03M	463321	1204112	D	1555	220R	6	-	-	-	-	(?)	-
AET751	12N/17E-10G	463241	1204040	D	1405	185	6	O	80	-	A1	Mc	D
ABJ080	12N/17E-10N	463220	1204125	D	1462	80	6	P(4.5in liner) 50-80	10	12	P48	Mv	D
AFC055	12N/17E-12M	463229	1203859	D	1335	55	5	OH 30-55	15	-	A	Plc	D
ACL438	12N/17E-15C	463202	1204058	D	1445	225	6	S(5in) 205-225	30	-	1	Mc	D
ABX328	12N/17E-18F	463156	1204439	D	1635	66	6	S(5in) 46-66	75	-	1	Mv	D
AFC059	12N/18E-04R	463311	1203354	I	1115	40	6	OH 32-40	30	-	A2	Plc	D
AFC058	12N/18E-04R	463312	1203352	D	1112	122R	6	-	-	-	-	(?)	-
AT04J1*	12N/18E-04R	463311	1203354	I	1115	20R	2	-	-	-	-	Qa	-
AFC061	12N/18E-05F	463338	1203559	D	1190	100	6	O	60	-	-	Plc	D
AFC057	13N/17E-24J	463553	1203814	D	1305	103	6	O	-	-	-	Mc	D
ABK166	13N/17E-34H	463425	1204048	D	1355	98	6	OH 74-98	100	-	A	Mc	D
AFC056	13N/17E-35Q	463355	1203944	D	1445	220R	6	-	-	-	-	(?)	-
ACE827	13N/17E-36B	463431	1203835	D	1340	280	6	OH 257-280	80	-	-	Mc	D

* Not an official well tag ID

Water Use: D-domestic supply; I-irrigation

Completed well depth: R-depth reported by well owner, no driller's log available

Completion type and open interval: O-open ended casing; OH-uncased open hole, P-casing perforations; S-well screen

Drawdown test method and duration: A-airlift test; B-bailer test, P-pumped

Source Aquifer: QA (Quaternary alluvium); Plc (continental sediments/sedimentary rocks of Pliocene age); Mc (continental sedimentary rocks of Miocene age); (Mv) Miocene volcanics, undifferentiated

Remarks: D-driller's log available for well

Table A2 - Drillers Lithologic Logs for Monitored Wells in the Ahtanum Valley

Well tag number	Local number	Driller's description of materials encountered during well construction	Thickness (feet)	Depth of bottom (feet)	Interpreted geologic unit	Well driller	Year drilled
ABK160	12N/17E-03M	No drillers log available	NA	NA	(?)	unknown	unknown
AET751	12N/17E-10G	Soil	8	8		Rank	1998
		Silt, gravel	10	18	Qa		
		Cemented gravel	87	105	Plc		
		Brown sandstone	30	135			
		Sand, water	5	140	Mc		
		Brown sandstone, clay	40	180			
		Gravel, water	5	185			
ABJ080	12N/17E-10N	Topsoil	2	2		Riddle	1984
		Large "river rocks" with sand and gravel	10	12	Qa		
		Gravel, hard cemented	33	45	Plc		
		Gray basalt, hard	25	70			
		Small gravel with sand and broken rock	10	80	Mv		
AFC055	12N/17E-12M	Topsoil	9	9	Qa	Jensen	1979
		Conglomerate, hard	9	18			
		Orange conglomerate, hard	6	24			
		Gray conglomerate, extremely hard	2	26	Plc		
		Orange conglomerate, extremely hard	12	38			
		Conglomerate, extremely hard	17	55			
ACL438	12N/17E-15C	Original well, no driller's log available	100	100	(?)	Rank	1997
		Gravel, cemented	70	170	Plc		
		Brown sandstone	42	212			
		Coarse sand, water	13	225	Mc		
ABX328	12N/17E-18F	Soil	4	4		Rank	1995
		Gravel	6	10	Qa		
		Gravel, cemented	11	21	Plc		
		Gravel, clay, and cinders	14	35	Mc		
		Gray basalt, water	14	49			
		Brown basalt	11	60	Mv		
		Brown basalt, gravel, water	6	66			
AFC059	12N/18E-04R	Soil	8	8		Rank	1988
		Soil, rock, and gravel	9	17	Qa		
		Silt, gravel, water	5	22			
		Cemented gravel, water	13	35			
		Cemented gravel	5	40	Plc		
AFC058	12N/18E-04R	No driller's log available	NA	NA	(?)	unknown	unknown
AT04J1*	12N/18E-04R	No driller's log available	NA	NA	Qa	unknown	unknown
AFC061	12N/18E-05F	Topsoil	6	6	Qa	Huhn	1987
		Sand, gravel, boulders, with brown clay seams, water	54	60			
		Brown clay, soft	4	64			
		Basalt gravel and "river rock" , water	23	87	Plc		
		Brown clay, soft	2	89			
		Sand and basalt gravel, water	16	105			

Table A2 - Drillers Lithologic Logs for Monitored Wells in the Ahtanum Valley

Well tag number	Local number	Driller's description of materials encountered during well construction	Thickness (feet)	Depth of bottom (feet)	Interpreted geologic unit	Well driller	Year drilled
		Sand and tan clay, water	18	123			
		Basalt gravel, water	2	125			
AFC057	13N/17E-24J	Topsoil	3	3		Cassel	1985
		Gravel, cobbles, conglomerate	8	11	Plc		
		Brown conglomerate with clay lenses	29	40			
		Gray clay, sticky	18	58			
		Brown clay, sandy	16	74			
		Brown clay, sticky	7	81			
		Brown conglomerate, some water	5	86	Mc		
		Tan clay	6	92			
		Brown sandstone, some water	8	100			
		Tan clay	3	103			
ABK166	13N/17E-34H	Topsoil	3	3	Qa	Riebe	1994
		Cobbles, gravel	5	8			
		Clay, sandy medium hard	26	34			
		Sandstone	21	55			
		Sandstone, sand, medium hard	15	70	Mc		
		Sandstone, hard	24	94			
		Sandstone, gravel, medium hard	4	98			
AFC056	13N/17E-35Q	No driller's log available	NA	NA	(?)	unknown	unknown
ACE827	13N/17E-36B	Gravel, cemented	12	12		Waterman	1996
		Gravel and cobbles, loose	6	18			
		Boulders, cobbels, gravel	6	24			
		Large cemented brown gravel and silt	6	30			
		Brown clay	6	36			
		Brown cemented gravel, hard	7	43			
		Cemented brown gravel and clay, medium hard	9	52			
		Dark brown cemented gravel and sandstone, hard	39	91			
		Large cemented gravel and cobbels with clay, hard	13	104			
		Brown cemented gravel with sandstone, hard	15	119	Plc		
		Brown sandstone	3	122			
		Brown to black cemented gravel	8	130			
		Brown sandstone, medium soft	2	132			
		Brown to black cemented gravel, hard	8	140			
		Brown sandstone	3	143			
		Brown to black cemented gravel, hard	17	160			
		Dark brown cemented gravel, loose	12	172			
		Brown cemented gravel with sandstone, hard	6	178			
		Brown sandstone, medium hard	14	192			
		Brown to black cemented gravel, hard	23	215			
		Green sandstone, medium hard	7	222			
		Large cemented gravel, hard	21	243			
		Brown sandstone, medium hard	11	254			
		Brown to black cemented gravel, medium hard	4	258	Mc		
		Tan to brown sandstone and cemented gravel	9	267			
		Brown sandstone, medium soft	8	275			
		Multi colored gravel with clay sandstone	5	280			

* not an official well tag number

Table A3 - Sampling Results for Monitored Wells in the Ahtanum Valley

[Explanation: J -analyte positively identified, the numeric result is an estimate; U -analyte not detected at or above the reported value; UJ -analyte not detected at or above the estimated value. P -the well was pumping, water level not measured; R -well recently pumped, water level slowly recovering; NA -well access restriction, water level not measured; * -laboratory measurement]

		Field measurements					Laboratory analyses							
Well Tag Number	Sample Date	Depth to Groundwater (ft below land surface)	Ground-water Temperature (deg C)	pH (standard units)	Specific Conductivity (uS/cm)	Dissolved Oxygen (mg/L)	Fecal Coliform (#/100mL)	Total Coliform (#/100mL)	Total Nitrate+ Nitrite as N (mg/L)	Total Persulfate Nitrogen (mg/L)	Chloride (mg/L)	Total Iron (ug/L)	Total Manganese (ug/L)
ABJ080	03/20/2001	8.4	9.7	--	237	4.7	1 U	4 J	1.1	1.2	2.2	24	5.1
ABJ080	06/12/2001	8.4	10.9	6.91	247	6.3	1 U	4	1.4	1.6	2.2	23	7.2
ABJ080	09/11/2001	11 R	13	--	300	4.4	1 UJ	1 J	1.2	1.3	2.3	1300	13.7
ABJ080	12/18/2001	8.8 R	12.6	6.78	279	8.4	1 U	3	2.3	2.5 J	2.3	20 U	6.1
ABJ080	03/20/2002	8.1	9.5	6.84	225	7.9	1 U	1 UJ	1.3	1.5	2.4	187	29.6
ABJ080	06/11/2002	9.6	10.7	6.99	247	6.1	1 U	1 J	0.86	1.0	2.5	78	11
ABJ080	09/04/2002	11.2	13.3	6.83	279*	5.7	4	24	1 J	1.1	2.9	61	18
ABJ080	12/10/2002	9.8	11.9	--	236	4.9	4	58 J	1.2	1.3	2.4	25 U	5
ABK160	03/21/2001	201.5	--	7.8*	432*		1 U	1 U	3.2	3.1	17.6	20 U	2 U
ABK160	06/12/2001	203.0	15.6	7.43	430	14.7	1 U	1 U	3.4	3.4	17.9	31	2 U
ABK160	09/11/2001	207.0	16.4	--	403	7.3	1 U	1 U	3.3	3.3	16.2	120	1.7
ABK160	12/19/2001	206.0	15.6	7.48	434	12.1	1 U	1 U	3.3	3.5 J	19.2	61	1.1
ABK160	03/21/2002	204.6	13.6	7.51	438	9.7	1 U	1UJ	3.4	3.5	19.6	31	1 U
ABK160	06/11/2002	205.3	15.6	7.67	422	11.3	1 U	1 U	3.4	3.4	18.3	25 U	5 U
ABK160	09/05/2002	209.0	16.4	7.52	430*	9.3	1 U	1 U	3.4 J	3.3	18.8	63	10 U
ABK160	12/11/2002	206.5	13.7	7.6 J*	424	5.5	1 U	1 U	3.3	3.5	18.6	41	5 U
ABK166	03/20/2001	10.8	13.3	--	328	13.9	1 U	1 U	3.2	3.4	12.4	26	2 U
ABK166	06/12/2001	P	13.8	6.65	329	14.8	1 U	1 U	2.9	2.9	12.7	20 U	2 U
ABK166	09/11/2001	16.7	13.6	--	328	11.7	1 U	1 U	2.9	3.0	12.3	10 U	1 U
ABK166	12/19/2001	14.7	--	--	--	--	35 J	73 J	3.2	3.4 J	12.0	43	1.4
ABK166	03/21/2002	13.2	--	--	--	--	1 U	1 UJ	3.4	3.5	12.5	20 U	1 U
ABK166	06/11/2002	14.3	13.4	6.74	352	15.8	1 U	1 U	3.6	3.5	13.8	25 U	5 U
ABK166	09/05/2002	16.3	12.9	6.64	363*	12.3	1 UJ	1 UJ	3.7 J	3.5	13.6	50 U	10 U
ABK166	12/11/2002	15.3	--	6.8*	--	--	1 U	1 U	3.3	3.6	12.7	25 U	5 U
ABX328	03/20/2001	18.8	10	--	183	1.6	1 UJ	1 UJ	0.23	0.23	1.2	20 U	2 U
ABX328	06/13/2001	19.4	10.9	7.22	187	2.2	1 U	1 U	0.22	0.24	0.85	20 U	2 U
ABX328	09/11/2001	P	11.3	--	185	2.5	1 UJ	1 UJ	0.22	0.26	0.97	10 U	1.8
ABX328	12/18/2001	19.4	9.7	7.22	187	3.2	1 UJ	1 U	0.21	0.23 J	1.1	20 U	1 U
ABX328	03/20/2002	19.1	9.5	7.3	188	3.6	1 U	1 U	0.23	0.26	1.2	22	1
ABX328	06/12/2002	18.5 R	10.4	7.23	189	4.0	1 UJ	1 UJ	0.28	0.30	1.2	25 U	5 U
ABX328	09/04/2002	19.6	10.8	7.28	194*	4.3	1 U	1 U	0.48 J	0.45	1.4	50 U	10 U
ABX328	12/10/2002	20.2	9.8	--	191	1.7	1 U	2	0.44	0.48	1.4	25 U	5 U

Table A3 - Sampling Results for Monitored Wells in the Ahtanum Valley

[Explanation: J -analyte positively identified, the numeric result is an estimate; U -analyte not detected at or above the reported value; UJ -analyte not detected at or above the estimated value. P -the well was pumping, water level not measured; R -well recently pumped, water level slowly recovering; NA -well access restriction, water level not measured; * -laboratory measurement]

		Field measurements					Laboratory analyses							
Well Tag Number	Sample Date	Depth to Groundwater (ft below land surface)	Ground-water Temperature (deg C)	pH (standard units)	Specific Conductivity (uS/cm)	Dissolved Oxygen (mg/L)	Fecal Coliform (#/100mL)	Total Coliform (#/100mL)	Total Nitrate+ Nitrite as N (mg/L)	Total Persulfate Nitrogen (mg/L)	Chloride (mg/L)	Total Iron (ug/L)	Total Manganese (ug/L)
ACE827	03/21/2001	75.6 R	--	--	--	--	--	--	--	--	--	--	--
ACE827	06/12/2001	83.3	14.8	7.07	200	15.0	1 U	1 U	1.3	1.3	3.3	20 U	3
ACE827	09/11/2001	91.9 R	15	--	200	10.6	1 U	1 U	1.3	1.3	3.3	12	4.3
ACE827	12/19/2001	79.1	--	--	--	--	--	--	--	--	--	--	--
ACE827	03/20/2002	76.8	--	--	--	--	--	--	--	--	--	--	--
ACE827	06/11/2002	80.2	14.5	7.31	209	14.6	1 U	1 U	1.3	1.3	3.9	25 U	5 U
ACE827	09/05/2002	95.5	14.5	7.25	211*	12.5	1 U	1 U	1.3 J	1.3 J	3.8	50 U	10 U
ACE827	12/10/2002	78.4	--	--	--	--	--	--	--	--	--	--	--
ACL438	03/20/2001	86.6	12.3	--	116	3.9	1 U	1 U	0.15	0.14	0.75	48	2 U
ACL438	06/13/2001	103.3	12.1	7.27	122	4.7	1 U	1 U	0.17	0.17	0.57	94	2 U
ACL438	09/11/2001	109.3	12.4	--	121	4.8	1 U	4 J	0.18	0.18	0.63	44	1 U
ACL438	12/18/2001	94.1	11.4	7.14	121	5.6	1 U	1 U	0.14	0.13 J	0.59	1010	1.6
ACL438	03/20/2002	90.5 R	11.4	7.15	121	5.4	1 U	1 U	0.15	0.16	0.63	74	1 U
ACL438	06/12/2002	102.8	12.6	7.11	127	6.1	1 U	1 U	0.19	0.19	0.80	420	5 U
ACL438	09/04/2002	111.7	12.7	7.36	126*	6.4	1 U	29	0.19 J	0.16	0.84	71	10 U
ACL438	12/10/2002	91.5	10.9	--	119	3.0	1 U	29 J	0.13	0.14	0.77	75	5 U
AET751	03/20/2001	72.5	12.4	--	131	6.7	1 U	1 U	0.21	0.20	0.74	52	2 U
AET751	06/12/2001	80.3	12.7	7.17	135	10.7	1 U	1 U	0.26	0.26	0.66	21	2 U
AET751	09/11/2001	89.4	12.7	--	136	5.7	1 U	1 U	0.32	0.31	0.71	15	1.2
AET751	12/18/2001	80.4	12.9	7.07	137	10.3	1 U	1 U	0.24	0.24 J	0.74	27	1.2
AET751	03/20/2002	76.8	11.2	7.13	136	7.6	1 U	1 U	0.22	0.23	0.61	24	1 U
AET751	06/12/2002	82.4	12.8	7.03	140	9.4	1 U	1 U	0.29	0.30	0.83	30	5 U
AET751	09/04/2002	93.0	12.9	7.24	143*	8.0	1 U	1 U	0.36 J	0.32	0.88	50 U	10 U
AET751	12/10/2002	83.1	11.6	--	136	5.7	1 U	5	0.23	0.24	0.74	25	5 U
AFC055	03/20/2001	11.0	11.5	--	288	5.2	1 U	3	0.65	0.67	2.1	20 U	2 U
AFC055	06/13/2001	11.5	12.2	6.96	284	5.2	1 U	3	0.48	0.53	1.8	20 U	2 U
AFC055	09/11/2001	22.3 S	12.6	--	230	4.6	1 U	9 J	0.99	0.98	1.8	10U	1 U
AFC055	12/18/2001	13.7	12.2	6.84	293	10.8	1 U	1 U	0.70	0.80 J	2.0	20 U	1 U
AFC055	03/20/2002	9.5	11.1	6.88	299	8.2	1 U	1 J	0.52	0.62	2.1	20 U	1 U
AFC055	06/12/2002	10.4	12.1	6.86	300	5.9	1 U	1 U	0.45	0.52	2.2	25 U	5 U
AFC055	09/04/2002	16.6 S	12.1	7.01	253*	6.4	1 U	7	0.67 J	0.69	1.8	50 U	10 U
AFC055	12/10/2002	13.6	11.2	--	290	5.2	1 U	1 U	0.48	0.59	1.9	25 U	5 U

Table A3 - Sampling Results for Monitored Wells in the Ahtanum Valley

[Explanation: J -analyte positively identified, the numeric result is an estimate; U -analyte not detected at or above the reported value; UJ -analyte not detected at or above the estimated value. P -the well was pumping, water level not measured; R -well recently pumped, water level slowly recovering; NA -well access restriction, water level not measured; * -laboratory measurement]

		Field measurements					Laboratory analyses						
Well Tag Number	Sample Date	Depth to Groundwater (ft below land surface)	Ground-water Temperature (deg C)	pH (standard units)	Specific Conductivity (uS/cm)	Dissolved Oxygen (mg/L)	Fecal Coliform (#/100mL)	Total Coliform (#/100mL)	Total Nitrate+ Nitrite as N (mg/L)	Total Persulfate Nitrogen (mg/L)	Chloride (mg/L)	Total Iron (ug/L)	Total Manganese (ug/L)
AFC056	03/21/2001	140.3	12.6	7.6*	315*	--	1 U	1 U	2.5	3.1	12.7	197	2 U
AFC056	06/12/2001	147.4	13.1	7.47	304	13.2	1 U	1 U	2.3	2.8	12.1	92	2 U
AFC056	09/11/2001	155.7	13.7	--	308	10.0	1 U	1 U	2.4	2.3	11.8	99	1 U
AFC056	12/19/2001	151.3	12.7	7.43	317	15.5	1 U	1 U	2.5	2.5 J	12.8	63	1.1
AFC056	03/21/2002	144.0	11.6	7.4	317	12.9	1 U	1 U	2.5	2.5	13.0	150	1 U
AFC056	06/11/2002	146.7	13.4	7.51	320	19.6	1 U	1 UJ	2.4	2.4	13.3	77	5 U
AFC056	09/05/2002	159.9	13.5	7.47	329*	16.1	1 U	1 U	2.4 J	2.3	13.1	370	10 U
AFC056	12/11/2002	146.4	12.2	7.6 J*	321	8.4	1 UJ	1 UJ	2.4	2.7	13.8	69	5 U
AFC057	03/21/2001	62.0	13.3	7.5*	812*	6.5	1 U	1 U	6.1	6.8	29	74	2 U
AFC057	06/12/2001	62.1	13.4	7.26	800	6.9	1 U	1 UJ	6.3	8.0	28.9	43	2 U
AFC057	09/11/2001	60.4	13.8	--	793	6.7	1 U	1 U	6.3	6.4	29.5	62	1.4
AFC057	12/19/2001	61.6	13.2	7.32	815	8.5	1 UJ	1 UJ	6.7	6.9 J	30.1	40	1.2
AFC057	03/21/2002	63.0	12.9	7.29	822	8.3	1 U	1 UJ	6.9	7.4	33.3	66	1 U
AFC057	06/11/2002	62.9	13.7	7.38	822	7.7	1 U	1 U	6.8	6.8	34.3	270	6.7
AFC057	09/05/2002	61.4	13.9	7.29	840*	7.6	1 UJ	1 UJ	7.1 J	6.7	34	68	10 U
AFC057	12/11/2002	60.1	12.8	7.4 J*	832	4.5	1 UJ	1 UJ	6.5	7.4	34.3	25 U	5 U
AFC058	03/21/2001	22.4	11.5	7.2*	256*	1.7	1 U	1 U	0.41	0.41	4.7	338	3.5
AFC058	06/13/2001	33.7	12	6.88	372	2.9	1 U	2	0.14	0.18	3.8	1410	13
AFC058	09/11/2001	43.3	12.2	--	282	2.9	1 U	1 UJ	0.32	0.36	4.4	552	5.2
AFC058	12/19/2001	28.6 R	12.3	6.83	243	2.9	1 U	1 U	0.37	0.41 J	4.4	193	2.4
AFC058	03/21/2002	25.1	11.7	6.81	244	2.7	1 U	1 U	0.38	0.41	4.8	130	1.6
AFC058	06/12/2002	30.1	12.3	6.84	347	7.1	1 U	1	0.17	0.22	3.9	130	5 U
AFC058	09/05/2002	45.3	12.2	6.85	265*	4.7	1 U	1 U	0.35 J	0.29	5.4	370	11
AFC058	12/11/2002	26.6	11.4	7.0*	253	2.6	1 U	1 U	0.29	0.34	4.5	65	5 U
AFC059	03/21/2001	10.4	--	--	--	--	--	--	--	--	--	--	--
AFC059	06/13/2001	10.2	--	--	--	--	--	--	--	--	--	--	--
AFC059	09/11/2001	11.4	--	--	--	--	--	--	--	--	--	--	--
AFC059	12/19/2001	11.2	--	--	--	--	--	--	--	--	--	--	--
AFC059	03/21/2002	9.9	--	--	--	--	--	--	--	--	--	--	--
AFC059	06/12/2002	8.0	--	--	--	--	--	--	--	--	--	--	--
AFC059	09/05/2002	10.2	--	--	--	--	--	--	--	--	--	--	--
AFC059	12/11/2002	11.1	--	--	--	--	--	--	--	--	--	--	--

Table A3 - Sampling Results for Monitored Wells in the Ahtanum Valley

[Explanation: J -analyte positively identified, the numeric result is an estimate; U -analyte not detected at or above the reported value; UJ -analyte not detected at or above the estimated value.
P -the well was pumping, water level not measured; R -well recently pumped, water level slowly recovering; NA -well access restriction, water level not measured; * -laboratory measurement]

		Field measurements					Laboratory analyses						
Well Tag Number	Sample Date	Depth to Groundwater (ft below land surface)	Ground-water Temperature (deg C)	pH (standard units)	Specific Conductivity (uS/cm)	Dissolved Oxygen (mg/L)	Fecal Coliform (#/100mL)	Total Coliform (#/100mL)	Total Nitrate+ Nitrite as N (mg/L)	Total Persulfate Nitrogen (mg/L)	Chloride (mg/L)	Total Iron (ug/L)	Total Manganese (ug/L)
AFC061	06/12/2001	31.6	11.6	7.01	171	10.5	1 U	1 U	0.95	0.97	6.4	54	2 U
AFC061	09/11/2001	40.8	12	--	173	9.6	1 U	1 U	1.0	1.0	6.6	81	1.6
AFC061	12/18/2001	20.4	12.1	6.97	175	14.0	1 U	1 U	1.0	1.1J	6.7	69	2.2
AFC061	03/21/2002	16.9	10.6	7.05	177	10.1	1 U	1 U	1.0	1.1	6.9	120	2.7
AFC061	06/12/2002	28.1	11.9	7.04	177	18.7	1 U	1 U	1.1	1.1	7.1	280	7.3
AFC061	09/05/2002	45.1 R	11.9	7.05	180*	13.7	1 U	1 U	1.1 J	1.1	7.1	220	10 U
AFC061	12/11/2002	18.8	11.4	7.3 J*	174	6.9	1 U	1 U	1.0	1.1	6.9	99	6
AT04J1*	06/13/2001	NA	10.2	6.89	260	6.1	1 U	2	0.19	0.22	2.7	51	2 U
AT04J1*	09/11/2001	NA	12.6	--	266	6.9	1 U	1 UJ	0.15	0.20	2.6	10 U	1 U
AT04J1*	12/19/2001	NA	13.3	6.79	222	8.1	1 U	1 UJ	0.04	0.80 J	1.9	3030	7.6
AT04J1*	03/21/2002	NA	11.1	6.87	196	6.2	1 U	1 U	0.05	0.10	1.9	30	1 U
AT04J1*	06/12/2002	NA	10.8	6.85	239	7.2	1 U	1 UJ	0.15	0.22	2.0	25 U	5 U
AT04J1*	09/05/2002	NA	12.8	6.81	339*	8.4	1 U	1 UJ	0.49 J	0.61	5.1	50 U	10 U

Table A4 - Quality Assurance Review of Field and Laboratory Duplicate Samples and Laboratory Method Blanks

[Explanation: U -analyte not detected at or above the reported value; UJ -analyte not detected at or above the estimated value; Bold values indicate an exceedence of the project precision criteria]

		Field Replicate Samples							Laboratory Duplicate and Blank Samples						
Sample Date		Total Nitrate+ Nitrite (as N) (mg/L)	Total Persulfate Nitrogen (mg/L)	Total Coliform (CFU/ 100mL)	Fecal Coliform (CFU/ 100mL)	Total Chloride (mg/L)	Total Iron (ug/L)	Total Manganese (ug/L)	Total Nitrate+ Nitrite (as N) (mg/L)	Total Persulfate Nitrogen (mg/L)	Total Coliform (CFU/ 100mL)	Fecal Coliform (CFU/ 100mL)	Total Chloride (mg/L)	Total Iron (ug/L)	Total Manganese (ug/L)
03/20/01	Sample	0.211	0.204	1U	1U	0.741	52	2U	0.227	0.232	1U	1U	2.19	--	--
	Rep/Duplicate	0.21	0.206	1U	1U	0.731	152	2U	0.232	0.23	1U	1U	2.2	--	--
	RPD	0.48	0.98	NA	NA	1.36	**98**	NA	2.18	0.87	NA	NA	0.46	--	--
	%RSD	0.24	0.49	NA	NA	0.68	**49**	NA	1.1	0.4	NA	NA	0.23	--	--
	Lab blank	--	--	--	--	--	--	--	--	--	--	--	--	20 U	2 U
06/13/01	Sample	0.221	0.238	1U	1U	0.846	20U	2U	2.31	8.02	1U	1U	28.9	--	--
	Rep/Duplicate	0.221	0.24	1U	1U	0.851	20U	2U	2.3	8.64	1U	1U	28.7	--	--
	RPD	0	0.84	NA	NA	0.59	NA	NA	0.43	7.44	NA	NA	0.69	--	--
	%RSD	0.0	0.4	NA	NA	0.3	NA	NA	0.22	3.7	NA	NA	0.35	--	--
	Lab blank	--	--	--	--	--	--	--	--	--	--	--	--	20 U	2 U
09/11/01	Sample	0.223	0.257	1UJ	1UJ	0.972	10U	1.8	3.31	--	1 UJ	1 UJ	0.979	--	--
	Rep/Duplicate	0.221	0.246	1UJ	1UJ	0.979	10U	1.5	3.2	--	1 UJ	1 UJ	0.974	--	--
	RPD	0.9	4.4	NA	NA	0.7	NA	**18.2**	3.4	NA	NA	NA	0.51	--	--
	%RSD	0.45	2.2	NA	NA	0.36	NA	**9.1**	1.7	NA	NA	NA	0.26	--	--
	Lab blank	--	--	--	--	--	--	--	--	--	--	--	--	10 U	1 U
12/18/01	Sample	0.212	0.234J	1U	1UJ	1.14	20U	1U	0.212	0.226 J	1 UJ	1 UJ	1.16	--	--
	Rep/Duplicate	0.213	0.226J	1UJ	1U	1.16	20U	1U	0.211	0.231 J	1 UJ	1 UJ	0.978	--	--
	RPD	0.5	3.5	NA	NA	1.7	NA	NA	0.47	2.2	NA	NA	**17**	--	--
	%RSD	0.24	1.7	NA	NA	0.9	NA	NA	0.24	1.1	NA	NA	**8.5**	--	--
	Lab blank	--	--	--	--	--	--	--	--	--	--	--	--	20 U	1 U
03/20/02	Sample	0.229	0.26	1U	1U	1.15	22	1	2.48	1.48	1 J	1U	12.5	--	--
	Rep/Duplicate	0.229	0.26	1U	1U	1.14	22	1U	2.44	1.48	1 UJ	1U	12.4	--	--
	RPD	0.0	0.0	NA	NA	0.9	0.0	NA	1.63	0.00	NA	NA	0.8	--	--
	%RSD	0.0	0.0	NA	NA	0.44	0.0	NA	0.81	0.00	NA	NA	0.4	--	--
	Lab blank	--	--	--	--	--	--	--	--	--	--	--	--	20 U	1 U
06/12/02	Sample	0.278	0.301	1UJ	1U	1.21	25U	5U	3.42	0.189	1 J	1 U	2.20	--	--
	Rep/Duplicate	0.278	0.301	1U	1UJ	1.17	25U	5U	3.41	0.191	1 J	1 U	2.19	--	--
	RPD	0.0	0.0	NA	NA	3.4	NA	NA	0.29	1.05	NA	NA	0.46	--	--
	%RSD	0.0	0	NA	NA	1.7	NA	NA	0.15	0.53	NA	NA	0.23	--	--
	Lab blank	--	--	--	--	--	--	--	0.01 U	0.025 U	--	--	0.10 U	25 U	5 U
09/04/02	Sample	0.484J	0.451	1U	1U	1.35	50U	10U	0.484	0.164	7	1 U	7.13	--	--
	Rep/Duplicate	0.484J	0.514	1U	1U	1.33	50U	10U	0.487	0.182	11	1 U	7.09	--	--
	RPD	0.0	**13.1**	NA	NA	1.5	NA	NA	0.62	**10.4**	44.4	NA	0.56	--	--
	%RSD	0.0	**6.5**	NA	NA	0.8	NA	NA	0.31	**5.2**	22.2	NA	0.28	--	--
	Lab blank	--	--	--	--	--	--	--	0.01 U	0.025 U	--	--	0.10 U	50 U	10 U
12/10/02	Sample	0.44	0.48	2	1 U	1.4	25U	5U	0.133	0.243	1 U	1 U	1.4	--	--
	Rep/Duplicate	0.44	0.46	2	1 U	1.38	25U	5U	0.132	0.24	1 U	1 U	1.34	--	--
	RPD	0.0	3.4	0.00	NA	1.4	NA	NA	0.8	1.24	NA	NA	4.4	--	--
	%RSD	0.0	1.7	0.0	NA	0.7	NA	NA	0.4	0.6	NA	NA	2.2	--	--
	Lab blank	--	--	--	--	--	--	--	0.01 U	0.025 U	--	--	0.10	25 U	5 U

Relative percent difference (RPD): Calculated for a pair of results, x_1 and x_2, as $100*(x_1-x_2)/(\text{average}[x_1 \text{ and } x_2])$

Percent relative standard deviation (%RSD): Calculated for a pair of results, x_1 and x_2, as $100*s/(\text{average } [x_1 \text{ and } x_2])$, where s is the standard deviation of the sample

Appendix B

Quality Assurance Review

The data quality objectives for this study were defined prior to the onset of data collection and are described in the study quality assurance project plan (Sinclair, 2002 and Table B-1). Quality assurance covers a broad array of field sampling and laboratory analytical activities. Some field activities, such as measuring the water level in a well, are largely procedural in nature and data quality can be assured by employing and adhering to standardized field methods (see below). Other activities, such as sample collection, require the analysis of quality control samples in order to evaluate data quality. The quality assurance procedures we followed for each of these broad activity classes is described below.

Table B-1 Project Data Quality Objectives

Parameter	Accuracy (2*precision + bias)	Precision (%RSD)	Bias	Lowest level of interest
Field Measurements				
Temperature (field)	NA	NA	NA	NA
Specific conductivity (field)	20	5	10	25 µS/cm @ 25 °C
pH (field)	20	5	10	NA
Dissolve oxygen (field)	20	5	10	0.5 mg/L
Laboratory Parameters				
Total persulfate nitrogen	20	5	10	0.1 mg/L
Nitrate+nitrite-N	20	5	10	0.1 mg/L
Coliform, total (MF)	70	30	10	1 CFU/100 mL
Coliform, fecal (MF)	70	30	10	1 CFU/100 mL
Chloride	20	5	10	1 mg/L
Iron, total	20	5	10	5 ug/L
Manganese, total	20	5	10	1 ug/L

Sample Handling and Chain of Custody

For this study we followed the quality control procedures specified in Barcelona et al. (1985) during sample collection and transport. Samples were collected in pre-cleaned bottles supplied by the Manchester Environmental Laboratory (MEL). Pre-acidified bottles were used to collect samples for nitrate+nitrite-N, and total persulfate nitrogen. To minimize the potential for contamination, metals samples were acidified upon arrival at the laboratory (usually less than 24 hours). Filled sample bottles were labeled and stored on ice pending delivery to the laboratory. Sample chain-of-custody procedures were followed throughout the project, and all samples arrived at the laboratory in good condition.

Four samples for pH and 11 samples for total and fecal coliform bacteria were not processed within accepted sample holding times. These results are flagged with a "J" qualifier to indicate that the samples were analyzed outside of the normal processing timeline (Tables A-3 and A-4). In addition, 16 samples for total coliform bacteria had high background counts of non-motile, non-total colonies which may interfere with the sheen color produced by the total coliforms. These results are also flagged with a "J" qualifier (estimated count) since the "true value" may be greater than the reported value.

The refrigerator used by the MEL for temporary storage of nutrient samples exceeded temperature acceptance limits for short periods in December 2001 and again in September 2002. The effect of these short-term temperature excursions on subsequent nutrient analyses is unknown. Accordingly the total persulfate nitrogen samples for December 2001 and nitrate+nitrite-N samples for September 2002 were assigned "J" qualifiers, since the reported results may differ from the "true" sample value.

Evaluation of Field Replicate and Laboratory Duplicate Samples

In order to assess overall sampling and analytical precision, field replicate samples were collected and submitted "blind"[1] to the laboratory during each sampling event. Precision for each of the field replicate and laboratory duplicate analyses was quantified by evaluating the relative percent difference (RPD[2]) and percent relative standard deviation (%RSD[3]) for each sample pair. The resulting values were then tabulated and compared to the project data quality objectives to assess overall data quality (Tables A4 and B1). The errors associated with field replicate and laboratory duplicate analyses were within the project acceptance criteria (5% and 10% for %RSD and RPD respectively) for all but a few sample pairs.

The project precision criteria for field and laboratory duplicate analyses were exceeded on five occasions (twice for total persulfate nitrogen, and once each for total iron, total manganese, and chloride) (Table A4). In most cases these exceedences were quite small and occurred in samples where the constituent concentrations were only slightly above the analytical detection limit. These excursions did not significantly affect data analysis and interpretation.

Laboratory Quality Assurance

The MEL follows a strict set of procedures to ensure the quality of the data they generate. Where appropriate, instrument calibration is performed before each analytical run and is checked against initial calibration verification standards and blanks. Calibration standards and blanks are analyzed at a frequency of approximately 10% during each run, and then again at the end of each sample run. The laboratory also uses procedural blanks, spiked samples, and laboratory control sample (LCS) analyses as additional checks of data quality. Throughout this study the

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[1] The term "blind" refers to "identical" samples that were submitted to the laboratory under different sample numbers.
[2] Calculated for a pair of results, x_1 and x_2, as $100*(x_1-x_2)/\text{average}[x_1 \text{ and } x_2]$)
[3] Calculated for a pair of results, x_1 and x_2, as $100*s/(\text{average}[x_1 \text{ and } x_2])$, where s is the standard deviation of the sample pair.

constituent concentrations for blank samples fell below the analytical detection limit for target analytes. Spiked sample and LCS analyses also met the specified acceptance criteria throughout this project. Based on this evaluation, the data generated during this study are of high quality and can be used without qualification except as noted above and in Table A3.