Ambient Groundwater Quality in the Moxee Valley Surficial Aquifer, Yakima County, January-June 2006

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Ambient Groundwater Quality in the Moxee Valley Surficial Aquifer, Yakima County, January-June 2006

By

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and
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Conversion Factors, Datums, and Abbreviations

Multiply	By	To Obtain
inch (in)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
square ft (ft^2)	0.0929	square meter (m^2)
acre	4,047	square meter (m^2)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
cubic foot (ft^3)	28.32	liter (L)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.59	square kilometer (km^2)
gallon (gal/min)	3.785	liter/min (L/min)

Temperature

To convert degrees Celsius (°C) to degrees Fahrenheit (°F), use the following equation:
°F= (°C x 1.8) + 32

To convert degrees Fahrenheit (°F) to degrees Celsius (°C), use the following equation:
°C= (°F-32)/1.8

Concentration

The concentrations of chemical constituents in water are presented in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Datums

Vertical coordinates are referenced to the North American Vertical Datum of 1988 (NAVD88). Altitude values represent the distance above or below the vertical datum in feet.

Horizontal coordinates are referenced to the North American Datum of 1983 (NAD83).

Abbreviations

DO	Dissolved oxygen
DOC	Dissolved organic carbon
MF	Membrane filter method
TDS	Total dissolved solids
TP	Total phosphorus
TPN	Total persulfate nitrogen

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Abstract

During January and June 2006, the Washington State Department of Ecology conducted a screening-level assessment of groundwater quality in the Moxee Valley. The valley lies just east of the city of Yakima in south-central Washington.

For this study, 26 broadly distributed domestic wells were sampled for field parameters, common nutrients, bacteria, and selected metals.

Concentrations of nitrate-N were found to be higher than the 10 mg/L federal drinking water standard in three wells. Five wells exceeded the primary standard for total coliform.

The highest nitrate-N concentrations (up to 18.2 mg/L) occurred in the lower valley near Moxee City where wells generally exhibited elevated concentrations of total persulfate nitrogen, total phosphorus, total dissolved solids, and conductivity, but little measurable iron or manganese.

By contrast, wells in the upper valley contained elevated concentrations of iron and manganese, but little, if any, measurable nitrate-N or total persulfate nitrogen. Wells in the upper valley also exhibited generally lower total phosphorus, chloride, total dissolved solids, and conductivity values than did wells in the lower valley.

Acknowledgements

We thank the many Moxee Valley residents who provided us access to their property and wells. This study would not have been possible without their interest and cooperation. We also thank Bob Raforth, Barb Carey, and Joan LeTourneau for their thoughtful reviews and edits of the draft report. Lastly, we thank the staff at the Manchester Environmental Laboratory who provided courier and analytical laboratory support.

Introduction

In 2006, the Washington State Department of Ecology (Ecology) conducted a screening-level assessment of ambient groundwater quality in the Moxee Valley, which lies adjacent to the city of Yakima, in south-central Washington (Figure 1). Population growth in and around the city of Yakima has accelerated in recent years, and portions of the Moxee Valley are rapidly transitioning from their traditional agricultural uses to residential and commercial development.

The valley's major population centers at Terrace Heights (population 6,447) and Moxee City (population 821) are served by public water and sanitary sewers. However, residents in rural areas of the valley rely on private wells and septic systems for their domestic water supply and wastewater disposal.

A previous sampling of 11 Moxee Valley wells by Ecology, in September 1992, revealed that nearly half of the wells produced water with nitrate+nitrite-N concentrations greater than 4 mg/L (Larson, 1993). One well exceeded the federal drinking water standard, of 10 mg/L, for nitrate-N.

This report documents Ecology's 2006 investigation, which was undertaken to provide an updated assessment of groundwater nutrient and bacteria concentrations and distribution within the valley.

Study Purpose and Scope

The major objectives of this study were to:

1. Provide current information about ambient groundwater quality conditions for the valley's surficial aquifers.
2. Establish a groundwater-monitoring network of private domestic wells that can be revisited, over time, to detect and assess potential groundwater quality changes resulting from ongoing urbanization and changing agricultural practices.
3. Determine if area groundwater nutrient or bacterial concentrations vary seasonally.

The preliminary work for this project began in August 2005, with the compilation and evaluation of existing groundwater data and area well reports.

Field sampling occurred in January and June 2006. Altogether, 26 wells were monitored for field parameters (temperature, pH, dissolved oxygen, conductivity, and groundwater level) and a small suite of laboratory-analyzed constituents (total persulfate nitrogen, nitrate+nitrite-N, total and fecal coliform, total phosphorus, dissolved organic carbon, chloride, total dissolved solids, iron, and manganese).

To the extent possible, wells were selected to provide a broad areal sampling of ambient groundwater level and water quality conditions in the uppermost surficial aquifer commonly used for domestic water supply. Well selection was not intentionally biased toward identifying specific pollution sources. Likewise, we did not attempt to identify the source(s) of observed water quality problems.

Study Area Description

The Moxee Valley is one of several east-west trending structurally-controlled valleys in the Yakima area (Figure 1). The valley bottom rises steadily toward the east, from an altitude of approximately 940 feet at the Yakima River to approximately 1,800 feet at the drainage divide that separates the Moxee Valley from the Black Rock Valley to the east. The valley is bounded on the north by the Yakima Ridge (elevation 3,000-4,100 feet) and on the south by the Rattlesnake Hills (elevation 2,192 feet).

The valley climate is characterized by hot, dry summers and relatively cool, damp winters. July and August are typically the warmest months with average maximum temperatures in the mid 80s °F. December and January are typically the coldest months with average minimum temperatures in the low 20s °F.

The valley's average annual precipitation ranges from less than 10 inches at Yakima (8.12 inches) and Moxee City (7.96 inches) to greater than 10 inches along the crest of Yakima Ridge (Figure 1). Approximately 45% of the annual precipitation at Moxee City falls between November and February, with relatively little precipitation during the summer growing season.

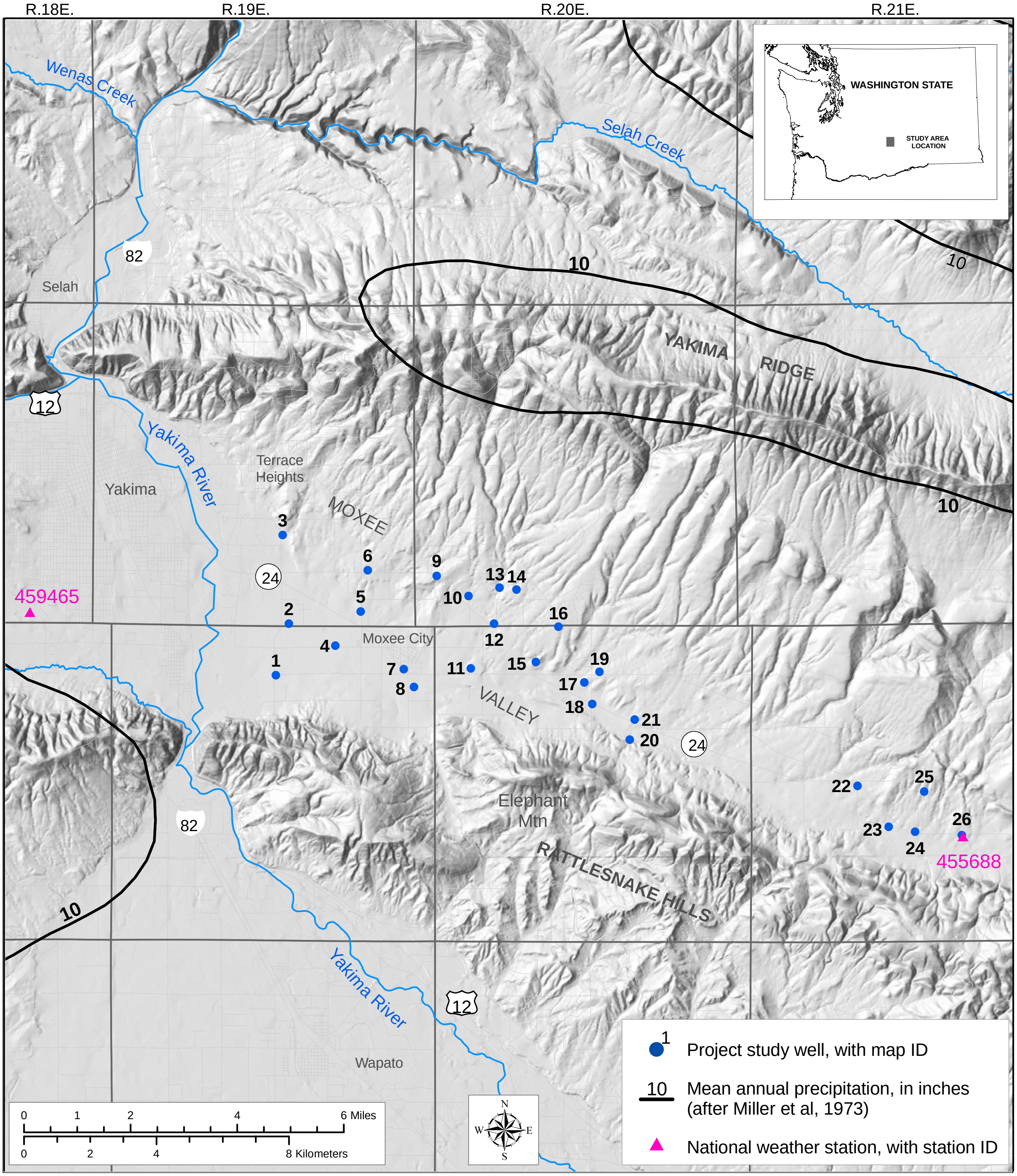

Figure 1 - Map of study wells, national weather stations, and distribution of mean annual precipitation

Despite a recent surge in commercial and residential development, agriculture remains the valley's dominant industry, with hops and fruit being the primary crops. The Moxee area is renowned for its aromatic hops and is one of the principal hop growing districts in the Yakima County which produces more than 75% of the annual U.S. hop crop (WIPMC, 2007). Hops are grown in the bottom lands of the lower and central valley, while fruit crops dominate the upper terraces and surrounding hill slopes.

The valley's agricultural water needs are met largely by surface water diverted from the Yakima River near Selah, although groundwater is also used for irrigation in some areas. River water is conveyed to area fields via a complex system of canals and ditches. Wastewater is returned to the river at approximately River Mile 107.5 by the Moxee Drain (Ebert and others, 2003).

Well Numbering and Location System

The well locations in this report are described using the township, range, section (TRS) 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 (Figure 2). Each 40-acre, quarter-quarter section is represented by a single capital letter. If a quarter-quarter section contains more than one inventoried well, a sequence number is included after the letter designation to assure uniqueness. For example, the first inventoried well in the northeast quarter of the southeast quarter of Section 35, Township 13N, Range 19E is represented as 13N/19E-35J01, the second well as 35J02, and so on (Figure 2).

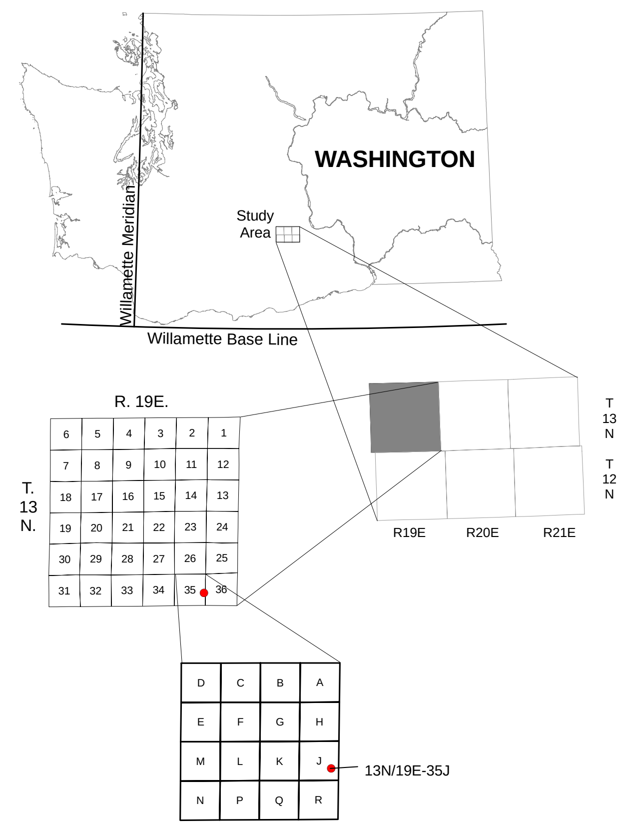

Figure 2 - Well numbering and location system

As an aid to future investigators, all previously non-tagged wells monitored during this study were fitted, where possible, with a Department of Ecology well identification tag. The tag contains a six-digit, alpha-numeric identifier consisting of three letters and three numbers (e.g. AHT027) that uniquely identifies each well. This identification system helps prevent potential conflicts inherent in the TRS numbering system. The two-by-three-inch aluminum identification tag was secured to the well casing, or another permanent fixture of the water system, with stainless steel banding.

Geologic Setting

The Moxee Valley is part of the Yakima Folds, a subdivision of the Columbia Basin Physiographic Province. The valley occupies one of several east-west trending synclinal[1] troughs within the Yakima Folds and is bounded by steep-sided anticlinal[2] ridges to the north (Yakima Ridge) and south (Rattlesnake Hills).

The valley was once part of an extensive basalt plain that formed during Miocene time, when huge volumes of lava erupted from fissures located southeast of the study area. At the same time, andesite-rich sediments were also being deposited along and upon the western portion of the plain by eastward-flowing streams that drained a volcanically-active upland to the west.

These depositional processes continued through numerous flow events over a period of several million years, 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 provided a heavy sediment load to streams and rivers that deposited sediments along and upon the western portion of the basalts.

Beginning in early Pliocene time, these rocks and sediments were folded by north-south compression and formed the broad anticlines and synclines of the Yakima Fold Belt. As folding progressed, 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. Active folding is thought to have ceased by late Pliocene time.

In Pleistocene time, the lower Moxee Valley was repeatedly inundated by backed-up water from catastrophic glacial floods that traversed central and eastern Washington. These floods deposited sediments across portions of the lower valley and are responsible for the fine-grained sands and silts that were later mobilized by the wind and deposited as loess throughout most of the valley bottom.

Hydrogeologic Units

The basalts, flood deposits, and other geologic materials underlying the Moxee Valley were previously grouped into four hydrogeologic units based on their geologic characteristics and water development potential (Jones and others, 2006). From oldest to youngest, the units are Miocene age basalts (Unit 4), consolidated Miocene age continental sediments (Unit 3), unconsolidated Pliocene-to-Pleistocene age continental sediments (Unit 2), and Holocene alluvium (Unit 1). Each of these units contains aquifers that are capable of supplying groundwater to wells (Table 1 and Figure 3).

The upper surface of Unit 4, which constitutes area bedrock, dips downward from east to west. Unit 4 lies within a few hundred feet of ground surface in the eastern valley bottom, and at depths of approximately 1,800 feet below ground surface near the Yakima River (Figure 3) (Jones and others, 2006.). The basalts of Unit 4 are dark-gray to black on fresh surfaces and weather to a gray-reddish-brown color. They are typically fine-grained and often have a jointed or blocky appearance in surface exposures.

In the western study area, Unit 4 is overlain by, and in some cases inter-bedded with, consolidated Miocene age continental sediments of Unit 3 (Figure 3). Unit 3 consists mostly of semi-consolidated clay, andesitic and pumiceous sandstone, and conglomerate composed of weathered andesite pebbles. Unit 3 generally increases in thickness from east to west and is several hundred feet thick in the valley interior west of Moxee City (Figure 3).

[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 in the center (Press and Siever, 1978).

Unit 3 is overlain throughout most of the valley by a thick sequence (up to 200 feet) of unconsolidated to weakly cemented gravel, sand, silt, and clay which collectively constitute Unit 2 (Table 1). Unit 2 sediments occur at land surface throughout most of the Moxee Valley. Exceptions occur locally in the central valley where Unit 2 deposits have been eroded or were never deposited, and in the lower valley near the Yakima River where they are overlain by alluvium (Unit 1) (Figure 3).

The alluvium of Unit 1 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.

Most shallow domestic wells in the valley interior are completed in hydrogeologic Unit 2 or in weakly consolidated sand and gravel lenses of Unit 3. These units are recharged by downward percolation of local precipitation, leakage from unlined irrigation ditches or streams, percolation of unconsumed irrigation water, and by upward discharge from the underlying basalts and inter-bedded sediments of Unit 4.

Table 1 – Lithologic and hydrologic characteristics of hydrogeologic units underlying the Moxee Valley

Period	Epoch	Geologic Unit	Unit symbol	Hydro-geologic unit [1]	Hydrogeologic unit characteristics [2]
Quaternary	Holocene	Alluvium	Qa	Unit 1	Recent alluvium of the Yakima River; unconsolidated deposits of well-rounded cobbles, gravel, sand, and silt ranging from 0-100+ feet thick with a median value of 20 feet.
	Pleistocene	Alluvial fan deposits	Qaf	Unit 2	Unconsolidated to weakly cemented deposits of gravel, loose sand and gravel, silt, and clay. Unit 2 ranges from 0 to 300+ feet thick with a median value of 80 feet. Includes loess, alluvial fan and landslide deposits, theThorp gravels, terraced deposits, and Missoula flood deposits. Present beneath Unit 1 in the lower valley and at ground surface throughout most of the valley bottom. Unit 2 can be a productive aquifer and is used extensively for domestic supply in the western valley.
		Landslides	Qls		
		Terraced deposits	Qt		
		Loess	Ql		
		Flood deposits, Touchet	Qfs(t)		
Tertiary	Pliocene	Continental sedimentary deposits, Thorp gravel	PLcg(t)		
	Miocene	Continental sedimentary deposits, Ellensburg Formation	Mc(e)	Unit 3	Consolidated sandstones, siltstones, shales, and conglomerates of the Ellensburg Formation and possible additional undefined continental sedimentary deposits. Unit 3 ranges from 0 to 1800+feet thick with a median value of 450 feet, and is a productive aquifer.
		Saddle Mountains basalt	Mv(s)	Unit 4	Basalts and interbedded sediments of the Saddle Mountains and Wanapum sub-groups. This unit outcrops along the hill slopes of Yakima Ridge and the Rattlesnake Hills and underlies Units 1-3 in the valley interior. Unit 4 is tapped by numerous deep irrigation wells.
		Wanapum basalt	Mv(w)		

1 - After Jones and others, 2006
2 - Unit thickness ranges from Jones and others, 2006

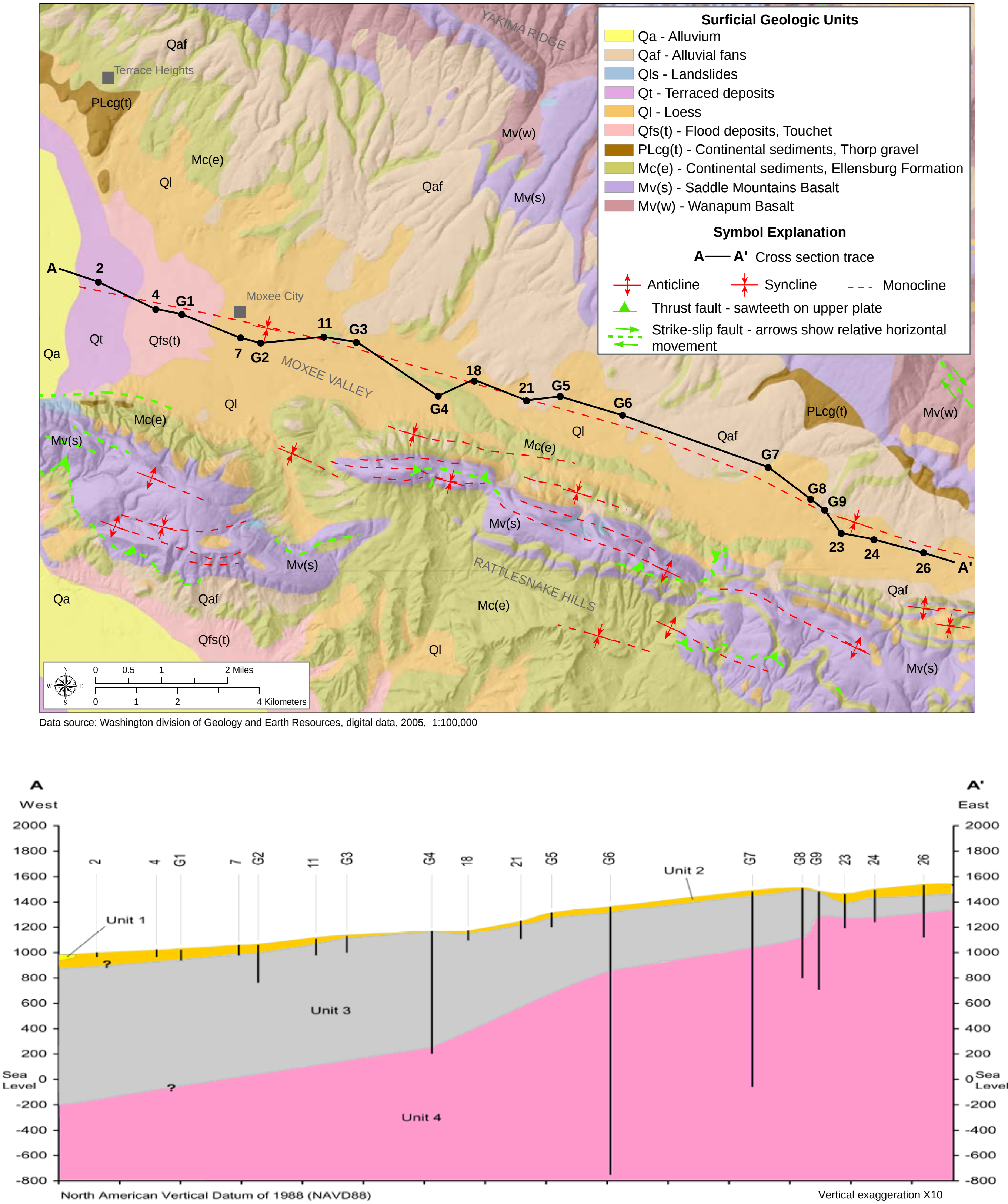

Figure 3 - Generalized surficial geology and hydrogeologic cross-section through the Moxee Valley

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Study Methods

Sampling for this project followed the field procedures specified in the project quality assurance plan (Sinclair, 2005). Twenty-six wells were sampled twice during the project (January and June 2006) for field parameters and selected laboratory constituents (Table 2).

Table 2 - Summary of field and laboratory methods and associated reporting limits

Parameter	Test Method	Reporting limit
Field Measurements		
Water level	Calibrated E-tape	0.1 foot
Temperature	Sentix® 41-3 probe[2]	0.1°C
Conductivity	Tetracon® 325 probe[2]	1 µS/cm
pH	Sentix® 41-3 probe[2]	0.1 SU
Dissolved Oxygen	Cellox® 325 probe[2]	0.1 mg/L
Laboratory Parameters		
Total persulfate nitrogen[1]	SM4500NB	0.025 mg/L
Nitrate+nitrite-N[1]	SM4500NO3I	0.01 mg/l
Total phosphorus[1]	EPA200.8M	0.001 mg/L
Dissolved organic carbon[1]	EPA415.1	1 mg/L
Total dissolved solids[1]	SM2540C	10 mg/L
Coliform, total (MF)	SM9222B	1 CFU/100mL
Coliform, fecal (MF)	SM9222D	1 CFU/100mL
Chloride[1]	EPA300.0	0.1 mg/L
Iron[1]	EPA200.7	50 ug/L
Manganese[1]	EPA200.7	10 ug/L

[1] Dissolved fraction

[2] Probe used with a WTW multiline P4 meter

MF: Membrane filter method

SU: Standard units

Study well locations were initially determined using a global positioning system (GPS) receiver and were updated where necessary using geo-rectified digital ortho-photos. The land surface altitude at each well was estimated using a geographic information system (GIS) based pixel matching process and digital Lidar data or a 10-meter digital elevation model (DEM). Lidar-derived elevations are considered accurate to ± 1 foot, while DEM-based elevations are considered accurate to ± 5 meters or approximately 16 feet.

Groundwater Levels

Groundwater levels were measured during each site visit using a calibrated electric well probe (Stallman, 1983). Duplicate measurements were made at each well to ensure measurement precision and to confirm that the water level was not recovering from recent pumping, or actively being drawn down by nearby pumping wells.

To prevent potential cross-contamination between wells, all water-level equipment was thoroughly cleaned prior to each use. The cleaning procedure consisted of a manual wipe down of the equipment with clean paper towels, followed by sequential rinses of 10% bleach solution and de-ionized water. Field personnel wore clean powder-free nitrile gloves while handling all equipment.

Water Quality Measurements and Sampling

All wells were purged prior to sampling using a closed-atmosphere flow cell and the water system pump. Samples were collected only from taps or hose bibs where "raw" (untreated) well water could be obtained. Purging continued until the difference in field parameter values for two successive 3-minute measurement periods differed by less than 5%. A Chemetrics™ photometric test kit was used prior to sampling to verify all field-meter-based dissolved oxygen concentrations less than 2 mg/L.

Water samples were collected via a clean, inline Y-fitting attached to the sample tap ahead of the flow cell. Samples were collected in clean containers supplied by the Manchester Environmental Laboratory. Samples for dissolved organic carbon (DOC) were field filtered using a Whatman puradisc™ 25 pp, 0.45 µm polypropylene-membrane-syringe filter. The remaining dissolved constituents (Table 2) were field-filtered using a new in-line 0.45 µm capsule filter.

Prior to filling the first sample container, a minimum of 200 ml of water was pumped through the filter and discarded. Samples for nitrate+nitrite-N, total persulfate nitrogen, total phosphorus, and DOC were collected in pre-acidified bottles containing sulfuric acid. Samples for iron and manganese were collected in a common pre-acidified bottle containing nitric acid. Filled bottles were tagged and stored in ice-filled coolers pending their arrival at the laboratory.

Study Findings

Groundwater Fluctuation and Movement

Groundwater level measurements from 46 area wells were used to develop generalized potentiometric contours for the Moxee Valley surficial aquifer system (Figure 4). Most of the wells used in this analysis are completed in hydrogeologic Units 2 or 3, and range from 17 to 365 feet deep. The average well depth was 139 feet. We measured groundwater levels in 22 of the wells in June 2006. The remaining wells were measured by USGS personnel in March or September 2001, as part of an ongoing investigation of the groundwater resources of the Yakima River basin. Figure 4 provides a generalized depiction of late-spring to early-summer groundwater conditions for the valley's principal surficial domestic supply aquifer system. It does not depict conditions for a specific hydrogeologic unit or point in time.

This evaluation indicates that area groundwater flows from upland recharge zones along the flanks of the Yakima Ridge and Rattlesnake Hills toward the valley interior and west toward natural points of discharge along the Yakima River. Deviations from this general pattern are apparent along portions of the Roza Canal and Moxee Drain where surface water/groundwater interactions influence groundwater levels in nearby wells.

Water levels in most of the study wells varied by 2 feet or less between January and June, 2006 (Appendix B, Table B-2). Wells in the lower valley, between Moxee City and the Yakima River, generally had higher water levels in June than in January. Wells in the upper valley, east of Moxee City, generally exhibited higher water levels in January. A few wells in the upper valley, particularly those near the eastern apex of the Roza Canal, exhibited higher water levels in June than in January.

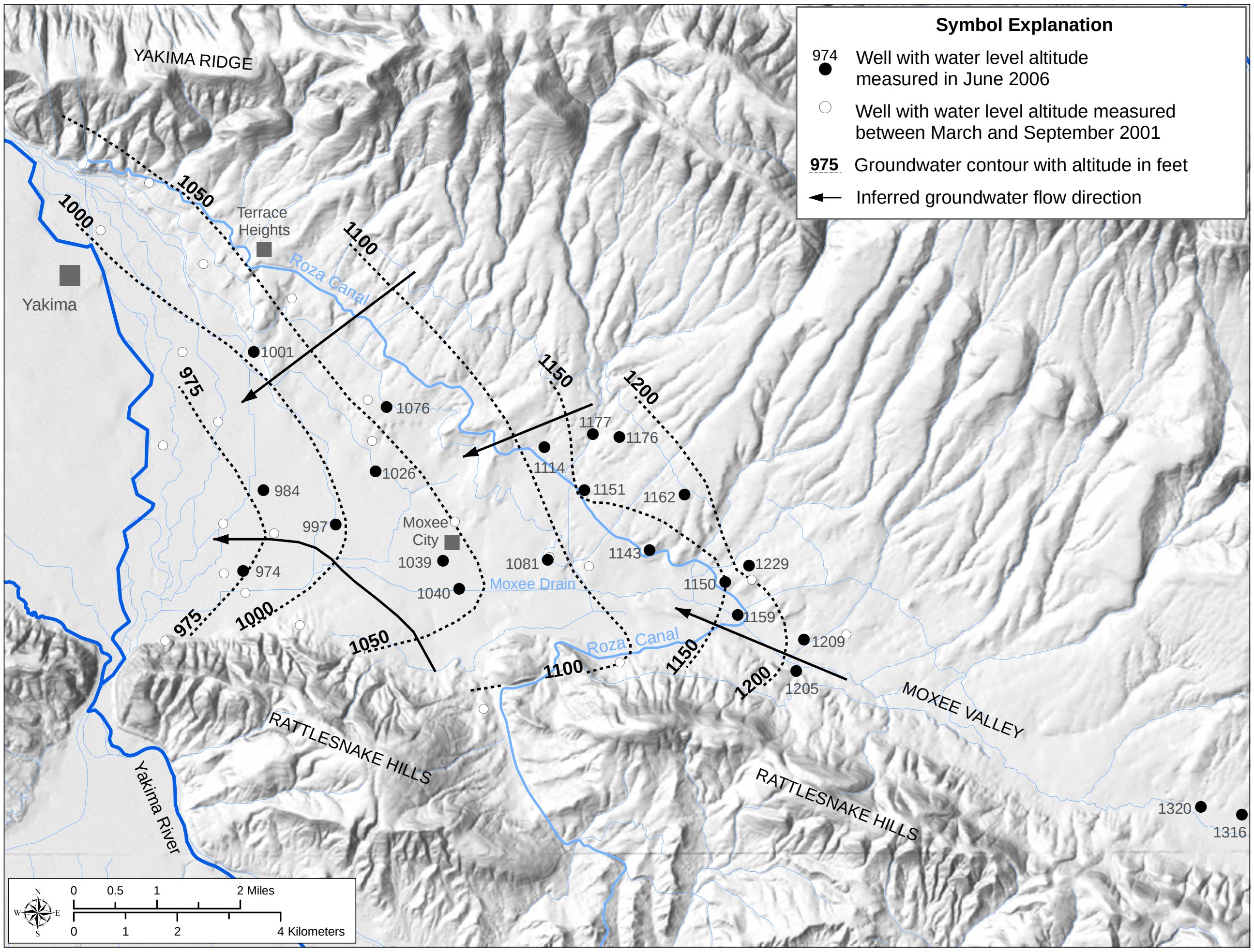

Figure 4 - Generalized potentiometric contours and inferred groundwater flow directions for the surficial domestic-supply aquifer of the Moxee Valley.

Groundwater Chemistry

Table 3 is a statistical summary of the water quality data collected during this project. The results for individual wells and parameters are summarized in Appendix B - Table B2, and in Figures 5A-5L.

Table 3 - Summary of field measurements and laboratory analytical results for groundwater samples collected in January and June, 2006

Parameter	Number of samples	Minimum	Maximum	25th Percentile	Median	75th Percentile
Field Measurements						
Temperature (°C)	47	10.7	17.7	13.5	14	15.1
pH (standard units)	47	7.09	8.16	7.53	7.81	7.97
Conductivity (µS/cm@25°C)	47	272	1028	319	452	602
Dissolved oxygen (mg/L)	46	0	7.4	0.08	0.15	1.85
Laboratory Parameters						
Coliform, fecal (#/100 ml)	47	1U	1UJ	1U	1U	1U
Coliform, total (#/100 ml)	47	1U	30	1U	1U	1U
Nitrate+nitrite-N (mg/L)[1]	47	0.01U	18.2	0.01U	0.01U	3.09
TP (mg/L)[1]	47	0.01	0.482	0.015	0.026	0.063
DOC (mg/L)[1]	47	1U	4.4	1U	1U	1.7
TPN (mg/L)[1]	47	0.025	18.6	0.025	0.08	3.63
TDS (mg/L)[1]	47	194	671	236	303	401
Chloride (mg/L)[1]	47	4.3	73.8	7.7	11.7	18.4
Iron (µg/L)[1]	47	50U	1600	50U	92	185
Manganese (µg/L)[1]	47	10U	548	10U	84	147

[1] Dissolved fraction
mg/L - miligram per liter
µg/L - microgram to liter
µs -microsiemens per centimeter
#/100ml - number of colonies per hundred millileter
U - not detected at or above the indicated value
UJ - not detected at or above the estimated value

The surficial aquifer system of the Moxee Valley contains two distinct water quality zones. The zones are defined by the relative concentrations and spatial distribution of oxygen-sensitive parameters such as nitrate, iron, and manganese. Groundwater in the lower valley (west of and including Moxee City) typically lies within 5 to 20 feet of ground surface and has dissolved oxygen concentrations greater than 1 mg/L in most areas. Groundwater samples from wells in this area contained little, if any, measurable iron or manganese. These wells also exhibited elevated concentrations of nitrate+nitrite-N, total persulfate nitrogen (TPN), total phosphorus (TP), chloride, dissolved organic carbon (DOC), total dissolved solids (TDS), and conductivity (Figures 5D-5L).

The upper valley (east of Moxee City) is characterized by greater depths to groundwater, typically finer grained aquifer materials, and lower dissolved oxygen concentrations. Most wells there contained elevated concentrations of iron and manganese and little, if any, measurable nitrate+nitrite-N or TPN. Wells in the upper valley also tended to have lower TP, chloride, DOC, TDS, and conductivity values than wells in the lower valley.

The distribution and concentration of TPN closely followed that for nitrate+nitrite-N throughout the study area. The good correspondence between TPN and nitrate+nitrite-N indicates that area groundwater contains little ammonia or organic nitrogen.

Fecal coliform bacteria were not detected in water from any of the sampled wells. Total coliform bacteria were identified in water samples from 5 wells at concentrations ranging from 1 to 30 CFU/100 ml (Figure 5H).

Groundwater temperatures generally followed seasonal air temperatures and were warmest in June (median 14.3 °C) and coolest in January (median 13.6 °C) (Figure 5A).

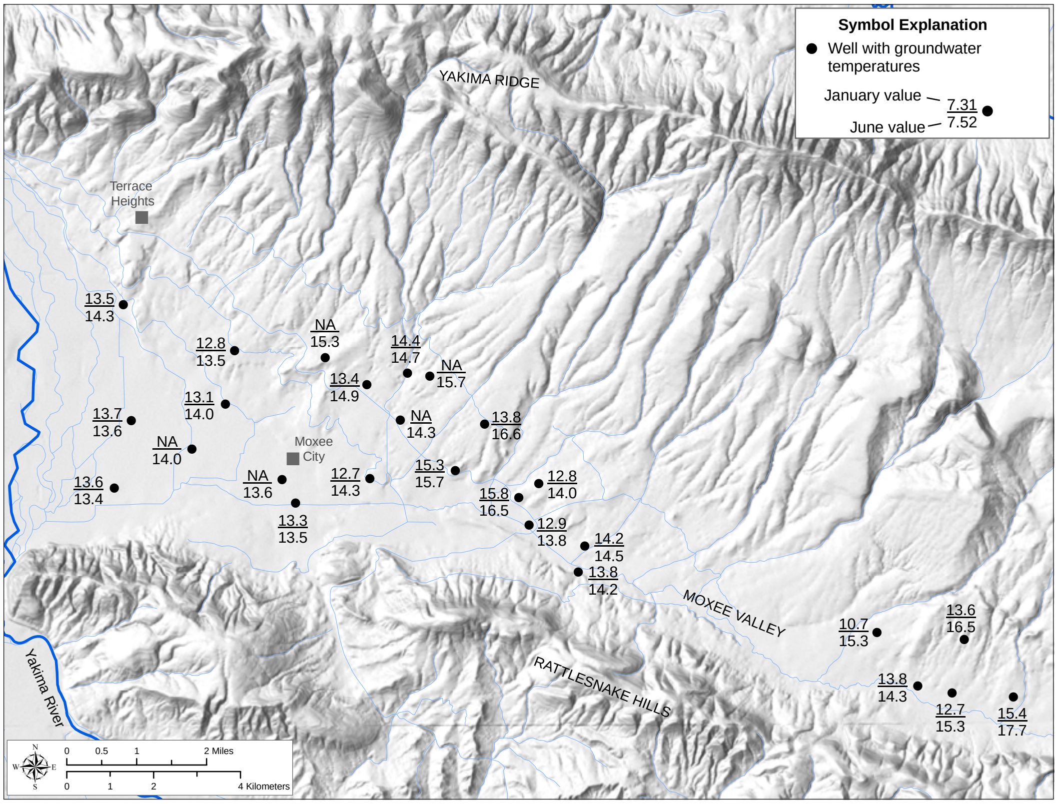

Figure 5A - Groundwater temperatures in sampled wells

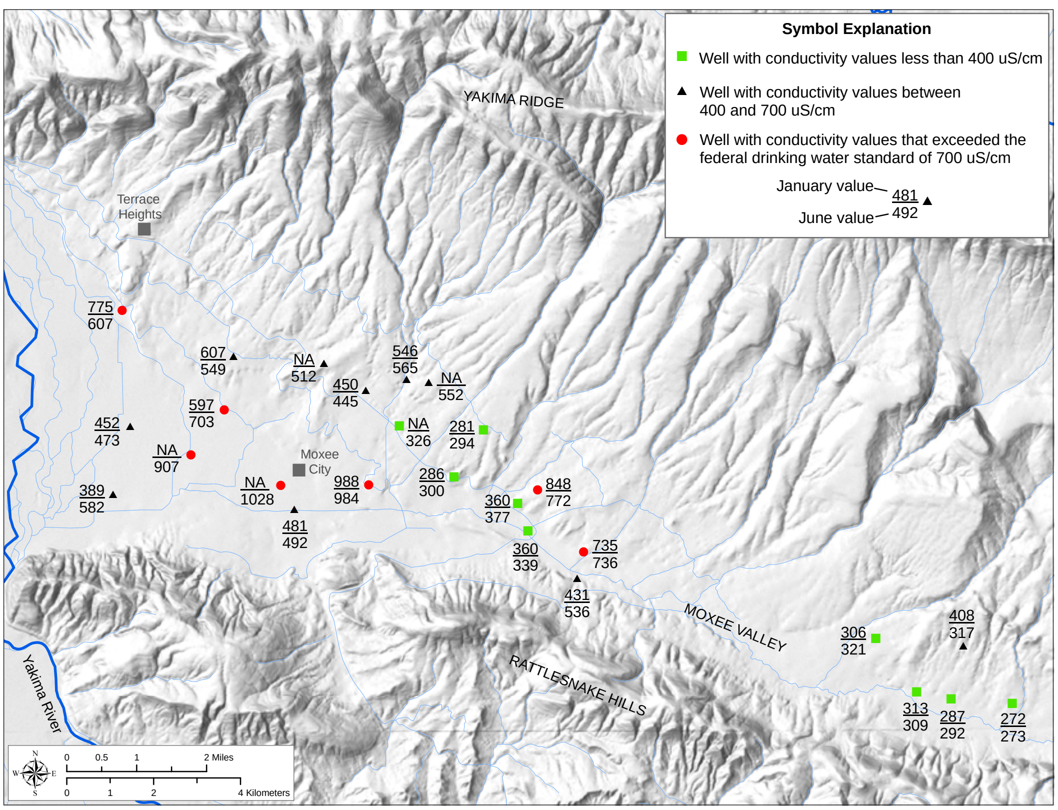

Figure 5B - Groundwater conductivity values in sampled wells

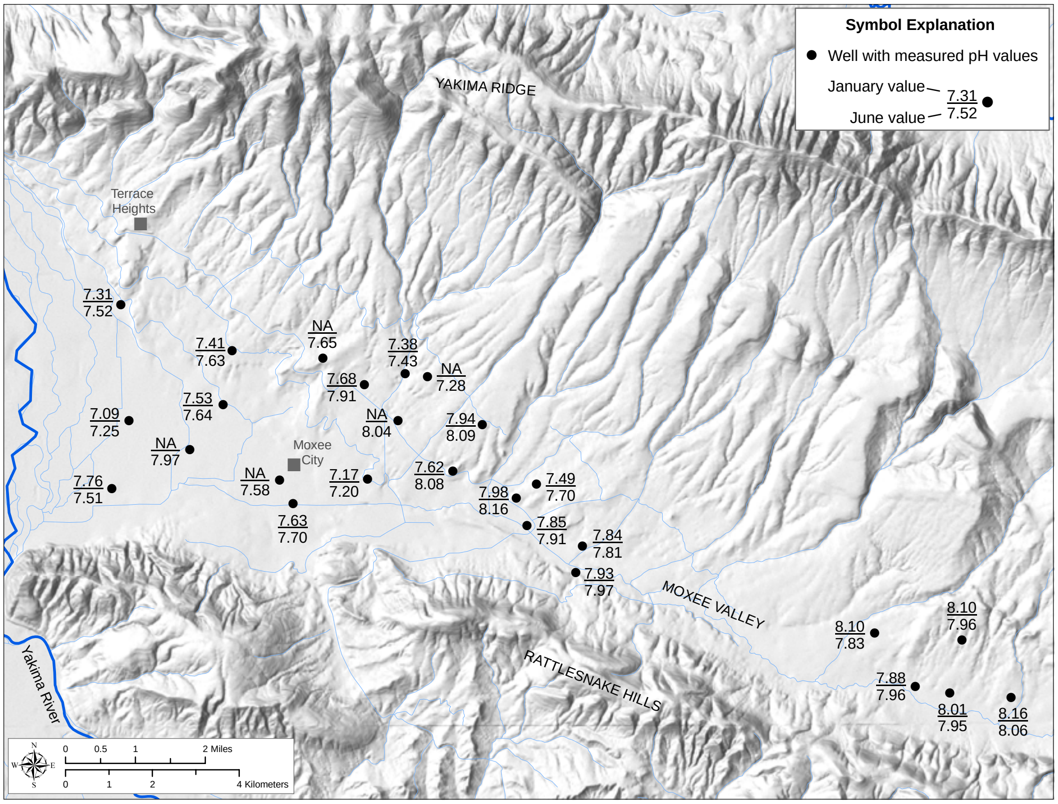

Figure 5C - Groundwater pH values in sampled wells

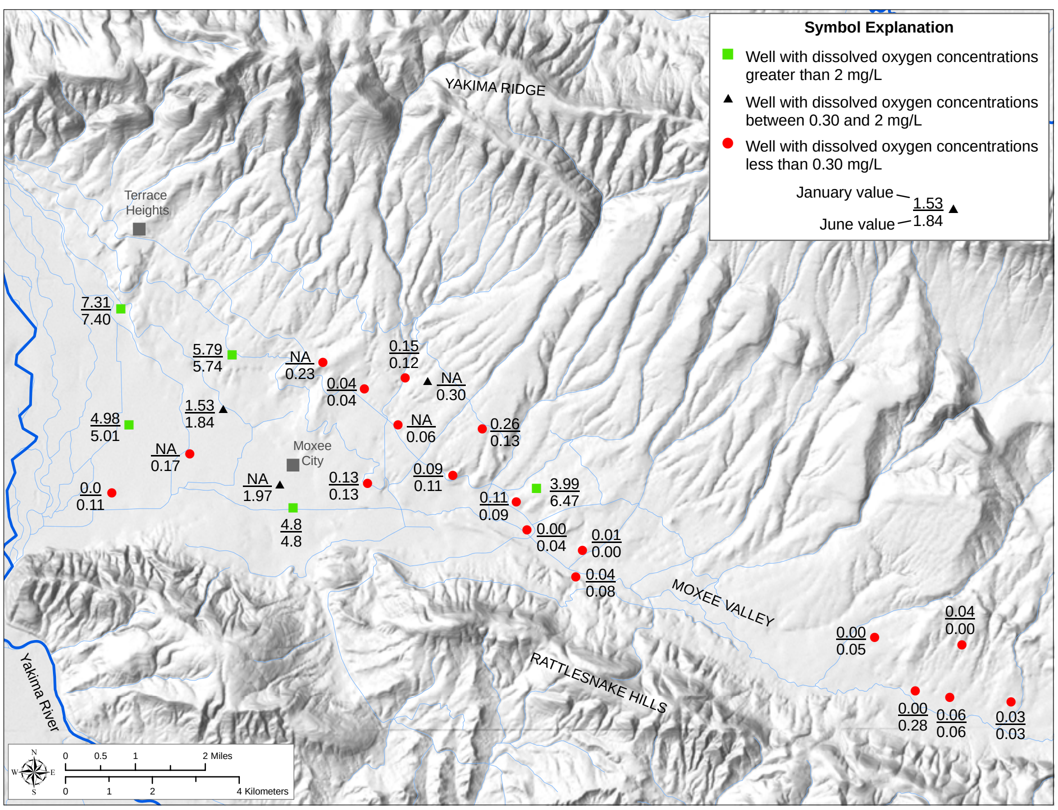

Figure 5D - Dissolved oxygen concentrations in groundwater from sampled wells

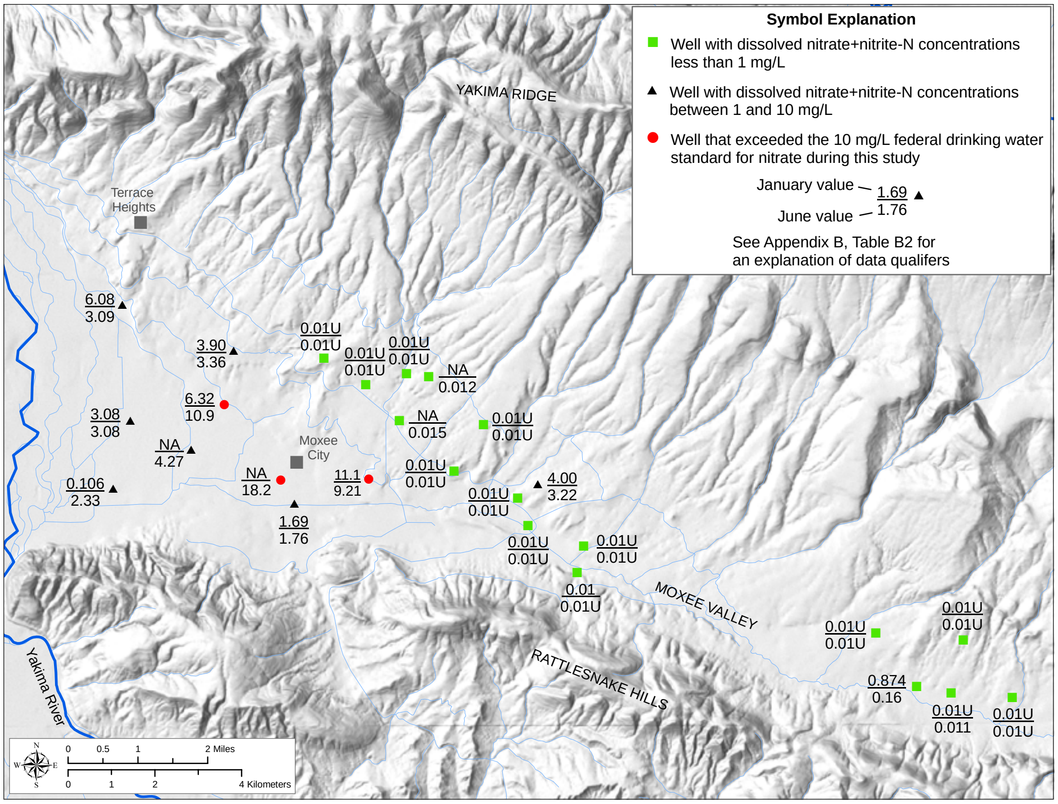

Figure 5E - Dissolved nitrate+nitrite-N concentrations in groundwater from sampled wells

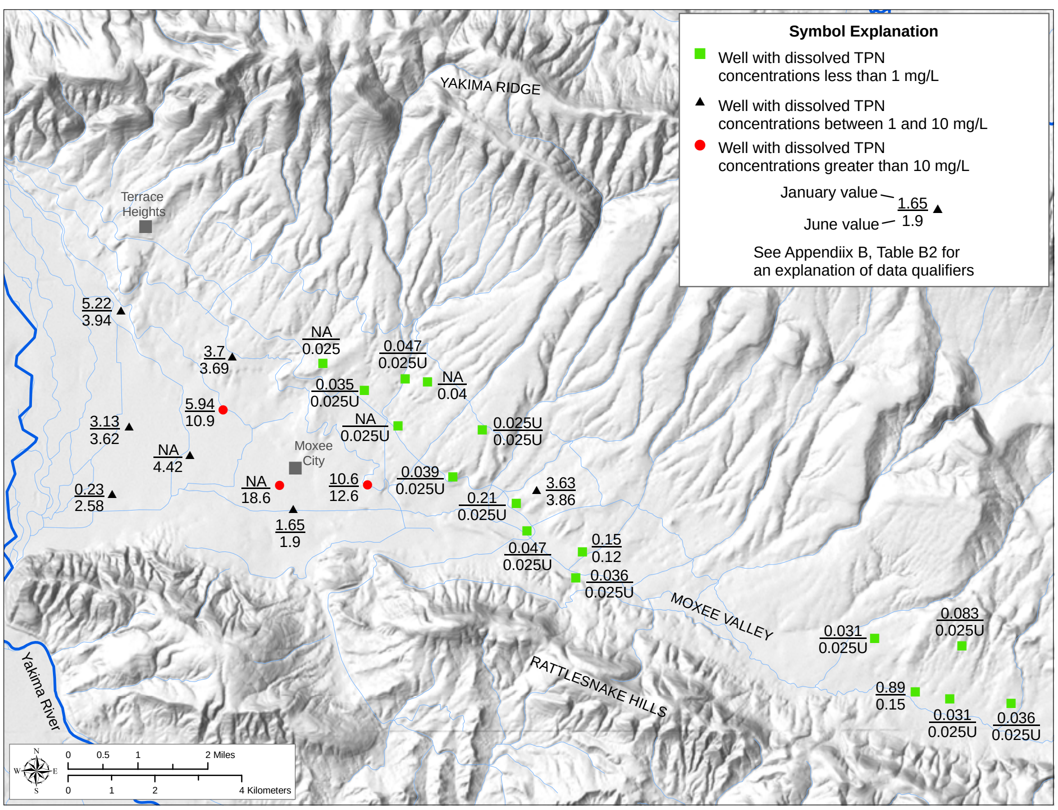

Figure 5F - Dissolved TPN concentrations in groundwater from sampled wells

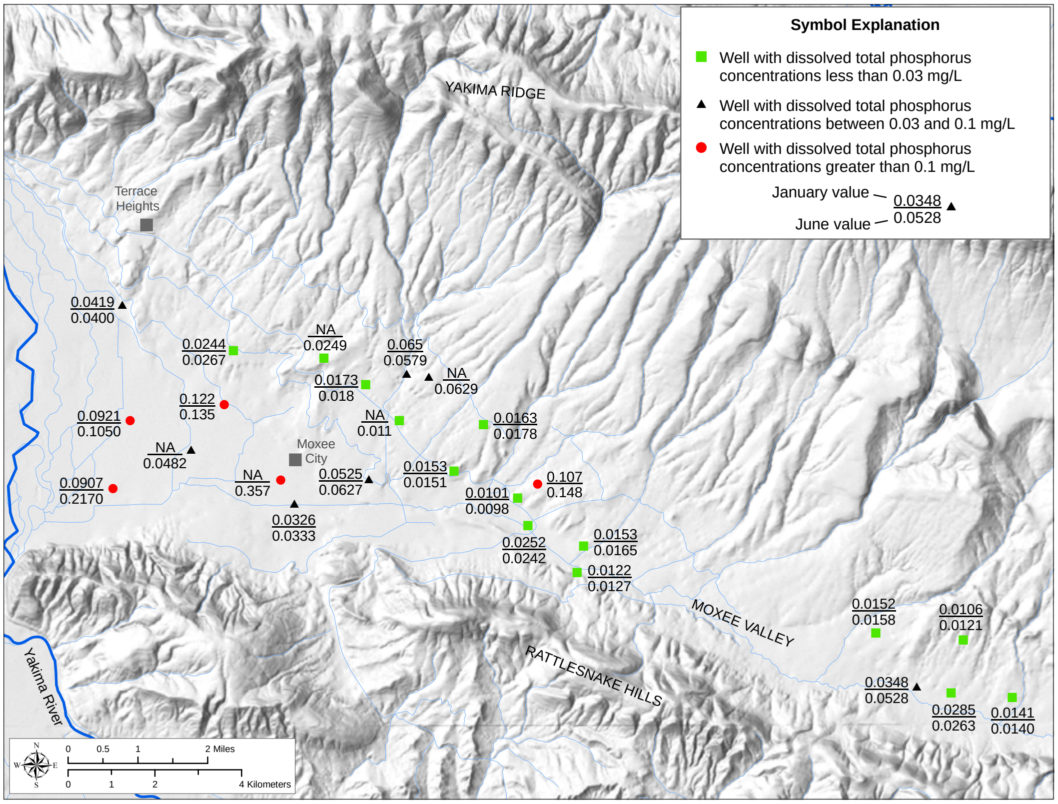

Figure 5G - Dissolved total phosphorus concentrations in groundwater from sampled wells

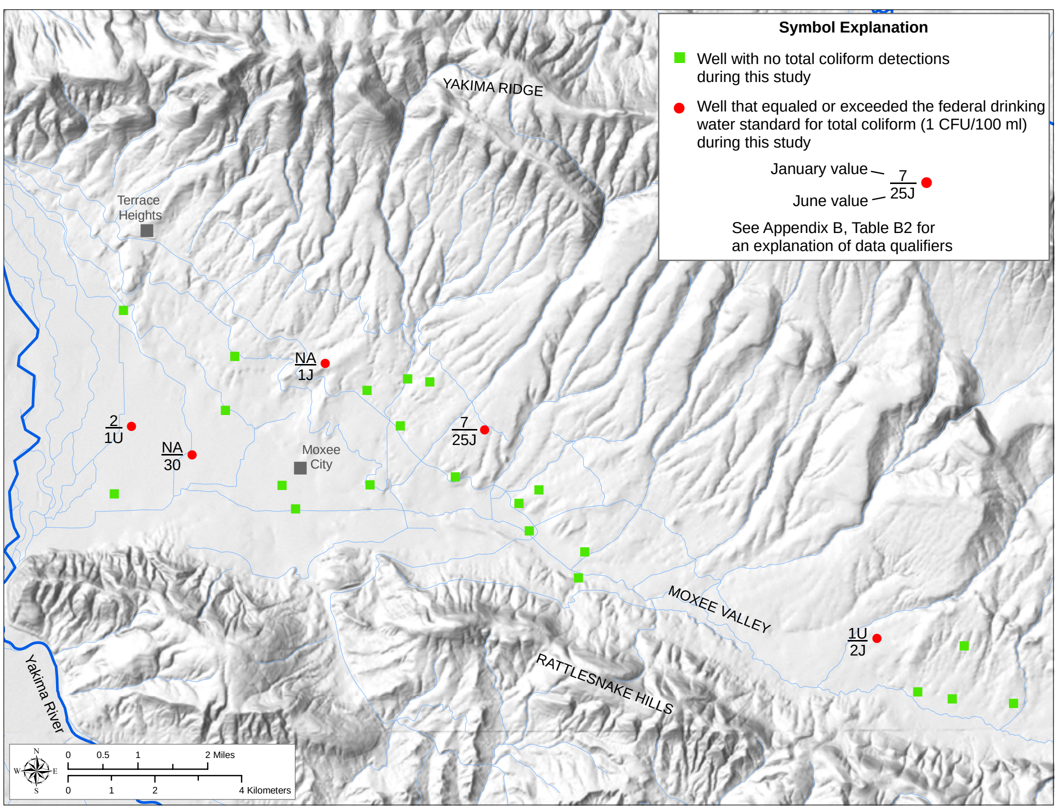

Figure 5H - Total coliform concentrations in groundwater from sampled wells

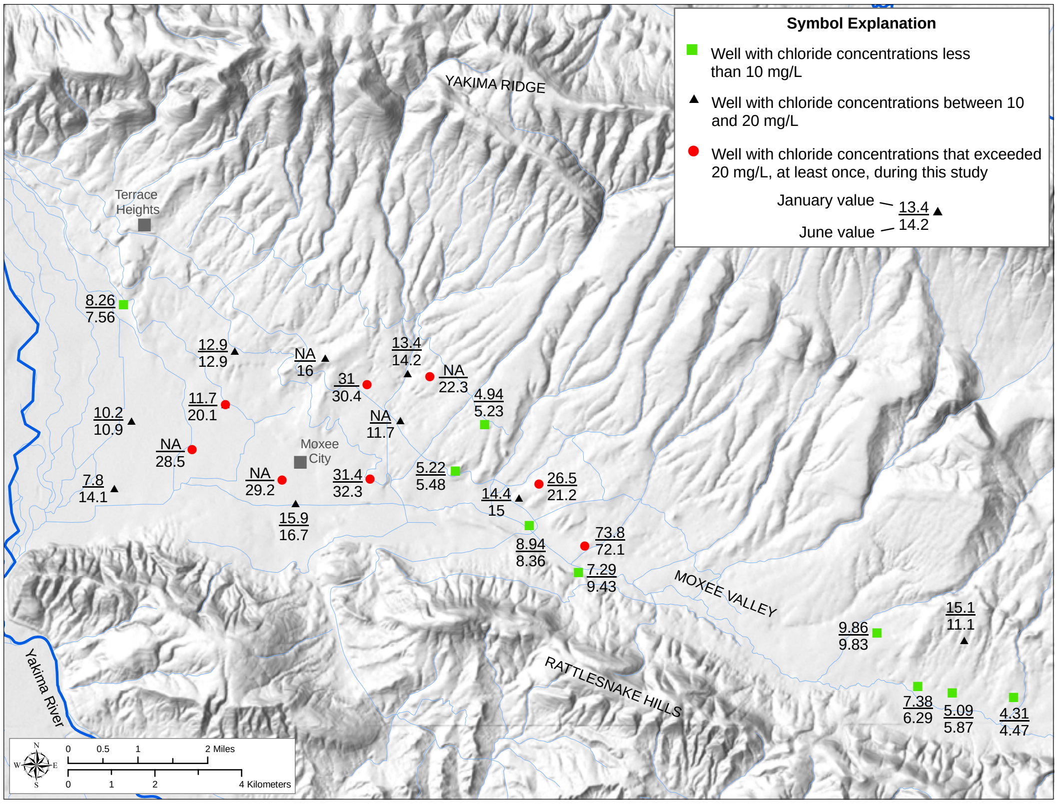

Figure 5I - Chloride concentrations in groundwater from sampled wells

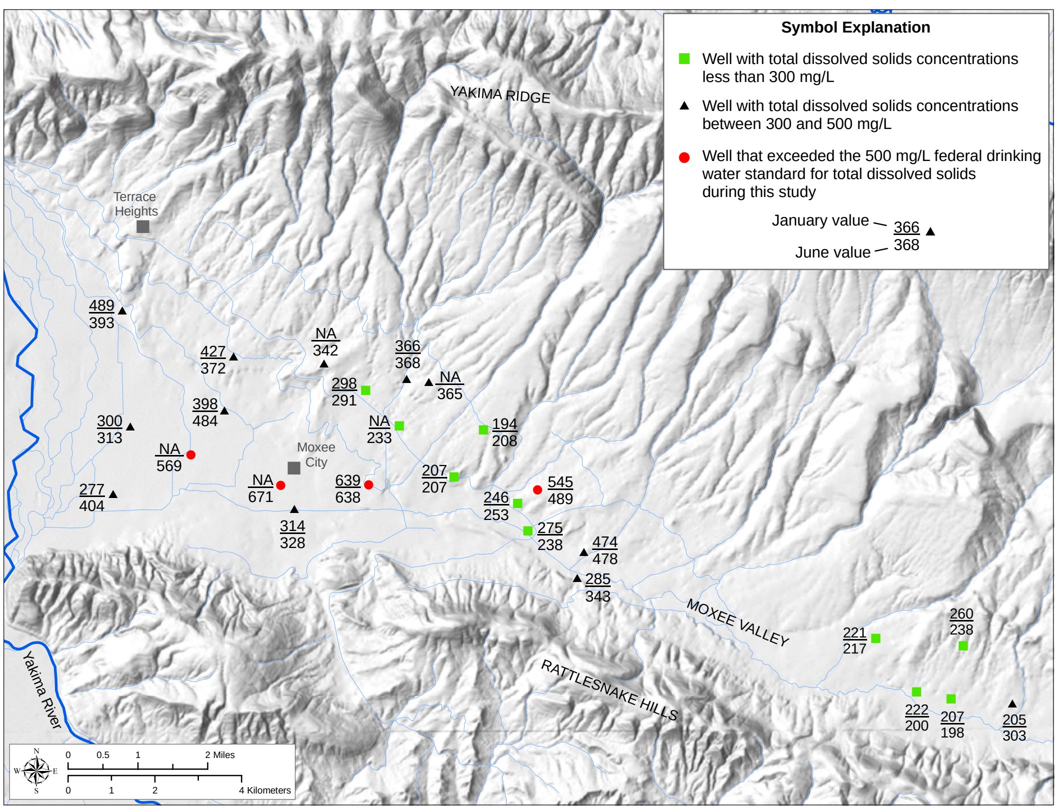

Figure 5J - Total dissolved solids concentrations in groundwater from sampled wells

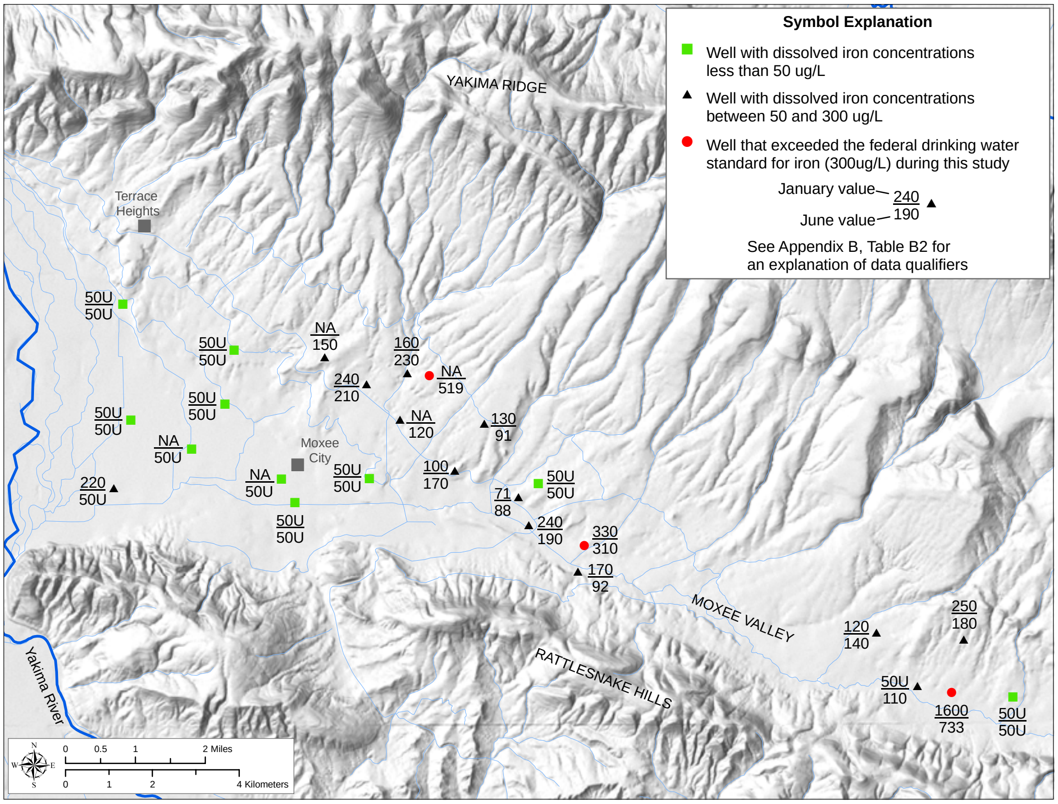

Figure 5K - Dissolved iron concentrations in groundwater from sampled wells

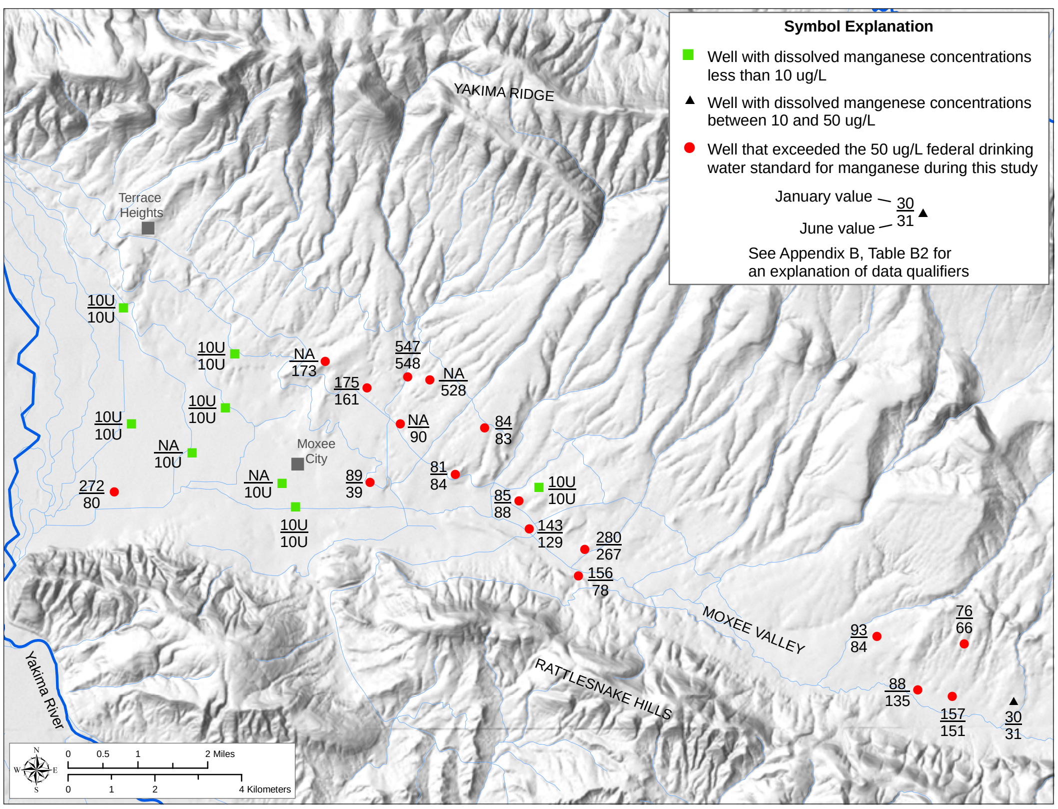

Figure 5L - Dissolved manganese concentrations in groundwater from sampled wells

Comparison to Water Quality Criteria

Most of the wells evaluated during this study met the primary (human-health based) public drinking water standards for total coliform and nitrate-N. Numerous wells, however, violated the secondary (aesthetic based) criteria for iron, manganese, TDS, and conductivity (Table 4).

Table 4- Maximum contaminant level and groundwater quality criteria

Parameter	Primary MCL[1]	Secondary MCL[1]	Groundwater Quality Criteria[2]
Field Measurements			
pH	None	None	6.5 - 8.5
Conductivity	None	700 umhos/cm	None
Temperature	None	None	None
Dissolved Oxygen	None	None	None
Laboratory Analyses			
TPN	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
TP	None	None	None
DOC	None	None	None
TDS	None	500 mg/L	500 mg/L
Iron (total)	None	300 µg/L	300 µg/L
Manganese (total)	None	50 µg/L	50 µg/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

Primary Maximum Contaminant Levels (MCLs)

Total coliform bacteria were detected in water from 5 wells at concentrations ranging from 1 to 30 CFU/100 ml (Table 3 and Figure 5H). Coliform bacteria represent a broad class of micro-organisms that naturally occur in untreated surface water, soil, or decaying vegetation. They are also found in the intestines of warm- and cold-blooded animals where they aid 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.

Those wells with total coliform violations were broadly distributed across the study area and in some cases had poorly secured or missing well caps. None of the sampled wells contained detectable levels of fecal coliform bacteria.

The 3 wells that exceeded the primary drinking water standard for nitrate-N are located in or near Moxee City. Concentrations of nitrate+nitrite-N [3] in these wells ranged from 10.9 to 18.2 mg/L. Six additional wells in the lower valley exhibited nitrate+nitrite-N concentrations between 1.7 and 6.1 mg/L.

High nitrate-N concentrations in groundwater may indicate contamination by animal waste, 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, since it can inhibit the oxygen-carrying capacity of blood and cause methemoglobinemia (blue-baby syndrome) in infants.

Secondary MCLs

Seventeen wells, or approximately 65% of those evaluated, exceeded the secondary drinking-water standard for manganese. Numerous wells also exceeded secondary standards for conductivity (7 wells), total dissolved solids (4 wells), and iron (3 wells).

Manganese is a vital micro-nutrient and is required to maintain plant and animal health. Manganese is regulated as a secondary contaminant in drinking water at concentrations greater than 50 ug/L (0.05 mg/L) due to its objectionable taste and tendency to stain laundry and plumbing fixtures.

[3] For this evaluation, nitrate-N and nitrate+nitrite-N are considered equivalent analyses, since nitrite-N concentrations in groundwater are typically small in comparison to nitrate-N (Matthess, 1982).

Iron is also a vital micro-nutrient in plant and animal life cycles and serves as an oxygen transporter in blood. Iron is considered a secondary contaminant in drinking water at concentrations greater than 300 ug/L (0.30 mg/L) since it can encrust plumbing fixtures or stain laundry. Most wells that exceeded the water quality standards for manganese or iron are located in the upper valley east of Moxee City, where groundwater dissolved oxygen concentrations are typically less than 0.30 mg/L (Figures 5K and 5L).

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. Total dissolved solids (TDS) is a related parameter that represents the total concentration of dissolved material in water. Conductivity and TDS are regulated as secondary contaminants in drinking water. TDS concentrations greater than 500 mg/L can corrode plumbing fixtures and pipes, may taste bad, and can have laxative effects on some people. Most of the wells with elevated conductivity or TDS values were located in the lower valley within and west of Moxee City.

Comparison With Previous Studies

Six of the wells sampled during this investigation were also sampled by Ecology in 1992, during a pesticide screening survey of the lower Moxee Valley (Larson, 1993). Four of these wells had higher nitrate+nitrite-N concentrations in 2006 than in 1992. In addition the minimum, maximum, and average concentrations for 2006 were all greater than their corresponding 1992 values (Table 5).

Table 5 - Comparison of nitrate+nitrite-N concentrations (mg/L) for six wells sampled in September 1992 and June 2006.

Map -ID	Well tag ID	Sept-1992[1]	Jun-2006[2]	RPD[3]
1	AHT027	1.28	2.33	58.17
2	AHT028	4.28	3.08	-32.61
3	AHT024	5.46	3.09	-55.44
4	AHT031	4.11	4.27	3.82
5	AHT025	5.04	10.9	73.53
7	AHT099	11.90	18.2	41.86
		Summary Statistics		
	Average	5.35	6.98	26.51
	Maximum	11.90	18.20	41.86
	Minimum	1.28	2.33	58.17

1 - Total

2 - Dissolved fraction

3 - Relative percent difference - calculated as:

100*(2006 value -1992 value)/Average of 2006 and 1992 values

These results are consistent with recent findings by Ebert and others (2003) who reported dissolved nitrate+nitrite-N concentrations ranging from approximately 4 to 8.5 mg/L in baseflow[4] water samples collected from the Moxee drain at Birchfield Road between 1991 and 2000. The drain data showed a statistically significant increase in dissolved nitrate+nitrite-N concentrations of approximately 0.038 to 0.048 mg/L per year, or about one third of the 0.12 mg/L per year average increase calculated from paired well samples collected in 1992 and 2006 (Table 5).

Viewed together, these findings suggest that groundwater nitrate concentrations may be increasing in the Moxee Valley, at least locally, over time.

[4] During baseflow (non-irrigation) periods water from subsurface field drains and shallow groundwater constitutes a greater portion of the total drain discharge.

Data Seasonality

Table 6 is a statistical summary of the water quality data collected during this study arranged by parameter and sample date. These data suggest that seasonal (winter vs. summer) differences in overall groundwater quality were relatively minor (Table 6).

Table 6 - Water quality summary for wells sampled in both January and June 2006

Parameter	Sample Month	Concentration[1] Maximum	Minimum	Average	Median	Total samples	Number of Non-detects[2]
Temperature (°C)	Jan	15.8	10.7	13.6	13.6	21	0
	Jun	17.7	13.4	14.8	14.3	21	0
pH (standard units)	Jan	8.16	7.09	7.71	7.76	21	0
	Jun	8.16	7.2	7.77	7.83	21	0
Conductivity	Jan	988	272	484	431	21	0
(µS/cm @ 25°C)	Jun	984	273	489	473	21	0
DO (mg/L)	Jan	7.31	0	1.47	0.10	20	0
	Jun	7.4	0	1.60	0.10	20	0
Fecal coliform	Jan	1 U	1 U	1 U	1 U	21	21
(#/100 ml)	Jun	1 U	1 U	1 U	1 U	21	21
Total coliform	Jan	7	1 U	1.3	1 U	21	19
(#/100 ml)	Jun	25	1 U	2.2	1 U	21	19
Nitrate+nitrite-N (mg/L)	Jan	11.1	0.01 U	1.77	0.01 U	21	11
(dissolved)	Jun	10.9	0.01 U	1.77	0.01 U	21	11
TP (mg/L)	Jan	0.122	0.0101	0.0401	0.0252	21	0
(dissolved)	Jun	0.217	0.0098	0.0505	0.0263	21	0
DOC (mg/L)	Jan	4.4	1 U	1.60	1 U	21	12
	Jun	4.1	1 U	1.41	1 U	21	15
TPN (mg/L)	Jan	10.6	0.025 U	1.703	0.150	21	1
(dissolved)	Jun	12.6	0.025 U	2.078	0.025 U	21	11
TDS (mg/L)	Jan	639	194	326	285	21	0
	Jun	638	198	332	313	21	0
Chloride (mg/L)	Jan	73.8	4.31	15.49	10.2	21	0
	Jun	72.1	4.47	15.88	11.1	21	0
Iron (µg/L)	Jan	1600	50 U	194.3	100	21	9
(dissolved)	Jun	733	50 U	142.6	91	21	9
Manganese (µg/L)	Jan	547	10 U	115.0	85	21	6
(dissolved)	Jun	548	10 U	99.2	80	21	6

1 - mg/L unless otherwise noted

2 - non-detect values were used to calculate the above statistics by assuming the sample concentration equaled the method detection limit

Summary and Conclusions

In 2006 Ecology conducted a screening-level assessment of ambient groundwater quality in the Moxee Valley, which lies adjacent to the city of Yakima. Twenty-six broadly distributed domestic wells were sampled in January and June 2006 for field parameters and targeted drinking water parameters including nutrients, bacteria, and selected metals. Most sampled wells met the primary public drinking water standards for total coliform and nitrate-N. Numerous wells in the upper valley violated secondary standards for iron, manganese, total dissolved solids (TDS), and conductivity.

Three wells exceeded the 10 mg/L federal drinking water standard for nitrate-N, and five wells exceeded the primary standard for total coliform. The highest nitrate+nitrite-N concentrations (up to 18.2 mg/L) occurred in the lower valley near Moxee City.

Groundwater in the lower valley typically lies within 5 to 20 feet of ground surface and has dissolved oxygen concentrations greater than 1 mg/L. Wells in this area generally exhibited elevated concentrations of nitrate+nitrite-N, total persulfate nitrogen (TPN), total phosphorus (TP), chloride, dissolved organic carbon (DOC), TDS, and conductivity. These wells indicated little, if any, measurable iron or manganese.

Wells in the upper valley usually had greater depths to groundwater and lower dissolved oxygen concentrations. Most wells in the upper valley contained elevated concentrations of iron and manganese and little, if any, measurable nitrate+nitrite-N or TPN. These wells also exhibited lower TP, chloride, DOC, TDS, and conductivity values than wells in the lower valley.

The results of this and previous studies (Larson, 1993; Ebert and others, 2003) suggest that groundwater nitrate+nitrite-N concentrations may be increasing in some areas of the valley.

Recommendations

This study provides a benchmark for assessing future changes in ambient groundwater quality conditions in the Moxee Valley. Periodic future monitoring of the network is encouraged to enable area residents and local public health officials to evaluate the effects of ongoing land-use changes on area groundwater quality.

As a near-term follow-up to this study, we recommend that targeted sampling be conducted to determine the extent and possible causes of elevated nitrate concentrations observed in shallow groundwater in and around Moxee City.

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Appendices

Appendix A - Quality Assurance Review

For this study we followed the sampling procedures specified in the project quality assurance plan (Sinclair, 2005). Wells were sampled using dedicated tubing and new in-line-cartridge or syringe-type filters. All samples were collected in pre-cleaned bottles supplied by the Manchester Environmental Laboratory. Sample bottles were labeled, bagged, and then stored in clean ice-filled coolers pending their arrival at the laboratory. Sample chain-of-custody procedures were followed throughout the project. Except as described below, all samples arrived at the laboratory in good condition and were processed and analyzed within accepted EPA holding times.

Laboratory

The Manchester Environmental Laboratory follows strict quality assurance procedures to both ensure and later evaluate the quality of their analytical results (WA State Department of Ecology, 2005). Where appropriate, instrument calibration is performed before each analytical run and checked against initial 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 run. The laboratory also evaluates procedural blanks, spiked samples, and laboratory control samples (LCS). The results of these analyses were summarized in a case narrative and submitted to the authors along with the analytical data package.

The laboratory's quality assurance narratives and supporting data for this project indicate that constituent concentrations for blank samples consistently fell below the analytical detection limit for target analytes. In addition, matrix spike samples, laboratory replicate samples, and LCS analyses all met applicable acceptance criteria (Table A-1).

Table A-1 - Project Measurement Quality Objectives

Parameter	LCS check standards (% recovery limits)	Duplicate sample (RPD)	Matrix spikes (% recovery limits)	Matrix spike duplicates (RPD)
Field Parameters				
pH	± 0.2 pH units	± 0.1 pH units	NA	NA
Conductivity	± 10 µm/cm	± 10 %	NA	NA
Temperature	± 0.1 C	± 5 %	NA	NA
Dissolved Oxygen	± 0.2 mg/L	NA	NA	NA
Laboratory analyses				
TPN	80-120 %	± 20 %	75-125 %	± 20 %
Nitrate+Nitrite-N	80-120 %	± 20 %	75-125 %	± 20 %
Coliform, total (MF)	NA	± 40 %	NA	NA
Coliform, fecal (MF)	NA	± 40 %	NA	NA
Chloride	90-110 %	± 20 %	75-125 %	± 20 %
TDS	80-120 %	± 20 %	75-125 %	± 20 %
Iron	85-115 %	± 20 %	75-125 %	± 20 %
Manganese	85-115 %	± 20 %	75-125 %	± 20 %

The bottles for four wells (AHT021, ABL384, AHT024, and AHT022) sampled in January 2006, and one well sampled in June 2006 (AFQ920), were not processed within the 24-hour maximum holding time for bacteria. The corresponding total and fecal coliform results for these wells were "J" coded to indicate that they are estimated values.

The January 2006 total coliform sample for well AHT027, and the June 2006 samples for wells ABW764, AHK167, AHT001, ALF075, ABL978, and ABL133 were also "J" coded due to potential interference by background colonies. The "true" value for these wells may be greater than or equal to the reported result.

Field

In order to assess sampling bias and overall analytical precision, field equipment blanks and replicate samples were prepared and submitted "blind"[5] to the laboratory during each sample event. Equipment blanks were prepared with laboratory grade de-ionized water and were filtered, where appropriate, in the same manner as actual samples.

Precision for each of the field replicate and laboratory duplicate analyses was quantified by evaluating the relative percent difference (RPD[6]) for each duplicate sample pair. The resulting values were tabulated and compared to the project data-quality objectives.

No equipment blanks contained detectable levels of target analytes. The field duplicates met project data quality objectives for all but two sample pairs: one for iron and one for total persulfate nitrogen (TPN) (Table A-2). The iron duplicate sample was less than five times the method quantitation limit and is therefore not considered significant. One of four sample pairs for TPN exceeded the project data quality objective by about 2%. The remaining three sample pairs met data quality objectives as did all laboratory replicate samples for TPN. This slight exceedance for a single duplicate pair represents an isolated incident and does not warrant data qualification.

The results of the laboratory and field quality assurance reviews suggest that the water quality data generated during this study are of high quality and can be used without further qualification.

[5] Blanks or field replicate samples that were submitted to the laboratory using disguised sample numbers

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

Table A2 - Quality assurance review of field and laboratory duplicates and sample blanks

Sample Date		Total Coliform (CFU/ 100mL)	Fecal Coliform (CFU/ 100mL)	Dissolved Nitrate+ Nitrite-N (mg/L)	Dissolved Total Persulfate Nitrogen (mg/L)	Dissolved Total Phosphorus (mg/L)	Dissolved Organic Carbon (mg/L)	Total Dissolved Solids (mg/L)	Dissolved Chloride (mg/L)	Dissolved Iron (ug/L)	Dissolved Manganese (ug/L)
Field Replicate and Equipment Blank Samples											
01/10/06	Sample	1 UJ	1 UJ	0.01	0.036	0.0122	1 U	285	7.29	170	156
	Rep/Duplicate	1 UJ	1 UJ	0.01 U	0.031	0.0122	1 U	299	7.29	170	157
	RPD	NA	NA	NA	14.93	0.00	-	4.79	0.00	0.00	0.64
	Sample blank	-	-	-	-	-	-	-	-	-	-
01/11/06	Sample	1 UJ	1 UJ	0.01 U	0.035	0.0173	1.3	298	31	240	175
	Rep/Duplicate	1 UJ	1 UJ	0.01 U	0.042	0.017	1.3	292	31	220	176
	RPD	NA	NA	NA	18.18	1.75	0.00	2.03	0.00	8.70	0.57
	Sample blank	-	-	-	-	-	-	-	-	-	-
01/12/06	Sample	-	-	-	-	-	-	-	-	-	-
	Rep/Duplicate	-	-	-	-	-	-	-	-	-	-
	RPD	-	-	-	-	-	-	-	-	-	-
	Sample blank	1 U	1 U	0.01 U	0.025 U	0.001 U	1 U	10 U	0.1 U	50 U	10 U
06/12/06	Sample	1 U	1 U	0.01 U	0.025 U	0.018	1 U	291	30.4	210	161
	Rep/Duplicate	1 UJ	1 U	0.01 U	0.025 U	0.0182	1 U	291	30.2	280	165
	RPD	NA	NA	NA	NA	1.10	NA	0.00	0.66	28.57	2.45
	Sample blank	-	-	-	-	-	-	-	-	-	-
06/15/06	Sample	1 UJ	1 UJ	9.21	12.6	0.0627	2.4	638	32.3	50 U	39
	Rep/Duplicate	1 U	1 U	9.3	10.1	0.0611	2.6	649	32.3	50 U	37
	RPD	NA	NA	0.97	22.03	2.58	8.00	1.71	0.00	NA	5.26
	Sample blank	1 U	1 U	0.01 U	0.025	0.001 U	1 U	10 U	0.1 U	50 U	10 U
Laboratory Replicate and Blank Samples											
01/09/06	Sample	1 U	1 U	-	-	-	-	-	-	-	-
	Rep/Duplicate	1 U	1 U	-	-	-	-	-	-	-	-
	RPD	NA	NA	-	-	-	-	-	-	-	-
	Sample blank	-	-	-	-	-	-	-	-	-	-
01/10/06	Sample	1 U	1 U	0.01 U	-	-	1 U	299	9.86	-	-
	Rep/Duplicate	1 U	1 U	0.01 U	-	-	1 U	295	9.84	-	-
	RPD	NA	NA	NA	-	-	NA	1.35	0.20	-	-
	Sample blank	-	-	-	-	-	-	-	-	-	-
01/11/06	Sample	1 UJ	1 UJ	0.01 U	0.025 U	-	1 U	545	5.22	160	547
	Rep/Duplicate	1 UJ	1 UJ	0.01 U	0.025 U	-	1 U	548	5.2	160	549
	RPD	NA	NA	NA	NA	-	NA	0.55	0.38	0.00	0.36
	Sample blank	-	-	-	-	-	-	-	-	-	-
01/12/06	Sample	1 U	1 U	-	1.65	-	-	277	7.8	-	-
	Rep/Duplicate	1 U	1 U	-	1.68	-	-	273	7.79	-	-
	RPD	NA	NA	-	1.80	-	-	1.45	0.13	-	-
	Sample blank	-	-	0.01 U	0.025 U	0.001 U	1 U	10 U	0.1 U	50 U	10 U
06/12/06	Sample	1 UJ	1 U	3.36	3.69	0.0267	1.8	233	12.9		
	Rep/Duplicate	1 UJ	1 U	3.37	3.63	0.0273	1.8	234	13		
	RPD	NA	NA	0.30	1.64	2.22	0.00	0.43	0.77		
	Sample blank	-	-	-	-	-	-	-	-	-	-
06/13/06	Sample	1 U	1 U					238	11.1		
	Rep/Duplicate	1 U	1 U					246	11.4		
	RPD	NA	NA					3.31	2.67		
	Sample blank	-	-	-	-	-	-	-	-	-	-
06/14/06	Sample	1 U	1 U	0.01 U	0.025 U	0.0098	4.1	368	14.2		
	Rep/Duplicate	1 U	1 U	0.01 U	0.025 U	0.0106	4.2	374	14.2		
	RPD	NA	NA	NA	NA	7.84	2.41	2	0.00		
	Sample blank	-	-	-	-	-	-	10 U	-	-	-
06/15/06	Sample	1 U	1 U			0.105		10 U			
	Rep/Duplicate	1 U	1 U			0.102		10 U			
	RPD	NA	NA			2.90		NA			
	Sample blank	-	-	0.01 U	0.025 U	0.001 U	1 U	10 U	0.1 U	50 U	10 U

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

Appendix B - Data Tables

Most of the project data presented in this report are available in digital format via Ecology's Environmental Information Management (EIM) database. Readers can access the EIM database from links provided on Ecology's home page at: www.ecy.wa.gov/ecyhome.html.

The data for this project are maintained in EIM under the following study name and user study ID:

EIM study name: Ambient groundwater quality in the Moxee Valley surficial aquifer, Yakima County, January-June, 2006

EIM user study ID: KSIN0002

Table B-1: Physical Description of Monitored Wells in the Moxee Valley, Yakima County

Map ID	Well ID tag number	Well location	Site latitude (decimal degrees)	Site longitude (decimal degrees)	Land surface altitude at well head (feet)	Completed well depth (feet)	Casing diameter (inches)	Well completion type and open interval (feet)	Groundwater level (feet below land surface)	Ground-water level date	Well yield (gpm)	Draw-down (feet)	Drawdown test method and duration (hours)
1	AHT027	12N/19E-10D	46.54922	120.43763	984	60	6	O	8	5/21/1990	100	-	A
2	AHT028	13N/19E-34Q	46.56327	120.43248	993	40	6	O	9.5	1/19/1981	60	-	A
3	AHT024	13N/19E-27G04	46.58735	120.43487	1030	65	6	O	25	1/5/1987	100	-	B
4	AHT031	12N/19E-02E	46.55728	120.41423	1014	60	6	O	-	-	80	20	B(1)
5	AHT025	13N/19E-35J	46.56661	120.40420	1031	37.5	5	O	3.5	2/5/1975	20	-	A
6	ABW764	13N/19E-25N	46.57776	120.40142	1104	130	6	P (110-130)	30	4/10/1995	35	-	A
7	AHT099	12N/19E-01P	46.55097	120.38724	1051	80	6	OH (60-80)	8	3/12/1986	20	40	A(1)
8	ACT642	12N/19E-12B	46.54605	120.38322	1058	102	6	O	20	3/24/1998	40	-	A
9	AHK167	13N/20E-31C	46.57626	120.37421	1272	253	6	P (233-253)	168	8/6/2002	42	-	A
10	ABL384	13N20E-31H	46.57069	120.36170	1201	153	6	O	80	10/11/1994	30	-	A
11	AFQ920	12N/20E-06R	46.55116	120.36112	1111	145	6	OH (140-145)	30	3/27/2001	30	-	A
12	ALF075	13N/20E-32P	46.56325	120.35164	1188	145	6	OH (117-145)	35	10/13/2004	42	-	A
13	AHT022	13N/20E-32G	46.57300	120.34944	1259	210	6	P (180-200)	60	2/9/1982	30	-	A
14	AAL960	13N/20E-32H	46.57240	120.34278	1335	265	6	OH (240-265)	155	10/2/1995	30	-	A
15	AHT023	12N/20E-05R	46.55271	120.33521	1223	260	6	P (240-260)	78	9/24/1993	80	-	A
16	ABL133	12N/20E-04C02	46.56240	120.32633	1358	310	6	P (290-310)	189	6/13/1994	42	-	A
17	AHT026	12N/20E-09A	46.54713	120.31613	1219	169	6	O	46.8	6/14/1988	-	-	-
18	AFE254	12/N20E-10M	46.54138	120.31302	1169	80	6	P (55-80)	12	3/22/2000	30	-	A
19	AAL867	12N/20E-03N04	46.55001	120.31011	1261	120	6	O	38	5/23/1994	25	-	A
20	AHT021	12N/20E-15B	46.53161	120.29832	1219	150	6	OH (130-150)	12	10/19/1988	60	-	A
21	ACL110	12N/20E-10R	46.53705	120.29635	1241	140	6	OH (118-140)	32	10/8/1996	32	-	A
22	ABL978	12N/21E-21D	46.51889	120.20867	1526	585	6	OH (471-585)	347	8/17/1994	50	-	A
23	AHT100	12N/21E-21Q	46.50774	120.19648	1459	365	6	OH (140-365)	116	4/10/1978	200	-	A
24	ACX892	12N/21E-22N	46.50620	120.18617	1493	265	6	O	170	11/13/1996	20	-	A
25	ACE506	12N/21E-22C	46.51729	120.18247	1636	550	6	OH (480-550)	343	9/24/1996	42	-	A
26	AHT030	12N/21E-27A03	46.50535	120.16778	1556	420	12	S (360-420)	316	6/8/1989	575	68	P(24)
Geologic control wells - not sampled during this study													
G1	AAF045	12N/19E-02K02	46.55613	120.40604	1026	101	6	OH (78-101)	27	2/2/1994	22	-	A
G2	-	12N/19E-01Q03	46.54986	120.38090	1060	305	6	O	10	12/19/2007	75	-	A
G3	ABL457	12N/20E-05P01	46.54992	120.35053	1117	140	6	P (80-140)	19.5	11/21/1994	60	-	A
G4	-	12N/20E-09P02	46.53815	120.32459	1162	965	10	O	2	11/15/1977	700	146	P(4)
G5	-	12N/20E-11P01	46.53795	120.28575	1305	120	6	O	-	-	-	-	-
G6	AAM730	12N/20E-13C01	46.53381	120.26594	1356	2117	20	P (?)	220	1994	1000	320	P (1)
G7	-	12N/21E-17Q03	46.52220	120.21966	1483	1551	20	P (961-1511)	16.6	7/10/1979	-	-	-
G8	-	12N/21E-21E01	46.51524	120.20620	1509	720	8	O	82	4/27/1982	450	-	A
G9	-	12N/21E-21L04	46.51281	120.20183	1482	782	8	S (772-782)	86	8/31/1979	800	-	A

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

Underlined land surface altitudes are considered accurate to +- 16 feet. All other values are accurate to +- 1 foot.

Table B2 - Sampling Results for Monitored Wells in the Moxee 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]

			Field measurements					Laboratory analyses										
Map ID	Well ID Tag number	Sample Date	Depth to groundwater (ft below land surface)	Ground-water Temperature (deg C)	pH (standard units)	Conductivity (uS/cm)	Dissolved Oxygen (mg/L)	Fecal Coliform (#/100mL)	Total Coliform (#/100mL)	Dissolved Nitrate+ Nitrite as N (mg/L)	Dissolved Total Phosphorus (mg/L)	Dissolved Organic Carbon (mg/L)	Dissolved Total Persulfate Nitrogen (mg/L)	Total Dissolved Solids (mg/L)	Dissolved Chloride (mg/L)	Dissolved Iron (ug/L)	Dissolved Manganese (ug/L)
1	AHT027	01/12/2006	11.0	13.6	7.76	389	0.00	1 U	1 UJ	0.106	0.0907	1.0 U	0.23	277	7.80	220	272
		06/15/2006	10.3	13.4	7.51	582	0.11	1 U	1 U	2.33	0.2170	1.0 U	2.58	404	14.1	50 U	80
2	AHT028	01/12/2006	9.5	13.7	7.09	452	4.98	1 U	2	3.08	0.0921	1.0 U	3.13	300	10.2	50 U	10 U
		06/15/2006	9.1	13.6	7.25	473	5.01	1 U	1 U	3.08	0.1050	1.0 U	3.62	313	10.9	50 U	10 U
3	AHT024	01/12/2006	26.7	13.5	7.31	775	7.31	1 UJ	1 UJ	6.08	0.0419	1.7	5.22	489	8.26	50 U	10 U
		06/14/2006	29.5	14.3	7.52	607	7.40	1 U	1 U	3.09	0.0400	1.0 U	3.94	393	7.56	50 U	10 U
4	AHT031	01/12/2006	18.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		06/15/2006	17.3	14.0	7.97	907	0.17	1 U	30	4.27	0.4820	2.1	4.42	569	28.5	50 U	10 U
5	AHT025	01/12/2006	4.4	13.1	7.53	597	1.53	1 U	1 U	6.32	0.122	1.7	5.94	398	11.7	50 U	10 U
		06/13/2006	5.1	14.0	7.64	703	1.84	1 U	1 U	10.9	0.1350	1.6	10.9	484	20.1	50 U	10 U
6	ABW764	01/12/2006	29.3	12.8	7.41	607	5.79	1 U	1 U	3.90	0.0244	2.3	3.7	427	12.9	50 U	10 U
		06/12/2006	27.7	13.5	7.63	549	5.74	1 U	1 UJ	3.36	0.0267	1.8	3.69	372	12.9	50 U	10 U
7	AHT099	01/10/2006	12.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		06/15/2006	12.3	13.6	7.58	1028	1.97	1 U	1 U	18.2	0.3570	2.3	18.6	671	29.2	50 U	10 U
8	ACT642	01/12/2006	18.4	13.3	7.63	481	4.80	1 U	1 U	1.69	0.0326	1.0 U	1.65	314	15.9	50 U	10 U
		06/15/2006	17.8	13.5	7.70	492	4.80	1 U	1 U	1.76	0.0333	1.0 U	1.9	328	16.7	50 U	10 U
9	AHK167	06/12/2006	-	15.3	7.65	512	0.23	1 U	1 J	0.01 U	0.0249	1 U	0.025	342	16.0	150	173
10	ABL384	01/11/2006	84.4	13.4	7.68	450	0.04	1 UJ	1 UJ	0.01 U	0.0173	1.3	0.035	298	31.0	240	175
		06/12/2006	86.5	14.9	7.91	445	0.04	1 U	1 U	0.01 U	0.0180	1 U	0.025 U	291	30.4	210	161
11	AFQ920	01/09/2006	29.3	12.7	7.17	988	0.13	1 U	1 U	11.1	0.0525	2.6	10.6	639	31.4	50 U	89
		06/15/2006	30.1	14.3	7.20	984	0.13	1 UJ	1 UJ	9.21	0.0627	2.4	12.6	638	32.3	50 U	39

			Field measurements					Laboratory analyses									
Map ID	Well ID Tag number	Sample Date	Depth to groundwater (ft below land surface)	Ground-water Temperature (deg C)	pH (standard units)	Conductivity (uS/cm)	Dissolved Oxygen (mg/L)	Fecal Coliform (#/100mL)	Total Coliform (#/100mL)	Dissolved Nitrate+ Nitrite as N (mg/L)	Dissolved Total Phosphorus (mg/L)	Dissolved Organic Carbon (mg/L)	Dissolved Total Persulfate Nitrogen (mg/L)	Total Dissolved Solids (mg/L)	Dissolved Chloride (mg/L)	Dissolved Iron (ug/L)	Dissolved Manganese (ug/L)
12	ALF075	06/12/2006	37.0	14.3	8.04	326	0.06	1 U	1 UJ	0.015	0.0110	1 U	0.025 U	233	11.7	120	90
13	AHT022	01/11/2006	81.1	14.4	7.38	546	0.15	1 UJ	1 UJ	0.01 U	0.0650	2.0	0.047	366	13.4	160	547
		06/14/2006	81.6	14.7	7.43	565	0.12	1 U	1 U	0.01 U	0.0579	1.2	0.025 U	368	14.2	230	548
14	AAL960	01/10/2006	157.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		06/14/2006	158.8	15.7	7.28	552	0.30	1 U	1 U	0.012	0.0629	1.2	0.04	365	22.3	519	528
15	AHT023	01/11/2006	79.8	15.3	7.62	286	0.09	1 U	1 U	0.01 U	0.0153	1.0 U	0.039	207	5.22	100	81
		06/14/2006	80.3	15.7	8.08	300	0.11	1 U	1 U	0.01 U	0.0151	1.0 U	0.025 U	207	5.48	170	84
16	ABL133	01/11/2006	195.6	13.8	7.94	281	0.28	1 U	7	0.01 U	0.0163	1.0 U	0.025 U	194	4.94	130	84
		06/14/2006	195.7	16.6	8.09	294	0.13	1 U	25 J	0.01 U	0.0178	1.0 U	0.025 U	208	5.23	91	83
17	AHT026	01/12/2006	68.8	15.8	7.98	360	0.11	1 U	1 U	0.01 U	0.0101	1.0 U	0.21	246	14.4	71	85
		06/14/2006	68.7	16.5	8.16	377	0.09	1 U	1 U	0.01 U	0.0098	1.0 U	0.025 U	253	15.0	88	88
18	AFE254	01/10/2006	10.9	12.9	7.85	360	0.00	1 U	1 U	0.01 U	0.0252	1.0 U	0.047	275	8.94	240	143
		06/13/2006	9.7	13.8	7.91	339	0.04	1 U	1 U	0.01 U	0.0242	1.0 U	0.025 U	238	8.36	190	129
19	AAL867	01/11/2006	43.3	12.8	7.49	848	3.99	1 U	1 U	4.00	0.107	4.4	3.63	545	26.5	50 U	10 U
		06/14/2006	31.6	14.0	7.70	772	6.47	1 U	1 U	3.22	0.148	4.1	3.86	489	21.2	50 U	10 U
20	AHT021	01/10/2006	12.5	13.8	7.93	431	0.04	1 UJ	1 UJ	0.01	0.0122	1.0 U	0.036	285	7.29	170	156
		06/14/2006	14.5	14.2	7.97	536	0.08	1 U	1 U	0.01 U	0.0127	1.0 U	0.025 U	343	9.43	92	78
21	ACL110	01/10/2006	30.9	14.2	7.84	735	0.01	1 U	1 U	0.01 U	0.0153	4.0	0.15	474	73.8	330	280
		06/13/2006	31.9	14.5	7.81	736	0.00	1 U	1 U	0.01 U	0.0165	3.6	0.12	478	72.1	310	267
22	ABL978	01/10/2006	-	10.7	8.10	306	0.00	1 U	1 U	0.01 U	0.0152	1.0 U	0.031	221	9.86	120	93
		06/13/2006	-	15.3	7.83	321	0.05	1 U	2 J	0.01 U	0.0158	1.0 U	0.025 U	217	9.83	140	84

			Field measurements					Laboratory analyses										
Map ID	Well ID Tag number	Sample Date	Depth to groundwater (ft below land surface)	Ground-water Temperature (deg C)	pH (standard units)	Conductivity (uS/cm)	Dissolved Oxygen (mg/L)	Fecal Coliform (#/100mL)	Total Coliform (#/100mL)	Dissolved Nitrate+ Nitrite as N (mg/L)	Dissolved Total Phosphorus (mg/L)	Dissolved Organic Carbon (mg/L)	Dissolved Total Persulfate Nitrogen (mg/L)	Total Dissolved Solids (mg/L)	Dissolved Chloride (mg/L)	Dissolved Iron (ug/L)	Dissolved Manganese (ug/L)
23	AHT100	01/09/2006	131.9	13.8	7.88	313	-	1 U	1 U	0.874	0.0348	1.0 U	0.89	222	7.38	50 U	88
		06/13/2006	139R	14.3	7.96	309	0.28	1 U	1 U	0.16	0.0528	1.0 U	0.15	200	6.29	110	135
24	ACX892	01/10/2006	165.9	12.7	8.01	287	0.06	1 U	1 U	0.01 U	0.0285	1.0 U	0.031	207	5.09	1600	157
		06/13/2006	177.3	15.3	7.95	292	0.06	1 U	1 U	0.011	0.0263	1.0 U	0.025 U	198	5.87	733	151
25	ACE506	01/11/2006	-	13.6	8.10	408	0.04	1 U	1 U	0.01 U	0.0106	1.7	0.083	260	15.1	250	76
		06/13/2006	-	16.5	7.96	317	0.00	1 U	1 U	0.01 U	0.0121	1 U	0.025 U	238	11.1	180	66
26	AHT030	01/10/2006	-	15.4	8.16	272	0.03	1 U	1 U	0.01 U	0.0141	1.0 U	0.036	205	4.31	50 U	30
		06/13/2006	-	17.7	8.06	273	0.03	1 U	1 U	0.01 U	0.0140	1.0 U	0.025 U	303	4.47	50 U	31

Table B-3: Drillers Lithologic Logs for Monitored Wells in the Moxee Valley, Yakima County

[Explanation: WB - water bearing]

Map ID	Well tag number	Local number	Year drilled	Driller's description of materials encountered during well construction	Thickness (feet)	Depth of bottom (feet)	Interpreted hydro-geologic unit
1	AHT027	12N/19E-10D	1990	Clay loam	2	2	
				Clay, hard, brown	3	5	
				Clay, sandy, brown	3	8	
				Conglomerate gravel and sandy clay, brown	8	16	
				Gravel and sand, coarse	44	60	Unit 2
2	AHT028	13N/19E-34Q	1981	Topsoil	6	6	
				Clay and gravel	4	10	
				Sand and gravel; WB	32	42	Unit 2
3	AHT024	13N/19E-27G04	1987	Topsoil	7	7	
				Sand and soil	3	10	
				Clay, brown	15	25	
				Clay and gravel, brown	8	33	
				Sand and gravel	9	42	
				Sand, gravel, and clay, brown	13	55	
				Sand; WB	10	65	Unit 2
4	AHT031	12N/19E-02E	1986	Sandy loam	28	28	
				Gravel	15	43	
				Clay, sandy, brown	2	45	
				Gravel	14	59	
				Gravel, cemented	1	60	Unit 2
5	AHT025	13N/19E-35J	1975	Topsoil	25	25	
				Conglomerate	12	37	Unit 2
6	ABW764	13N/19E-25N	1995	Soil and cobbles	8	8	
				Gravel, cemented	11	19	
				Clay and gravel	10	29	
				Clay, brown	21	50	
				Clay, sandy, brown	5	55	Unit 2
				Sandstone	8	63	
				Sandstone and shale, hard	12	75	
				Sandstone	40	115	
				Sandstone and gravel; WB	15	130	Unit 3
7	AHT099	12N/19E-01P	1986	Sandy loam	35	35	
				Gravel, coarse	2	37	
				Hardpan	33	70	Unit 2
				Sand-rock	10	80	Unit 3
8	ACT642	12N/19E-12B	1998	Topsoil	34	34	
				Gravel	21	55	
				Clay	8	63	
				Gravel and clay	7	70	
				Clay	27	97	Unit 2
				Sandstone	5	102	Unit 3
9	AHK167	13N/20E-31C	2002	Topsoil	3	3	
				Boulders (small) and brown clay	5	8	
				Clay and sand, brown	28	36	Unit 2
				Sandstone and clay, brown	122	158	

Map ID	Well tag number	Local number	Year drilled	Driller's description of materials encountered during well construction	Thickness (feet)	Depth of bottom (feet)	Interpreted hydro-geologic unit
				Sandstone, brown, small gravel, and clay	7	165	
				Sandstone, brown, small gravel, and sand; WB	22	187	
				Clay and sand, brown	54	241	
				Clay and sand, blue	6	247	
				Sandstone (dark gray), sand, and gravel; WB	6	253	Unit 3
10	ABL384	13N/20E-31H	1994	Soil	3	3	
				Hardpan	4	7	
				Gravel, cemented	13	20	
				Clay and gravel	41	61	
				Clay	31	92	
				Clay and gravel	12	104	
				Clay	34	138	Unit 2
				Sand, shale, and clay	14	152	
				Clay, blue	1	153	Unit 3
11	AFQ920	12N/20E-06R	2001	Unknown, no log	18	18	
				Conglomerate	32	50	Unit 2
				Sandstone and clay, brown	30	80	
				Sandstone, trace water	5	85	
				Sandstone, brown	30	115	
				Sandstone; WB	5	120	
				Sandstone and clay	15	135	
				Sandstone; WB	10	145	Unit 3
12	ALF075	13N/20E-32P	2004	Topsoil	1	1	
				Basalt gravel, large, and brown clay	18	19	Unit 2
				Sandstone, brown, and clay	77	96	
				Clay and sand, green, hard	13	109	
				Basalt, broken, gray, with green clay	6	115	
				Basalt, broken, gray, with green clay; WB	20	135	
				Sandstone, dark gray; WB	10	145	Unit 3
13	AHT022	13N/20E-32G	1982	Topsoil	3	3	
				Boulders	9	12	
				Gravel, coarse, with brown clay	108	120	
				Clay, brown	20	140	
				Clay, blue, and gravel	55	195	
				Gravel; WB	15	210	Unit 2
14	AAL960	13N/20E-32H	1995	Topsoil	2	2	
				Gravel, cemented	23	25	
				Gravel	103	128	
				Clay	32	160	
				Gravel	7	167	
				Clay, tan	18	185	
				Clay, blue	10	195	
				Sand; WB	5	200	Unit 2
				Sandstone with clay and shale layers; WB	65	265	Unit 3
15	AHT023	12N/20E-05R	1993	Topsoil, brown	1	1	
				Caliche and cobbles, brown	4	5	
				Sand and gravel, brown	9	14	
				Clay, sandy, brown	18	32	Unit 2
				Sandstone, brown	50	82	
				Clay and clay shale, blue	58	140	

Map ID	Well tag number	Local number	Year drilled	Driller's description of materials encountered during well construction	Thickness (feet)	Depth of bottom (feet)	Interpreted hydro-geologic unit
				Sandstone, blue	18	158	
				Clay shale, blue, trace water	23	181	
				Clay, blue	56	237	
				Sandstone, blue; WB	23	260	Unit 3
16	ABL133	12N/20E-04C02	1994	Topsoil	3	3	
				Gravel and clay, brown	5	8	
				Clay, brown	54	62	
				Basalt, gravel, and brown clay	11	73	
				Clay, gravel, and sand, brown	59	132	Unit 2
				Sandstone (green) and brown clay	38	170	
				Sandstone, green, with brown clay, gravel, and green sand; WB	50	220	
				Sandstone, brown and green; WB	20	240	
				Sandstone, green; WB	70	310	Unit 3
17	AHT026	12N/20E-09A	1988	Caliche cobbles, hard, white	11.5	11.5	
				Clay and gravel, medium hard, brown	4.5	16	Unit 2
				Clay shale, hard, green	2	18	
				Clay and gravel, medium hard, brown	18	36	
				Sandy clay and gravel, medium hard, green	22	58	
				Shale, sandstone, and clay, hard, blue	7	65	
				Clay, medium soft, blue	7	72	
				Sandstone and shale, blue-black; WB	6	78	
				Sandstone, shale, and clay, hard, blue-black	25	103	
				Clay and shale, medium-soft, green to blue gray	20	123	
				Clay, medium soft, blue	15	138	
				Clay and shale, medium hard, blue	3	141	
				Clay, medium hard, blue	16	157	
				Sandy clay and sandstone, medium hard, trace water	5	162	
				Gravel, coarse, and sandstone, medium hard	9	171	Unit 3
18	AFE254	12N/20E-10M	2000	Topsoil	2	2	
				Silt, sandy, cemented, with brown cobbles	23	25	Unit 2
				Sandstone and small gravel, brown	6	31	
				Clay, blue-gray	19	50	
				Sandstone, clay layers, and small dark gravel, blue	30	80	Unit 3
19	AAL867	12N/20E-03N04	1994	Caliche gravel, brown	6	6	
				Clay and gravel, green	5	11	
				Clay, brown	11	22	Unit 2
				Clay and sandstone, brown	8	30	
				Clay, tan	6	36	
				Clay, sandy, green	3	39	
				Sandstone, brown	5	44	
				Clay, green	6	50	
				Basalt sandstone, green	6	56	
				Sandstone and clay, green	30	86	
				Sandstone, gray	8	94	
				Clay, sandy, green	8	102	
				Shale and sandstone, green	12	114	
				Sandstone, gray	6	120	Unit 3
20	AHT021	12N/20E-15B	1988	Topsoil	12	12	
				Sand	6	18	Unit 2
				Sandstone and clay, brown	40	58	

Map ID	Well tag number	Local number	Year drilled	Driller's description of materials encountered during well construction	Thickness (feet)	Depth of bottom (feet)	Interpreted hydro-geologic unit
				Clay and sand, dark gray	49	107	
				Clay and gravel, dark gray	6	113	
				Clay and sand, dark gray	15	128	
				Sandstone, dark gray	12	140	
				Sandstone, dark gray; WB	10	150	Unit 3
21	ACL110	12N/20E-10R	1996	Topsoil, brown	5	5	
				Caliche gravel, white to black	1	6	
				Clay, sandy, brown	18	24	
				Clay, brown	8	32	
				Clay, blue to gray	4	36	Unit 2
				Sandstone and clay, blue to gray	2	38	
				Clay, blue to green	13	51	
				Sand, gravel, cobbles, black to blue	8	59	
				Clay and gravel, blue to green	5	64	
				Sandstone, blue	7	71	
				Clay, green to gray	12	83	
				Clay and clay/shale, green to gray	8	91	
				Sandstone, green to gray	3	94	
				Sandstone, blue	12	106	
				Clay, sandy, blue	6	112	
				Sandstone, blue	28	140	Unit 3
22	ABL978	12N/21E-21D	1994	Topsoil	3	3	
				Clay, brown with basalt boulders	13	16	
				Clay and sand, brown	94	110	Unit 2
				Basalt boulders, broken basalt, and brown clay	108	218	
				Basalt, gray	35	253	
				Clay, brown	17	270	
				Basalt, gray	20	290	
				Clay, dark gray	10	300	
				Clay, dark gray, and sandstone	15	315	
				Sandstone, gray	30	345	
				Sandstone and small gravel	75	420	
				Sand, brown	30	450	
				Sand, brown; WB	20	470	Unit 3
				Basalt, gray, vesicular; WB	8	478	
				Basalt, gray, with white crystals	7	485	
				Basalt, gray, and hard blue clay	9	494	
				Basalt, gray	80	574	
				Basalt, black; WB	2	576	
				Basalt, brown, and hard blue clay; WB	4	580	
				Basalt, black, and hard blue clay; WB	5	585	Unit 4
23	AHT100	12N/21E-21Q	1978	Topsoil	5	5	
				Gravel and boulders	15	20	
				Clay, green	55	75	Unit 2
				Sandstone with gravel and clay layers	9	84	
				Sandstone	21	105	
				Rock, broken, with sandstone layers	25	130	
				Cinder rock; WB	5	135	
				Sandstone with black rock layers	50	185	
				Sandstone and vesicular lava rock; WB	20	205	Unit 3
				Basalt; WB from 200 to 220 feet	135	340	
				Sandstone; WB	25	365	Unit 4

Map ID	Well tag number	Local number	Year drilled	Driller's description of materials encountered during well construction	Thickness (feet)	Depth of bottom (feet)	Interpreted hydro-geologic unit
24	ACX892	12N/21E-22N	1998	Soil	8	8	
				Sand and gravel	6	14	
				Sand, gravel, and clay	53	67	Unit 2
				Clay and sand, brown	50	117	
				Clay and basalt rock, dark brown	20	137	
				Clay, blue, and black basalt	88	225	Unit 3
				Basalt, black, with trace of water	5	230	
				Basalt, black	25	255	
				Basalt, black; WB	10	265	Unit 4
25	ACE506	12N/21E-22C	1996	Topsoil	2	2	
				Clay, brown, with small basalt boulders	21	23	Unit 2
				Gravel, cemented, and brown clay	83	106	
				Gravel, cemented, and blue clay	19	125	
				Gravel, brown sandstone, and brown clay	40	165	
				Conglomerate and black sand, with crystals	12	177	
				Clay, green, with green sandstone and gravel	28	205	Unit 3
				Basalt, gray, and green clay	12	217	
				Basalt, gray, and green crystals	35	252	
				Basalt, gray and black	20	272	
				Basalt, black to brown, broken	4	276	
				Basalt, black to brown, with green shale	2	278	
				Basalt, gray, hard	32	310	
				Basalt, black, with blue clay and sand	5	315	
				Basalt, black to gray, and blue shale	73	388	
				Clay, blue-green	30	418	
				Basalt, gray, and blue clay, medium	32	450	
				Basalt, gray, and blue clay, hard, cracked	10	460	
				Basalt, gray, hard	30	490	
				Basalt, black to gray, with white crystals; WB	30	520	
				basalt, gray, hard	13	533	
				Basalt, gray, and hard brown shale	10	543	
				Basalt, gray, and blue shale, with white crystals	9	552	Unit 4
26	AHT030	12N/21E-27A03	1989	Topsoil	5	5	
				Gravel, cemented	3	8	
				Gravel and boulders, cemented	5	13	Unit 2
				Sandstone and clay, brown	40	53	
				Gravel, cemented, and clay, brown	12	65	
				Clay, gravel, medium, brown	10	75	
				Gravel, cemented, and clay, brown	18	93	
				Sandstone and gravel	7	100	
				Basalt, boulders, and gravel	21	121	
				Gravel, cemented, hard, and clay, brown	7	128	
				Sandstone and clay, brown	18	146	
				Gravel, cemented, soft	49	195	
				Gravel, cemented, basalt, hard	23	218	
				Clay and gravel, soft, brown	1	219	
				Clay and medium gravel, blue	13	232	Unit 3
				Basalt, clay, fractured, black	19	251	
				Basalt, clay, fractured, black	7	258	
				Clay and basalt, soft, blue	13	271	
				Clay and basalt, soft, blue	12	283	
				Basalt, clay, hard, blue	8	291	
				Sandstone, hard, with clay and gravel, blue	49	340	

Map ID	Well tag number	Local number	Year drilled	Driller's description of materials encountered during well construction	Thickness (feet)	Depth of bottom (feet)	Interpreted hydro-geologic unit
				Sandstone, soft	5	345	
				Sandstone, cemented, blue	19	364	
				Sand and gravel	6	370	
				Basalt and shale, soft	10	380	
				Basalt, shale, and sandstone, blue	10	390	
				Basalt, shale, fractured, blue	10	400	
				Basalt, fractured, brown to green	15	415	
				Basalt, fractured, hard, black	5	420	Unit 4
G1	AAF045	12N/19E-02K02	1994	Soil	14	14	
				Loam	18	32	
				Clay and gravel	9	41	
				Gravel	9	50	
				Clay and gravel	6	56	
				Gravel	12	68	
				Clay and gravel	14	82	
				Clay	7	89	Unit 2
				Sandstone	7	96	
				Clay	5	101	Unit 3
G2	-	12N/19E-01Q03	1977	Topsoil, gravely brown	1	1	
				Clay, brown with medium gravel	3	4	
				Clay, brown	28	32	
				Gravel, medium with black sand; WB	21	53	
				Clay, brown with fine black gravel	15	68	
				Sand, brown; WB	3	71	Unit 2
				Clay, brown	20	91	
				Sand, brown, coarse; WB	3	94	
				Clay, brown	18	112	
				Clay, brown, medium dense	16	128	
				Sand, brown, coarse; WB	6	134	
				Clay, brown	6	140	
				Sand, brown, coarse; WB	9	149	
				Claystone, light brown, medium soft	11	160	
				Gravel, brown, fine; WB	10	170	
				Clay, brown	8	178	
				Gravel and sand, brown; WB	12	190	
				Clay, brown	7	197	
				Claystone, brown, medium soft	31	228	
				Sand, black, medium; WB	4	232	
				Clay, brown	16	248	
				Gravel, brown, fine; WB	8	256	
				Clay, gray	10	266	
				Sand, gray, medium to fine; WB	16	282	
				Claystone, black, medium hard	2	284	
				Sand, black, medium to coarse; WB	21	305	Unit 3
G3	ABL457	12N/20E-05P01	1994	Topsoil	8	8	
				Gravel	8	16	
				Gravel with tan clay	2	18	
				Gravel, cemented, hard	9	27	
				Gravel, medium brown, cemented	7	34	Unit 2
				Sandstone, white, soft, with sandy tan clay	3	37	
				Clay, brown, sticky	1	38	
				Gravel, medium brown, cemented	3	41	
				Clay, sandy, brown, soft	11	52	

Map ID	Well tag number	Local number	Year drilled	Driller's description of materials encountered during well construction	Thickness (feet)	Depth of bottom (feet)	Interpreted hydro-geologic unit
				Gravel, brown, cemented, hard	5	57	
				Shale, brown with sandy clay	12	69	
				Shale, brown, hard	3	72	
				Sandstone, brown, with tan sticky clay	2	74	
				Shale, brown, hard	13	87	
				Sandstone, brown	3	90	
				Sandstone, brown, with tan clay	8	98	
				Clay, tan, sticky	12	110	
				Sandy clay, tan, with sandstone	5	115	
				Shale, brown, with sandy clay, tan	11	126	
				Sandstone, brown, hard	5	131	
				Shale, brown, hard, with tan clay	4	135	
				Clay, tan, sticky	1	136	
				Sandstone, brown	4	140	Unit 3
G4	-	12N/20E-09P02		Topsoil	4	4	
				Sand, brown, fine	6	10	Unit 2
				Hardpan and sandstone	8	18	
				Sandstone	9	27	
				Gravel, seepage	13	40	
				Clay, brown	23	63	
				Clay, green, sticky	112	175	
				Sand	3	178	
				Clay, green	47	225	
				Sand, black, fine	4	229	
				Clay	41	270	
				Clay, light green, and gravel	14	284	
				Clay, green	8	292	
				Sand; WB	5	297	
				Clay, light green, sticky	53	350	
				Clay, gray and cemented gravel	60	410	
				Gravel and sand; WB	10	420	
				Clay, blue-green, and sand	68	488	
				Sand	4	492	
				Clay, gray, sticky	58	550	
				Clay, green	10	560	
				Clay	20	580	
				Clay and sand	68	648	
				Clay, light green	17	665	
				Sand	5	670	
				Clay	44	714	
				Gravel; WB	3	717	
				Sand	3	720	
				Clay, blue-green, sticky	20	740	
				Gravel and sand; WB	10	750	
				Clay, sticky	15	765	
				Sand	5	770	
				Clay	5	775	
				Sand	22	797	
				Clay, sticky	13	810	
				Sand; WB	60	870	
				Clay, brown, hard	35	905	
				Sand and gravel, cemented	3	908	
				Sand with gravel layers	12	920	Unit 3
				Basalt, black, fractured, with clay	6	926	
				Basalt, multi-colored	14	940	

Map ID	Well tag number	Local number	Year drilled	Driller's description of materials encountered during well construction	Thickness (feet)	Depth of bottom (feet)	Interpreted hydro-geologic unit
				Basalt, black, hard	18	958	
				Basalt, soft, fractured	2	960	
				Basalt, black, soft, with red rock	12	972	Unit 4
G5	-	12N/20E-11P01	1992	Topsoil	3	3	
				Gravel and boulders, cemented	18	21	
				Sandy clay, brown	5	26	
				Silty clay, green	12	38	
				Clay, dark green	10	48	Unit 2
				Sandstone and shale, green-black, hard	2	50	
				Sandstone, black, hard	15	65	
				Basalt, black	10	75	
				Shale, black, hard	16	91	
				Clay and shale, green, sticky	1	92	
				Shale, dark green	28	120	Unit 3
G6	AAM730	12N/20E-13C01	1993	Topsoil	8	8	
				Caliche	32	40	Unit 2
				Clay and gravel, tan-brown	130	170	
				Clay, green to tan	30	200	
				Sand, gravel, and green clay	220	420	
				Clay with gravel and basalt	30	450	
				Clay, brown, with rock	58	508	Unit 3
				Basalt, black to tan	42	550	
				Basalt, gray, hard, fractured	21	571	
				Basalt with occasional clay or sand interbeds	1546	2117	Unit 4
				(see original well report for more detail)			
G7	-	12N/21E-17Q03	1979	Overburden	43	43	Unit 2
				Clay and gravel	2	45	
				Clay, gravel, and boulders	87	132	
				Clay and gravel	132	264	Unit 3
				Basalt and clay	120	384	
				Sand, gravel, and clay	70	454	
				Basalt, gray	88	542	
				Basalt, with occasional clay or gravel interbeds	1009	1551	Unit 4
				(see original well report for more detail)			
G8	-	12N/21E-21E01	1982	Topsoil	5	5	
				Gravel, cemented	15	20	Unit 2
				Sandstone	50	70	
				Gravel, cemented, and clay	45	115	
				Gravel, cemented	105	220	
				Basalt, fractured; WB	20	240	
				Clay	20	260	
				Clay, sandy	53	313	
				Clay, soft, with gravel layers	25	338	
				Sandstone	62	400	Unit 3
				Basalt, broken	13	413	
				Basalt, gray, hard	59	472	
				Basalt, black	198	670	
				Basalt, broken; WB	50	720	Unit 4
G9	-	12N/21E-21L04	1979	Topsoil	6	6	
				Gravel, cemented	2	8	Unit 2
				Silt, sand, gravel, conglomerate	13	21	

Map ID	Well tag number	Local number	Year drilled	Driller's description of materials encountered during well construction	Thickness (feet)	Depth of bottom (feet)	Interpreted hydro-geologic unit
				Rock and boulders, decomposed	14	35	
				Gravel and boulders, cemented	28	63	
				Clay, tan, hard, with gravel and boulder lens	27	90	
				Basalt, gray, broken	38	128	
				Andesitic basalt, gray, creviced	42	170	
				Shale, gray and black, sloughing	18	188	
				Conglomerate, tan, sloughing	14	202	Unit 3
				Basalt, gray, creviced and shale, black	10	212	
				Basalt, grey, creviced, very hard	156	368	
				Sandy clay, tan, seepage	30	398	
				Sandstone, blue, and sand; WB	8	406	
				Sand, blue to tan, with clay, shale, and gravel	92	498	
				Clay, gravel, and sand, tan; WB	58	556	
				Basalt and clay, gray, broken	2	558	
				Basalt, broken, and shale	44	602	
				Basalt, gray, fractured	125	727	
				Sandy clay and shale, blue	45	772	
				Sand, blue; WB	8	780	
				Rock, black, broken, and coarse sand	2	782	Unit 4