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Results of the First Season of Shallow Aquifer Recharge Testing at the Hall-Wentland Site, Umatilla County, Oregon and Walla Walla County, Washington

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Prepared for

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Section 1: Introduction

The Hall-Wentland (H-W) shallow aquifer recharge project is one of several projects in both the Washington and Oregon portions of the Walla Walla Basin being done to field test the feasibility of using seasonal, winter and spring, shallow aquifer recharge (SAR) to help address water supply, stream flow, and habitat issues. It is anticipated that H-W SAR test project will run for several years. Ultimately, the goals of this project are to provide information useful for assessing:

- The viability of methods used at the H-W SAR Test Site to effectively recharge the shallow aquifer system in the Walla Walla Basin.
- If feasible, infrastructure and operational needs for a more effective SAR program.
- The fate of recharged groundwater with respect to meeting water supply, stream flow, and habitat needs.

This report summarizes the results of the first season of SAR testing at the Hall-Wentland Test Site (the Test Site), focusing primarily on describing work activities, data collected, and preliminary observations and interpretations. As testing progresses over the next several years it is anticipated that future project reports will build on data and recommendations presented in this report. This future work would likely include more detailed analysis of the fate and movement of recharge water added to the aquifer.

In the winter/spring of 2003 and the autumn/winter/spring of 2003/2004 Mr. Tom Page, working with local landowners in the Beet Road, Winesap Road, and State Line Road area (Figures 1 and 2) (approximately 2.5 miles west-southwest of College Place, Washington) collected information to evaluate the effectiveness of winter irrigation in improving flows in McEvoy spring creek. Winter irrigation was conducted on property owned by Mr. A.J. Wentland and Mr. Gordan Hall located on the south side of State Line Road near Winesap Road (Figure 3). The Hall-Wentland properties are located in Oregon, a few hundred yards south of the Washington-Oregon border. A 0.5 cubic feet per second (cfs) Oregon winter irrigation water right was used for this local effort. Mr. Page's activities included periodic water level measurements in several domestic and irrigation wells near the Hall-Wentland properties and between these properties and the Walla Walla River at the Burlingame Ditch Diversion. Mr. Page took the initiative in this because he had observed declining flows and the loss of fish habitat in McEvoy spring creek over the past 40 years.

In response to the anecdotal observations of Mr. Page and others and the observations of professional staff with agencies in both states, the Walla Walla Watershed (WRIA 32) planning unit in Washington, Walla Walla Basin Watershed Council (WWBWC) in Oregon, and the Walla Walla Watershed Alliance (WWWA) in both Washington and Oregon have expressed concern about declining shallow aquifer water levels and the possible effects this could have on spring creek and Walla Walla River flows. To help address this concern, the Washington Department of Ecology (Ecology) provided Walla Walla County with a grant to test the feasibility of SAR at two sites in the the Walla Walla Basin.

As noted above, this report describes the first season of testing at the H-W Test Site. The work described herein was done by Kennedy/Jenks Consultants, and subcontractors, under a contract from HDR, Inc. (HDR Project no. 17530). HDR was the prime contractor for the Walla Walla County Watershed Planning Department who was funded by the Washington Department of Ecology (Ecology) to conduct SAR testing. The permit holder for the project is Walla Walla River Irrigation District (WWRID). Specific team members for the project include:

- Ms. Cathy Schaeffer and Mr. Matt Rajnus, Walla Walla County.
- Mr. Allen Evans, PE, HDR Project Manager.
- Dr. Kevin Lindsey, LHG, Kennedy/Jenks Project Manager and Technical Lead.
- Mr. Terry Tolan, RG, Kennedy/Jenks Senior Hydrogeologist.
- Mr. Jon Travis, Kennedy/Jenks Technical Support.
- Mr. John Fazio, Fazio Engineering, Project Engineer.
- Mr. Tom Page, Site Operator.

In addition, the project could not have been carried out without the cooperation and support of the permit holder, WWRID, Test Site landowners, Mr. A.J. Wentland and Mr. Gordon Hall, and nearby landowners who allowed access to their property for the purpose of data collection and monitoring.

Although the work described herein was funded by a Washington State agency (e.g., Ecology), much of the work, including recharge operations, were done in the State of Oregon, a few hundred yards south of the Washington-Oregon border (Figures 1 and 2). Consequently, much of the monitoring and testing done for this project was permitted under an Oregon Limited License for testing shallow aquifer recharge as laid out in Oregon Administrative Code (OAR) 690-350-0020. The Limited License is administered by the Oregon Water Resources Department (OWRD), with concurrence from other State of Oregon agencies, Oregon Environmental Quality Department (ODEQ) and Oregon Department of Fish and Wildlife (ODFW), and Ecology.

The remainder of this report describes the work done on and near the Site to prepare for testing, monitoring and testing, and the test results. Sections of this report include:

- Test site geographic, geologic, and hydrogeologic conditions (Section 2).
- Description of the regulatory framework, physical Site layout, and methods used (Section 3).
- Test results (Section 4).
- Recommendations for future work at the Test Site (Section 5).

Section 2: Setting

The purpose of this section is to describe the geographic setting of the Site and the basic geologic and hydrogeologic setting of the Walla Walla Basin.

2.1 Geographic Setting

This section briefly introduces the physical setting of the Site, including location. The Site is located on two pieces of adjacent private property on the south side of Stateline Road approximately 2.5 miles south-southwest of College Place, Washington, just south of the Oregon-Washington border (Figures 1 and 2). The Site is in the SE 1/4, NW 1/4, Section 14, T6N, R35E. The western part of the Site is owned by Mr. A.J. Wentland, the eastern part of the Site is owned by Mr. Gordon Hall. Overall, the Site is an approximately 300 foot long (north-south) by 150 foot wide (east-west) rectangle (Figure 2). Farming, including hay, orchards, and other crops, irrigated pasture, and low density rural residential land use predominates on all sides of the Site.

Interviews with the current land owners reveal that both portions of the Site were used as orchards until approximately 15 years ago. At that time the orchards were removed, the Wentland portion was converted to wheat farming and the Hall portion converted to pasture. Wheat farming on the Wentland portion of the Site continued until approximately 4 years ago when farming was converted to alfalfa.

Irrigation water currently is delivered to the western (Wentland) portion of the Site via a branch ditch off a ditch known as Wells Ditch (Figure 3). Wells Ditch receives water from the East Fork of the Little Walla Walla River (ELWW) (Figure 3). A head gate for controlling Wells Ditch flow is located at the Wells Ditch diversion off the ELWW. Flow into the branch ditch which carries water to the Test Site is controlled by a check-board structure (Figure 4) located on Wells Ditch several hundred yards south of the Site. The branch ditch onto the Site terminates in an approximately 10 foot by 10 foot pond from which water is pumped for irrigation use (Figure 5). Wells Ditch, and the branch ditch, are the conduit by which water was supplied to the Site for the first season of SAR testing.

2.2 Geologic Setting

The Test Site is located within the eastern portion of the Walla Walla Basin (the Basin) (Figure 6). The Walla Walla Basin is a structural basin bounded on the south and southwest by the Horse Heaven Hills anticline, the east by the Blue Mountains uplift, and the north by the Palouse Slope (Figure 6). The Basin is partially filled by a sequence of Miocene to Recent continental clastic sediments. These sediments are up to 800, or more, feet thick in parts of the Basin and they overlie Miocene continental flood basalt of the Columbia River Basalt Group (CRBG). These sediments host a shallow aquifer system in the eastern Walla Walla Basin (Newcomb, 1965). This aquifer system is the target of the H-W SAR project, consequently, the sediments overlying basalt are the focus of this review of Test Site physical conditions. Basalt geology and structural geology are summarized briefly at the end of this discussion.

2.2.1 Sedimentary Geology

The Miocene to Recent sedimentary strata overlying basalt in the Walla Walla Basin can be divided into several main lithostratigraphic units, including: (1) Quaternary fine-grained deposits and loess, (2) Quaternary gravel deposits, and (3) Mio-Pliocene strata (Figure 7). Newcomb (1965) also described several terrace sequences within the Basin. These are not described in this report because they typically do not host aquifers. The basic physical characteristics and distribution of suprabasalt sediments in the region around the study area are briefly summarized in the following sections.

2.2.1.1 Quaternary fine-grained deposits and Loess

A variety of Quaternary aged fine (clay/silt/fine sand dominated) units are found throughout the eastern Basin. Above elevations of approximately 1150 to 1200 feet above sea level (msl) these deposits consist predominantly of loess. Isolated hills found on the valley floor and much of the hill mass north and west of the Walla Walla airport consist predominantly of Pleistocene Cataclysmic Flood deposited silt and sand. Reworked flood deposits and loess form local accumulations of fine strata across the valley floor. Characteristics displayed by each of these deposits are summarized further in the following paragraphs.

Loess - Pleistocene loess (also called the Palouse Formation) consists of eolian (wind-deposited), massive to poorly stratified silt and very fine sand deposits that display evidence of pedogenic (soil forming) modification (Figure 8) (Busacca and MacDonald, 1994). Pedogenic calcium carbonate may also be found in these loess deposits. Loess can range from less than 1 foot to several tens of feet-thick in the area (Newcomb, 1965). These loess deposits are thought to range from greater than 50,000 years old to less than 10,000 year old, making loess older than, age-equivalent to, and younger than the Touchet Beds.

Flood deposits - Cataclysmic Floods (e.g., Missoula or Bretz Floods) periodically inundated the Walla Walla valley between approximately 1,000,000 and 12,000 years ago depositing primarily silt and sand (Baker and others, 1991; Waitt and others, 1994). Sand and silt deposited in the Walla Walla Basin by these flood waters consist of stratified, normally graded, interbedded felsic silt and felsic to basaltic fine to medium sand (Figure 9). Finer grained layers tend to be brown to tan colored, coarser layers brown to gray-brown colored. Individual beds (or layers) usually range from a few inches to less than 3 feet-thick. These strata commonly do not display significant cementing, although some pedogenic calcium carbonate (caliche or hardpan) can be observed in the upper parts of these deposits where they are exposed at the Earth's surface. A range of soft-sediment deformation features and cross-cutting clastic dikes are commonly found in this unit (Fecht and others, 1999). Cataclysmic Flood deposits, also known as Touchet Beds, form most of the small hills located across the Walla Walla valley floor and along the base of the Blue Mountains to an elevation of approximately 1100 feet above mean sea level (msl).

Reworked fines – Discontinuous deposits of clay, silt, and fine sand are found on the flat valley floor across the Walla Walla Basin and in the drainages flowing into the Basin off adjacent highlands bordering the Basin. These fine grained deposits are inferred to be locally reworked loess and cataclysmic flood deposits which are eroded off upland areas and deposited into the drainages that cross cut the area. As such, these strata form what are essentially flood plain areas along modern stream courses. Except where good outcrops displaying bedding features and lithology occur, these strata are generally indistinguishable from their parent materials.

2.2.1.2 Quaternary gravel deposits

Uncemented and nonindurated sandy to gravelly strata is found in the shallow subsurface beneath much of the eastern Basin. Based on previously described outcrops of uncemented strata found elsewhere in the Basin (Newcomb, 1965) these gravely deposits probably are basaltic, moderately to well bedded, have a silty to sandy matrix, are generally uncemented, and contain thin silty interbeds (Figure 10). These uncemented and nonindurated gravels are generally equivalent to Newcomb's (1965) younger alluvial sand and gravel and are interpreted to record stream deposition in the Walla Walla Basin by streams draining off the adjacent Blue Mountains.

The age of these uncemented sand and gravel deposits is not well constrained. In some parts of the Basin these strata are found underlying loess and Touchet Beds. In the channels of the modern stream drainages (e.g., Walla Walla River, Mill Creek, Reser Creek, Russell Creek, Cottonwood Creek, etc.) these gravelly sediments are interpreted to be actively deposited and they may be contemporaneous with or younger than the Quaternary fines. Based on these stratigraphic relationships Quaternary gravel predates, is contemporaneous with, and post-dates Pleistocene cataclysmic flooding, giving these deposits ages of as little as a few thousand, hundreds, or even tens of years old to as old as 1 million years or more.

2.2.1.3 Mio-Pliocene strata

The predominant basin-filling strata found in the eastern Walla Walla Basin consists of a sequence of indurated sand and gravel dominated deposits generally overlying a sequence of siltstone and claystone deposits containing local to widespread interbedded sand and gravel. These strata range from less than 10 feet thick along the edge of the basin to over 800 feet thick in the structurally deepest part of the Basin. These strata are inferred to range in age from approximately 10+ to 2 million years old, giving them a Mio-Pliocene age. This assumed age is based on regional sediment stratigraphy trends described in Fecht and others (1987), Smith and others (1989), and Lindsey (1996). However, to our knowledge no absolute age dates are available for these strata in the Walla Walla Basin.

The Mio-Pliocene strata are generally equivalent to Newcomb's (1965) old gravel and old clay units. For the purpose of this report Mio-Pliocene strata are divided into two main units, a conglomerate unit and a fine unit. These are described in the following paragraphs.

Mio-Pliocene conglomerate - A sequence of variably cemented sandy gravel with a muddy to sandy, silcic to calcic matrix underlies much of the Walla Walla Basin. Field reconnaissance reveals thin, localized, discontinuous caliche at the top of these strata at some locations. Based on physical characteristics seen in rare outcrops of analogous strata and borehole log descriptions, these indurated gravel and sand predominantly are basaltic in composition and typically have a slightly too well developed red, red brown, and yellow brown color (Figure 11). Drill cuttings collected from wells recently drilled near Milton-Freewater, Oregon, show that these strata may also contain some micaceous and felsic intervals. Mio-Pliocene conglomerate is differentiated from the younger Quaternary gravels by color changes, the presence of weathered basalt gravel clasts, clay matrix, and cements which are absent in the younger gravels. Mio-Pliocene conglomerate are inferred to record deposition by the ancestral Salmon-Clearwater-Snake and Walla Walla River systems and include river channel deposits (sand and gravel), overbank and flood plain deposits (sand and silt), and lake deposits (silt and clay).

Mio-Pliocene fines - The Mio-Pliocene conglomerate is generally underlain by fine deposits variously described as silt, sandy silt, sandy mud, and blue, green, and yellow clay. However, review of driller's logs and logging of drill cuttings we have been able to collect from wells drilled in the Oregon part of the Basin and in a recently drilled well just north of the Test Site (Figure 12) suggest sandy and even gravelly intervals are present locally in these fine strata. These logs also reveal: (1) areas where strata correlative to one of the two units (conglomerate and fines) are absent and/or (2) areas where the inferred contact between the two units varies greatly in depth over distances of less than one mile. Given this, it is likely that the top of the Mio-Pliocene fines and bottom of the Mio-Pliocene conglomerate is not a single, continuous surface as suggested by Newcomb (1965). It is more likely that these strata interfinger and that two distinctive units are not present. Given this, the contact between the conglomerate and fines may not actually be a single, continuous surface. Bedding and stratigraphic relationships within these strata are unknown, making it difficult to determine if these predominantly fine strata are of a floodplain or lacustrine origin.

2.2.2 Basalt and Structural Geology

The CRBG underlies the entire Walla Walla Basin (Newcomb, 1965). Several miles west of the Test Site the top of basalt lies approximately 700 feet below ground surface (bgs). In the Basin, the CRBG may be as much as 5,000 feet thick and it consists of multiple, layered, stratiform, laterally widespread sheet basalt flows. The contacts between these basalt flows, referred to as interflow zones, occasionally contain interstratified sedimentary strata. Interflow zones, which commonly consist of vesicular to rubbly basalt, are separated by dense, largely impermeable, strataform basalt flow interiors. Aquifers found in the CRBG usually are hosted by interflow zones.

As noted earlier, the Test Site is located within the eastern portion of the Walla Walla structural basin which is inferred to have developed as the consequence of strike-slip tectonics (Kienle, 1980; WPPSS, 1981; USDOE, 1988). Previous geologic and hydrogeologic investigations (Newcomb, 1965, 1969; Farooqui and Thoms, 1980; Kienle, 1980; Swanson and others, 1980; WPPSS, 1981; Mann and Meyer, 1993; Schuster, 1994) have identified a number of faults and folds within the eastern Basin. The overall structural fabric of the Basin is defined by a number of up-faulted (horst) and down-faulted (graben) blocks superimposed on a relatively broad synclinal low that trends beneath the cities of Walla Walla and College Place. Previous investigations of the Basin (e.g., Farooqui and Thoms, 1980; Kienle, 1980; Swanson and others, 1980; WPPSS, 1981; Mann and Meyers, 1993) have noted that most of the faults exposed display evidence indicating both strike-slip (left- and right-lateral) and dip-slip displacement. This is expected given the nature of the major regional structures (Walulla Fault and Hite Fault Systems) that bound this portion of the Basin. Another expected consequence is the presence of numerous secondary and tertiary tectonic shears/ joints (faults) and folds cross-cutting the Basin created by the “local” stress regime between the major regional structures. The effects of folds and faults on the sedimentary strata in the immediate vicinity of the Test Site are not known.

2.3 Hydrogeologic Setting

Given the focus of the SAR project on the shallow aquifer system in the eastern Walla Walla Basin, an aquifer system hosted by sedimentary strata overlying the CRBG, this review of area and regional hydrogeology focuses on that aquifer system.

2.3.1 Physical Properties

The majority of the suprabasalt aquifer is hosted by the Mio-Pliocene conglomerate unit, although the uppermost part of the aquifer is found, at least locally, in the younger alluvial, or Quaternary, gravel unit. The suprabasalt aquifer is generally characterized as unconfined, but it does, at least locally, display evidence of semi-confined conditions. Variation between semi-confined and unconfined conditions within the aquifer system is probably controlled by sediment lithology (e.g., facies – coarse versus fine) and induration (e.g., cementation, compaction). Groundwater movement into, and through, the suprabasalt aquifer also is inferred to be controlled by sediment lithology and induration.

Given the physical properties of the Quaternary gravel (non-indurated sand and gravel) versus those of the Mio-Pliocene conglomerate (e.g., finer matrix and the presence of naturally occurring cement), Mio-Pliocene conglomerate probably has generally lower permeability and porosity than the Quaternary gravel. Consequently, suprabasalt aquifer groundwater flow velocities are inferred to be less where the water table lies within the Mio-Pliocene conglomerate than where it lies within the younger, more permeable Quaternary gravel. In addition, where the Quaternary gravel is saturated, this uncemented, high permeability gravel and sand may form preferred pathways for groundwater movement and areas of increased infiltration capacity in the shallow parts of the suprabasalt aquifer system.

Very little hydraulic property information is available for the suprabasalt aquifer. Newcomb (1965) reports average effective porosity of 5 percent in the old gravel (e.g., the Mio-Pliocene conglomerate). Given the physical characteristics of the overlying alluvial gravel, we suspect its average effective porosity is higher. Basin-wide estimates of the hydraulic properties of old gravel (e.g., the Mio-Pliocene conglomerate) aquifer system were made by Barker and Mac Nish (1976) as part of their effort to produce a digital model of this aquifer system. This modeling work used estimated hydraulic conductivity and transmissivity of $1.5\text{x}10^{-4}$ feet/second to $7.6\text{x}10^{-3}$ feet/second and 10,000 feet^2/day to 60,000 feet^2/day, respectively, for the entire suprabasalt aquifer. As with Newcomb's (1965) effective porosity estimate, we suspect hydraulic conductivity and transmissivity would be higher in saturated alluvial gravel than in saturated Mio-Pliocene conglomerate.

2.3.2 Groundwater levels and flow direction

Groundwater flow in the suprabasalt aquifer in the Walla Walla Basin area generally is thought to be from east to west. However, locally this flow is diverted towards the Walla Walla River and other streams where the suprabasalt aquifer water table is higher than the stream. Where this occurs, streams are, in part, fed by groundwater discharge. However, along many reaches of the Walla Walla River and other streams in the Basin, the suprabasalt water table may be, at least locally, below the bed of the stream during some or all of the year. When and where this occurs, such stream reaches probably lose water to the suprabasalt aquifer, thus acting as a recharge source for groundwater.

The elevation of the water table within the suprabasalt aquifer is known to vary seasonally. Barker and Mac Nish (1976, p. 25) determined that the month of January was the time of year when this aquifer is under the smallest amount of pumping stress and that water table most reflects unmodified conditions. In some portions of the Basin, seasonal changes in the water table elevation can be as great as 50 feet (Newcomb, 1965; Pacific Groundwater Group, 1995).

There is little recent and comprehensive data showing suprabasalt aquifer water table elevations in the eastern Basin. Water level data reported on well logs, and the few reports written for the Basin, suggest groundwater levels near the Walla Walla River (and many of the spring creeks) historically were relatively shallow, commonly less than 5 feet deep. With increased groundwater use over the past 20 years these water levels are generally thought to have declined, at least locally. A review of the U.S. Geological Survey water well level database for this area (available online at http://nwis.waterdata.usgs.gov/usa/nwis/gwlevels) also suggests this. This groundwater level decline is thought to account for, at least in part, the reduction in spring creek flow reported by many land owners in the Basin. We did not find an up-to-date map that portrays water table elevations in the eastern Basin.

2.3.3 Aquifer recharge

Recharge to the suprabasalt sediment aquifer is derived from infiltration of surface water (e.g., where streams enter the basin), leakage from irrigation ditches, applied irrigation water, direct precipitation, and to a lesser extent leakage from the CRBG aquifer system (Newcomb, 1965; Barker and Mac Nish, 1976; Pacific Groundwater Group, 1995). The majority of this recharge probably occurs in the spring when streams flowing into the Basin reach peak discharges. Precipitation on parts of the Basin floor where the alluvial gravel and older, Miocene-Pliocene strata lie at, or near, the surface may also provide some natural recharge. With flood control and channelization of the Walla Walla River and smaller streams, natural recharge via infiltration from surface waters has probably decreased with continued development.

Artificial recharge of the suprabasalt aquifer from agricultural practices and water conveyance systems has become an important component of the Basin's hydrologic system since the 1920's and 1930's. This recharge is thought to have historically contributed water to at least some shallow water wells and springs (Newcomb, 1965). Artificial recharge probably occurs through irrigation ditch leakage and infiltration past the root zone in irrigated fields. With the advent of ditch/channel lining and reduction in the practice of flood irrigation, this type of recharge has probably decreased. Reduced natural and artificial recharge will, and probably does, account for decreased suprabasalt aquifer water table levels. Decline in water table levels in-turn probably account for reduced spring flows and base level discharge to the Walla Walla River.

Discharge from the suprabasalt aquifer occurs in a number of ways, including direct discharge to streams, springs and seeps, pumped water wells, evapotranspiration, and localized leakage to the CRBG aquifer system (Newcomb, 1965; Barker and Mac Nish, 1976; Pacific Groundwater Group, 1995).

2.3.4 Hydraulic Continuity

There is little information in available reports that addresses the exact nature and extent of hydraulic continuity between the suprabasalt sediment aquifer system and surface waters (hydraulic continuity) in the Basin. However, generally it is accepted, based on anecdotal and empirical observations, that there is a significant degree of continuity between the suprabasalt sediment aquifer system and surface water. General information on this hydraulic connection in the Basin is found in Piper and others (1936), Newcomb (1965), Mac Nish and Barker (1976), Barker and Mac Nish (1976), Bauer and Vaccaro (1990), and Pacific Groundwater Group (1995).

The nature and extent of hydraulic continuity between the CRBG aquifer and surface waters within the Basin is not well understood, but generally assumed to be very limited because of the presence of the relatively impermeable "old clay" unit that overlies the CRBG (Newcomb, 1965). Pacific Groundwater Group (1995, p. 29) also concluded that hydraulic continuity between the CRBG aquifer and local streams within the Basin is very low because of: (1) the relatively impermeable characteristics of both CRBG flow dense interiors and the overlying old clay unit and (2) Carbon-14 age dating of CRBG groundwater which indicates ages of 18,000 to 22,000 years.

Their also appears to be little evidence supporting a significant hydraulic connection between the suprabasalt aquifer and basalt aquifer. However, as noted by Newcomb (1965, p. 34), the presence of uncased (unsealed) water wells can create man-made pathways for vertical groundwater movement that would have not previously existed. The extent to which unsealed wells provide a vertical groundwater pathway in this portion of the Basin has not been evaluated. Given these observations though modeling studies (Barker and Mac Nish, 1976: Mac Nish and Barker, 1976) suggest there is steady leakage from the basalt aquifer system into the suprabasalt sediment aquifer. These modeling studies estimated a net annual total of 10,000 acre-feet of water moving from the CRBG aquifer into the sediments.

2.3.5 Water Quality

No up-to-date comprehensive groundwater quality data for the study area was found. However, an Oregon Department of Environmental Quality (ODEQ) report (Richerson and Cole, 2000) prepared for the northern portion of Umatilla County, immediately adjacent to the Stateline bordering the southern edge of the study area, does provide insights into possible groundwater quality conditions.

Two water quality parameters presented in the ODEQ report suggest groundwater quality in the uppermost suprabasalt aquifer near the Stateline is relatively good with regard to ODEQ standards. These parameters, total dissolved solids (TDS) and nitrate-N, range from 150 to 250 mg/l and 0.5 to 4.5 mg/l, respectively on the Oregon side of the Stateline. Concentrations of these parameters decrease from north to south toward where the Walla Walla River enters the valley. This trend suggests the introduction of low nitrate-N and TDS surface water into the groundwater system and supports Newcomb's (1965) conclusion that surface water recharge of shallow groundwater occurs where the Walla Walla River enters the Basin. The increase in TDS and nitrate-N concentrations as suprabasalt groundwater moves north into the Basin is inferred to be, at least in part, the result of the relative increase in recharge from irrigation water reaching the suprabasalt aquifer. If the water quality trend reported in Richerson and Cole (2000) for Oregon continues into Washington, one would expect groundwater quality parameters at the Stateline to be similar to those seen immediately south in Oregon.

Section 3: Regulatory Framework, Site Physical Layout, and Methods

As noted in the introduction, the H-W SAR Test Site was selected for this project because of its past use by local land owners as an informal recharge site. This section describes the regulatory framework which the project operated under, site physical layout, and methods used to conduct site characterization, monitoring, and SAR testing.

3.1 Regulatory Framework

Because the actual Test Site where water was discharged to the ground for aquifer recharge is located in the State of Oregon, activities at it related to the test are regulated under Oregon law. Permission to conduct the test, including permission to use water for the purpose of shallow aquifer recharge was granted under OWRD Limited License 915 (the License) issued to the Walla Walla River Irrigation District (WWRID) on 17 November 2005. The license, which is good for the period of 17 November 2005 through 15 April 2010, grants WWRID the authority to conduct SAR testing at the Hall-Wentland Site. A copy of the License is attached to this report as Appendix A.

Some of the primary regulatory conditions that needed to be met for the test project include the following:

- Fish screens and flow measurement weirs need to be installed as directed by ODFW and OWRD prior to the start of the test season. These structures need to be maintained in good working order when recharge testing is being done.
- The approved test season extends from 1 November of one year through 15 April of the succeeding year.
- Source water and groundwater sampling and analysis (e.g., monitoring).

- Testing can only be done when a minimum stream flow of 3.5 cubic feet per second (cfs) is met on the East Fork of the Little Walla Walla River as measured at Ecology gauging station 32H090 on State Line Road.

- The License also set minimum stream flow requirements for the Walla Walla River if water is ever to be diverted from it, into the ELWW for delivery to the test site via the ELWW and Wells Ditch system.

3.2 Physical Layout

The basic physical layout of the Test Site as it was constructed and used during the test season reported on herein is shown on Figure 13 and summarized below:

- A fish screen and flow measurement weir (Figure 14), as required by the License conditions, were installed at the turnout for the branch ditch leading to the Test Site off of Wells Ditch. The turn out structure was modified to accommodate the weir and screen. These structures are both temporary and only in place during testing.

- Water is carried to the Test Site from Wells Ditch via the previously existing branch ditch (Figure 15). This ditch was not modified for the first season of SAR testing described herein.

- Flow volume onto the Site was measured using a weir constructed in the branch ditch as it enters the Site (Figure 16). This structure also is temporary and only in place during testing.

- The Site itself consists of an alfalfa field (the western portion) and pasture (the eastern portion). For this testing season the only onsite modifications were some shallow ditches hand dug to allow better water flow out of the branch ditch and onto the Site (Figure 17). For this season the team decided to not construct infiltration basins or trenches for several reasons:

    - The short time frame of the recharge season once we deployed to the field and started work argued against conducting additional onsite improvements. The team decided to not engage in any additional preparation activity that would have potentially delay test start up.

  - At the time of the test the landowners had not given the team explicit permission to engage in extensive onsite excavation. Until we have that we are not going to engage in significant excavation activity.

  - We wanted to test unmodified fields to start building a baseline infiltration picture so that, if we ever build trenches or ponds we have data to compare to and evaluate the potential benefits of constructed infiltration features versus unmodified fields.

- Three purpose-built shallow groundwater monitoring wells, HW-1, HW-2, and HW-3, were built on or very near the site to facilitate water quality sampling and water level monitoring. The locations of these wells are shown on Figure 2. Geologic logs and as-built diagrams for these wells are reproduced in Appendix B.

- A number of previously existing water wells were used to collect additional water level measurements before, during, and after testing. The locations of these wells, MC-1 through MC-10, are shown on Figure 2. Water well logs for these wells, if they could be found, are reproduced in Appendix C. Geologic and hydrologic information from these, and the monitoring wells, are discussed later in this report. Table 1 presents a compilation of interpreted geologic unit top surface elevation and thickness data for wells used in this project.

3.3 Methodology

Testing and monitoring activities for this project were carried out as described in revision 3 of the project monitoring and test plan (Kennedy/Jenks, 2005) and in accordance with the provision of the License. Those documents specified monitoring locations, sampling frequency and analytes, and procedures to be used in data collection, analysis, and reporting. Methodologies used to implement the monitoring and test plan and requirements of the License are summarized in this section.

3.3.1 Water Level and Flow Measurements

Water levels in wells were measured using two basic methods, a manual method and an automated method. The manual method, done periodically in both water wells and monitoring wells, was done using an electronic water level sounder, or e-tape. Prior to measuring water level with an e-tape, it would be checked by depressing the test button. If the test light and beeper responded to the test, the e-tape was lowered into the well until the light and beeper indicated water was encountered. When this happened the e-tape would be raised and lowered several times to check the reading. The depth to water below a marked reference point on the well would then be read off the marked tape. Water level data for the water wells was collected approximately weekly prior to, during, and immediately following the test.

Automated water level measurements were collected using self contained pressure transducers and data loggers (transducers). One transducer suspended from a steel cable was installed in each of the three monitoring wells. The transducers were manufactured by Solinst. Periodically the transducers were removed from the wells and data was transferred from them to a laptop computer. When this was done a manual water level measurement also was collected to provide a check for the transducer data. The transducers were programmed to collect a measurement at the top of the hour prior, during, and immediately following the test.

Flow measurements in the branch ditch at the turnout off Wells Ditch and where the branch ditch entered the Test Site were collected using a transducer. The transducer measurements were calibrated to a staff gauge at each weir. The staff gauges were in turn calibrated to the weirs which were standard 3 foot wide sharp-edge, rectangular weirs. Transducer data was converted to flow over the weir (in cfs) using the standard conversion for a three foot rectangular weir.

3.3.2 Water Quality Sampling

Both surface water and groundwater were sampled and analyzed for the project. Source water was collected in the branch ditch at the measurement weir installed where the ditch enters the Site (Figure 16) when the branch ditch was flowing. If it was not flowing at the time of sampling, samples would be collected at the Wells Ditch diversion to the branch ditch. Groundwater was collected from the three purpose-built monitoring wells. All samples were placed bottles supplied by the analytical laboratory (Kuo Testing Laboratory). The bottles were compatible with the test analytes and as they were collected they were placed in an iced cooler for shipment to the laboratory. Samplers field notes, chain of custody forms, and laboratory reports are reproduced in Appendix C.

Source water samples were collected directly into the sample bottle by dipping the bottle into the ditch. If surface debris was present in the ditch at the sampling location an attempt was made to remove the debris. Field water quality parameters were measured at the time of sample collection.

Groundwater was collected from monitoring wells by pumping the water to the surface using a sampling pump. Each well was purged prior to sample collection, with a minimum purge volume being equal to three casing volumes as calculated at the time of sampling. Field water quality parameters were measured periodically during purging. If, after three well volumes were purged the field parameters were still changing purging continued until those parameters stabilized. Once a well was purged the sample was pumped directly into the sample bottle.

3.3.3 Test Operations

The Site, including turnouts, control gates, and water distribution was manually operated by the project engineer and site operator. Once testing started their main activities focused on removing obstructions in the ditch system, cleaning the fish screen, and manually reading staff gauges. They also shifted the delivery point of recharge water onto the Site as needed by plugging berms and opening sluices. On the Site proper, water was simply allowed to perculate into the ground without the aid of trenches, ponds, and ditches or the removal of topsoil. Throughout the test the Site operator and site engineer visited the Site at least every 2 to 3 days and were on-call to address landowner concerns and needs with respect to the test.

Section 4: Site Conditions

Site conditions are characterized using a mix of area and regional information and Site specific data collected during the project. Using this information and data, this section describes the geologic and hydrogeologic conditions at the Site and in its immediate vicinity. Because the target of this SAR test project is the shallow aquifer, typically found within several tens of feet of the Earth's surface and hosted by the suprabasalt sediments, this discussion focuses on approximately the upper 200 feet of the sedimentary strata underlying the Site area. For the purpose of the following discussion this interval is referred to in the remainder of this discussion as the shallow sediments.

4.1 Site Geology

Three primary sedimentary units dominate the shallow sediments in the vicinity of the Site, Quaternary fines, Quaternary gravels, and Mio-Pliocene conglomerate. Unit distribution and characteristics, interpreted from onsite drilling and existing well logs, are summarized in the following bullets:

- Quaternary fines – In the immediate Site vicinity these strata consist predominantly of Pleistocene Cataclysmic Flood deposits, e.g., Touchet Beds. These strata compose the bulk of the small hills found west, northwest, and east of the Site, where the unit can be 50 feet or more thick. On the flat valley floor where the Site is located this unit is thin to absent, forming a discontinuous surface layer that probably consists predominantly of reworked Touchet Beds and loess.

- Quaternary gravels – These uncemented, basaltic gravels underlie essentially the entire Site area except locally along the ELWW River (Figure 18). At the Site the unit is interpreted to be approximately 10 feet thick. It is inferred to thicken to the north (up to 15 feet thick), south (25 feet thick), east (40 feet thick), and west (15 to 20 feet thick).

- Mio-Pliocene conglomerate – These older, indurated, basaltic gravels (conglomerate) underlie the entire Site area. The top of the unit forms an undulating surface that generally dips to the north-northwest (Figure 19). The top of the unit appears to be slightly higher in elevation beneath the Site than elsewhere in the immediate area. The base of this unit appears to lie approximately 200 to 240 feet below ground surface (bgs) in the vicinity of the Site (Table 1), making it approximately 150 to 200 feet thick in the Site area.

The shallow sediment sequence in the Site area is underlain by several hundred feet of fine strata interpreted to be Mio-Pliocene fines. Based on geologic logging of cuttings from a recently drilled well located approximately 1 mile north of the Site (Figure 12), the fine strata in the Test Site area consist predominantly of green, gray, and blue claystone and brown, occasionally micaceous siltstone. These fine strata also contain significant interbedded conglomerate and sand.

4.2 Site Hydrogeology

The shallow aquifer underlying the Site area generally is found 10 to 30 feet bgs. It is interpreted to be unconfined at the Test Site because of the absence of any overlying confining lithologies. Based on the water levels measured to-date it generally appears to form a north-northwest dipping surface, suggesting groundwater flow generally towards the Walla Walla River (Figure 20). Data collected prior to testing suggests the water table in the immediate vicinity of the Test Site may dip more to the west than north, essentially away from the ELWW River (Figure 20). At the Test Site the shallow aquifer water table lies at an elevation of 735 to 745 feet, sloping northwards to an elevation of 680 to 690 feet near the Walla Walla River. The water table generally has a gradient of 0.0057 foot per foot, or 30 feet per mile. Additional water level measurements from other shallow wells in the area are needed to better constrain the water table in the Site area.

The work conducted for the project to-date did not result in the collection of aquifer hydrologic property data, such as permeability, hydraulic conductivity, and transmissivity. This data gap will need to be filled in future investigations and is contingent on the availability of funding necessary to collect the data.

4.3 Surface Water

Surface water in the immediate vicinity of the Site is found in both streams (such as the East and West Little Walla Walla River, McEvoy spring creek, Walla Walla River) and irrigation ditchs, most notably Wells Ditch and its branches (Figure 3). Both the East and West Little

Walla Walla Rivers have been heavily modified by artificial channelization and irrigation diversions. The basic characteristics of several of the streams and ditches close to the Test Site are summarized in the following bullets:

- East Little Walla Walla River – This stream is the main source of water for the Test Site, being delivered to the Site via Wells Ditch. The Limited License stipulates that testing can only be done when flows in this stream meet or exceed 3.5 cubic feet per second (cfs) as measured at Ecology gauge 32H090 located on the north side of State Line Road. Water in the ELWW is derived from a combination of spring and baseflow seepage along gaining reaches and surface flow out of the WWRID irrigation system located several miles upstream (south) of the Test Site. Based on historical records for the ELWW gauge this stream generally flows between 3 and 5 cfs except during precipitation events when flow can be as much as 8 to 9 cfs. During the test described herein, flow at the Ecology gauge met or exceeded the 3.5 cfs minimum flow (Table 2) mandated by the Limited License.

- Wells Ditch is an artificial ditch constructed to divert water from the East Little Walla Walla River to irrigated farmland located west of that stream. Flow in Wells Ditch is controlled by a manually operated head gate on the ELWW River. Flow through the Ditch usually varies from none to approximately 3 to 4 cfs.

- McEvoy spring creek is an informally named spring feed stream lying north of the Site and draining northwards into the Walla Walla River. Historical flows (1930's through 1970's) in this spring creek averaged between 3 and 4 cfs, although in recent years flow typically is less than 0.5 cfs (T. Page, personal comm.). The source of water for this creek is generally thought to be shallow groundwater flowing north towards the Walla Walla River.

4.4 Water Quality

Water quality data was collected prior to testing from the 3 purpose built groundwater monitoring wells, HW-1, HW-2, and HW-3, and the branch ditch. This was done in order to better characterize background water quality conditions prior to testing (which began on 6 March 2006) so that there was a baseline to measure test effects against. As described in the test and monitoring plan (Kennedy/Jenks, 2005) two types of parameters were collected: (1) field measurement (pH, temperature, electrical conductivity, and turbidity) and basic chemistry (nitrate-N, nitrite-N, hardness, total dissolved solids, chloride, soluable reactive phosphorus, chemical oxygen demand, coliform presene/absence, and e-coli presence/absence) and (2) synthetic organic compounds (Table 3). Pretest water quality results are summarized below and in Tables 4 and 5. Laboratory reports are included in Appendix D.

- Nitrate-N concentration in groundwater and surface water (Figure 21) prior to testing did not exceed 1.8 mg/l, having a measured range of approximately 0.2 to 1.7 mg/l. Concentrations in surface water generally were lower than in groundwater. Up gradient groundwater (HW-2) generally had lower concentrations than down gradient groundwater (HW-1).

- Hardness ranged from approximately 50 mg/l in surface water to slightly higher than 80 mg/l in some groundwater samples (Figure 22). Up gradient groundwater hardness was generally higher than down gradient groundwater hardness.

- Total dissolved solids (TDS) ranged from approximately 100 mg/l to 170 mg/l in all samples (Figure 23). Like hardness, TDS generally was higher in up gradient groundwater than down gradient groundwater.

- Chloride concentrations (Figure 24) measured for this project are difficult to interpret because laboratory analysis problems. A number of laboratory analysis returned non-detect at values higher than the laboratory method detection limit. Given these uncertainties though, chloride concentrations generally appear to be lower in surface water and lower in up gradient versus down gradient groundwater.

- Soluable reactive phosphorus (SRP) data (Figure 25) experienced some of the same apparent laboratory problems as chloride. Nevertheless, surface water SRP is higher than groundwater and up gradient groundwater SRP is lower than down gradient SRP.

- Field pH ranged from approximately 7.3 to 6.4 (Figure 26). Surface water pH is higher than groundwater pH. There is no readily discernable up gradient to down gradient trend in groundwater pH prior to testing.

- Electrical conductivity ranged from 1000 to 1500 mS/cm (Figure 27), with surface water generally being lower than groundwater. Up gradient groundwater generally had higher values than down gradient groundwater.

Two SOC's were detected in the pre-test water quality analysis, diethyl phthalate and di(ethylhexyl)-phthalate (Table 5). Both of these occurred in surface water and groundwater. No up gradient to down gradient trends can be readily ascertained from the SOC data collected to-date.

Section 5: Test Results

This section describes and interprets data collected during the test, which ran from 6 March 2006 through 15 April 2006. A timeline, describing pre-test, test, and post-test events relevant to data interpretation also is included.

5.1 Timeline

A chronology of specific events and activities undertaken at and near the Site before, during, and following testing, starting with receipt of the Limited License is presented below.

17 November 2005. Limited License to conduct test granted to WWRID by OWRD. License is good for a period of 5 years.

19 and 20 December 2005. Monitoring wells HW-1, HW-2, and HW-3 drilled and constructed for use as near Site monitoring points, including collection of water quality samples.

20 January 2006. Pressure transducers installed in the three monitoring wells.

2 February 2006. First pre-test water quality samples collected as called for in test and monitoring plan.

8 February 2006. Pressure transducers installed in Wells Ditch at the branch ditch turnout to the Site and in the branch ditch where it enters the Site.

21 February 2006. Site visit with ODFW and OWRD staff to visually inspect fish screen and gauging weirs, and get their concurrence that these structures are acceptable for the test. Verbal concurrence received on Site, written concurrence received several days latter.

22 February 2006. Second pre-test water quality sampling event.

24 February 2006. Wells Ditch diversion from East Little Walla Walla River closed to reduce flow into Wells Ditch and the Site area. This was done to facilitate final work at the Wells Ditch diversion to the Site and see if groundwater level would drop at the Site.

2 March 2006. Third pre-test water quality sampling event.

6 March 2006. Testing started at approximately 0949 when water started flowing down the branch ditch to the Test Site. Water spread onto the Hall (east) portion of the Test Site via simple breaks in the berm bordering the branch ditch as it comes onto the Test Site.

9 March 2006. Fourth water quality sampling event.

7 April 2006. Standing water in Hall field (eastern) portion of Test Site spreading into areas the landowner did not want inundated. Branch ditch to Test Site shut down while adjustments are made in how water distributed onto the Test Site.

10 April 2006. Testing resumes with water largely being delivered to Wentland (western) portion of the Test Site.

12 April 2006. Fifth water quality sampling event.

15 April 2006. Test terminated for the season as per the Limited License. Fish screen and measurement weirs removed the following week.

11 May 2006. Final (sixth) water quality sampling event.

5.2 Onsite Conditions and Water Delivered

Based on pressure transducer data collected at the diversion weir off Wells Ditch, and converting that data to flow which is based on the size of the weir, approximately 82 acre-feet of water was diverted toward the Test Site during the six weeks of the test (Figure 28). During the first two weeks (between 6 and 20 March) of the test water was delivered at an average rate of approximately 0.6 to 0.9 cfs. During the second 2 weeks delivery rates increased to approximately 0.8 to 1.6 cfs. In the final 2 weeks of the test, ending on 15 April, delivery rates for water diverted to the test site generally ranged from 1.0 to 2.4 cfs. All water delivered to the Site during the test was derived entirely from ambient flow in the ELWW. No water was purposely supplied to the test from the Walla Walla River via the ELWW.

Data collected from the Site weir appears to be unreliable as it shows a number of instantaneous flow rates (Figure 29) in excess of those measured at the Wells Ditch diversion weir (Figure 28). This unreliability is thought to be due to the low vertical drop across the weir as shown in Figure 16. Given the low gradient of the branch ditch it proved difficult to construct a weir with sufficient drop for reasonable measurements at higher flow rates when water would back-up across the weir. If these peak flows are disregarded than average flows onto the Site are estimated to range from 0.4 to 1.5 cfs with rates generally increasing as the test progressed. If these estimated flows are correct, several tenths of a cfs appear to be lost as water flows down the branch ditch from Wells Ditch to the Test Site.

Prior to the 7 April temporary test shut down all water delivered to the Test Site was distributed onto its eastern portion, the Hall field. Water was simply allowed to flow out of the branch ditch onto the Hall field via breaches in the berm bordering the ditch (Figure 17). After the restart of the test on 10 April recharge test water was delivered predominantly onto the western portion of the Test Site, the Wentland field.

5.3 Water Table

This discussion of water table changes before, during, and after testing focuses on two major subjects. One is water table changes in the monitoring wells containing transducers. The other focuses on the manually measured water supply wells. Figures associated with this discussion include hydrographs for the transducer data collected from the 3 monitoring wells (Figure 30), hydrographs for the manually measured water wells (Figure 31), and water table maps constructed for several times during and following testing (Figures 32, 33, and 34).

5.3.1 Transducer Data from Monitoring Wells

All three monitoring wells displayed water level changes interpreted to be in response to testing. All three wells displayed water level decreases corresponding to the pre-test shut down of Wells Ditch and the branch ditch, water level increases corresponding to the start of testing, and falls and rises corresponding to the 7 April temporary shut down. Water level changes in each of the three monitoring wells are summarized below and shown on Figure 30.

In HW-1, located at the northern end of the Site, water level began to rise within a few hours of the start of testing from an initial level of approximately 735.5 feet to a high of approximately 744 feet just prior to the 7 April event. When the test was temporarily shut down water level in HW-1 fell to approximately 738.5 feet, reaching that level on 13 April, 3 days after the test restart. After the restart water level rose too approximately 739.3 feet on 16 April. From then on water level in the well declined continuously to the end of data collection on 11 May.

Well HW-2, although located up gradient of the Site, also appears to have responded to testing. Beginning within a few hours of the start of testing water level in HW-2 began to slowly rise, increasing approximately 1.5 feet from the start of testing until 28 March. At that point, until the end of the test water level in the well experienced a significant rise of approximately 14 feet. Following the end of the test on 15 April water level dropped to a low of approximately 748 feet on 11 May. This post test water level is higher than pretest and early test levels.

Well HW-3 is, like HW-1, located down gradient of the Test Site. Water level in it was the lowest of the three monitoring wells, and it shows the smallest absolute elevation changes during the test. Starting at an elevation of approximately 733 feet water level in the well slowly rose to approximately 735 feet during the portion of the test leading up to the 7 April temporary shut down. After the test restart water level in the well rose to its highest recorded level during the test, an elevation of approximately 735.8 feet. This level was reached on 16 April, one day after the end of the test. This well displayed a larger rise than the other down gradient well following the temporary shut down. This suggests that the shift in recharge from the eastern to the western portion of the Test Site shifted the general direction and location of the recharged groundwater mound sufficiently for this well to respond more than the other down gradient well (HW-1).

5.3.2 Manual Measurements from Water Wells

Three water wells located near the Test Site, MC-7, MC-8, and MC-9, also display water level changes (Figure 31) interpreted to correspond to test activities. Measured weekly, water levels in all three of these wells rose following the start of testing and each show declines and subsequent rises soon after the 7 April temporary test shut down. Water level measurements taken following the end of testing on 15 April show water levels declining in all three wells. Well MC-8, located essentially on the Site, shows the largest water level fluctuations (rising approximately 10 feet) of all water wells monitored during the test.

Water wells MC-1 through MC-6 (except MC-5 which was generally plugged by debris), all located down gradient of the Site, displayed varying water level changes (Figure 31). Wells MC-

4 and MC-6, located closest to the Site, generally show decreasing water levels from before the start of testing into early to mid March. At that point they both show rising water levels until the first measurement following the end of the test. At that time water levels in the two wells began to fall, which continued to the last measurement on 9 May. Water level in well HW-3 declined until late March. Between 3 April and 10 April it rose, followed again by a decline. Water levels in wells MC-1 and MC-2, located approximately 1.5 miles north of the Site were generally rising throughout most of the period of the test.

Well MC-10, located approximately 0.5 miles up gradient (south) of the Test Site, displayed water levels that generally rose during the test and fell following the test. It is conceivable, from the data colleted to-date, that water levels in most of the MC wells, except MC-1 and MC-2, were influenced by the test. In particular, MC-7, MC-8, and MC-9 responded to testing, all showing levels interpreted to reflect the April 7-10 shut down and restart. The water level changes seen in MC-10 suggest up gradient propagation of recharge effects (e.g., mounding) extend at least 0.5 miles.

5.4 Water Quality

Two water quality sampling events were conducted during the test, one on 9 March and one on 12 April. Water quality parameters showed some change from pretest conditions as follows:

- Nitrate-N rose slightly, but stayed under 2 mg/l during the test. During the test nitrate-N concentrations became the highest in well HW-2, the up gradient well (Figure 21). It stayed the highest of all measured concentrations following the test.
- Hardness stayed relatively the same before and during the test, with only minor decreases in well HW-2, the up gradient well (Figure 22). Following testing hardness increased in well HW-2.
- TDS decreased during the test, with measured concentrations being lowest in the source water (Figure 23). Following testing TDS increased in all thee wells.
- Although there are some problems with the chloride data as noted earlier, chloride concentrations appear to have stayed relatively low during the test (Figure 24).

- SRP increased as testing proceeded. Tis increase stopped after the end of testing (Figure 25).
- pH in groundwater decreased during testing. Source water had the highest pH during the test (Figure 26).
- Electrical conductivity increased in the two down gradient wells during the test and decreased in the up gradient well, HW-2. Source water electrical conductivity increased during the test, although to lower values than seen in the wells (Figure 27). Following testing up gradient electrical conductivity increased, down gradient it seemed to stabilize.
- SOC's were not detected in either source water or groundwater during the test (Table 4).

Based on the water quality data collected during the first SAR test season at the H-W Site, introduction of surface water into the shallow suprabasalt aquifer groundwater system by infiltration may have had some, relatively minor influence on groundwater quality. The slight rise in nitrate-N concentrations seen in groundwater may be due to flushing of nutriest held in the vadose zone by recharge water. If so, with continued testing one would expect this effect to become less with longer recharge events and/or larger volumes of recharge water. The same trend seen in SRP, and again, it may be due to soil flushing of nutrients by recharge water. Also, it could be related to the slightly higher SRP of the source water leading to increased groundwater SRP as the test adds this water to the aquifer system. The inverse trends seen in TDS, it decreases as the test continues, may reflect flushing of the vadose zone soil column by low TDS source water and/or simply dilution of higher TDS groundwater by lower TDS surface water.

Section 6: Summary and Recommendations

6.1 Summary

This report presented the results of a shallow aquifer recharge test conducted at the Hall-Wentland Site located just south of the Washington-Oregon border. The testing reported on in this report is the first of several seasonal tests currently planned for the Hall-Wentland Site. Such seasonal SAR testing will be conducted during the winter and early spring in the next few years. This, and subsequent SAR testing at the Hall-Wentland Test Site, was done to begin evaluating the feasibility of using SAR to help restore depleted shallow sediment aquifer groundwater levels and improve flow in spring creeks and streams. Testing at the Hall-Wentland Site is permitted under a Limited License granted by the Oregon Water Resources Department. This license authorizes testing for a total of five years, and specifies a recharge season each year as extending from November of one calendar year to April of the following year.

SAR testing utilized ambient stream flows in the East Little Walla Walla River. Water was diverted form this stream to the Test Site via an irrigation ditch known as Wells Ditch and a branch ditch off Wells Ditch which delivered it to the Tests Site. Flow rate in the branch ditch leading to the Test Site was measured at two temporary weirs, one at Wells Ditch and one where the branch ditch enters the Test Site. A fish screen was placed at the head of the branch ditch leading to the Test Site to prevent unwanted fish entrapment and loss. Pre-test groundwater levels and water quality were monitored via three monitoring wells built at the Test Site and 10 previously built water supply wells located up to 2 miles away from the Test Site. These wells also were monitored during and following testing.

The aquifer targeted for testing is hosted by suprabasalt sediments. At the Hall-Wentland Site these strata consist predominantly of pebble to cobble gravel and conglomerate overlain by a thin veneer of non-indurated pebble to cobble gravel. The suprabasalt sediment aquifer system at the Test Site is unconfined, groundwater flow in it is predominantly towards the north, and water quality shows relatively minor impacts from human activities. The unconfined water table at the Test Site lies approximately 20 feet below ground surface. Based on these depths, and the water table data collected for this project, the nearby East Little Walla Walla River and Wells Ditch appear to be providing recharge to the aquifer in the Test Site area.

The test event reported on in this report began on 6 March 2006 and concluded on 15 April 2005. A total of approximately 82 acre-feet of water was diverted from Wells Ditch, and of this amount it is estimated that approximately 60 to 70 acre-feet was actually delivered to the Test Site. The difference is inferred to be seepage out of the branch ditch as water flows through it. Recharge water was distributed onto the eastern portion of the Test Site for most of the test. Late in the test, recharge water was distributed predominantly onto the western portion of the Test Site. In both cases, water was allowed to simply flow onto the ground surface and percolate into the ground without the use of infiltration ponds and trenches.

SAR testing resulted in the formation of a groundwater mound beneath the Test Site. Recharge water appeared to move north and northwest, with several of the water wells down gradient of the Test Site appearing to show the effects of recharge. The effects of the recharge mound also appear to have propagated up gradient at least 0.5 miles. During recharge several groundwater parameters displayed changes suggestive of flushing of constituents from the soil column and/or dilution of groundwater by surface recharge water. Following the end of the test the recharge mound quickly dissipated.

6.2 Recommendations

Based on the first season of SAR testing at the H-W Test Site we have a number of recommendations. Some are short term and should be achievable with current funding projected for the project for the 2006/2007 recharge season. Other, both short and long-term, recommendations probably are not achievable with current funding and would require the securing of new funds.

Short term recommendations for the 2006/2007 recharge season which might be met with current funding include:

- Spreading water over both sides of the recharge site, either continuously or cyclically.

- Removal of debris and find sediment from both Wells Ditch and the branch ditch to the site.

- Adding additional water wells to the manually measured water well network, especially west of the current wells.

- Manually track flows in Wells Ditch using additional staff gauges.

Short term recommendations for 2006/2007 that would likely require additional funding include:

- Installing transducers in water wells or new monitoring wells to better constrain water levels before, during, and after testing.

- Installing a transducer in monitoring points in Wells Ditch both above and below the diversion to the Test Site.

- Conduct an aquifer test in the immediate Test Site area in either an existing water well (if its construction and physical condition can be determined) or ina purpose built new well.

Longer term recommendations, all requiring additional funding includes those in the previous three bullets and the following:

- Expand the size and capacity of the ELWW and Wells Ditch system.

- Address WWRID concerns (with physical structures and/or regulatory exclusions) regarding false fish attraction issues related to the purposely introduction of Walla Walla River water to the ELWW and Wells Ditch system.

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Tables

Well ID	Easting	Northing	Surface Elevation	Qf Top	Qf Thickness	Qg top	Qg Thickness	Mpc Top	Mpc Thickness	Mpf Top
635-09G	388566	5096882	683	683	14	669	30	639	>146	-
635-09J1	388962	5096419	700	NP	0	700	45	655	>65	-
635-09R	389180	5095705	728	728	7	NP	0	721	>73	-
635-10B	390437	5096862	708	708	5	703	3	700	>130	-
635-10C	389722	5097201	692	692	3	689	20	669	>84	-
635-10H	390619	5096737	715	715	5	710	15	695	>144	-
635-10H1	390665	5096408	726	726	9	NP	0	717	153	564
635-10J	390687	5096283	732	732	10	NP	0	722	>49	-
635-10J2	390521	5096286	728	728	8	720	5	715	>89	-
635-10N	389593	5095803	729	729	5	724	20	704	>30	-
635-10Q	390395	5095889	732	732	13	719	9	710	>90	-
635-11E	391239	5096707	723	723	18	705	4	701	>62	-
635-11Q	391909	5095629	800	800	59	741	14	727	125	602
635-14F1	391483	5095124	766	766	7	759	28	731	>125	-
635-15G1	390205	5095255	765	765	27	738	8	730	>46	-
HW1	390630	5095033	764	NP	0	764	9	755	>42	-
HW2	390649	5094642	771	771	1	770	9	761	>40	-
HW3	390470	5095071	757	757	1	756	13	743	>36	-
LEIBER	390652	5094491	765	NP	0	765	20	745	>78	-
MC-10	391067	5094039	797	NP	0	797	32	765	>58	-
MC-3a	390224	5095995	733	NP	0	733	18	715	222	493
MC-4	390367	5095686	740	NP	0	740	11	729	>34	-
MC-5	390262	5095119	759	759	14	NP	0	745	>46	-
MC-9	390804	5094715	771	NP	0	771	40	731	>10	-
U4215	391605	5094530	781	NP	0	781	8	773	>134	-
U4224	391220	5094548	784	784	18	766	33	733	>74	-
U4249	390345	5094767	771	NP	0	771	10	761	163	598
U54912	389594	5094308	771	NP	0	771	30	741	>73	-
U54970	389936	5094641	764	NP	0	764	47	717	201	516

Table 1. Geologic unit tops and thicknesses for wells used in this report.

Date	Staff Gauge Reading (ft)	Flow (cfs)
21-Feb	0.34	3.75
27-Feb	0.42	4.57
3-Mar	0.41	4.47
4-Mar	0.42	4.57
5-Mar	0.42	4.57
6-Mar	0.34	3.75
7-Mar	0.42	4.57
8-Mar	0.32	3.54
10-Mar	0.32	3.54
13-Mar	0.32	3.54
14-Mar	0.32	3.54
16-Mar	0.32	3.54
17-Mar	0.33	3.65
20-Mar	0.33	3.65
22-Mar	0.32	3.54
23-Mar	0.33	3.65
27-Mar	0.38	4.16
28-Mar	0.38	4.16
29-Mar	0.39	4.27
30-Mar	0.39	4.27
3-Apr	0.39	4.27
4-Apr	0.48	5.25
5-Apr	0.39	4.27
6-Apr	0.45	4.91
7-Apr	0.46	5.02
8-Apr	0.6	7.27
10-Apr	0.65	>7.9
13-Apr	0.49	5.36
14-Apr	0.46	5.02
17-Apr	0.62	7.63
22-Apr	0.64	>7.9
24-Apr	0.6	7.27
2-May	0.6	7.27
9-May	0.6	7.27

Table 2. Flow before, during, and after at the Ecology gauge on the East Little Walla Walla River.

Table 3. Synthetic organic compounds analyzed for this report.

DOH#	Compounds	Units	SRL	Trigger	MCL	Comments
	Carbamates in Drinking water					
146	Carbofuran	ug/L	1.8	1.8	40.0	EPA Regulated
148	Oxymal	ug/L	4.0	4.0	200.0	EPA Regulated
141	3-Hydroxycarbofuran	ug/L	2.0	2.0		EPA Unregulated
142	Aldicarb	ug/L	1.0	1.0		EPA Unregulated
143	Aldicarb Sulfone	ug/L	1.6	1.6		EPA Unregulated
144	Aldicarb Sulfoxide	ug/L	1.0	1.0		EPA Unregulated
145	Carbaryl	ug/L	2.0	2.0		EPA Unregulated
147	Methomyl	ug/L	1.0	4.0		EPA Unregulated
326	Propoxur(Baygon)	ug/L	1.0			State Unregulated
327	Methiocarb	ug/L	4.0			State Unregulated
	Synthetic Organic Compounds					
33	Endrin	ug/L	0.02	0.02	2.0	EPA Regulated
34	Lindane (BHC-Gamma)	ug/L	0.04	0.04	0.2	EPA Regulated
35	Methoxychlor	ug/L	0.20	0.20	40.0	EPA Regulated
117	Alachlor	ug/L	0.40	0.40	2.0	EPA Regulated
119	Atrazine	ug/L	0.20	0.20	3.0	EPA Regulated
120	Benzo(a)pyrene	ug/L	0.04	0.04	0.2	EPA Regulated
122	Chlordane Technical	ug/L	0.40	0.40	2.0	EPA Regulated
124	Di(ethylhexyl)-Adipate	ug/L	1.30	1.30	400.0	EPA Regulated
125	Di(ethylhexyl)-phthalate	ug/L	1.30	1.30	6.0	EPA Regulated
126	Heptachlor	ug/L	0.08	0.08	0.4	EPA Regulated
127	Heptachlor epoxide (A & B)	ug/L	0.04	0.04	0.2	EPA Regulated
128	Hexachlorobenzene	ug/L	0.20	0.20	1.0	EPA Regulated
129	Hexachlorocyclo-Pentadiene	ug/L	0.20	0.20	50.0	EPA Regulated
133	Simazine	ug/L	0.15	0.15	4.0	EPA Regulated
118	Aldrin	ug/L	0.20	0.20		EPA Unregulated
121	Butachlor	ug/L	0.40	0.40		EPA Unregulated
123	Dieldrin	ug/L	0.20	0.20		EPA Unregulated
130	Metolachlor	ug/L	1.00	1.00		EPA Unregulated
131	Metribuzin	ug/L	0.20	0.20		EPA Unregulated
132	Propachlor	ug/L	0.20	0.20		EPA Unregulated
179	Bromacil	ug/L	0.20	0.20		State Unregulated
183	Prometon	ug/L	0.20	0.20		State Unregulated
190	Terbacil	ug/L	0.20	0.20		State Unregulated
202	Diazinon	ug/L	0.20	0.20		State Unregulated
208	EPTC	ug/L	0.30	0.30		State Unregulated
232	4,4-DDD	ug/L	0.20	0.20		State Unregulated
233	4,4-DDE	ug/L	0.20	0.20		State Unregulated
234	4,4_DDT	ug/L	0.20	0.20		State Unregulated
236	Cyanazine	ug/L	0.20	0.20		State Unregulated
239	Malathion	ug/L	0.20	0.20		State Unregulated
240	Parathion	ug/L	0.20	0.20		State Unregulated
243	Trifluralin	ug/L	0.20	0.20		State Unregulated

96	Napthalene	ug/L	0.10	0.10		PAHs
154	Fluorene	ug/L	0.20	0.20		PAHs
244	Acenaphthylene	ug/L	0.20	0.20		PAHs
245	Acenaphthene	ug/L	0.20	0.20		PAHs
246	Anthracene	ug/L	0.20	0.20		PAHs
247	Benz(a)anthracene	ug/L	0.10	0.10		PAHs
248	Benzo(b)fluoranthene	ug/L	0.20	0.20		PAHs
249	Benzo(g,h,i)perylene	ug/L	0.20	0.20		PAHs
250	Benzo(k)fluoranthene	ug/L	0.20	0.20		PAHs
251	Chrysene	ug/L	0.20	0.20		PAHs
252	Dibenzo(A,H)anthracene	ug/L	0.20	0.20		PAHs
253	Fluoranthene	ug/L	0.20	0.20		PAHs
255	Indeno(1,2,3-CD)Pyrene	ug/L	0.20	0.20		PAHs
256	Phenanthrene	ug/L	0.20	0.20		PAHs
257	Pyrene	ug/L	0.20	0.20		PAHs
258	Benzyl Butyl Phthalate	ug/L	0.60	0.60		Phthalates
259	Di-N-Butyl Phthalate	ug/L	0.60	0.60		Phthalates
260	Diethyl Phthalate	ug/L	0.60	0.60		Phthalates
261	Dimethyl Phthalate	ug/L	0.60	0.60		Phthalates
36	Toxaphene	ug/L	2.0	2.0	3.0	PCBs/Tocxaphene
173	Aroclor 1221	ug/L	20.0	20.0		PCBs/Tocxaphene
174	Aroclor 1232	ug/L	0.5	0.5		PCBs/Tocxaphene
175	Aroclor 1242	ug/L	0.5	0.3		PCBs/Tocxaphene
176	Aroclor 1248	ug/L	0.1	0.1		PCBs/Tocxaphene
177	Aroclor 1254	ug/L	0.1	0.1		PCBs/Tocxaphene
178	Aroclor 1260	ug/L	0.2	0.2		PCBs/Tocxaphene
180	Aroclor 1016	ug/L	0.1	0.1		PCBs/Tocxaphene
	Herbicides in Drinking Water					
37	2,4-D	ug/L	0.2	0.2	70.0	EPA Regulated
38	2,4,5-TP (Silvex)	ug/L	0.4	0.4	50.0	EPA Regulated
134	Pentachlorophenol	ug/L	0.1	0.1	1.0	EPA Regulated
137	Dalapon	ug/L	2.0	2.0	200.0	EPA Regulated
139	Dinoseb	ug/L	0.4	0.4	7.0	EPA Regulated
140	Picloram	ug/L	0.2	0.2	500.0	EPA Regulated
138	Dicamba	ug/L	0.2	0.2		EPA Unregulated
135	2,4 DB	ug/L	1.0	1.0		State Unregulated
136	2,4,5 T	ug/L	0.4	0.4		State Unregulated
220	Bentazon	ug/L	0.5	0.5		State Unregulated
221	Dichloroprop	ug/L	0.5	0.5		State Unregulated
223	Actiflorfin	ug/L	2.0	2.0		State Unregulated
225	Dacthal (DCPA)	ug/L	0.1	0.1		State Unregulated
226	3,5-Dichlorobenzoic Acid	ug/L	0.5	0.5		State Unregulated

MDL -->								NO3-N		NO2-N	Hardness	TDS		Cl		Soluble Reactive Phosphorous		COD		
								0.084		0.0023	0.11	21.1		0.297		0.0433		8.0		

Sample ID	Date	Lab No.	pH	Temp. C	Electrical Conductivity (mS/cm)	Turbidity (NTU)	NO_3-N (mg/L)		NO_2-N (mg/L)	Hardness (mg/L)	TDS (mg/L)		Cl (mg/L)		Soluble Reactive Phosphorous (mg/L)		COD (mg/L)	Total Coliform (per 100ml)	E-Coli (per 100ml)
Surface	2/2/2006	80603	7.29	10.0	1027	14.40	0.206		0.030	50.42	100		18.7		0.197		14	present	present
Surface	2/22/2006	80884	7.21	9.5	1044	10.80	0.620		NA	48.90	108		6.2		0.146		23	present	present
Surface	3/3/2006	81009	6.94	9.7	1144	26.50	0.940	<	0.002	NA	160	<	0.3	<	0.043		820	present	present
Surface	4/12/2006	81717	7.29	14.9	1300	16.10	0.610	<	0.002	51.50	66		6.0		0.100		14	present	present

Sample ID	Date	Lab No.	pH	Temp. C	Electrical Conductivity (mS/cm)	Turbidity (NTU)	NO_3-N (mg/L)		NO_2-N (mg/L)	Hardness (mg/L)	TDS (mg/L)		Cl (mg/L)		Soluble Reactive Phosphorous (mg/L)		COD (mg/L)	Total Coliform (per 100ml)	E-Coli (per 100ml)
HW-1	2/2/2006	80600	6.67	10.3	1120	0.10	0.566		0.020	57.75	110		25.0		0.224	<	8	absent	absent
HW-1	2/22/2006	80881	6.48	7.0	1000	0.34	1.690		-	55.00	98		9.4		0.139		9	present	present
HW-1	3/2/2006	81006	6.59	12.2	1178	0.15	0.680		0.050	58.90	170		5.0		0.100		404	absent	absent
HW-1	3/9/2006	81156	6.62	11.3	1142	0.13	1.210	<	0.002	62.00	112		5.0	<	0.043	<	8	absent	absent
HW-1	4/12/2006	81714	6.39	9.8	1400	0.12	1.420	<	0.002	60.10	72		5.0		0.170	<	8	present	present

Sample ID	Date	Lab No.	pH	Temp. C	Electrical Conductivity (mS/cm)	Turbidity (NTU)	NO_3-N (mg/L)		NO_2-N (mg/L)	Hardness (mg/L)	TDS (mg/L)		Cl (mg/L)		Soluble Reactive Phosphorous (mg/L)		COD (mg/L)	Total Coliform (per 100ml)	E-Coli (per 100ml)
HW-2	2/2/2006	80601	6.60	14.0	1434	6.82	0.390		0.021	72.41	126		25.0		0.208	<	8	present	absent
HW-2	2/22/2006	80882	6.60	13.1	1441	1.23	0.930		NA	77.00	128		7.8		0.114		19	present	absent
HW-2	3/3/2006	81007	6.74	12.8	1506	0.02	0.720		0.050	77.50	166		5.0		0.100		743	absent	absent
HW-2	3/9/2006	81157	6.78	12.5	1470	0.71	0.950	<	0.002	82.00	126	<	0.3	<	0.043	<	8	absent	absent
HW-2	4/12/2006	81715	6.30	13.4	1400	12.50	1.690	<	0.002	63.00	82		5.0		0.120	<	8	present	present

Sample ID	Date	Lab No.	pH	Temp. C	Electrical Conductivity (mS/cm)	Turbidity (NTU)	NO_3-N (mg/L)		NO_2-N (mg/L)	Hardness (mg/L)	TDS (mg/L)		Cl (mg/L)		Soluble Reactive Phosphorous (mg/L)		COD (mg/L)	Total Coliform (per 100ml)	E-Coli (per 100ml)
HW-3	2/2/2006	80602	6.53	12.4	1193	0.16	0.391		0.017	60.38	108		31.2		0.083	<	8	absent	absent
HW-3	2/22/2006	80883	6.64	12.3	1181	0.14	0.900		NA	62.70	106		15.6		0.107		14	absent	absent
HW-3	3/3/2006	81008	6.48	13.0	1223	0.12	0.700	<	0.002	60.80	158	<	0.3	<	0.043		615	absent	absent
HW-3	3/9/2006	81158	6.86	12.4	1178	0.20	0.920	<	0.002	64.00	96		8.0	<	0.043		13	absent	absent
HW-3	4/12/2006	81716	6.52	13.2	1500	0.05	1.020	<	0.002	62.60	88		5.0		0.100	<	8	absent	absent

Table 4. Field and basic parameter analysis results.

Table 5. Synthetic organic coumpound analysis results.

Date	2/2/2006	2/2/2006	2/2/2006	2/2/2006
Well ID	HW-1	HW-2	HW-3	Surface
Chemical				
Carbamates in Drinking water				
Carbofuran	ND	ND	ND	ND
Oxymal	ND	ND	ND	ND
3-Hydroxycabofuran	ND	ND	ND	ND
Aldicarb	ND	ND	ND	ND
Aldicarb sulfone	ND	ND	ND	ND
Aldicarb sulfoxide	ND	ND	ND	ND
Carbaryl	ND	ND	ND	ND
Methomyl	ND	ND	ND	ND
Propoxur (Baygon)	ND	ND	ND	ND
Methiocarb	ND	ND	ND	ND
Synthetic Organic Compounds				
Endrin	ND	ND	ND	ND
Lindane (BHC-Gamma)	ND	ND	ND	ND
Methoxychlor	ND	ND	ND	ND
Alachlor	ND	ND	ND	ND
Atrazine	ND	ND	ND	ND
Benzo(a)pyrene	ND	ND	ND	ND
Chlordane Technical	ND	ND	ND	ND
Di(ethylhexyl)-Adipate	ND	ND	ND	ND
Di(ethylhexyl)-phthalate	**3.7**	**1.6**	ND	**4.1**
Heptachlor	ND	ND	ND	ND
Heptachlor Epoxide A&B	ND	ND	ND	ND
Hexachlorobenzene	ND	ND	ND	ND
Hexachlorocyclo-Pentadiene	ND	ND	ND	ND
Simazine	ND	ND	ND	ND
Aldrin	ND	ND	ND	ND
Butachlor	ND	ND	ND	ND
Dieldrin	ND	ND	ND	ND
Metolachlor	ND	ND	ND	ND
Metribuzin	ND	ND	ND	ND
Propachlor	ND	ND	ND	ND
Bromacil	ND	ND	ND	ND
Prometon	ND	ND	ND	ND
Terbacil	ND	ND	ND	ND
Diazinon	ND	ND	ND	ND
EPTC	ND	ND	ND	ND
4,4-DDD	ND	ND	ND	ND
4,4-DDE	ND	ND	ND	ND
4,4-DDT	ND	ND	ND	ND
Cyanazine	ND	ND	ND	ND
Malathion	ND	ND	ND	ND
Trifluralin	ND	ND	ND	ND

Table 5. Synthetic organic coumpound analysis results.

Napthalene	ND	ND	ND	ND
Fluorene	ND	ND	ND	ND
Acenaphthylene	ND	ND	ND	ND
Acenaphthene	ND	ND	ND	ND
Anthracene	ND	ND	ND	ND
Benz(A)anthracene	ND	ND	ND	ND
Benzo(B)fluoranthene	ND	ND	ND	ND
Benzo(G,H,I)peryene	ND	ND	ND	ND
Benzo(K)fluoranthene	ND	ND	ND	ND
Chrysene	ND	ND	ND	ND
Dibenzo(A,H)anthracene	ND	ND	ND	ND
Fluoranthene	ND	ND	ND	ND
Indeno(1,2,3-CD)pyrene	ND	ND	ND	ND
Phenanthrene	ND	ND	ND	ND
Pyrene	ND	ND	ND	ND
Benzyl Butyl Phthalate	ND	ND	ND	ND
Di-N-Butyl Phthalate	ND	ND	ND	ND
Diethyl Phthalate	**1.1**	ND	**1.5**	**2.2**
Dimethyl Phthalate	ND	ND	ND	ND
Toxaphene	ND	ND	ND	ND
Aroclor 1221	ND	ND	ND	ND
Aroclor 1232	ND	ND	ND	ND
Aroclor 1242	ND	ND	ND	ND
Aroclor 1248	ND	ND	ND	ND
Aroclor 1254	ND	ND	ND	ND
Aroclor 1260	ND	ND	ND	ND
Aroclor 1016	ND	ND	ND	ND
Herbicides in Drinking Water				
2,4-D	ND	ND	ND	ND
2,4,5-TP (Silvex)	ND	ND	ND	ND
Pentachlorophenol	ND	ND	ND	ND
Dalapon	ND	ND	ND	ND
Dinoseb	ND	ND	ND	ND
Picloram	ND	ND	ND	ND
Dicamba	ND	ND	ND	ND
2,4 DB	ND	ND	ND	ND
2,4,5 T	ND	ND	ND	ND
Bentazon	ND	ND	ND	ND
Dichlorprop	ND	ND	ND	ND
Actiflorfin	ND	ND	ND	ND
Dacthal (DCPA)	ND	ND	ND	ND
3,5-Dichlorobenzoic Acid	ND	ND	ND	ND
Velpar (hexazinone)	ND	ND	ND	ND
Bronate (bromoxynil)				
Gramoxone (paraquat)				

Table 5. Synthetic organic coumpound analysis results.

Date	3/3/2006	3/3/2006	3/3/2006	3/3/2006
Well ID	HW-1	HW-2	HW-3	Surface
Chemical				
Carbamates in Drinking water				
Carbofuran	ND	ND	ND	ND
Oxymal	ND	ND	ND	ND
3-Hydroxycabofuran	ND	ND	ND	ND
Aldicarb	ND	ND	ND	ND
Aldicarb sulfone	ND	ND	ND	ND
Aldicarb sulfoxide	ND	ND	ND	ND
Carbaryl	ND	ND	ND	ND
Methomyl	ND	ND	ND	ND
Propoxur (Baygon)	ND	ND	ND	ND
Methiocarb	ND	ND	ND	ND
Synthetic Organic Compounds				
Endrin	ND	ND	ND	ND
Lindane (BHC-Gamma)	ND	ND	ND	ND
Methoxychlor	ND	ND	ND	ND
Alachlor	ND	ND	ND	ND
Atrazine	ND	ND	ND	ND
Benzo(a)pyrene	ND	ND	ND	ND
Chlordane Technical	ND	ND	ND	ND
Di(ethylhexyl)-Adipate	ND	ND	ND	ND
Di(ethylhexyl)-phthalate	ND	ND	ND	ND
Heptachlor	ND	ND	ND	ND
Heptachlor Epoxide A&B	ND	ND	ND	ND
Hexachlorobenzene	ND	ND	ND	ND
Hexachlorocyclo-Pentadiene	ND	ND	ND	ND
Simazine	ND	ND	ND	ND
Aldrin	ND	ND	ND	ND
Butachlor	ND	ND	ND	ND
Dieldrin	ND	ND	ND	ND
Metolachlor	ND	ND	ND	ND
Metribuzin	ND	ND	ND	ND
Propachlor	ND	ND	ND	ND
Bromacil	ND	ND	ND	ND
Prometon	ND	ND	ND	ND
Terbacil	ND	ND	ND	ND
Diazinon	ND	ND	ND	ND
EPTC	ND	ND	ND	ND
4,4-DDD	ND	ND	ND	ND
4,4-DDE	ND	ND	ND	ND
4,4-DDT	ND	ND	ND	ND
Cyanazine	ND	ND	ND	ND
Malathion	ND	ND	ND	ND
Trifluralin	ND	ND	ND	ND

Table 5. Synthetic organic coumpound analysis results.

Napthalene	ND	ND	ND	ND
Fluorene	ND	ND	ND	ND
Acenaphthylene	ND	ND	ND	ND
Acenaphthene	ND	ND	ND	ND
Anthracene	ND	ND	ND	ND
Benz(A)anthracene	ND	ND	ND	ND
Benzo(B)fluoranthene	ND	ND	ND	ND
Benzo(G,H,I)peryene	ND	ND	ND	ND
Benzo(K)fluoranthene	ND	ND	ND	ND
Chrysene	ND	ND	ND	ND
Dibenzo(A,H)anthracene	ND	ND	ND	ND
Fluoranthene	ND	ND	ND	ND
Indeno(1,2,3-CD)pyrene	ND	ND	ND	ND
Phenanthrene				
Pyrene	ND	ND	ND	ND
Benzyl Butyl Phthalate	ND	ND	ND	ND
Di-N-Butyl Phthalate	ND	ND	ND	ND
Diethyl Phthalate	ND	ND	ND	ND
Dimethyl Phthalate	ND	ND	ND	ND
Toxaphene	ND	ND	ND	ND
Aroclor 1221	ND	ND	ND	ND
Aroclor 1232	ND	ND	ND	ND
Aroclor 1242	ND	ND	ND	ND
Aroclor 1248	ND	ND	ND	ND
Aroclor 1254	ND	ND	ND	ND
Aroclor 1260	ND	ND	ND	ND
Aroclor 1016	ND	ND	ND	ND
Herbicides in Drinking Water				
2,4-D				
2,4,5-TP (Silvex)	ND	ND	ND	ND
Pentachlorophenol	ND	ND	ND	ND
Dalapon	ND	ND	ND	ND
Dinoseb	ND	ND	ND	ND
Picloram	ND	ND	ND	ND
Dicamba	ND	ND	ND	ND
2,4 DB				
2,4,5 T				
Bentazon				
Dichlorprop				
Actiflorfin				
Dacthal (DCPA)				
3,5-Dichlorobenzoic Acid				
Velpar (hexazinone)	ND	ND	ND	ND
Bronate (bromoxynil)	ND	ND	ND	ND
Gramoxone (paraquat)	ND	ND	ND	ND

Figures

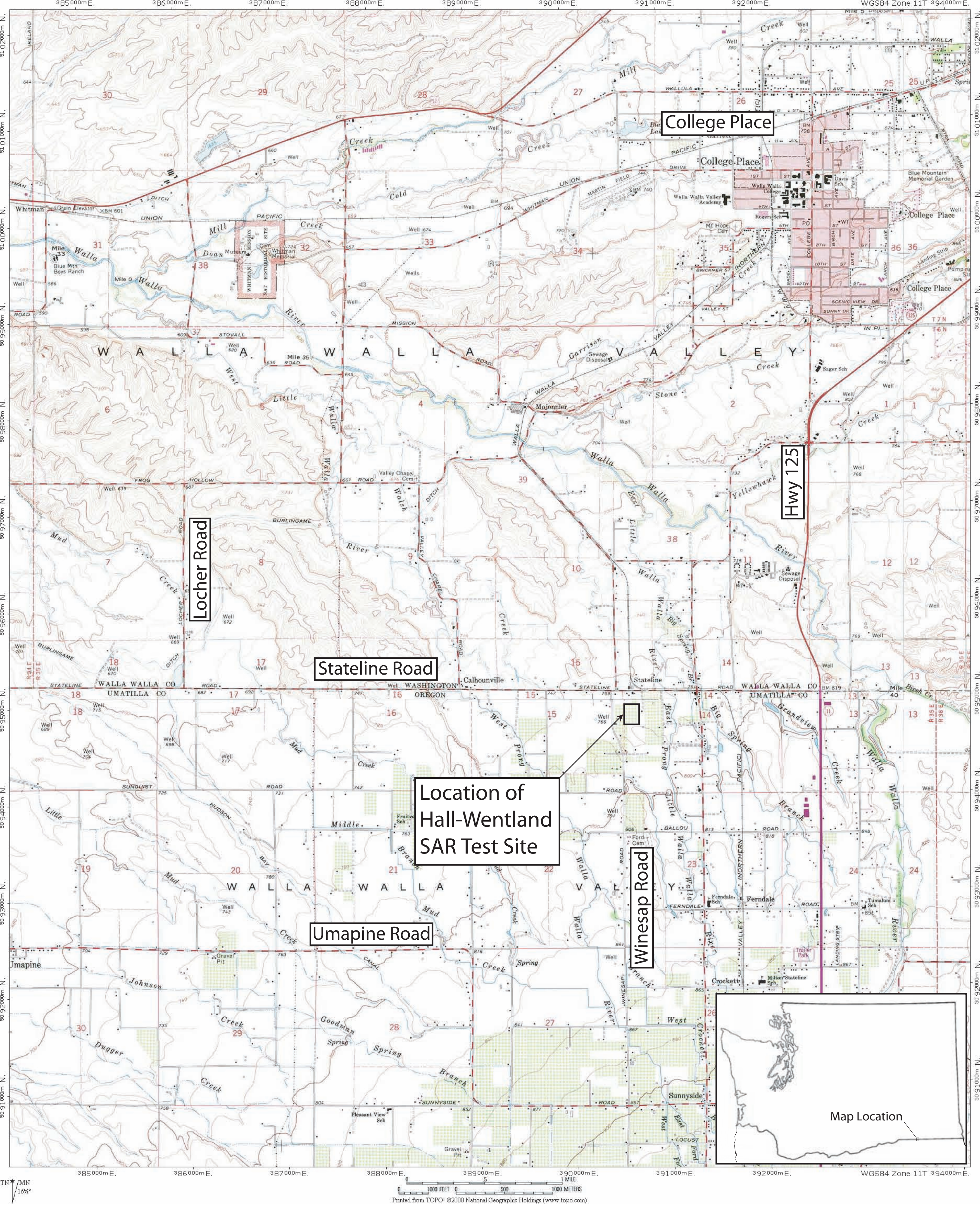

Figure 1. Area and regional setting.

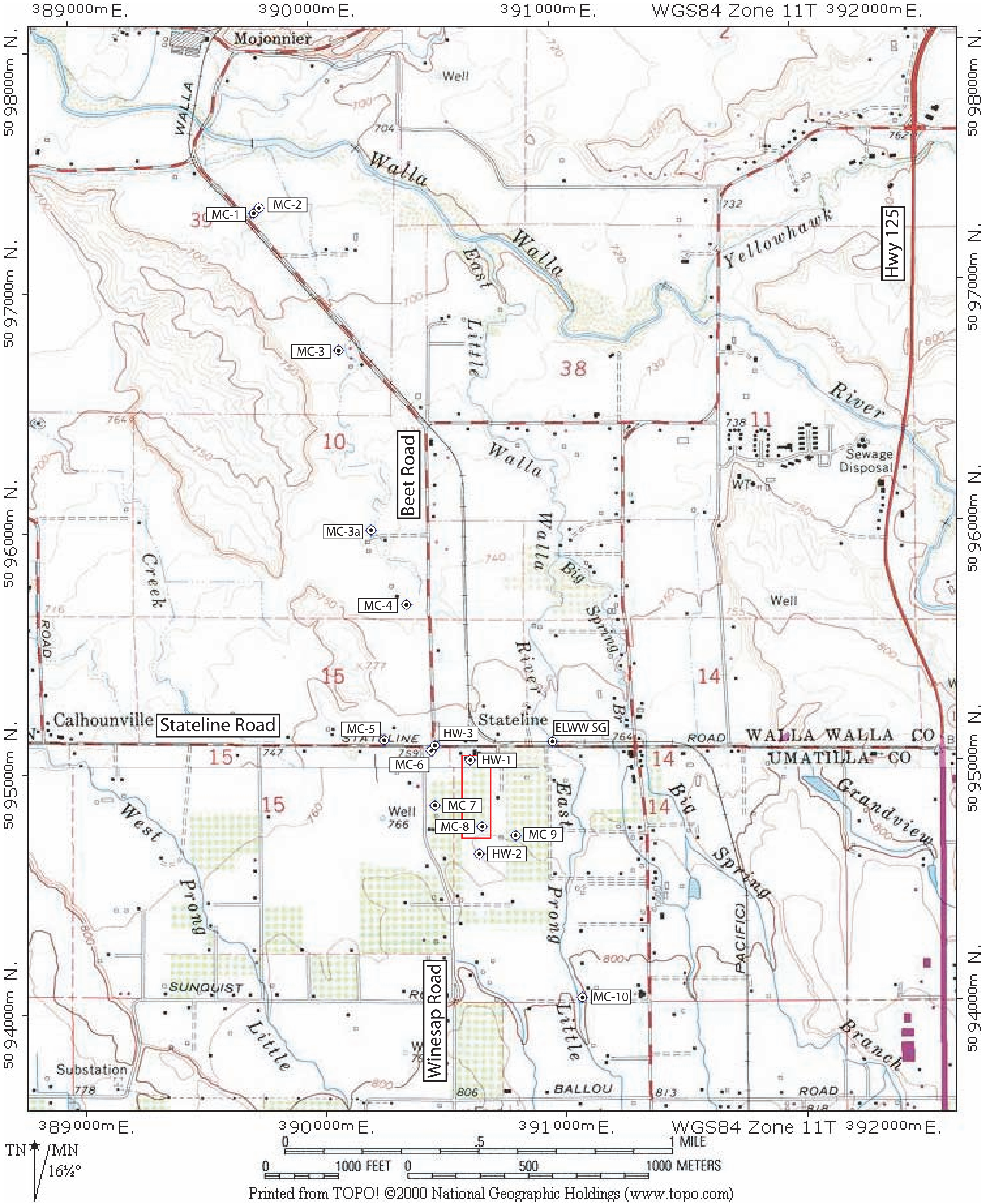

Figure 2. Local setting and location map.

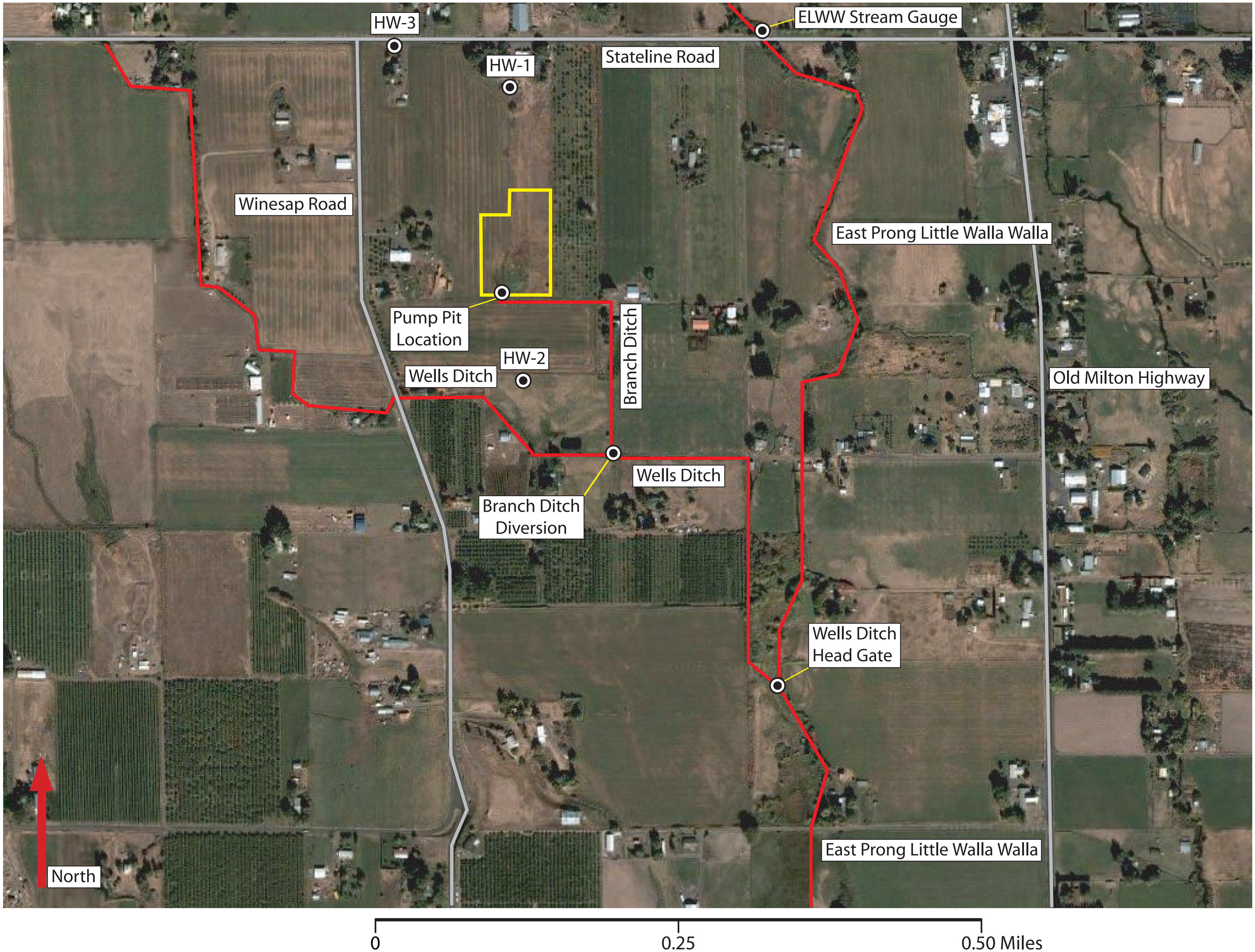

Figure 3. Irrigation ditches and streams in the Test Site area.

Figure 4. Photograph of the diversion head gate for the branch ditch on Wells Ditch.

Figure 5. Irrigation pump sump pit at the Test Site

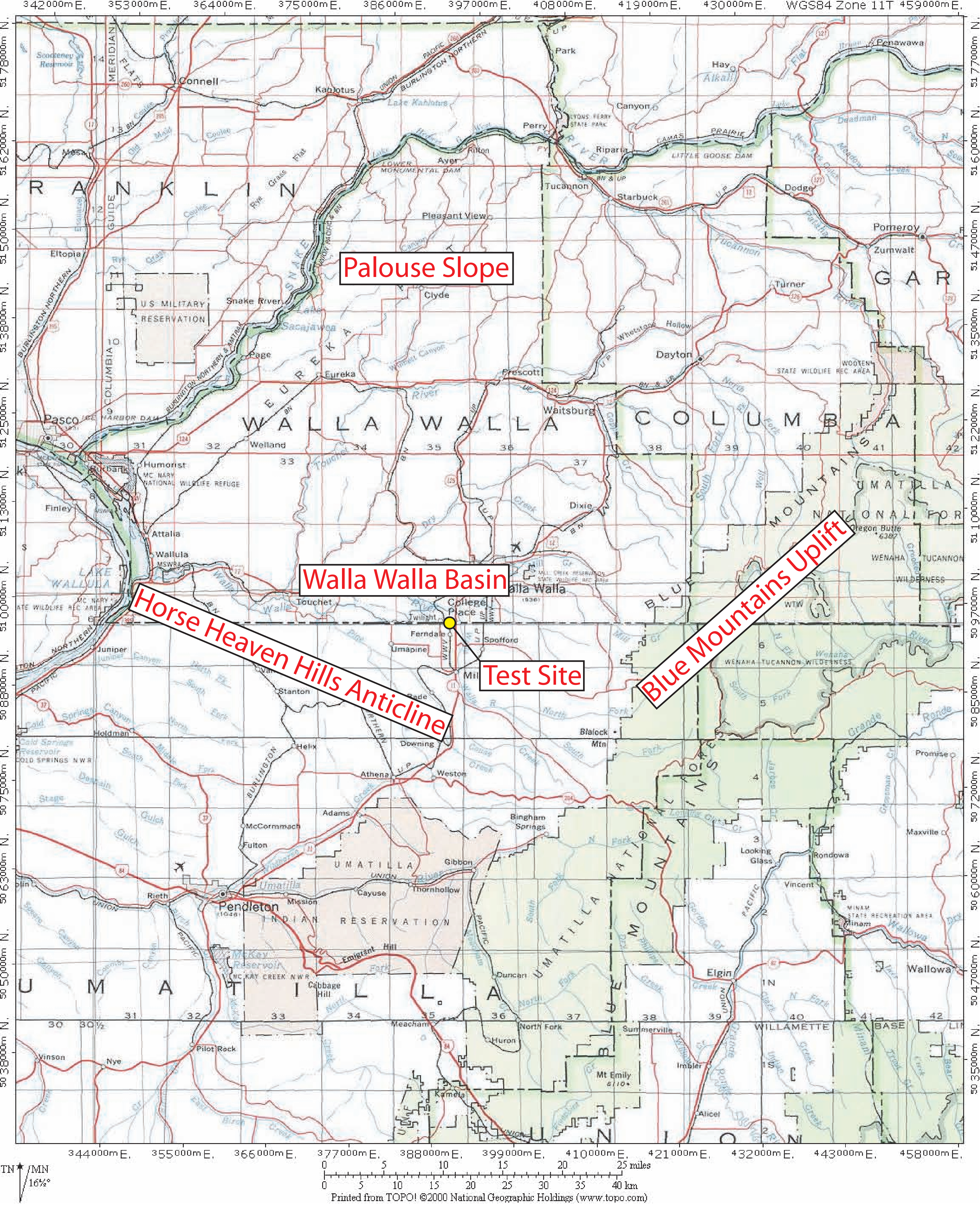

Figure 6. Map showing the location of the Walla Walla Basin relative to the Horse Heaven Hills anticline, Blue Mountains uplift, and Palouse Slope.

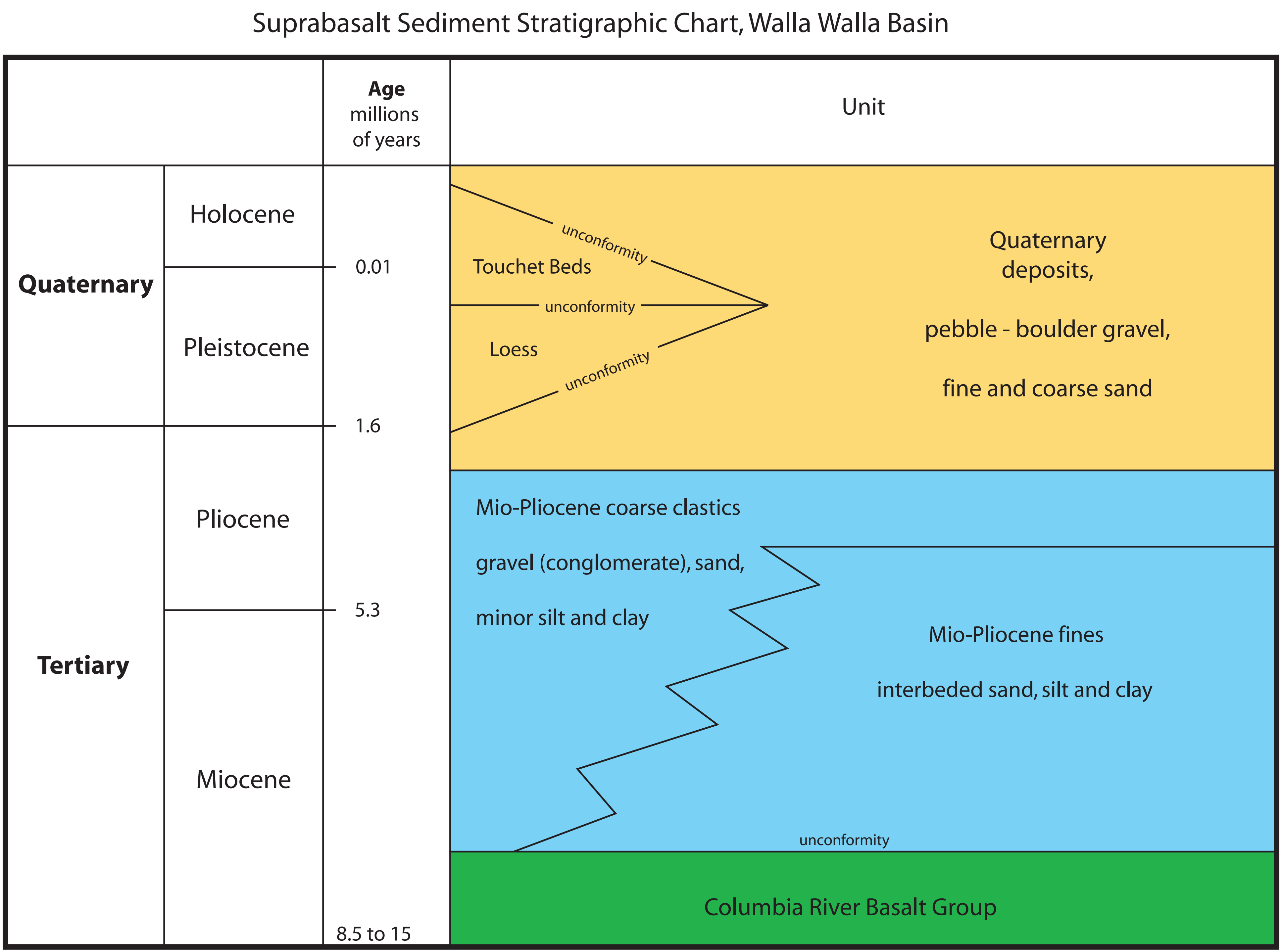

Figure 7. Generalized suprabasalt sediment stratigraphic chart for the Walla Walla Basin.

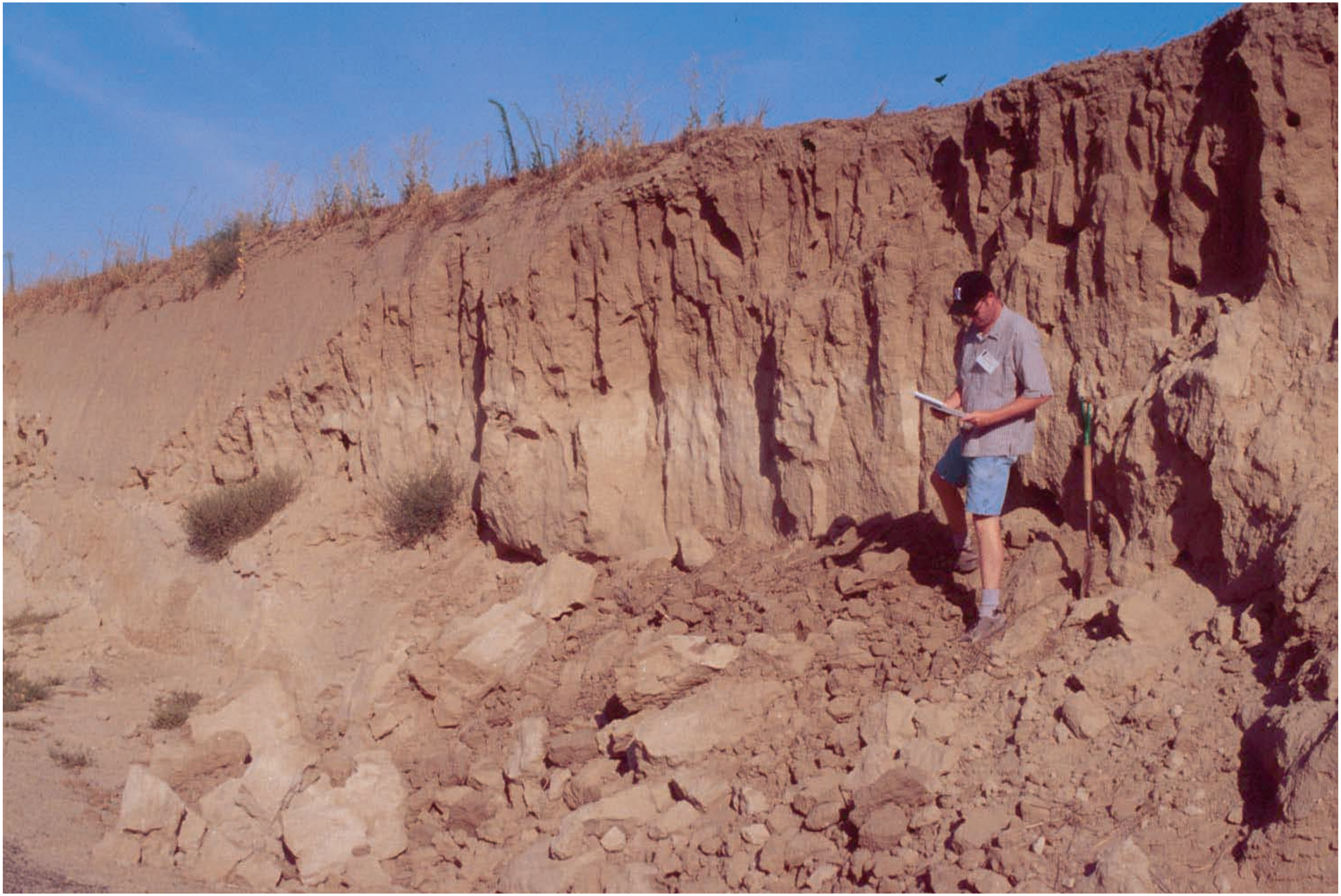

Figure 8. Outcrop photograph of loess.

Figure 9. Photograph of Touchet Beds (Pleistocene Cataclysmic Flood deposits).

Figure 10. Photograph of Quaternary gravel deposit.

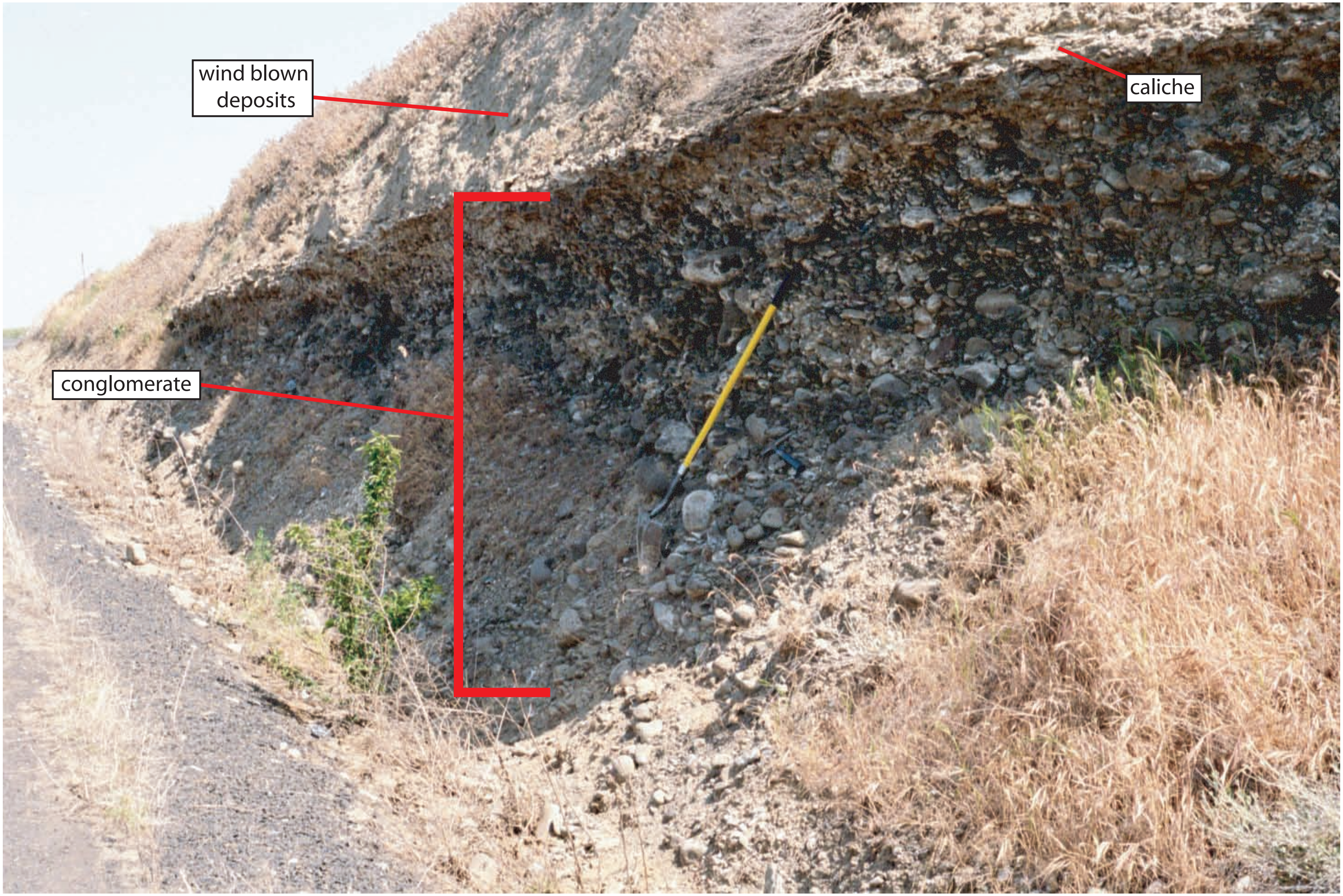

Figure 11. Outcrop of indurated Mio-Pliocene conglomerate.

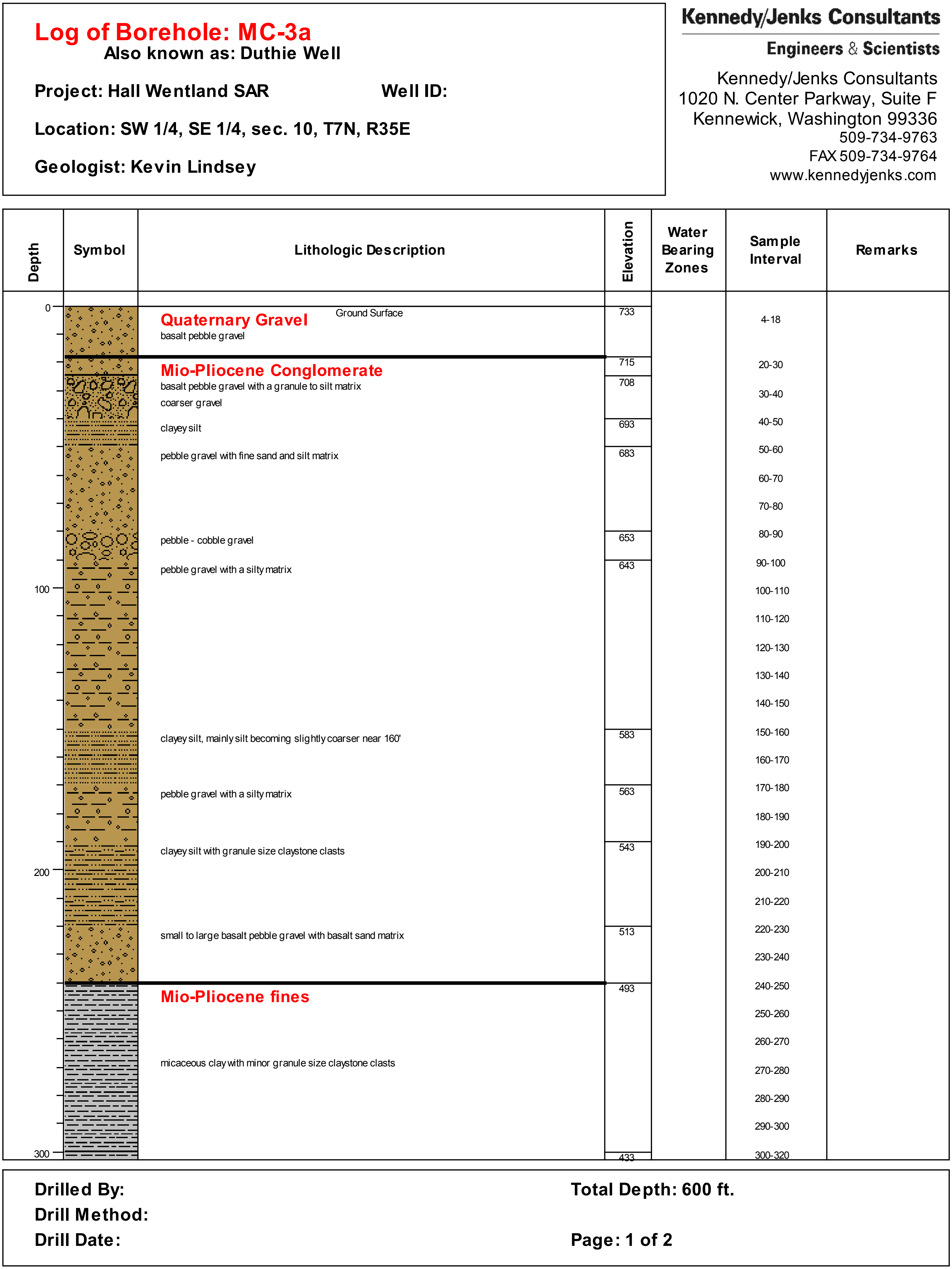

Figure 12. Interpreted geologic log for well MC-3a (Duthie well)

Log of Borehole: MC-3a

Also known as: Duthie Well

Project: Hall Wentland SAR **Well ID:**

Location: SW 1/4, SE 1/4, sec. 10, T7N, R35E

Geologist: Kevin Lindsey

Kennedy/Jenks Consultants
Engineers & Scientists

Kennedy/Jenks Consultants
1020 N. Center Parkway, Suite F
Kennewick, Washington 99336
509-734-9763
FAX 509-734-9764
www.kennedyjenks.com

Depth	Symbol	Lithologic Description	Elevation	Water Bearing Zones	Sample Interval	Remarks
		micaceous clay with minor granule size claystone clasts			320-340 340-360 360-380 380-400	
400		fine silt - fine sandstone	333		420	
		fine sandstone cemented matrix with basalt pebbles	303		440	
		basalt pebble gravel coarsening downward with a sandy matrix	283		460 480	
500		silty fine sand with small claystone clasts	233		500	
		silty fine sand	213		520 540	
		silty fine sand with claystone and caliche clasts	183		560	
		basalt, claystone and caliche clasts with a micaceous clay matrix	163		580	
600			133		600	

Drilled By: **Total Depth: 600 ft.**

Drill Method:

Drill Date:

Figure 12. (continued)

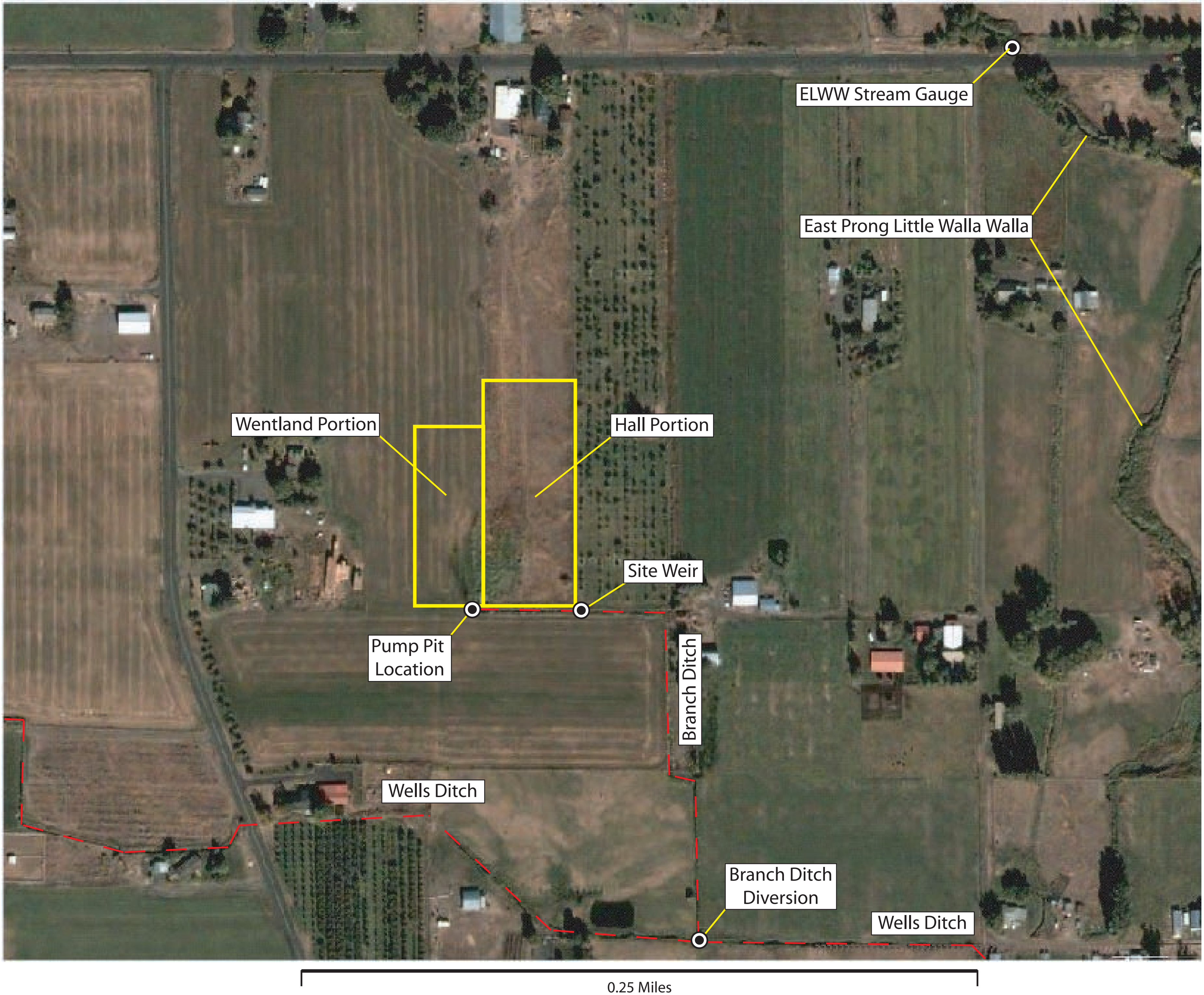

Figure 13. Site specific layout map for the Test Site.

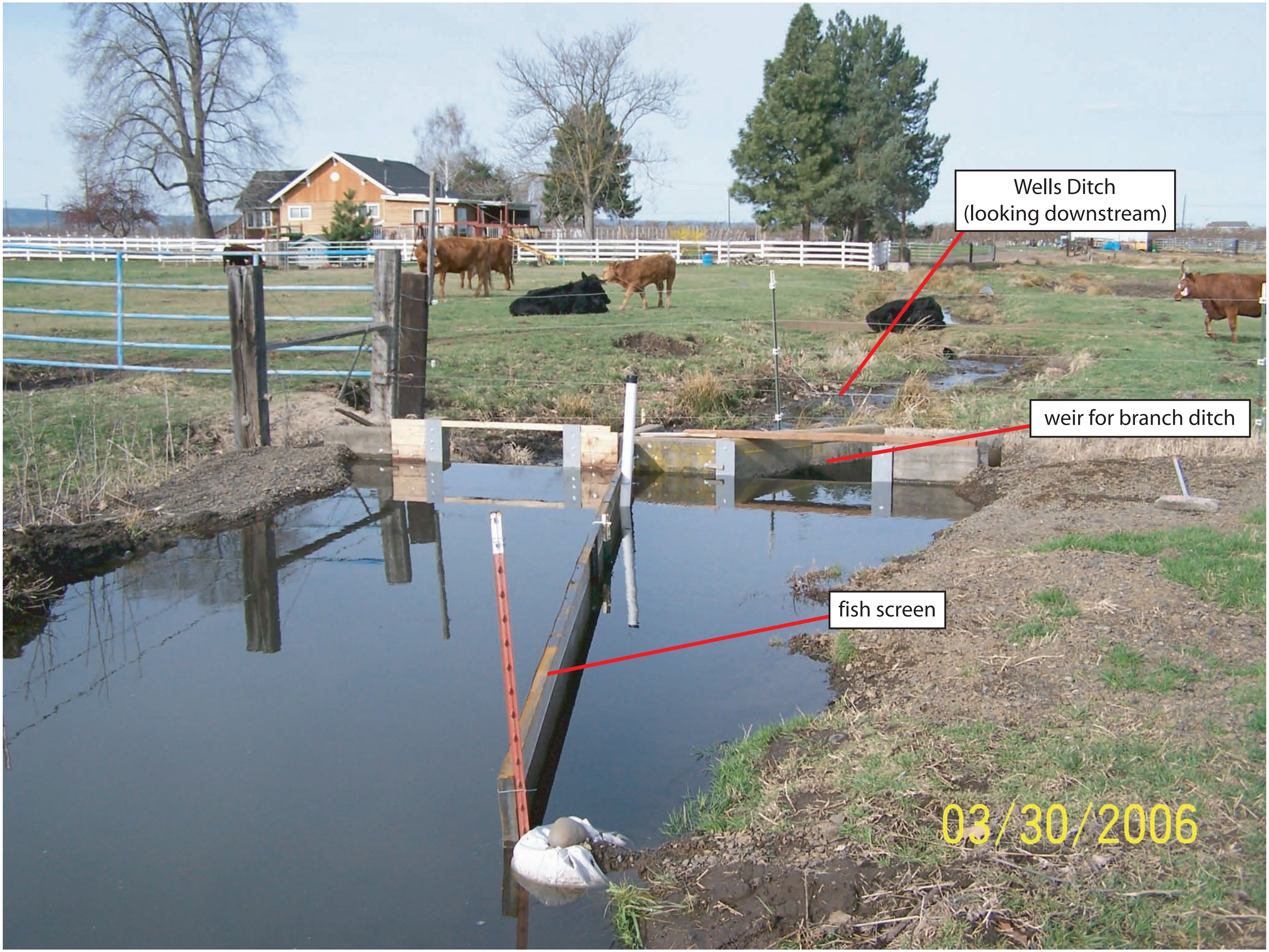

Figure 14. Photograph of the fish screen and weir at the branch ditch diversion off Wells Ditch.

Figure 15. Branch ditch leading north to the Test Site.

Figure 16. Photograph of the measurement weir on the branch ditch leading onto the Test Site.

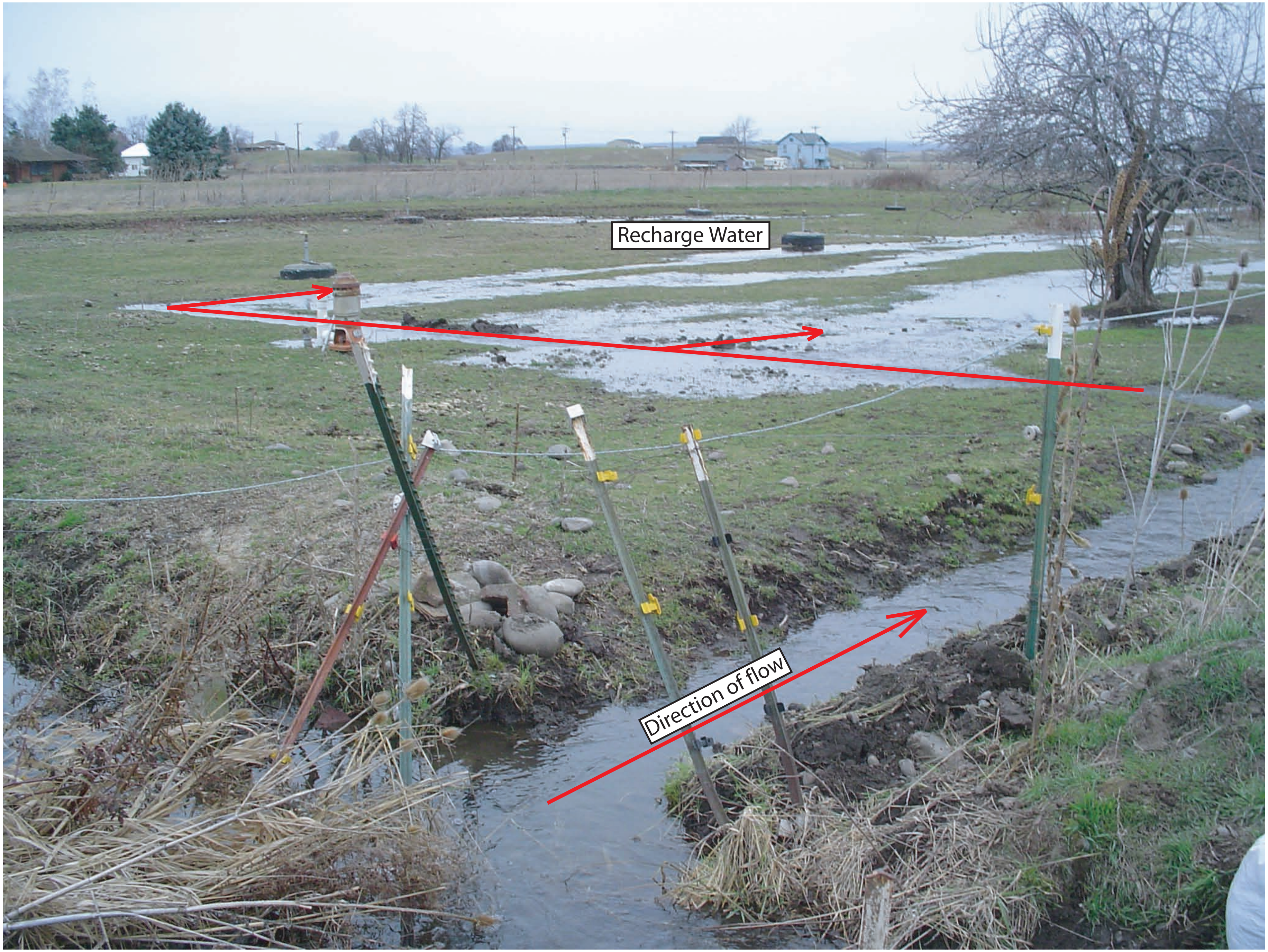

Figure 17. Breach in berm with recharge test water flowing out onto the Hall(western) portion of the Test Site.

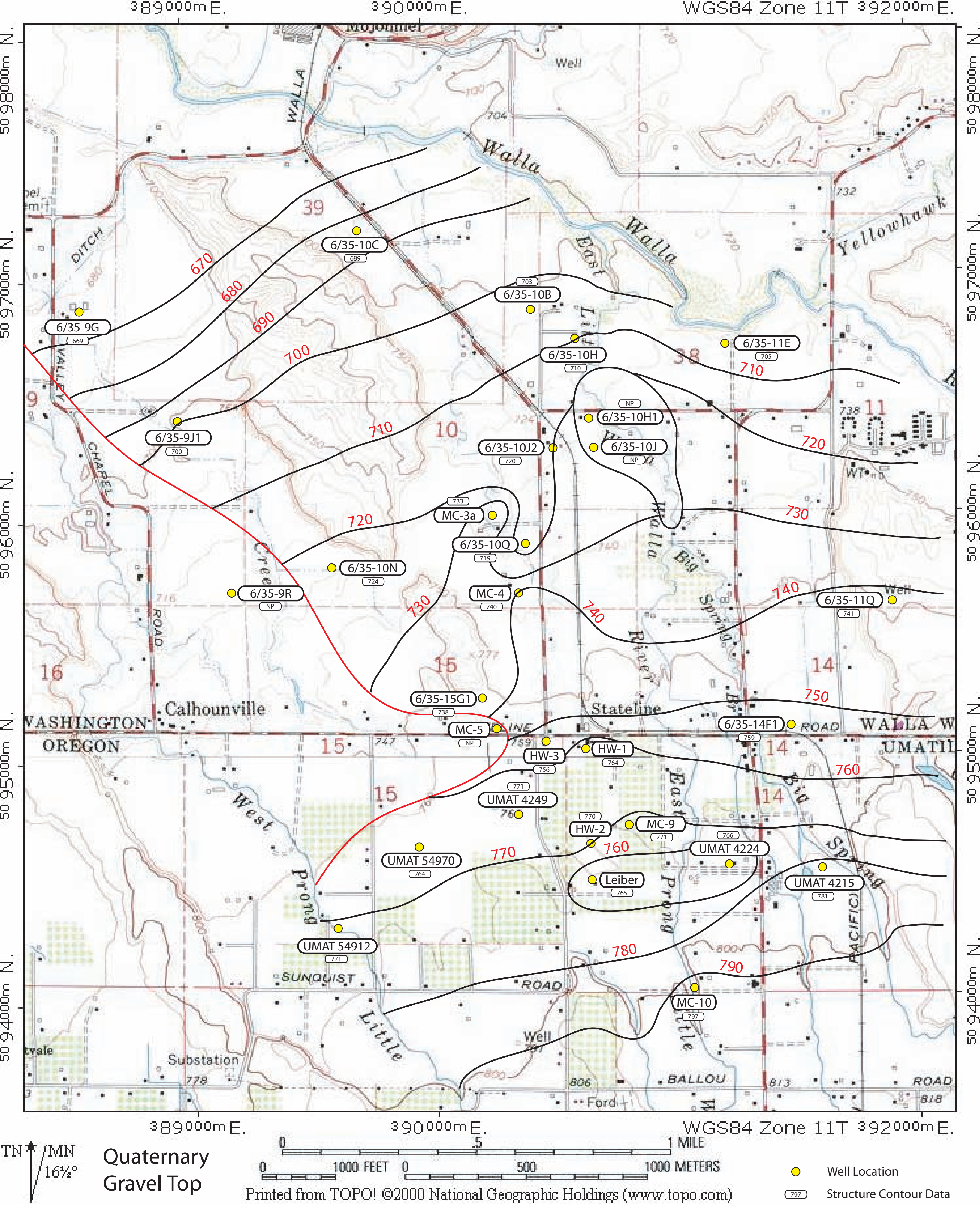

Figure 18. Structure contour map of the top of the Quaternary gravel in the Test Site area.

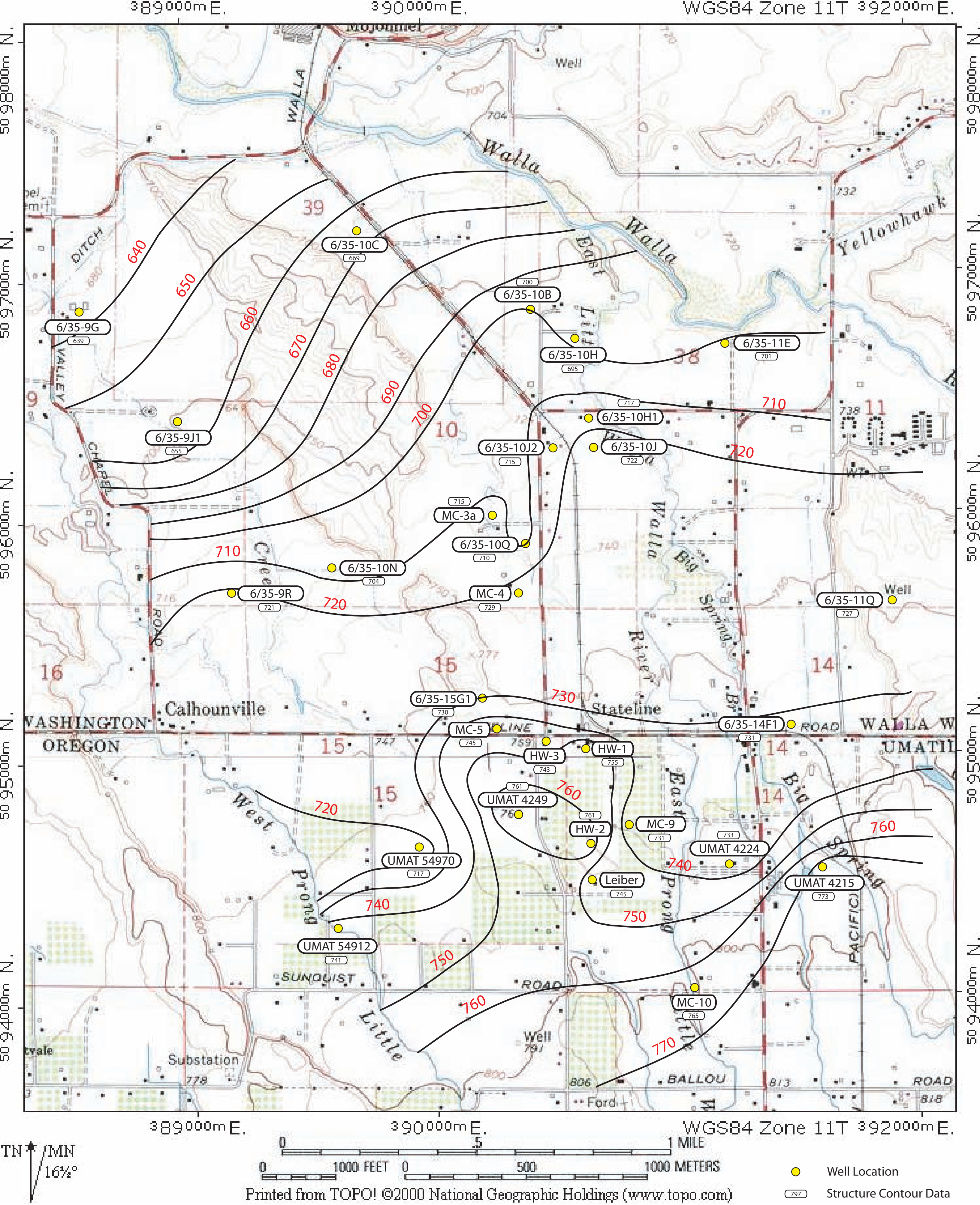

Figure 19. Structural contour map of the top of the Mio-Pliocene conglomerate in the Test Site area.

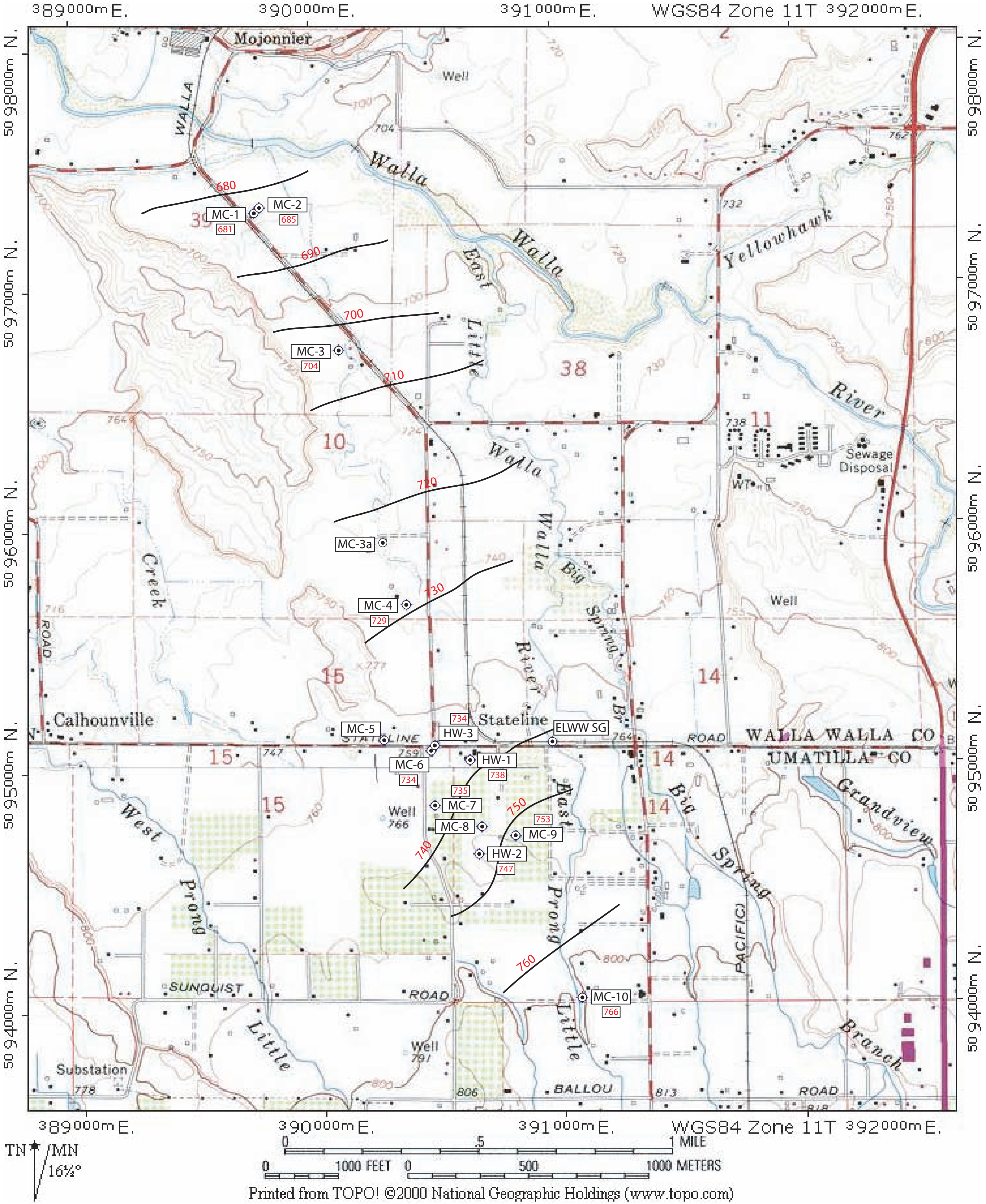

Figure 20. Water table map for early February 2006.

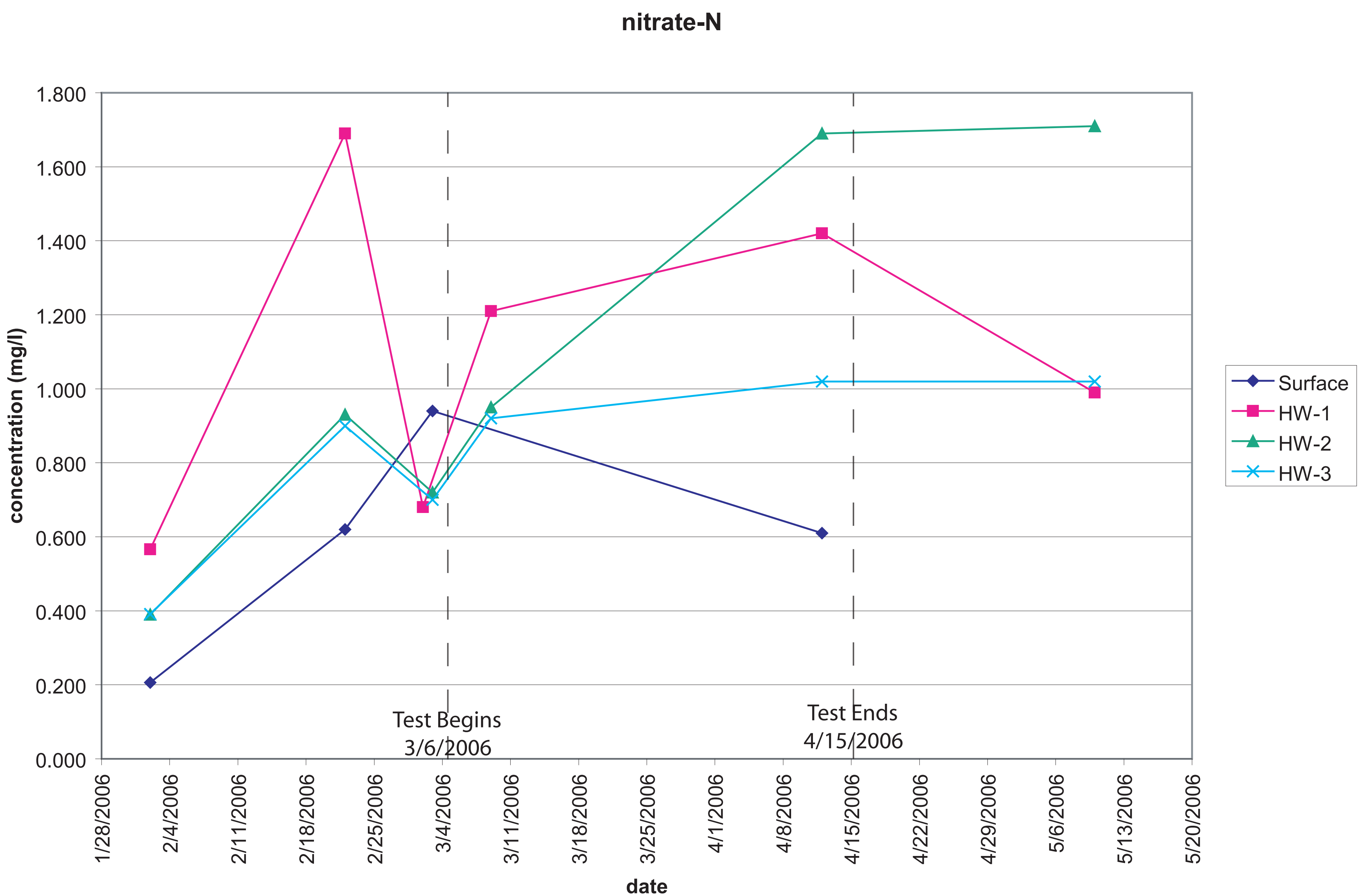

Figure 21. Graph showing nitrate-N concentrations in monitoring wells and surface water

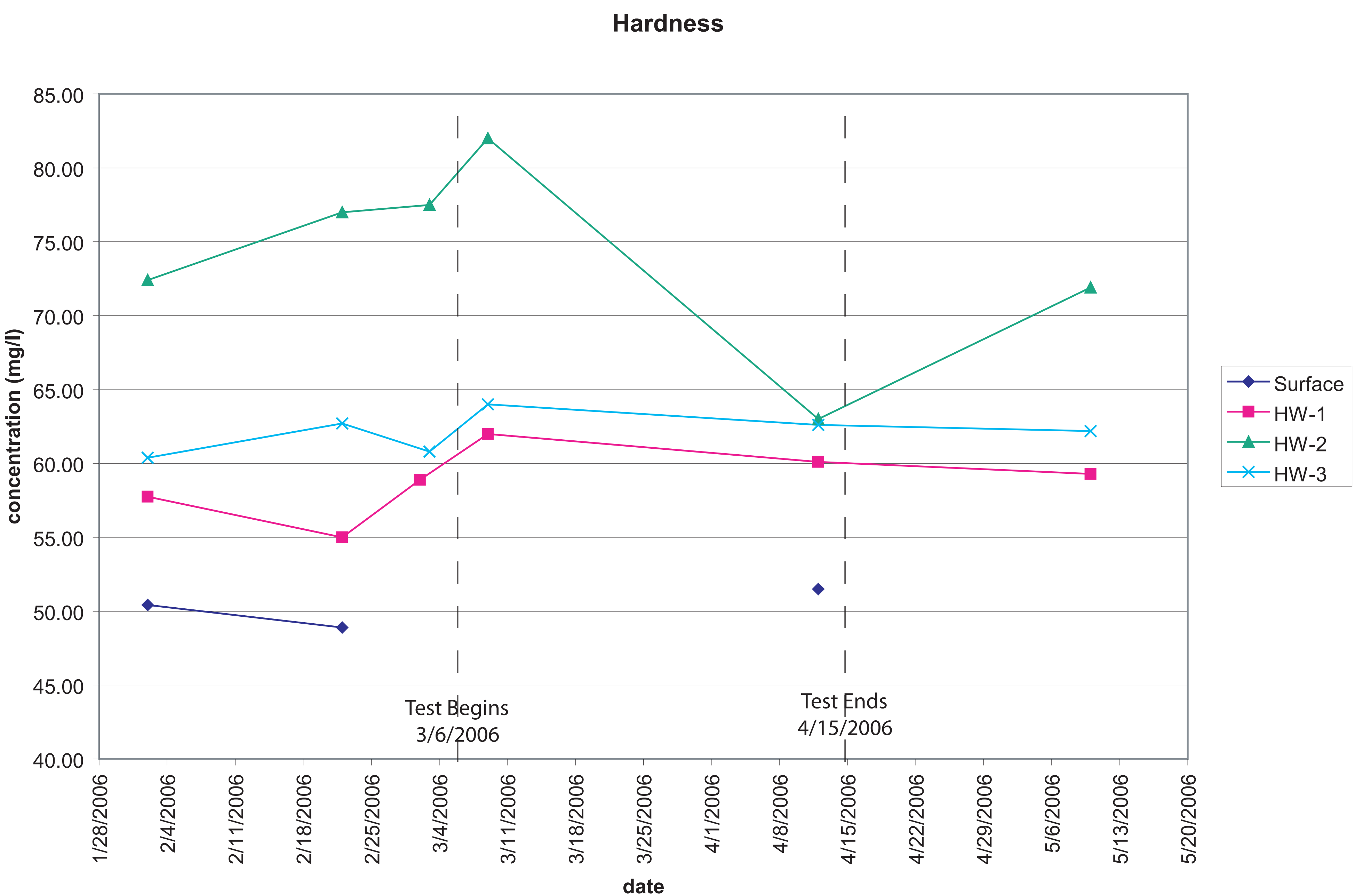

Figure 22. Graph showing hardness concentrations in monitoring wells and surface water

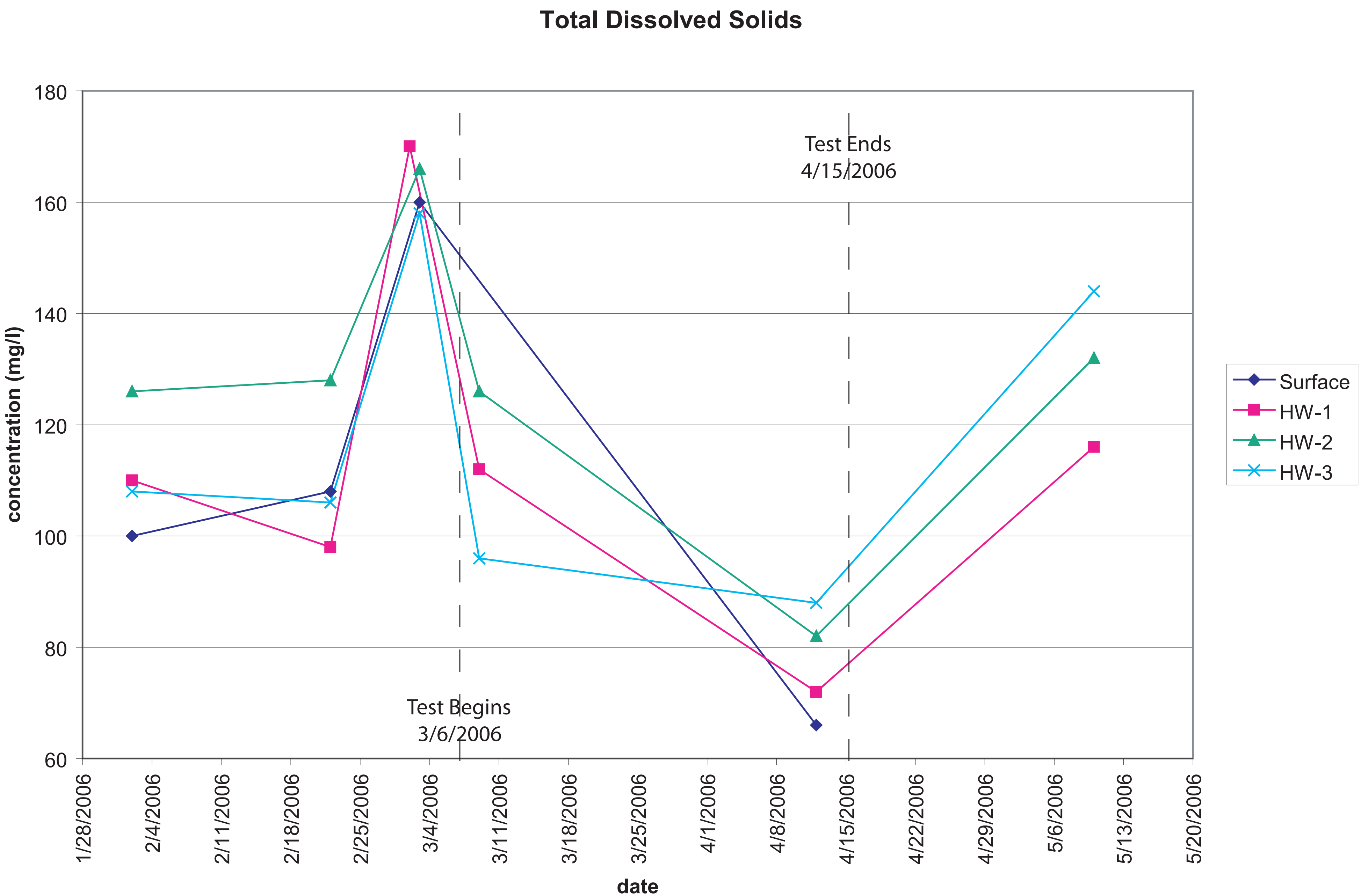

Figure 23. Graph showing total dissolved solids concentrations in monitoring wells and surface water

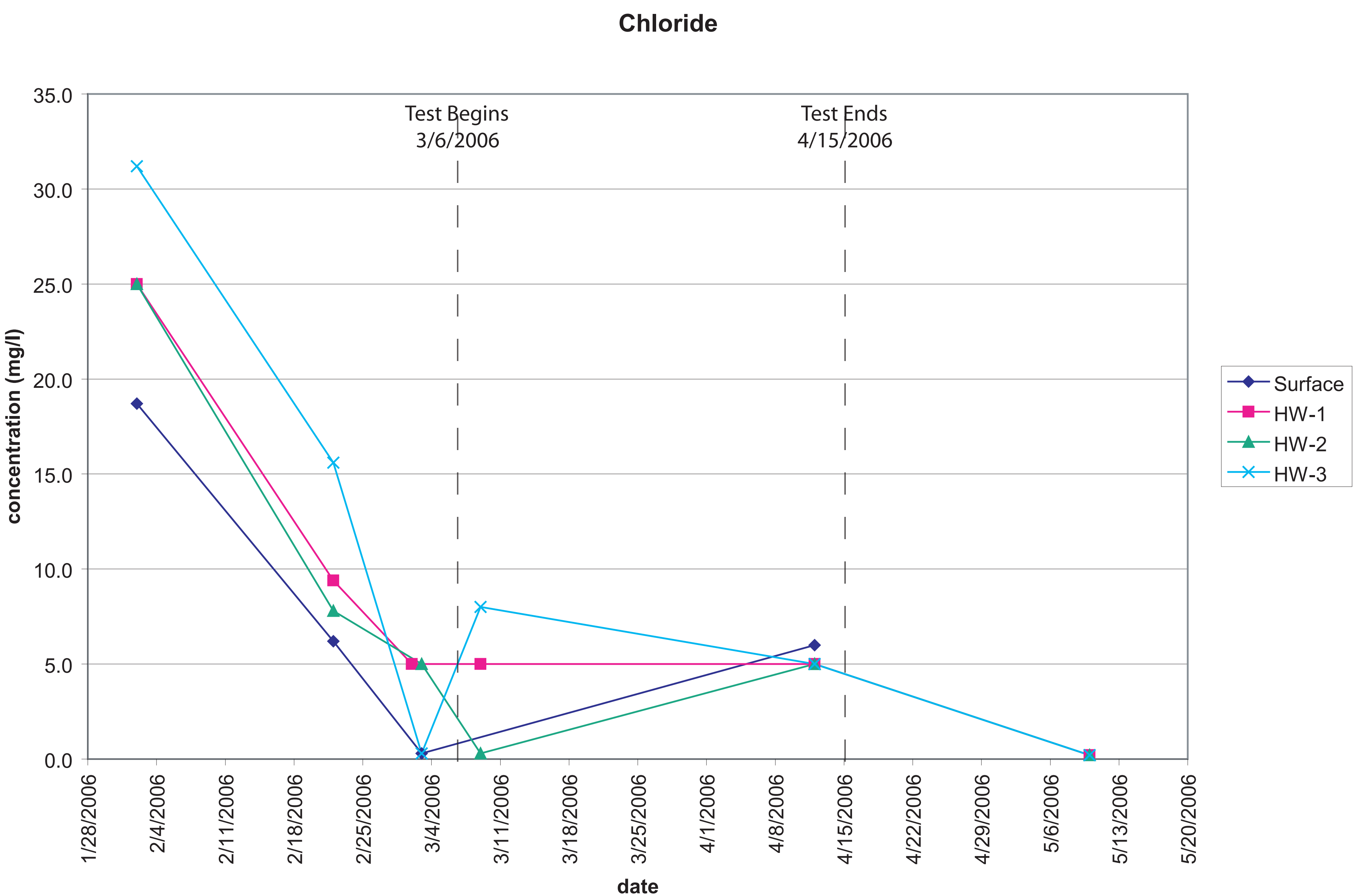

Figure 24. Graph showing chloride concentrations in monitoring wells and surface water

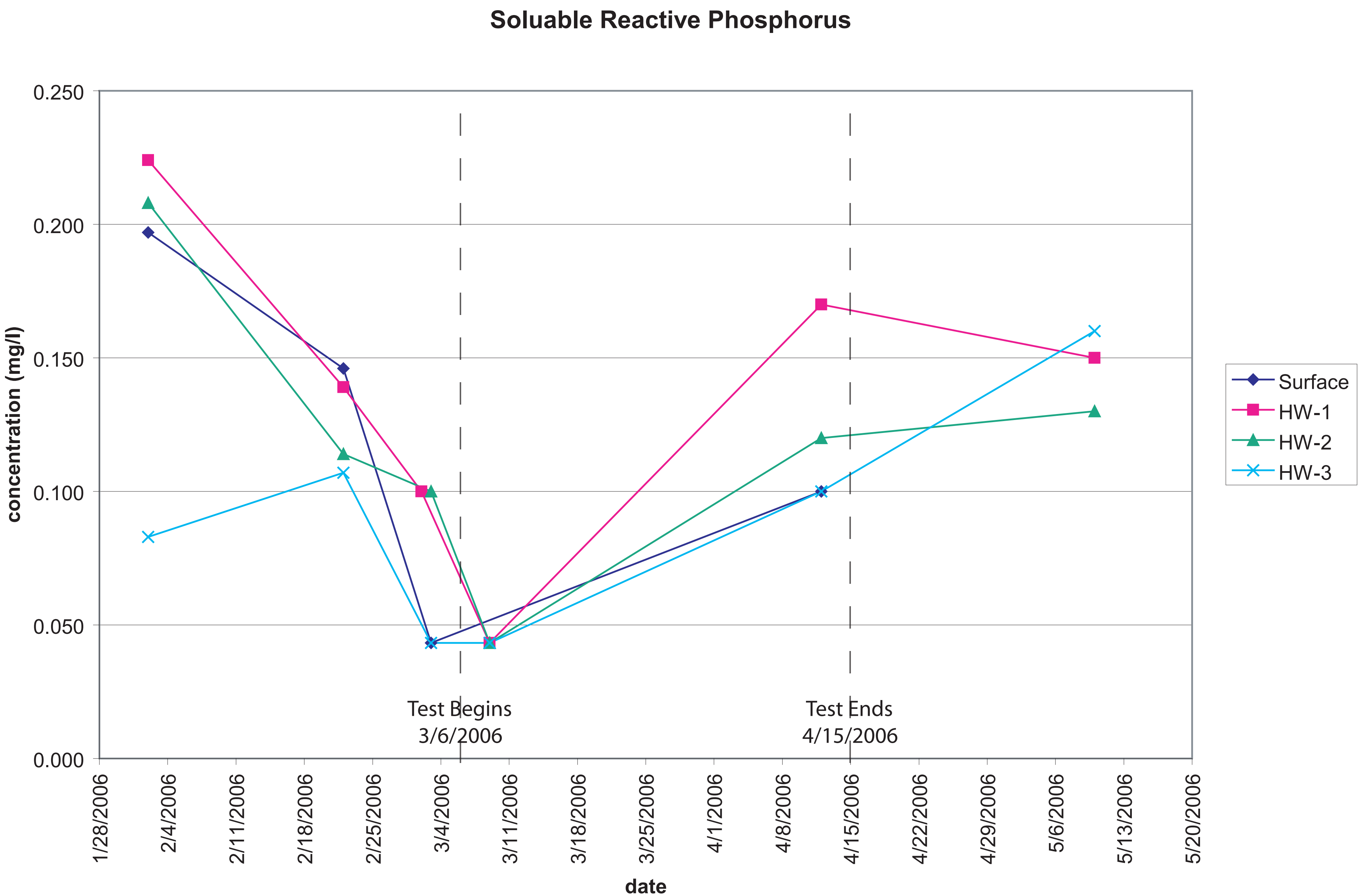

Figure 25. Graph showing soluable reactive phosphorous concentrations in monitoring wells and surface water

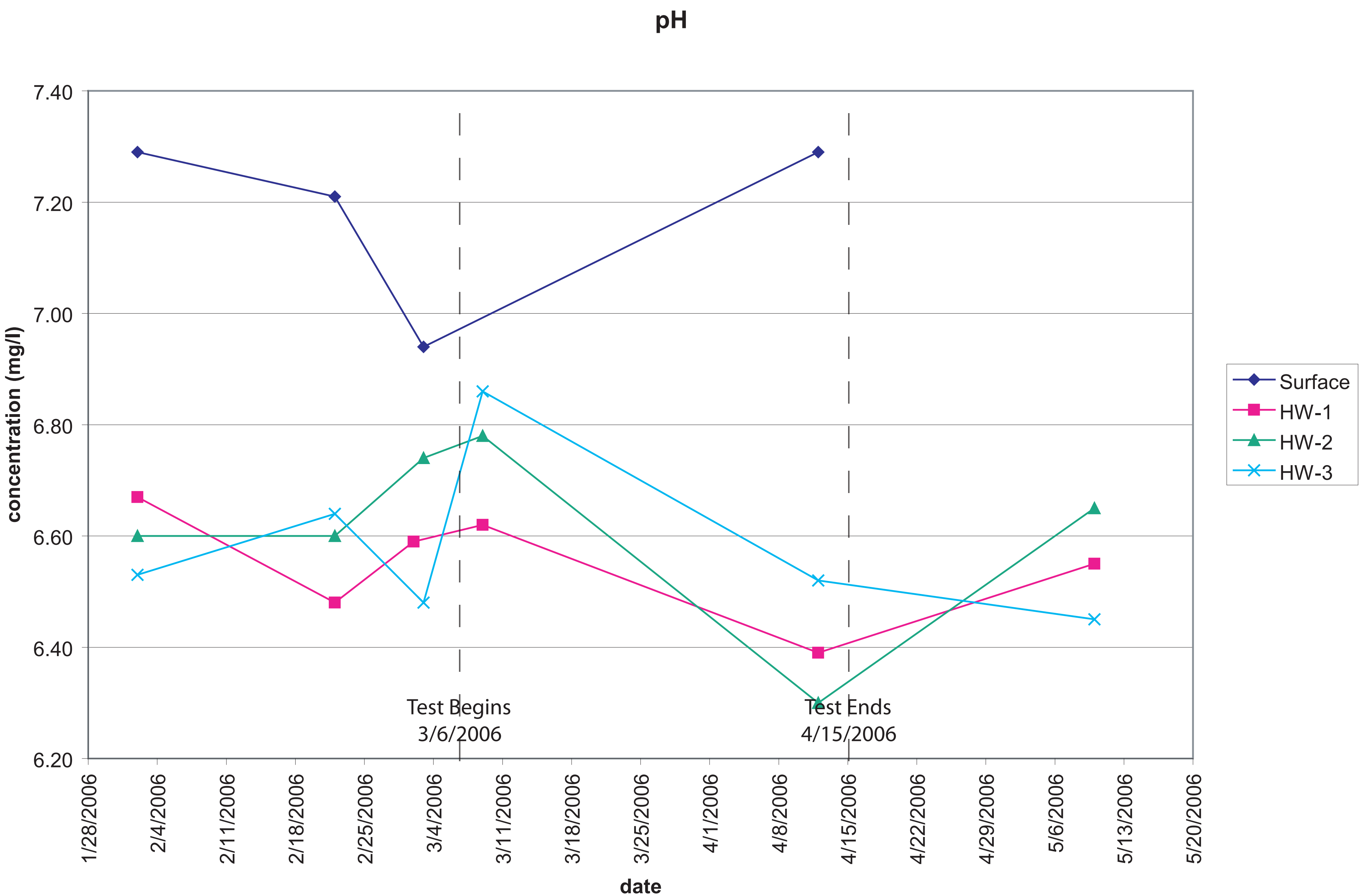

Figure 26. Graph showing pH in monitoring wells and surface water

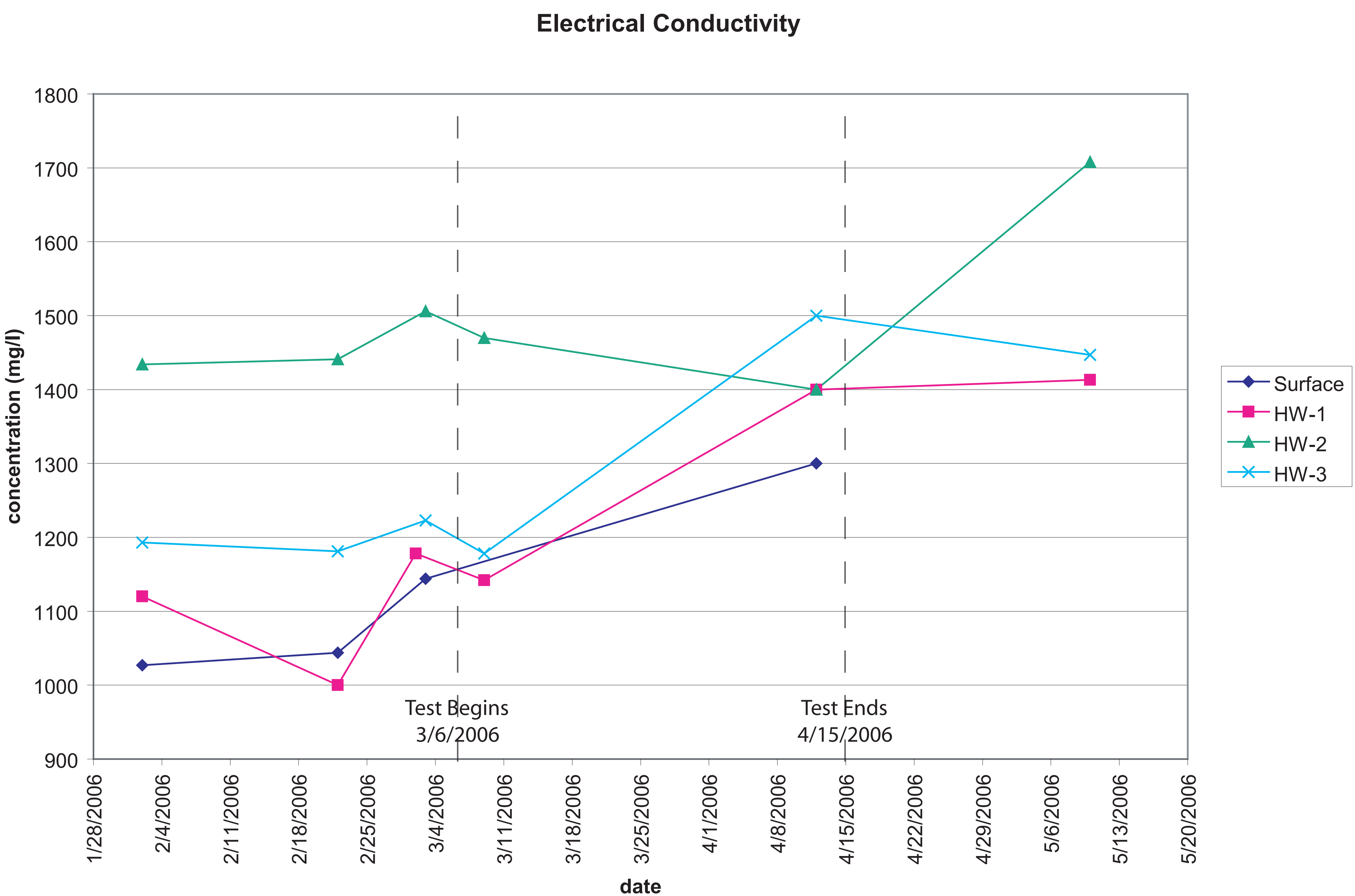

Figure 27. Graph showing electrical conductivity in monitoring wells and surface water

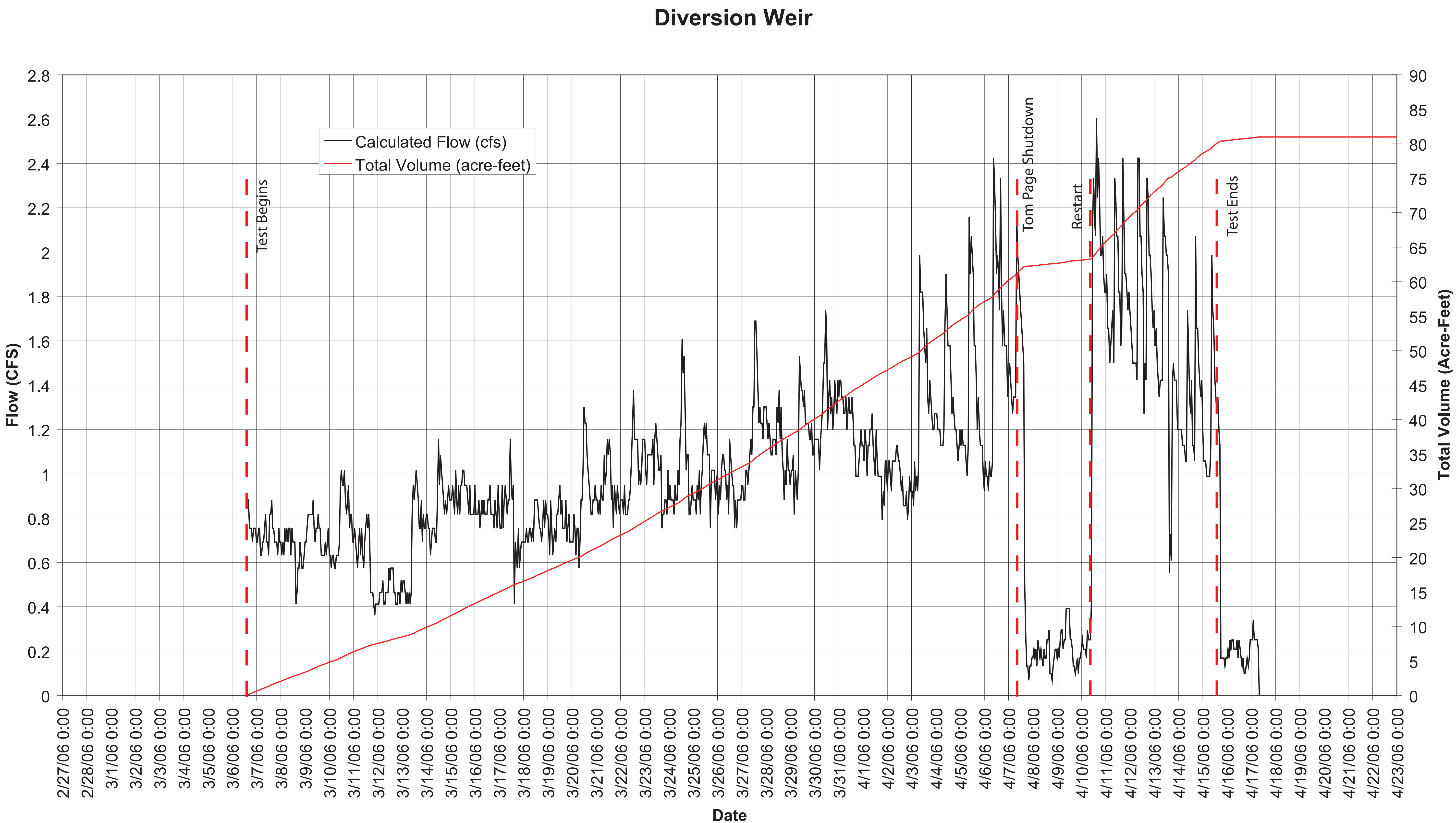

Figure 28. Hydrograph for branch ditch diversion gauge.

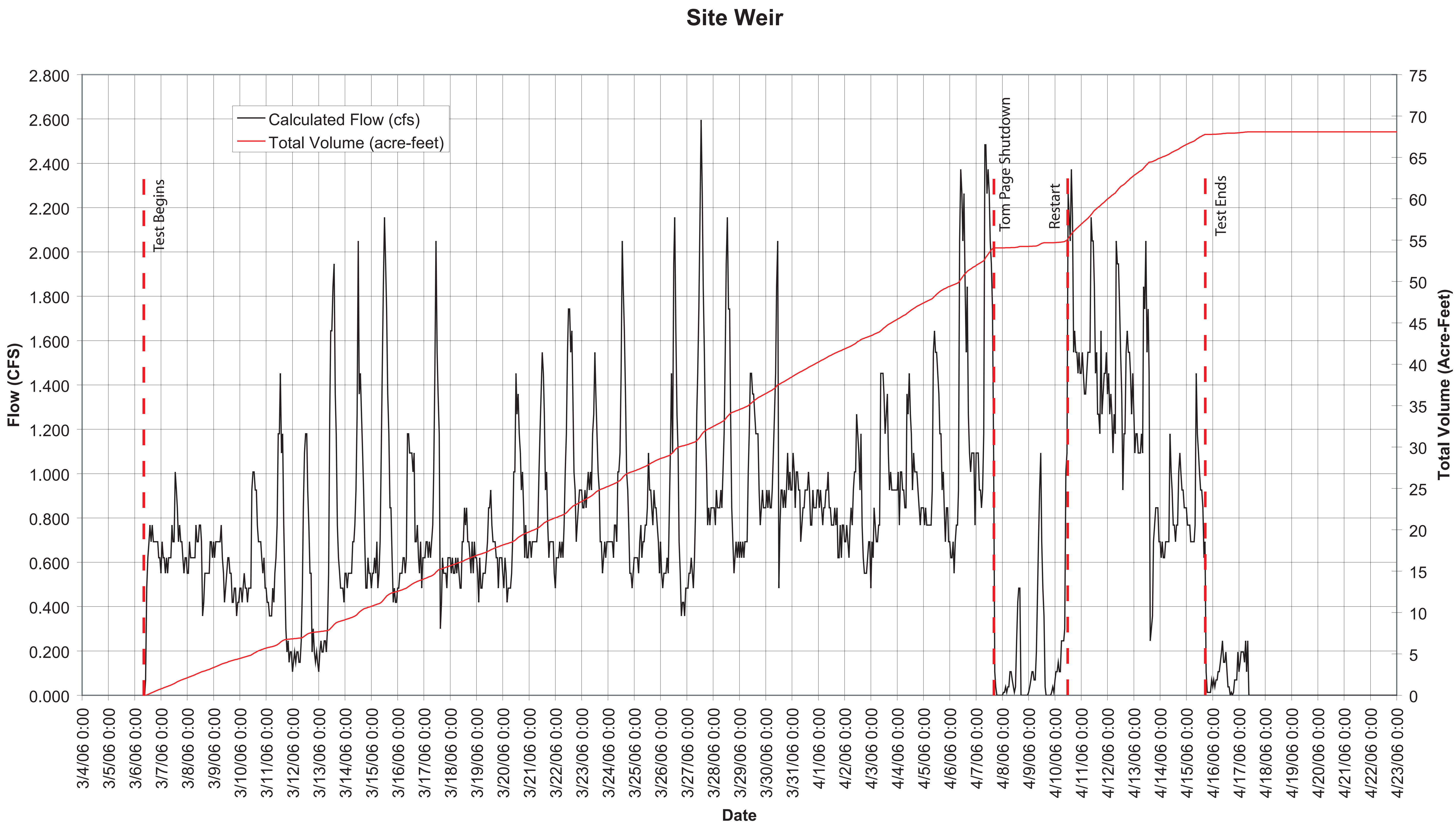

Figure 29. Hydrograph for branch ditch gauge at the Test Site.

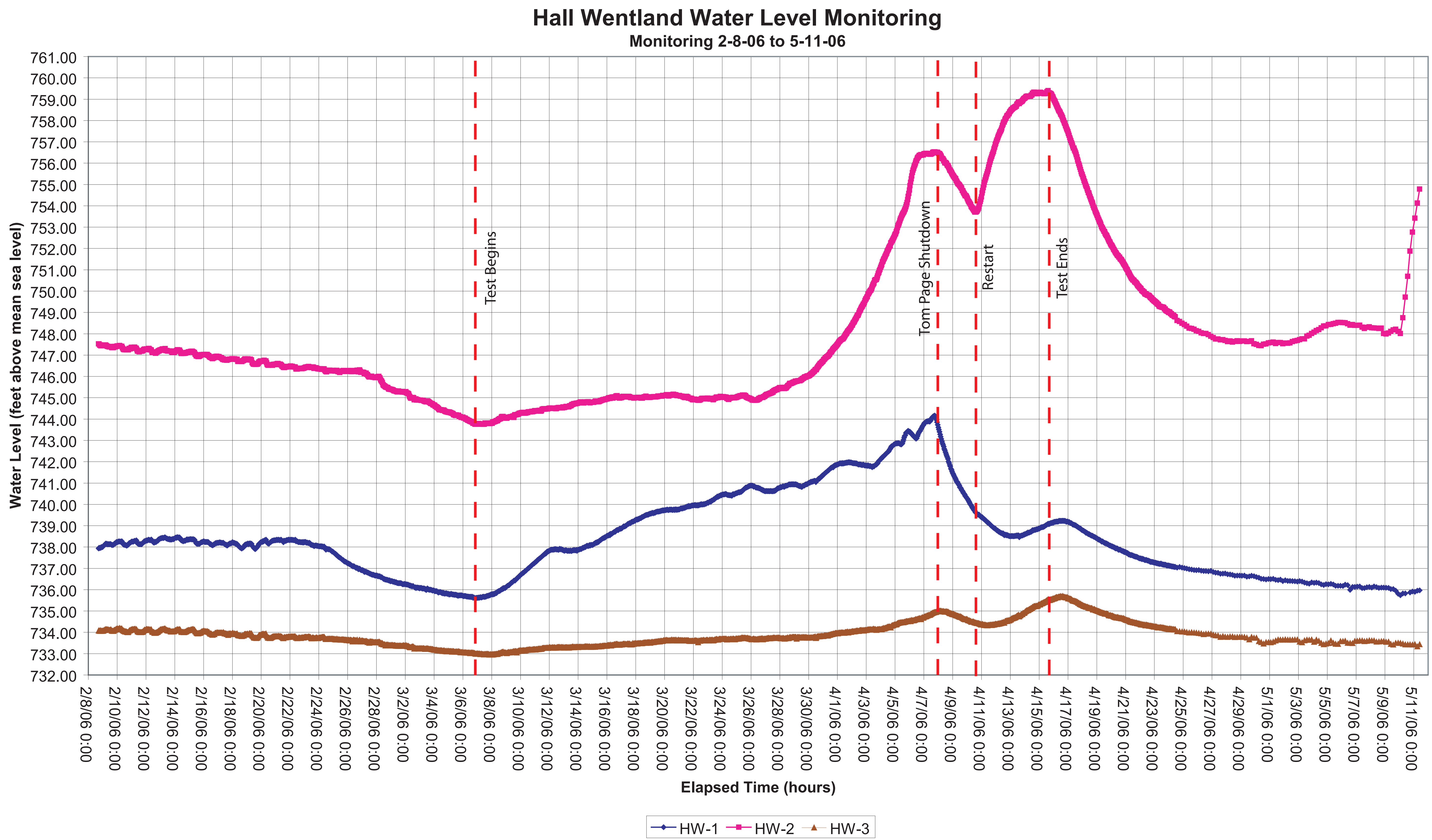

Figure 30. Hydrographs for the three monitoring wells.

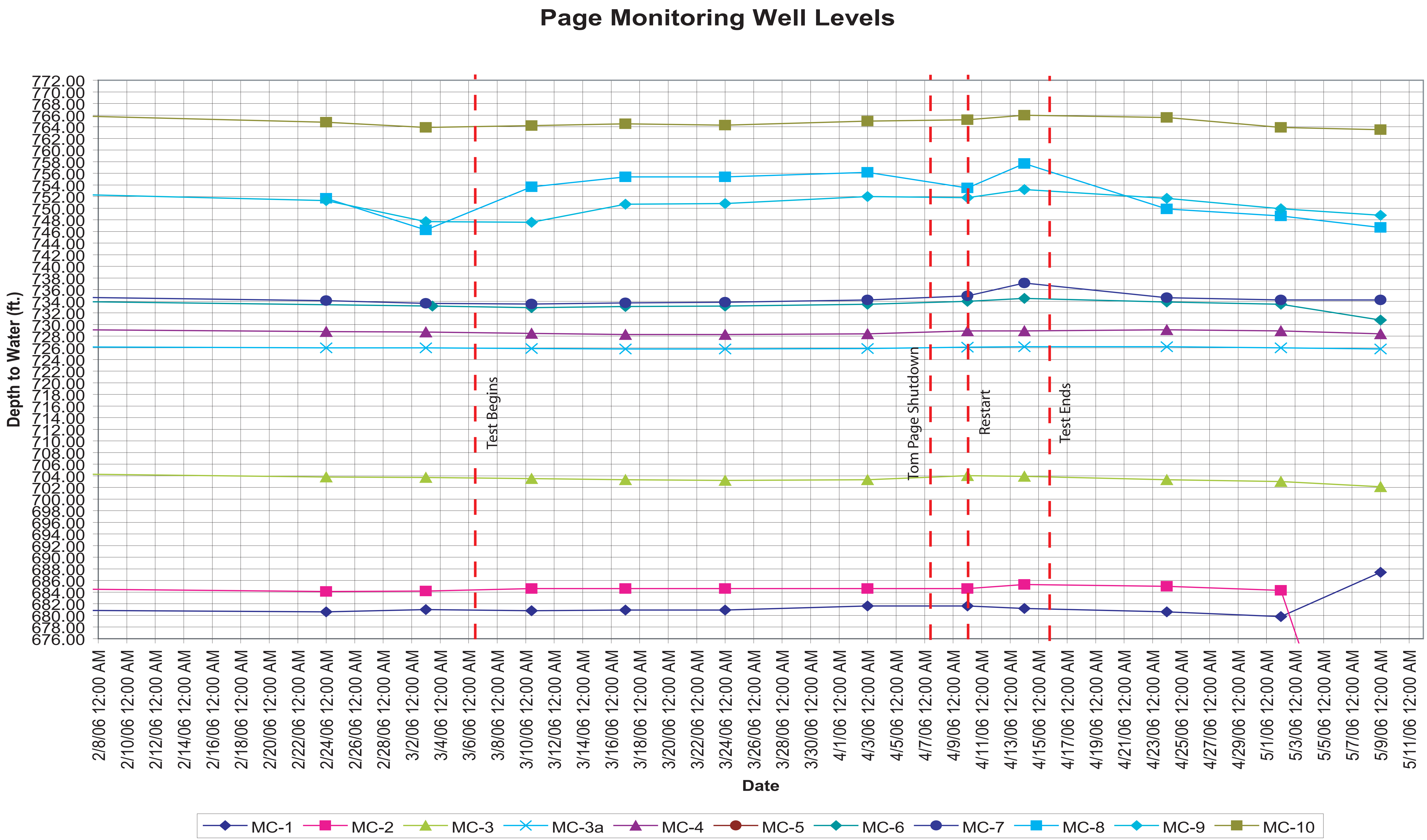

Figure 31. Hydrographs for the manually measured water wells.

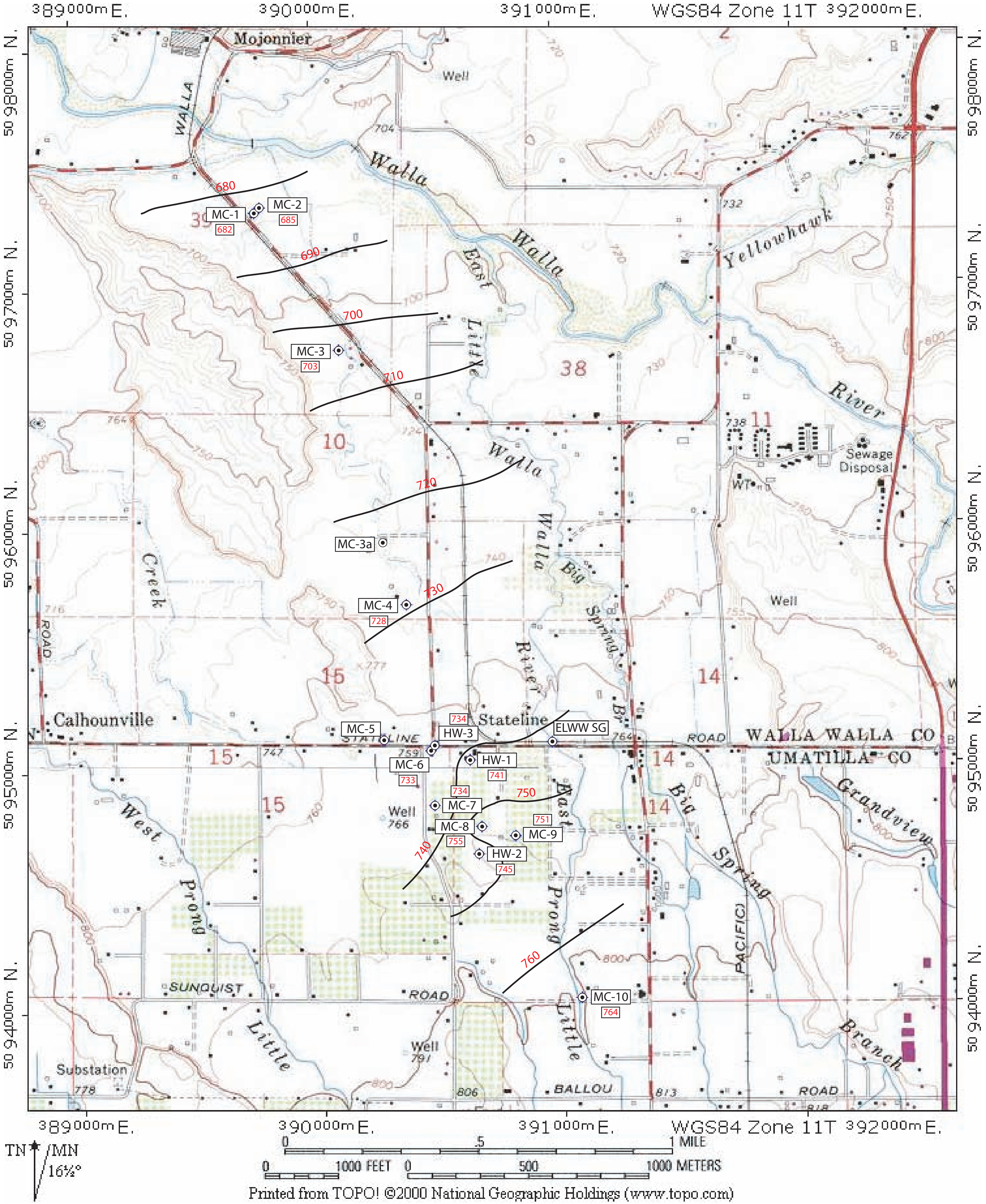

Figure 32. Water table map for late March 2006, after the start of testing.

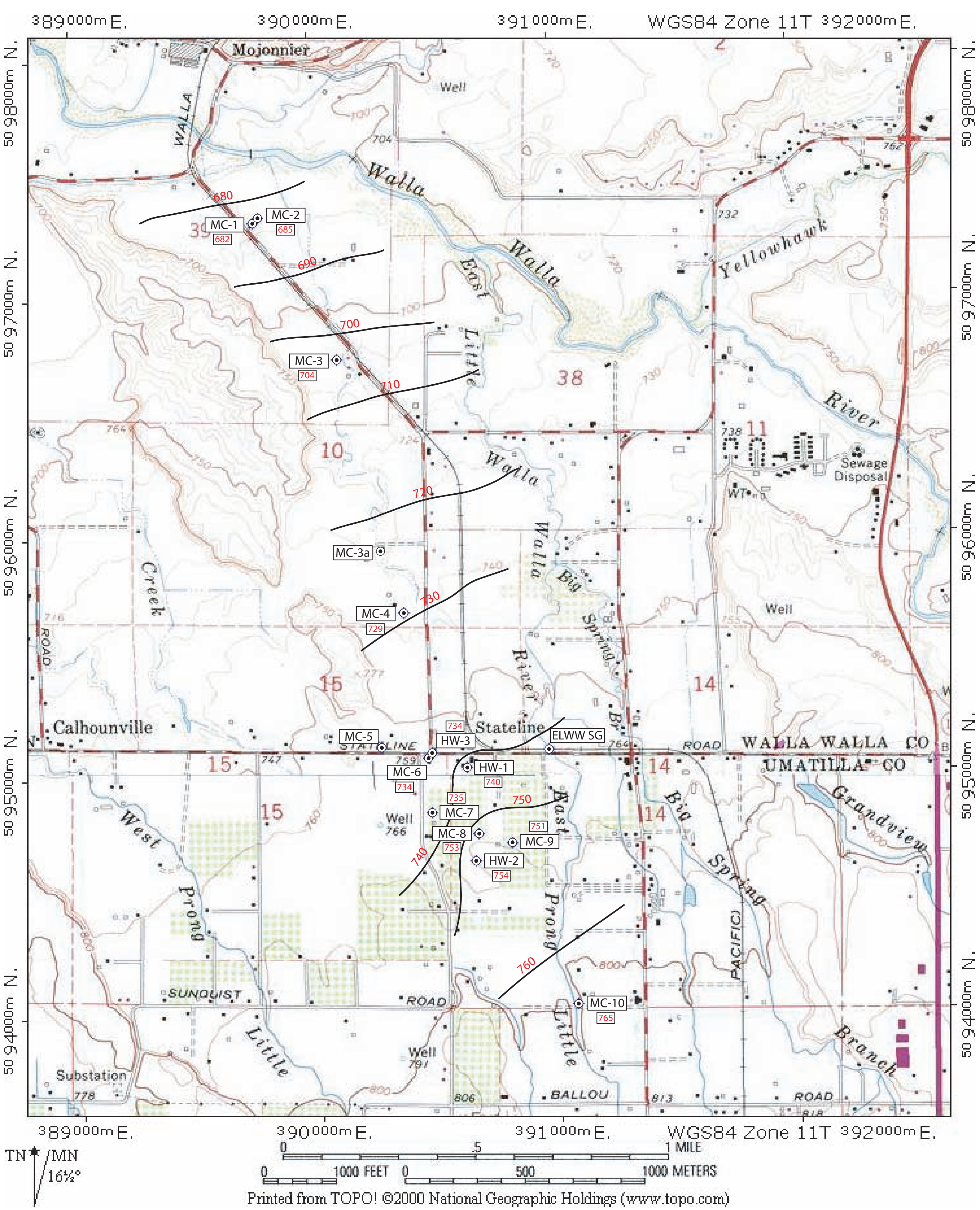

Figure 33. Water table map for early April 2006, soon before the end of testing.

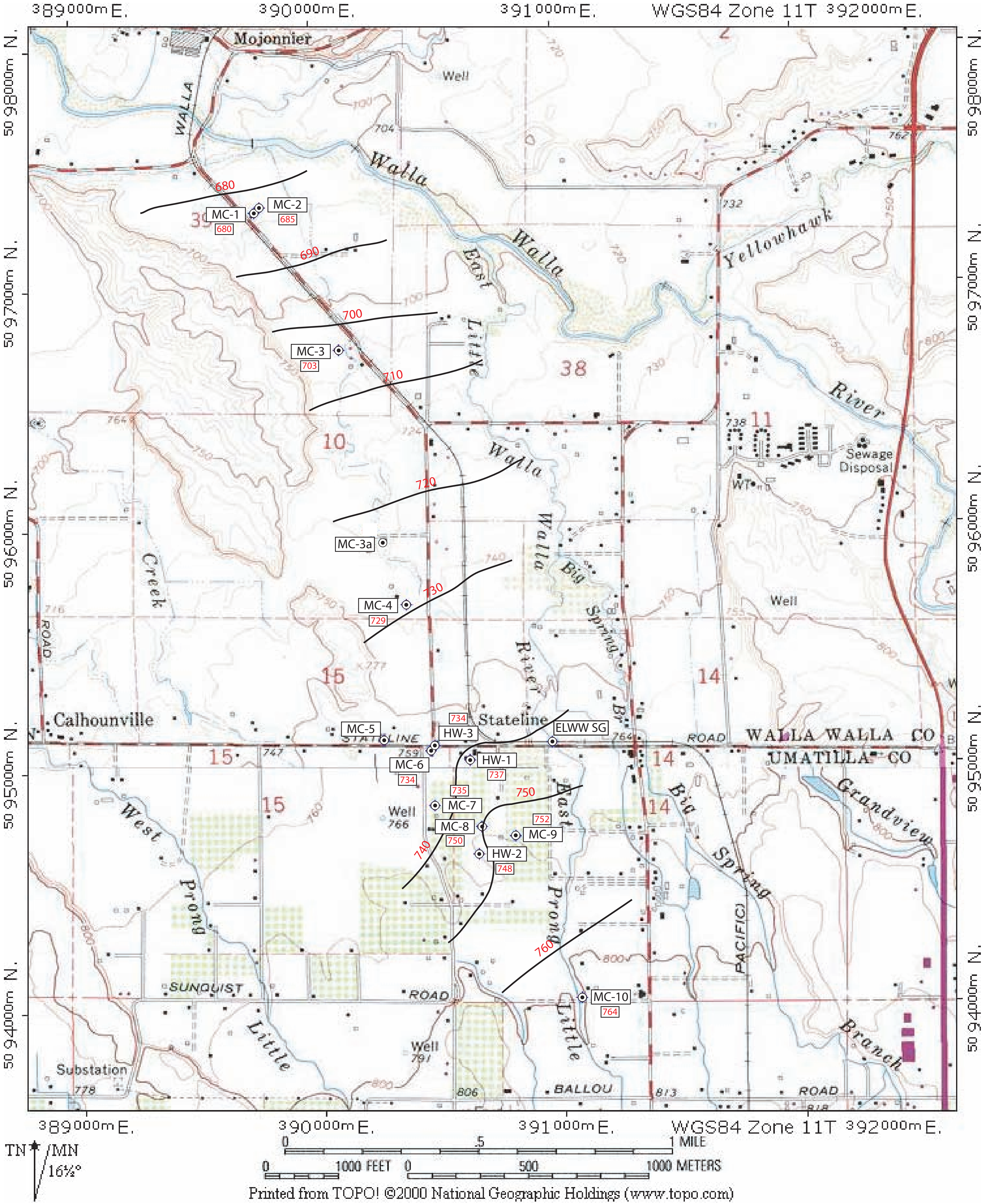

Figure 34. Water table map for late April 2006, after the end of testing.

Appendix A

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Appendix B

Geologic Logs and As-Built Diagrams

Appendix C

Well Logs for Existing Water Wells Used in the Analysis of the Test Site Area

Appendix D

Water Quality Chain of Custody Forms, Field Reports, and Laboratory Reports