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Hydrogeology and Groundwater Modeling Evaluation

TICKNER FARM SUBDIVISION

Tumwater, Washington

Prepared For:

HW SEATTLE, LLC

Project No. 20200033H001
April 23, 2020

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1.0 INTRODUCTION

Associated Earth Sciences, Inc. (AESI) is pleased to present this report documenting our groundwater flow analysis services for the proposed Tickner Farm Subdivision project. HW Seattle, LLC retained AESI to evaluate development requirements per City of Tumwater Ordinance 02005-003. Our work was completed in general accordance with our scope of work dated March 25, 2020, and is based on email correspondence and conversations with Mr. Jeff Pantier, of Hatton Godat Pantier, Inc.

1.1 Project and Site Description

1.1.1 Previous Work

AESI's knowledge of the project site is based on our involvement with the property between 2005 and 2008 (AESI, 2006a; AESI, 2006b). Our fieldwork at that time included monitoring well installation, exploration pits, and groundwater level monitoring at the project, then referred to as Tumwater-Doelman. No fieldwork occurred for the current study.

1.1.2 Proposed Development

The project site is composed of approximately 292 acres in Tumwater, Washington west of Littlerock Road near the intersection of 76th Avenue SW in portions of Sections 8 and 9 of Township 17 North and Range 2 West. Overall, the site is generally low-lying and gently undulating with a topographic relief of approximately 60 feet. The majority of the site is currently farmed, and several related structures and residences exist along the eastern portion of the site. The site contains a northeast to southwest-oriented small ridge near the center of the property. From this center ridge, the overall topography gently slopes to the northwest. The site is relatively flat east of the ridge. Wetlands are identified at the lowest elevations on the northwestern portion of the site and along the western south and north property boundaries. Single-family residential development is currently proposed for the site, and preliminary plans indicate stormwater generated by road, roof, and lot runoff will be accommodated by retention/detention facilities onsite, if possible. The site is located within the boundary of the Salmon Creek Basin. The location of the site relative to surrounding geographical features is shown on Figure 1.

1.2 Purpose and Scope

The City of Tumwater (City) has development standards (Ordinance 2005-003) for new development located within the Salmon Creek Basin in response to flooding caused by high groundwater conditions from 1997 and 1999. The development standards include three steps that development project proponents must take in order to minimize potential flooding due to proposed project stormwater infiltration facilities. A description of each step is provided below.

Steps 1 and 2 were addressed in our previous hydrogeologic study dated March 24, 2020 (AESI, 2020). The study described in this report is intended to address Step 2.

Step 1: Initial Screening Process. Develop reliable site-specific information or information from neighboring properties regarding groundwater levels and correlate to 1999 conditions to demonstrate at least 6 feet of separation between stormwater drainage facilities and groundwater elevations during high groundwater events.

Step 2: Site-Specific Monitoring. Install piezometers at the project site to monitor groundwater levels. Predict 1999 depth-to-groundwater at the project site by correlating on-site data to 1999 high groundwater conditions.

Step 3: Mounding Analysis. If less than 6 feet of separation is indicated, perform mounding analysis using approved numerical modeling software to determine whether groundwater mounding would result in either a water level elevation gain greater than 0.5 feet at property boundaries, or increased groundwater flooding, or both.

Following Pacific Groundwater Group (PGG) guidelines detailed in the City's Ordinance, AESI's linear regression analysis with the Black Hills High School (BHHS) well did not provide adequate characterization of groundwater flooding for the 1999 high groundwater elevation as required by the City's Ordinance. We used numerical groundwater modeling to estimate the 1999 high groundwater conditions at the Tickner Farm Subdivision site.

AESI used MODFLOW, the numerical groundwater flow model developed by the U.S. Geological Survey (USGS), to simulate groundwater conditions in the Vashon recessional outwash (Qvr) beneath the site. While the development standards specifically require MODFLOW to accomplish the mounding analysis (Step 3), the purpose of this numerical groundwater model is to simulate seasonal high groundwater levels in the Qvr aquifer during 1999 (Step 2). AESI compares the modeled results to the PGG analytical approach completed in our previous hydrogeologic study (AESI, 2020).

1.3 Authorization and Limitations

AESI's hydrogeological and geotechnical engineering services are provided as a consultant to HW Seattle, LLC. Authorization to proceed was received from HW Seattle, LLC via email from Jeff Pantier on March 26, 2020. This report has been prepared for the exclusive use of HW Seattle, LLC and their agents, for specific application to this project. Within the limitations of scope, schedule, and budget, AESI's services have been performed in accordance with generally accepted hydrogeologic and geotechnical engineering practices in effect in this area at the time this report was prepared. No other warranty, express or implied, is made.

2.0 GEOLOGIC AND HYDROGEOLOGIC CONDITIONS

2.1 General

Subsurface conditions in the vicinity of the project site are inferred from AESI's and others' explorations completed onsite, review of explorations and water wells completed by others in the vicinity, and review of applicable geologic literature, Light Detection and Ranging (LIDAR) maps, and other documents.

2.2 Regional Setting and Geology

The project site and vicinity, including sections of the City of Tumwater, is located within a northeast-southwest-trending basin bounded by Tertiary bedrock to the north, west, and southeast. Unconsolidated sediments in this basin were deposited over multiple glacial and interglacial periods over the past 2.5 million years. During glacial periods, large continental glaciers expanded from British Columbia and periodically extended down into the Puget Sound as a broad, tongue of ice commonly referred to as the Puget Lobe, covering the Puget Lowland with up to several thousand feet of ice. In the southern Puget Lowlands, the Puget Lobe is differentiated into two sub-lobes, the Olympia Lobe and the Yelm Lobe. The Puget Lobe deposited a variety of glacial sediments, including outwash sand and gravel from meltwater streams, proglacial lacustrine silts and clays, and glacial till deposited at the base and along the margins of the active glacial ice. During and following the recession of the glacier, meltwater emanating from the receding glacial ice front eroded areas of the drift plain and subsequently deposited recessional outwash sand and gravel deposits.

Prominent topographic features on this upland surface were deposited and scoured or eroded by various glacial processes during the Vashon Stade of the Fraser Glaciation, the most recent glaciation. Vashon lodgement till is an unsorted, non-stratified sediment that was deposited or "smeared" beneath the sole of active glacial ice. Lodgement till deposited by the Olympia Lobe mantles the surface around Black Lake and Black River and bedrock outcrops to the east and south of Mima Prairie, forming linear convex "whale back" ridges termed drumlins or flutes. These landforms are distinctly visible on LIDAR and parallel the south-southwesterly ice flow direction across the region. During the late-stage glacial retreat, the basin was a major pathway for glacial meltwater drainage (Walsh and Logan, 2005). Regional mapping indicates high-energy outwash channels primarily occupied areas on the southern side of the basin (Logan et al., 2009) and carved an erosional channel north of the Tickner Farm Subdivision, inferred to extend from Olympia through the southern end of Black Lake (Walsh et al., 2003).

2.3 Site Geology

The near-surface geologic conditions of the site are composed predominantly of sediments derived from the Vashon glaciation. The ground surface topography and our current interpretation of subsurface conditions are represented in a series of cross-sections whose

locations are shown on Figure 2 (Figures 3 through 6). Exploration logs including subsurface descriptions are included in Appendix A. Vashon recessional outwash (Qvr) and Vashon lodgement till (Qvt) sediments have been identified at the site. The explorations performed for our previous studies encountered approximately 25 to over 50 feet of medium dense, brown, silty fine sand to fine sandy silt interpreted to represent Qvr (AESI, 2006a; AESI, 2006b). In several locations on the eastern side of the site, the Qvr graded to sand with gravel. Qvt underlies the Qvr predominantly on the central to eastern half of the site. Qvt sediments encountered consisted of dense, brown to gray, silty sand with gravel.

2.4 Hydrogeologic Conditions

A groundwater study in northern Thurston County performed by the USGS (Drost et al., 1998) indicates that a shallow and several deep aquifers likely exist in the sediments underlying the project site. A shallow, unconfined (water table) aquifer is expected to exist in the Qvr sands encountered on the site generally overlying the low-permeability Qvt. Groundwater in the Qvr aquifer flows towards surface water features and ultimately discharges at the Deschutes River, Black Lake or River, and Salmon Creek or recharges deeper aquifer intervals. The Qvr aquifer can be an important water supply in local areas. However , in many areas of the County it is thin and/or unsaturated and relatively few water supply wells are completed in it (Drost et al., 1998).

The Qvr aquifer present beneath the site responds to seasonal precipitation patterns. Groundwater elevation hydrographs for on-site monitoring wells are included in Appendix B.

3.0 HYDROGEOLOGIC CONCEPUTAL MODEL

3.1 General

The hydrogeologic conceptual model is constructed from a review of data collected by AESI and others. This data includes, but is not limited to, on- and off-site exploration borings and groundwater monitoring wells, water well reports for domestic water supply wells on file with the Washington State Department of Ecology (Ecology), and published and grey literature documents containing hydrogeologic parameters, hydrogeologic relationships and cross-sections, groundwater model studies, groundwater contour maps, and geologic maps. Full references are provided in Section 8.0. Pertinent reviewed documents include reports prepared by PGG (2000, 2004, 2018), documents and data provided by Washington Department of Natural Resources (WADNR) (Walsh et al., 2003; Walsh and Logan 2005; Logan et al., 2009), subsurface data available on the WADNR Geologic Information Portal, including geotechnical borings on file with the WADNR and water wells on file with Ecology, and documents and data provided by the USGS (Drost et al., 1998, 1999).

3.2 Hydrostratigraphy

The Vashon recessional outwash (Qvr) aquifer present in the shallow subsurface is developed primarily above very low-permeability Vashon lodgement till (Qvt) beneath the eastern side of the site (Figures 3 through 6). Qvt was not encountered in deep borings on the western side of the site. Regional mapping and review of subsurface data indicate the lodgement till is variable in thickness near the site.

3.3 Hydrologic Boundary Conditions

Hydrologic boundaries of the groundwater flow system include surface water bodies, recharge, and evapotranspiration.

Significant surface water is present adjacent to the site within the river valleys to the west and east of the site. The Deschutes River (east), and Black River and Lake (west) are important hydrologic features that serve as outflows for groundwater in the aquifer system. Salmon River, a tributary to the Black River, also influences groundwater flow at the vicinity of the site.

Rainfall data beginning in 1941 is available from the Olympia Airport weather station located approximately 2½ miles east of the Tickner Farm Subdivision site. Annual precipitation at the Olympia Airport has ranged from approximately 27.0 to 72.6 inches per year, with a median of about 50.6 inches per year. Water years 1997 and 1999 are the 3rd wettest and wettest years on record with 68.2 and 72.6 inches, respectively. Groundwater in the aquifers beneath the Tickner Farm Subdivision site is primarily sourced from infiltration of precipitation.

Evapotranspiration limits groundwater recharge during the summer months more than the winter months. Evapotranspiration can be estimated using the nearest pan evaporation station. Monthly average Class A pan evaporation data is available from PUYALLUP 2 W EXP STN over the period of record from 1931 to 1995. Monthly evaporation during this period ranged from less than 1 inch per month during the winter months to about 5 to 6 inches per month during the summer months. Per the Western Washington Hydrologic Model (WWHM), potential evapotranspiration (PET) is a fraction of the pan evaporation based on a pan coefficient.

3.4 Available Data

3.4.1 Groundwater Elevations

AESI collected water level data from nineteen monitoring wells, including continuous water level data (collected hourly with electronic data loggers) from nine of the monitoring wells. The period of record for the water level data began in August 2005 and concluded in September 2008. However, the duration of water level monitoring is variable due to multiple phases of exploration over the period of record. Groundwater information from off-site wells BHHS (Figure 2) and LRS-01/LRS-01A completed by others were compiled into the AESI database.

LRS-01 (old) and LRS-01A (current) are located approximately 2,500 feet northeast of the site along 70th Avenue SW.

The groundwater dataset included sixteen surveyed wells completed by AESI and others, two off-site surveyed wells completed by others, and three non-surveyed wells completed by AESI. Logs for the AESI monitoring wells are included in Appendix A. Figure 2 shows the locations of the monitoring wells completed for the Tumwater-Doelman project and the nearby BHHS well. Groundwater elevation hydrographs for AESI monitoring wells are included in Appendix B as Figures B-01 through B-03, and groundwater level data collected manually from the on-site wells between August 2005 and September 2008 are presented in our previous report (AESI, 2020). On-site monitoring wells include:

- MW-1 through MW-5 installed by Robinson and Noble, Inc. (2000);
- MW-6 installed by the property owner;
- MW-7 through MW-16 installed by AESI (2006a);
- MW-17 through MW-19 installed by AESI (2006b).

Surveyed elevations of monitoring wells MW-1 through MW-16 were provided by Hatton Godat Pantier to reference datum National Geodetic Vertical Datum of 1929 (NGVD29) for elevation. Monitoring wells MW-17 through MW-19 were not surveyed.

Groundwater elevation data from the BHHS well was provided by Mr. Charles "Pony" Ellingson of PGG in an email on March 17, 2020. The period of record for the BHHS groundwater level measurements was between May 1996 and February 2016.

Groundwater elevation data from the LRS-01 & LRS-01A well was obtained on the Thurston County Public Works website.

Groundwater elevations in monitoring wells on the eastern side of the site are higher than on the west side, with a relatively flat gradient, sloping gently to the west. These wells include MW-2, MW-3, MW-4, MW-5, MW-6, MW-7, MW-8, MW-9, and MW-16. The groundwater gradient steepens toward the west, beginning approximately in the middle of the site. Monitoring wells in the central and western portions of the site include MW-1, MW-10, MW-11, MW-12, MW-13, MW-14, and MW-15. The hydrographs show a significant seasonal fluctuation in groundwater levels seasonally, with higher levels occurring in the winter months, and lower levels in the summer. The seasonal groundwater fluctuations in the western portion of the site are on the order of 8 to 10 feet, while in the eastern wells, the fluctuations are typically 5 to 7 feet.

3.4.2 River Discharge

Deschutes River daily discharge data is available from USGS gauge stations, the nearest (#12080010) of which is located at Tumwater, Washington approximately 3 miles northeast of

the site. The period of record at the Tumwater station spans the years 1945 to 1954, 1957 to 1964, and 1990 to present. The closest Black River discharge data is available from USGS station #12029000 near Little Rock, Washington located approximately 6 miles southwest of the site. The period of record at the Little Rock station briefly spanned 1942 to 1950. River baseflow information is taken from Ecology's Water Supply Bulletin No. 60, *Estimated Baseflow Characteristics of Selected Washington Rivers and Streams* (Sinclair and Pitz, 1999).

3.4.3 Hydraulic Conductivity

Two "Hydrogeologic Framework" reports published by the USGS contain relevant hydrogeologic information to the Tickner Farm Subdivision site (Vaccaro et al., 1998; Drost et al., 1998). These reports include ranges of hydraulic conductivities for geologic units found within their respective study sites, which include the Tickner Farm Subdivision. These reports obtain values from specific capacity data from water well reports, which are biased towards the more productive zones in the units, and aquifer tests that are limited to the major water-producing aquifers. Locally the hydraulic conductivity of these units may vary from the reported values. Based on 50 wells with specific capacity data, Drost et al. (1998) reported Qvr hydraulic conductivity values range from 14 to 2,100 feet per day (ft/day) with median of about 160 ft/day.

4.0 NUMERICAL MODEL

The hydrogeologic conceptual model discussed above was numerically implemented using MODFLOW, a three-dimensional finite-difference groundwater model that was originally developed in the 1980s by the USGS (McDonald and Harbaugh, 1988). MODFLOW solves a system of linear groundwater flow equations using a finite-difference methodology. The code is based on equations for Darcy's Law and the conservation of fluid volume. The finite-difference method solves a set of differential-flow equations to find the distribution of groundwater elevations (or "head") for the model domain at a user-defined time step. This is accomplished by placing a network of grid cells over the flow system of the model domain and calculating the heads at each node such that the net change in volume is near-zero at the end of each time step. Each grid cell is assigned to a layer and these layers must extend across the model domain. Hydrogeologic properties, boundary conditions, and observations are assigned on a cell-to-cell basis.

MODFLOW is capable of simulating both steady-state and transient flow in a variety of aquifer types, boundary conditions, and hydrologic stresses and considered the standard for numerical solution to the equations of flow in saturated porous media.

This section describes the construction of the numerical model. Section 5.0 describes the model calibration procedure and calibration statistics of the predictive model. Section 6.0 describes

the results of the predictive model. Graphical inputs and outputs of the MODFLOW model are presented in Appendix C.

4.1 Code Selection

MODFLOW-NWT was selected to implement the numerical model. MODFLOW-NWT is a Newton formulation of MODFLOW-2005, which can better represent unconfined aquifers and surface-water/groundwater interactions than its predecessors (Niswonger, 2011). Groundwater Vistas (Version 7), developed by Environmental Simulations, Inc., was used as a graphical user interface to facilitate input and analyze output from MODFLOW (Rumbaugh and Rumbaugh, 2017).

4.2 Simulation Type

Three numerical models were developed:

1. Steady State - simulating 2008 seasonal high conditions across the site to develop parameters and initial conditions for transient models.

2. Transient - spanning water years 2001 to 2008 to calibrate model parameters. Weekly stress periods with daily time steps.

3. Transient - spanning water years 1980 to 2008 to simulate seasonal high groundwater over water years 1997 to 1999 and verify model calibration relative to water level observations during water years 2006 to 2008. Monthly stress periods spanning water years 1980 to 1994 and weekly stress periods with daily time steps from 1995 through 2008.

4.3 Model Structure

4.3.1 Model Grid

The groundwater flow model was constructed with a finite-difference grid consisting of one layer. The horizontal grid spacing varied from 50 feet at the site to about 1,000 feet near the edge of the model grid (Figure C-01 in Appendix C). The simulated area includes approximately 15,000 acres and 17,542 total active cells.

4.3.2 Model Layers

The hydrostratigraphy beneath the site and vicinity is simplified into a single model layer (Layer 1) to represent the general conditions within the shallow aquifer at the site and vicinity. Layer 1 represents the aquifer consisting of Qvr sands and gravels and recent alluvial deposits along the Deschutes River, Salmon River, and Black River. These deposits are inferred to be

hydraulically connected. The simplified model represents this unit as laterally transmissive throughout the model domain. The ground surface elevation (top of Layer 1) is based on LIDAR topography data. The bottom elevation of Layer 1 was defined as the top of the underlying Qvt confining unit as determined by a combination of on-site subsurface data, subsurface data obtained on the WADNR Geologic Information Portal, WADNR geologic maps, and data from Drost et al. (1998). Generally, the Qvr aquifer thickens to the north and east towards mapped paleochannels (Walsh et al., 2003). The Qvr aquifer locally thickens to the west within the Tickner Farm Subdivision.

4.4 Boundary Conditions

In MODFLOW, boundary conditions are used to represent the exchange of flow between the active model domain (grid) and the external system (inactive cells). Boundary conditions are the source-sink term in the model governing equation and can be divided into three categories: specified head, specified flux, and head-dependent flux. Head-dependent flux boundary conditions require an input term called conductance which is a numerical simplification of Darcy's Law in the MODFLOW code. Conductance is a factor calculated from hydraulic conductivity, saturated thickness, and cell geometry to relate the difference in head to the rate of flow. Boundary conditions utilized in the model are shown in Figure C-02 and described below.

4.4.1 Constant Head (CHD)

Constant-head cells are a type of specified head boundary condition generally used to represent known hydrologic boundaries at the edges of the actively modeled area. The modeler specifies the boundary head and groundwater fluxes into or out of the boundary are calculated from the simulated head in adjacent cells, the boundary cell geometry, and hydraulic conductivity. The constant-head cell is a unique kind of boundary that is appropriate for locations where the boundary head is known and where the boundary strongly influences groundwater flow in its surrounding area.

Constant-head cells were assigned along the east and west boundaries of Layer 1 simulating the Deschutes River and Black River and Lake, respectively. Boundary heads were set close to ground surface per LIDAR topography. Specified head boundary conditions are reasonable as these rivers are important hydrogeologic boundaries to groundwater flow in the region.

4.4.2 River (RIV)

A two-way head-dependent boundary condition is the River (RIV) cell option. RIV is most commonly used to represent interactions of rivers and streams with a simulated aquifer. RIV can also simulate the interaction of lakes with a simulated aquifer. Cells assigned this boundary condition permit flow into or out of the model. The flow rate out of the model is determined by the difference in the calculated piezometric head and the reference river elevation (gaining

river). If the calculated head drops below the river or lake bed elevation, the flow into the model is determined by the difference in the calculated piezometric head and the bed elevation. The model inputs require the head elevation, bed elevation, and river conductance.

River cells were assigned along the southern boundary of Layer 1 to simulate Salmon Creek. River cells were also assigned to Layer 1 to simulate Trosper Lake and Barnes Lake. RIV stages were set close to ground surface with assumed RIV bed depths of 2 feet for Salmon Creek and 5 feet for the lakes. RIV bed conductance was assigned values of 1,000 to 100,000 square feet per day (ft^2/day) for Salmon Creek and 800,000 to 2,500,000 ft^2/day for the lakes. The conductance value assigned to cells is proportional to the area or length of the RIV boundary occupying the cell.

4.4.3 Drain (DRN)

The Drain (DRN) cells are a one-way head-dependent flux boundary that is always a groundwater sink. DRN can simulate constructed elements such as drain pipes and a variety of other structures and natural features such as springs. The boundary allows both the boundary head and the boundary flux to vary in response to the calculated heads in the interior of the model. If the piezometric head is below the drain elevation, the drain flow is zero. The model inputs specify the drain elevation and drain conductance.

Drain cells were assigned to Layer 1 to represent the drains along the boundary of the BHHS site. Drains were assigned relatively high conductance values of 1,000,000 ft^2/day determined from the Barclift groundwater model by PGG (2018). The drains were assigned elevations and were transiently-activated during water years according to the Barclift groundwater model by PGG (2018).

4.4.4 Unsaturated Zone Flow (UZF)

The Unsaturated Zone Flow (UZF) package is a combination of a specified flux boundary condition and groundwater flow package. Specified flux cells in the UZF package are used to apply a recharge rate in the model domain. These rates are multiplied by the horizontal cell area to obtain a volumetric flux rate which represents the amount of water entering the model from land surface. The package simulates the vertical flow of water through the unsaturated zone to the saturated zone using an unsaturated flow equation approximation. The Brooks-Corey function is used to define the relation between unsaturated hydraulic conductivity and water content (Brooks and Corey, 1966). Variables used by the UZF package include initial and saturated water contents, saturated vertical hydraulic conductivity, and an exponent in the Brooks-Corey function. Residual water content is calculated internally as the difference between saturated water content and specific yield. This is different than "base" MODFLOW where recharge immediately enters the saturated groundwater regime. UZF also simulates groundwater discharge where the water table exceeds land surface. High

groundwater levels may reject infiltration assuming this water converts to runoff and does not recharge the groundwater system.

The UZF package simulates monthly or weekly recharge, determined from a combination of rainfall and evapotranspiration. UZF inputs are discussed in the Section 4.6 below.

4.4.5 No-Flow Boundaries

No-flow boundaries are not a boundary condition but rather the absence of one along the edge of the model grid domain. No-flow boundaries are appropriate where groundwater flow is assumed to be approximately parallel to the model grid edge or at the base of the model if no deep percolation is assumed.

No-flow boundaries were assumed on the edges of the grid where a boundary cell was not assigned. Groundwater flow is assumed to be parallel to the model edge in these areas. No-flow boundaries were assumed on the northern and southern edges of Layer 1, representing the Qvt-mantled bedrock outcrops that terminate the Qvr aquifer. No-flow boundaries were assigned where Qvt is mapped at the surface along the drumlinized topography above Black River. A no-flow boundary was also assumed at the base of the model as the underlying Qvt unit is very low permeability.

4.5 Aquifer Properties

4.5.1 Hydraulic Conductivity

K values for Layer 1 ranged from about 8 ft/day to 2,000 ft/day and were assigned vertical K values of $1/10^{th}$ the horizontal value. The distribution of K values within the vicinity of the site correspond to the sediment types encountered in the saturated portion of the Qvr above Qvt (Figures 3 through 6). The high K values modeled on the eastern side of the site correspond to the high-permeability, Qvr fluvial sand and gravel and low K values modeled on the western side of the site correspond to the lower-permeability Qvr fine sands and silts. Distribution of K values outside the vicinity of the site are generally consistent with distributions of surficial deposits shown on geologic maps. These values are representative recessional outwash sands and fall within the range of literature values (Drost et al., 1998; Vaccaro et al., 1998).

4.5.2 Specific Yield and Porosity

Layer 1 was simulated as an unconfined aquifer. Specific yield and porosity for Layer 1 was assigned values of 0.30 and 0.26, respectively. Specific yield was adjusted during model calibration. These values are generally consistent with a non-glacially consolidated outwash sand or gravel.

4.5.3 Unsaturated Zone Flow Parameters

Vadose parameters were estimated from the average soil texture class of on-site samples. A saturated vertical hydraulic conductivity of 4 ft/day was assigned across model Layer 1 representing the relatively silty fine sand encountered in the upper sections of on-site borings. A Brooks-Corey exponent of 3.5 was chosen using tables from Schaake (2000) and Brooks and Corey (1966).

4.6 Recharge

Recharge was applied evenly across the model domain based on precipitation and evapotranspiration data from WWHM. WWHM includes daily precipitation values since 1941 from the Olympia Airport weather station located approximately 2½ miles east of the site, and monthly average Class A pan evaporation data from the PUYALLUP 2 W EXP STN from 1931 to 1995. A precipitation factor (P_{fact}) of 1.111 and pan coefficient (c_{pan}) of 0.76 were utilized per WWHM to adjust the weather station data to the site. Pan coefficients in WWHM are taken from NOAA Technical Report NWS 33, *Evaporation Atlas for the Contiguous 48 United States*.

Modeled recharge applied to the model domain was calculated as the precipitation (P) times the precipitation factor (P_{fact}) minus the pan evaporation (E_{pan}) times the pan coefficient (c_{pan}):

$$R = P * P_{fact} - E_{pan} * c_{pan}$$

Based on this calculation, little to no recharge is estimated during the months of June through September. Average yearly recharge is generally consistent with the 37 inches per year assumed in the vicinity of the site by Drost et al. (1999). The precipitation factor was adjusted during model calibration to represent rainfall conditions more accurately at the site as described in Section 5.3.1.

5.0 MODEL CALIBRATION

Model calibration is the process of establishing a unique set of parameters, boundary conditions, and stresses which produce simulated heads and fluxes that match with field-measured values with the lowest residual. Residuals are calculated as the observed value minus the simulated value. The model calibration workflow in both the steady-state model and the 2001-2008 transient model included a combination of manual adjustments and automated parameter estimation. We present calibration statistics of the predictive model to support our model-simulated groundwater levels and 1999 flooding areas.

5.1 Calibration Procedure

Initial calibration efforts included manual parameterization of the hydrogeologic system supported from on-site explorations. Later efforts included automated PEST package optimization (Version 14.0) (Watermark Numerical Computing, 2020) intervened with manual

adjustments to parameters. PEST is a model-independent parameter estimation software package that commonly assists the calibration of groundwater models. The function of the PEST software is to solve an inversion problem, which is the process of calculating a single parameter set with a special set of properties from a set of field measurements.

Automated parameter estimation summons mathematical approximations to navigate n-dimensional solution space, where n is the number of parameters adjusted simultaneously. The PEST package was set up to adjust many parameters to capture the expectation that hydraulic properties can vary significantly over a single hydrogeologic unit. Highly parameterized inverse problems required a process called regularization to reach a unique solution. Regularization is intended to result in parameter fields that appear geologically reasonable based on user knowledge. User knowledge is expressed in the calibration dataset as parameter initial values, bounds, and weights.

5.2 Water Level Observations, Calibration Targets, and Weighting

Water level observations from wells considered in the analysis came from select on-site monitoring wells (MW-1 to MW-15), the BHHS well, and LRS-01A. Daily data logger or monthly hand readings were used as head observation targets in the model. Targets provide a ground truth to simulated conditions within the model. Calibrating to head observations is a key component of groundwater flow model calibration. All head observations came from surveyed wells that had several observations over multiple seasons and interpreted to be consistent with the hydrologic system and expected seasonal fluctuations.

Weighting of targets allows PEST to "see" target residuals during parameter estimation. In the steady-state simulation, targets included nearly simultaneous water levels during February of 2008 and all wells considered were given equal weight. A weighting scheme was employed in the transient simulation to distribute calibration emphasis amongst head observation targets.

1. Wells that were equipped with data loggers included daily observations in the model, therefore data logger readings were given 1/30th the weight of monthly hand readings in order to achieve similar weighting amongst wells.

2. Zero weights were assigned to data that did not match with seasonal hydrograph trends. For example, MW-9 and MW-15 screens were completed too high and water levels fell below the screen during the summer and fall.

3. Water level readings during the peak of the hydrograph were weighted more heavily to emphasize seasonal groundwater highs.

5.3 Calibration Parameters

The following sections describe the three parameters that were adjusted during calibration: precipitation factor (recharge), hydraulic conductivity, specific yield. Hydraulic conductivity and specific yield were included in PEST calibration.

5.3.1 Recharge

Initial recharge rates included a precipitation factor on rainfall data from the Olympia Airport of 1.111 (+11.1%) per the WWHM. Comparison with monthly precipitation data obtained from PRISM climate group (Parameter-elevation Relationships on Independent Slopes Model) suggests the precipitation factor of 1.017 (+1.7%) (Figure C-03). The calibrated model included a precipitation factor of 1.064 (+6.4%), approximately between the two estimates. Weekly recharge rates during the predictive model period are presented on Figure C-04.

5.3.2 Hydraulic Conductivity

Hydraulic conductivity (K) was implemented in the model as zones delineated across Layer 1. Initial K values were based on existing information as described in the hydrogeologic conceptual model. The upper and lower bounds were based on the range of Qvr hydraulic conductivity identified in Drost (1998). The structure and distribution of zonation was refined during early automated model calibration efforts that incorporated pilot points in the steady-state model. Ratios of horizontal to vertical hydraulic conductivity (10:1) remained constant during model calibration. K zones were imported into the 2001-2008 transient model for parameter estimation of specific yield. Minor localized K zone adjustments were made during the transient model calibration to match the seasonal groundwater fluctuations. The initial and calibrated K fields range from about 8 ft/day to 2,000 ft/day. The calibrated horizontal K field is presented in Figures C-05 and C-06.

5.3.3 Specific Yield

An initial specific yield of 0.20 was assigned based on values from the USGS (Morris and Johnson, 1967; Johnson, 1967) and assigned bounds of 0.1 to 0.3. Automated parameter estimation resulted in a slight change from the initial value. The specific yield of Layer 1 was calibrated to 0.26 which generally corresponds to a sand or gravel.

5.4 Calibration Results

The presented calibration statistics come from the predictive model simulation. The calibration statistics show a suitable degree of model calibration that supports simulated groundwater levels and 1999 flooding results (Table 1). A calibration plot of the simulated and observed transient water levels in monitoring wells is presented on Figure C-07. Simulated vs observed groundwater hydrograph at the BHHS well is shown on Figure C-08. Simulated and observed groundwater hydrographs in on-site monitoring wells are shown on Figures C-09 through C-12.

5.4.1 Observations

A common domain-wide objective of model calibration is to reduce the root mean square error (RMSE) below 10% of the range of observed water levels, and ideally less than 5%. The RMSE divided by the range in observations is the normalized root mean squared error (NRMSE). Considering individual targets this objective is also to reduce residuals below the level of observation error or expected observation uncertainty. The degree of model calibration was considered acceptable when these conditions were met.

The entire water level observation dataset had a mean error (ME), mean absolute error (MAE), normalized root mean squared error (NRMSE), and correlation coefficient (R^2) of -0.19 feet, 1.07 feet, 4.37%, and 0.993, respectively. The AESI water level observation dataset had a ME, MAE, NRMSE, and R^2 of -0.23 feet, 1.07 feet, 4.37%, and 0.993, respectively. NRMSE values are well within the model acceptance criteria of 10% of the measured range and below the ideal 5% of the measured range. The ME is near zero and the MAE is about 1 foot.

Table 1
Transient Calibration Results - Water Level Observations

Dataset	# of Obs.	ME (ft)	MAE (ft)	NRMSE	Range in Obs. (ft)
AESI	6,456	-0.23	1.07	4.37%	29.40
Total	6,646	-0.19	1.07	4.39%	29.40

Data includes weighted observation from surveyed wells only. Total includes BHHS well.
Obs. = Observations
ME = Mean Error
MAE = Mean Absolute Error
NRMSE = Normalized Root Mean Squared Error
ft = feet

5.4.2 Baseflow

Discharge to the boundary representing the Deschutes River was compared to that measured at USGS gauge station (#12080010) at Tumwater, Washington. The gauge at Tumwater, Washington is located near the northeast boundary of the modeled area and its average annual baseflow is 1.81 cubic feet per second per square mile of drainage area ($ft^3/s/mi^2$) based on Ecology's Water Supply Bulletin No. 60 (Sinclair and Pitz, 1999). The modeled drainage area to the Deschutes River was estimated to be 13 mi^2 and average yearly baseflow contribution was simulated to be 1.76 $ft^3/s/mi^2$. The simulated flux along the Deschutes River boundary condition generally matches expected yearly baseflow contributions. Baseflow contributions to the Black River were considered reasonable relative to the available data that spans a short period of record.

6.0 MODEL PREDICTION

The following section describes the results of the predictive groundwater model simulation of seasonal high groundwater levels during water year 1999. The transient model simulated water years 1980 through 2008. This transient period includes a model "spin-up" period using monthly stress periods and recharge rates from water year 1980 through 1994, and weekly stress periods and recharge rates from water year 1995 through water year 2008 to verify the model calibration.

Table 2 includes the analytical and model-derived 1999 high water elevation for each of the monitoring wells. The shallowest depth to water is calculated as the highest groundwater predicted under either analysis.

Table 2
Hypothetical 1999 High Groundwater Elevations

Monitoring Well	Ground Surface Elevation	Calculated 1999 GW Elevation - Linear Analysis (AESI, 2020)	Simulated 1999 GW Elevation - MODFLOW	Hypothetical 1999 Depth to Water - MODFLOW
MW-1	180.05	165.51	167.83	12.22
MW-2	204.18	185.48	184.29	19.89
MW-3	190.14	186.05	185.00	5.14
MW-4	190.76	187.68	188.89	1.87
MW-5	190.72	186.51	186.69	4.03
MW-6	187.50	186.31	185.30	2.20
MW-7	195.71	186.97	186.94	8.77
MW-8	194.24	186.67	186.30	7.94
MW-9	206.68	**	184.83	21.85
MW-10	181.30	174.16	175.42	5.88
MW-11	172.82	169.00	168.66	4.16
MW-12	179.87	162.60	164.48	15.39
MW-13	182.94	184.34	182.70	0.24
MW-14	179.64	167.16	171.40	8.24
MW-15	163.04	159.59	160.37	2.67
MW-16	190.69	186.81	186.68	4.01

GW = groundwater
**MW-9 elevation data not used in AESI, 2020

6.1 MODFLOW Predicted Groundwater Flooding Areas

Our MODFLOW analysis predicts 1999 high groundwater conditions including depth-to-groundwater and inundation across the site. Groundwater elevation head simulated

during the 1999 high groundwater period were exported from the MODFLOW model cells and interpolated to obtain a potentiometric surface (contours on Figure 7). LIDAR land surface topography was subtracted from the potentiometric surface to obtain a MODFLOW-derived depth of flooding inundation map (Figure 8) including contours depicting the depth of inundation across the site. Inundation was predicted to be less than 2.5 feet.

Our analysis shows areas on the site where groundwater flooding is predicted during the 1999 high groundwater period. Areas that experienced groundwater flooding are distributed across the site, and include low-lying swales in the western, central, and northeastern portions of the site. Flooding is predicted along and within the margins of the existing surveyed wetlands located in the north-central, northwest, and southwest areas of the site. Limited flooding is predicted in the southeastern portion of the site (Figure 8).

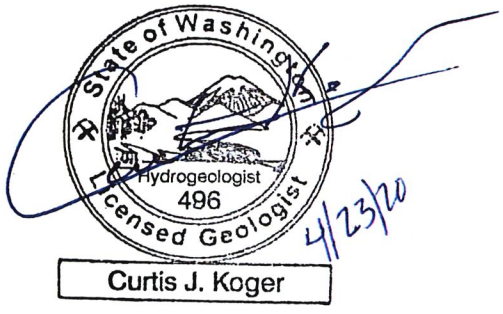
6.2 Comparison of Groundwater Flooding Areas – Analytical and MODFLOW

Figure 9 presents a comparison of the predicted flooding areas calculated using the analytical approach (AESI, 2020) and simulated by the MODFLOW model. In general, the MODFLOW analysis predicts slightly less flooding in the central and southeastern portions of the site and slightly different areas of flooding in the northeastern portion of the site. Predicted 1999 flooding areas along the surveyed wetlands located in the western portion of the site are nearly identical under either analysis method.

7.0 CLOSURE

We have enjoyed working with you on this study and are confident that these recommendations will aid in the successful completion of your project. If you should have any questions or require further assistance, please do not hesitate to call.

Sincerely,
ASSOCIATED EARTH SCIENCES, INC.
Kirkland, Washington



Matthew J. Porter, G.I.T.
Staff Geologist

Curtis J. Koger, L.G., L.E.G., L.Hg.
Senior Principal Geologist/Hydrogeologist

8.0 REFERENCES

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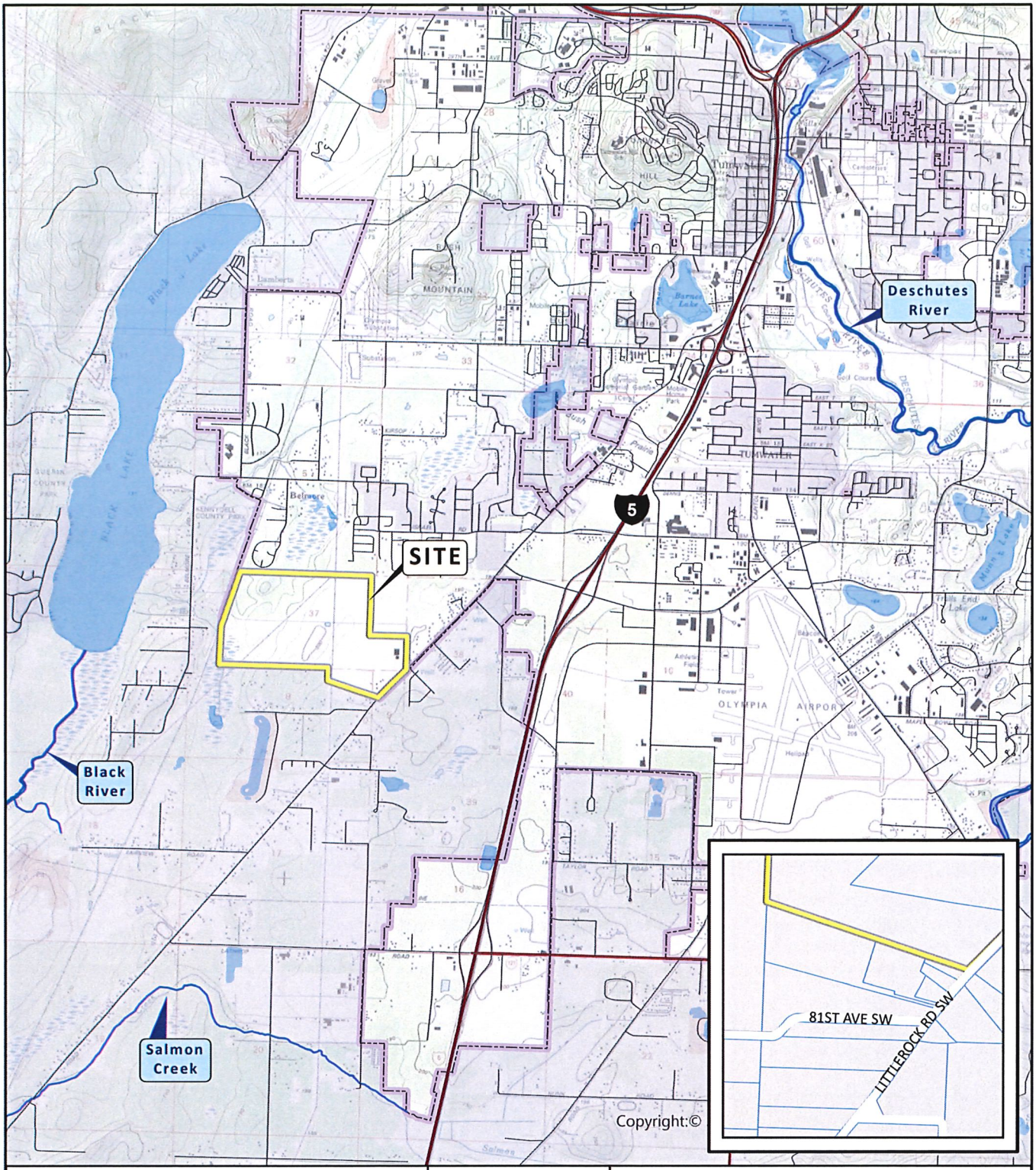


DATA SOURCES / REFERENCES:
USGS: 7.5' SERIES TOPOGRAPHIC MAPS, ESRI/I-CUBED/NGS 2013
THURSTON CO. STREETS, PARCELS, CITY 3/20
LOCATIONS AND DISTANCES SHOWN ARE APPROXIMATE

N

0 4000
Feet

NOTE: BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION

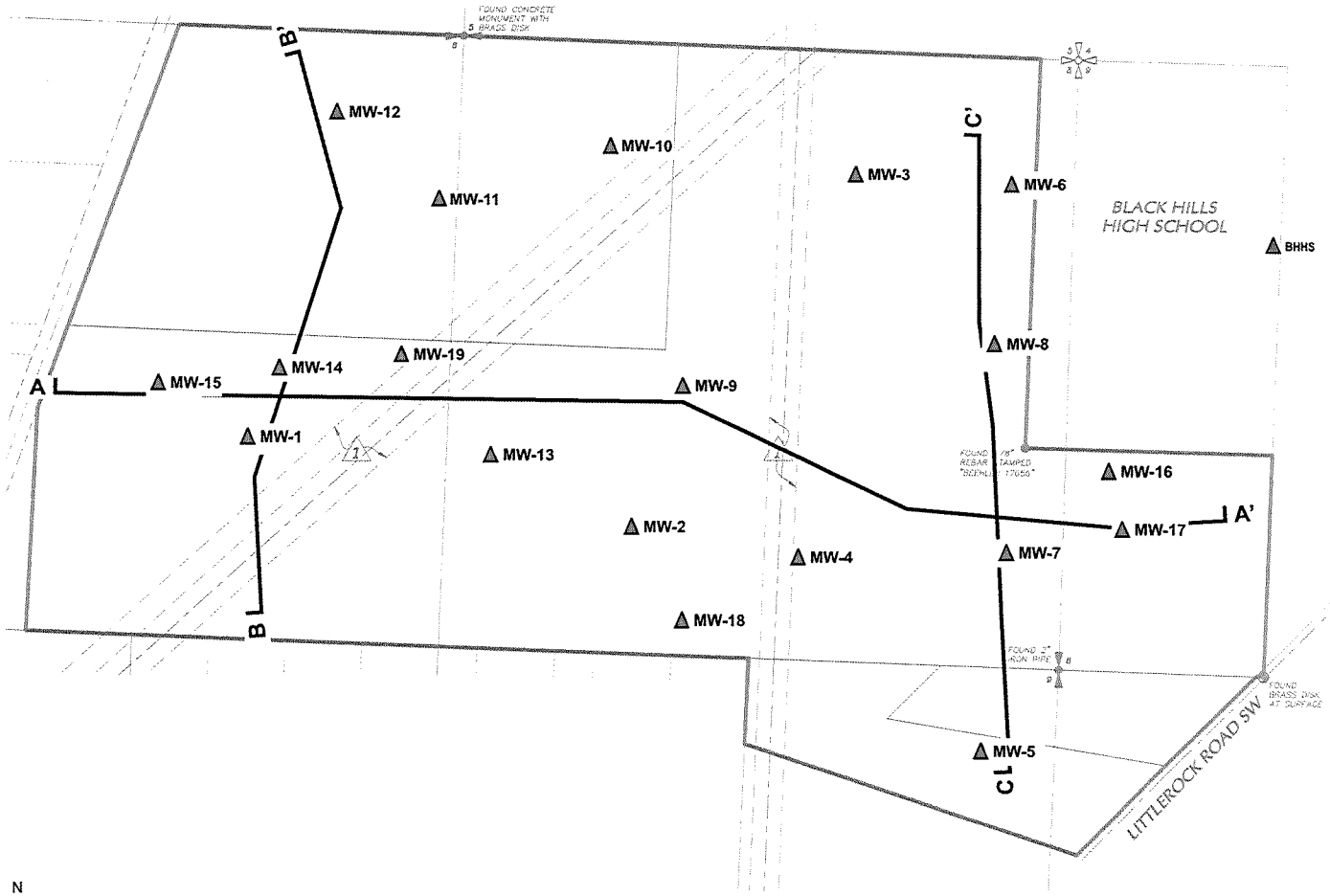
associated earth sciences incorporated

VICINITY MAP

TICKNER FARM
THURSTON COUNTY, WASHINGTON

PROJ NO.	DATE:	FIGURE:
20200033H001	4/20	1

G:\GIS_Projects\aaY2020\200033 Tickner Farm\aprx_mxd\200033H001 F1F7 GWflood_Tick0420.aprx



LEGEND:

- MW — MONITORING WELL
- BHHS — BLACK HILLS HIGH SCHOOL (BHHS) MONITORING WELL

CONTOUR INTERVAL = N/A

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:
1. BASE MAP REFERENCE: HATTON GODAT PANTIER ENGINNERS AND SURVEYORS, DOELMAN PROPERTY MONITORING WELL EXHIBIT MAP, UNDATED

BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION.

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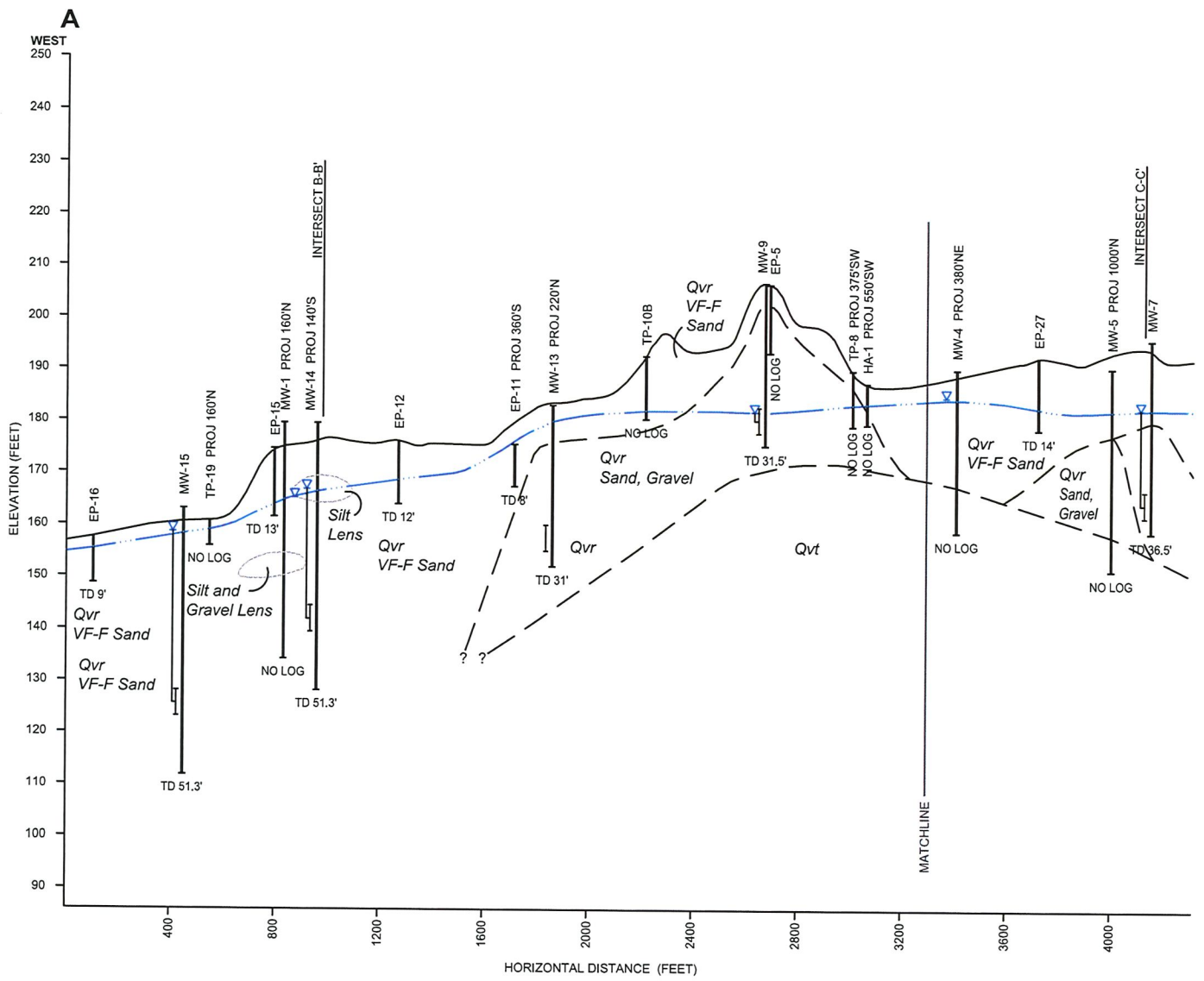
SITE AND EXPLORATION PLAN

TICKNER FARM SUBDIVISION
TUMWATER, WASHINGTON

PROJ NO.	DATE:	FIGURE:
20200033H001	4/20	2

200033 Tickner \ 20200033H001 F2 S-E 4-20.cdr



LEGEND:

Qvr	VASHON RECESSIONAL OUTWASH
VF-F Sand	PREDOMINATELY VERY FINE TO FINE SAND, VARIABLE SILT
MC-C Sand	PREDOMINATELY MEDIUM TO COARSE SAND, MINOR SILT, MINOR GRAVEL
Sand,Gravel	PREDOMINATELY SAND AND GRAVEL, VARIABLE SILT
Silt	PREDOMINATELY SILT, MINOR FINE SAND
Qvt	VASHON LODGEMENT TILL
	EXPLORATION MW - MONITORING WELL HA - HAND AUGER EP - EXPLORATION PIT TP - TEST PIT
	STATIC WATER LEVEL
	SCREENED INTERVAL
TD	TOTAL DEPTH OF BORING
	GEOLOGIC CONTACT
	INFERRED GROUNDWATER TABLE 2/15/06

VERTICAL EXAGGERATION = 20X

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE

NOTES:

1. THE SUBSURFACE CONDITIONS PRESENTED IN THIS GEOLOGIC CROSS-SECTION ARE BASED ON AN INTERPRETATION OF CONDITIONS ENCOUNTERED IN WIDELY SPACED EXPLORATIONS COMPLETED AT THE SUBJECT SITE AND RELEVANT SITE INFORMATION DEVELOPED AND PROVIDED BY OTHERS. THE SUBSURFACE INTERPRETATIONS PRESENTED IN THIS GEOLOGIC CROSS-SECTION SHOULD NOT BE CONSTRUED AS A WARRANTY OF ACTUAL SUBSURFACE CONDITIONS AT THE SITE. OUR EXPERIENCE HAS SHOWN THAT SOIL AND GROUNDWATER CONDITIONS CAN VARY SIGNIFICANTLY OVER SMALL DISTANCES.

2. SOME LOGGED WATER LEVELS WERE NOT USED TO CALCULATE HYPOTHETICAL HIGH GROUNDWATER DUE TO PROJECTED DISTANCE FROM CROSS-SECTION.

BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION

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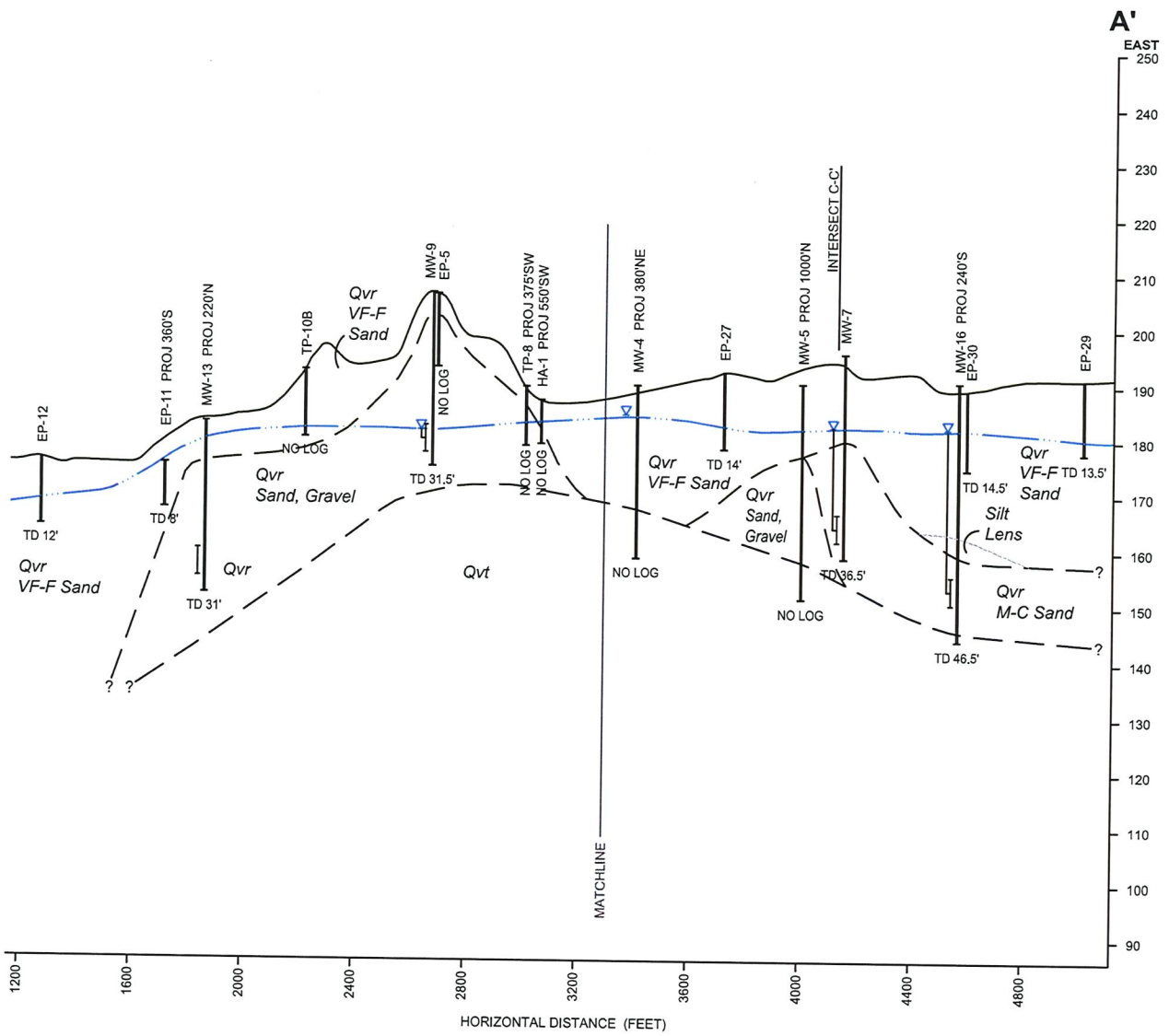
SCHEMATIC HYDROGEOLOGIC CROSS-SECTION A - A' WEST

TICKNER FARM SUBDIVISION
TUMWATER, WASHINGTON

PROJ NO.	DATE:	FIGURE:
20200033H001	4/20	3

200033 Tickner\200033 GeoSects.dwg LAYOUT: F3 Sect A-A West 4-20



LEGEND:

Qvr	VASHON RECESSIONAL OUTWASH
VF-F Sand	PREDOMINATELY VERY FINE TO FINE SAND, VARIABLE SILT
MC-C Sand	PREDOMINATELY MEDIUM TO COARSE SAND, MINOR SILT, MINOR GRAVEL
Sand,Gravel	PREDOMINATELY SAND AND GRAVEL, VARIABLE SILT
Silt	PREDOMINATELY SILT, MINOR FINE SAND
Qvt	VASHON LODGEMENT TILL
	EXPLORATION MW - MONITORING WELL HA - HAND AUGER EP - EXPLORATION PIT TP - TEST PIT
	STATIC WATER LEVEL
	SCREENED INTERVAL
TD	TOTAL DEPTH OF BORING
	GEOLOGIC CONTACT
	INFERRED GROUNDWATER TABLE 2/15/06

VERTICAL EXAGGERATION = 20X

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE

NOTES:

1. THE SUBSURFACE CONDITIONS PRESENTED IN THIS GEOLOGIC CROSS-SECTION ARE BASED ON AN INTERPRETATION OF CONDITIONS ENCOUNTERED IN WIDELY SPACED EXPLORATIONS COMPLETED AT THE SUBJECT SITE AND RELEVANT SITE INFORMATION DEVELOPED AND PROVIDED BY OTHERS. THE SUBSURFACE INTERPRETATIONS PRESENTED IN THIS GEOLOGIC CROSS-SECTION SHOULD NOT BE CONSTRUED AS A WARRANTY OF ACTUAL SUBSURFACE CONDITIONS AT THE SITE. OUR EXPERIENCE HAS SHOWN THAT SOIL AND GROUNDWATER CONDITIONS CAN VARY SIGNIFICANTLY OVER SMALL DISTANCES.

2. SOME LOGGED WATER LEVELS WERE NOT USED TO CALCULATE HYPOTHETICAL HIGH GROUNDWATER DUE TO PROJECTED DISTANCE FROM CROSS-SECTION.

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SCHEMATIC HYDROGEOLOGIC CROSS-SECTION A - A' EAST

TICKNER FARM SUBDIVISION
TUMWATER, WASHINGTON

PROJ NO.	DATE:	FIGURE:
20200033H001	4/20	4

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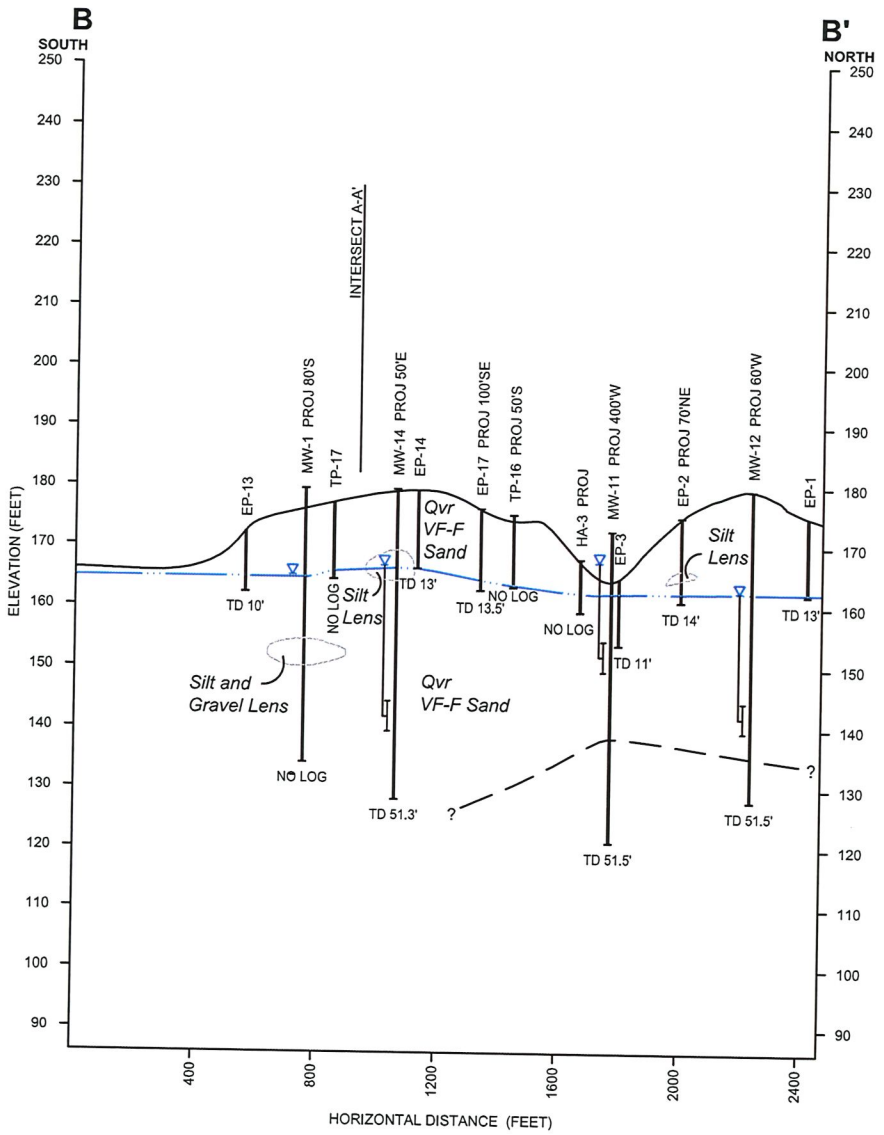

LEGEND:

Qvr	VASHON RECESSIONAL OUTWASH
VF-F Sand	PREDOMINATELY VERY FINE TO FINE SAND, VARIABLE SILT
MC-C Sand	PREDOMINATELY MEDIUM TO COARSE SAND, MINOR SILT, MINOR GRAVEL
Sand,Gravel	PREDOMINATELY SAND AND GRAVEL, VARIABLE SILT
Silt	PREDOMINATELY SILT, MINOR FINE SAND
Qvt	VASHON LODGEMENT TILL
	EXPLORATION MW - MONITORING WELL HA - HAND AUGER EP - EXPLORATION PIT TP - TEST PIT
	STATIC WATER LEVEL
	SCREENED INTERVAL
TD	TOTAL DEPTH OF BORING
	GEOLOGIC CONTACT
	INFERRED GROUNDWATER TABLE 2/15/06

VERTICAL EXAGGERATION = 20X

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE

NOTES:

1. THE SUBSURFACE CONDITIONS PRESENTED IN THIS GEOLOGIC CROSS-SECTION ARE BASED ON AN INTERPRETATION OF CONDITIONS ENCOUNTERED IN WIDELY SPACED EXPLORATIONS COMPLETED AT THE SUBJECT SITE AND RELEVANT SITE INFORMATION DEVELOPED AND PROVIDED BY OTHERS. THE SUBSURFACE INTERPRETATIONS PRESENTED IN THIS GEOLOGIC CROSS-SECTION SHOULD NOT BE CONSTRUED AS A WARRANTY OF ACTUAL SUBSURFACE CONDITIONS AT THE SITE. OUR EXPERIENCE HAS SHOWN THAT SOIL AND GROUNDWATER CONDITIONS CAN VARY SIGNIFICANTLY OVER SMALL DISTANCES.

2. SOME LOGGED WATER LEVELS WERE NOT USED TO CALCULATE HYPOTHETICAL HIGH GROUNDWATER DUE TO PROJECTED DISTANCE FROM CROSS-SECTION.

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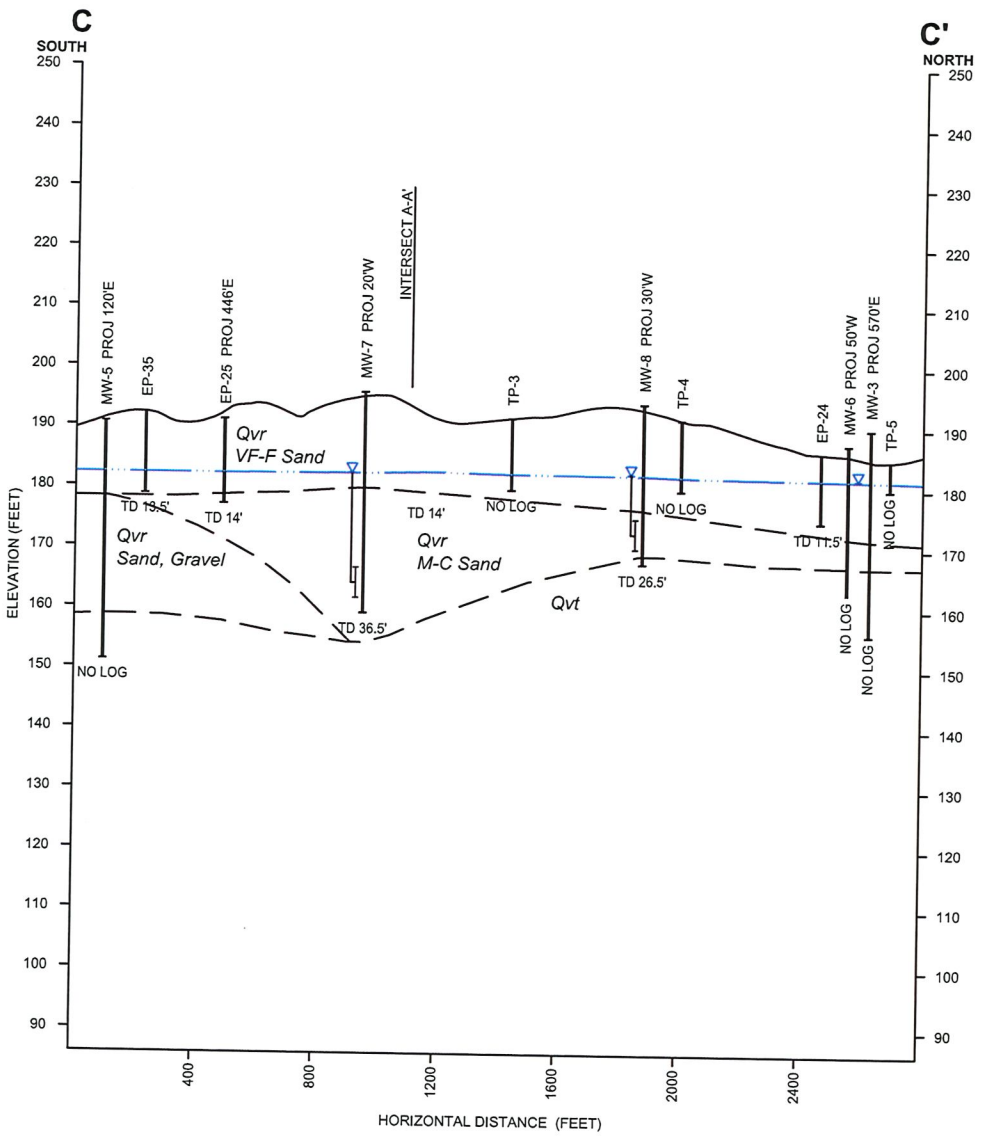
SCHEMATIC HYDROGEOLOGIC CROSS-SECTION B - B'

TICKNER FARM SUBDIVISION
TUMWATER, WASHINGTON

PROJ NO.	DATE:	FIGURE:
20200033H001	4/20	5



LEGEND:

Qvr	VASHON RECESSIONAL OUTWASH
VF-F Sand	PREDOMINATELY VERY FINE TO FINE SAND, VARIABLE SILT
MC-C Sand	PREDOMINATELY MEDIUM TO COARSE SAND, MINOR SILT, MINOR GRAVEL
Sand,Gravel	PREDOMINATELY SAND AND GRAVEL, VARIABLE SILT
Silt	PREDOMINATELY SILT, MINOR FINE SAND
Qvt	VASHON LODGEMENT TILL
I	EXPLORATION MW - MONITORING WELL HA - HAND AUGER EP - EXPLORATION PIT TP - TEST PIT
▽	STATIC WATER LEVEL
I	SCREENED INTERVAL
TD	TOTAL DEPTH OF BORING
/	GEOLOGIC CONTACT
▽	INFERRED GROUNDWATER TABLE 2/15/06

VERTICAL EXAGGERATION = 20X

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE

NOTES:
1. THE SUBSURFACE CONDITIONS PRESENTED IN THIS GEOLOGIC CROSS-SECTION ARE BASED ON AN INTERPRETATION OF CONDITIONS ENCOUNTERED IN WIDELY SPACED EXPLORATIONS COMPLETED AT THE SUBJECT SITE AND RELEVANT SITE INFORMATION DEVELOPED AND PROVIDED BY OTHERS. THE SUBSURFACE INTERPRETATIONS PRESENTED IN THIS GEOLOGIC CROSS-SECTION SHOULD NOT BE CONSTRUED AS A WARRANTY OF ACTUAL SUBSURFACE CONDITIONS AT THE SITE. OUR EXPERIENCE HAS SHOWN THAT SOIL AND GROUNDWATER CONDITIONS CAN VARY SIGNIFICANTLY OVER SMALL DISTANCES.

2. SOME LOGGED WATER LEVELS WERE NOT USED TO CALCULATE HYPOTHETICAL HIGH GROUNDWATER DUE TO PROJECTED DISTANCE FROM CROSS-SECTION.

BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION

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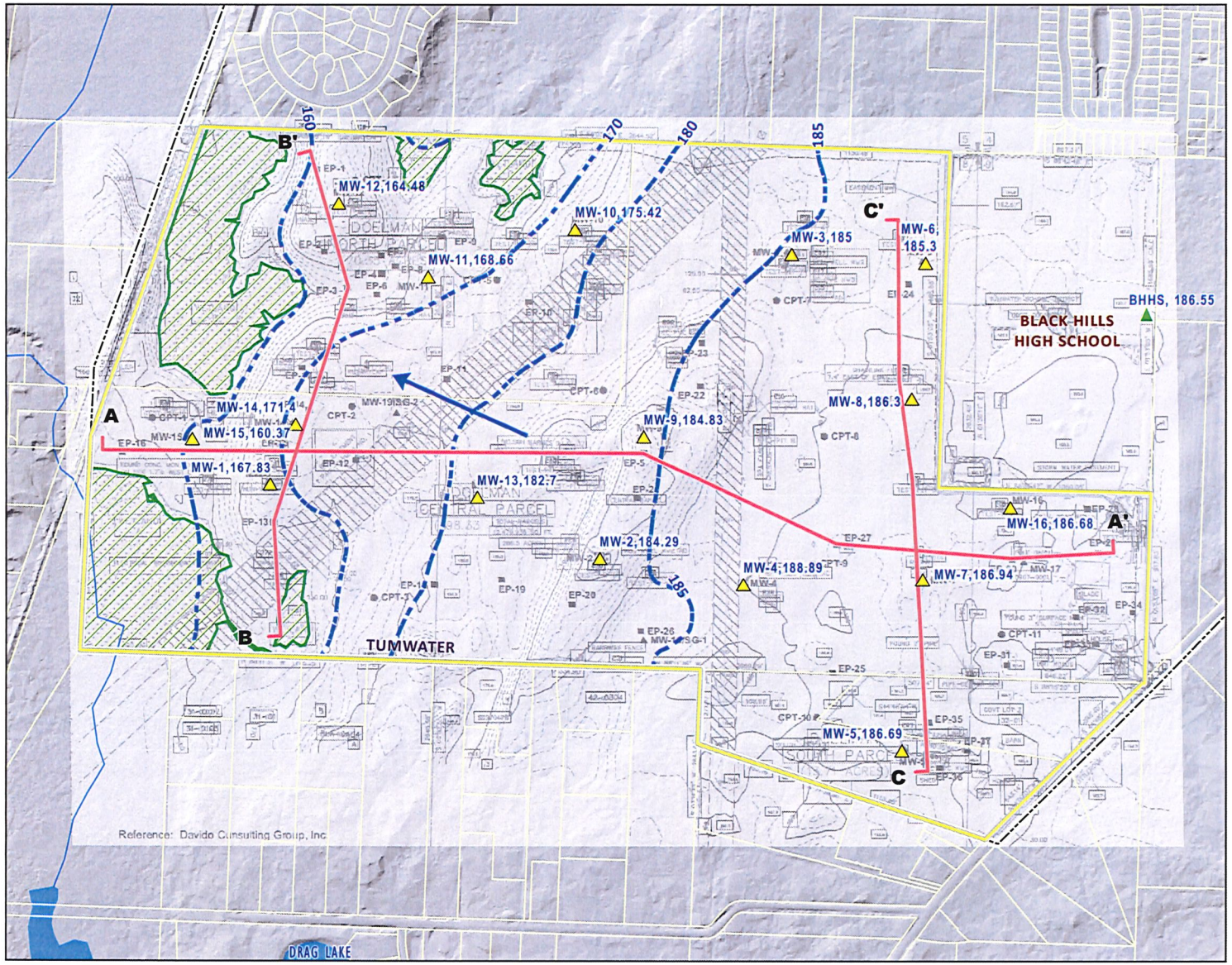
SCHEMATIC HYDROGEOLOGIC CROSS-SECTION C - C'

TICKNER FARM SUBDIVISION
TUMWATER, WASHINGTON

PROJ NO.	DATE:	FIGURE:
20200033H001	4/20	6

200033 Tickner\ 200033 GeoSects.dwg LAYOUT: F6 Sect C-C 4-20



SITE

MONITORING WELL, LABELED WITH MODELED 1999 HIGH GROUNDWATER ELEVATION

BHHS WELL, LABELED WITH MODELED 1999 HIGH GROUNDWATER ELEVATION

GROUNDWATER FLOW DIRECTION

GROUNDWATER CONTOUR

DELINEATED WETLAND

CITY BOUNDARY

PARCEL

DATA SOURCES / REFERENCES:
THURSTON CO LIDAR FROM WASHINGTON STATE LIDAR PORTAL
GRID CELL SIZE IS 3.25', FLOWN JUNE / JULY 2011
THURSTON CO: PARCELS, CITY 3/20
SURVEYED BASE MAP FROM 2005, DAVIDO CONSULTING GROUP
ENVIROVECTOR: WETLAND BOUNDARIES, 3/20

LOCATIONS AND DISTANCES SHOWN ARE APPROXIMATE

N

0 500
FEET

BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION

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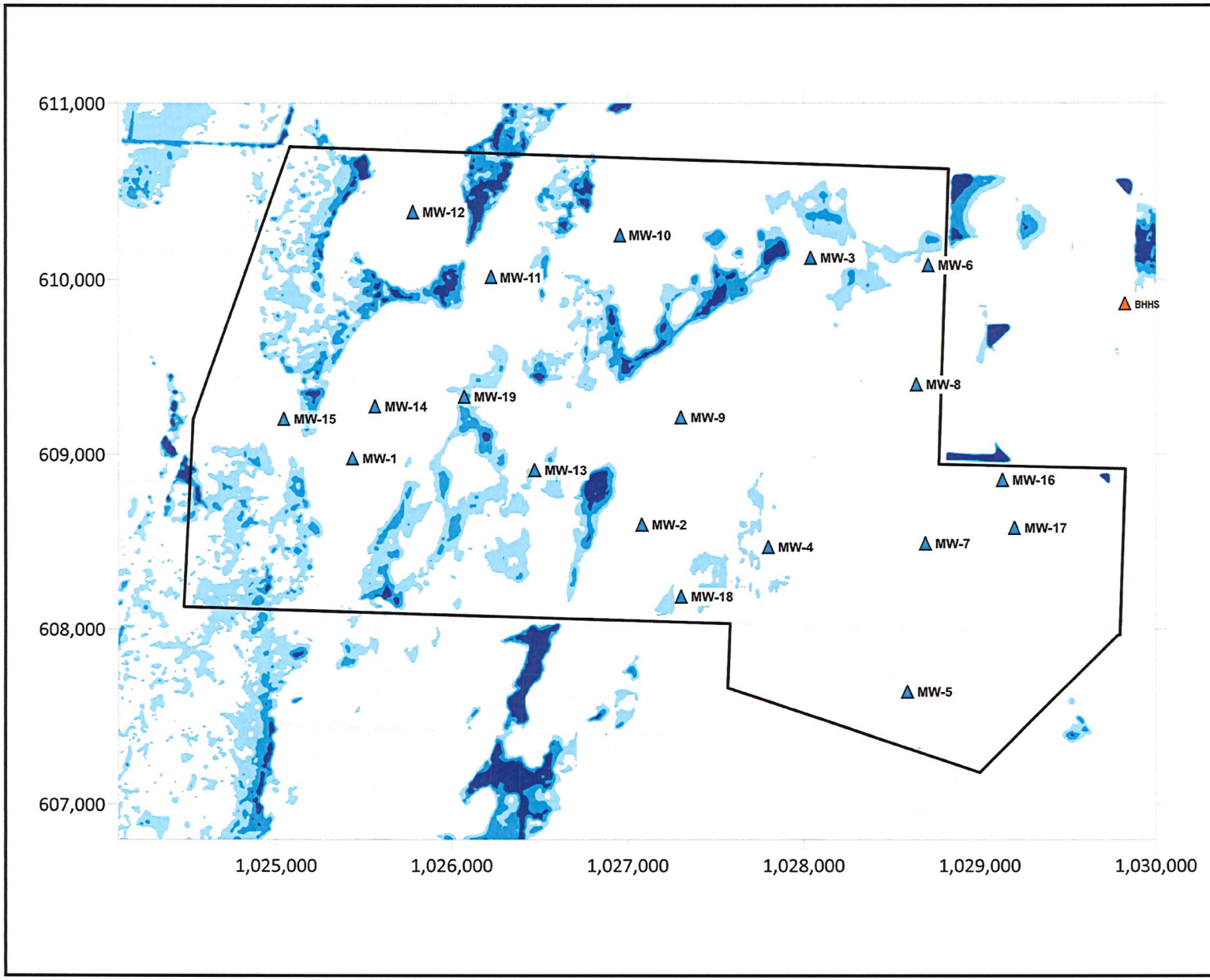
HIGH GROUNDWATER ELEVATION CONTOURS

TICKNER FARM SUBDIVISION
TUMWATER, WASHINGTON

PROJ NO.	DATE:	FIGURE:
20200033H001	4/20	7

G:\GIS_Projects\aay\2020\200033 Tickner Farm\aprx_mxd\200033H001 F7 GWelev_Tick0420.aprx



LEGEND:

- MW — MONITORING WELL
- BHHS — BLACK HILLS HIGH SCHOOL (BHHS) MONITORING WELL
- SITE BOUNDARY
- 1 / 0.5 / 0 — INUNDATION (SHOWN IN FEET ABOVE GROUND SURFACE) - MAXIMUM INUNDATION WITHIN SITE IS LESS THAN 2.5 FEET

CONTOUR INTERVAL = N/A

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:
1. COORDINATES: NAD83(HARN) WASHINGTON STATE PLANE SOUTH (FEET)

BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION.

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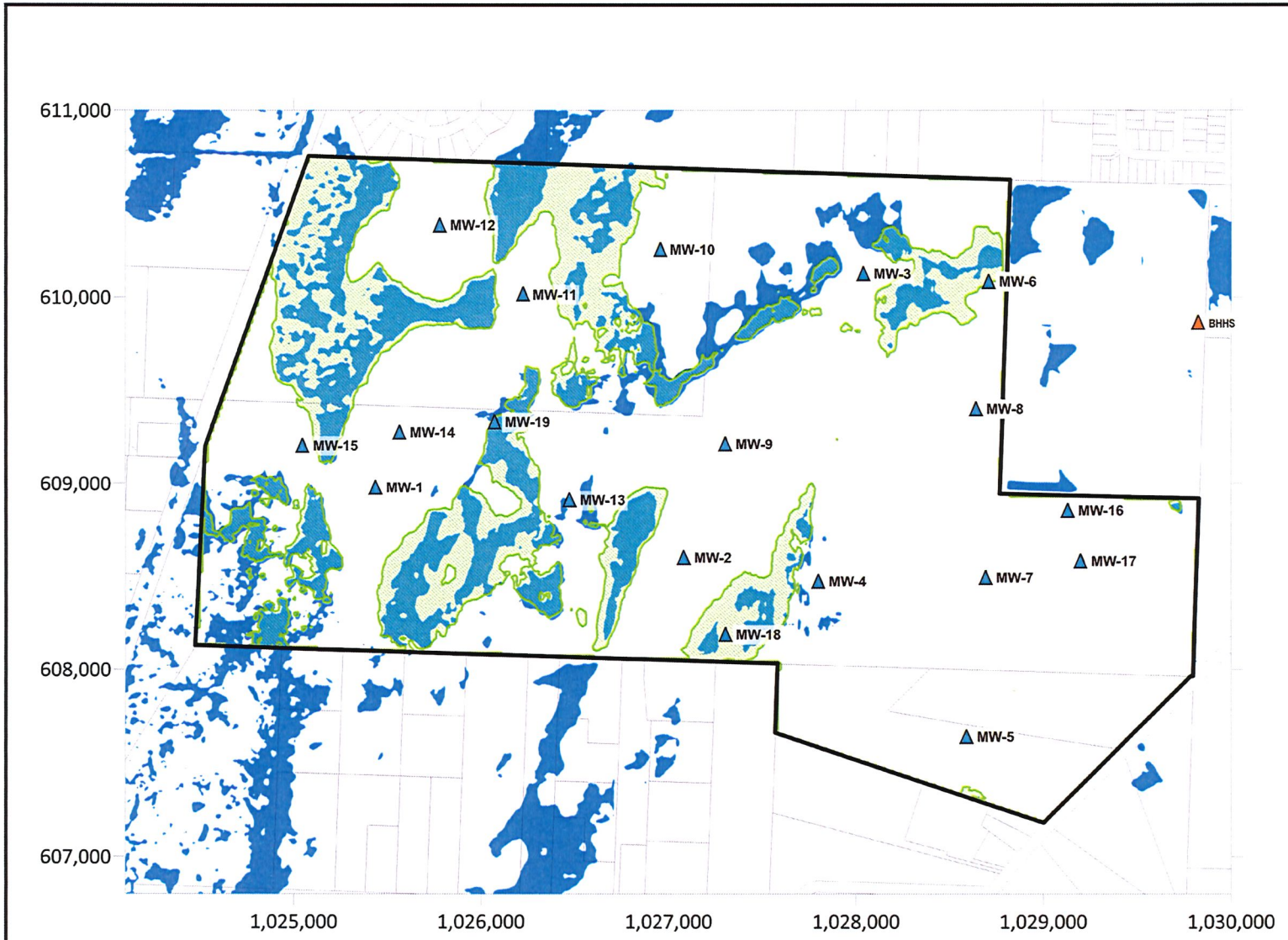
MODFLOW PREDICTED WATER YEAR 1999 INUNDATION

TICKNER FARM SUBDIVISION
TUMWATER, WASHINGTON

PROJ NO.	DATE:	FIGURE:
20200033H001	4/20	8

200033 Tickner \ 20200033H001 F8 Inundate 4-20.cdr



LEGEND:

- MW — MONITORING WELL
- BHHS — BLACK HILLS HIGH SCHOOL (BHHS) MONITORING WELL
- SITE BOUNDARY
- MODFLOW FLOODING
- ANALYTICAL FLOODING - SHOWN ONLY WITHIN SITE BOUNDARY

CONTOUR INTERVAL = N/A

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:
1. COORDINATES: NAD83(HARN) WASHINGTON STATE PLANE SOUTH (FEET)

BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION.

associated earth sciences incorporated

PREDICTED 1999 FLOODING AREAS COMPARISON

TICKNER FARM SUBDIVISION
TUMWATER, WASHINGTON

PROJ NO.	DATE:	FIGURE:
20200033H001	4/20	9

200033 Tickner \ 20200033H001 F9 Flood Compare 4-20.cdr

APPENDIX A

AESI Exploration Logs

Exploration and Wells Logs from Others

Coarse-Grained Soils - More than 50% [1] Retained on No. 200 Sieve	Gravels - More than 50% [1] of Coarse Fraction Retained on No. 4 Sieve	≤5% Fines [5]	GW	Well-graded gravel and gravel with sand, little to no fines
			GP	Poorly-graded gravel and gravel with sand, little to no fines
		≥12% Fines [5]	GM	Silty gravel and silty gravel with sand
			GC	Clayey gravel and clayey gravel with sand
	Sands - 50% [1] or More of Coarse Fraction Passes No. 4 Sieve	≤5% Fines [5]	SW	Well-graded sand and sand with gravel, little to no fines
			SP	Poorly-graded sand and sand with gravel, little to no fines
		≥12% Fines [5]	SM	Silty sand and silty sand with gravel
			SC	Clayey sand and clayey sand with gravel
Fine-Grained Soils - 50% [1] or More Passes No. 200 Sieve	Silts and Clays Liquid Limit Less than 50		ML	Silt, sandy silt, gravelly silt, silt with sand or gravel
			CL	Clay of low to medium plasticity; silty, sandy, or gravelly clay, lean clay
			OL	Organic clay or silt of low plasticity
	Silts and Clays Liquid Limit 50 or More		MH	Elastic silt, clayey silt, silt with micaceous or diatomaceous fine sand or silt
			CH	Clay of high plasticity, sandy or gravelly clay, fat clay with sand or gravel
			OH	Organic clay or silt of medium to high plasticity
Highly Organic Soils			PT	Peat, muck and other highly organic soils

Terms Describing Relative Density and Consistency

	Density	SPT [2] blows/foot
Coarse-Grained Soils	Very Loose	0 to 4
	Loose	4 to 10
	Medium Dense	10 to 30
	Dense	30 to 50
	Very Dense	>50
	Consistency	**SPT [2] blows/foot**
Fine-Grained Soils	Very Soft	0 to 2
	Soft	2 to 4
	Medium Stiff	4 to 8
	Stiff	8 to 15
	Very Stiff	15 to 30
	Hard	>30

Test Symbols

G = Grain Size
M = Moisture Content
A = Atterberg Limits
C = Chemical
DD = Dry Density
K = Permeability

Component Definitions

Descriptive Term	Size Range and Sieve Number
Boulders	Larger than 12"
Cobbles	3" to 12"
Gravel	3" to No. 4 (4.75 mm)
Coarse Gravel	3" to 3/4"
Fine Gravel	3/4" to No. 4 (4.75 mm)
Sand	No. 4 (4.75 mm) to No. 200 (0.075 mm)
Coarse Sand	No. 4 (4.75 mm) to No. 10 (2.00 mm)
Medium Sand	No. 10 (2.00 mm) to No. 40 (0.425 mm)
Fine Sand	No. 40 (0.425 mm) to No. 200 (0.075 mm)
Silt and Clay	Smaller than No. 200 (0.075 mm)

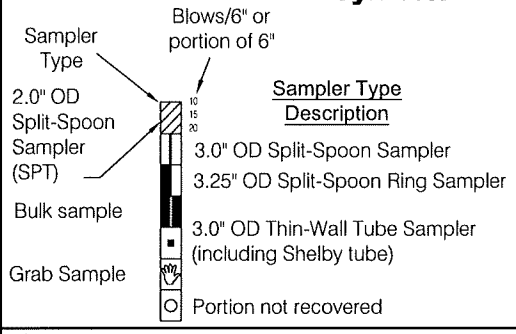
[3] Estimated Percentage

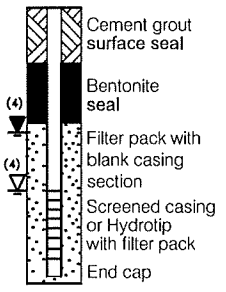
Component	Percentage by Weight
Trace	<5
Some	5 to <12
Modifier (silty, sandy, gravelly)	12 to <30
Very *modifier* (silty, sandy, gravelly)	30 to <50

Moisture Content

Dry - Absence of moisture, dusty, dry to the touch
Slightly Moist - Perceptible moisture
Moist - Damp but no visible water
Very Moist - Water visible but not free draining
Wet - Visible free water, usually from below water table

Symbols





(1) Percentage by dry weight
(2) (SPT) Standard Penetration Test (ASTM D-1586)
(3) In General Accordance with Standard Practice for Description and Identification of Soils (ASTM D-2488)
(4) Depth of ground water
▼ ATD = At time of drilling
▽ Static water level (date)
(5) Combined USCS symbols used for fines between 5% and 12%

Classifications of soils in this report are based on visual field and/or laboratory observations, which include density/consistency, moisture condition, grain size, and plasticity estimates and should not be construed to imply field or laboratory testing unless presented herein. Visual-manual and/or laboratory classification methods of ASTM D-2487 and D-2488 were used as an identification guide for the Unified Soil Classification System.

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Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KE05351A	MW-7	1 of 1

Project Name: Tumwater-Doelman
Elevation (Top of Well Casing): 197.26'
Water Level Elevation: 182.38'
Drilling/Equipment: Boretec/HSA
Hammer Weight/Drop: 140# / 30"

Location: Tumwater, WA
Surface Elevation (ft): 195.71'
Date Start/Finish: 11/8/05,11/8/05
Hole Diameter (in): 8"

Depth (ft)	Water Level	WELL CONSTRUCTION	ST	Blows/ 6"	Graphic Symbol	DESCRIPTION
		Aboveground monument Cement 0 to 3'				**Sod/Topsoil** Moist, dark brown, silty SAND, roots. **Vashon Recessional Outwash**
5		2" PVC (Schedule 40) casing +1.59' to 34'		3 3 2		Moist, silty very fine to fine SAND.
10		Bentonite chips 3' to 26'		5 4 5		As above.
15	▽			3 2 6		Upper 10": wet, brown, silty very fine to fine SAND, trace orange staining. Lower 2": wet, brown, silty very fine to fine SAND, trace gravel. Driller's note: gravel at 16'.
20				9 6 7		Wet, brownish gray, coarse SAND, few fine gravel, trace silt.
25		Sandpack 26' to 34'		3 3 5		Wet, gray, medium SAND, trace coarse sand, trace silt.
30		2" pvc (Schedule 40) screen slot 0.010" 29' to 34'		4 8 10		Wet, gray, medium to coarse SAND, trace silt. Driller's note: formation is heaving - sand forced into end of rods.
		Threaded end cap				
35		Native sand		10 6 12		Wet, gray, fine to coarse SAND, few gravel, trace to few silt.
						Boring terminated at 36.5 feet Well completed at feet on 11/8/05.

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample

M - Moisture
▽ Water Level (2/15/06)
▼ Water Level at time of drilling (ATD)

Logged by: SS
Approved by:

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Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KE05351A	MW-8	1 of 1

Project Name: Tumwater-Doelman
Elevation (Top of Well Casing): 196.59'
Water Level Elevation: 182.16'
Drilling/Equipment: Boretec/HSA
Hammer Weight/Drop: 140# / 30"

Location: Tumwater, WA
Surface Elevation (ft): 194.24'
Date Start/Finish: 11/09/05,11/09/05
Hole Diameter (in): 8"

Depth (ft)	Water Level	WELL CONSTRUCTION	ST	Blows/6"	Graphic Symbol	DESCRIPTION
		Aboveground monument Cement 0 to 2'				**Sod/Topsoil** Moist, dark brown, silty SAND, roots. **Vashon Recessional Outwash**
5		2" PVC (Schedule 40) casing +2.38' to 20'		3 3 2		Moist, brown, silty very fine to fine SAND.
10		Bentonite chips 2' to 16'		6 7 8		Moist, grayish brown, silty very fine to fine SAND.
15	▽	Sandpack 16' to 25'		6 4 3		As above, very moist, trace orange staining. Driller's note: gravel at 17.5'.
20		2" PVC (Schedule 40) screen slot 0.010" 19' to 24' Threaded end cap		13 12 10		Very moist, brownish gray, fine to coarse SAND, few fine gravel, trace to few silt. Water at ~23' ATD.
25		Native sand		21 50/5" 50/6"		**Vashon Lodgement Till** Wet, gray, silty SAND with gravel; tan, orange, red mottling; disintegrating gravel. Boring terminated at 26.5 feet Well completed at feet on 11/09/05.
30						

Sampler Type (ST):
- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample

M - Moisture
▽ Water Level (2/15/06)
▼ Water Level at time of drilling (ATD)

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Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KE05351A	MW-9	1 of 1

Project Name: Tumwater-Doelman
Elevation (Top of Well Casing): 209.11'
Water Level Elevation: 181.78'
Drilling/Equipment: Boretec/HSA
Hammer Weight/Drop: 140# / 30"

Location: Tumwater, WA
Surface Elevation (ft): 206.68'
Date Start/Finish: 11/9/05,11/9/05
Hole Diameter (in): 8"

Depth (ft)	Water Level	WELL CONSTRUCTION	ST	Blows/ 6"	Graphic Symbol	DESCRIPTION
		Aboveground monument Cement 0 to 2'				**Sod/Topsoil** Moist, brown to dark brown, silty SAND, roots. **Vashon Recessional Outwash** Moist, brown, very fine to fine SAND, trace to few silt.
						Driller's note: gravel at 3' to 4'.
5		2" PVC (Schedule 40) casing +2.80' to 25'		5 28 30		Moist, brown, silty fine to coarse SAND with gravel.
10		Bentonite chips 2' to 20'		32 20 25		Moist, brown, fine to coarse SAND with gravel, trace silt.
15				2 2 2		Driller's note: less gravel at 14' to 16'. As above; poor sample recovery - slough in sample; blow count likely not representative.
20		Sandpack 20' to 29'		17 31 36		Moist, brownish gray, medium to coarse SAND with gravel, trace to few silt.
						Cuttings wet.
25	▽	2" PVC (Schedule 40) Screen slot 0.010" 24' to 29'		12 33 38		Moist, brownish gray, fine to coarse SAND with gravel, trace to few silt.
		Threaded end cap				Cuttings wet.
30		Sandpack and native sand 29' to 31.5'		31 39 50/4"		Very moist, gray, medium to coarse SAND with gravel, trace to few silt, trace orange staining.
35						Boring terminated at 31.5 feet Well completed at feet on 11/9/05. Note: blow counts overstated due to gravel content, where present.

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample

M - Moisture
▽ Water Level (2/15/06)
▼ Water Level at time of drilling (ATD)

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Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KE05351A	MW-10	1 of 1

Project Name: Tumwater-Doelman
Location: Tumwater, WA
Elevation (Top of Well Casing): 183.99'
Surface Elevation (ft): 181.30'
Water Level Elevation: 172.65'
Date Start/Finish: 11/10/05,11/10/05
Drilling/Equipment: Boretec/HSA
Hole Diameter (in): 8"
Hammer Weight/Drop: 140# / 30"

Depth (ft)	Water Level	WELL CONSTRUCTION	ST	Blows/ 6"	Graphic Symbol	DESCRIPTION
		Aboveground monument Cement 0 to 2'				**Sod/Topsoil** Moist, brown to dark brown, silty SAND, roots, trace wood chips. **Vashon Recessional Outwash**
5		1 1/4" PVC (Schedule 40) casing +2.73' to 24'		2 2 2		Moist, brown, silty very fine to fine SAND.
10	▽	Bentonite chips 2' to 22'		5 7 8		Very moist, brownish gray, very fine to fine SAND, few silt.
15				4 4 5		Wet, as above, trace orange staining (thin layer of oxidation).
20		Sandpack 22' to 30'		3 6 7		Wet, brownish gray, fine SAND, few silt, trace orange staining.
25		1 1/4" PVC (Schedule 40) hand-slotted 24' to 29'		3 7 9		Wet, brownish gray, very fine to fine SAND, few silt, trace orange staining, thin layer of medium to coarse sand.
30		Glued end cap Sandpack and native sand 30' to 36.5'		6 19 28		**Vashon Lodgement Till** Wet, brownish gray, silty SAND, few gravel.
35				17 33 45		As above.
						Boring terminated at 36.5 feet Well completed at feet on 11/10/05.

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample

M - Moisture
Water Level (2/15/06)
Water Level at time of drilling (ATD)

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Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KE05351A	MW-11	1 of 2

Project Name	Tumwater-Doelman	Location	Tumwater, WA
Elevation (Top of Well Casing)	175.42'	Surface Elevation (ft)	172.82'
Water Level Elevation	167.44'	Date Start/Finish	11/10/05,11/10/05
Drilling/Equipment	Boretec/HSA	Hole Diameter (in)	8"
Hammer Weight/Drop	140# / 30"		

Depth (ft)	WELL CONSTRUCTION	ST	Blows/ 6"	DESCRIPTION
	Aboveground monument Cement 0 to 3'			**Sod/Topsoil** Moist, brown, silty SAND, roots. **Vashon Recessional Outwash**
5	1 1/4" PVC (Schedule 40) casing +2.69' to 25'		4 5 5	Moist, brownish gray, silty very fine to fine SAND to very fine sandy SILT, moderate orange staining (oxidation).
10	Bentonite chips 3' to 22'		6 6 6	Wet, gray, fine SAND, few silt.
15			5 5 4	Wet, gray, very fine to fine SAND, few silt, trace orange staining, trace mica flakes.
20			6 7 9	Wet, brownish gray, fine SAND, few silt, moderate orange staining.
25	Sandpack 22' to 36' 1 1/4" PVC (Schedule 40) screen hand-slotted 25' to 30'		9 12 14	Wet, gray, very fine to fine SAND, few silt.
30	Glued end cap		6 8 11	Wet, bluish gray, fine SAND, trace to few silt.
35	Native sand 36' to 51.5'		5 5 7	Wet, bluish gray, very fine sandy SILT.

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample

M - Moisture

- Water Level (2/15/06)
- Water Level at time of drilling (ATD)

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Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KE05351A	MW-11	2 of 2

Project Name	Tumwater-Doelman	Location	Tumwater, WA
Elevation (Top of Well Casing)	175.42'	Surface Elevation (ft)	172.82'
Water Level Elevation	167.44'	Date Start/Finish	11/10/05,11/10/05
Drilling/Equipment	Boretec/HSA	Hole Diameter (in)	8"
Hammer Weight/Drop	140# / 30"		

Depth (ft)	Water Level	WELL CONSTRUCTION	ST	Blows/ 6"	Graphic Symbol	DESCRIPTION
				7 7 8		As above.
45		Native sand 36' to 51.5'		6 8 9		Wet, gray, very fine sandy SILT.
50				5 6 9		As above.
						Boring terminated at 51.5 feet Well completed at feet on 11/10/05.
55						
60						
65						
70						
75						

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- Water Level (2/15/06)
- Water Level at time of drilling (ATD)

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Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KE05351A	MW-12	1 of 2

Project Name	Tumwater-Doelman	Location	Tumwater, WA
Elevation (Top of Well Casing)	182.34'	Surface Elevation (ft)	179.87'
Water Level Elevation	162.63'	Date Start/Finish	11/10/05,11/10/05
Drilling/Equipment	Boretec/HSA	Hole Diameter (in)	8"
Hammer Weight/Drop	140# / 30"		

Depth (ft)	WELL CONSTRUCTION	ST	Blows/ 6"	DESCRIPTION
	Aboveground monument Cement 0 to 3'			**Sod/Topsoil** Moist, brown, silty SAND, roots. **Vashon Recessional Outwash**
5	1 1/4" PVC (Schedule 40) casing +2.52' to 35' Bentonite chips 3' to 32'		2 3 3	Moist, brown, very fine sandy SILT, trace orange staining (oxidation).
10			2 2 3	Moist, brownish gray, fine SAND, few silt, trace orange staining in thin layers (oxidation).
15			4 4 4	Moist, gray, silty very fine SAND, trace orange staining.
20	▽		3 2 3	Wet, brown, silty very fine SAND, trace mica flakes.
25			3 2 3	Wet, brownish gray, silty very fine SAND, trace mica flakes, trace orange staining.
30	Sandpack 32' to 40'		4 7 8	Wet, brown, very fine to fine SAND, trace to few silt, heavy orange staining in bands.
35	1 1/4" PVC (Schedule 40) screen hand-slotted 35' to 40' Glued end cap		4 5 8	Wet, brown to gray, silty very fine SAND, trace orange staining, trace mica flakes.

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample

M - Moisture

▽ Water Level (2/15/06)

▼ Water Level at time of drilling (ATD)

Logged by: SS

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Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KE05351A	MW-12	2 of 2

Project Name: Tumwater-Doelman
Location: Tumwater, WA
Elevation (Top of Well Casing): 182.34'
Surface Elevation (ft): 179.87'
Water Level Elevation: 162.63'
Date Start/Finish: 11/10/05,11/10/05
Drilling/Equipment: Boretec/HSA
Hole Diameter (in): 8"
Hammer Weight/Drop: 140# / 30"

Depth (ft)	Water Level	WELL CONSTRUCTION	ST	Blows/ 6"	Graphic Symbol	DESCRIPTION
				4 6 8		Wet, bluish gray, very fine SAND, few silt.
45		Sandpack and native sand 40' to 51.5'		2 3 4		Wet, bluish gray, very fine sandy SILT, trace mica flakes.
50				3 3 5		Wet, bluish gray, SILT, thin lens of fine sand.
						Boring terminated at 51.5 feet Well completed at feet on 11/10/05.
55						
60						
65						
70						
75						

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample

M - Moisture

- Water Level (2/15/06)
- Water Level at time of drilling (ATD)

Logged by: SS

Approved by:

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Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KE05351A	MW-13	1 of 1

Project Name: Tumwater-Doelman
Location: Tumwater, WA
Elevation (Top of Well Casing): 185.47'
Surface Elevation (ft): 182.94'
Water Level Elevation: 180.76'
Date Start/Finish: 11/9/05,11/9/05
Drilling/Equipment: Boretec/HSA
Hole Diameter (in): 8"
Hammer Weight/Drop: 140# / 30"

Depth (ft)	Water Level	WELL CONSTRUCTION	ST	Blows/ 6"	Graphic Symbol	DESCRIPTION
		Aboveground monument Cement 0 to 2'				**Sod/Topsoil** Moist, brown to dark brown, silty SAND, trace gravel, roots. **Vashon Recessional Outwash**
5	▽	2" PVC (Schedule 40) Casing +2.55' to 23' Bentonite chips 2' to 11'		4 8 18		Moist, brown, silty fine to coarse SAND, few fine gravel; orange and tan mottling; slight oxidation.
10		Sandpack and native sand 11' to 31'		20 42 50/4"		Moist, brown to gray, silty fine to coarse SAND, with gravel; orange and tan mottling.
15				20 36 50/4"		Very moist to wet, brownish gray, silty medium to coarse SAND with gravel; orange and tan mottling; becoming wet at 16'.
20				25 47 50/5.5"		Wet, brownish gray, medium to coarse SAND, few gravel, trace silt. Driller's note: some heaving from above - depth uncertain.
25		2" PVC (Schedule 40) screen 0.010" 23' to 28' Threaded end cap		30 50/5"		As above.
30				33 50/5.5"		Wet, gray, medium to coarse SAND with gravel, trace silt.
35						Boring terminated at 31 feet Well completed at feet on 11/9/05. Note: blow counts overstated due to gravel content, where present.

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample

M - Moisture

- Water Level (2/15/06)
- Water Level at time of drilling (ATD)

Logged by: SS

Approved by:

NWWELL- B 05351A.GPJ BORING.GDT 1/23/20

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Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KE05351A	MW-14	1 of 2

Project Name	Tumwater-Doelman	Location	Tumwater, WA
Elevation (Top of Well Casing)	182.22'	Surface Elevation (ft)	179.64'
Water Level Elevation	166.85'	Date Start/Finish	11/11/05,11/11/05
Drilling/Equipment	Boretec/HSA	Hole Diameter (in)	8"
Hammer Weight/Drop	140# / 30"		

Depth (ft)	Water Level	WELL CONSTRUCTION	S T	Blows/ 6"	Graphic Symbol	DESCRIPTION
		Aboveground monument Cement 0 to 2'				**Sod/Topsoil** Moist, brown, silty SAND, roots. **Vashon Recessional Outwash**
5		1 1/4" PVC (Schedule 40) casing +2.57' to 40'		2 1 1		Moist, brown to gray, fine SAND, trace to few silt, trace orange staining.
10		Bentonite chips 2' to 37'		4 4 4		Moist to very moist, gray, silty very fine SAND to very fine sandy SILT with lenses of brown silt.
15	▽			6 4 3		Upper 6": very moist, brown to gray, SILT, brown mottling. Lower 12": very moist, brown to gray, fine SAND, trace orange staining.
20				2 2 2		Wet, brownish gray, silty very fine to fine SAND, trace mica flakes, trace orange staining.
25				3 4 5		Wet, brownish gray, fine SAND, few silt; occasional silt seams (~2mm thick).
30				3 4 4		Upper 6": wet, brownish gray, fine SAND, trace to few silt. Lower 6": wet, brownish gray, very fine sandy SILT.
35				3 4 5		Wet, brownish gray, silty very fine to fine SAND, trace orange staining, trace mica flakes.
		Sandpack 37' to 49'				

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample

M - Moisture

▽ Water Level (2/15/06)

▼ Water Level at time of drilling (ATD)

Logged by: SS

Approved by:

NWWELL- B 05351A.GPJ BORING.GDT 1/23/20

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Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KE05351A	MW-14	2 of 2

Project Name: Tumwater-Doelman
Elevation (Top of Well Casing): 182.22'
Water Level Elevation: 166.85'
Drilling/Equipment: Boretec/HSA
Hammer Weight/Drop: 140# / 30"

Location: Tumwater, WA
Surface Elevation (ft): 179.64'
Date Start/Finish: 11/11/05,11/11/05
Hole Diameter (in): 8"

Depth (ft)	Water Level	WELL CONSTRUCTION	ST	Blows/ 6"	Graphic Symbol	DESCRIPTION
		1 1/4" PVC (Schedule 40) screen hand-slotted 40' to 45'		4 6 14		Wet, brownish gray, very fine to fine SAND, few silt; trace orange staining (in thin bands).
45		Glued end cap		4 4 5		As above.
		Native sand 49' to 51.5'				Wet, brownish gray, silty very fine SAND, trace orange staining (banding), trace thin silt seams.
50				3 3 5		Boring terminated at 51.5 feet Well completed at feet on 11/11/05.
55						
60						
65						
70						
75						

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample

M - Moisture

- Water Level (2/15/06)
- Water Level at time of drilling (ATD)

Logged by: SS

Approved by:

NWWELL- B 05351A.GPJ BORING.GDT 1/23/20

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Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KE05351A	MW-15	1 of 2

Project Name	Tumwater-Doelman	Location	Tumwater, WA
Elevation (Top of Well Casing)	165.28'	Surface Elevation (ft)	163.04'
Water Level Elevation	158.68'	Date Start/Finish	11/11/05,11/11/05
Drilling/Equipment	Boretec/HSA	Hole Diameter (in)	8"
Hammer Weight/Drop	140# / 30"		

Depth (ft)	Water Level	WELL CONSTRUCTION	ST	Blows/ 6"	Graphic Symbol	DESCRIPTION
		Aboveground monument Cement 0 to 3'				**Sod/Topsoil** Moist, dark brown, silty SAND, roots. **Vashon Recessional Outwash**
5	▽	1 1/4" pvc (Schedule 40) casing +2.48' to 35'		3 2 3		Very moist, brown, very fine to fine SAND, few silt, trace orange staining, trace mica flakes.
10		Bentonite chips 3' to 32'		2 2 2		Very moist, brown, silty very fine to fine SAND, tan and orange staining, trace mica flakes.
15				3 5 5		Wet, brown, silty very fine to fine SAND, trace mica flakes.
20				2 3 3		As above.
25				4 6 8		Wet, gray, fine SAND, few silt.
30				4 4 4		As above.
		Sandpack 32' to 48'				
35		1 1/4" pvc (Schedule 40) screen hand-slotted 35' to 40'		3 5 8		Wet, gray, very fine to fine SAND, few silt.
		Glued end cap				

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample

M - Moisture

- Water Level (2/15/06)
- Water Level at time of drilling (ATD)

Logged by: SS

Approved by:

NWWELL- B 05351A.GPJ BORING.GDT 1/23/20

associated earth sciences incorporated

Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KE05351A	MW-15	2 of 2

Project Name	Tumwater-Doelman	Location	Tumwater, WA
Elevation (Top of Well Casing)	165.28'	Surface Elevation (ft)	163.04'
Water Level Elevation	158.68'	Date Start/Finish	11/11/05,11/11/05
Drilling/Equipment	Boretec/HSA	Hole Diameter (in)	8"
Hammer Weight/Drop	140# / 30"		

Depth (ft)	Water Level	WELL CONSTRUCTION	ST	Blows/ 6"	Graphic Symbol	DESCRIPTION
				4 5 6		As above.
45				5 7 10		Wet, gray, silty very fine SAND.
		Native sand 49' to 51.5'				
50				4 6 9		Wet, bluish gray, silty very fine to fine SAND.
						Boring terminated at 51.5 feet Well completed at feet on 11/11/05.
55						
60						
65						
70						
75						

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- Water Level (2/15/06)
- Water Level at time of drilling (ATD)

Logged by: SS

Approved by:

NWWELL- B 05351A.GPJ BORING.GDT 1/23/20

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Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KE05351A	MW-16	1 of 2

Project Name	Tumwater-Doelman	Location	Tumwater, WA
Elevation (Top of Well Casing)	193.22'	Surface Elevation (ft)	190.69'
Water Level Elevation	182.23'	Date Start/Finish	11/8/05,11/8/05
Drilling/Equipment	Boretec/HSA	Hole Diameter (in)	8"
Hammer Weight/Drop	140# / 30"		

Depth (ft)	WELL CONSTRUCTION	ST	Blows/ 6"	DESCRIPTION
	Aboveground monument Cement 0 to 3'			**Sod/Topsoil** Loose, moist, dark brown, silty fine SAND, roots. **Vashon Recessional Outwash**
5	2" PVC (Schedule 40) casing +2.51' to 35'		3 3 2	Moist, brown, silty very fine to fine SAND.
10	Bentonite chips 3' to 32'		3 5 5	Very moist, brown, silty very fine to fine SAND, trace orange staining.
15			4 4 3	Very moist to wet, brown, as above, trace to moderate orange staining. Becoming wet at 16'.
20			3 3 3	Wet, brown, silty very fine to fine SAND, trace orange staining.
25			6 11 13	Wet, gray to dark gray, fine SAND, trace silt.
30			3 4 8	Wet, gray, very fine sandy SILT to SILT, trace orange staining.
	Sandpack 32' to 46.5'			Driller's note: becoming dense at 32'.

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample

M - Moisture

- Water Level (2/15/06)
- Water Level at time of drilling (ATD)

Logged by: SS

Approved by:

NWWELL- B 05351A.GPJ BORING.GDT 1/23/20

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Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KE05351A	MW-16	2 of 2

Project Name: Tumwater-Doelman
Location: Tumwater, WA
Elevation (Top of Well Casing): 193.22'
Surface Elevation (ft): 190.69'
Water Level Elevation: 182.23'
Date Start/Finish: 11/8/05,11/8/05
Drilling/Equipment: Boretec/HSA
Hole Diameter (in): 8"
Hammer Weight/Drop: 140# / 30"

Depth (ft)	Water Level	WELL CONSTRUCTION	ST	Blows/ 6"	Graphic Symbol	DESCRIPTION
		2" PVC (Schedule 40) screen slot 0.010" 35' to 40'		4 6 6		Wet, brownish gray, coarse SAND, few fine gravel.
40		Threaded end cap		4 7 8		Upper 6": wet, gray, medium SAND, trace silt. Lower 2": wet, brownish gray, silty SAND, trace gravel.
		Sandpack				
45				26 39 37		Upper 6": wet, gray, medium SAND, few coarse sand, trace silt. **Vashon Lodgement Till** Lower 6": wet, gray, silty SAND, few gravel. Boring terminated at 46.5 feet Well completed at feet on 11/8/05.
50						
55						
60						
65						

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample

M - Moisture

- Water Level (2/15/06)
- Water Level at time of drilling (ATD)

Logged by: SS

Approved by:

NWWELL- B 05351A.GPJ BORING.GDT 1/23/20

associated earth sciences incorporated

Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KE05351A	MW-17	1 of 1

Project Name: Tumwater-Doelman
Elevation (Top of Well Casing): ~192'
Water Level Elevation: ~181'
Drilling/Equipment: Davies/HSA
Hammer Weight/Drop: 140# / 30"

Location: Tumwater, WA
Surface Elevation (ft): ~189'
Date Start/Finish: 4/3/06,4/3/06
Hole Diameter (in): 7"

Depth (ft)	Water Level	WELL CONSTRUCTION	S T	Blows/ 6"	Graphic Symbol	DESCRIPTION
		Aboveground monument Cement 0 to 1.5' 1 1/4" PVC Schedule 80 +2.80' to 15'		2 2 1		**Topsoil/Sod** Moist, black, silty fine SAND; trace to few roots; few roots at 6".
5		Bentonite Chips 1.5' to 10.5'		2 3 3		Moist, gray, fine SAND, trace silt; trace faint orange staining.
10	▽	Bentonite pellets 10.5' to 12' Sand pack 12' to 25'		2 5 5		Wet, gray, fine SAND, trace to few silt; thin (2-3mm thick) layers of silty SAND in lower 6".
15		1 1/4" PVC Schedule 80 screen, 0.010" slot 15' to 25'		1 2 5		Wet, gray, fine SAND, trace medium sand, trace silt.
20				1 4 6		Wet, gray, fine SAND, trace to few silt.
25				5 8 9		As above. Boring terminated at 26.5 feet Well completed at feet on 4/3/06.
30						
35						

Sampler Type (ST):
- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample

M - Moisture
▽ Water Level (8.25' bgs 4/3/06)
▼ Water Level at time of drilling (ATD)

Logged by: SS/BAA
Approved by:

NWWELL- B 05351A.GPJ BORING.GDT 1/23/20

associated earth sciences incorporated

Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KE05351A	MW-18	1 of 2

Project Name	Tumwater-Doelman	Location	Tumwater, WA
Elevation (Top of Well Casing)	~187'	Surface Elevation (ft)	~185'
Water Level Elevation	~181.5'	Date Start/Finish	4/3/06,4/3/06
Drilling/Equipment	Davies/HSA	Hole Diameter (in)	7"
Hammer Weight/Drop	140# / 30"		

Depth (ft)	Water Level	WELL CONSTRUCTION	ST	Blows/ 6"	Graphic Symbol	DESCRIPTION
		Aboveground monument Cement 0' to 2'		2 3 4		**Topsoil Sod** Moist, brown, silty fine SAND to fine sandy SILT; trace to few roots; trace organics (wood chips).
		Bentonite chips 2' to 5'				
5		1 1/4" PVC Schedule 80 +2.32 to 10' Bentonite Pellets 5' to 7'		4 5 5		Wet, gray with heavy orange staining, fine sandy SILT. At 5.8': silt lens, gray heavy oxidation, clay present (1.5" thick). At 6': silty fine SAND, gray with heavy oxidation.
		Silica sand 7' to 20'				
10		1 1/4" PVC Schedule 80 screen, 0.010" slot 10' to 20'		34 15 14		At 10': wet, brownish gray, medium to coarse SAND, trace silt. At 11': wet, light brown, fine to coarse SAND with gravel, few silt.
15				37 50/6"		Wet, light brown, fine to coarse SAND with gravel, few silt.
20		BOH 20', re-drilled new hole to set screen at 20'		37 50/5"		Wet, grayish brown, silty fine to coarse SAND with gravel.
25				12 50/6"		Wet, grayish brown, medium to coarse SAND, few fine gravel, trace to few silt.
30				42 50/4"		Wet, grayish brown, silty fine to coarse SAND with gravel.
35		Bentonite chips (abandoned 1st hole with bentonite chips)		43 32 50/4"		Wet, light brownish gray, fine SAND, trace to few silt, trace fine GRAVEL, thin layers of silty fine SAND.

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample

M - Moisture

Water Level (5.79' TOC 4/3/06)

Water Level at time of drilling (ATD)

Logged by: SS/BAA

Approved by:

NWWELL- B 05351A.GPJ BORING.GDT 1/23/20

associated earth sciences incorporated

Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KE05351A	MW-18	2 of 2

Project Name	Tumwater-Doelman	Location	Tumwater, WA
Elevation (Top of Well Casing)	~187'	Surface Elevation (ft)	~185'
Water Level Elevation	~181.5'	Date Start/Finish	4/3/06,4/3/06
Drilling/Equipment	Davies/HSA	Hole Diameter (in)	7"
Hammer Weight/Drop	140# / 30"		

Depth (ft)	Water Level	WELL CONSTRUCTION	ST	Blows/ 6"	Graphic Symbol	DESCRIPTION
				19 20 50/6"		Wet, gray, fine to medium SAND, trace silt, with thin layers of light brownish gray silty fine SAND.
45				15 50/5"		Wet, gray, medium to coarse SAND, few gravel, trace silt.
						Boring terminated at 46.5 feet Well completed at feet on 4/3/06.
50						
55						
60						
65						
70						
75						

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample

M - Moisture

Water Level (5.79' TOC 4/3/06)

Water Level at time of drilling (ATD)

Logged by: SS/BAA

Approved by:

NWWELL-B 05351A.GPJ BORING.GDT 1/23/20

associated earth sciences incorporated

Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KE05351A	MW-19	1 of 1

Project Name: Tumwater-Doelman
Location: Tumwater, WA
Elevation (Top of Well Casing): ~176'
Surface Elevation (ft): ~173'
Water Level Elevation: ~169'
Date Start/Finish: 4/3/06,4/3/06
Drilling/Equipment: Davies/HSA
Hole Diameter (in): 7"
Hammer Weight/Drop: 140# / 30"

Depth (ft)	Water Level	WELL CONSTRUCTION	ST	Blows/ 6"	Graphic Symbol	DESCRIPTION
		Above Ground Monument Cement 0 to 1' Bentonite pellets 1' to 2' Bentonite chips 2' to 5'		2 3 3		Topsoil/Sod: moist, brown to dark brown, silty fine SAND to fine sandy SILT; trace to few roots; trace organics.
5	▼ ▽	1 1/4" PVC schedule 80 +2.67' to 7' Silica sand 5' to 19'		3 5 6		Upper 8": wet, gray, silty fine SAND; heavy oxidation. Lower 10": wet, gray, fine sandy SILT, silt lenses, clay present; heavy oxidation.
10				2 4 4		Wet, brownish gray with heavy orange staining, stratified fine sandy SILT with frequent silty fine SAND lenses; micaceous.
15		1 1/4" PVC schedule 80 screen, 0.010" slot 7' to 17'		0 2 3		Wet, grayish brown, fine sandy SILT; moderate oxidation; micaceous.
20		Bentonite chips 19' to 25'		1 5 6		Wet, bluish gray, fine sandy SILT, clay present; micaceous.
25		Bentonite and Native 22' to 25'		1 4 5		Wet, grayish brown, fine sandy SILT; minor oxidation.
30						Boring terminated at 26.5 feet Well completed at feet on 4/3/06.
35						

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample

M - Moisture

- Water Level (5.62' bgs 4/4/06)
- Water Level at time of drilling (ATD)

Logged by: SS/BAA

Approved by:

NWWELL- B 05351A.GPJ BORING.GDT 1/23/20

LRS-06

SOIL BORING / MONITORING WELL LOG FOR B-3

Client:	Thurston County	**Contractor:**	Vironex Ray Carden		**Start**	**Finish**
Site Name:	4032 88th Rd.	**Method:**	Geoprobe	**Date**	9/9/98	9/9/98
Location:	Tumwater, WA	**Sampler:**	Continuous	**Time:**	6:30	8:30
AHR Job #:	1055	**Logged By:**	Nadine Romero			

Depth (feet)	Core Num	Blow Count	PID* (ppm)	Description of Sample Material	Observations	Completion Information:
3.0						Steel Stick-Up Protector in Cement Surface Seal
2.5						
2.0				Notes: Has not rained in Olympia for several months		
1.5						
1.0					Well Stick Up= 3.2 ft	
0.5						
0.0				Land Surface		
-0.5						Bentonite Chips
-1.0				Loose, Dry, Red Brown, fine silty SAND (loam)		
-1.5						
-2.0						
-2.5						1" PVC Riser
-3.0						
-3.5						
-4.0	1			Loose, Red Brown, medium SAND, w/ mottling		
-4.5						
-5.0				Loose, Wet, Red Brown, medium SAND	***Water Lvl @ 4.48' bls***	▼
-5.5						-----
-6.0						10-20 Silica Sand
-6.5						
-7.0				Loose, Wet, Grey Medium SAND w/grading		
-7.5				(w/ red brown SAND layer @7.0 to 7.5 ft)		
-8.0	2					
-8.5						1" PVC 0.010 Slot Well Screen
-9.0						
-9.5						
-10.0						
-10.5				Loose, Wet, Grey Coarse SAND		
-11.0	3					
-11.5				Dense, Dk. Grey Silty CLAY (TILL)		
-12.0				w/ gravel End of Boring @ 12.0 feet		
-12.5						
-13.0						
-13.5						
-14.0						
-14.5						
-15.0						
-15.5						

2843 70TH Ave SW

LRS-01A

SOIL BORING / MONITORING WELL LOG FOR B-4

Client:	Thurston County	**Contractor:**	Vironex Ray Carden		
Site Name:	~~0925 Walter St. SW~~	**Method:**	Geoprobe		
Location:	Olympia, WA	**Sampler:**	Continuous	**Date**	9/9/98
AHR Job #:	1055	**Logged By:**	Nadine Romero	**Time:**	9:00

Start	**Finish**
9/9/98	9/9/98
9:00	12:30

Depth (feet)	Core Num	Blow Count	PID* (ppm)	Description of Sample Material	Observations	Completion Information:
3.0						Steel Stick-Up Protector in Cement Surface Seal
2.5						
2.0				Notes: Has not rained in Olympia for several months		
1.5						
1.0					Well Stick Up= 3.25 ft	
0.5						
0.0				Land Surface		
-0.5						Bentonite Chips
-1.0				Loose, Black, Loamy fine SAND		
-1.5						
-2.0						
-2.5						1" PVC Riser
-3.0				Loose, Black, Loamy fine SAND		
-3.5						
-4.0	1					
-4.5						
-5.0						
-5.5				Loose, Moist, Light Brown, fine to medium SAND		
-6.0						
-6.5						
-7.0				Loose, Moist, Light Brown, fine to medium SAND		
-7.5	2			w/ some mottling @7.0 ft.		
-8.0						
-8.5				(3" red-brwn clay @8.0 ft & @ 8.7 ft)		
-9.0						
-9.5				Loose, Light Brown, coarse SAND		
-10.0						
-10.5						
-11.0				Loose, Light Brown, medium SAND		
-11.5						
-12.0	3			Loose, Light Brown, coarse SAND		
-12.5						
-13.0						
-13.5				Loose, Light Brown, fine SAND		
-14.0					15.1'	
-14.5					***Water Lvl @ 14.5 bls***	▼
-15.0	4			Loose, Wet, Light Brown, fine SAND		
-15.5						

2843 70TH Ave SW
B-4 (cont)

LRS-01A

SOIL BORING / MONITORING WELL LOG FOR B-4 (Cont.)

Client:	Thurston County	**Contractor:**	Vironex Ray Carden		**Start** / **Finish**
Site Name:	8925 Walter Ct. SW	**Method:**	Geoprobe	**Date**	9/9/1998 / 9/9/98
Location:	Olympia, WA	**Sampler:**	Continuous	**Time:**	9:00 / 12:30
AHR Job #:	1055	**Logged By:**	Nadine Romero		

Depth (feet)	Core Num	Blow Count	PID* (ppm)	Description of Sample Material	Observations	Completion Information:
-16.0						
-16.5						
-17.0	4			Loose, Wet, Brown, medium SAND		
-17.5						
-18.0						
-18.5						
-19.0	5			Loose, Wet, Brown, medium SAND		
-19.5						
-20.0						
-20.5						
-21.0						
-21.5	6			Loose, Wet, Drk. Brown, medium SAND		
-22.0				w/stratification		1" PVC Riser
-22.5						
-23.0				Loose, Wet, Brown, coarse SAND		
-23.5	7			w/ 1" silty red clay seam		
-24.0						
-24.5						
-25.0				Loose, Wet, Brown, coarse SAND		
-25.5	8			w/ gravel		
-26.0						
-26.5						-------
-27.0						10-20
-27.5	9					Silica
-28.0						Sand
-28.5					Screened 27 -32 ft	
-29.0				Loose, Wet, Brown, medium SAND	bgs	
-29.5	10			w/ gravel		
-30.0						1" PVC
-30.5						0.020 Slot
-31.0				Loose, Wet, Brown, medium SAND		Well
-31.5	11					Screen
-32.0				Dense, Grey, silty CLAY TILL @31.9 ft.		Plug
-32.5						
-34.0				End of Boring @34.0 ft.		

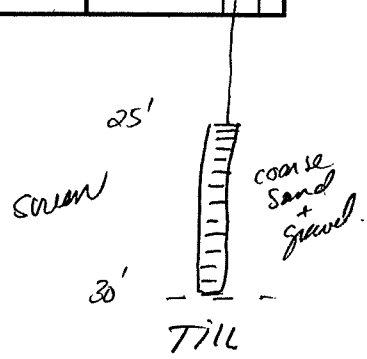
3804 93rd Ave

LRS-07A

SOIL BORING / MONITORING WELL LOG FOR B-5

Client:	Thurston County	**Contractor:**	Vironex Ray Carden		
Site Name:	~~8925 Walter Ct. SW~~	**Method:**	Geoprobe	**Start**	**Finish**
Location:	Olympia, WA	**Sampler:**	Continuous	**Date** 9/9/98	9/9/98
AHR Job #:	1055	**Logged By:**	Nadine Romero	**Time:** 13:30	15:30

Depth (feet)	Core Num	Blow Count	PID* (ppm)	Description of Sample Material	Observations	Completion Information:
3.0						Steel Stick-Up Protector in Cement Surface Seal
2.5						
2.0				Notes: Has not rained in Olympia for several months		
1.5						
1.0					Well Stick Up= 3.30 ft	
0.5						
0.0				Land Surface		
-0.5						Bentonite Chips
-1.0				Loose, Brown, Fine to Medium SAND		
-1.5						
-2.0						
-2.5						1" PVC Riser
-3.0				Loose, Brown, Fine to Medium SAND		
-3.5				w/ 3" red mottled silty fine sand @3.5 ft		
-4.0	1					
-4.5						
-5.0						
-5.5				Loose, Light Brown, Fine to Medium SAND	Moist	
-6.0						
-6.5						
-7.0				Loose, Drk Brown, Fine to Medium SAND		
-7.5	2			w/ Black fragments – hard "crunchy" volcanic glass.	*Water Lvl @ 7.7 ft. bls*	▼
-8.0						
-8.5				3" seam of Drk Brown Peat @8.5 ft.		
-9.0				3" Reddish brown Coarse SAND		
-9.5				Stiff, Reddish brown silty fine SAND w/ mottling		
-10.0				and stratification		
-10.5						
-11.0						
-11.5						
-12.0	3					
-12.5				Stiff, Brown-reddish, silty fine SAND; w/ mottling		
-13.0				wet @14.0 ft.		
-13.5						
-14.0						
-14.5						
-15.0	4			Loose, Wet, Brown, coarse SAND w/gravel		
-15.5						



File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT
STATE OF WASHINGTON

Application No. 82-4676

Permit No. .....

(1) OWNER: Name THURSTON COUNTY - SHOP Address TILLEY ROAD

(2) LOCATION OF WELL: County THURSTON SE ¼ NE ¼ Sec. 22 T. 17 N., R. 2W W.M.

Bearing and distance from section or subdivision corner 403' W and 435' N from the E¼ cor sec. 22

(3) PROPOSED USE: Domestic ☐ Industrial ☐ Municipal ☒
Irrigation ☐ Test Well ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one) 2
New well ☒ Method: Dug ☐ Bored ☐
Deepened ☐ Cable ☒ Driven ☐
Reconditioned ☐ Rotary ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well 8 inches.
Drilled 87 ft. Depth of completed well ..... ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 8 " Diam. from +1 ft. to 62 ft.
Threaded ☐ ..... " Diam. from ..... ft. to ..... ft.
Welded ☒ ..... " Diam. from ..... ft. to ..... ft.

Perforations: Yes ☐ No ☒
Type of perforator used .....
SIZE of perforations ..... in. by ..... in.
..... perforations from ..... ft. to ..... ft.
..... perforations from ..... ft. to ..... ft.
..... perforations from ..... ft. to ..... ft.

Screens: Yes ☒ No ☐
Manufacturer's Name JOHNSON
Type WIRE WOUND Model No. .....
Diam. ..... Slot size ..... from ..... ft. to ..... ft.
Diam. 8 Slot size 10 from 62 ft. to 66 ft.

Gravel packed: Yes ☐ No ☒ Size of gravel: .....
Gravel placed from ..... ft. to ..... ft.

Surface seal: Yes ☒ No ☐ To what depth? 18 ft.
Material used in seal BENTONITE
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? ..... Depth of strata .....
Method of sealing strata off .....

(7) PUMP: Manufacturer's Name F-W
Type: SUB H.P. 3-3½

(8) WATER LEVELS: Land-surface elevation above mean sea level .... 200 ft.
Static level 11-9" ft. below top of well Date 2-85
Artesian pressure ..... lbs. per square inch Date .....
Artesian water is controlled by ..... (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☒ No ☐ If yes, by whom? TIMS
Yield: gal./min. with ..... ft. drawdown after ..... hrs.
" 40 gpm " @ 34-0½ "
" 50 gpm " @ 41-0 "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test .....
Bailer test ..... gal./min. with ..... ft. drawdown after ..... hrs.
Artesian flow ..... g.p.m. Date .....
Temperature of water ..... Was a chemical analysis made? Yes ☒ No ☐

(10) WELL LOG:
Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.

MATERIAL	FROM	TO
PIT RUN - FILL MATERIAL	0	11
FINE BROWN SAND	11	19
TIGHT SAND AND GRAVEL	19	28
HARDPAN	28	30
SEEPAGE	30	31
HARD PAN	31	45
SAND AND GRAVEL - TIGHT	45	47
SAND AND GRAVEL - LOOSE	47	53
SAND AND GRAVEL -	53	55
HARDPAN	55	58
WATER BRG. SAND AND GRAVEL	58	67
MED. SAND	67	69
SAND AND CLAY - SOUPY	69	77
GREY CLAY - OPEN BAT	77	87

Work started Feb 1985 Completed Feb 1985

WELL DRILLER'S STATEMENT:

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

NAME TIMS WELL DRILLING (Person, firm, or corporation) (Type or print)

Address 6906 33RD AVE SE

[Signed] ..... (Well Driller)

License No. 0832 Date 3/10, 1985

(USE ADDITIONAL SHEETS IF NECESSARY)

ECY 050-1-20

ie Original and First Copy with
partment of Ecology
cond Copy — Owner's Copy
ird Copy — Driller's Copy

WATER WELL REPORT G2-24924 Application No. ~~G2-24979~~

STATE OF WASHINGTON

Permit No. ~~G2-24979P~~

1) OWNER: Name WESLEY ANDERSON Address 2719 70 AV SW OLYMPIA

LOCATION OF WELL: County THURSTON SE ¼ SW ¼ Sec 14 T. 17 N., R. 2 W.W.M.

earing and distance from section or subdivision corner

3) PROPOSED USE: Domestic ☐ Industrial ☐ Municipal ☑ community
Irrigation ☐ Test Well ☐ Other ☐

4) TYPE OF WORK: Owner's number of well (if more than one).... 2
New well ☑ Method: Dug ☐ Bored ☐
Deepened ☐ Cable ☐ Driven ☐
Reconditioned ☐ Rotary ☐ Jetted ☐

5) DIMENSIONS: Diameter of well 6 inches.
Drilled 47 ft. Depth of completed well 47 ft.

6) CONSTRUCTION DETAILS:

Casing installed: ____" Diam. from 6 ft. to 46 ft.
Threaded ☐ ____" Diam. from ____ ft. to ____ ft.
Welded ☑ ____" Diam. from ____ ft. to ____ ft.

Perforations: Yes ☐ No ☑
Type of perforator used
SIZE of perforations ____ in. by ____ in.
____ perforations from ____ ft. to ____ ft.
____ perforations from ____ ft. to ____ ft.
____ perforations from ____ ft. to ____ ft.

Screens: Yes ☐ No ☑
Manufacturer's Name
Type Model No.
Diam. ____ Slot size ____ from ____ ft. to ____ ft.
Diam. ____ Slot size ____ from ____ ft. to ____ ft.

Gravel packed: Yes ☐ No ☑ Size of gravel:
Gravel placed from ____ ft. to ____ ft.

Surface seal: Yes ☑ No ☐ To what depth? 18 ft.
Material used in seal CEMENT
Did any strata contain unusable water? Yes ☐ No ☑
Type of water? Depth of strata
Method of sealing strata off

(7) PUMP: Manufacturer's Name MYERS
Type: SUB H.P. 5

(8) WATER LEVELS: Land-surface elevation above mean sea level.... 150 ft.
Static level 20 ft. below top of well Date 3/15/77
Artesian pressure lbs. per square inch Date
Artesian water is controlled by (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☑ No ☐ If yes, by whom?
Yield: 60 gal/min. with 8 ft. drawdown after 6 hrs.
" " " "
" " " "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test
ller test gal./min. with ft. drawdown after hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? Yes ☐ No ☐

(10) WELL LOG:

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.

MATERIAL	FROM	TO
TOPSOIL	1	3
SAND & DARK	3	4
SAND & LIGHT	4	16
HARD PAN	16	30
SILT	30	37
GRAVEL	37	47

Well #2 to be covered under new application

Work started 19 Completed 19

WELL DRILLER'S STATEMENT:

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

NAME COWLITZ DRILLING
(Person, firm, or corporation) (Type or print)

Address R-5 Box 280

[Signed] (Well Driller)

License No. 0084 Date 8/20/, 19 77

No. 7256—OS—(Rev. 4-71). OK WM (USE ADDITIONAL SHEETS IF NECESSARY) Loc'd 12-21-77

File Original with Department of Ecology
Second Copy - Owner's Copy
Third Copy - Driller's Copy

WATER WELL REPORT
STATE OF WASHINGTON

Notice of Intent W117132
UNIQUE WELL I.D. # AFC 789
Water Right Permit No.

(1) OWNER: Name David & Carol Rees (L. Burk) Address (16616 Williams Lane SW, Rochester)

(2) LOCATION OF WELL: County Thurston SW 1/4 SE 1/4 Sec 25 T 17 N.R. 3W WM

(2a) STREET ADDRESS OF WELL: (or nearest address) 10739 Creekwood Dr. SW, Olympia, WA

TAX PARCEL NO.: 43050000500

(3) PROPOSED USE: [X] Domestic [ ] Industrial [ ] Municipal [ ] Irrigation [ ] Test Well [ ] Other [ ] DeWater

(4) TYPE OF WORK: Owner's number of well (if more than one)
[X] New Well Method: [ ] Deepened [ ] Dug [ ] Bored [ ] Reconditioned [ ] Cable [ ] Driven [ ] Decommission [X] Rotary [ ] Jetted

(5) DIMENSIONS: Diameter of well 6 inches
Drilled 58 feet. Depth of completed well 58 ft.

(6) CONSTRUCTION DETAILS
Casing Installed:
[X] Welded 6 " Diam. from +2 ft. to 58 ft.
[ ] Liner installed " Diam. from ft. to ft.
[ ] Threaded " Diam. from ft. to ft.

Perforations: [X] Yes [ ] No
Type of perforator used Slot
SIZE of perforations 5/32 in. by 2 in.
96 perforations from 46 ft. to 55 ft.

Screens: [ ] Yes [X] No [ ] K-Pac Location
Manufacturer's Name
Type Model No.
Diam. Slot Size from ft. to ft.
Diam. Slot Size from ft. to ft.

Gravel/Filter packed: [ ] Yes [X] No [ ] Size of gravel/sand
Material placed from ft. to ft.

Surface seal: [X] Yes [ ] No To what depth? 15 ft.
Material used in seal bentonite
Did any strata contain unusable water? [ ] Yes [ ] No
Type of water? Depth of strata
Method of sealing strata off

(7) PUMP: Manufacturer's Name
Type: H.P.

(8) WATER LEVELS: Land-surface elevation above mean sea level ft.
Static level 24 ft. below top of well Date 12/14/98
Artesian pressure lbs. per square inch Date
Artesian water is controlled by (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? [ ] Yes [ ] No If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.
Yield: gal./min. with ft. drawdown after hrs.
Yield: gal./min. with ft. drawdown after hrs.
Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test
Bailer test gal./min. with ft. drawdown after hrs.
Airtest 20 gal./min. with 24 ft. drawdown after 2 hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? [ ] Yes [X] No

(10) WELL LOG or DECOMMISSIONING PROCEDURE DESCRIPTION
Formation: Describe by color, character, size of material and structure, and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information. Indicate all water encountered.

MATERIAL	FROM	TO
Top Soil	0	3
Sandy Clay	3	12
Hardpan	12	30
Sand & Gravel w/water	30	40
Gravel w/water	40	58

Work Started 12/15/98 Completed 12/16/98

WELL CONSTRUCTION CERTIFICATION:
I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.
Type or Print Name Terry Gavin License No. 0151
(Licensed Driller/Engineer)
Trainee Name License No.
Drilling Company Chehalis Well Drilling
(Signed) Terry Gavin License No. 01510
(Licensed Driller/Engineer)
Address 1718 Harrison Ave., Centralia
Contractor's Registration No CHEHAWD123N4 Date 1/23/99

(USE ADDITIONAL SHEETS IF NECESSARY)

Ecology is an Equal Opportunity and Affirmative Action employer. For special accommodation needs, contact the Water Resources Program at (360) 407-6600. The TDD number is (360) 407-6006.

ECY 050-1-20 (11/98)

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. 068141

UNIQUE WELL I.D. # ABA 869

Water Right Permit No. G2-07765P

(1) **OWNER:** Name CITY OF TUMWATER Address 555 ISRAEL ROAD, TUMWATER, WA

(2) **LOCATION OF WELL:** County THURSTON COUNTY SE 1/4 SE 1/4 Sec 03 T. 17 N., R 2 W.M.

(2a) **STREET ADDRESS OF WELL** (or nearest address) ISRAEL ROAD

(3) **PROPOSED USE:** ☐ Domestic ☐ Irrigation ☐ DeWater Industrial ☐ Test Well ☐ Municipal ☒ Other ☐

(4) **TYPE OF WORK:** Owner's number of well (if more than one) 93-01

Abandoned ☐ New well ☒ Method: Dug ☐ Bored ☐
Deepened ☐ Cable ☒ Driven ☐
Reconditioned ☐ Rotary ☐ Jetted ☐

Tum. well #11-93

(5) **DIMENSIONS:** Diameter of well 16 inches.
Drilled 154'6" feet. Depth of completed well ____ ft.

(6) **CONSTRUCTION DETAILS:**

Casing Installed: 16" Diam. from 0 ft. to 109 ft.
Welded ☒
Liner Installed ☐ ____" Diam. from ____ ft. to ____ ft.
Threaded ☐ ____" Diam. from ____ ft. to ____ ft.

Perforations: Yes ☐ No ☒
Type of perforator used ____
SIZE of perforations ____ in. by ____ in.
____ perforations from ____ ft. to ____ ft.
____ perforations from ____ ft. to ____ ft.
____ perforations from ____ ft. to ____ ft.

Screens: Yes ☒ No ☐
Manufacturer's Name JOHNSON
Type STAINLESS STEEL Model No. 14"
Diam. 14 Slot size 60 from 109 ft. to 113 ft.
Diam. 14 Slot size 120 from 113 ft. to 117 ft.

Gravel packed: Yes ☐ No ☒ Size of gravel ____
Gravel placed from ____ ft. to ____ ft.

Surface seal: Yes ☒ No ☐ To what depth? ____ ft.
Material used in seal CEMENT/BENTONITE
Did any strata contain unusable water? Yes ☒ No ☐
Type of water? ____ Depth of strata ____
Method of sealing strata off CEMENT/BENTONITE

(7) **PUMP:** Manufacturer's Name ____
Type: ____ H.P. ____

(8) **WATER LEVELS:** Land-surface elevation above mean sea level 191 ft.
Static level 35 ft. below top of well Date 5/29/93
Artesian pressure ____ lbs. per square inch Date ____
Artesian water is controlled by ____ (Cap, valve, etc.)

* (9) **WELL TESTS:** Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☒ No ☐ If yes, by whom? PGG
Yield: 175 gal./min. with ____ ft. drawdown after ____ hrs.

* "SEE ATTACHED" " " "
" " " "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level
* "SEE ATTACHED"					

Date of test 7/2/93 - 7/3/93
Bailer test ____ gal./min. with ____ ft. drawdown after ____ hrs.
Airtest ____ gal./min. with stem set at ____ ft. for ____ hrs.
Artesian flow ____ g.p.m. Date ____
Temperature of water ____ Was a chemical analysis made? Yes ☐ No ☐

(10) **WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION**

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

MATERIAL	FROM	TO
TOP SOIL	0'	3'
BROWN SAND	3'	6'
SAND W/SILT TRACES	6'	23'
DIRTY BROWN SAND W/TRACE OF WATER	23'	39'
BROWN SAND W/TRACE OF GRAVEL		
WATERBEARING	39'	45'
DIRTY SAND AND GRAVEL W/SILT		
SOME COBBLES	45'	56'
LARGE GRAVELS AND SAND W/SILT	56'	63'
CEMENTED GRAVEL TILL	63'	75'
BROWN SAND AND GRAVEL W/TRACE CLAY	75'	80'
REAL DIRTY BROWN SAND & GRAVEL		
W/INTERBEDDED CLAY	80'	105'
LARGE GRAVELS & SAND W/CLAY	105'	109'
BINDER, DARK BROWN, WATERBEARING		
MEDIUM-COURSE SAND, SOME GRAVEL,		
BROWN, WATERBEARING	109'	111'
LARGE COBBLES & SAND, BROWN GRAVEL		
WATERBEARING	111'	119'
LARGE GRAVELS & SAND W.TRACE OF		
BINDER,	119'	127'
LAYERED SILT SAND & GRAVEL	127'	135'
DIRTY SAND & GRAVEL, SLIGHTLY		
SILTY	135'	150'
MEDIUM-COURSE SAND W/GREEN CLAY	150'	154'

RECEIVED JUN 22 A9:54 DEPARTMENT OF ECOLOGY SW REGIONAL OFFICE

Work Started JUNE 7, 1993 Completed XXX JULY 8, 1993

WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME HOKKAIDO DRILLING & DEV CORP (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)

Address P.O. BOX 100, GRAHAM, WA 98338

(Signed) Robert B. Carpenter (WELL DRILLER) License No. 1239

Contractor's Registration No. HOKKADD178D3 Date JUNE 16, 1994

(USE ADDITIONAL SHEETS IF NECESSARY)

ECL 050-1-20 (2/93)

The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. W-40414

UNIQUE WELL I.D. # ABF 588

Water Right Permit No. G2-28195

(1) **OWNER:** Name CITY OF TUMWATER Address 555 ISRAEL ROAD

(2) **LOCATION OF WELL:** County THURSTON - SW 1/4 SW 1/4 Sec 10 T. 17 N., R. 2 W.M.

(2a) **STREET ADDRESS OF WELL** (or nearest address) BUSH MIDDLE SCHOOL

(3) **PROPOSED USE:** ☐ Domestic ☐ Industrial ☐ Municipal ☒ ☐ Irrigation ☐ Test Well ☐ Other ☐ ☐ DeWater

(4) **TYPE OF WORK:** Owner's number of well (if more than one) 94-08

TUM. well 14-94

Abandoned ☐ New well ☒ Method: Dug ☐ Bored ☐ Deepened ☐ Cable ☒ Driven ☐ Reconditioned ☐ Rotary ☐ Jetted ☐

(5) **DIMENSIONS:** Diameter of well 16 inches. Drilled ____ feet. Depth of completed well ____ ft.

(6) **CONSTRUCTION DETAILS:**

Casing installed: 16" Diam. from 1 ft. to 158 ft. Welded ☐ Liner installed ☐ Threaded ☐ ____" Diam. from ____ ft. to ____ ft. ____" Diam. from ____ ft. to ____ ft.

Perforations: Yes ☐ No ☒

Type of perforator used ____

SIZE of perforations ____ in. by ____ in.

____ perforations from ____ ft. to ____ ft.

____ perforations from ____ ft. to ____ ft.

____ perforations from ____ ft. to ____ ft.

Screens: Yes ☒ No ☐

Manufacturer's Name JOHNSON

Type 304 STAINLESS STEEL Model No. ____

Diam. 14" Slot size 140 from 70 ft. to 90 ft.

Diam. 14" Slot size 140 from 94 ft. to 101 ft.

Gravel packed: Yes ☐ No ☒ Size of gravel ____

Gravel placed from ____ ft. to ____ ft.

Surface seal: Yes ☒ No ☐ To what depth? 29 ft.

Material used in seal CEMENT-BENTONITE

Did any strata contain unusable water? Yes ☐ No ☐

Type of water? ____ Depth of strata ____

Method of sealing strata off ____

(7) **PUMP:** Manufacturer's Name ____ Type: ____ H.P. ____

(8) **WATER LEVELS:** Land-surface elevation above mean sea level 188.8 ft.

Static level 12.6 ft. below top of well Date 5/2/94

Artesian pressure ____ lbs. per square inch Date ____

Artesian water is controlled by ____ (Cap, valve, etc.)

(9) **WELL TESTS:** Drawdown is amount water level is lowered below static level

Was a pump test made? Yes ☐ No ☐ If yes, by whom? PGG

Yield: 638 gal./min. with ____ ft. drawdown after ____ hrs.

" "SEE ATTACHED" " "

" " " "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level
"SEE ATTACHED"					

Date of test 4/30/94 TO 5/1/94

Bailer test ____ gal./min. with ____ ft. drawdown after ____ hrs.

Airtest ____ gal./min. with stem set at ____ ft. for ____ hrs.

Artesian flow ____ g.p.m. Date ____

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

(10) **WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION**

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

MATERIAL	FROM	TO
TOP SOIL	0"	6"
BROWN SAND	6"	6'
DIRTY BROWN SAND, TRACE OF GRAVEL		
SLIGHTLY SILTY	6'	15'
DIRTY SAND & GRAVEL WATERBEARING		
W/TRACE OF BROWN BINDER	15'	28'-6"
GRAY CEMENTED TILL	28'6"	31'
SAND & GRAVEL W/BINDER	31'	35'
WATERBEARING SAND & GRAVEL	35'	45'
BROWN WATERBEARING SAND & GRAVEL		
W/BINDER	45'	73'
TIGHT SAND & GRAVEL W/BINDER	73'	75'
LARGE GRAVEL & SAND WATERBEARING	75'	80'
GRAY SAND & GRAVEL W/BROWN,GRAY		
& GREEN BINDER	80'	100'
LARGE GRAVELS & SAND, WATERBEARING		
W/BALLS OF BINDER	100'	121'
TIGHT BROWN TILL	121'	124'
TIGHT GREEN TILL	124'	129'
DIRTY GREEN GRAY SAND & GRAVEL	129'	134'
W/SILT & PEAT		
GREEN SAND & GRAVEL	134'	154'
BLUE SAND & GRAVEL	154'	158'
GREEN SILTY CLAY	158'	

RECEIVED JUN 22 94 A 9:54 DEPARTMENT OF ECOLOGY SW REGIONAL OFFICE

Work Started MARCH 31, 1994 Completed MAY 4, 1994

WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME HOKKAIDO DRILLING & DEVELOPING CORP (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)

Address P.O. BOX 100, GRAHAM, WA 98338

(Signed) Robert B. Carpenter (WELL DRILLER) License No. 1239

Contractor's Registration No. HOKKADD178D3 Date JUNE 17, 1994

(USE ADDITIONAL SHEETS IF NECESSARY)

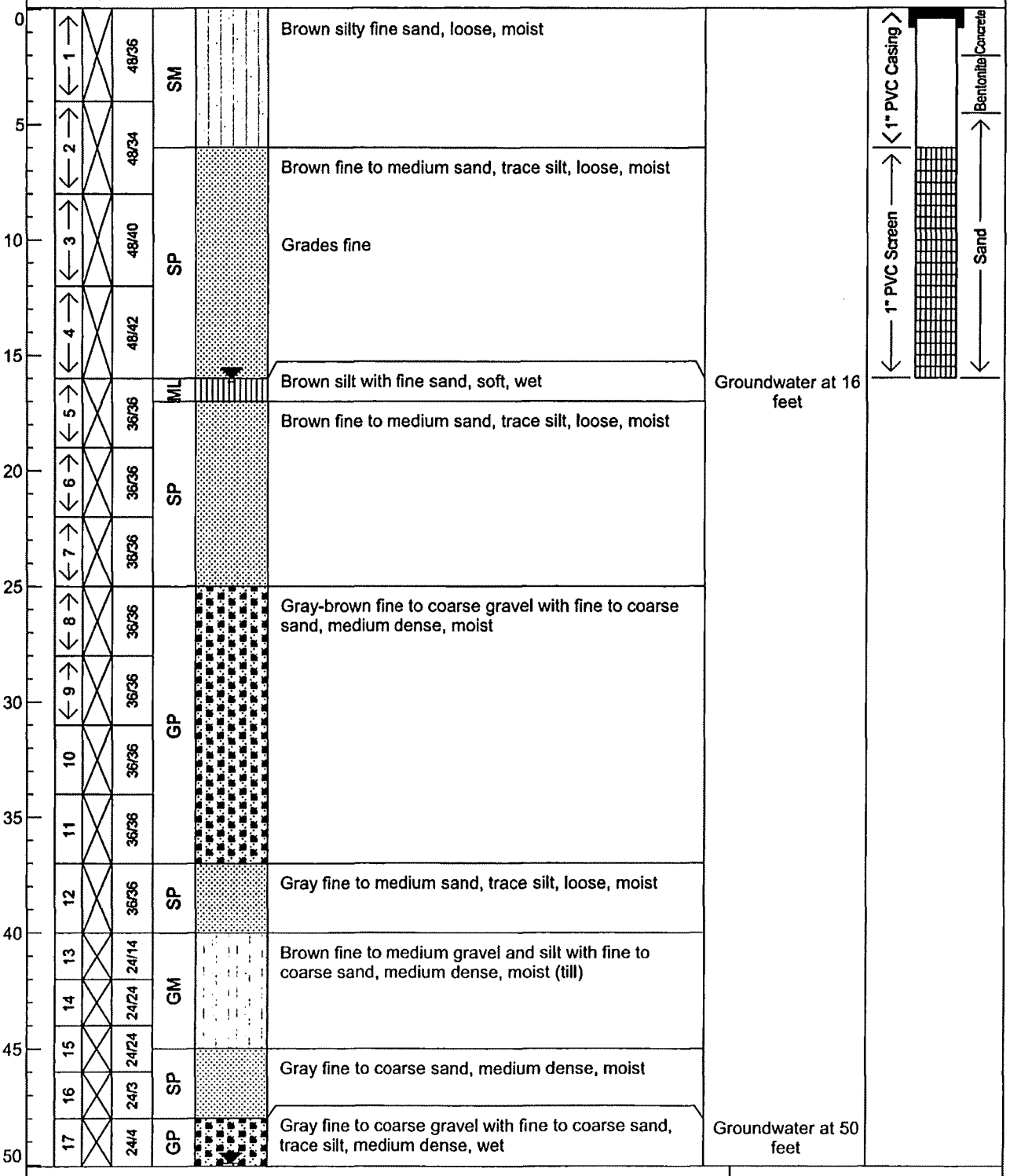
ECL 050-1-20 (2/93)

The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

PROJECT: **TCI Cablevision of Washington**
PROJECT NO.: **503-001-01**
LOCATION: **8110 River Road SE, Olympia, WA**

MW-1

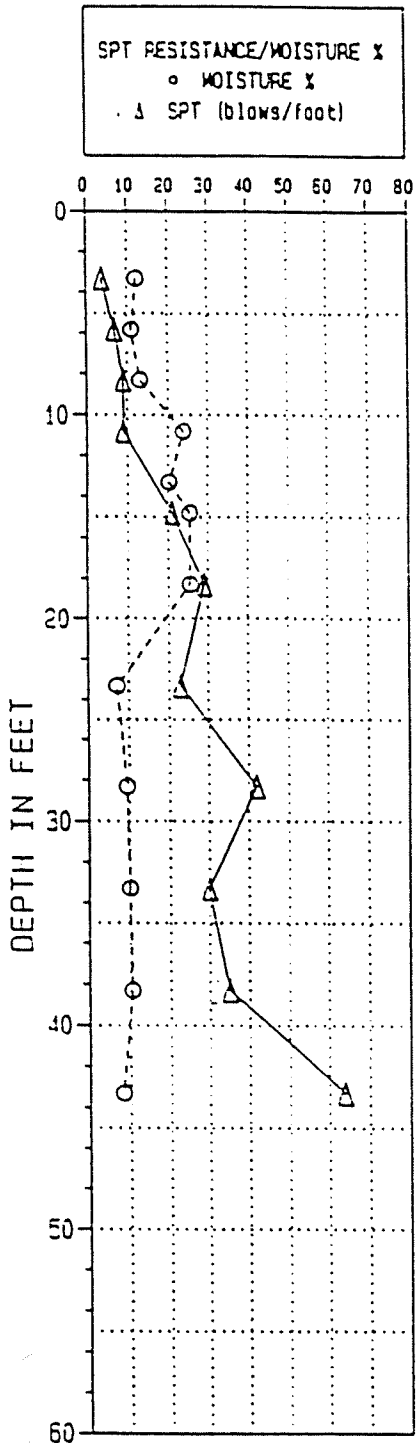
DATE: **11/29/10**
TOTAL DEPTH: **50 Feet**



Drilling Contractor: **ESN NW**
Driller: **Nole**
Drilling Equipment: **AMS Power Probe**
Drilling Method: **Direct Push Probe**
Logged By: **Kevin VanDehey**

INSIGHT GEOLOGIC, INC.

HONG WEST & ASSOCIATES
BORING LOG



SAMPLES | SYMBOLS | DESCRIPTION | PIEZOMETER

SP — Very loose to loose, dark brown, fine SAND: massive; few roots; damp; fine organic debris.
(Topsoil)

SP — Loose to medium dense, brown gray, fine SAND: few 1 to 3 in. interbeds of silty fine sand below 5 feet; moist to wet below 13 feet.
(Fine Outwash)

- saturated & waterbearing below 15 feet.
- few scattered fine gravel in sample at 17.8 to 18.3 feet.

GP — Medium dense to dense, gray, silty fine GRAVEL: some sand; gravel sub to well-rounded; several clasts broken by sampler; wet.
(Outwash)

- interbedded gravelly coarse SAND with silt at 32.5 feet.

SM — Very dense, gray, silty SAND: some gravel; moist.
(Glacial Till)

Bottom of boring at 44.0 feet.

Note: Approx. 12 inches forest duff and topsoil removed during drill pad preparation.

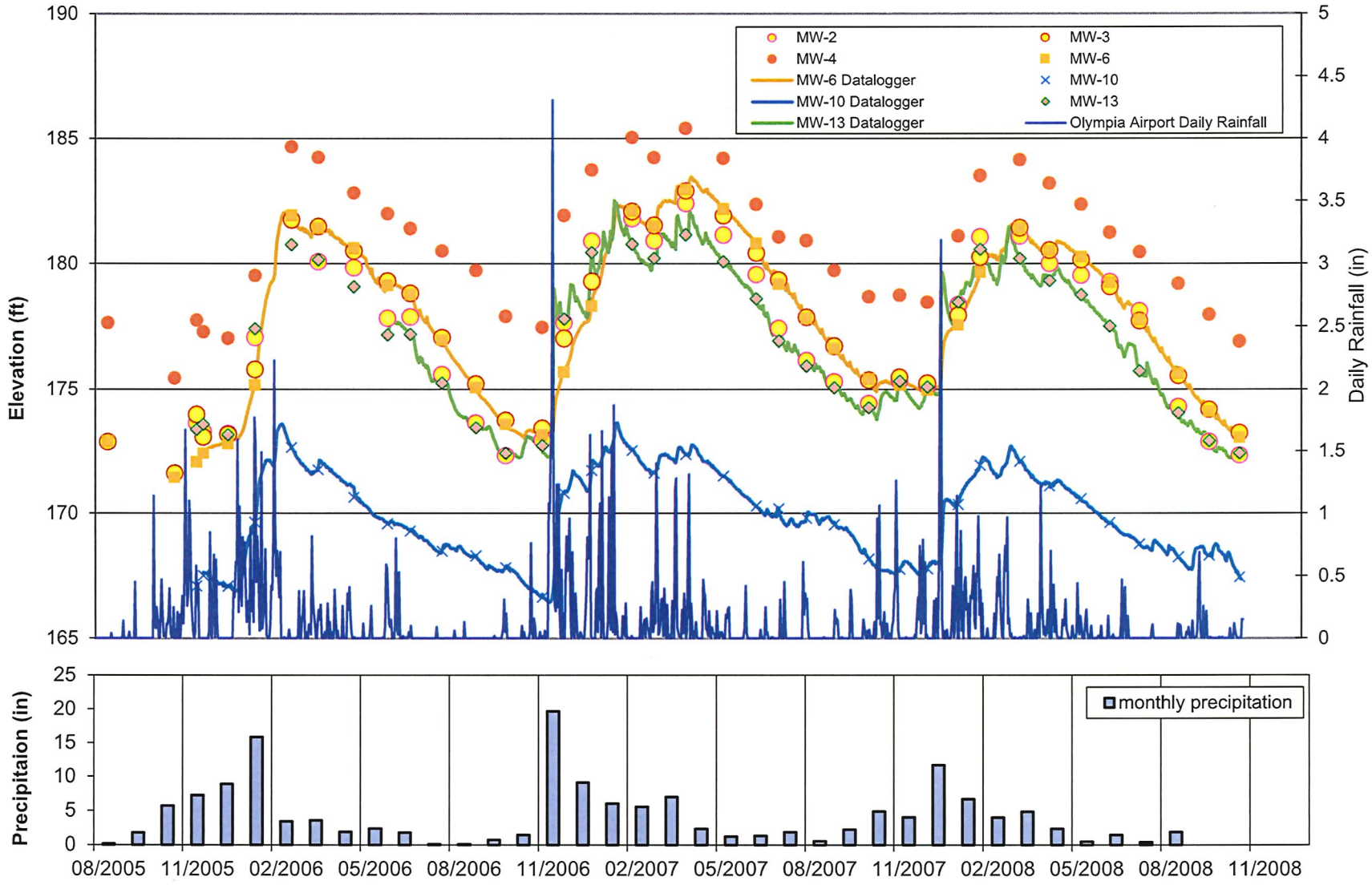
PROJECT NAME: Labor & Industries Building Project
LOCATION: 11th Avenue & 73rd Street; Tumwater, WA.
PROJECT NUMBER: 90059

BORING BH-9

DATE DRILLED: June 6, 1990
SURFACE ELEVATION: 193.56 ft.
TOTAL DEPTH: 44.0 ft.

APPENDIX B

Groundwater Hydrographs



Groundwater Hydrograph

Monitoring Wells MW-2, MW-3, MW-4, MW-6, MW-10 and MW-13

Tickner Farm Subdivision

Tumwater, Washington

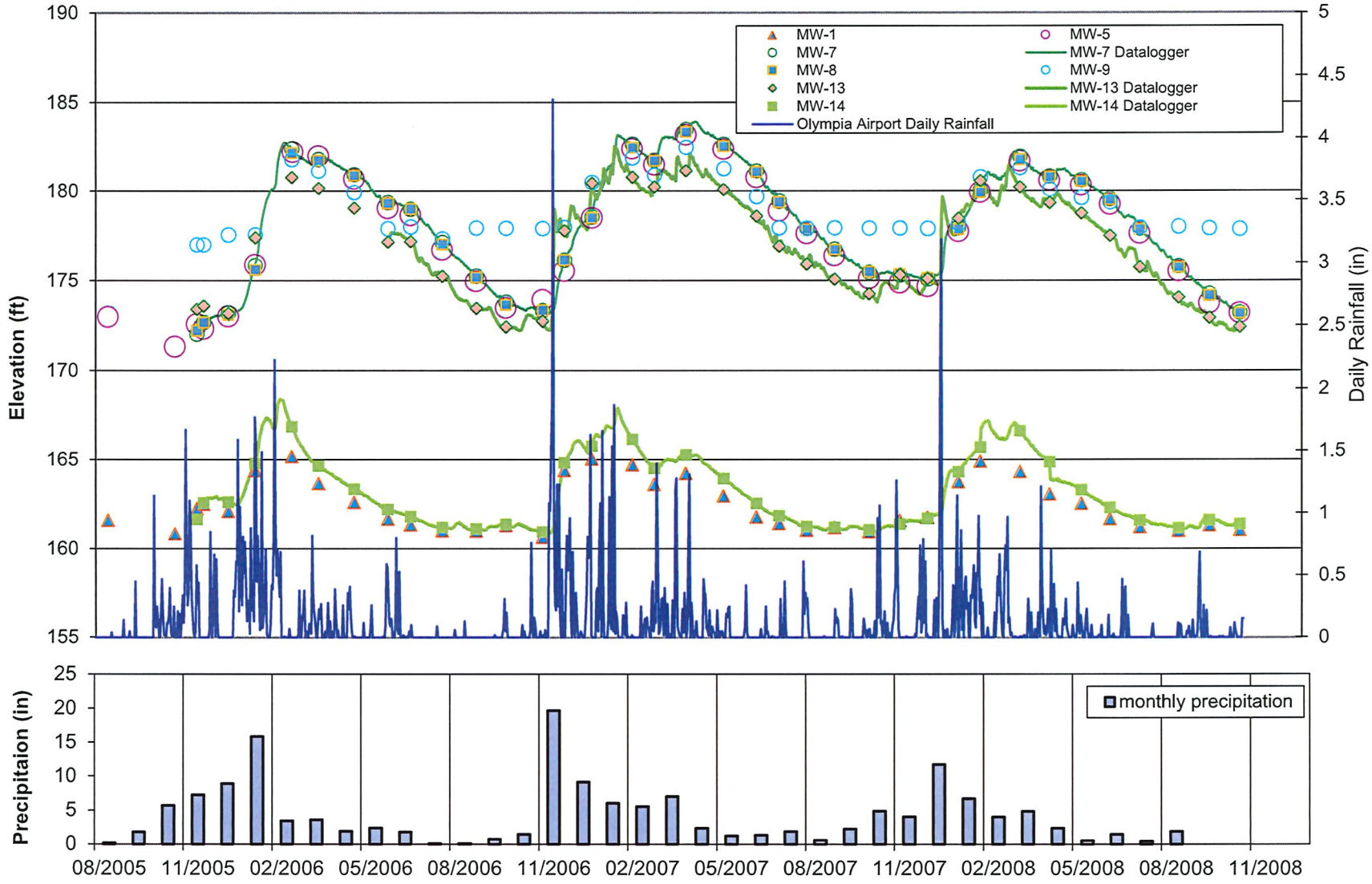
Figure B-1

Project No.: 20200033H001

Date: 04/2020

Associated Earth Sciences, Inc.

www.aesgeo.com



Groundwater Hydrograph

Wells MW-1, MW-5, MW-7, MW-8, MW-9, MW-13, and MW-14

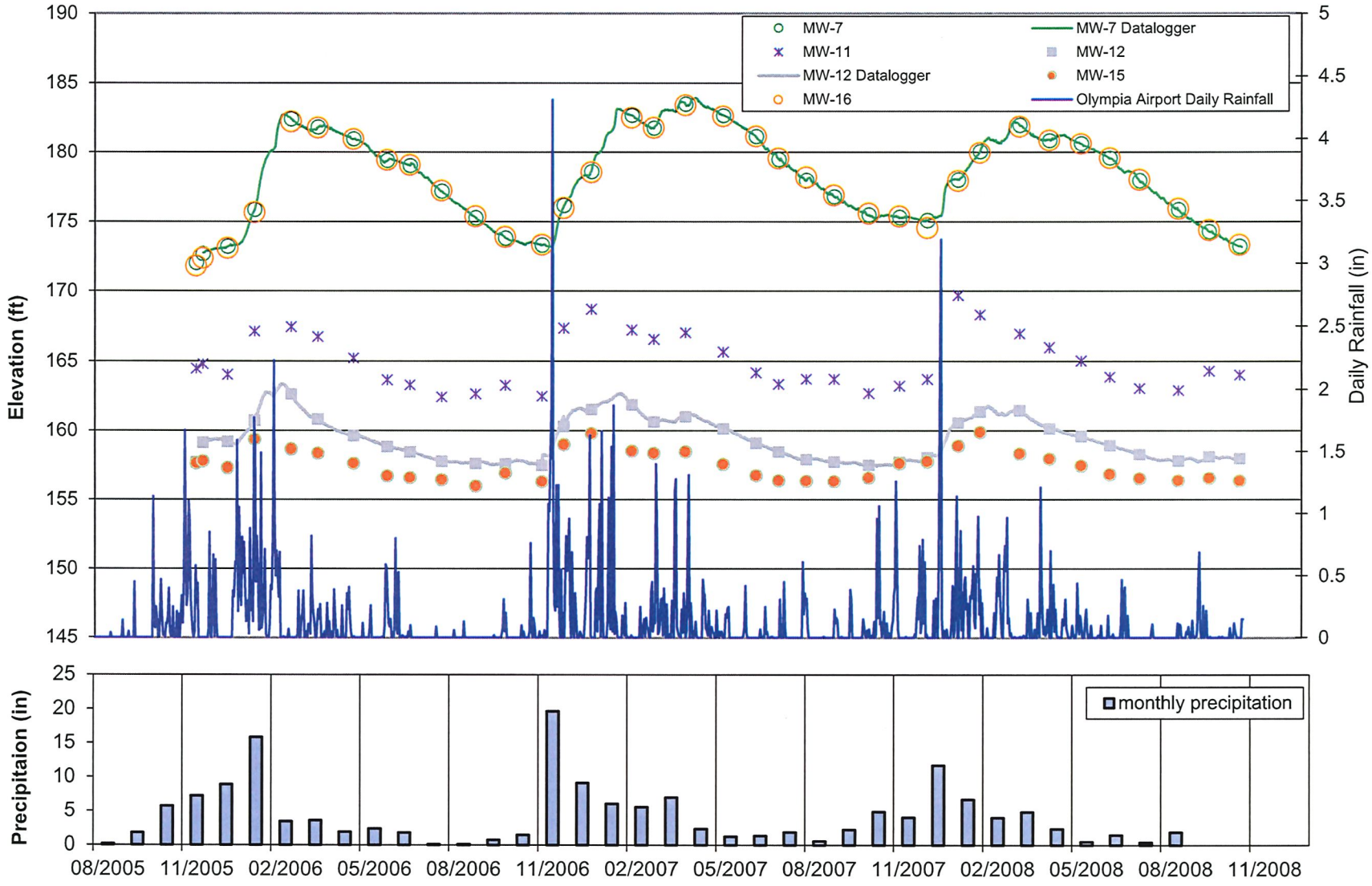
Tickner Farm Subdivision

Tumwater, Washington

Figure B-2

Project No.: 20200033H001

Date: 04/2020



Groundwater Hydrograph
Monitoring Wells MW-7, MW-11, MW-12, MW-15, and MW-16
Tickner Farm Subdivision
Tumwater, Washington

Figure B-3
Project No.: 20200033H001
Date: 04/2020

Associated Earth Sciences, Inc.
www.aesgeo.com

APPENDIX C

Graphical Model Outputs and Inputs

Figure C-01:

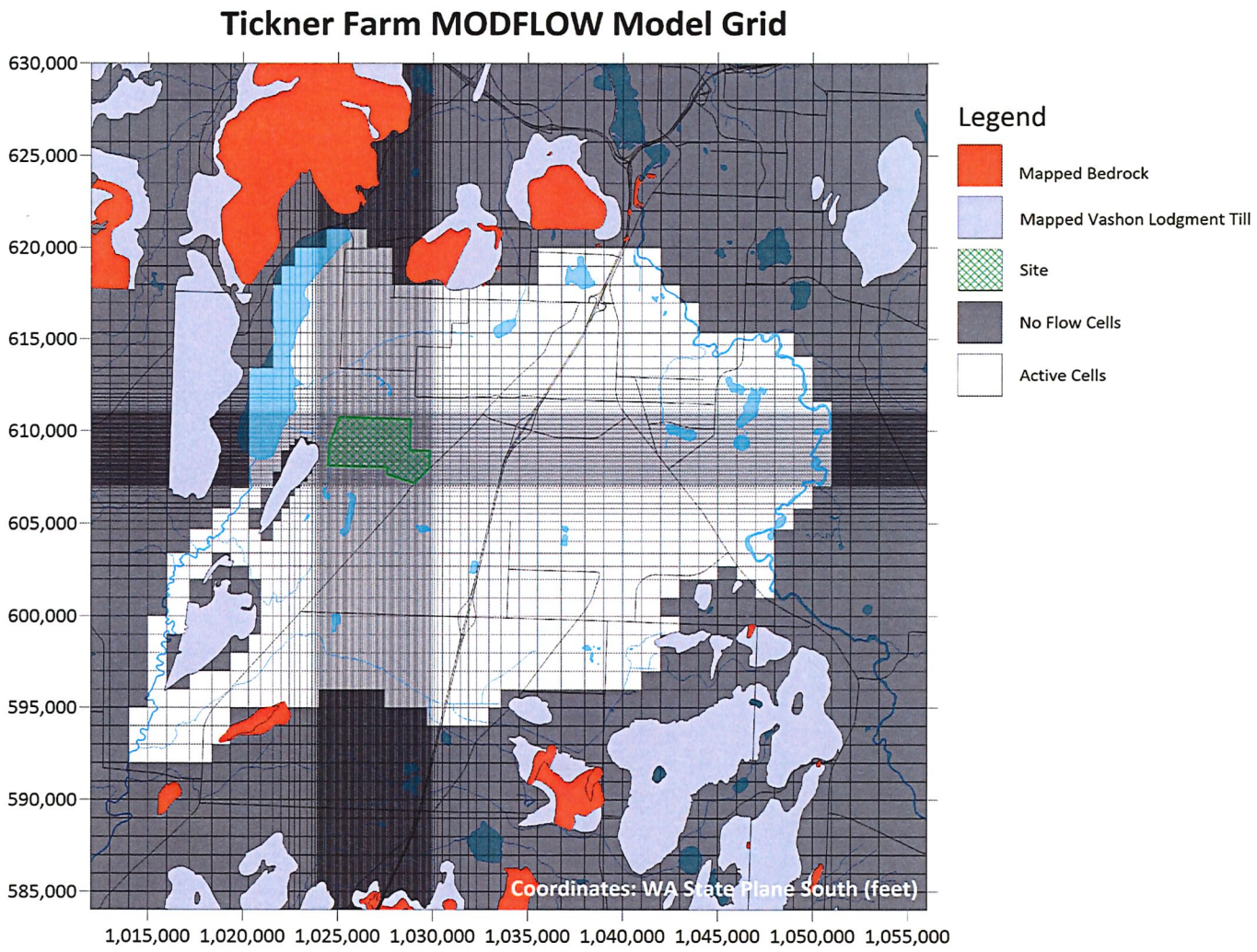

Tickner Farm MODFLOW Model Grid
630,000
625,000
620,000
615,000
610,000
605,000
600,000
595,000
590,000
585,000
1,015,000
1,020,000
1,025,000
1,030,000
1,035,000
1,040,000
1,045,000
1,050,000
1,055,000
Coordinates: WA State Plane South (feet)
Legend
Mapped Bedrock
Mapped Vashon Lodgment Till
Site
No Flow Cells
Active Cells

Figure C-02:

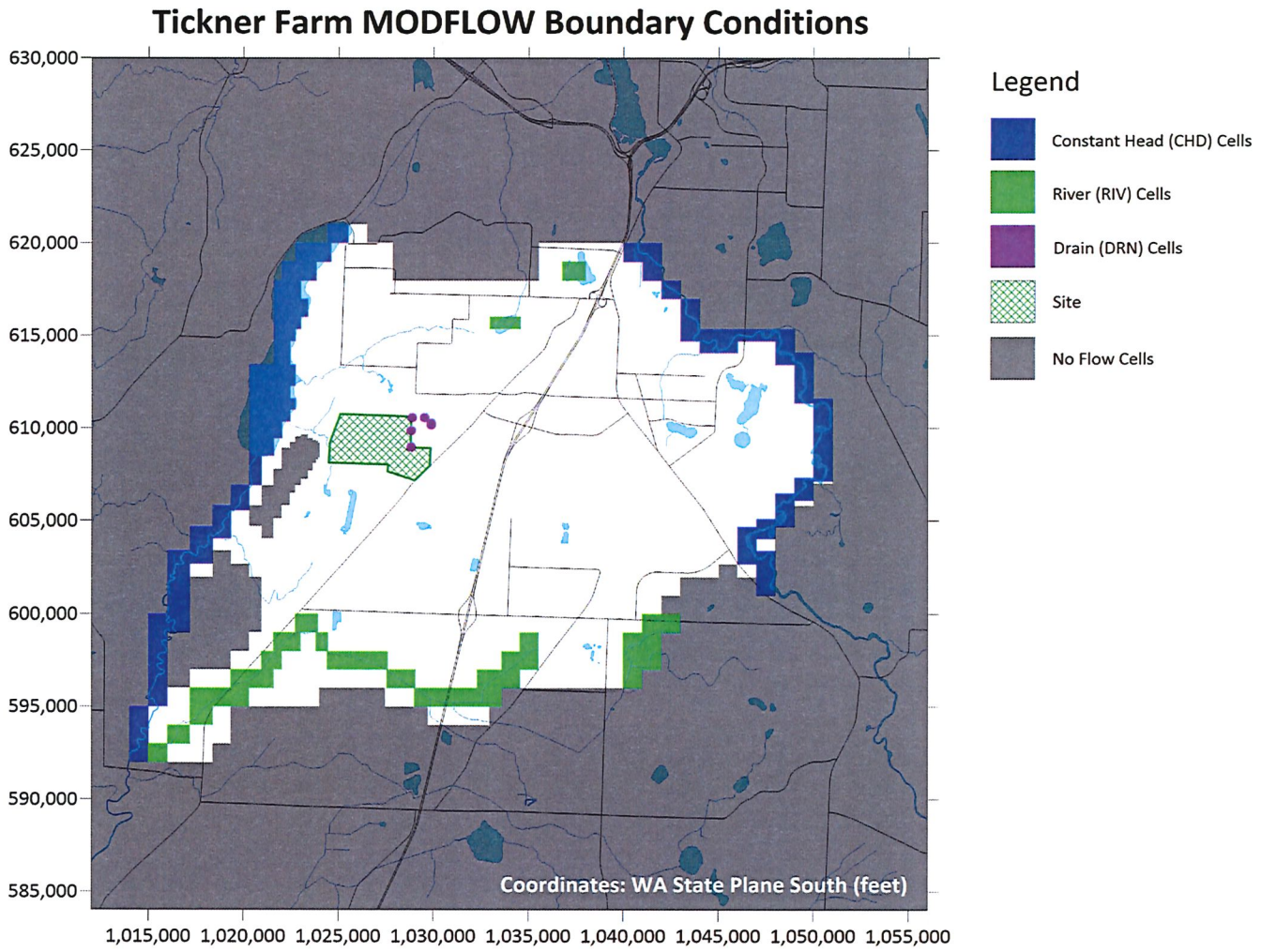

Tickner Farm MODFLOW Boundary Conditions
630,000
625,000
620,000
615,000
610,000
605,000
600,000
595,000
590,000
585,000
1,015,000
1,020,000
1,025,000
1,030,000
1,035,000
1,040,000
1,045,000
1,050,000
1,055,000
Coordinates: WA State Plane South (feet)
Legend
Constant Head (CHD) Cells
River (RIV) Cells
Drain (DRN) Cells
Site
No Flow Cells

Figure C-03:

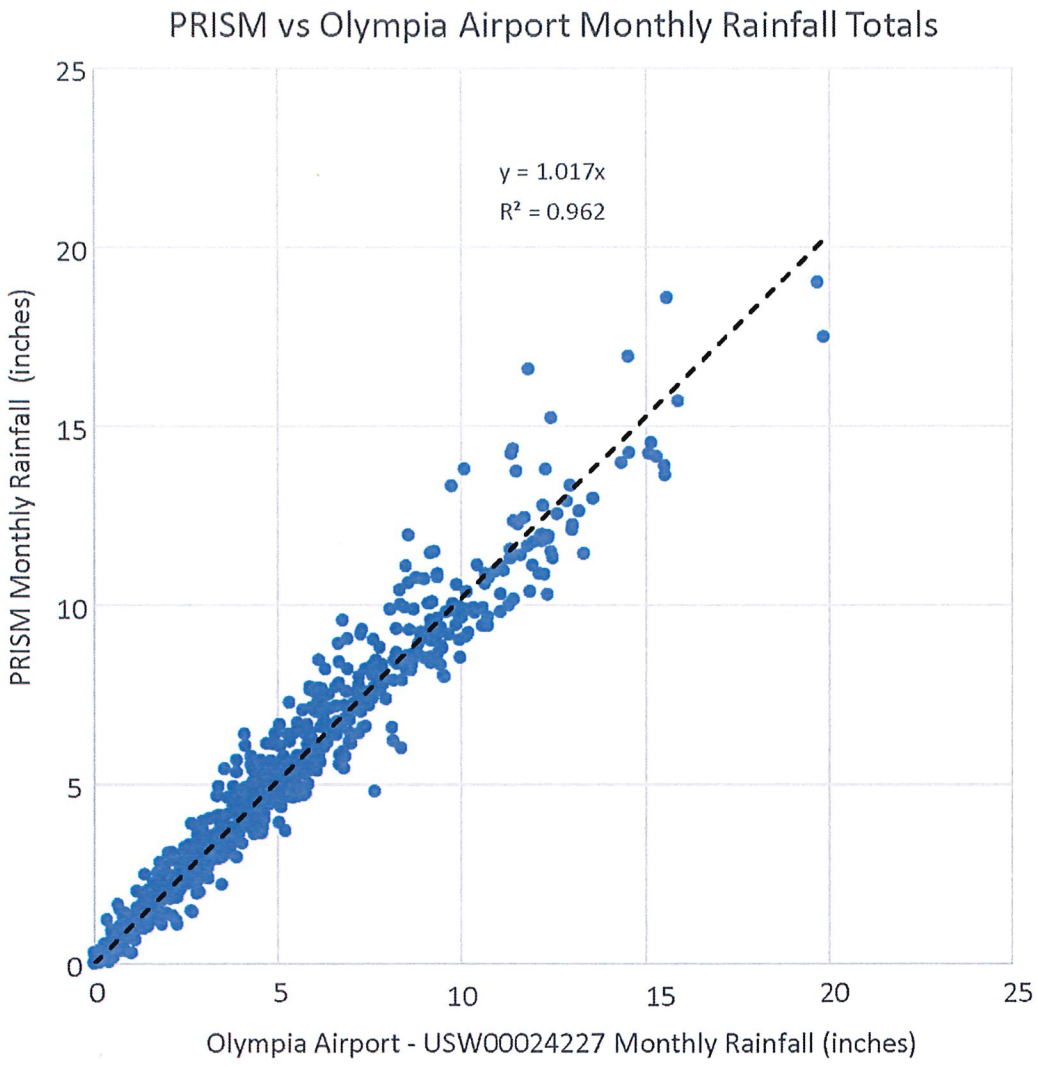

PRISM vs Olympia Airport Monthly Rainfall Totals
y = 1.017x
R² = 0.962
PRISM Monthly Rainfall (inches)
Olympia Airport - USW00024227 Monthly Rainfall (inches)
0
5
10
15
20
25

Figure C-04:

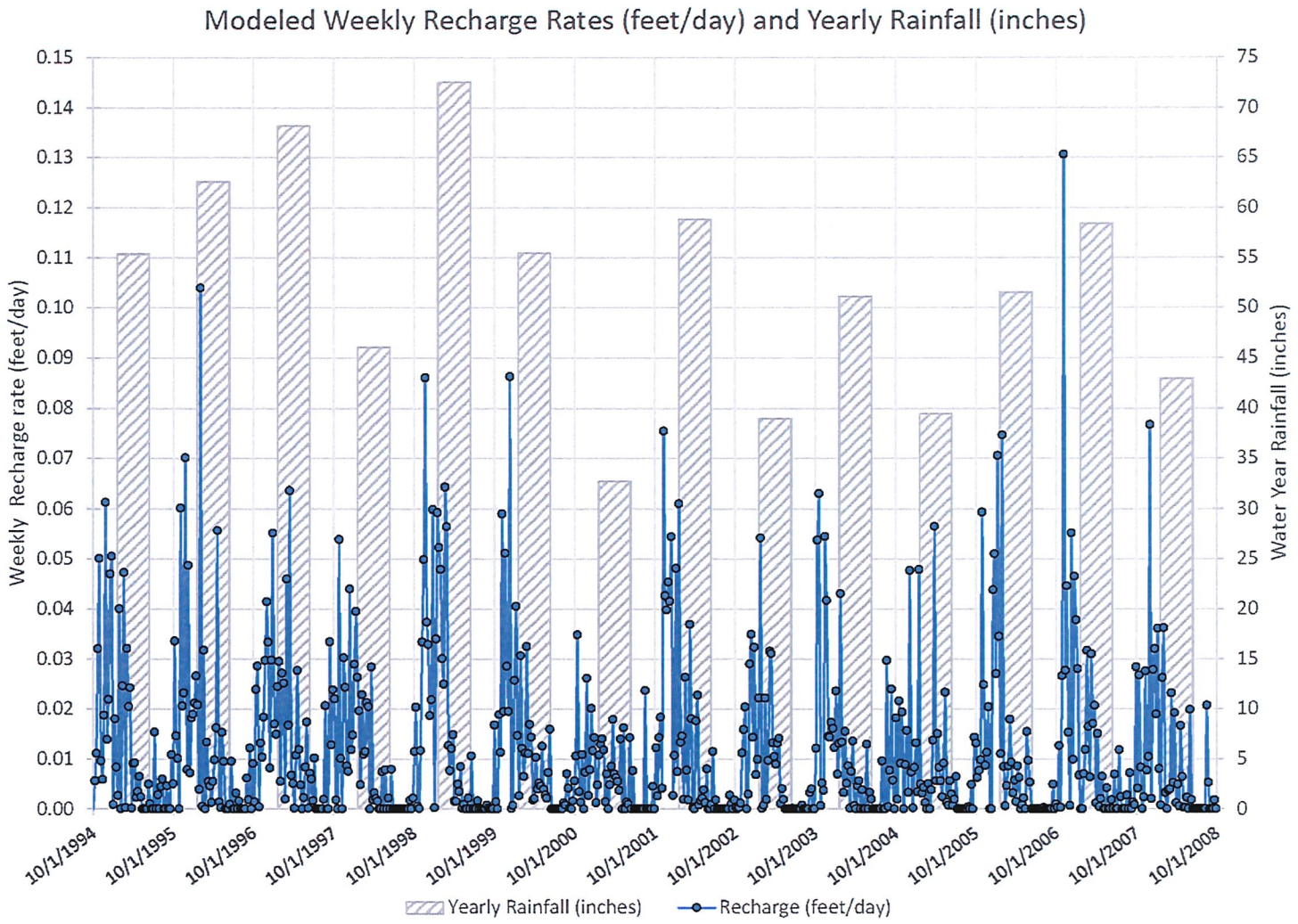

Modeled Weekly Recharge Rates (feet/day) and Yearly Rainfall (inches)
Weekly Recharge rate (feet/day)
Water Year Rainfall (inches)
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
10/1/1994
10/1/1995
10/1/1996
10/1/1997
10/1/1998
10/1/1999
10/1/2000
10/1/2001
10/1/2002
10/1/2003
10/1/2004
10/1/2005
10/1/2006
10/1/2007
10/1/2008
Yearly Rainfall (inches)
Recharge (feet/day)

Figure C-05:

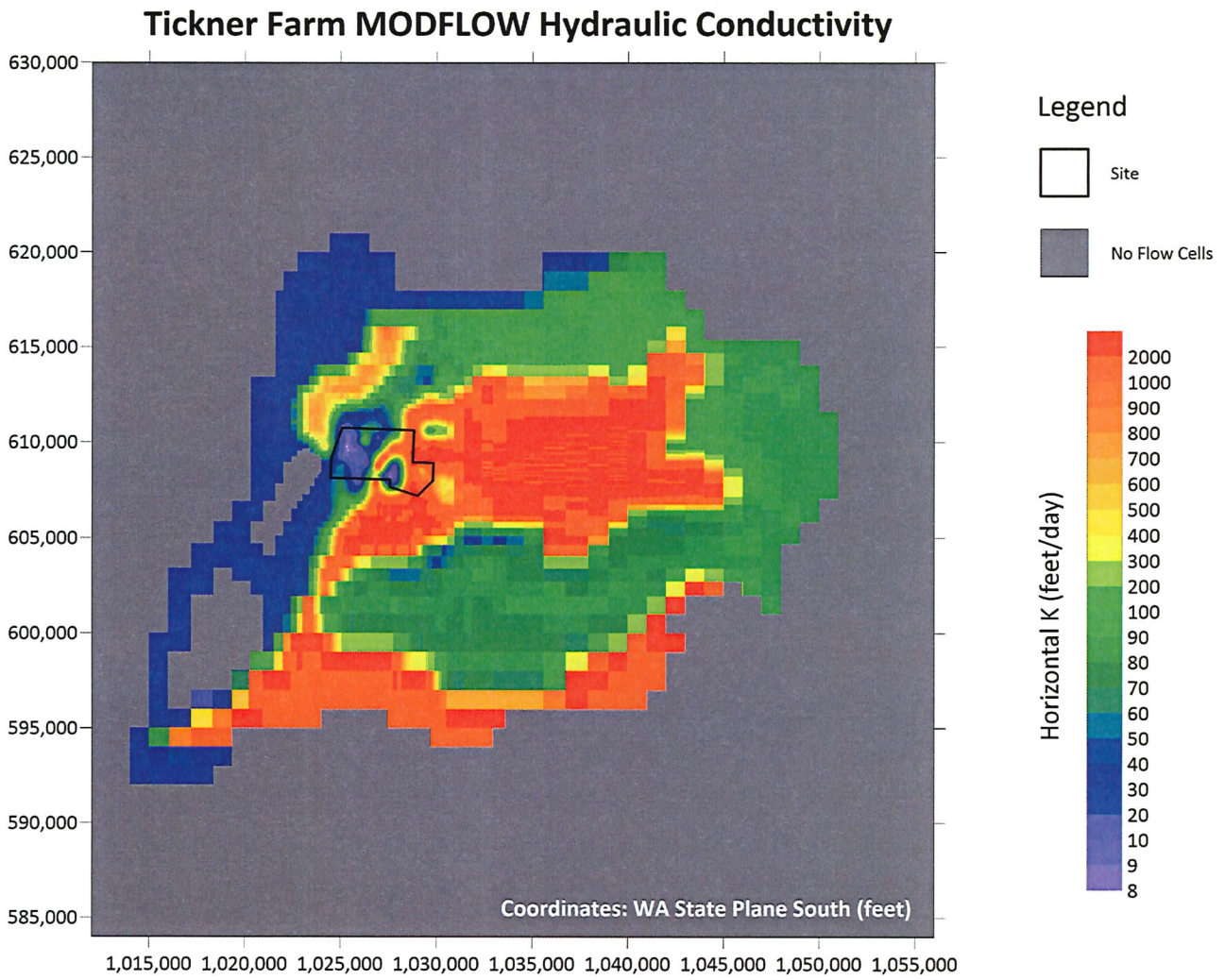

Tickner Farm MODFLOW Hydraulic Conductivity
630,000
625,000
620,000
615,000
610,000
605,000
600,000
595,000
590,000
585,000
1,015,000
1,020,000
1,025,000
1,030,000
1,035,000
1,040,000
1,045,000
1,050,000
1,055,000
Coordinates: WA State Plane South (feet)
Legend
Site
No Flow Cells
Horizontal K (feet/day)
2000
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8

Figure C-06:

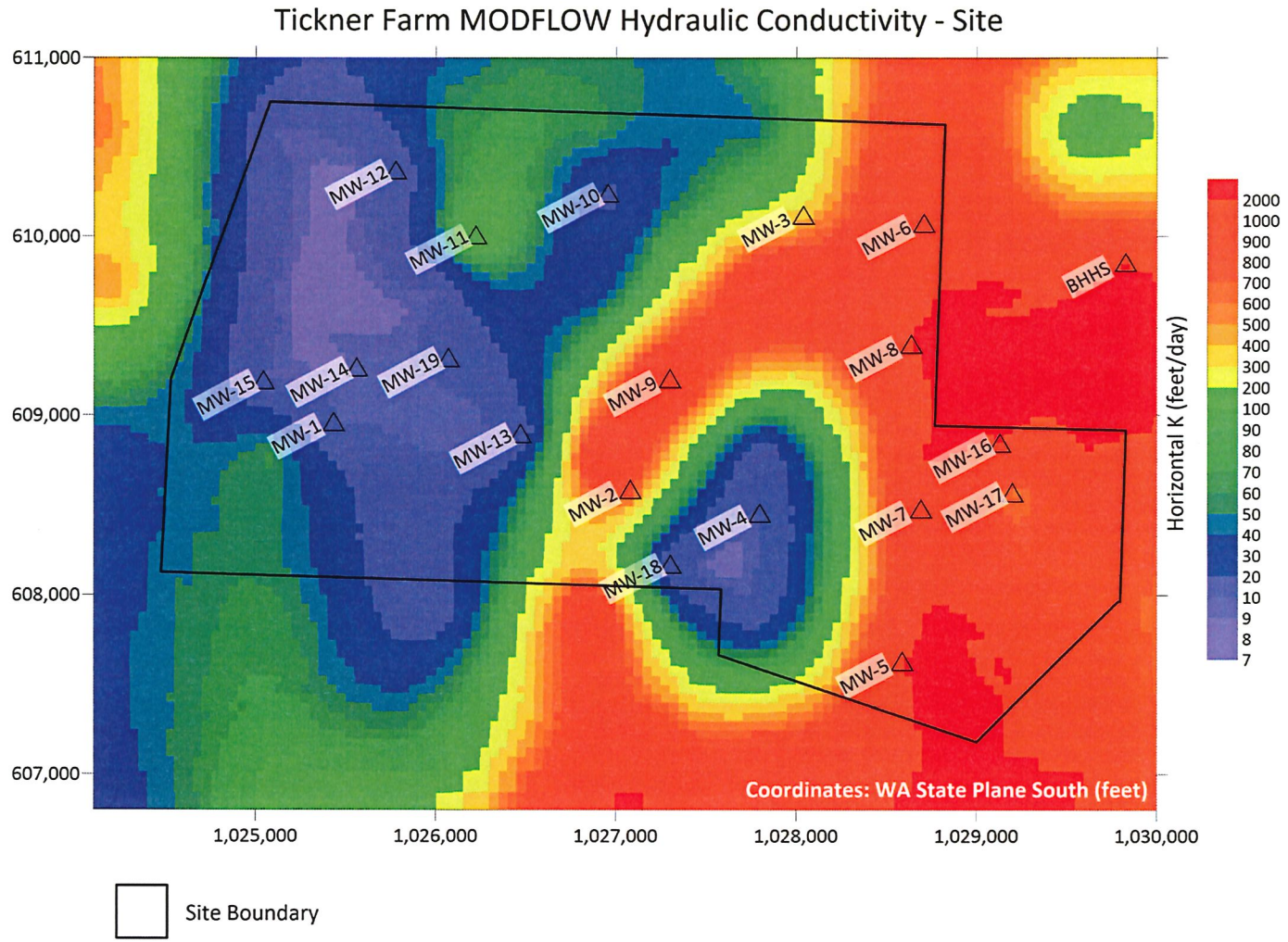

Tickner Farm MODFLOW Hydraulic Conductivity - Site
611,000
610,000
609,000
608,000
607,000
1,025,000
1,026,000
1,027,000
1,028,000
1,029,000
1,030,000
MW-12
MW-10
MW-11
MW-3
MW-6
BHHS
MW-15
MW-14
MW-19
MW-8
MW-9
MW-1
MW-13
MW-16
MW-2
MW-4
MW-7
MW-17
MW-18
MW-5
Coordinates: WA State Plane South (feet)
Horizontal K (feet/day)
2000
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
Site Boundary

Figure C-07:
Observed versus Simulated Water Levels. Plot shows all well data (AESI, BHHS, and LRS-01A)

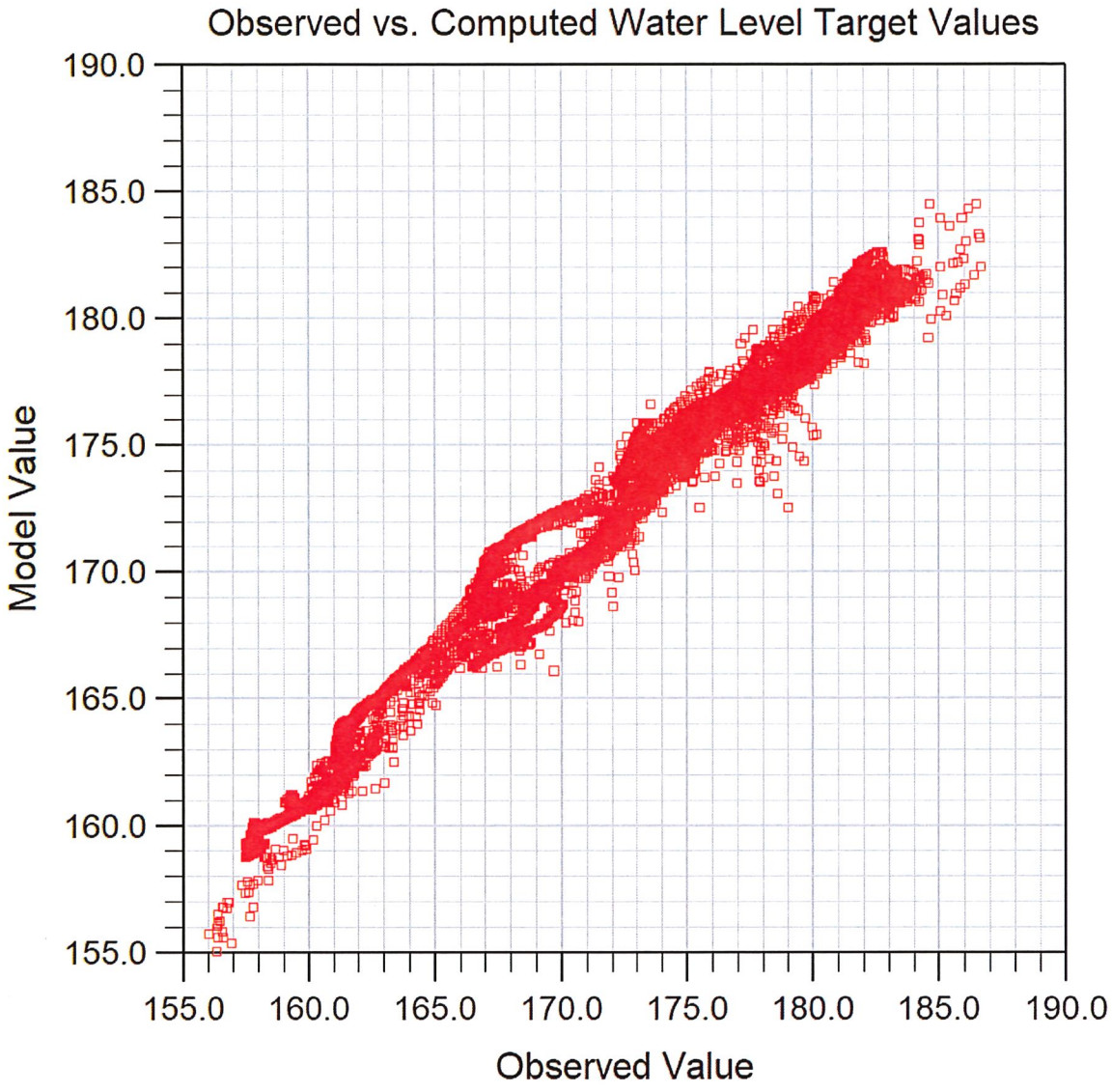


Figure C-08:

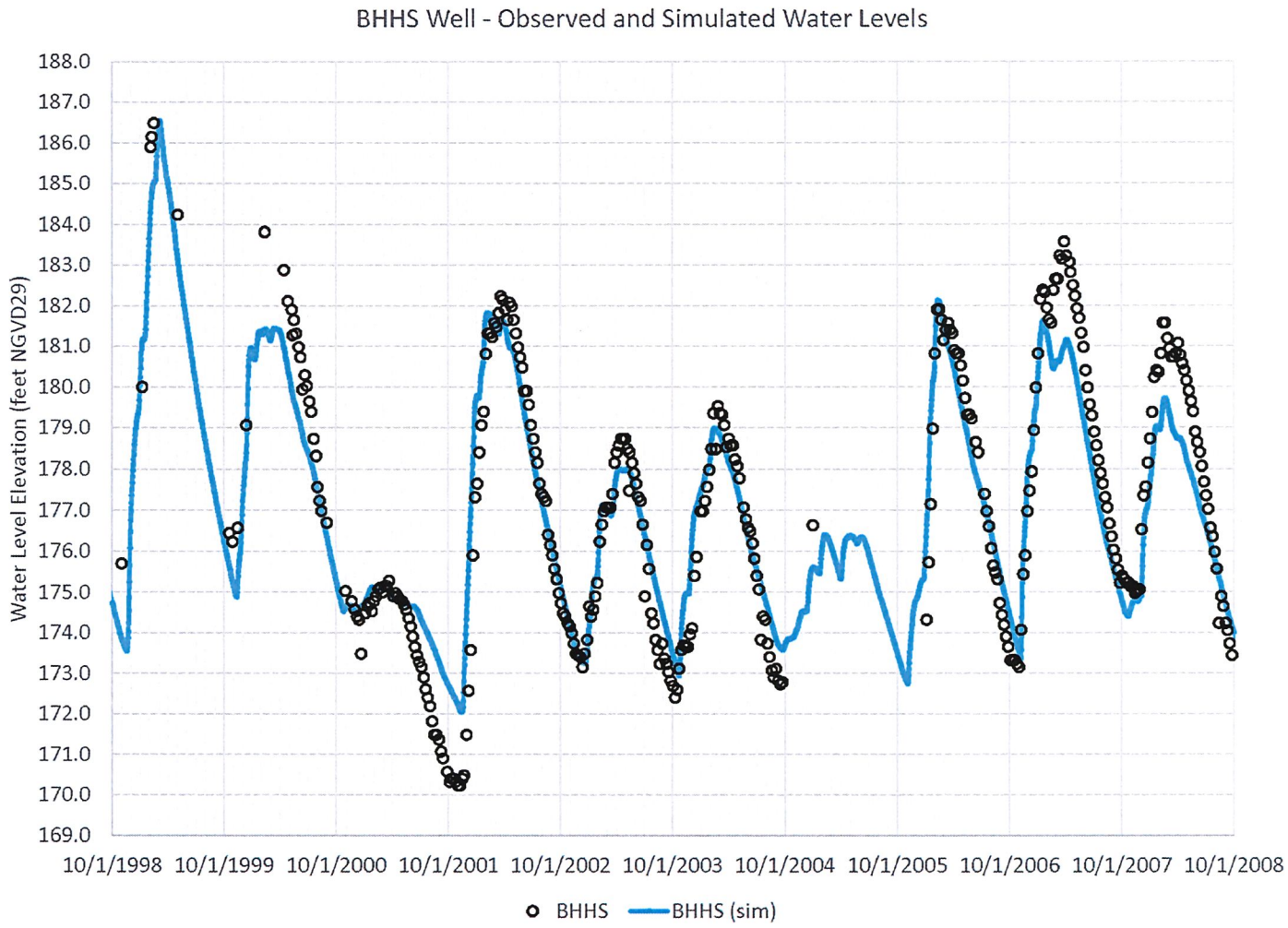

BHHS Well - Observed and Simulated Water Levels
Water Level Elevation (feet NGVD29)
188.0
187.0
186.0
185.0
184.0
183.0
182.0
181.0
180.0
179.0
178.0
177.0
176.0
175.0
174.0
173.0
172.0
171.0
170.0
169.0
10/1/1998
10/1/1999
10/1/2000
10/1/2001
10/1/2002
10/1/2003
10/1/2004
10/1/2005
10/1/2006
10/1/2007
10/1/2008
BHHS
BHHS (sim)

Figure C-09:

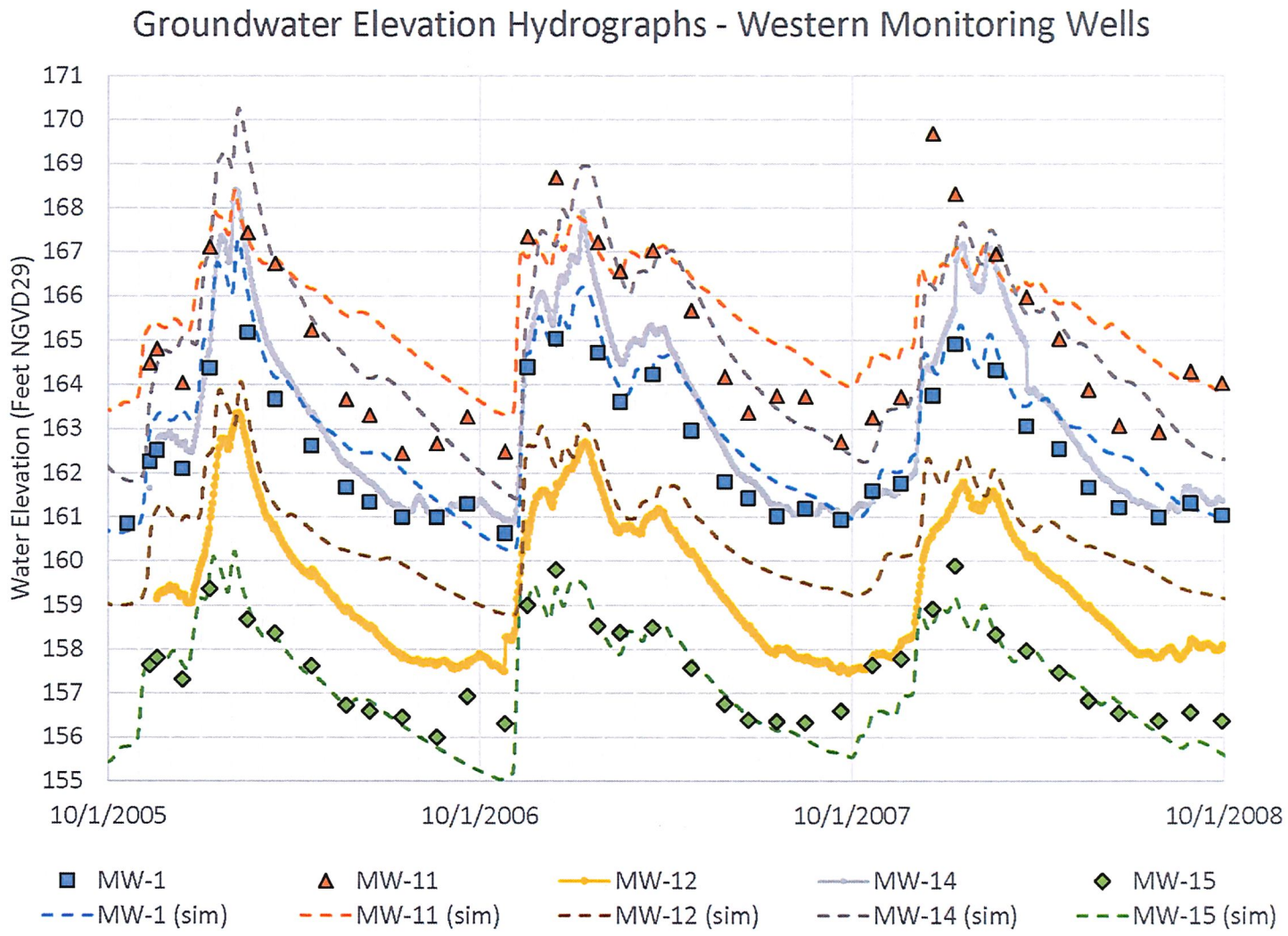

Groundwater Elevation Hydrographs - Western Monitoring Wells
Water Elevation (Feet NGVD29)
171
170
169
168
167
166
165
164
163
162
161
160
159
158
157
156
155
10/1/2005
10/1/2006
10/1/2007
10/1/2008
MW-1
MW-11
MW-12
MW-14
MW-15
MW-1 (sim)
MW-11 (sim)
MW-12 (sim)
MW-14 (sim)
MW-15 (sim)

Figure C-10:

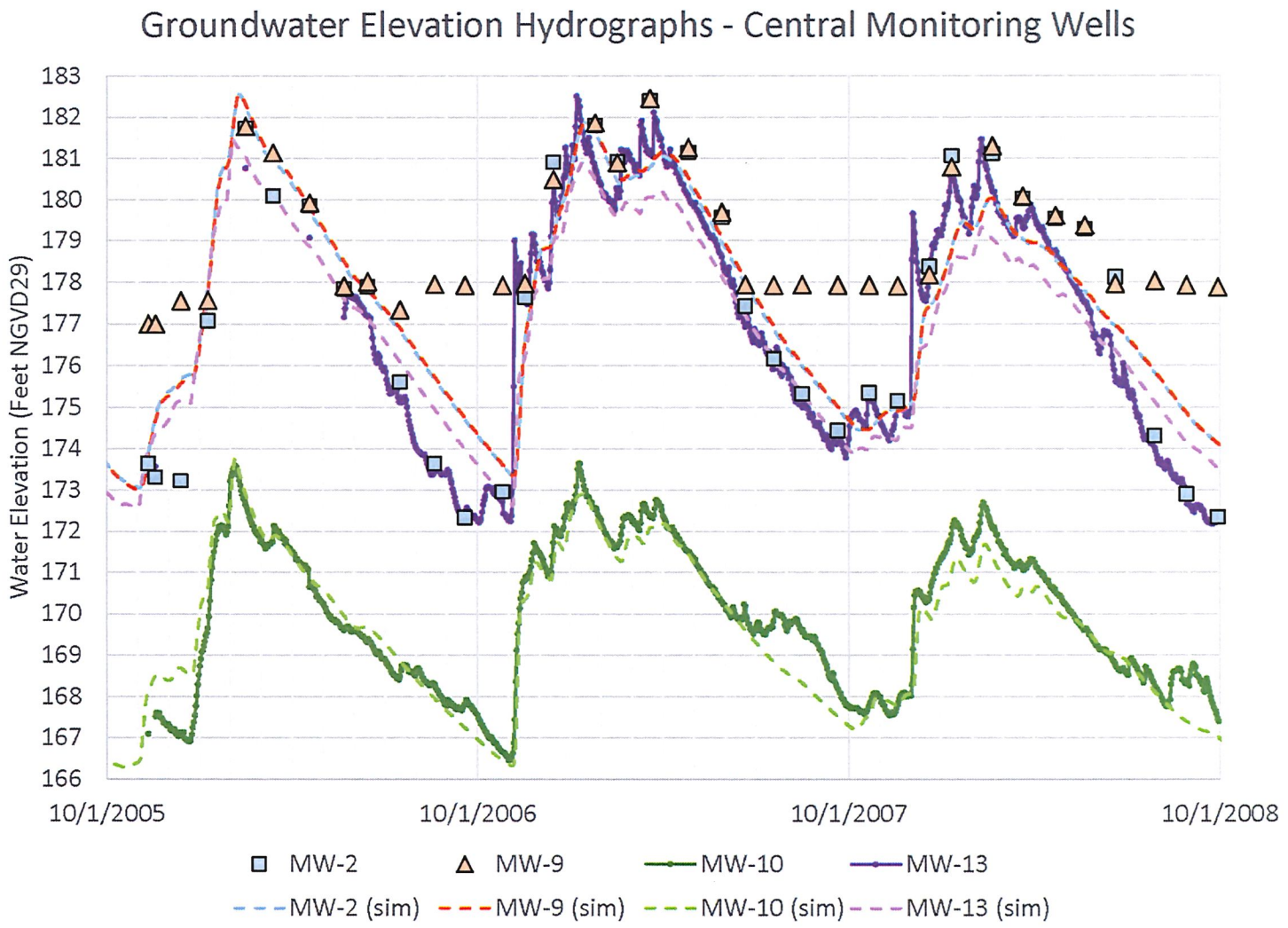

Groundwater Elevation Hydrographs - Central Monitoring Wells
Water Elevation (Feet NGVD29)
183
182
181
180
179
178
177
176
175
174
173
172
171
170
169
168
167
166
10/1/2005
10/1/2006
10/1/2007
10/1/2008
MW-2
MW-9
MW-10
MW-13
MW-2 (sim)
MW-9 (sim)
MW-10 (sim)
MW-13 (sim)

Figure C-11:

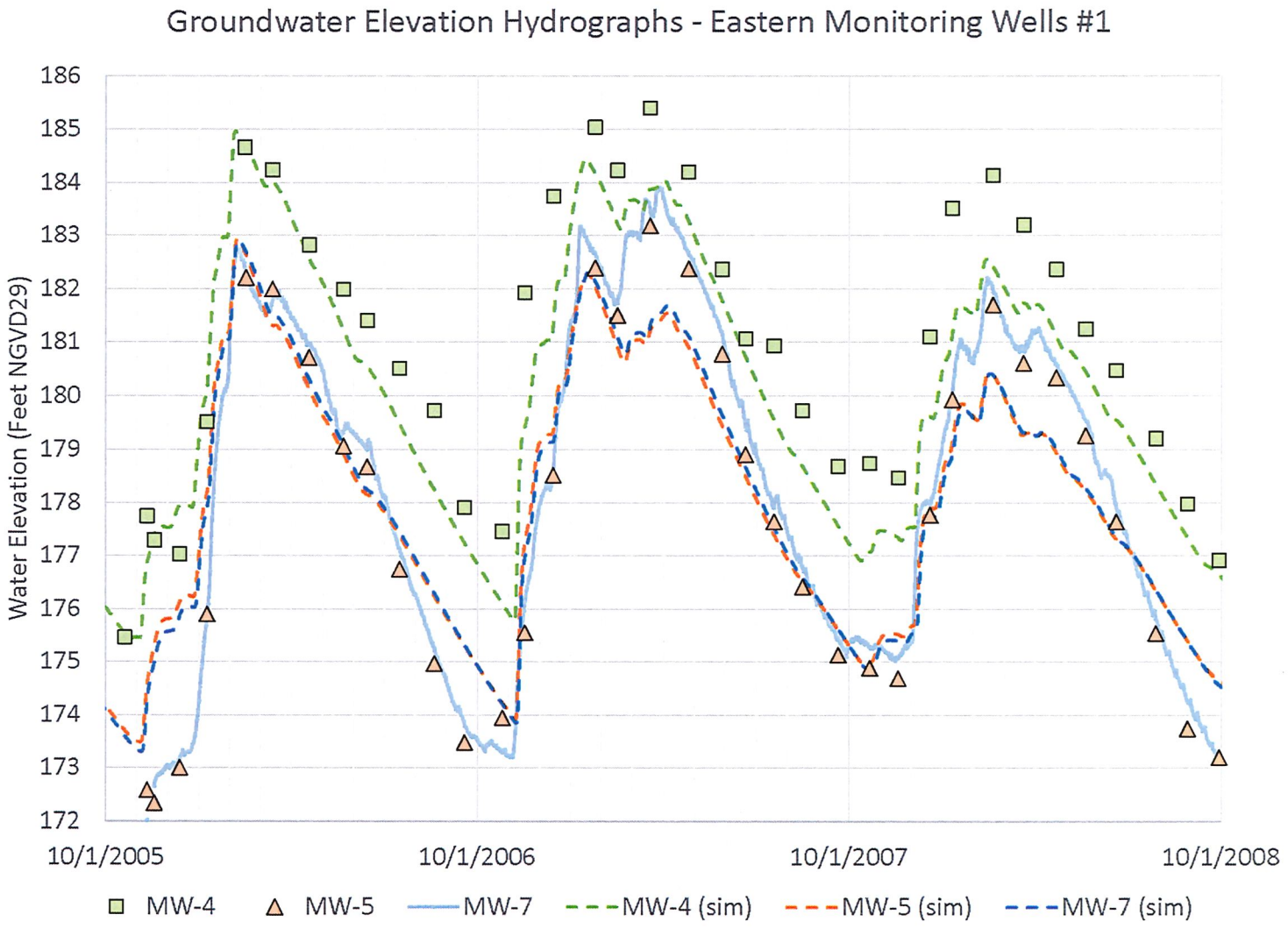
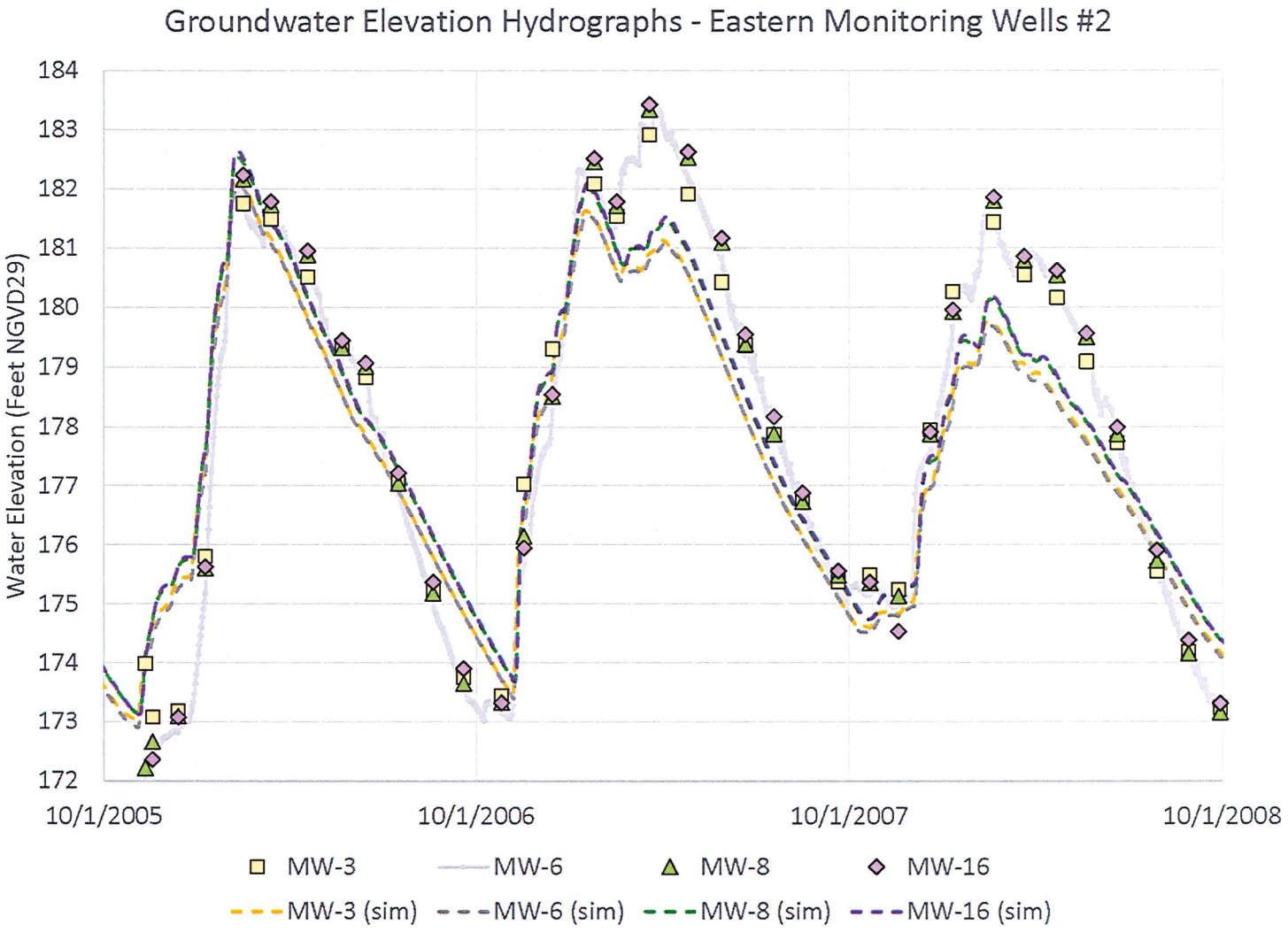

Groundwater Elevation Hydrographs - Eastern Monitoring Wells #1
Water Elevation (Feet NGVD29)
186
185
184
183
182
181
180
179
178
177
176
175
174
173
172
10/1/2005
10/1/2006
10/1/2007
10/1/2008
MW-4
MW-5
MW-7
MW-4 (sim)
MW-5 (sim)
MW-7 (sim)

Figure C-12:


Groundwater Elevation Hydrographs - Eastern Monitoring Wells #2
Water Elevation (Feet NGVD29)
184
183
182
181
180
179
178
177
176
175
174
173
172
10/1/2005
10/1/2006
10/1/2007
10/1/2008
MW-3
MW-6
MW-8
MW-16
MW-3 (sim)
MW-6 (sim)
MW-8 (sim)
MW-16 (sim)