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May 11, 2017

Mr. Allan Berry, PE
Mr. Derrick Yates
City of Fairview
1300 NE Village St.
Fairview, OR 97024

Re: Review and Comments for *Ethylene Dibromide in Groundwater – Occurrence, Hydrogeology and Possible Sources,* by EVREN Northwest

Gentlemen:

GSI Water Solutions, Inc. (GSI) reviewed the December 2, 2016 document: *Ethylene Dibromide in Groundwater – Occurrence, Hydrogeology and Possible Sources,* prepared by EVREN Northwest (ENW) for Townsend Farms. ENW prepared the subject report to document the results of its evaluation of potential occurrences and sources of Ethylene Dibromide (EDB) found in water supply wells owned and operated by Townsend Farms and the City of Fairview (City). The purpose of our review was to evaluate and inform the City about the potential implications of the analysis and conclusions of the report relative to the protection of the City's water supply wells. Our comments are intended to provide the City with information to support City engagement with the Oregon Department of Environmental Quality (ODEQ) cleanup staff and Oregon Health Authority Drinking Water Program (OHA DWP) about source water protection priorities for the City.

EDB, a halogenated compound used as a lead scavenging additive to leaded gas, and as a fumigant (until banned in 1984), has been detected in the City's water supply production wells 5 and 6, beginning in 2005. EDB also has been detected in wells owned by Townsend Farms at higher concentrations than those found in the City's wells. Townsend Farms is located roughly a quarter of a mile north to northeast of the City's supply wells 5 and 6. We understand that ENW prepared the subject report to attempt to clarify the nature and potential sources of the EDB detected in the City's and Townsend Farms' wells. ENW concluded that the EDB detected in the City's wells 5 and 6 and Townsend Farms' wells is from a source(s) potentially associated with past agricultural land practices in areas "upgradient," or south of the aforementioned wells.

We have focused our review on issues directly pertinent to understanding of potential contaminant threats to the City's water supply wells, specifically regarding ENW's interpretations of hydrogeologic conceptual model, well completions, and the capture zone analysis used in reaching its conclusions.

Hydrogeologic Conceptual Model

ENW developed a relatively detailed Hydrogeologic Conceptual Model (HCM) as a basis from which to draw its conclusions regarding potential sources of EDB in groundwater. Two particular aspects ENW's HCM merit comment and clarification: (1) the interpreted hydrostratigraphy in the City's wells; and (2) the interpreted groundwater gradient and flow direction. Comments on these key aspects of the HCM are summarized as follows:

Hydrostratigraphy

ENW interprets the City's wells 5, 6, 8 and 9 to be screened in the conglomerate unit of the Troutdale Sandstone Aquifer (TSA). However, each of these wells have been previously interpreted to be completed in the deeper Sand and Gravel Aquifer (SGA) unit by GSI, Oregon Water Resources Department (OWRD), and work by others in this portion of the Portland Basin. City wells 5 and 6 are completed in the upper section of the SGA, whereas wells 8 and 9 penetrate the full coarse-grained sequence of the SGA.

Completion of these wells in the SGA has been demonstrated on the basis of stratigraphic interpretation, aquifer testing, water quality and analysis of hydraulic responses in City wells to stresses imposed by major nearby pumping centers (e.g., City of Portland) and the Columbia River using information derived from numerous groundwater supply projects for various entities in the area over the past 20 years, including the cities of Portland, Fairview, Gresham and Troutdale, Rockwood Water People's Utility District (RWPUD) and Interlachen People's Utility District (IWPUD). GSI has synthesized information from these investigations with work completed by others (e.g., , Parametrix, 1992and Bet and Rosner, 1993) to develop a conceptual model of the hydrostratigraphy and groundwater flow conditions in the vicinity of the City, as well as to refine the Deep Aquifer Yield (DAY) numerical groundwater flow model used to delineate capture zones for wells owned by Portland, Fairview, Gresham and RWPUD.

City wells 5, 6 , 8 and 9 respond to each other and pumping of other wells documented to be completed in the SGA (e.g., RWPUD and City of Portland)

We have attached the following select references that document the basis for our interpretation:

- Cross sections prepared for the Fairview Well 8 siting evaluation (GSI, 2001)
- A technical memorandum prepared for OWRD in support of a time extension for groundwater permit G-7029, which is the water right associated with City Well 6 (GSI, 2015)
- A technical memorandum prepared for OWRD in support of an amendment for groundwater permit G-9808, which is a water right associated with City Well 5 (GSI, 2005)

Groundwater Flow

ENW states that regional groundwater flow (in the TSA) is in a northward direction, towards "groundwater discharge areas along the Columbia Slough and Fairview Lake" citing Morgan and McFarland (1996) and Rapid Soil Solutions ([RSS] 2016). ENW uses this assumption as part of its rationale for concluding that the source of EDB in the City's and Townsend Farms' wells is located south of the Townsend Farms property. We noted that RSS seems to conflate groundwater flow in the deep aquifers such as the SGA with that in the shallow-most aquifers by citing USGS Science

Investigations Report 2008-5059. The SGA and TSA are deep, confined aquifers that are generally hydraulically isolated from the water table modeled in the USGS report and therefore, the flow in the water table aquifer has no bearing on flow in these deeper aquifers.

Gradients in the SGA (and TSA) in the 1980s and early 1990s did indicate northerly flow directions in the vicinity of the City (Porcello and Leighton, 2001), towards the regional discharge point where these aquifers are connected to the Columbia River paleochannel, and ultimately the river itself (not Fairview Lake or the Columbia Slough, as stated in the ENW report). However, development and pumping of the SGA resulted in a regional decline in the piezometric surface of the SGA, ultimately stabilizing in the late 1990s at a level approximately coincident with the Columbia River early in the genesis of Portland's Columbia South Shore Well Field (CSSWF). As a result, the regional gradient between the deep aquifers (TSA and SGA) and Columbia River paleochannel deposits/river has shown seasonal reversals such that the river appears to recharge the deep aquifers on at least a seasonal basis.

Pumping centers in the basin create more localized cones of depression in the regional piezometric surface, further complicating flow patterns. The City relies entirely on its wells as its source of water supply; consequently, two or more of the City's wells are operated daily, which locally alters gradients and creates a persistent cone-of-depression around the wells. The combination of a lowered regional piezometric surface and localized pumping influences has reduced or eliminated the ambient natural gradients recorded in the 1980s.

Another hydrogeologic factor also influences groundwater flow under regional and local pumping stresses: the SGA is connected to the Blue Lake Aquifer (BLA) and Columbia River through an erosional window in Confining Unit 2 (CU2) that is coincident with the City of Portland's BLA production well PW-18. This connection heavily influences the capture zone of City Well 8, which is located near the erosional window in CU2.

Groundwater Capture Zones

The regionally lowered SGA piezometric surface, more wide-spread pumping centers in the SGA in Fairview, RWPUD, Gresham and Portland, as well as the connection between the deep aquifers and the Columbia River have greatly altered the regional flow field in the SGA and altered groundwater gradients. These effects are illustrated in capture zones for the City's production wells delineated using the DAY Model. The DAY Model is a 3-dimensional, numerical groundwater flow model developed originally by the City of Portland for wellhead protection and groundwater supply management purposes, and is the accepted tool for capture zone delineations by entities who participate in the administration of the CSSWF wellhead protection plan. Accordingly, the DAY Model was used to delineate capture zones for the CSSWF by the City of Portland, and then subsequently by RWPUD, Gresham and the City as new wells have been drilled by each entity.

Attached are figures showing the capture zones delineated for the City's wells using the DAY Model. These delineations incorporate the effect of pumping of all other major SGA, TSA and BLA production wells, based on typical operational practices and production records obtained from each municipal entity. The capture zones delineated for the City's wells using the DAY Model show that the City's wells draw water from the north and northeast. Capture by City Well 8 is heavily influenced by the SGA connection with the BLA and Columbia River through the erosional window in

CU2. Capture by City wells 5, 6 and 9 is heavily influenced by the RWPUD/Gresham pumping center, located in the vicinity of NE 192nd and Halsey Street. Attached is a report (GSI, 2011) that summarizes the process and assumptions utilized in developing the capture zones delineated for the City's wells.

The capture zones utilized by ENW in its report were obtained from the DEQ Profiler site. These capture zones were delineated by the OHA DWP, likely utilizing an analytical model and imposed ambient south-to-north gradient; we surmise the gradient was assumed based on an earlier study, such USGS Water Supply Paper 2470-A (1996). The model used by OHA DWP does not appear to incorporate major boundary conditions (e.g., the connection with the river), the influence of other pumping centers, nor the changes in the regional flow field over the past several decades. The resulting modeled capture zones are thus determined by the assumed regional ambient gradient imposed in the model and do not reflect the actual gradients present in the area since the late 1990s. The resulting capture zones suggest that all City wells primarily capture water from a southerly direction, which is highly unlikely. The City is in the process of providing the OHA DWP with the capture zones delineated with the DAY Model and supporting documentation, and will be requesting that these capture zones delineated by the OHA DWP be replaced by those delineated using the DAY Model.

Summary

GSI's review of the ENW report on the nature and potential sources of EDB detected in Townsend Farms and City water supply wells identified several mistaken assumptions and interpretations that have a bearing on how the City should focus its source water protection and supply planning efforts. The primary corrections to misinterpretations in the ENW report of interest to the City include:

- The City's wells 5, 6, 8 and 9 are completed in the SGA and not, as interpreted by ENW, the TSA.
- The earlier documented regional flow direction in the SGA (and TSA) relied on by ENW in developing their conclusions has been heavily altered over the past several decades by the long-term effects of regional pumping and more transient and localized influences of pumping centers in the area. A strong ambient south-to-north gradient is no longer present in the vicinity of the City.
- Modeling of capture zones for the City's wells using the best available and most accepted tool (DAY Model) show capture in a northerly and northeasterly direction from the wells, rather than a southerly direction.

In summary, ENW has misinterpreted the hydrostratigraphy in this area of the Portland Basin and relies on outdated information about groundwater flow and capture by the City's wells in claiming that the source of EDB is located south of Townsend Farms' and the City's wells. In our opinion, EDB detected in the City's wells is not likely to be associated with land practices located south of the City's wells, as indicated in the ENW report because (1) it is unlikely that surface application of EDB would penetrate through the thick sequence of aquifers and confining units that separate the deep

supply aquifers from surface activities, and (2) capture zone analysis indicates that the City's wells capture their water from areas located north and northeast.

The source and distribution of EDB contamination in the upper SGA are not understood; however, capture zone analysis and the timing of the EDB detections in the City's wells suggest the presence of a source located in a northeasterly direction from the City's wells 5 and 6. These unknowns affect the ability of the City to utilize existing wells and infrastructure, and also greatly affect how and where the City can site a new groundwater source. We recommend that the City request that the DEQ cleanup program continue its efforts to delineate the extent and distribution of contamination in the upper SGA, and focus its efforts on identifying potential sources and characterizing the distribution of EDB contamination north and east of City wells 5 and 6.

We greatly appreciate the opportunity to provide the City with our input on this matter. Please give us a call if you have any questions.

Sincerely,

Groundwater Solutions, Inc. dba
GSI Water Solutions, Inc.

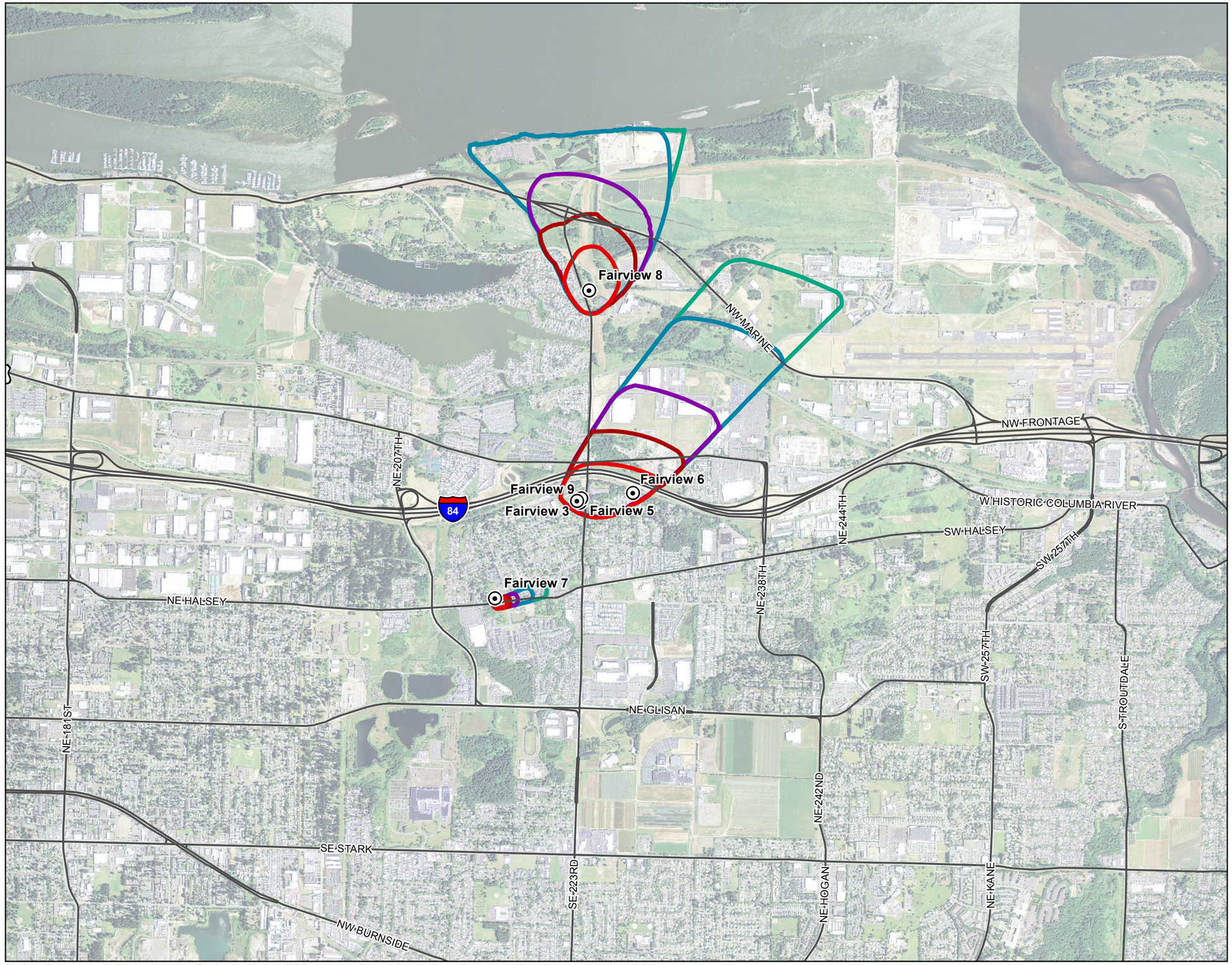
Walter Burt, RG
Principal Hydrogeologist

Attachments

FIGURE 1

Groundwater Capture Zones for City of Fairview Production Wells

City of Fairview, Oregon



LEGEND

- City of Fairview Production Wells
- Highways and Major Roads

Groundwater Capture Zones

- 2 Year
- 5 Year
- 10 Year
- 20 Year
- 30 Year

N

0 1200 2400 3600

Feet

GSI Water Solutions, Inc.

MAP NOTES:

Projection: Oregon State Plane North
Datum: North American Datum of 1983
Date: August 11, 2011

File Path: P:\Portland\117 - Fairview\014 - 2011 GW Services\Project_GIS\Project_mxds\Figure1_Capture_Zones_Revised.mxd, Date: August 11, 2011 3:54:12 PM

FIGURE 2

Groundwater Capture Zones for City of Fairview Production Wells

City of Fairview, Oregon

LEGEND

Groundwater Capture Zones

- 2 Year
- 5 Year
- 10 Year
- 20 Year
- 30 Year

Production Wells

- City of Fairview
- Rockwood Water PUD
- Portland Water Bureau
- City of Troutdale
- Wood Village
- Highways and Major Roads

N

0 2000 4000 6000

Feet

GSI Water Solutions, Inc.

MAP NOTES:

Projection: Oregon State Plane North
Datum: North American Datum of 1983
Date: August 11, 2011

File Path: P:\Portland\117 - Fairview\014 - 2011 GW Services\Project_GIS\Project_mxds\Figure2_Nearby_Wells_Revised.mxd, Date: August 11, 2011 3:55:23 PM

Attachment A
Technical Memorandum
Delineation of Capture Zones Contributing Groundwater to Production Wells,
City of Fairview Wellhead Protection Program

Water Solutions, Inc.

Technical Memorandum

To: Linda Hulme – City of Fairview

From: John Porcello, RG – GSI Water Solutions, Inc.
Walter Burt, RG - GSI Water Solutions, Inc.

Date: August 8, 2011

Re: Delineation of Capture Zones Contributing Groundwater to Production Wells:
City of Fairview Wellhead Protection Program

This technical memorandum presents delineations of the areas contributing groundwater to five municipal water supply wells owned by the City of Fairview (City), Oregon. Figures 1 and 2 show the locations of the City's five production wells and the combined areas contributing groundwater to these wells over time periods of 2, 5, 10, 20, and 30 years. These areas are herein referred to as time-dependent groundwater capture zones and, together with consideration of the City's jurisdictional limits, will form the basis for the City to establish wellhead protection areas for use in its development of a wellhead protection program.

The remainder of this memorandum presents the following information:

- The general methodology that was used to develop the time-dependent groundwater capture zones;
- The pumping scenarios that were simulated for the City's production wells and for production wells owned by other public water providers in the region;
- A summary description of the numerical model of the local groundwater aquifers;
- Information on how the numerical model was used to develop the City's time-dependent groundwater capture zones;
- A brief discussion of the delineation results
- A list of references cited in this technical memorandum

General Methodology

The delineation work was conducted as follows:

1. A typical operational scenario for each City production well and for the production wells owned by other public water providers in the region was developed based on recent and planned use of the wells. This step identified the future anticipated timing, duration, and rate of pumping from each well.

2. The production schedule for each well was entered into the Deep Aquifer Yield (DAY) model, which is a detailed three-dimensional numerical groundwater flow model of the local and regional groundwater systems.

3. The DAY model was then run to calculate time-varying groundwater elevations, groundwater flow directions, and groundwater velocities on a monthly or more frequent basis, and for time periods lasting 2, 5, 10, 20, and 30 years.

4. Using the model results, imaginary particles were then placed near the City's production wells in the model and traced forward and backwards in time to identify their three-dimensional movement.

5. The particle traces calculated by the model were then examined to determine the capture zone area contributing groundwater to each well during each of the five model simulation time periods of interest (2, 5, 10, 20, and 30 years).

6. Using a geographic information system (GIS), the capture zones for each well were then overlain and re-drawn to create the final capture zones that will be adapted by the City to serve as the basis for their wellhead protection management area.

Details are presented below regarding (1) the derivation of the pumping scenarios to model (for the City, the Portland Water Bureau, and other public water providers) and (2) the design and execution of the model simulations.

City of Fairview Wellfield Operations

The City's wellfield is currently comprised of five wells (wells 5, 6, 7, 8, and 9). Well 7 is completed in the Troutdale Sandstone Aquifer (TSA), while the other four wells are each completed in the underlying Sand and Gravel Aquifer (SGA), which is the deepest aquifer in the region. Figure 2 shows the locations of these wells and the locations of other public water supply wells in the general vicinity. A sixth production well, Well 3 was decommissioned in 2011 after Well 9 was installed as a replacement source.

The well field is the primary water supply source for the City, although the City maintains interties with other water providers. Rockwood Water People's Utility District (RWPUD) serves a small portion of the City, providing a combination of Bull Run surface water and groundwater source water to these customers not served directly by the City's water utility.

The City operates its wells to meet a seasonal demand profile, and cycles each primary supply well daily. Each well is pumped typically pumped for 3 to 10 hours per day, depending on the capacity of the well and demand at the time. City maintains detailed records of system demands and pumping by individual wells, including volumes and rates on a daily and monthly basis. The capacities of the City's wells and authorized rates under the current water rights are shown in Table 1. Table 2 summarizes the seasonal demands and average daily production volumes by the City's wells for each month of 2008, 2009 and 2010. For delineation modeling purposes, an average pumping rate was derived for each well assuming continuous pumping each month, rather than incorporating time steps to account for each daily pumping cycle for each well. The average rate is the rate required to pump the portion of the monthly demand produced by each well, assuming that the well is operated continuously each day throughout the month. The average pumping rate was multiplied by a factor of 1.25 to account for uncertainty and potential future growth in demand. Table 2 summarizes the average pumping rates for the City's wells for each month and the delineation rates that incorporate the 1.25 multiplier factor. We assumed for the delineation of Well 7 capture zones that the well will only be used on an emergency basis, and simulated an emergency event with a duration of three weeks in August once every five years.

Portland Wellfield Operations

The Columbia South Shore Wellfield (CSS Wellfield, also called the CSSW), is an approximately 100-MGD municipal wellfield that serves as the emergency backup and supplemental water supply for the Portland Bull Run system. The CSS Wellfield is owned by the City of Portland and operated by the PWB, and is used as a seasonal supplemental water source during the summer and early fall. The CSS Wellfield also serves as an emergency backup water source that can be used, if needed, in the event of excessive turbidity or a catastrophic event in the Bull Run watershed, which is the Bureau's primary source of drinking water. Emergency use occurs infrequently, whereas the well field is used for seasonal supplemental use nearly every year. The CSS Wellfield contains 27 production wells, which are each completed in one of three different aquifers. Fifteen wells are completed in the SGA north of NE Sandy Boulevard; three of these wells lie between Blue Lake and NE 181st Avenue, and the other 12 SGA wells are situated from NE 162nd Avenue to just west of Interstate 205. The remaining wells are completed in shallower aquifers in the CSS Wellfield area, including the Troutdale Sandstone Aquifer (TSA) and the Blue Lake Aquifer (BLA).

Table 3 summarizes the CSS Wellfield operations that were simulated in the groundwater model during delineation of time-dependent groundwater capture zones for the City of Fairview. The simulated operational scenario for the CSS Wellfield consists of 45 consecutive days of simultaneous pumping from all 27 CSS Wellfield production wells during the late summer and early fall, at average daily production rates equal to 90 percent of the total capacity of each well. As shown in Table 3, this results in 101.5 million gallons per day (MGD) of pumping during CSS Wellfield operations, which is similar to the 96 MGD production rate that occurred during recent CSS Wellfield operations in the late summer of 2006. Table 3 also shows that the simulated pumping rates for this seasonal operating scenario result in a pumping rate from the SGA of approximately 51 MGD, which is 50 percent of the CSS Wellfield's total pumping capacity.

The simulated pumping schedule for the CSS Wellfield is the same schedule that was used to delineate 2-year capture zones for the CSS Wellfield, as described by GSI (2007). While this pumping schedule for the CSS Wellfield has been simulated for all five time periods in the City of Fairview capture zone analysis (2, 5, 10, 20, and 30 years), it was used by PWB to delineate only one of the capture zones for the CSS Wellfield (the 2-year capture zone). During a planning process to strengthen and upgrade its Groundwater Protection Program, Bureau personnel (as documented by Leighton, 2002) also delineated 10-year and 30-year capture zones using different CSS Wellfield pumping scenarios that involved seasonal supplemental water use, short-term emergency pumping during Bull Run turbidity events, and a three-year continuous pumping scenario (in the event of a future catastrophic loss of water supply from PWB's primary Bull Run water source). Consequently, the representation of CSS Wellfield pumping that was used to delineate time-related groundwater capture zones for the City of Fairview is different than was used by PWB to delineate 10-year and 30-year capture zones for the CSS Wellfield. However, this difference is considered to be of minor importance in the effort by the City of Fairview to establish a wellhead protection program because (1) only a portion of the City of Fairview's capture zones extend as far north as the CSS Wellfield, and (2) those areas fall within the PWB wellhead protection management area (where PWB, rather than the City of Fairview, has jurisdiction for land use and groundwater protection activities).

Wellfield Operations of Other Groundwater Users

Pumping operations were also simulated for the following five groundwater users who own and operate wells in the vicinity of the City's production wells and the CSS Wellfield:

- Rockwood Water People's Utility District (RWPUD): Three wells completed in the SGA
- City of Troutdale: Six wells (one in the TSA, five in the SGA)
- City of Wood Village: One well completed in the SGA
- City of Vancouver: Two wells completed in the SGA near I-205, between about ½ and 2 miles north of the Columbia River
- SEH America: One well completed in the SGA near I-205, about 3 ½ miles north of the Columbia River

Long-term average pumping rates for these wells were obtained from water use records and operational plans. For RWPUD, pumping was simulated on a two-year cycle that assumes an alternating annual production volume every other year because of curtailed PWB water deliveries, as based on RWPUD's past experience (GSI, 2010). Table 4 summarizes the RWPUD pumping that was simulated during the capture zone delineation efforts for both RWPUD (GSI, 2010) and the City of Fairview.

Simulated Pumping Schedule from the SGA

The SGA is the primary aquifer targeted by the City and other neighboring public water providers. Table 5 shows the simulated pumping schedule from the SGA for each major well

owner that has some or all of its wells completed in that aquifer. Key notes about the information contained in Table 5 are as follows:

- The time variation in the distribution of pumping stresses from the SGA was controlled by the timing of RWPUD pumping and PWB pumping. Because of the PWB pumping schedule, the model's simulation of SGA pumping is far greater from September 1 through October 15 than during the rest of a given calendar year. Daily groundwater production volumes from the RWPUD wellfield range from 0.11 MGD to 6.14 MGD (see Table 4), while daily production from PWB's CSS Wellfield during the 45 days each year that it occurs is much higher (51.1 MGD from the SGA alone, plus 50.4 MGD from other aquifers, as shown in Table 3 and as discussed by GSI, 2007).

- In Oregon, the combined pumping from the other SGA municipal users (Troutdale and Wood Village) is simulated as 1.65 MGD (for Troutdale) and 0.58 MGD (for Wood Village), for a combined 2.23 MGD. This production rate is simulated as occurring on a continuing basis; although some seasonality in production likely occurs for these wells, this was deemed to be a minor consideration for the purpose of delineating capture zones for the City of Fairview.

- The combined pumping from the three SGA wells in southeastern metropolitan Vancouver is simulated as 9.29 MGD each day on a continuous basis. Seasonally variable pumping was not simulated given the significant distances of these wells from the City of Fairview.

DAY Model Description

The DAY model was developed in 2001 by PWB to simulate groundwater movement in and near the CSS Wellfield (Leighton and Porcello, 2001). This model is the main computer tool used by PWB to understand a variety of groundwater flow issues related to the CSS Wellfield. The model's construction and calibration are documented in a report by Leighton and Porcello (2001). The model was developed from a regional model of the Portland geologic basin that was constructed by the U.S. Geological Survey (Morgan and McFarland, 1996).

The DAY model simulates horizontal and vertical groundwater movement in 9 model layers, including interaction with nearby surface water bodies (particularly the Columbia River). The model uses the U.S. Geological Survey's MODFLOW finite-difference modeling software (Harbaugh and McDonald, 1996a and 1996b) to calculate groundwater elevations, flow directions, flow velocities, and volumetric flow throughout the model domain. The model also uses the U.S. Geological Survey's MODPATH software (Pollock, 1994) to delineate groundwater capture zones, using the output from the MODFLOW model. Both software packages are operated using the Groundwater Vistas® groundwater modeling platform (Environmental Simulations, Inc. [ESI], Version 5, 2007), which is a visually-based tool for managing the development and application of numerical groundwater flow models.

Two notable revisions were made to the model after completion of the original model development effort in 2001 (and before the model was used to delineate time-dependent groundwater capture zones for the City):

1. A new zone for hydraulic conductivity (zone number 77) was added to the Sand and Gravel Aquifer (SGA) in model layer 7, in an area located south and southeast of the CSS Wellfield. The location of this new zone and the magnitude of hydraulic conductivity in this zone (105 feet per day) were selected based on aquifer testing and modeling results conducted at RWPUD's Cascade 3&4 pumping station (ESI, 2003; Groundwater Solutions, Inc., 2003).

2. On behalf of PWB, in 2009, GSI converted the model's grid system from Universal Transverse Mercator (UTM) coordinates to Oregon State Plane Coordinates, North American Datum (NAD) 83/91, International Feet (see GSI [2009] for further details).

Other aquifer hydraulic properties programmed into the model were developed on the basis of a detailed model calibration effort that was performed during the original model development effort (Leighton and Porcello, 2001). Typical values of the aquifer hydraulic properties for the three aquifers that are the source of groundwater to public water providers in the region are as follows:

- Specific yield and effective porosity: 0.15
- Horizontal hydraulic conductivity: 30 to 105 ft/day
- Vertical anisotropy (the ratio of horizontal to vertical hydraulic conductivity): Between 10:1 and 50:1

Numerical Modeling Procedure for Fairview Capture Zone Delineation

The delineation work began with the delineation of the 2-year groundwater capture zone. This delineation was conducted by running the DAY model for a two-year period using a total of 28 stress periods. Pumping rates from each production well were held constant during a given stress period, but were allowed to vary between stress periods according to the operational scenarios described above (see Tables 3, 4, and 5). This approach produced a transient MODFLOW model simulation that provided time-varying groundwater elevations, flow directions, flow velocities, and volumetric flows throughout the model domain. These transient MODFLOW results were then imported into MODPATH for each stress period and were used by MODPATH to delineate the two-year capture zones. For the 5-year, 10-year, 20-year, and 30-year delineations, the MODFLOW model was run by repeating the 2-year pumping scenario for as long as necessary to match the time period for which delineations were being conducted; for example, the 10-year delineation consisted of running the 2-year pumping schedule a total of five times.

The groundwater flow field that initialized each simulation was the long-term average groundwater flow condition without any pumping from the SGA or other aquifers (GSI, 2009). The output from this initializing model was then imported into, and used as the initial condition for each transient delineation model run.

The capture zone delineation itself was performed by importing the MODFLOW results and using reverse particle-tracking techniques. For a given production well, the reverse particle tracking technique consisted of placing 300 imaginary particles in a circular pattern around each well, with 100 particles placed near the top of the aquifer, 100 particles placed near the bottom of

the aquifer, and the remaining 100 particles placed in the middle of the aquifer. For a given time-dependent capture zone (2, 5, 10, 20, or 30 years), the particle traces from the reverse tracking simulations were then superimposed in a GIS system and studied to identify the outer boundaries of the capture zones. Some capture zones generated by the model extended part way beneath the Columbia River, but not into Clark County, Washington; these capture zones were truncated at the south shore of the river.

Delineation Results

The capture zone boundaries are shown in Figures 1 and 2. These two figures differ only in terms of the geographic extent of the base map behind which the capture zones are displayed. Key observations about the five time-related capture zones are as follows:

- Well 8, and wells 5, 6 and 9 define two distinct and separate capture zone areas in the SGA. Well 7 also defines a small separate and distinct capture zone within the TSA. The shape and orientation of the capture zone area incorporating wells 5, 6 and 9 is controlled to some extent by RWPUD pumping, whereas the Well 8 capture zone is more defined by its proximity to the river and the Blue Lake Aquifer.

- Except for the 2-year capture zone, the capture zones for Well 8 are irregular in shape because of a significant contribution of water from the overlying Blue Lake Aquifer. Additionally, the extent of these capture zones for Well 8 are not significantly influenced by pumping from the CSS Wellfield, because the delineation process assumes that PWB operates the wellfield for only a limited period of time (45 days) each year.

References

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Table 1
Production Capacities and Authorized Rates for Production Wells
Groundwater Capture Zone Delineations
City of Fairview, Oregon

Well	Aquifer	Capacity (gpm)	Authorized Water Right Rate (gpm)	Model Location (row, column, layer)	Comment
5	SGA	600	1,436	174, 262, 7 174, 263, 7	Well 5 and 9 cannot be pumped simultaneously at their respective capacities. The current maximum pumping rate is limited to maximum authorized rate of the water right for the two wells.
9	SGA	1,735	(combined)		
6	SGA	290	987	174, 265, 7	Well was used as supplemental supply for the City, but now only is used only for emergency purposes due to poor water quality. The maximum capacity of the well is less than the maximum authorized water right rate.
7	TSA	241	301	181, 251, 4	Well is used only for emergency purposes due to poor water quality.
8	SGA	1,200	1,198	150, 263, 7	Well 8 is one of the primary water supply sources for the City and the capacity of the well approximately equals the maximum authorized water right rate.
TOTAL		**4,066**	**3,922**		

Abbreviations: SGA = Sand and Gravel Aquifer TSA = Troutdale Sandstone Aquifer gpm = gallons per minute MGD = millions of gallons per day

GSI Water Solutions, Inc.

Table 2
Seasonal Distribution of System-Wide Groundwater Pumping
Groundwater Capture Zone Delineations
City of Fairview, Oregon

	Average Monthly Production from Well Field (MG)			Average Daily Well Field Production (MGD)			Average Pumping Rate[1] (gpm)									Delineation Rate[2] (gpm)			
							2008			2009			2010						
Month	2008	2009	2010	2008	2009	2010	Well 6	Well 8	Well 5/Well 9 Pumping Combined	Well 6	Well 8	Well 5/Well 9 Pumping Combined	Well 6	Well 8	Well 5/Well 9 Pumping Combined	Well 6	Well 8	Well 5/Well 9 Pumping Combined	Well 7 Pumping[3]
Jan	15.40	15.13	15.12	0.50	0.50	0.50	***36***	184	125	1	***213***	137	0	202	***148***	***45***	***266***	***185***	
Feb	13.83	13.85	13.98	0.45	0.46	0.47	***32***	165	112	1	***195***	125	0	187	***137***	***40***	***244***	***171***	
Mar	15.23	17.13	15.99	0.54	0.57	0.53	***39***	201	137	1	***241***	155	0	214	***157***	***49***	***301***	***196***	
Apr	15.27	15.41	15.17	0.49	0.51	0.51	***36***	182	124	1	***217***	139	0	203	***149***	***44***	***271***	***186***	
May	19.68	19.54	17.38	0.66	0.65	0.58	***47***	243	165	1	***275***	177	0	232	***170***	***59***	***344***	***213***	
Jun	24.77	27.24	18.16	0.80	0.91	0.61	***58***	296	202	1	***383***	246	0	243	***178***	***72***	***479***	***222***	
Jul	37.69	36.03	33.02	1.26	1.20	1.10	***91***	465	317	2	***507***	326	0	441	***323***	***113***	***633***	***404***	
Aug	33.58	32.82	32.57	1.08	1.09	1.09	***78***	401	273	2	***462***	297	0	435	***319***	***98***	***577***	***399***	***163***
Sep	26.83	29.18	19.31	0.87	0.97	0.64	***62***	320	218	1	***410***	264	0	258	***189***	***78***	***513***	***236***	
Oct	16.61	17.77	14.92	0.55	0.59	0.50	***40***	205	140	1	***250***	161	0	199	***146***	***50***	***312***	***183***	
Nov	15.19	16.40	15.19	0.49	0.55	0.51	***35***	181	124	1	***231***	148	0	203	***149***	***44***	***288***	***186***	
Dec	17.32	16.13	14.19	0.58	0.54	0.47	***42***	214	146	1	***227***	146	0	190	***139***	***52***	***284***	***174***	

Abbreviations

MG = Million Gallons
MGD = Million Gallons Per Day
gpm = gallons per minute

Notes

Bold and italicized figures are the rates selected for delineation

[1]Average Pumping Rate = Pumping rate needed to produce the portion of the City's demand volume met by each well for each month during the year, assuming that the well is operated continuously each month

[2]Delineation rate = 1.25 x average daily pumping rate

[3]Well 7 delineation assumes use only during a 21 day emergency event once every 5 years. The pumping rate averages the pumping for 21 days over the entire 31 days of the month in which it occurs

GSI Water Solutions, Inc.

Table 3
Simulated Pumping Rates for CSS Wellfield Operations
Groundwater Capture Zone Delineations
City of Fairview, Oregon

Well Number	Pumping Capacity (gpm)	90% of Pumping Capacity (gpm)	90% of Pumping Capacity (MGD)	Percentage of Total CSS Wellfield Pumping
BLUE LAKE AQUIFER (BLA)				
12	4,500	4,050	5.8	5.7%
13	7,000	6,300	9.1	8.9%
17b	3000	2,700	3.9	3.8%
18	7,000	6,300	9.1	8.9%
19	8,800	7,920	11.4	11.2%
Subtotal	30,300	27,270	39.3	38.7%
TROUTDALE SANDSTONE AQUIFER (TSA)				
3	1,340	1,206	1.7	1.7%
5	1,055	950	1.4	1.3%
10	1,336	1,202	1.7	1.7%
15	665	599	0.9	0.8%
26	1,677	1,509	2.2	2.1%
28	1,512	1,361	2.0	1.9%
29	1,000	900	1.3	1.3%
Subtotal	8,585	7,727	11.1	11.0%
SAND AND GRAVEL AQUIFER (SGA)				
1	2,740	2,466	3.6	3.5%
2	3,100	2,790	4.0	4.0%
4	2,170	1,953	2.8	2.8%
6	3,200	2,880	4.1	4.1%
7	1,470	1,323	1.9	1.9%
8	1,550	1,395	2.0	2.0%
9	2,420	2,178	3.1	3.1%
11	3,230	2,907	4.2	4.1%
14	1,894	1,705	2.5	2.4%
16	2,740	2,466	3.6	3.5%
34	3,000	2,700	3.9	3.8%
35	2,900	2,610	3.8	3.7%
36	2,721	2,449	3.5	3.5%
37	3,600	3,240	4.7	4.6%
38	2700	2,430	3.5	3.4%
Subtotal	39,435	35,492	51.1	50.4%
Total	**78,320**	**70,488**	**101.5**	**100%**

Abbreviations:

CSS = Columbia South Shore
BLA = Blue Lake Aquifer
SGA = Sand and Gravel Aquifer
TSA = Troutdale Sandstone Aq
gpm = gallons per minute
MGD = millions of gallons per

Note: The conversion from gpm to MGD assumes that each well is operating 24 hours per day.

GSI Water Solutions, Inc.

Table 4
Simulated Pumping Schedule for RWPUD Wellfield Operations
Groundwater Capture Zone Delineations
City of Fairview, Oregon

Year No.	Analogous Historical Period	Duration (Days)	Simulated RWPUD Wellfield Daily Production (MG)	Well 5 Daily Production (MG)	Wells 3&4 Daily Production (MG)	Simulated RWPUD Wellfield Instantaneous Production (gpm)	Well 5 Instantaneous Production (gpm)	Wells 3&4 Instantaneous Production (gpm)
1	Jan-08	31	1.07	1.07	0.00	1,790	1,790	0
	Feb-08	28	0.54	0.54	0.00	900	900	0
	Mar-08	31	0.11	0.11	0.00	179	179	0
	Apr-08	30	0.16	0.16	0.00	272	272	0
	May-08	31	0.95	0.95	0.00	1,581	1,581	0
	Jun-08	30	2.46	2.46	0.00	4,098	4,098	0
	Jul-08	31	4.54	3.00	1.54	7,569	5,000	2,569
	Aug-08	31	4.28	3.00	1.28	7,130	5,000	2,130
	Sep-08	30	1.40	1.40	0.00	2,333	2,333	0
	Oct-08	31	0.24	0.24	0.00	408	408	0
	Nov-08	30	3.46	3.00	0.46	5,771	5,000	771
	Dec-08	31	2.60	2.60	0.00	4,340	4,340	0
2	Jan-09	31	4.82	3.00	1.82	8,030	5,000	3,030
	Feb-09	28	0.27	0.27	0.00	452	452	0
	Mar-09	31	0.23	0.23	0.00	380	380	0
	Apr-09	30	0.14	0.14	0.00	232	232	0
	May-09	31	0.83	0.83	0.00	1,378	1,378	0
	Jun-09	30	2.86	2.86	0.00	4,761	4,761	0
	Jul-09	31	6.14	3.00	3.14	10,237	5,000	5,237
	Aug-09	31	3.99	3.00	0.99	6,652	5,000	1,652
	Sep-09	30	1.51	1.51	0.00	2,512	2,512	0
	Oct-09	31	1.99	1.99	0.00	3,318	3,318	0
	Nov-09	30	0.38	0.38	0.00	634	634	0
	Dec-09	31	0.17	0.17	0.00	287	287	0

Notes:
1) This cycle is repeated for as many years as necessary to delineate the 5-year, 10-year, and 30-year groundwater capture zones.
2) Each RWPUD well is assumed to operate for 10 hours on any given day.

RWPUD = Rockwood Water People's Utility District MG = millions of gallons gpm = gallons per minute

GSI Water Solutions, Inc.

Table 5
Simulated Two-Year Cycle of Daily Production Volumes from SGA Wells Owned by Fairview and Others
Groundwater Capture Zone Delineations
City of Fairview, Oregon

Year No.	Analogous Historical Period	Duration (Days)	Simulated Daily Production from the SGA (MGD)					
			City of Fairview	PWB CSS Wellfield	RWPUD	City of Troutdale	City of Wood Village	Southeastern Metropolitan Area of Vancouver, WA
1	Jan-2008	31	0.50	0	1.07	1.65	0.58	9.29
	Feb-2008	28	0.45	0	0.54	1.65	0.58	9.29
	Mar-2008	31	0.54	0	0.11	1.65	0.58	9.29
	Apr-2008	30	0.49	0	0.16	1.65	0.58	9.29
	May-2008	31	0.66	0	0.95	1.65	0.58	9.29
	Jun-2008	30	0.80	0	2.46	1.65	0.58	9.29
	Jul-2008	31	1.26	0	4.54	1.65	0.58	9.29
	Aug-2008	31	1.08	0	4.28	1.65	0.58	9.29
	1st Half of Sept-2008	15	0.44	51.1	1.40	1.65	0.58	9.29
	2nd Half of Sept-2008	15	0.44	51.1	1.40	1.65	0.58	9.29
	1st Half of Oct-2008	15	0.28	51.1	0.24	1.65	0.58	9.29
	2nd Half of Oct-2008	16	0.28	0	0.24	1.65	0.58	9.29
	Nov-2008	30	0.49	0	3.46	1.65	0.58	9.29
	Dec-2008	31	0.58	0	2.60	1.65	0.58	9.29
2	Jan-2009	31	0.50	0	4.82	1.65	0.58	9.29
	Feb-2009	28	0.46	0	0.27	1.65	0.58	9.29
	Mar-2009	31	0.57	0	0.23	1.65	0.58	9.29
	Apr-2009	30	0.51	0	0.14	1.65	0.58	9.29
	May-2009	31	0.65	0	0.83	1.65	0.58	9.29
	Jun-2009	30	0.91	0	2.86	1.65	0.58	9.29
	Jul-2009	31	1.20	0	6.14	1.65	0.58	9.29
	Aug-2009	31	1.09	0	3.99	1.65	0.58	9.29
	1st Half of Sept-2009	15	0.49	51.1	1.51	1.65	0.58	9.29
	2nd Half of Sept-2009	15	0.49	51.1	1.51	1.65	0.58	9.29
	1st Half of Oct-2009	15	0.30	51.1	1.99	1.65	0.58	9.29
	2nd Half of Oct-2009	16	0.30	0	1.99	1.65	0.58	9.29
	Nov-2009	30	0.55	0	0.38	1.65	0.58	9.29
	Dec-2009	31	0.54	0	0.17	1.65	0.58	9.29

Notes:

1) This cycle is repeated for as many years as necessary to delineate Fairview's 5-year, 10-year, 20-year, and 30-year groundwater capture zones.
2) See Figure 2 for SGA well locations. (Note: For Troutdale, Vancouver, and SEH America, most or all SGA wells are outside the map view frame.)
3) SGA wells in the southeastern portion of metropolitan Vancouver, WA are owned and operated by SEH America (1 well) and the City of Vancouver (two wells -- Ellsworth Springs and Station 7).

Abbreviations:

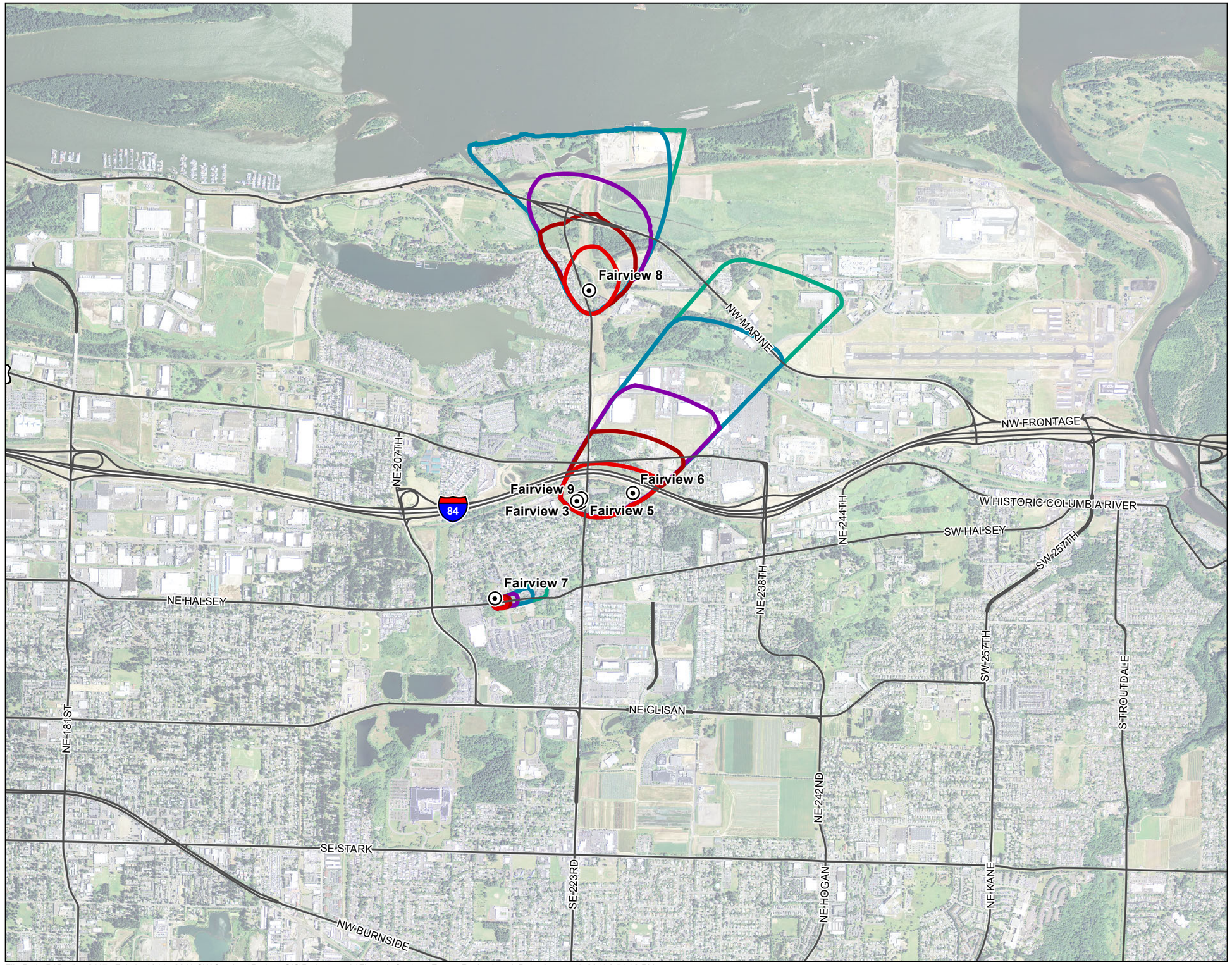
RWPUD = Rockwood Water People's Utility District
PWB = Portland Water Bureau
CSS = Columbia South Shore
SGA = Sand and Gravel Aquifer
MGD = millions of gallons per day
WA = Washington

GSI Water Solutions, Inc.

FIGURE 1

Groundwater Capture Zones for City of Fairview Production Wells

City of Fairview, Oregon



LEGEND

- City of Fairview Production Wells
- Highways and Major Roads

Groundwater Capture Zones

- 2 Year
- 5 Year
- 10 Year
- 20 Year
- 30 Year

N

0 1200 2400 3600

Feet

GSI Water Solutions, Inc.

MAP NOTES:

Projection: Oregon State Plane North
Datum: North American Datum of 1983
Date: August 11, 2011

File Path: P:\Portland\117 - Fairview\014 - 2011 GW Services\Project_GIS\Project_mxds\Figure1_Capture_Zones_Revised.mxd, Date: August 11, 2011 3:54:12 PM

FIGURE 2

Groundwater Capture Zones for City of Fairview Production Wells

City of Fairview, Oregon

LEGEND

Groundwater Capture Zones

- 2 Year
- 5 Year
- 10 Year
- 20 Year
- 30 Year

Production Wells

- City of Fairview
- Rockwood Water PUD
- Portland Water Bureau
- City of Troutdale
- Wood Village
- Highways and Major Roads

N

0 2000 4000 6000

Feet

GSI Water Solutions, Inc.

MAP NOTES:

Projection: Oregon State Plane North
Datum: North American Datum of 1983
Date: August 11, 2011

File Path: P:\Portland\117 - Fairview\014 - 2011 GW Services\Project_GIS\Project_mxds\Figure2_Nearby_Wells_Revised.mxd, Date: August 11, 2011 3:55:23 PM

Attachment B
Technical Memorandum
Conceptual Hydrogeologic Model Summary: City of Fairview, Oregon
Transfer Application T-9808

Groundwater Solutions, Inc.
55 SW Yamill Street, Suite 400 Portland, Oregon 97204
ph: 503.239.8799 fx: 503.239.8940 e: groundwatersolutions.com

TECHNICAL MEMORANDUM

Conceptual Hydrogeologic Model Summary: City of Fairview, Oregon Transfer Application T-9808

PREPARED FOR: Donn Miller, RG - Oregon Water Resources Department

PREPARED BY: Walter Burt, RG

COPIES: Bob Cochran, PE – City of Fairview

DATE: June 6, 2005

REGISTERED PROFESSIONAL OREGON WALTER C BURT G1402 GEOLOGIST

Expires: 05/31/2006

This memorandum summarizes Groundwater Solutions, Inc.'s (GSI) recent evaluation and interpretations of the hydrostratigraphy of Pliocene alluvial aquifers in the vicinity of the City of Fairview (City), Oregon. The information provided below is a synopsis of the detailed technical information provided to you in support of the City of Fairview's transfer application, T-9808 during a meeting on May 3, 2005.

The hydrostratigraphy in the vicinity of City of Fairview Wells 3 and 5 has been interpreted in two significantly different ways since the late 1980s relative to the hydrostratigraphic nomenclature of Hartford and McFarland (1989). One interpretation, completed for the USGS Portland Basin Study, shows the top of the Sand and Gravel Aquifer (SGA) unit to be present at an approximate elevation of –300 feet MSL at the location of City of Fairview Well 3 and Well 5, based entirely on the log of Fairview Well 3. This interpretation implies that Well 5 is completed in the TSA, rather than the SGA.

GSI and other investigators have developed a different interpretation of the hydrostratigraphy at Fairview Well 3 and Well 5. This interpretation is based on the accumulation of understanding from numerous subsurface geologic and hydrogeologic investigations conducted in the Gresham, Rockwood and Fairview areas during and subsequent to the USGS study. The data and concepts used to develop the interpretation used in the conceptual model presented by GSI are taken from investigations by the cities of Gresham, Portland and Fairview, Rockwood Water PUD, and by various parties involved in the East Multnomah County (Boeing/Cascade Corporation) groundwater plume remediation. GSI personnel have been involved in many of these investigations or compiled much of this information as part of the development of an area-wide conceptual groundwater model for ongoing groundwater supply projects for various entities in the area, including the City of Fairview. GSI has interpreted the approximate elevation of the top of the SGA at Fairview Well 3 and Well 5 to be –145 feet MSL, putting the production zones for both wells in the SGA. This interpretation was utilized for Transfer Application T-9808, and is consistent with the

lines of evidence from iterative refinement of the conceptual model used by GSI. Additionally, the interpretation echoes similar findings of other investigators, including Bet and Rosner (1993) of Landau and Associates and Parametrix (1992), who worked on the Boeing/Cascade groundwater remediation in this area. Hydrogeologic information supporting our interpretation of the conceptual hydrogeologic model in the vicinity of the City of Fairview is summarized in the following sections.

Hydrostratigraphy

A substantial amount of detailed hydrogeologic investigation work has been completed in the Fairview and Gresham areas subsequent to earlier investigations; this work has clarified the hydrostratigraphy to the south and east of Blue Lake and Fairview Lake. The prior USGS work necessarily relied on a relatively limited amount of data that was available for interpretation of the hydrostratigraphy south and east of the City of Portland Well Field. In addition, interpretations of the hydrostratigraphy relative to the nomenclature described in Hartford and McFarland (1989) become less straightforward in the Fairview area because the characteristics of the alluvial sediment sequence of the TSA, CU2 and the SGA become less distinct south and east of the Portland Well Field. This is particularly true in the vicinity of Fairview Well 3 and Portland Piezometer 33AD, where the proportion and distribution of finer-grained materials increase, and thus complicate interpretation of hydrostratigraphic units.

More recent work in the Fairview and west Gresham areas by Parametrix (1992), Bet and Rosner (1993) and GSI (2001 and 2005) have developed a hydrostratigraphic conceptual model based on the current understanding of the south-dipping structure in the vicinity of Blue Lake and Fairview Lake that is consistent in its depiction of the geometry and distribution of the TSA, CU2 and SGA. Over a wide area, this model is generally similar to the prior USGS model, but differs in the area encompassing the terraces south of Fairview Lake, including the vicinity of Fairview wells 3 and 5. As we discussed in our May 3 meeting, the USGS interpretation of the unit contacts in Fairview Well 3 would result in an improbable thickness and structural geometry of the TSA and CU2 based on the depth, attitude and thickness of these units to the north and west of Fairview Well 3. The attached GSI cross-section B – B′ (GSI, 2001 and 2005) shows the two differing hydrostratigraphic interpretations in the vicinity of Fairview Well 3 and Well 5. Cross-sections by Bet and Rosner (1993), Parametrix (1992) also are attached to this letter for comparison with the interpretations, as is a map showing the approximate locations of the sections.

Aquifer Water Levels

Approximate static water level elevations and apparent responses in the Fairview Well 5 hydrograph indicate that the well is completed in the SGA. Information supporting this conclusion includes the following:

1. Comparison of static water levels in the TSA and SGA in 33AD indicate a substantial head difference between the TSA and the SGA in the vicinity of the uplands in Fairview. The TSA water level elevation at 33AD on December 20, 2000 was 78 feet (City of Portland Datum[COP]), whereas the SGA water level elevation on the same date at 33AD was approximately 5 feet (COP). The static

water level in Fairview Well 5 on February 22, 2005 was 105.5 feet below the measuring point, or at an estimated elevation of between 5 and 15 feet. The substantial difference in groundwater elevations in the TSA and SGA at 33AD, and the similarity in the elevations between the SGA piezometer at 33AD and Fairview Well 5 indicate that Fairview Well 5 is completed in the SGA.

2. A drawdown response in a Well 5 hydrograph was noted during a period of pumping of the SGA by the City of Portland at wells P-7 and P-14.

Aquifer Testing

The results of an aquifer pumping test support the conclusion that Fairview Well 5 is completed in the SGA. The City of Fairview completed an aquifer pumping test using Fairview Well 5 as the pumping well. Well 5 was pumped at an average discharge rate of 680 gallons per minute (gpm) for approximately 30 hours. Water levels in the SGA and TSA piezometers in 33AD were electronically monitored prior to and during the test. A transmissivity of 15,600 gallons per day per foot (gpd/ft) was calculated for the aquifer at Well 5. This transmissivity value is at the low end of the range observed in the SGA. Interpretation of the response in the 33AD piezometers was complicated by other stresses in the aquifer, and thus the results are not conclusive. However, information from the test that supports the conclusion that Well 5 is completed in the SGA includes the following:

1. No discernible response was noted in the hydrograph of the TSA piezometer tube at 33AD although drawdowns of 1.5 to 2.5 feet were predicted for 33AD. The hydrograph for the TSA piezometer shows an overall declining water level trend prior to, throughout and after the test. The magnitude and timing of the water level decline in the 33AD TSA piezometer suggests that Fairview Well 5 is not completed in the TSA.

2. An apparent response to pumping Fairview Well 5 was noted in the data from the SGA piezometer tube. However, interpretation of the response was complicated by another stress that occurred during the recovery period of the test. This aquifer stress may correspond to a period of pumping of City of Portland SGA wells during a supply event for pilot testing of ultraviolet (UV) treatment equipment. The apparent response in the SGA tube during the Fairview Well 5 test and potentially during City of Portland SGA pumping suggests that Fairview Well 5 is completed in the SGA.

Summary

Refinements to the hydrogeologic conceptual model in the vicinity of the City of Fairview indicate that the City of Fairview wells 3 and 5 are completed in the SGA. This conclusion is based on the following observations:

- Updated interpretations based on the current understanding of the depth, thickness and structural attitude of hydrostratigraphic units in the area of Fairview wells 3 and 5 indicate that the SGA is present at the elevations of the production intervals of the wells.

- Aquifer water levels in Well 5 are consistent with nearby SGA levels and are significantly lower than those measured in the TSA.
- The results of aquifer testing indicate an apparent hydraulic response in the SGA from pumping Well 5 and a hydraulic response in Well 5 that potentially corresponds to a stress in the SGA also was noted.

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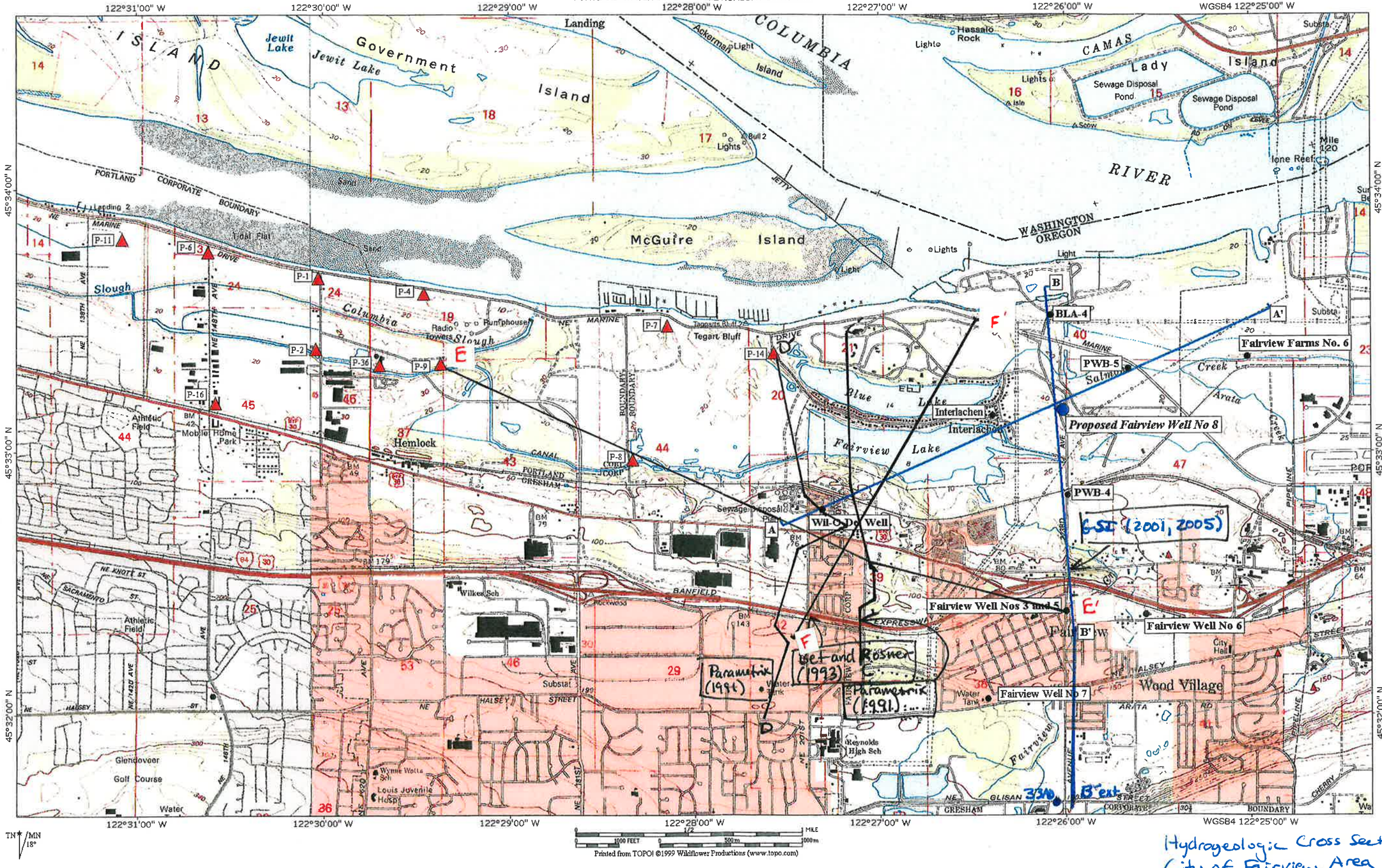
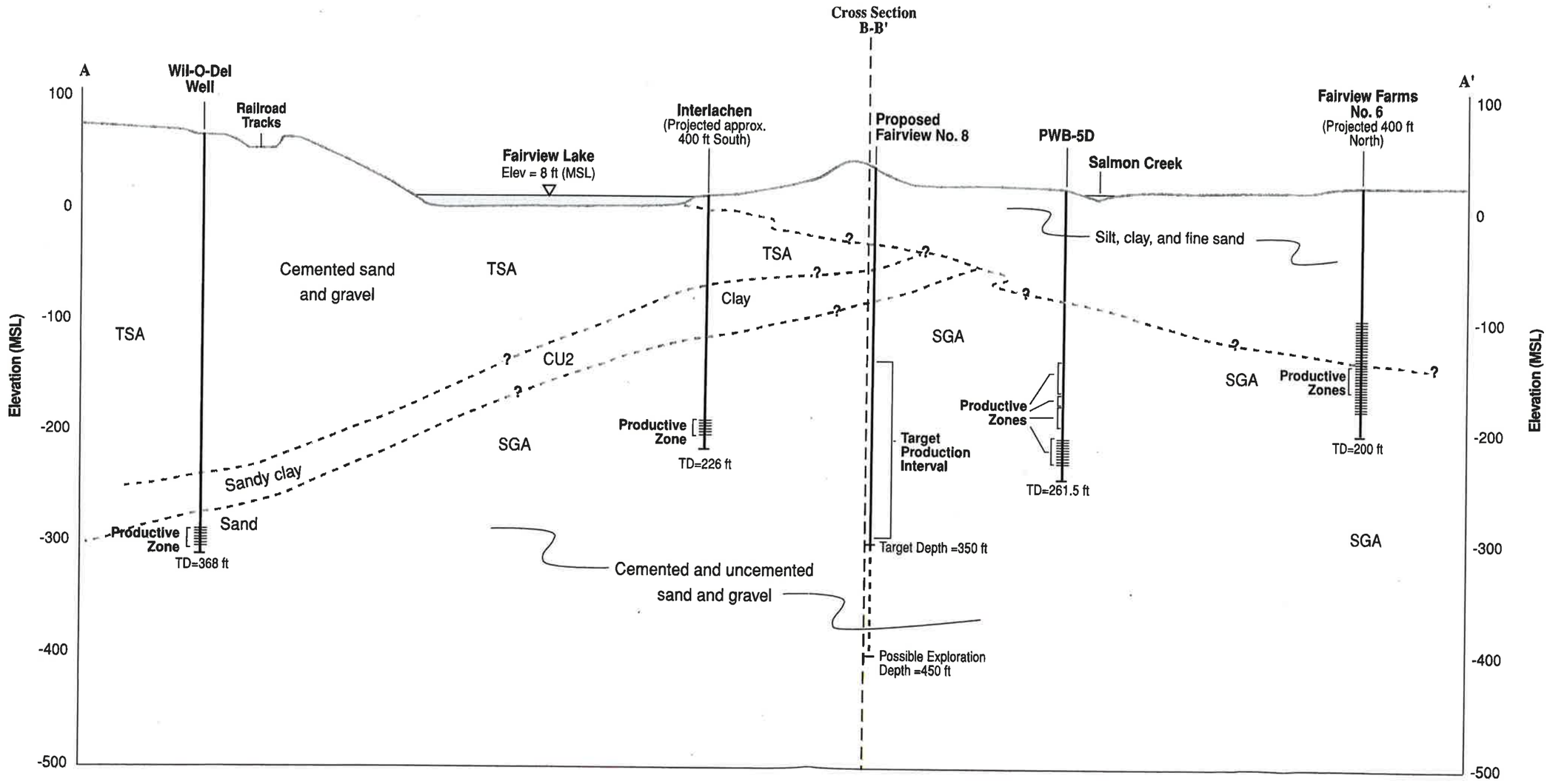
PORTLAND WATER BUREAU WELL NUMBERS 28 AND 34



Hydrogeologic Cross Sections
City of Fairview Area



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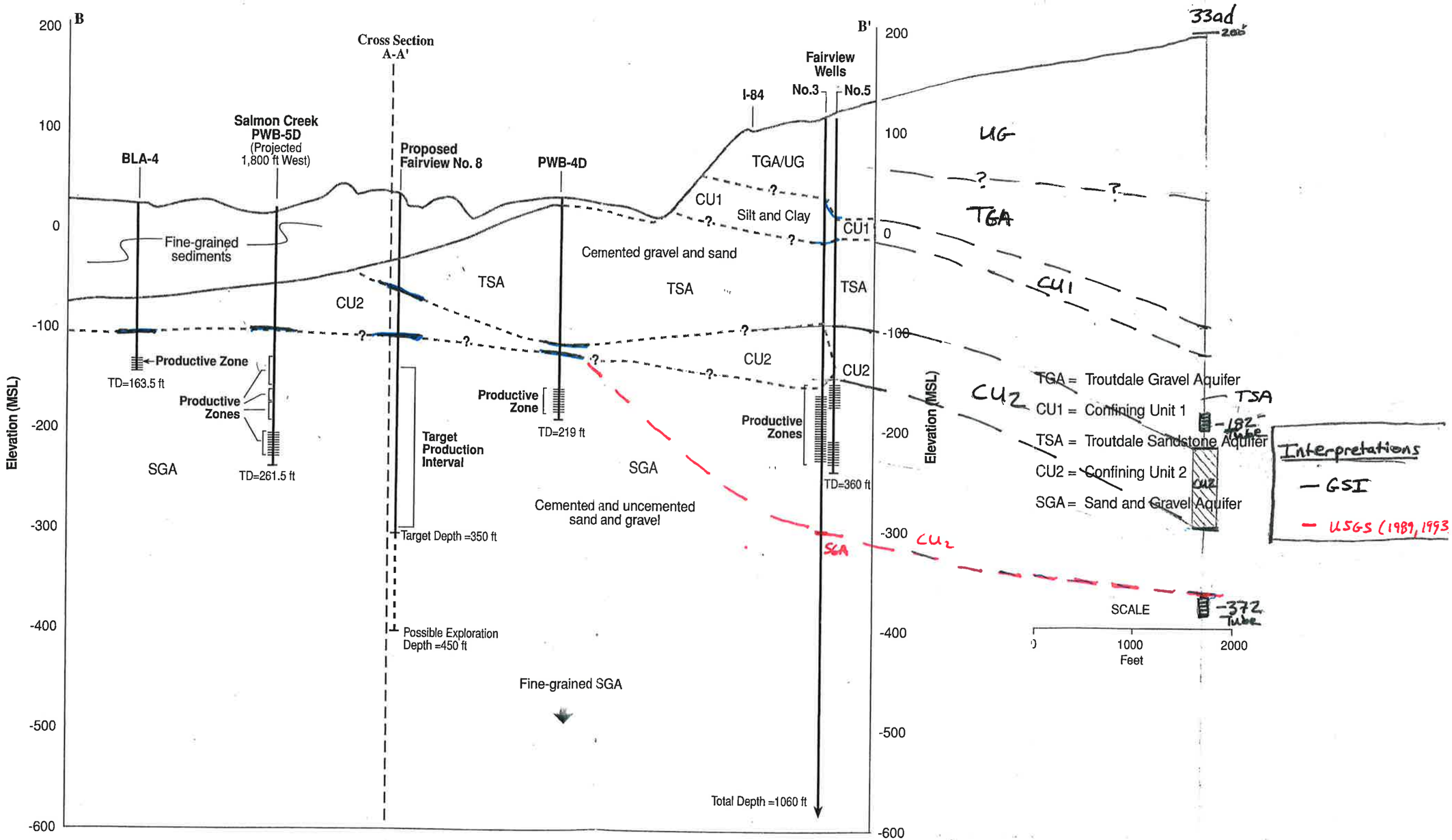
ph:503.239.8799 fx:503.239.8940 e:groundwatersolutions.com

SCALE
0 1000 2000
Feet

TSA = Troutdale Sandstone Aquifer
CU2 = Confining Unit 2
SGA = Sand and Gravel Aquifer

FIGURE 2A
Cross Section A-A'
FAIRVIEW WELL SITING STUDY



Groundwater Solutions Inc.
3758 SE Milwaukie Ave. Portland, Oregon 97202
ph:503.239.8799 fx:503.239.8940 e:groundwatersolutions.com

FIGURE 2B
Cross Section B-B'
FAIRVIEW WELL SITING STUDY

Parametrix (1991)

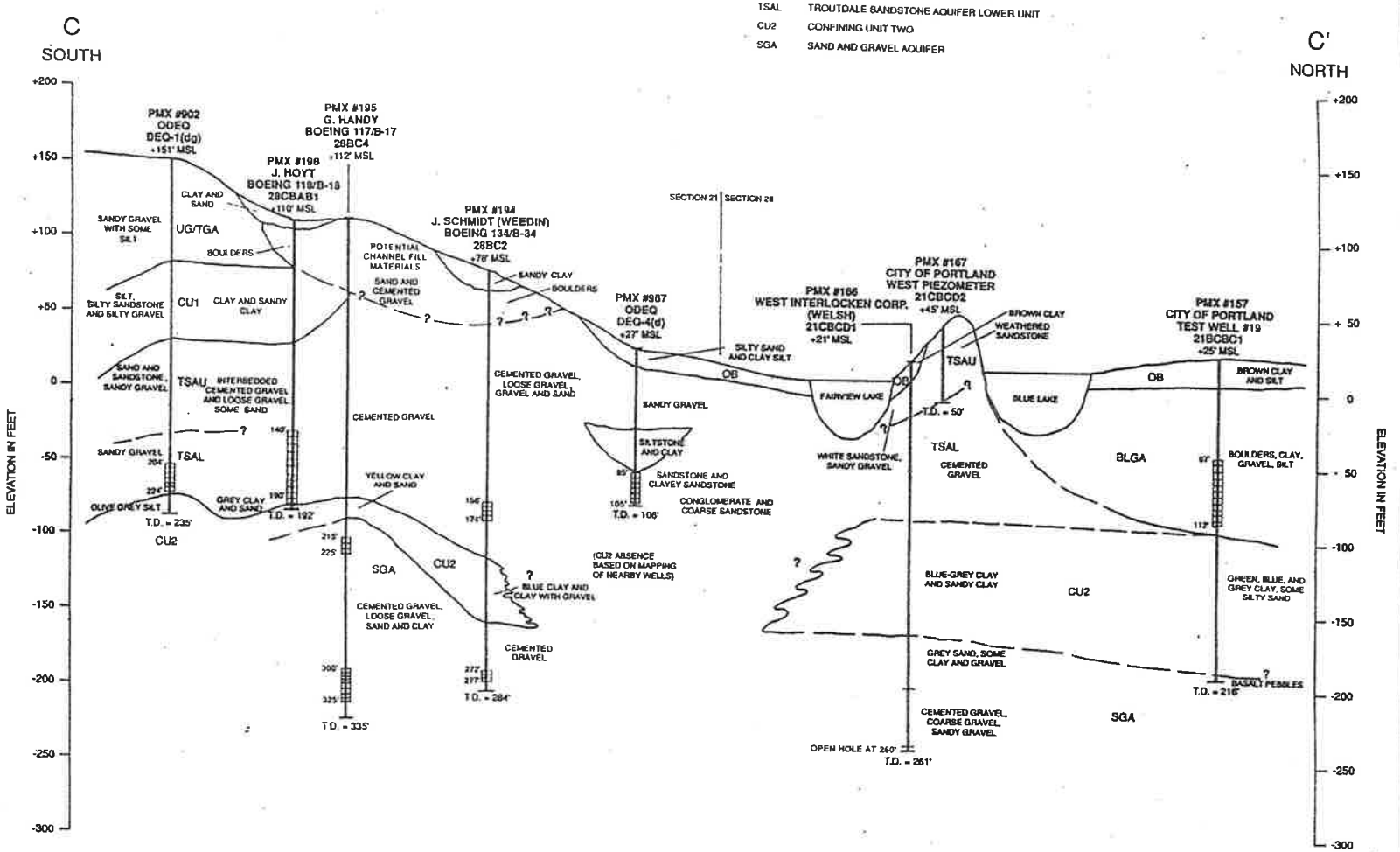


FIGURE 14.
DETAILED MODELING AREA
East Multnomah County Ground Water Project
Cross-Section C-C'

SCALE IN FEET
0 500 1,000 HORIZONTAL SCALE
0 50 100 VERTICAL SCALE
(10 : 1 VERTICAL TO HORIZONTAL EXAGGERATION)

Oregon Department of Environmental Quality
prepared by
Parametrix, Inc.
July 30, 1991

Parametrix (1991)

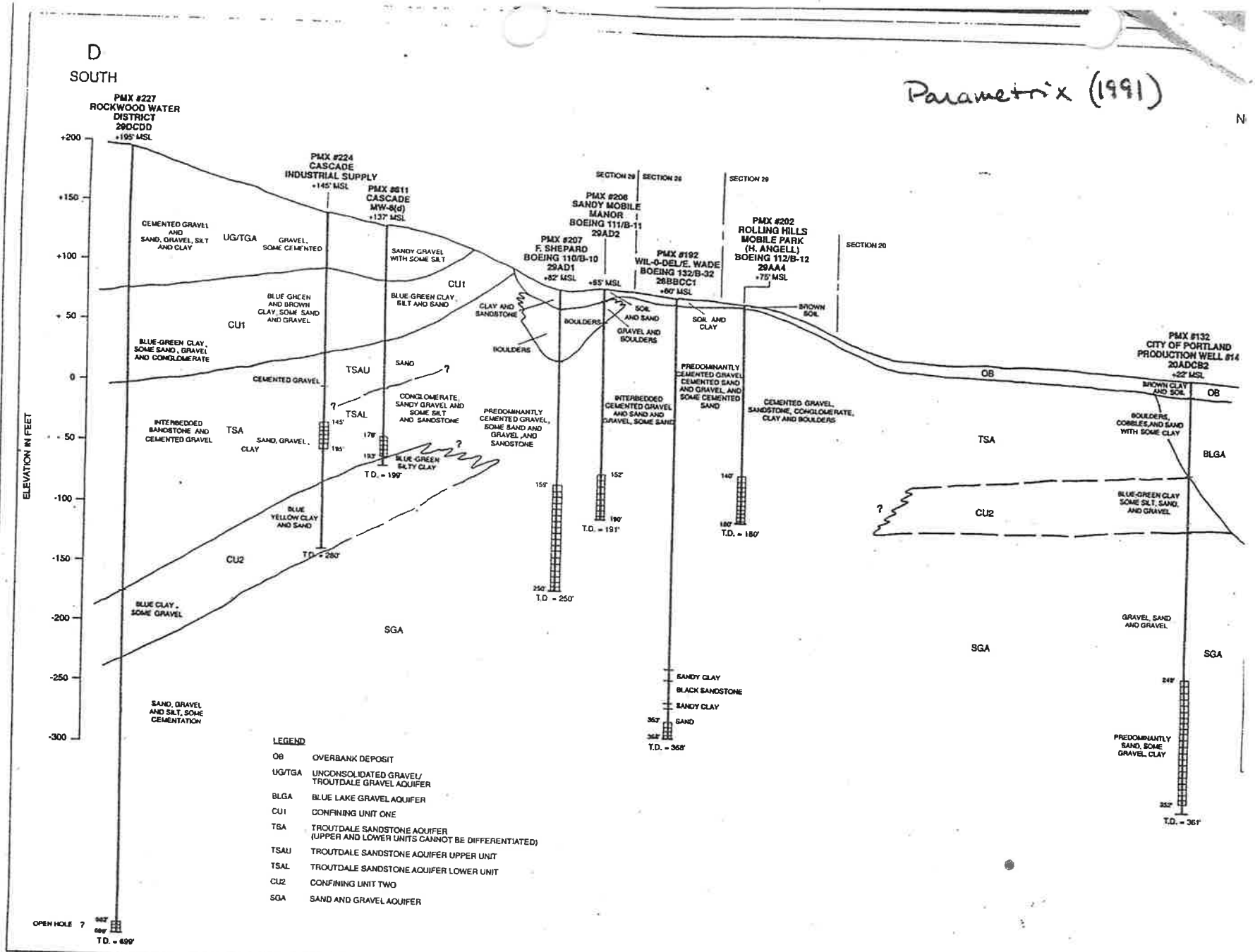
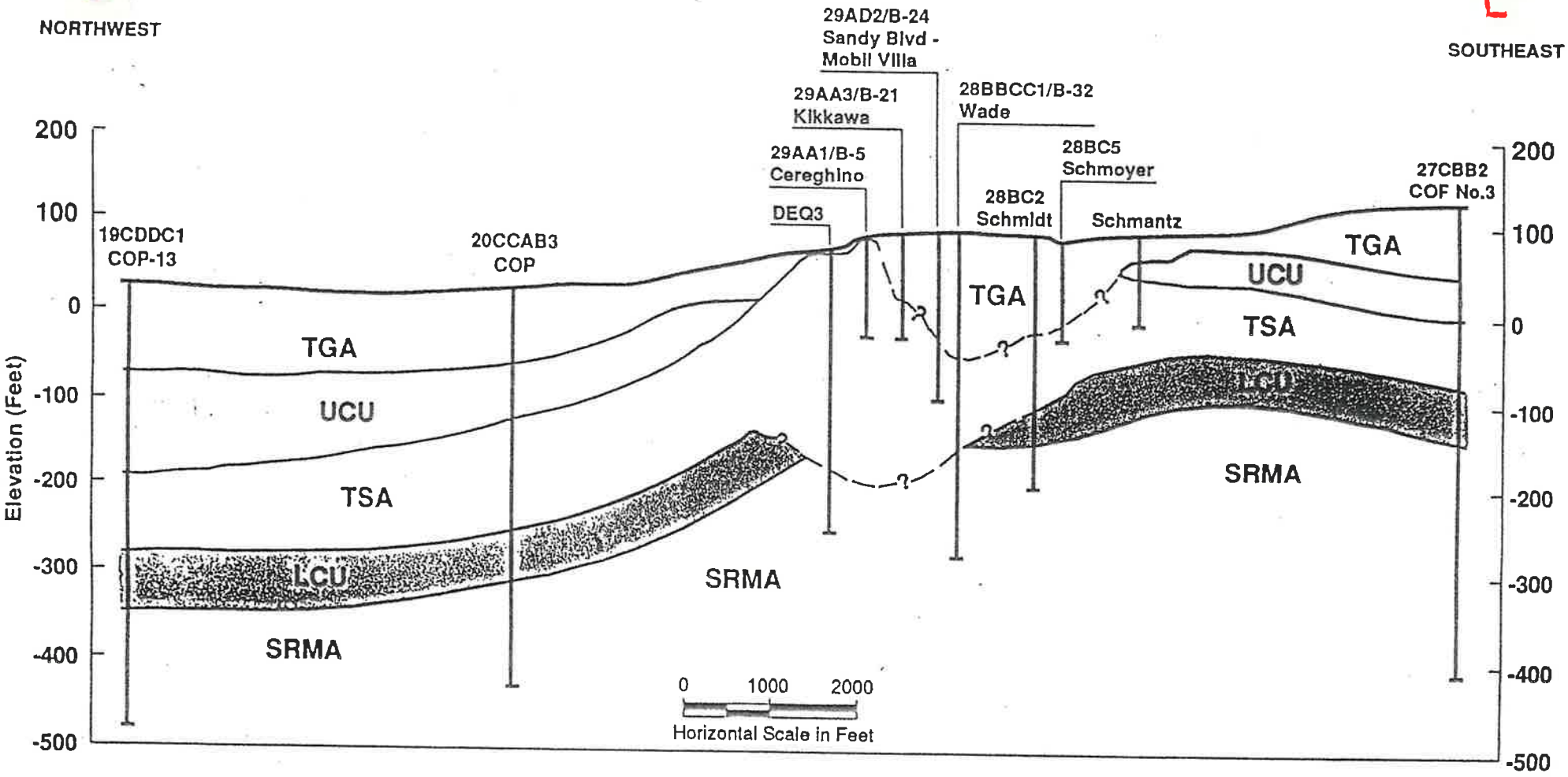


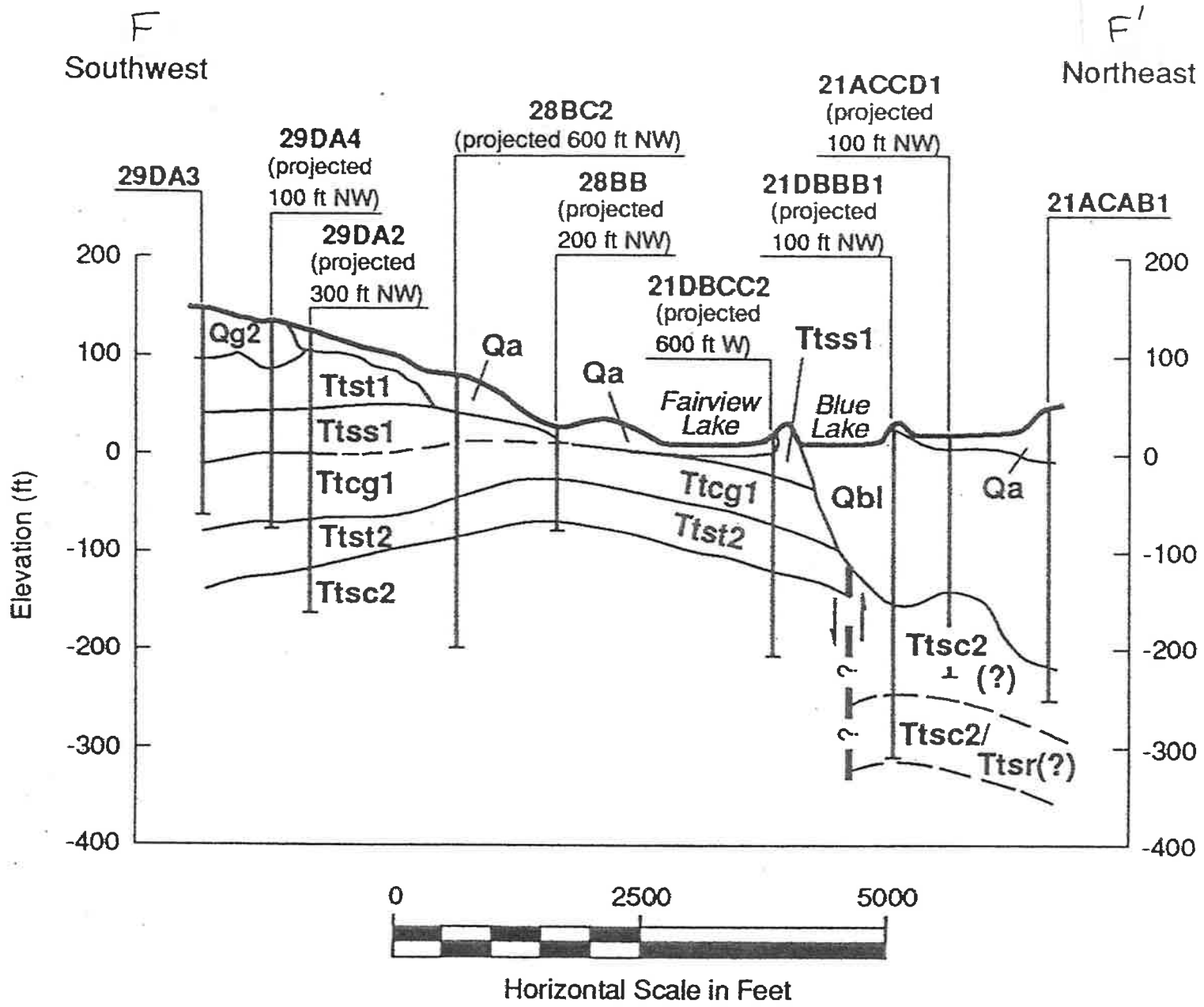
FIGURE 15.
DETAILED MODELING AREA
East Multnomah County Ground Water Project
Cross-Section D-D'

Oregon Department of Environmental
prepared by
Parametrix, Inc.
July 30, 1991

Cross Section B-B'



Bet and Rosner (19
(Cross-section B'-B')



Attachment C
Technical Memorandum
Conceptual Hydrogeologic Model Summary, City of Fairview, Oregon
Aquifer Completion of Well 6 (MULT 3104), Water Use Permit G-7029

GSI Water Solutions, Inc.

Technical Memorandum

To: Karl Wozniak, RG – Oregon Water Resources Department

From: Ted Ressler, RG, CWRE – GSI Water Solutions, Inc.
Walter Burt, RG – GSI Water Solutions, Inc.
Robyn Cook, RG – GSI Water Solutions, Inc.

CC: City of Fairview

Date: May 11, 2015

Re: **Conceptual Hydrogeologic Model Summary, City of Fairview, Oregon**
Aquifer Completion of Well 6 (MULT 3104), Water Use Permit G-7029.

This technical memorandum (TM) summarizes GSI Water Solutions, Inc.'s (GSI) evaluation and interpretation of the hydrostratigraphy of Pliocene alluvial aquifers in the vicinity of Fairview, Oregon. This TM is being submitted in response to the preliminary findings by Oregon Department of Water Resources (OWRD) regarding the aquifer in which City of Fairview (Fairview) Well 6 is completed, as determined during the Permit Extension Groundwater Review for Permit G-7029 (see Attachment 1). Specifically, OWRD concluded that Well 6 produces water from the Troutdale Sandstone Aquifer (TSA). This determination is based on hydrostratigraphy defined by the USGS in Hartford and McFarland (1989). However, information gathered as part of extensive subsurface geologic and hydrogeologic investigations conducted in the vicinity of the cities of Gresham and Fairview between 1990 and the present support an alternative interpretation of the hydrostratigraphy for this portion of the Portland Basin. More recent interpretations by GSI and others of the hydrostratigraphy suggest that Well 6 is actually completed in the Sand and Gravel Aquifer (SGA). In addition to hydrostratigraphic interpretation, GSI has compiled hydraulic data that demonstrates a strong connection between Well 6 and other wells recognized by OWRD as being completed in the SGA.

Hydrostratigraphy

The hydrostratigraphy in the vicinity of several of Fairview's water supply wells, former Well 3 (now decommissioned), Well 5, Well 9, and Well 6 has been interpreted in two significantly different ways since the late 1980s. One interpretation, completed for the USGS Portland Basin Study (Hartford and McFarland, 1989), established the top of the SGA unit based on the well log of Fairview Well 3. This interpretation implied that Well 5, located approximately 75 feet from Well 3, was completed in the TSA, rather than the SGA. The prior USGS work necessarily relied on a relatively limited amount of data

available for interpretation of the hydrostratigraphy south and east of the City of Portland Well Field. Subsequent studies have shown that the hydrostratigraphy relative to the nomenclature described in Hartford and McFarland (1989) is less straightforward in the Fairview area, relative to the Portland Well Field, because the distinctions between the alluvial sediment sequence of the TSA, Confining Unit 2 (CU2) and the SGA become less obvious. This is particularly true in the vicinity of Fairview Wells 3, 5, 9, and 6 and City of Portland Piezometer 33AD, where the proportion and distribution of finer-grained materials increase, thus complicating interpretation of hydrostratigraphic units.

In 2005, GSI provided OWRD with a synthesis of more recent hydrogeologic information for the area including numerous subsurface geologic and hydrogeologic investigations by various parties involved in the East Multnomah County (Boeing/Cascade Corporation) groundwater plume remediation and others conducted by the cities of Gresham, Portland and Fairview, and Rockwood People's Utility District (RWPUD) as part of the development of an area-wide conceptual groundwater model for ongoing groundwater supply projects. Over a wide area, this model is generally similar to the prior USGS model, but differs in the area encompassing the terraces south of Fairview Lake, including the vicinity of Fairview Wells 3, 5, 9 and 6. The alternative interpretation of the hydrostratigraphy shows Fairview's Well 5 to be completed in the SGA. Based on the information provided by GSI to OWRD in 2005 (GSI, 2005), OWRD accepted the alternative interpretation of the hydrostratigraphy that showed Well 5 to be completed in the SGA (OWRD, 2005).

Fairview Well 6 is located approximately 1,180 feet east of, and at roughly the same elevation as Well 5. Well 6 also is drilled and constructed to a similar depth as Well 5, tapping similar sand and gravel layers interpreted to be part of the upper SGA. On the basis of similar stratigraphic position as Well 5 and the updated interpretation of the hydrostratigraphy in the area, GSI has interpreted Well 6 to be completed in the SGA. Additional hydrogeologic information that supports this interpretation is provided in the following sections.

Groundwater Elevations

Groundwater elevations differ between wells completed in the TSA and SGA, as documented by several sources (Hartford and McFarland, 1989 and 1996; Leighton and Porcello, 2001; GSI 2001 and 2005; L). The groundwater elevations of wells completed in the SGA are significantly lower than the groundwater elevations of TSA wells (see attached Figures 1 and 2 from Hartford and McFarland, 1989). GSI measured groundwater elevations at several wells in the Fairview area in 2005, and again in 2010 (Table 1).

Table 1a. Summary of Groundwater Elevations Observed in 2005

Aquifer	Well	Date	DTW (ft)	GS Elev (ft)	GW Elev (ft)
TSA	33ad_382	2/22/2005	160.91	200	39
SGA	COF 3	3/2/2005	114	120	6
	COF 5	2/22/2005	115.5	120	5
	COF 6	3/2/2005	110	115	5
	COF 8	2/22/2005	21.5	38	17
	33ad_569	2/22/2005	194.71	200	5

Table 1b. Summary of Groundwater Elevations Observed in 2010

Aquifer	Well	Date	DTW (ft)	GS Elev (ft)	GW Elev (ft)
TSA	COF 7	10/5/2010	158.2	190	32
SGA	COF 3	10/5/2010	114.5	120	6
	COF 5	10/5/2010	114.8	120	5
	COF 6	10/5/2010	105.9	115	9
	COF 8	10/5/2010	31.7	38	6
	COF 9	10/5/2010	115.6	120	4

Notes: COF – City of Fairview; DTW = Depth to water; GS Elev = Ground surface elevation; GW Elev = Groundwater Elevation in feet above mean sea level.

The observed groundwater elevations at Fairview Well 6 correspond closely with other wells completed in the SGA. These data suggest that Fairview Well 6 is open to the SGA and not the TSA.

Hydraulic Testing

Measurements of water level changes at Fairview Well 6 during pumping of Fairview Well 5 also support the conclusion that Fairview Well 6 is completed in the SGA. Hydrographs showing water level measurements from Fairview Wells 5 and 6 for the period of January 1 through January 8, 2012 are shown on Figure 3. Fairview Well 5 was pumped at approximately 600 gallons per minute (GPM) during routine pumping cycles. The water level response observed in Fairview Well 6 was relatively instantaneous to the beginning and end of the pumping cycles at Fairview Well 5. A drawdown of 17 feet was observed in Fairview Well 6 after pumping Fairview Well 5 for approximately 9 hours.

Summary and Conclusions

Refinements to the hydrostratigraphic conceptual model in the vicinity of Fairview suggest that Fairview Well 6 is completed in the SGA rather than the TSA. Hydrogeologic data collected from known TSA and SGA wells support this alternate interpretation of the hydrostratiography:

- Aquifer water levels in Fairview Well 6 are consistent with nearby SGA levels and are significantly lower than those measured in the TSA.
- The water level at Fairview Well 6 responds distinctly and strong to pumping at Fairview Well 5, a well previously acknowledged by OWRD to be completed in the SGA.

References

Bet, J.N and M.L Rosner. 1993. Geology near Blue Lake County Park, eastern Multnomah County, Oregon. Oregon Geology, Volume 55, Number 3.

Hartford, S.V. and W.D. McFarland. 1989. Lithology, thickness, and extent of hydrogeologic units underlying the East Portland Area, Oregon. U.S. Geological Survey, Water-Resources Investigations Report 88-4110.

Hartford, S.V. and W.D. McFarland. 1996. Description of the Ground-Water Flow System in the Portland Basin, Oregon and Washington. U.S. Geological Survey, Water-Supply Paper 2470-A.

GSI. 2001. City of Fairview Production Well Site Evaluation. Technical Memorandum prepared by Groundwater Solutions, Inc. for the City of Fairview, August 31, 2001.

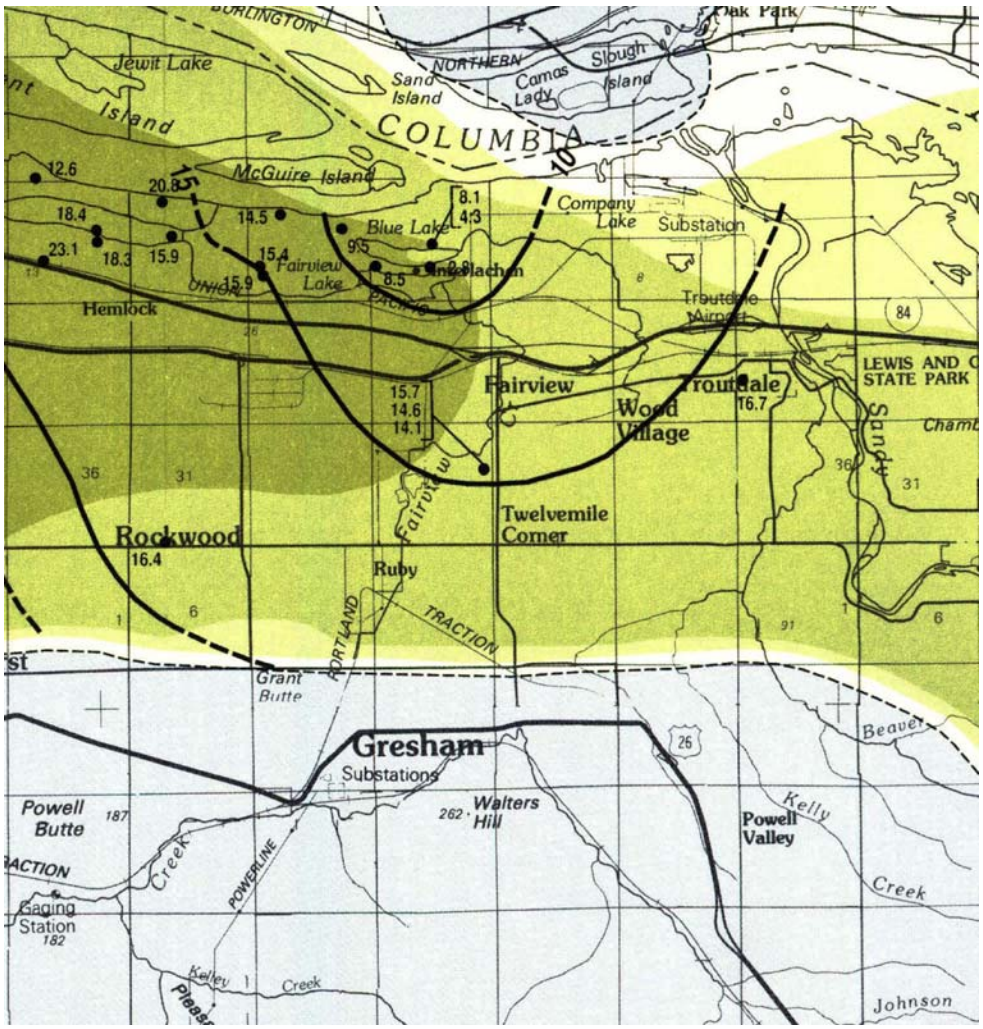
GSI. 2005. Conceptual Hydrogeologic Model Summary: City of Fairview, Oregon Transfer Application T-9808.

Leighton, J. and J. Porcello. 2001. Deep Aquifer Yield Groundwater Flow Model: Report on Model Development, Calibration and Testing. City of Portland Bureau of Water Works and CH2M HILL. July 2001.

OWRD. 2005. Note from Donn Miller dated June 8, 2005, hand written on GSI's Conceptual Hydrogeologic Model Summary: City of Fairview, Oregon Transfer Application T-9808, June 6, 2005.

Well Log Inventory

Well Name	Well Log	Abandonment Log
Well 3	MULT 1363/1364	MULT 106483
Well 5	MULT 1368/69818	n/a
Well 6	MULT 3104	n/a
Well 7	MULT 53960	n/a
Well 8	MULT 66769	n/a
Well 9	MULT 102164	n/a
33AD	(see Attachment 2)	n/a



THICKNESS OF UNIT, IN FEET

- 0 to 199
- 200 to 399
- 400 to 799
- 800 to 1,199

BOUNDARY SHOWING EXTENT OF UNIT

BOUNDARY OF STUDY AREA

100 GROUND–WATER LEVEL CONTOUR.—Shows altitude, in feet, of ground–water level, spring 1988. Dashed where approximate. Contour interval is variable. Datum is sea level.

15.9 FIELD–LOCATED WELL.—Completed in unit. Number is altitude in feet above sea level.

1:100,000

0 1 2 3 4 5 MILES

0 1 2 3 4 5 KILOMETERS

N

MAP NOTES:
Date: September 17, 2014
Data Sources: Portion of Plate 5 "Map Showing Extent, Thickness, and Spring 1988 Water Levels for the Sand and Gravel Aquifer" from USGS WSP 2470-A

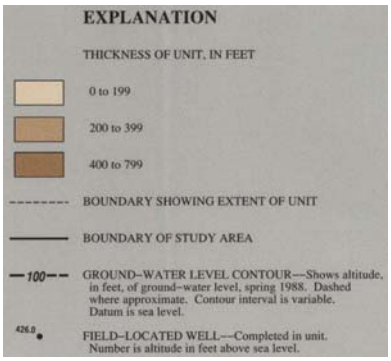
FIGURE 1

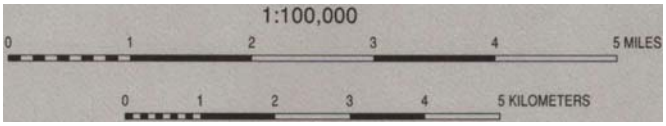
Groundwater Elevation of SGA

City of Fairview Water Rights Support

GSI Water Solutions, Inc.

Document Path: P:\Portland\117 - Fairview\019-FY14-15 GW Services\Project_GIS\Project_mxds\Figure1_GW_Elevation_of_SGA.mxd





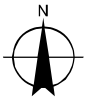


FIGURE 2

Groundwater Elevation of TSA

City of Fairview Water Rights Support

MAP NOTES:
Date: September 17, 2014
Data Sources: Portion of Plate 4 "Map Showing Extent, Thickness, and Spring 1988 Water Levels for the Troutdale Sandstone Aquifer" from USGS WSP 2470-A

GSI Water Solutions, Inc.

Document Path: P:\Portland\117 - Fairview\019-FY14-15 GW Services\Project_GIS\Project_mxds\Figure2_GW_Elevation_of_TSA.mxd

Water level response at Well 6 (MULT 3104) to pumping at Well 5 (MULT 1368/69818)

- Well 6 is located approximately 1,180 feet E-NE of Well 5
- Relatively instantaneous response to pumping at Well 5
- Drawdown of 17 feet after 9 hours of pumping at Well 5

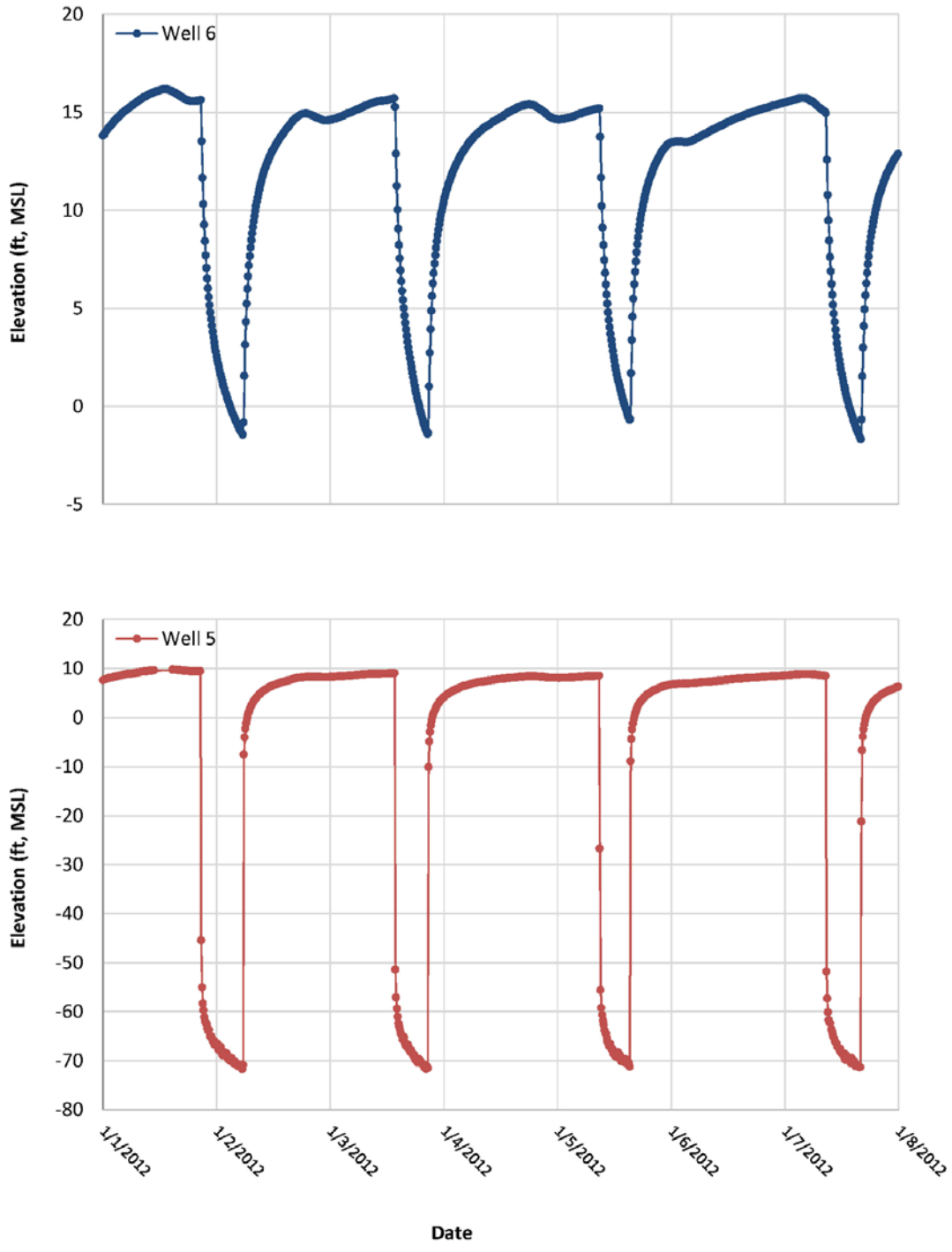


FIGURE 3

Fairview Well 6 Response to Pumping at Well 5

City of Fairview Water Rights Support

Date: September 18, 2014

GSI Water Solutions, Inc.

Document Path: P:\Portland\117 - Fairview\019-FY14-15 GW Services\Project_GIS\Project_mxds\Figure3_Well6_Reponse_to_Pumping_at_Well5.mxd

Attachment 1

Water Resources Department **State of Oregon**

Interoffice Memorandum March 22, 2012

To: File G-7563 (Permit G-7029, City of Fairview)

From: Karl Wozniak KW

Subject: Aquifer Designation for Well 6

The Municipal Extension Review of November 1, 2011 notes that Fairview Well 6 (MULT 3104) produces from the Troutdale Sandstone Aquifer. This conclusion was based on hydrogeologic unit designations made by the U.S. Geological Survey (Swanson and others, 1993) for the city's old Well 6 (MULT 1357) at the same well site.

On March 22, 2012, Ted Ressler and Walt Burt of GSI Water Solutions, Inc. presented an alternative interpretation of the hydro-stratigraphy of the area that suggests that Well 6 may actually produce from the upper part of the Sand and Gravel Aquifer. This alternative interpretation is based on a variety of hydrogeologic data that have been collected in recent years.

A preliminary review of the data at the meeting suggests that the alternative interpretation may be reasonable. GSI will write a report for placement in the file that synthesizes the new data and summarizes the new interpretation. When time permits, OWRD Groundwater Section will review the report and all existing data in order to make a final determination of the source aquifer for Well 6. Until then, the designation of the Troutdale Sandstone Aquifer as the source of water on the permit should be considered as tentative, not definitive.

Attachment 2

IN/3E 32AA2

(Rockwood Water District. Drilled by R.J. Strasser Drilling Co., 1976.)

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Top soil	5	5	Sandy clay	18	203
Sandy silty gravel	19	24	Cobbles, boulders	4	207
Sandy, gravelly, clayey silt	2	26	Sandstone	60	267
Sandy, silty gravel	10	36	Sandy gravel	22	289
Cobbely, gravelly, clayey sand	7	43	Clayey, sandy gravel	28	317
Sandy, silty gravel	69	112	Clean fine sand	35	352
Gravelly clay	4	116	Tight, sandy, gravelly silt	12	364
Sandy, silty gravel	3	119	Sand with silt stringers	12	376
Sandy, clay, brown	37	156	Clayey sand	12	388
Clay, blue	22	178	Sandy clay	12	400
Fine sandy silt	7	185			

IN/3E 33AD

(Water Bureau. Drilled by Hansen Drilling Co., 1976.)

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Fill	5	5	Black and green gravels with gray and white clay lenses	57	192
Gravel, small to medium (losing mud)	20	25	Black and green gravel with green to gray sandy clay	56	248
Gray clay, moderately indurated	5	30	Gravel with a light brown sandy clay matrix	19	267
Gray silty clay	4	34	Gravel with a light brown sandy clay matrix, slightly cemented	36	303
Yellow-brown micaceous sand	6	40	Green sandstone?	3	306
Light yellow sandy clay	6	46	Light brown silty clay	8	314
Gray sandy clay	3	49	Gravel, black sandstone, and brown clayey sand	7	321
Gray "sticky" clay	4	53	Black "glassy" sandstone	7	328
Black and green gravels	13	66	Black sandstone, gravel, and gray to brown silty to clayey sand	10	338
Green-gray to gray-brown sandy clay	6	72	Brown clayey sand	8	346
Black and green gravels interbedded with sandy clays	14	86			
Gray sandy clay	2	88			
Black and green gravels interbedded with sandy clays	24	112			
Black and green gravels with green sandy clay	23	135			

IN/3E 33AD
(Water Bureau. Drilled by Hansen Drilling Co., 1976.)
(Continued)

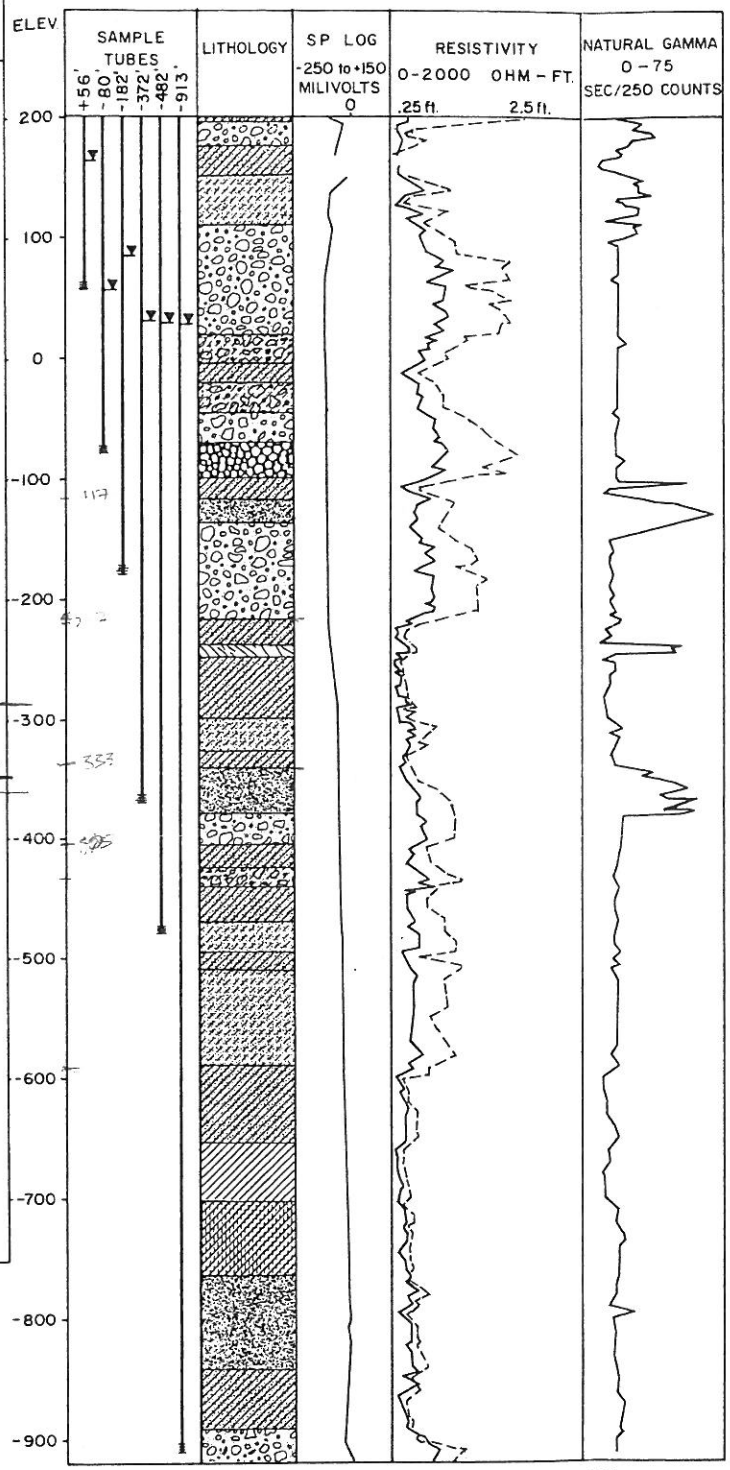
Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Gravel, black sandstone, and brown clayey sand	4	350	Gray micaceous sand with a varying content of light blue-green sandy clay	86	792
Basalt and quartzite gravel with gray clayey sand to sandy clay lenses	57	407	Gray-green silty clay and gray sand	55	847
Gravel with gray silty sand (Circulation lost at 415')	9	416	Gray sand and wood in various stages of decay. Some almost coal.	4	851
Sandy clay with gravel? (No circulation)	20	436	Green-gray silty clay	52	903
Siltstone? (No circulation)	8	444	Gray sandy clay ? (Circulation lost at 928')	42	945
Light brown to gray sandy clay	33	477	Sandstones of coarse grained and well rounded basalt, quartzite, and jaspers, with clay lenses ? (Sample, but no circulation)	101	1046
Light green-gray sandy and silty clay	22	499	Gravel with clay ? (Sample, but no circulation)	12	1058
Light green-gray sandy clay. Lens with approx. 50% mica near 500' level	35	534	Soft clay ? (Sample, but no circulation)	28	1086
Gray silty clay	7	541	Gray sandy clay with small gravel (Some samples, but no circulation)	14	1100
Black claystone	7	548	Gravel and gray clay (No circulation)	28	1128
Black sandstone interbedded with green to gray and green silty clay	16	564			
Black sandstone with small gravel (¼" to ½"). Percentage of gravel increasing with greater depth	16	580	(Samples from lower portion of hole tested with HCl with no reaction)		
Gravel with sandstone ? (No circulation)	26	606			
Green-gray sandy clay ? (No circulation)	20	626			
Interbedded clay and gravel ? (No circulation)	13	639			
Light blue-green sandy clay to clayey sand	57	696			
Light blue-green sandy clay	10	706			

AVENUE & STARK STREET

NATURAL GAMMA
0-100
SEC/250 COUNTS

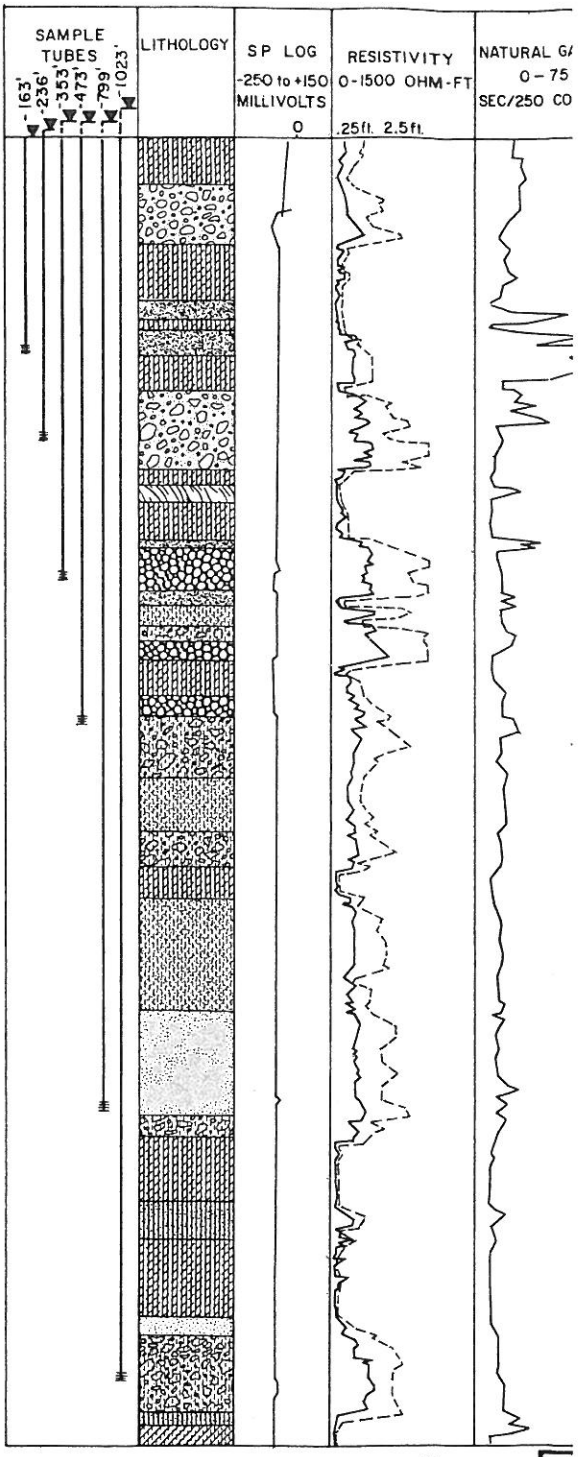
50 FEET
50 FEET
000 FEET

EXPLORATORY WELL IN/3E 33AD
@ N.E. FAIRVIEW AVENUE & GLISAN STREET



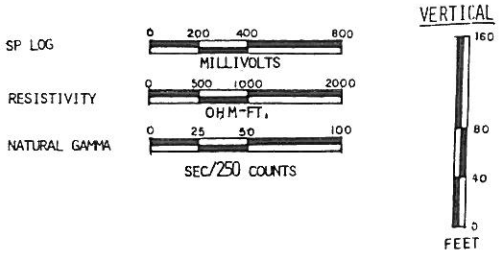
ELEVATION OF TOP OF WELL . . . . . 200 FEET
ELEVATION OF BOTTOM OF WELL. . . . . -928 FEET
TOTAL WELL DEPTH . . . . . 1128 FEET

EXPLORATORY WELL IN/3E 20CB2
ON N.E. 185th DRIVE



ELEVATION OF TOP OF WELL . . . . . 20 FEET
ELEVATION OF BOTTOM OF WELL. . . . . -1070 FEET
TOTAL WELL DEPTH . . . . . 1090 FEET

SCALES



NOTES

1. SP LOG IS THE SPONTANEOUS POTENTIAL LOG.
2. NUMBERS UNDER THE HEADING SAMPLE TUBES INDICATE THE ELEVATION OF THE BOTTOM OF THE SCREENS AT THE END OF EACH TUBE.