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.

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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

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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

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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.

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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

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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:

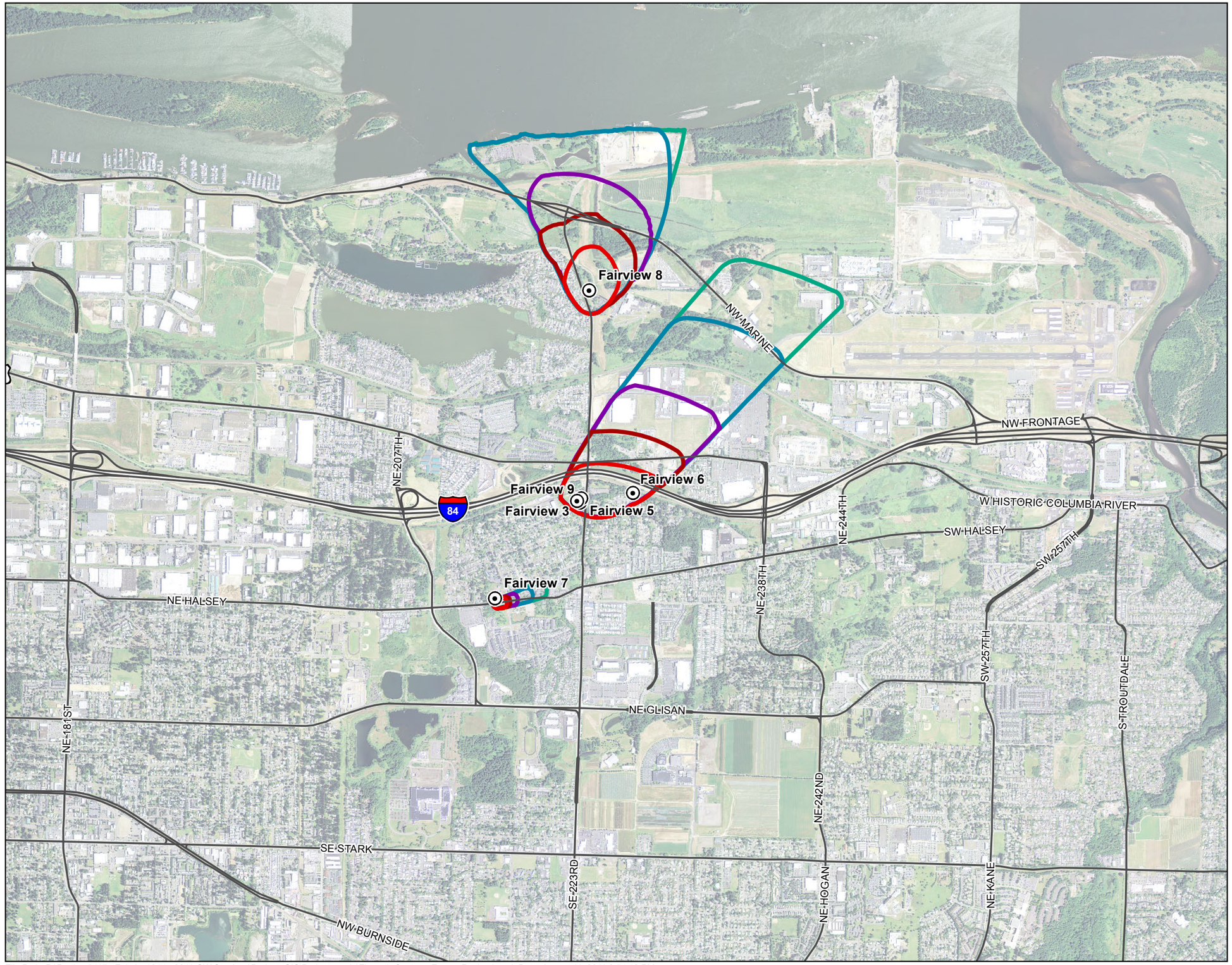
RWPUD = Rockwood Water People's Utility District
PWB = Portland Water Bureau
CSS = Columbia South Shore
SGA = Sand and Gravel Aquifer
MGD = millions of gallons per day
WA = Washington

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

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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