GSI Water Solutions, Inc.

Technical Memorandum

To: Eric Liljequist - City of Woodburn

From: Ted Ressler, *RG, CWRE* - GSI Water Solutions

Ryan Dougherty, *EIT* - GSI Water Solutions

Date: April 11, 2019

Re: City of Woodburn – Production Well Siting Evaluation

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1. Introduction

GSI Water Solutions, Inc. (GSI) presents this technical memorandum to the City of Woodburn (City) to summarize the findings and results of a Production Well Siting Evaluation, and to provide GSI's recommendations regarding the siting of a new production well for the City.

As outlined in GSI's letter proposals dated August 14th, 2018 and January 15th, 2019, the objective of the Production Well Siting Evaluation was to evaluate and compare the four potential locations identified by the City (**Figure 1**) for siting of a new municipal production well with target production capacity of 800 to 1,000 gallons per minute (gpm).

This technical memorandum is organized in the following structure:

- **Section 1 - Introduction:** This section presents the background, objectives, and organization of the Production Well Siting Evaluation.
- **Section 2 - Well Siting Evaluation Framework:** This section presents the evaluation framework for the Production Well Siting Evaluation, including an overview of well siting criteria and scoring methodology.
- **Section 3 - Well Siting Results:** This section presents the methodology of characterization and scoring results for each of the potential well site locations.
- **Section 4 - GSI Recommendations:** This section summarizes the results of the Production Well Siting Evaluation and provides GSI recommendation regarding the siting of a new municipal production well.

2. Well Siting Evaluation Framework

2.1 Overview of Well Siting Criteria and Scoring Methodology

GSI developed a framework to evaluate and compare the characteristics of each of the four potential well site locations (**Figure 1**), which included evaluating each potential well site by the following five criteria:

1. **Hydrogeology:** The thicknesses, depths, and yields of hydrogeologic units in the local area.
2. **Land Use Compatibility:** The compatibility of land use classifications at each site for the siting of public utility facilities such as production wells, pump houses, and conveyance lines.
3. **Contaminant Source Survey:** Identification and characterization of potential contaminant sources in the local area.
4. **Setback Requirements and Site Ownership:** The feasibility of meeting regulatory setback requirements for water supply wells at each site and reviewing potential property ownership constraints.
5. **Pumping Interference:** The potential pumping interference from a new production well on the City's existing wells and vice versa.

Infrastructure improvements necessary for the connection of a new production well at each of the potential well sites was evaluated by the City in its selection of the four potential well sites; hence, water system infrastructure was not a criteria directly included in this Production Well Siting Evaluation.

Each of the four potential well site locations was evaluated by the five well siting criteria outlined above, with scores being assigned to each criteria to aid in comparing well site locations. The methodology for scoring each well site location included assigning one of three overall scores to each criteria, being:

Positive (+)	Favorable site attributes are present, and/or minimal challenges are associated with development of the site.
Neutral (0)	Favorable site attributes are negated by unfavorable attributes, and/or moderate challenges are associated with development of the site.
Negative (-)	Unfavorable site attributes are present, and/or significant challenges are associated with development of the site.

Therefore, using the scoring methodology in conjunction with the well siting criteria, the maximum score a potential well site location can receive is 5 (+), or a positive (+) score for each well siting criteria.

2.2 Scoring Methodology

This section details the scoring methodology specific to each of the five well siting criteria.

Hydrogeology

The hydrogeology of each potential well site is critical for maximizing production capacity of a well. To compare the hydrogeologic characteristics of each potential well site location, the following parameters were considered:

- Aquifer Thickness: Conceptually, for an aquifer with a relatively homogenous composition, a larger aquifer thickness corresponds to a greater production capacity as more water bearing material is available for development. In this well siting evaluation, sites with larger aquifer thicknesses are scored more favorably than sites with small aquifer thicknesses.

- Available Drawdown: Available drawdown is the height of water in a well above the pump intake. Generally for wells completed in the same aquifer, a larger available drawdown will accommodate higher pumping rates, longer pumping durations, and subsequently higher production. In this well siting evaluation, sites with more available drawdown are scored more favorably than sites with less available drawdown.
- Well Specific Capacities: Specific capacity is a hydrogeologic metric that provides a general indication of aquifer production capacity, and is defined as the yield of water from a well (gallons per minute [gpm]) per unit of drawdown relative to the aquifer's static water level (feet). In this well siting evaluation, sites in the vicinity of wells with higher specific capacities are scored more favorably than sites with low specific capacities.

Land Use Compatibility

The land use compatibility classification of site regulates how the site can be developed and what uses can be allowed on the site. In this well siting evaluation, sites in which the development of a public utility facility (such as a production well and pump house) is an allowed use or conditional use are scored more favorably than sites not currently zoned to accommodate public utility facilities.

Contaminant Source Survey

The proximity of potential contaminant sources can be problematic for production wells as pumping operations can draw contaminants into the well and potentially degrade the groundwater quality to a level that requires additional treatment or abandonment of the production well. In this well siting evaluation, sites that are proximal to few potential contaminant sources are scored more favorably than sites that are proximal to many potential contaminant sources.

Setback Requirements and Site Ownership

Various regulatory authorities including the Drinking Water Services section of the Oregon Health Authority[1] (OHA) and the Oregon Water Resources Department[2] (OWRD) specify standards for the siting of water supply wells in the form of setback requirements. Key setback requirements for the siting of water supply wells include:

Setback Distance (feet)	**Setback Description**	**Regulatory Authority**
5	Any permanent structure not including pump houses	OWRD
50	Gravity sewer lines or septic tanks	OHA, OWRD
100	Maintain a 100 ft radius of control (aka. Sanitary Control)	OHA
100	Potential contaminant sources (ex. USTs, fuel storage)	OHA
500	Surface water	OHA
500	Hazardous waste storage, disposal, or treatment	OWRD

While some setback requirements can be waived if special construction measures are implemented, this well siting evaluation scores sites that are able to meet key setback requirements more favorably than sites that are unable to meet key setback requirements.

Additionally, site ownership is considered to determine the ease with which each well site could be developed with a public utility facility (such as a pump house). In this well site evaluation, sites that are owned by the City are scored more favorably than sites that are privately owned.

[1] See OAR 333-061-0050 (2)(a)(B-G) for OHA setback requirements

[2] See OAR 690-210-0030 (1) for OWRD setback requirements

Pumping Interference

Pumping interference occurs when the pumping operations of one well reduce the available drawdown and production capacity of a neighboring well. This phenomenon is commonly observed when production wells are in close proximity and draw groundwater from the same aquifer system. In this well site evaluation, sites that have a larger available drawdown after accounting for drawdown at the well during routine operation and pumping interference are scored more favorably than sites that have smaller available drawdown.

3. Well Siting Results

This section details the methodology of characterization for the well siting criteria and the resulting scoring results for each of the four potential well site locations.

3.1 Hydrogeology

Hydrogeologic Characterization

To evaluate the local hydrogeology of the four potential well site locations, GSI reviewed available geologic reports (USGS 1998; USGS 2001; USGS 2005), geologic spatial data (DOGAMI, 2015), and well logs and water quality data (OWRD, 2017) to develop a conceptual model of the local hydrogeologic system.

The City of Woodburn and the four potential well site locations (**Figure 1**) lie in the northern portion of the Willamette Valley, and are approximately bounded to the east and west by the Pudding and Willamette Rivers, respectively. Geologically, the Willamette Valley is classified as a broad alluvial plain that is primarily composed of alluvial fill. The majority of groundwater used in the Willamette Valley is sourced from these alluvial units (USGS, 2001).

Following review of available geologic information, GSI developed a map of surficial geology (**Figure 2**) and three cross sections (**Figures 3 through 5**) to further characterize subsurface conditions including the thickness, depths, and potential water yields of the hydrogeologic units. These cross sections convey the following information with respect to local hydrogeology:

- In the local area of the City's four potential well site locations, three primary hydrogeologic units were identified, being (from youngest to oldest):
    - **Missoula Flood Deposits:** Also referred to as part of the "Willamette Silt Unit", the Missoula Flood Deposits originated from sequential cataclysmic flood events from prehistoric Glacial Lake Missoula. In this portion of the Willamette Valley, the Missoula Flood Deposits are generally composed of stratified silts, clays, fine sands, and gravels with low water yields due to the abundance of fine grained material (USGS, 2001).
    - **Willamette Aquifer Unit:** The Willamette Aquifer is the source aquifer of the City's existing production wells and is generally composed of two course grained geologic units in the northern portion of the Willamette Valley. It is often difficult to differentiate between these two units as their physical composition and spatial distribution is similar (USGS, 2001).
        - Weathered Terrace Gravels: Originating from the weathering and deposition of igneous/volcaniclastic terraces of the Western Cascades, this unit generally consists of an upper horizon of silt and clay (thickness of 15-30 feet) followed by a lower horizon of stratified layers of cemented gravels and sands (thickness of 100-200 feet). Water yields from this unit are generally less than that of the Troutdale Equivalent due to the presence of more fine grained material.
        - Troutdale Equivalent: Originating from the high energy deposition of gravels and volcaniclastics via the ancestral Willamette River, the Troutdale Equivalent in the northern portion of the Willamette Valley generally consists of poorly sorted gravels and sands with thicknesses of 30-120 feet. High water yields are characteristic of this unit due to its course grained nature.
    - **Monroe Clay:** Also referred to as part of the "Willamette Confining Unit", the Monroe Clay unit originates from marine sedimentary rocks and fine grained volcanoclastic material of the Western Cascades. The Monroe Clay unit is the largest unit of the Willamette Valley by volume, and is generally composed of clays, shales, and

sandstones. Hydrogeologically, the Monroe Clay Unit is characterized as a confining unit due its low permeability (USGS, 1998).

- The static water level of the Willamette Aquifer in the local area is approximately 20-50 feet below ground surface (bgs), and varies seasonally by approximately 40 feet (Well 2 [MARI 2218], OWRD Monitoring Well). Based on local static water levels (**Figures 3 through 5**) the natural flow of groundwater is to the north-northeast, which is in-line with the general gradient of the regional aquifer system (USGS, 1998).
- The specific capacities of local wells sourcing water from the Willamette Aquifer averaged approximately 20.7 gpm/ft, indicating a potentially moderate aquifer production capacity. For comparison, a state survey of 142 wells sourcing water from the Willamette Aquifer found that 40% of wells had a specific capacity between 7 and 40 gpm/ft (USGS, 1998).

Scoring Results

With respect to hydrogeology, the following results and scores were developed for each of the four potential well site locations:

Well Site ID	Overall Score	Scoring Rational
Site 1	(+)	(+) The Willamette Aquifer is approximately 160 feet thick in the vicinity of Site 1; of this total thickness, the more productive Troutdale Equivalent is approximately 75 feet thick. (0) Assuming that a new well will seal off the Weathered Terrace Gravel unit and that the pump will be positioned above the Troutdale Equivalent unit, approximately 120 feet of initial available drawdown is available at Site 1 (Figure 3). (+) Specific capacities within a half mile radius of Site 1 ranged from 7 to 20 gpm/ft, with a geometric mean of 13.8 gpm/ft from a total of 3 wells.
Site 2	(+)	(0) The Willamette Aquifer is approximately 180 feet thick in the vicinity of Site 2; of this total thickness, the more productive Troutdale Equivalent is approximately 50 feet thick. (+) Assuming that a new well will seal off the Weathered Terrace Gravel unit and that the pump will be positioned above the Troutdale Equivalent unit, approximately 200 feet of initial available drawdown is available at Site 2 (Figure 3). (+) Specific capacities within a half mile radius of Site 2 ranged from 3.8 to 78.7 gpm/ft, with a geometric mean of 17.3 gpm/ft from a total of 2 wells.
Site 3	(+)	(+) The Willamette Aquifer is approximately 150 feet thick in the vicinity of Site 3; of this total thickness, the more productive Troutdale Equivalent is approximately 90 feet thick. (+) Assuming that a new well will seal off the Weathered Terrace Gravel unit and that the pump will be positioned above the Troutdale Equivalent unit, approximately 170 feet of initial available drawdown is available at Site 3 (Figure 3). (0) Specific capacities within a half mile radius of Site 3 ranged from 7 to 18.6 gpm/ft, with a geometric mean of 11.4 gpm/ft from a total of 2 wells.
Site 4	(0)	(0) The Willamette Aquifer is approximately 170 feet thick in the vicinity of Site 4; of this total thickness, the more productive Troutdale Equivalent is approximately 45 feet thick. However, there is a considerable degree of uncertainty associated with the depth and thickness of the Willamette Aquifer at Site 4 due to a lack of available information from adjacent wells. Additionally, the Willamette Aquifer as a whole appears to be thinning in the direction of Site 4 (Figure 5), which could limit the potential yield of the site. (+) Assuming that a new well will seal off the Weathered Terrace Gravel unit and that the pump will be positioned above the Troutdale Equivalent unit, approximately 190 feet of initial available drawdown is available at Site 4 (Figure 5). (0) Only one specific capacity was available within a half mile radius of Site 4, and equaled 18.6 gpm/ft. While this specific capacity is comparable to the other well sites, there is no additional data supporting whether this is specific capacity is representative of the area, or if this result is anomalous.

Comparison of the four well sites shows that no well site substantially stands above the others in terms of favorable hydrogeologic characteristics or potential water yield. While Site 1 and Site 3 have a larger thickness of the more productive aquifer unit (Troutdale Equivalent), these sites have lower specific capacities than Site 2 and Site 4. In contrast, while Site 2 and Site 4 have higher

specific capacities, the large spread between specific capacities at Site 2 (3.8 and 78.7) and small sample size for both Site 2 and Site 4 (Site 2=2 wells, Site 4=1well) suggests uncertainty regarding the capacity of the aquifer in the vicinity of these sites. With respect to available drawdown, Site 2 and Site 4 have the largest initial available drawdown (Site 2=200 feet, Site 4=190 feet). However, while the available drawdown at Site 1 and Site 3 is less than that of Site 2 and Site 4, the available drawdown at these two sites is still favorable for installation of a new production well.

3.2 Land Use Compatibility

Land Use Compatibility Characterization

To evaluate the land use compatibility of the four potential well site locations, GSI reviewed tax lot data (Marion County, 2011) and contacted the City of Woodburn Community Development Department and the Marion County Planning Department to determine whether development of a public utility facility (such as a production well and pump house) is an allowed use or conditional use.

Scoring Results

Results of GSI's land use compatibility evaluation are presented on **Table 1**. Results and scores specific to each potential well site location are discussed below:

Well Site ID	Overall Score	Scoring Rational
Site 1	(+)	(+) Site 1 is located within the city limits of the City of Woodburn, therefore the City has regulatory authority[3] over the site's land use compatibility and development. The land use zoning code of Site 1 is public/semi-public (P/SP). Development of public utility facilities under this zoning code is allowed outright.
Site 2	(+)	(+) Site 2 is located within the city limits of the City of Woodburn, therefore the City has regulatory authority over the site's land use compatibility and development. The land use zoning code of Site 2 is commercial general (CG). Development of public utility facilities under this zoning code is allowed outright.
Site 3	(+)	(+) Site 3 is located within the City of Woodburn's UGB, therefore Marion County has regulatory authority[4] over the site's land use compatibility and development. The land use zoning code of Site 3 is urban transitional (UT-20). Development of public utility facilities under this zoning code is allowed outright.
Site 4	(+)	(+) Site 4 is located within the City of Woodburn's UGB, therefore Marion County has regulatory authority over the site's land use compatibility and development. The land use zoning code of Site 4 is urban transitional (UT-20). Development of public utility facilities under this zoning code is allowed outright.

In summary, the development of public utility facilities (such as a production well and pump house) is a land use that is allowed outright for all four well sites.

3.3 Contaminant Source Survey

Contaminant Source Survey Characterization

To identify and characterize potential contaminant sources within the vicinity of the four potential well site locations, GSI reviewed contaminant source spatial data from DEQ (DEQ, 2018) and GSI procured a third party environmental data report (Appendix A) to verify the accuracy of DEQ's spatial data.

Following the review of available datasets, GSI developed a map of the locations of identified potential contaminant sources within a one mile radius of each well site (**Figure 6**). Information associated with these potential contaminant sources are presented on **Table 2** and also included in **Appendix A**. The following general observations regarding potential contaminant sources have been noted for the local area:

[3] See Woodburn Development Ordinance (WDO) Table 2.03A and Table 2.04A

[4] See Marion County Code Chapter 16.13

- A total of 37 unique potential contaminant sources were identified within a one mile radius of each well site.
- Of the 37 identified potential contaminant sources, a majority (78%) were associated with underground storage tanks (USTs) for diesel, gasoline, or heating oil. Approximately 48% of these USTs were identified as active or former leaking underground storage tanks (LUSTs).
- Of the 37 identified potential contaminant sources, seven were associated with the generation of hazardous waste. These hazardous waste generators are located in the northwest portion of the City's UGB (**Figure 6**), and are primarily associated with gas stations or waste disposal of chemicals by distribution warehouses. All seven of these facilities are located downgradient of the potential well sites by at least three quarters of a mile.
- Based on local static water levels, the flow of groundwater appears to be to the north-northeast. A majority of the identified potential contaminant sources were located downgradient (i.e., north-northeast) of the potential well sites (**Figure 6**).
- While 37 potential contaminant sources were identified within a one mile radius of each well site, it is unlikely that any of these potential contaminant sources will impact the groundwater quality of each well site because all of the potential contaminant sources are located within the Willamette Silt Unit and that the confining nature of the Willamette Silt Unit will prevent contaminants from migrating downward to groundwater of the target aquifer. Additionally, several; of the City's existing production wells (Well 7, Well 9, and Well 11) are located in closer proximity to the majority of the identified potential contaminant sources and these existing wells have not historically been impacted by the identified potential contaminant sources. Therefore, it is likely that the four potential well site locations will similarly be protected from the identified potential contaminant sources.

The third party environmental radius map reports (**Appendix A**) verified the accuracy of the DEQ's potential contaminant source dataset and also provided additional information associated with historical potential contaminant sources. However, none of these historical potential contaminant sources were identified as risks to the siting of a new production well as they are classified as non-active sites, or sites where cleanup has been completed.

Scoring Results

Results of GSI's contaminant source survey are presented on **Table 2**. Results and scores specific to each potential well site location are discussed below:

Well Site ID	Overall Score	Scoring Rational
Site 1	(0)	(0) Site 1 had a total of 2 potential contaminant sources within a one mile radius. However, it is not likely that any of the identified potential contaminant sources will impact the groundwater quality of Site 1, as the confining nature of the Willamette Silt Unit will likely prevent contaminants from migrating to groundwater of the target aquifer. (+) Site 1 is upgradient and distal (>0.5 miles) to a majority of the identified potential contaminant sources.
Site 2	(0)	(0) Site 2 had the highest total number of potential contaminant sources within a one mile radius, with a total of 35 potential contaminant sources being identified. However, it is not likely that any of the identified potential contaminant sources will impact the groundwater quality of Site 2, as the confining nature of the Willamette Silt Unit will likely prevent contaminants from migrating to groundwater of the target aquifer. (+) Site 2 is upgradient and distal (>0.5 miles) to a majority of the identified potential contaminant sources.
Site 3	(0)	(0) Site 3 had a total of 8 potential contaminant sources identified within a one mile radius. However, it is not likely that any of the identified potential contaminant sources will impact the groundwater quality of Site 2, as the confining nature of the

		Willamette Silt Unit will likely prevent contaminants from migrating to groundwater of the target aquifer. (+) Site 3 is upgradient and distal (>0.5 miles) to a majority of the identified potential contaminant sources.
Site 4	(0)	(0) Site 4 had the lowest total number of potential contaminant sources within a one mile radius, with a total of 1 potential contaminant source being. However, it is not likely that the identified potential contaminant source will impact the groundwater quality of Site 4, as the confining nature of the Willamette Silt Unit will likely prevent contaminants from migrating to groundwater of the target aquifer. (+) Site 4 is upgradient and distal (>0.5 miles) to a majority of the identified potential contaminant sources.

While all four potential well sites scored approximately equivalently, Well Site 4 had the fewest number (total of 1) of potential contaminant sources within a one mile radius, followed by Site 1 (total of 2). While Site 2 and Site 3 have a higher number of potential contaminant sources located within a one mile radius, it is unlikely that any of the identified potential contaminant sources will impact the groundwater quality of at any of the four potential well sites due to:

- The general low risk associated with the majority of potential contaminant sources (residential USTs);
- The confining/protective buffer of the Willamette Silt Unit; and
- All sites being naturally upgradient of a majority of the identified potential contaminant sources.
- No history of detections related to the identified potential contaminant sources at the City's existing production wells, several of which are located in closer proximity to the potential contaminant sources than the three potential well sites being evaluated.

3.4 Setback Requirements and Site Ownership

Setback Requirements and Site Ownership Characterization

To evaluate whether each of the four potential well sites could meet applicable regulatory standards[5] for the siting of water supply wells (ie. setback requirements), GSI reviewed regulatory setback distances (see Section 2.2) and mapped features impacting setback requirements and developed setback radii for each well site (**Figure 7**). Additionally, GSI evaluated the ownership of each well site to determine the ease with which each well site could be developed with a public utility facility (such as a pump house). Site ownership information is presented on **Table 1**.

Scoring Results

Results of GSI's setback requirement and site ownership evaluation specific to each potential well site location are discussed below:

Well Site ID	Overall Score	Scoring Rational
Site 1	(+)	(+) It is likely all regulatory setback distances (see Section 2.2) can be met for a new water supply well. (+) Site 1 is owned by the City of Woodburn.
Site 2	(0)	(+) It is likely all regulatory setback distances (see Section 2.2) can be met for a new water supply well. (-) Site 2 is privately owned (MWVP, Inc.).
Site 3	(0)	(+) It is likely all regulatory setback distances (see Section 2.2) can be met for a new water supply well. (-) Site 3 is privately owned (Weisz Family, LLC).
Site 4	(+)	(+) It is likely all regulatory setback distances (see Section 2.2) can be met for a new water supply well. (0) Site 1 is owned by the State of Oregon.

[5] See OAR 333-061-0050 (2)(a)(B-G) for OHA setback requirements; See OAR 690-210-0030 (1) for OWRD setback requirements

While it is likely that each of the three potential well site locations can meet regulatory setback requirements (see Section 2.2), Site 1 and Site 4 scored more favorably than Site 2 and Site 3 due to ownership of the sites by the City (Site 1) and the State of Oregon (Site 4). Because these two sites are owned by either the City (Site 1) or State of Oregon (Site 4) it is likely that development and operation of a public utility facility (such as a pump house) could be accomplished with ease.

3.5 Pumping Interference

Pumping Interference Characterization

To estimate the potential pumping interference (drawdown) between each of the four potential well site locations and existing local wells, GSI reviewed pump test data provided by the City (**Appendix B**) and hydrogeologic reports (USGS 1998; USGS 2005) to develop aquifer parameters for the Willamette Aquifer. These aquifer parameters were then used to estimate the potential pumping interference of each potential well site using the Cooper-Jacob method, under the following pumping assumptions/pumping scenario:

Parameter / Assumption	Source
Confined aquifer conditions	Conservative assumption
Transmissivity of 35,000 gpd/ft	Well 12 pump test data (**Appendix B**)
Storage coefficient of 0.07	USGS 1998; USGS 2005
Constant pumping rate of 1,000 gpm	Target capacity of new well site
Pumping duration of 274 days	Conservative assumption

The pumping scenario outlined above was developed to provide a conservative estimate of potential pumping interference due to the uncertainty associated with characteristics of the Willamette Aquifer at each potential well site location (ie. spatial variability of storage coefficients, transmissivity, etc.).

GSI estimated potential pumping interference (drawdown) for the pumping scenario outlined above and developed a map of anticipated drawdown in the area of each well site location (**Figure 8**). The following general observations and trends regarding potential pumping interference have been noted for the pumping scenario outlined above:

- The horizontal extent of pumping interference at any of the four well site locations is conservatively estimated to be 3,500 feet. GSI defines the extent of pumping interference as the point where drawdown was equal to or less than 5 feet.
- For Site 1 and Site 3, it is anticipated that only one City well (Well 12) will induce/experience pumping interference. Site 2 and Site 4 are not anticipated to meaningfully (<5 feet) interfere with any existing City wells.
- For all four well site locations, it is anticipated that existing high rate irrigation wells (authorized rate >200 gpm) will result in pumping interference. The list of high rate irrigation wells and their cumulative pumping interference on each of the four well site locations is presented on **Table 3**.
- While there is some uncertainty regarding the aquifer parameters utilized in the pumping interference evaluation, it should be noted that the refinement of aquifer parameters should not impact the well site scoring results because all four well sites will experience uniform changes to the horizontal extent and magnitude of pumping interference.

Scoring Results

Results of GSI's pumping interference evaluation are presented on **Table 3**. Results and scores specific to each potential well site location are discussed below:

Well Site ID	Overall Score	Scoring Rational
Site 1	(-)	(-) Site 1 is anticipated to experience total interference of 19 feet, from existing City wells (10 feet, Well 12) and high rate irrigation wells (9 feet). (-) After accounting for; initial available drawdown (at seasonal low static conditions), estimated well pump dimensions and submergence requirements, drawdown at the new production well, and pumping interference, the remaining available drawdown at Site 1 is estimated to be 28 feet (See Table 3 for details).
Site 2	(+)	(0) Site 2 is anticipated to experience total interference of 12 feet, exclusively from high rate irrigation wells. (+) After accounting for; initial available drawdown (at seasonal low static conditions), estimated well pump dimensions and submergence requirements, drawdown at the new production well, and pumping interference, the remaining available drawdown at Site 2 is estimated to be 108 feet (See Table 3 for details).
Site 3	(0)	(-) Site 3 is anticipated to experience total interference of 16 feet, from existing City wells (7 feet, Well 12) and high rate irrigation wells (9 feet). (+) After accounting for; initial available drawdown (at seasonal low static conditions), estimated pump dimensions and submergence requirements, drawdown at the new production well, and pumping interference, the remaining available drawdown at Site 3 is estimated to be 75 feet (See Table 3 for details).
Site 4	(+)	(0) Site 4 is anticipated to experience total interference of 10 feet, exclusively from high rate irrigation wells. (+) After accounting for; initial available drawdown (at seasonal low static conditions), estimated pump dimensions and submergence requirements, drawdown at the new production well, and pumping interference, the remaining available drawdown at Site 4 is estimated to be 97 feet (See Table 3 for details).

In terms of potential pumping interference and remaining available drawdown, Site 2 and Site 4 score more favorably than Site 1 and Site 3 as it is anticipated that Site 2 and Site 4 will not meaningfully interfere with existing City wells and that approximately 100 feet of available drawdown will remain for either site after consideration of estimated drawdown at the well during operation and pumping interference.

Site 1 was found to be the least favorable in terms of potential pumping interference and remaining available drawdown due to the interference that is anticipated to be induced/experienced by Well 12 (10 feet) and the comparatively low remaining available drawdown of 28 feet. Site 3 was scored less favorably than Site 2 and Site 4 due to a lower remaining available drawdown of 75 feet. However, it is likely that the remaining available drawdown of Site 3 (75 feet) should be sufficient for supporting year-round pumping, regardless of variations in encountered aquifer conditions or seasonal water level fluctuations.

4. GSI Recommendations

The cumulative results of the City's Production Well Siting Evaluation are presented on **Table 4**. Based on the results of the categories evaluated in this Production Well Siting Evaluation, Site 2 and Site 4 ranked the highest overall (3+) with Site 1 and Site 3 scoring slightly lower (2+). A summary of the positive and negative elements of each of the well sites is provided below:

- **Site 2:** Site 2 scored favorably in terms of potential pumping interference, as it is anticipated that Site 2 will not meaningfully (<5 feet) interfere with any existing City wells and will have the largest remaining available drawdown (108 feet). Site 2 scored equivalently or higher than the three other well sites in terms of hydrogeology, land use compatibility, and potential contaminant sources. Site 2 scored less favorably than Site 1 and Site 4 in terms of site ownership, as Site 2 is privately owned, and thus is anticipated to have higher site development costs.

- **Site 4:** Similar to Site 2, Site 4 scored favorably in terms of potential pumping interference, as it is anticipated that Site 4 will not meaningfully (<5 feet) interfere with any existing City wells and will have a substantial remaining available drawdown (97 feet). However, in terms of hydrogeology, Site 4 scored lower than the other three well sites due to; the limited thickness of the more productive Troutdale Equivalent unit, the apparent thinning of the Willamette Aquifer near Site 4 (**Figure 4**), and the degree of uncertainty associated with the hydrogeologic setting. While Site 4 scored the least favorable in terms of hydrogeology, it scored equivalently or higher than the other well sites in terms of land use compatibility, potential contaminant sources, and site ownership (owned by the State of Oregon).

- **Site 3:** Site 3 scored equivalently or higher than the other well sites in terms of hydrogeology, land use compatibility, and potential contaminant sources. However, Site 3 scored less favorably in terms of site ownership because Site 3 is privately owned, and also in terms of potential pumping interference due to the anticipated magnitude of interference induced/experienced by other existing City wells (7 feet, Well 12) and a slightly less amount of remaining available drawdown (75 feet).

- **Site 1:** Site 1 scored the most favorably in terms of site ownership, as the property is owned outright by the City. Additionally, Site 1 scored equivalently or higher than the other three well sites for hydrogeology, land use compatibility, and potential contaminant sources. However, Site 1 scored the least favorably in terms of potential pumping interference due to the anticipated magnitude of interference induced/experienced by other existing City wells (10 feet, Well 12), and the minimal amount of remaining available drawdown (28 feet) compared to the other well sites.

On the basis of the findings from this Production Well Siting Evaluation, GSI recommends Site 2 for development of the planned new municipal production well.

We appreciate this opportunity to work with the City on this project. Please contact us if you have any questions regarding this technical memorandum.

Sincerely,
GSI Water Solutions, Inc.

Ted Ressler, *RG, CWRE*
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Ryan Dougherty, *EIT*
Staff Hydrogeologist

Figures:

Tables:

Appendices:

References:

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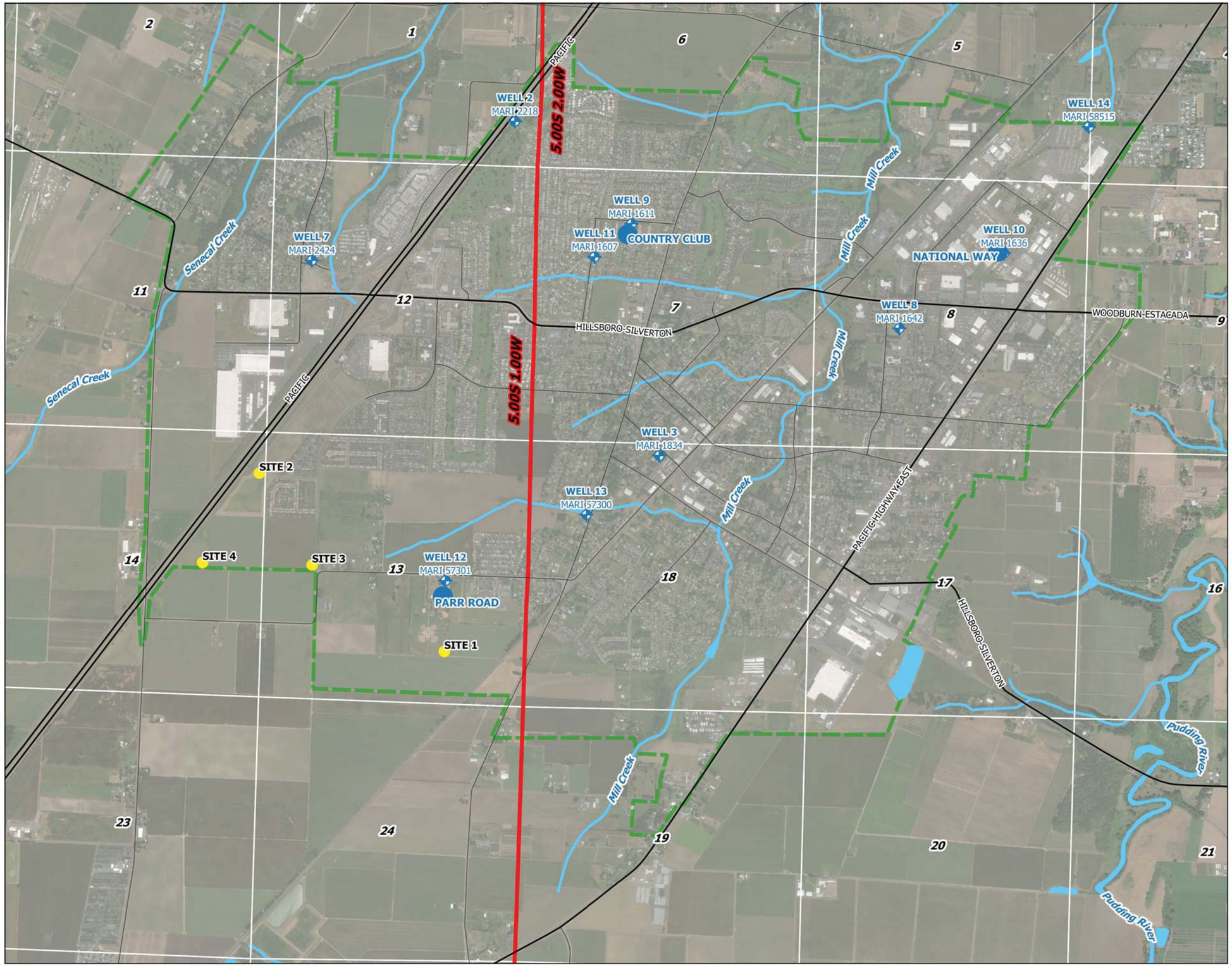
Figures

FIGURE 1

Site Location and Proposed Well Sites

City of Woodburn Well Siting



LEGEND

- Proposed Well Site
- City Well
- Water Treatment Plant
- Road
- Watercourse
- Woodburn UGB

N

0 950 1900 2850

Feet

Date: August 20, 2018
Data Sources: OWRD, USGS

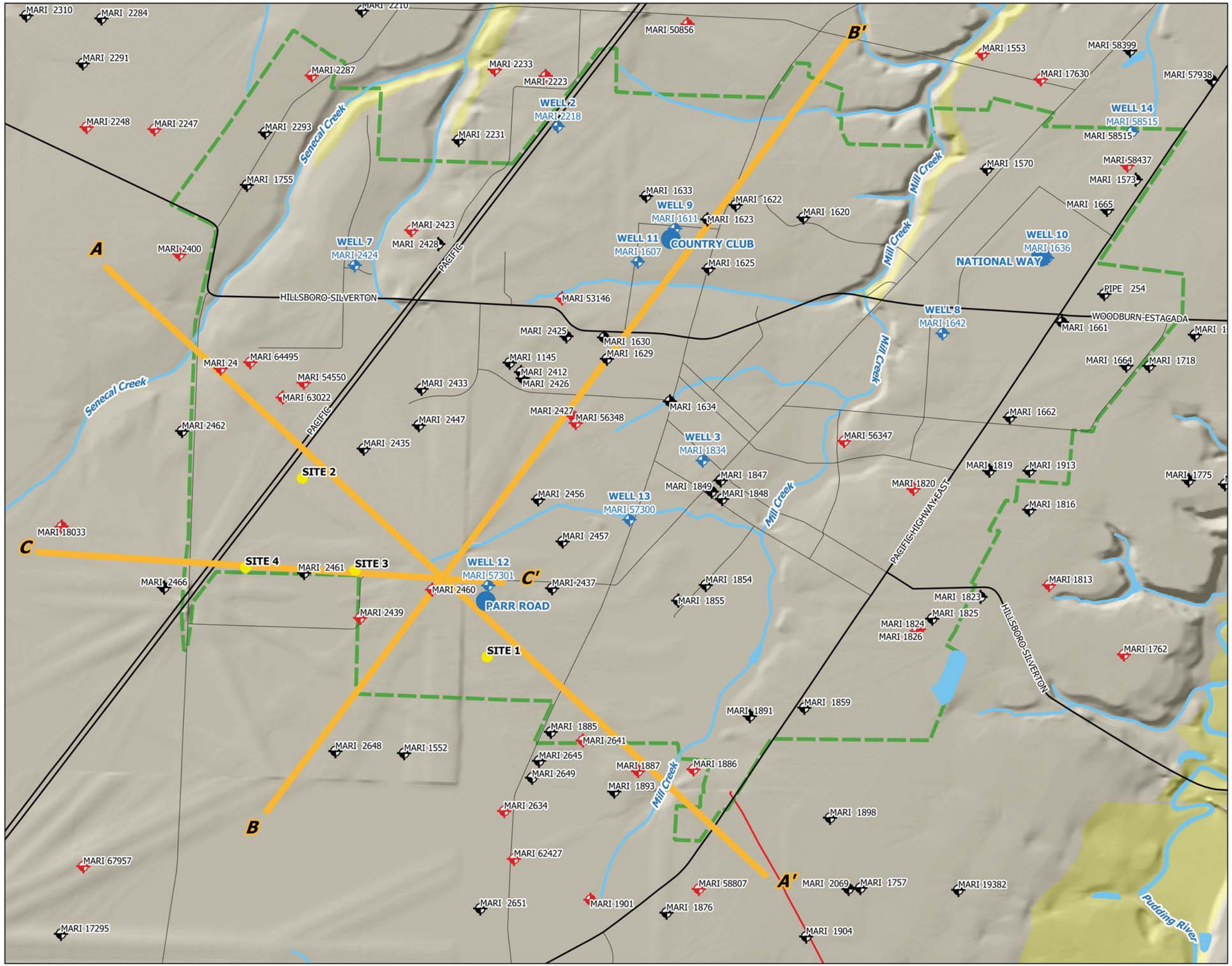
GSI Water Solutions, Inc.

Document Path: Y:\0762_Woodburn\Source_Figures\002_Well_Siting

FIGURE 2

Surficial Geology and Well Log Locations

City of Woodburn Well Siting



LEGEND

- Proposed Well Site
- City Well
- Well (>200 ft)
- Well
- Cross Section Transect
- Water Treatment Plant
- Road
- Watercourse
- Woodburn UGB

Geology Legend

- Known Fault (DOGAMI)
- Inferred Fault
- Alluvial Deposits (Qal, Qaff): Unconsolidated silts, sands, and gravels
- Missoula Flood Deposits (Qoal, Qff2): Stratified silts, clays, sands and gravels

N

0 950 1900 2850

Feet

Date: August 20, 2018
Data Sources: OWRD, USGS, DOGAMI

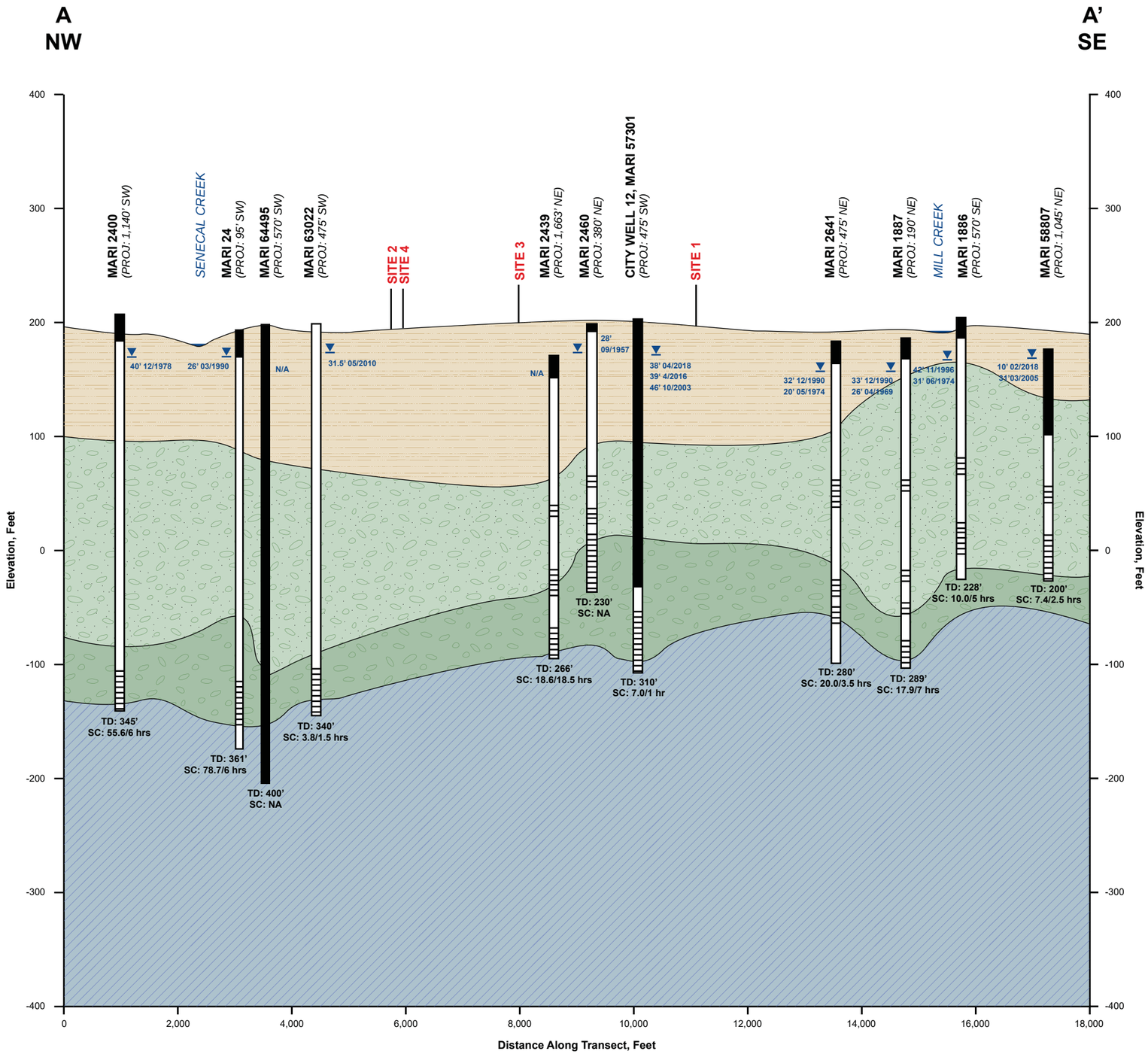
GSI Water Solutions, Inc.

Document Path: Y:\0762_Woodburn\Source_Figures\002_Well_Siting

FIGURE 3

Cross Section A-A'

City of Woodburn Well Siting



LEGEND

- Static Water Level at Well

Geology

- Missoula Flood Deposit
- Willamette Aquifer
  - *Willamette Basin Weathered Terrace*
  - *Troutdale Equivalent Formation*
- Monroe Clay

Well

- Cement Seal
- Casing
- Screen/Perforated Casing
- Open Borehole

NOTES:

GPM	Gallons per Minute
PROJ	Projected
SC	Specific Capacity
TD	Total Depth
NA	Not Applicable - Water level measurement excluded due to projection distance or unavailable data.

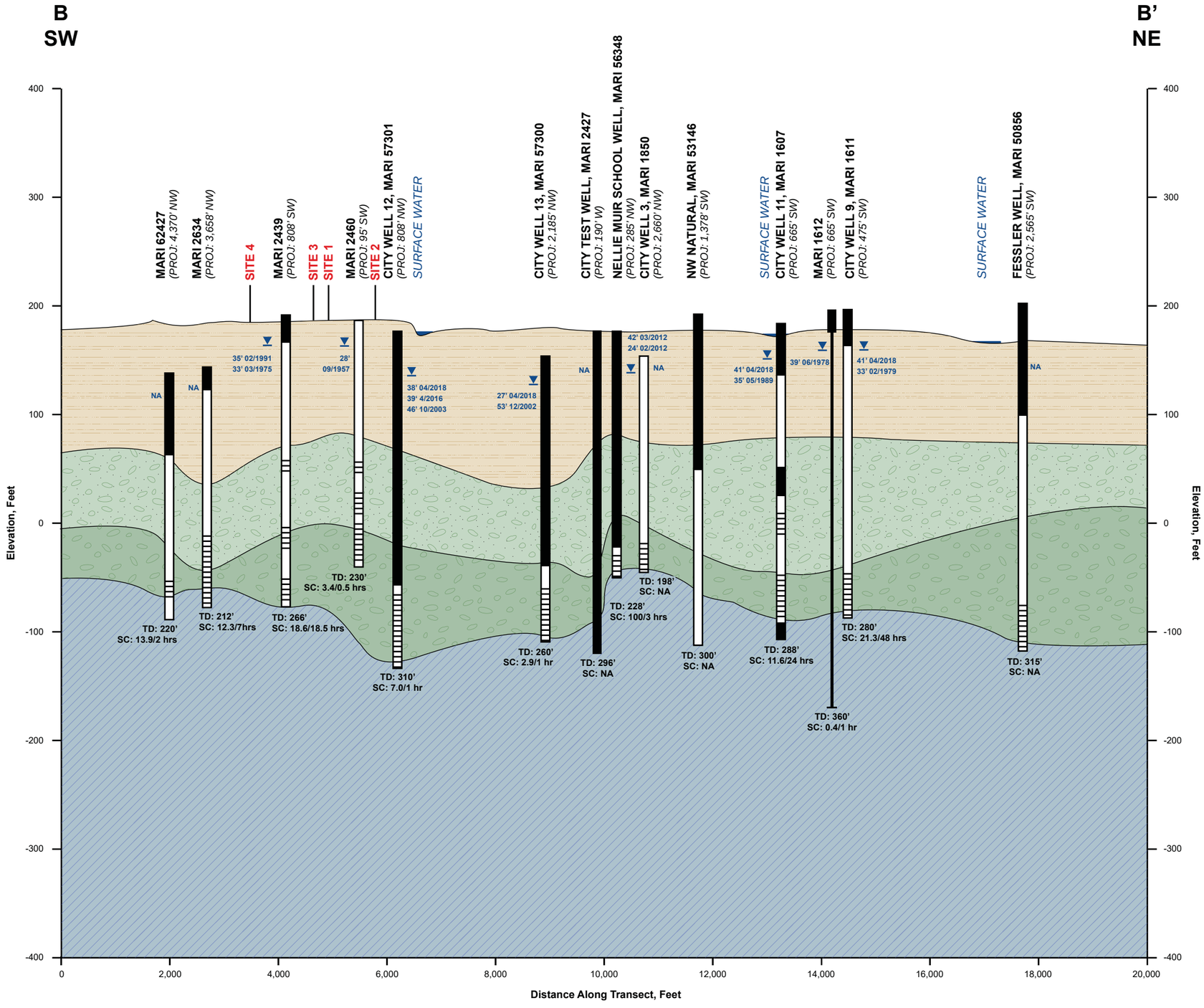
GSI Water Solutions, Inc.

Y:\0762_Woodburn\Source_Figures\002_Well_Siting

FIGURE 4

Cross Section B-B'

City of Woodburn Well Siting



LEGEND

- Static Water Level at Well

Geology

- Missoula Flood Deposit
- Willamette Aquifer
  - *Willamette Basin Weathered Terrace*
  - *Troutdale Equivalent Formation*
- Monroe Clay

Well

- Cement Seal
- Casing
- Screen/Perforated Casing
- Open Borehole

NOTES:

GPM	Gallons per Minute
PROJ	Projected
SC	Specific Capacity
TD	Total Depth
NA	Not Applicable - Water level measurement excluded due to projection distance or unavailable data.

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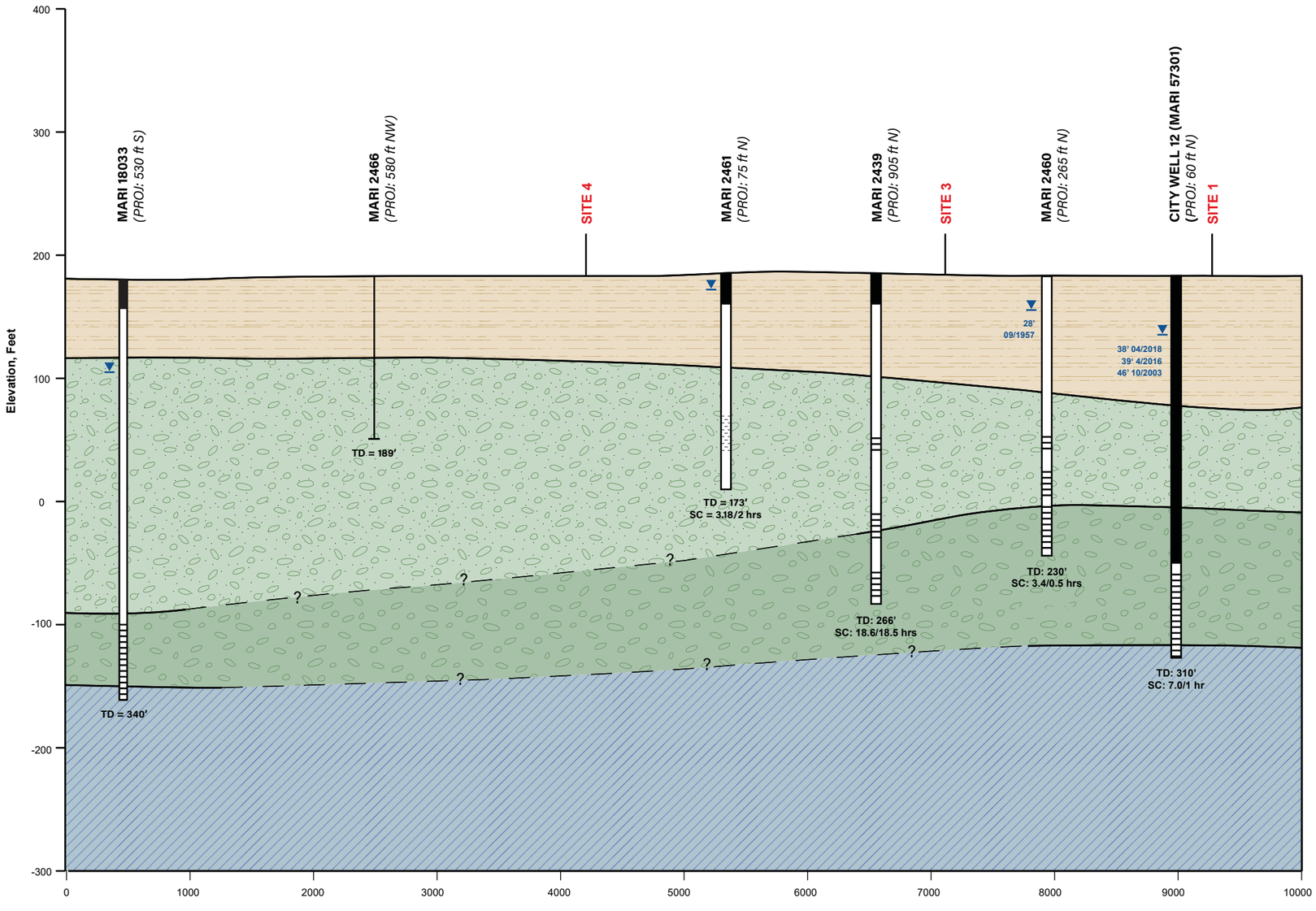
Y:\0762_Woodburn\Source_Figures\002_Well_Siting

FIGURE 5

Cross Section C-C'

City of Woodburn Well Siting



LEGEND

- Static Water Level

Geology

- Missoula Flood Deposit

Willamette Aquifer

- *Willamette Basin Weathered Terrace*
- *Troutdale Equivalent Formation*
- Monroe Clay

Well

- Cement Seal
- Casing
- Screen/Perforated Casing
- Open Borehole

NOTES:

GPM Gallons per Minute
PROJ Projected
SC Specific Capacity
TD Total Depth
NA Not Applicable - Water level measurement excluded due to projection distance or unavailable data.

Date: February 21 2019

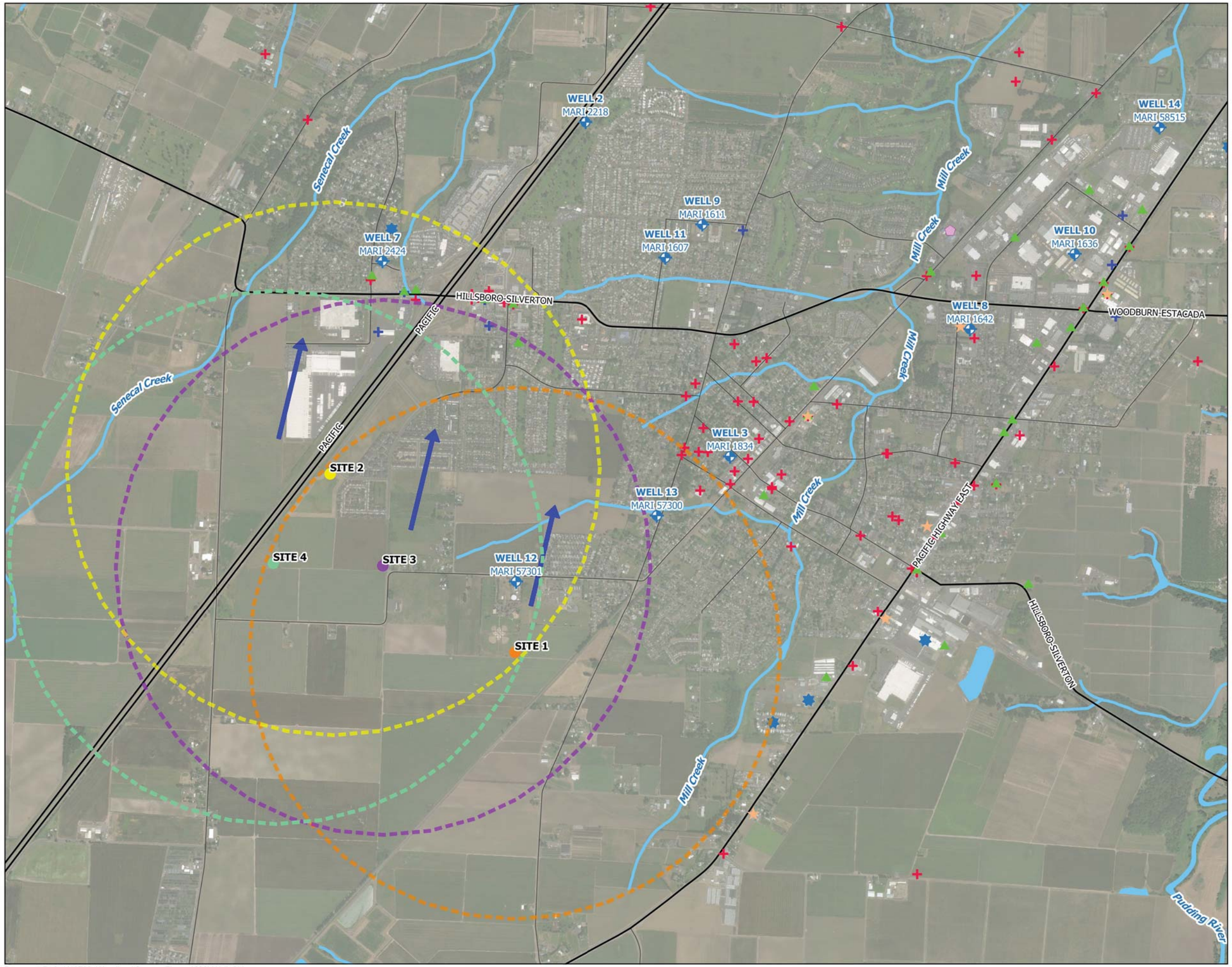
GSI Water Solutions, Inc.

Y:\0762_Woodburn\Source_Figures\002_Well_Siting

FIGURE 6

Contaminant Source Survey

City of Woodburn Well Siting



LEGEND

- Proposed Well Site
- 1 Mile Radius from Proposed Well Sites
- City Well
- Road
- Watercourse
- Infrerred Groundwater Flow Direction
- Woodburn UGB

Contaminant Source Survey Legend

- Environmental Cleanup Site Information (ECSI)
- Hazardous Waste (HAZWASTE)
- Underground Storage Tanks (UST)
- Leaking Underground Storage Tanks (LUST)
- Solid Waste Information Facility Tracking (SWIFT)
- Water Quality Underground Injection Control (WQUIC)

N

0 950 1900 2850
Feet

Date: August 20, 2018
Data Sources: OWRD, USGS, DEQ

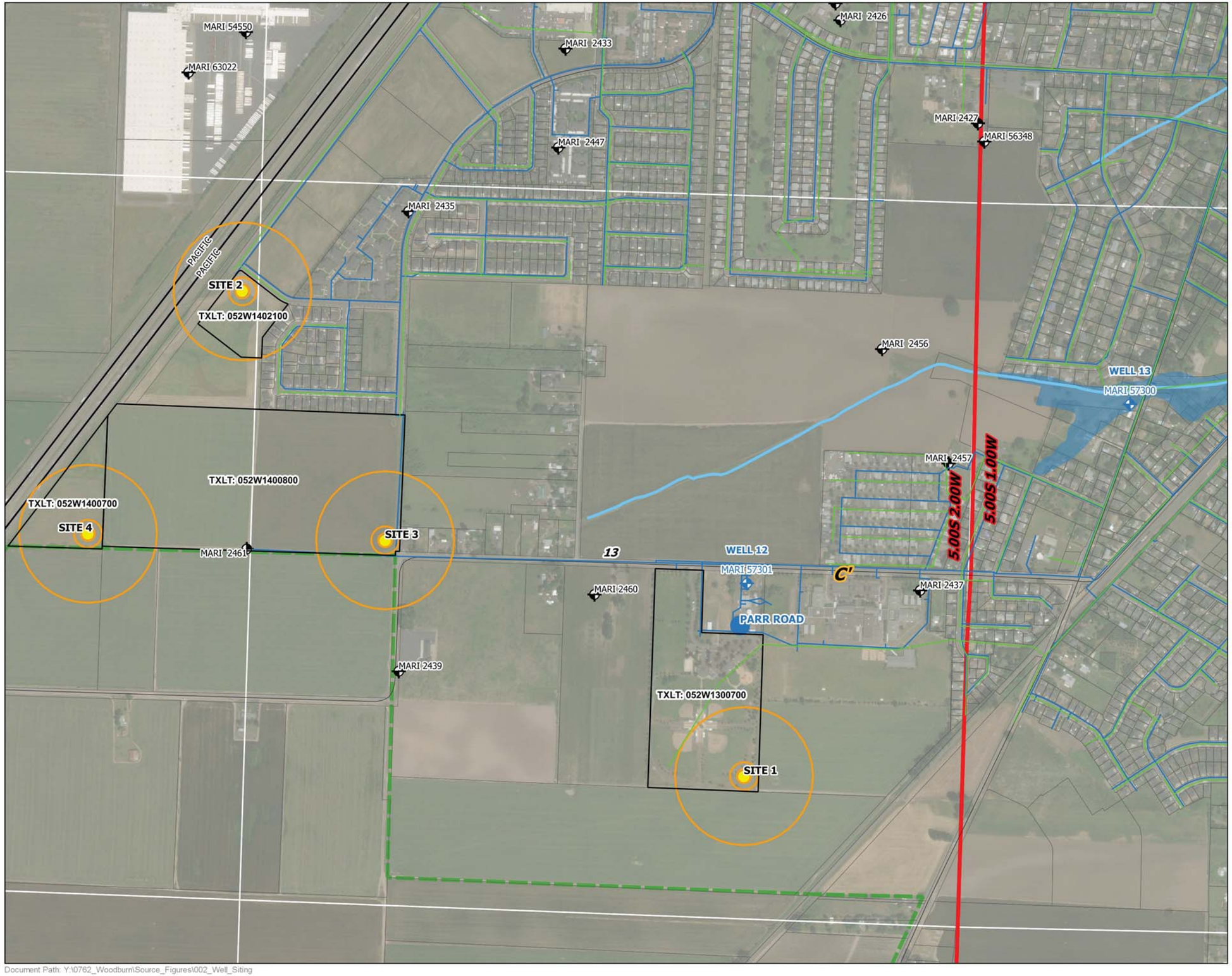
GSI Water Solutions, Inc.

Document Path: Y:\0762_Woodburn\Source_Figures\002_Well_Siting

FIGURE 7

OHA Setbacks

City of Woodburn Well Siting



LEGEND

- Proposed Well Location
- OHA Setback Radii (50, 100, 500 feet)
- City Well
- Well
- Water Treatment Plant
- Water Line
- Road
- Sewer Line
- Elevation Contour (5 feet)
- Taxlots of Interest
- Woodburn UGB
- Watercourse
- 100-Year Floodplain

Proposed Well Locations

Location	Latitude	Longitude
Site 1	45.13180	-122.87438
Site 2	45.14121	-122.88897
Site 3	45.13631	-122.88472
Site 4	45.13626	-122.89312

N

0 350 700 1050

Feet

Date: August 20, 2018
Data Sources: OWRD, USGS, DOGAMI

GSI Water Solutions, Inc.

Document Path: Y:\0762_Woodburn\Source_Figures\002_Well_Siting

FIGURE 8

Estimated Pumping Interference

City of Woodburn Well Siting

LEGEND

- Proposed Well Site
- City Well
- Well (>200 ft)
- Well
- Road
- Watercourse

Pumping Interference Legend

Estimated Drawdown (ft)

- 18
- 13
- 10
- 9
- 8
- 7
- 5

N

0 800 1600 2400

Feet

Date: August 20, 2018
Data Sources: OWRD, USGS, DOGAMI

GSI Water Solutions, Inc.

Document Path: Y:\0762_Woodburn\Source_Figures\002_Well_Siting

Tables

Table 1: Land Use Compatibility Summary

Well Site ID	Regulatory Authority	Acres	Tax Lot ID	Tax Lot Address	Owner	Land Use Zoning Code	Within Sensitive Groundwater Area	Land Use Compatibility Determination for Public Utilities[1]
Well Site 1	City of Woodburn (Within City Limits)	24.74	052W1300700	900 Parr Rd NE	City of Woodburn	P/SP	No	**Allowed Outright**
Well Site 2	City of Woodburn (Within City Limits)	5.16	052W1402100	Hooper St NE	MWVP Inc.	CG	No	**Allowed Outright**
Well Site 3	Marion County (Within UGB)	50.78	052W1400800	-	Weisz Family LLC	UT-20	No	**Allowed Outright**
Well Site 4	Marion County (Within UGB)	16.08	052W1400700	-	State of Oregon	UT-20	No	**Allowed Outright**

Notes:

1 - Land Use Compatibility for public utilities (ie. production well, pump house, conveyance lines) as specified by Marion County Code for Well Sites 3 (Chapter 16.13) or Woodurn Development Codes (Table 2.01A and 2.04A)

CG - Commercial General

UT - Urban Transitional

P/SP - Public

Table 2: Contaminant Source Survey Summary

Well Site ID	Search Radius	Potential Contaminant Sources						Total Count
		Environmental Cleanup Sites (ECSI)	Hazardous Waste Sites (HAZWASTE)	Underground Storage Tanks (UST)	Leaking Underground Storage Tanks (LUST)	Solid Wastee Information Facility (SWIFT)	Water Quality Underground Injection Control (WQUIC)	
Well Site 1	1 mile	0	0	0	2	0	0	**2**
Well Site 2	1 mile	0	7	15	12	0	1	**35**
Well Site 3	1 mile	0	1	7	0	0	0	**8**
Well Site 4	1 mile	0	0	1	0	0	0	**1**

Notes:

Information from DEQ Facility Profile Database, 2018; for additional information, see Woodburn EDR Well Site Composite Report 2018

Table 3: Pumping Interference Summary

Well Site ID	Magnitude of Interference[1]			Total Estimated Interference	Remaining Available Drawdown[3] (feet)
	City Wells	High Rate Irrigation Wells[2]	Private Wells		
Well Site 1	Medium (10 ft)	Low (9 ft)	Negligible	High (19 ft)	**28**
Well Site 2	Negligible	Medium (12 ft)	Negligible	Medium (12 ft)	**108**
Well Site 3	Low (7 ft)	Low (9 ft)	Negligible	High (16 ft)	**75**
Well Site 4	Negligible	Medium (10 ft)	Negligible	Medium (10 ft)	**97**

Notes:

[1] Potential pumping interference calculated for each well site location using the Cooper-Jacob method, assuming the following aquifer/pumping parameters:

- Transmissivity of 35,000 gpd/ft
- Storativity of 0.07
- Pumping rate of 1,000 gpm for City wells and pumping rates specific towater rights for high volume irrigation wells (See Note 2)
- Pumping duration of 274 days

Criteria for rating the magnitude of interference included:

- High: >15 feet
- Medium: 10-15 feet
- Low: 5-10 feet
- Negligible: <5 feet

[2] High rate irrigation wells defined as groundwater right holders with an authorized rate of at least 200 gpm. Identified high rate irrigation wells within 0.5 miles of each well site include:

Well Site 1

Water Right ID	Well ID; Rate
Certificate 47638	MARI 2439; 228 gpm
Certificate 85681	MARI 2437; 250 gpm
Certificate 45554	MARI 2641; 560 gpm
Certificate 40440	MARI 1552; 282 gpm

Well Site 2

Water Right ID	Well ID; Rate
Permit G-11936	MARI 24; 528 gpm
Certificate 91911	MARI 2462; 416 gpm
Certificate 36320	MARI 2461; 470 gpm
Certificate 44644	MARI 2447; 389 gpm

Well Site 3

Water Right ID	Well ID; Rate
Certificate 36320	MARI 2461; 470 gpm
Certificate 47638	MARI 2439; 228 gpm

Well Site 4

Water Right ID	Well ID; Rate
Certificate 36320	MARI 2461; 470 gpm
Certificate 47638	MARI 2439; 228 gpm
GR 1065	MARI 2466; 384 gpm

[3] Remaining available drawdown for each well site location calculated using the following equation and assumptions/parameters:

Remaining Available Drawdown = (Initial Available Drawdown) - (Pump Submergence) - (New Well Drawdown) - (Total Estimated Interference)

- Initial available drawdown (ie. pre-pumping drawdown) calculated by reducing the initial available drawdown of Cross Section A-A' by 40 fee (average summer water level reduction) at OWRD monitoring of Well 2), assuming the pump of the new production well will be positioned above the well screen assembly of the Troutdale Equivalent (See Section 3.1)
- Pump length and pump submergence requirement of 20 ft for all three well site locations
- New production well drawdown of 63 ft for all three well site locations, based on equation of Note 1
- Total estimated interference is specific to each well site location (Column 5 of this table)

Table 4: Production Well Siting Results

Well Site ID	Well Siting Criteria										Total Score
	Hydrogeology		Land Use Compatibility		Contaminant Source Survey		Setback Requirements and Site Ownership		Pumping Interference		
	Rationale	Rating	Rationale	Rating	Rationale	Rating	Rationale	Rating	Rationale	Rating	
Well Site 1	(+) The Willamette Aquifer is 160 feet thick; the Troutdale Equivalent unit is 75 feet thick. (0) Approximately 120 feet of initial available drawdown (summer). (+) Specific capacities proximal to Site 1 had a geometric mean of 13.8 gpm/ft from a total of 3 wells.	(+)	(+) The land use zoning code of Site 1 is public/semi-public (P/SP). Development of public utility facilities under this zoning code is allowed outright.	(+)	(0) A total of 2 potential contaminant sources were identified within a 1 mile radius of Site 1, however, it is not likely that any of the identified potential contaminant sources will impact the groundwater quality at Site 1. (+) Site 1 is upgradient and distal (>0.5 miles) to a majority of the identified potential contaminant sources.	(0)	(+) It is likely all regulatory setback distances can be met for a new water supply well. (+) Site 1 is owned by the City of Woodburn.	(+)	(0) Site 1 is anticipated to experience total interference of 19 feet from existing City wells (Well 12) and high rate irrigation wells. (-) Remaining available drawdown at Site 1 is estimated to be 28 feet (See Table 3 for details).	(-)	**2 (+)**
Well Site 2	(0) The Willamette Aquifer is 180 feet thick; the Troutdale Equivalent unit is 50 feet thick. (+) Approximately 200 feet of initial available drawdown (summer). (+) Specific capacities proximal to Site 2 had a geometric mean of 17.3 gpm/ft from a total of 2 wells.	(+)	(+) The land use zoning code of Site 2 is commercial general (CG). Development of public utility facilities under this zoning code is allowed outright.	(+)	(0) A total of 35 potential contaminant sources were identified within a 1 mile radius of Site 2, however, it is not likely that any of the identified potential contaminant sources will impact the groundwater quality at Site 2. (+) Site 2 is upgradient and distal (>0.5 miles) to a majority of the identified potential contaminant sources.	(0)	(+) It is likely all regulatory setback distances can be met for a new water supply well. (-) Site 2 is privately owned (MWVP, Inc.).	(0)	(0) Site 2 is anticipated to experience total interference of 12 feet, exclusively from high rate irrigation wells. (+) Remaining available drawdown at Site 2 is estimated to be 108 feet (See Table 3 for details).	(+)	**3 (+)**
Well Site 3	(+) The Willamette Aquifer is 150 feet thick; the Troutdale Equivalent unit is 90 feet thick. (+) Approximately 170 feet of initial available drawdown (summer). (0) Specific capacities proximal to Site 3 had a geometric mean of 11.4 gpm/ft from a total of 2 wells.	(+)	(+) The land use zoning code of Site 3 is urban transitional (UT-20). Development of public utility facilities under this zoning code is allowed outright.	(+)	(0) A total of 8 potential contaminant sources were identified within a 1 mile radius of Site 3, however, it is not likely that any of the identified potential contaminant sources will impact the groundwater quality at Site 3. (+) Site 3 is upgradient and distal (>0.5 miles) to a majority of the identified potential contaminant sources.	(0)	(+) It is likely all regulatory setback distances can be met for a new water supply well. (-) Site 3 is privately owned (Weisz Family, LLC).	(0)	(0) Site 3 is anticipated to experience total interference of 16 feet, from existing City wells (Well 12) and high rate irrigation wells. (0) Remaining available drawdown at Site 3 is estimated to be 75 feet (See Table 3 for details).	(0)	**2 (+)**
Well Site 4	(0) The Willamette Aquifer is 170 feet thick; the Troutdale Equivalent unit is 45 feet thick, however there is considerable uncertainty associated with hydrogeologic setting. (+) Approximately 190 feet of initial available drawdown (summer). (0) Specific capacities proximal to Site 4 were 18.6 gpm/ft from a total of 1 well.	(0)	(+) The land use zoning code of Site 4 is urban transitional (UT-20). Development of public utility facilities under this zoning code is allowed outright.	(+)	(0) A total of 1 potential contaminant source was identified within a 1 mile radius of Site 4, however, it is not likely thatthe identified potential contaminant source will impact the groundwater quality at Site 4. (+) Site 4 is upgradient and distal (>0.5 miles) to a majority of the identified potential contaminant sources.	(0)	(+) It is likely all regulatory setback distances can be met for a new water supply well. (0) Site 4 is owned by the State of Oregon	(+)	(0) Site 4 is anticipated to experience total interference of 10 feet, exclusively from high rate irrigation wells. (+) Remaining available drawdown at Site 4 is estimated to be 97 feet (See Table 3 for details).	(+)	**3 (+)**