Water Solutions, Inc.

TECHNICAL MEMORANDUM

Desktop Study to Rank Sites by Suitability for Infiltration of Advanced Treated (Class A) Wastewater, North Santiam Canyon, Oregon

To: Peter Olsen, PE / Keller Associates
James Bledsoe, PE / Keller Associates

From: Matt Kohlbecker, RG / GSI Water Solutions, Inc.
Ellen Svadlenak / GSI Water Solutions, Inc.
Jason Melady, RG / GSI Water Solutions

Date: October 8, 2020

This technical memorandum, prepared by GSI Water Solutions, Inc. (GSI), summarizes a desktop evaluation of the potential to infiltrate advanced treated (Class A) wastewater at ten sites in the North Santiam Canyon communities of Mill City, Gates, Detroit, and Idanha, Oregon.

1. Introduction

The communities of Mill City, Gates, Detroit, and Idanha have partnered to create the North Santiam Sewer Authority to plan for the development of a new joint wastewater treatment system in the study area shown in Figure 1. The motivation for the new wastewater treatment system is that three of the communities—Detroit, Gates and Idanha—currently rely on individual septic systems, and Mill City relies on a step sewer system that is more than 25 years old and may require costly repairs or upgrades in the coming years. The new joint wastewater treatment system will provide a net environmental benefit to the scenic North Santiam Canyon due to improved wastewater treatment, and will facilitate economic investments because retail and industrial development will no longer be limited by insufficient septic drain field capacity. The projected average annual daily flows for the combination of the wastewater treatment systems are about 0.27 million gallons per day (MGD) (Keller Associates, 2017)[1].

This technical memorandum presents a desktop evaluation of the suitability of soils in the North Santiam Canyon to infiltrate advanced treated (Class A) wastewater, and is focused on the two areas where wastewater infiltration facilities may be located: the Gates-Mill City sewer basin and the Detroit-Idanha sewer basin (Figure 1). The technical memorandum evaluates ten sites that were identified by representatives from the communities of Mill City, Gates, Detroit, and Idanha at a meeting in September 2020 based on the following characteristics: (1) the level of effort for site development, (2) potential permitting challenges, (3) the volume of water that can likely be infiltrated based on aquifer characteristics, (4) the permeability of surficial soils, and (5) the aerial extent of the aquifer beneath the infiltration facility. The sites are ranked by infiltration potential with the objective of selecting four of the sites for infiltration testing to measure soil permeability

[1] Average annual daily flows are estimated to be 84,200 gallons per day for Detroit and Idanha, and 188,100 gallons per day for Gates and Mill City (Keller Associates, 2017).

(two sites will be located in the Gates-Mill City sewer basin and two sites will be located in the Detroit-Idanha sewer basin). This technical memorandum is organized as follows:

- Section 1: Introduction.
- Section 2: Geology, Hydrogeology and Soils in the North Santiam Canyon.
- Section 3: Methods for Evaluating Infiltration Potential at Ten Sites.
- Section 4: Results of Infiltration Site Ranking.
- Section 5: Conclusions and Recommendations.

The main text of this technical memorandum provides an overview of GSI's evaluation. Detailed technical documentation of the evaluation is provided in Attachment A and Attachment B.

2. Geology, Hydrogeology, and Soils in the North Santiam Canyon

The evaluation of infiltration potential is based on the geologic, hydrogeologic, and soil characteristics in the North Santiam Canyon. This section provides background about the geology and hydrogeology (Section 2.1) and surficial soils (Section 2.2) in the Gates-Mill City sewer basin and Detroit-Idanha sewer basin, based on studies by the U.S. Geological Survey, U.S. Department of Agriculture (USDA), Oregon Department of Geology and Mineral Industries, and doctoral thesis dissertations. Field assessment of infiltration characteristics were not evaluated as part of this analysis, but is recommended for subsequent phases of the project as part of additional feasibility analysis and preliminary system design.

2.1 Geologic and Hydrogeologic Setting

The North Santiam Canyon was formed by valley glaciers from Mt. Jefferson that advanced through the ancestral North Santiam River drainage about 800,000 years ago, reaching as far west as the community of Mehama (Thayer, 1939; James, 2003)[2]. The glaciers carved a U-shaped valley out of the layers of ash and lava that comprised the ancestral ground surface, which was subsequently filled with alluvial material deposited and reworked by streams in the watershed (Thayer, 1934; 1939) (called the "valley-filling alluvium" in this technical memorandum).

The rocks and sediments in the North Santiam Canyon are divided into the geologic units shown in Figure 2 (Gates-Mill City sewer basin) and Figure 3 (Detroit-Idanha sewer basin). Geologic cross sections through each sewer basin are provided in Figure 4 (Gates-Mill City sewer basin) and Figure 5 (Detroit-Idanha sewer basin). As shown in the cross sections, the valley-filling alluvium in the U-shaped glacial valley is primarily comprised of Alluvium of the Santiam River and Glacial Fluvial Deposits (Glacial Till):

- **Alluvium of the Santiam River.** The Alluvium of the Santiam River is comprised of recently-deposited coarse sands and gravels along the banks of the Santiam River that is present in the Detroit-Idanha sewer basin but absent in the Gates-Mill City sewer basin. Based on logs of water wells from the Oregon Water Resources Department, the Alluvium of the Santiam River appears to range from about 30 feet thick to over 100 feet thick[3], and groundwater in the Alluvium of the Santiam River is shallow (reported at depths ranging from 10 to 15 feet below ground surface[4]). Groundwater in the Alluvium of the Santiam River is likely hydraulically connected to the Santiam River. The hydraulic connection to the Santiam River is important for facility permitting (specifically, the Department of Environmental Quality will likely require a National Pollutant Discharge Elimination System, or NPDES, permit for facilities that infiltrate wastewater into the Alluvium of the Santiam River, see Section 3.2.2 for discussion).
- **Glacial Fluvial Deposits (Glacial Till).** Glacial till is a heterogeneous accumulation of sediment deposited by glaciers that includes clay, sand, and boulders (Molina, 2004), and is characterized by a wide range of

[2] Thayer (1939) correlates the Mill City glacial stage with the Sherwin stage in the Sierra Nevada.
[3] See MARI 60494 (34 feet thick) and LINN 5552 (over 100 feet thick)
[4] See LINN 5552, MARI 56680, MARI 60494, and MARI 56070

hydraulic properties due to the highly complex depositional environment. Highly permeable soils are present where gravel and sand were deposited by high-energy meltwater streams, which may occur as long, narrow channels of limited size and distribution (i.e., if deposited by streams flowing within or under glaciers) or as aerially-extensive outwash (i.e., if deposited downvalley of the glacier). Low permeability soils are present where silts were deposited in moraine-dammed lakes, or matrix-supported clayey boulder units were deposited as lateral moraines or ground moraines. As such, a site-specific investigation is necessary to confirm the hydraulic properties of till at a given location.

While the glacial till near Gates and Mill City (called the "Mill City Till") and the glacial till near Detroit and Idanha (called the "Detroit Till") are lithologically similar (Thayer, 1939), the Detroit Till is considerably thinner and less extensive than the Mill City Till. Specifically, near Idanha, the glacial till is approximately ½ mile wide and about 100 feet thick, while near Mill City, the glacial till is an approximately 1.5 miles wide and about 200 feet thick (Priest et al., 1987; Thayer, 1939). Based on logs of water wells in the Gates-Mill City sewer basin from the Oregon Water Resources Department, groundwater in the glacial till is deep, generally ranging from about 40 to 70 feet below ground surface. In addition, the permeability of the till is variable, with well yields ranging from less than 60 gallons per minute[5] to 800 gallons per minute[6]. An aquifer that yields 60 gpm to a well would not likely support a large infiltration facility, but an aquifer that yields 800 gpm to a well would likely support a large infiltration facility.

2.2 Surficial Soil Conditions

The USDA has developed a database of surficial soil properties (i.e., the upper 6 feet of soil) for the United States on a county-by-county basis. Table 1 lists the soils that the USDA has identified in the valley-filling alluvium of the North Santiam Canyon in the Gates-Mill City sewer basin and the Detroit-Idanha sewer basin. Soils are grouped by their saturated hydraulic conductivity, which is the rate that water moves through a soil per unit area per unit hydraulic gradient[7]. As shown in Table 1, the surficial soils in the valley filling alluvium are characterized by saturated hydraulic conductivities ranging from less than 0.5 inches per hour (in/hr) to 60 in/hr. Note that surficial soils with the highest saturated hydraulic conductivity occur in the Gates-Mill City sewer basin.

Based on the USDA soil property database, GSI developed maps showing the infiltration potential of surficial soils. The maps are provided in Figure 6 (Gates-Mill City sewer basin) and Figure 7 (Detroit-Idanha sewer basin). GSI classified the infiltration potential of soils as "poor," "marginal," "good," or "excellent" using the following methods:

- Surficial soils with a **poor** infiltration potential are characterized by a saturated hydraulic conductivity of less than 0.5 inches per hour, *OR* a slope of greater than 30%, *OR* the presence of a restrictive layer (e.g., bedrock) within 6 feet of ground surface.
- Surficial soils with a slope of less than 30% *AND* no restrictive layer within 6 feet of ground surface were assigned the following infiltration potentials based on their saturated hydraulic conductivity:
  - **Marginal**, if the saturated hydraulic conductivity was between 0.5 in/hr and 5 in/hr,
  - **Good**, if the saturated hydraulic conductivity was between 5 in/hr and 10 in/hr, and
  - **Excellent**, if the saturated hydraulic conductivity was greater than 10 in/hr.

[5] See LINN 3500, LINN 3505, and LINN 2589
[6] See LINN 2588 (440 gpm) and LINN 55301 (800 gpm)
[7] USDA provides a range of saturated hydraulic conductivity values for each soil horizon, and provides the approximate thickness of each horizon. We developed an average value of saturated hydraulic conductivity for each soil horizon, and then calculated an overall average for the soil group using Equation (4-41) of Fetter (1994), which weights saturated hydraulic conductivity by the thickness of each soil horizon.

In the Gates-Mill City sewer basin (Figure 6), soils with good to excellent potential for infiltration are primarily located in the central part of the valley. Some soils adjacent to the Santiam River have a high saturated hydraulic conductivity, but are characterized by a "poor" infiltration potential because they are located within areas of steep slopes (over 30%) or are characterized by a restrictive layer within 6 feet of ground surface (typically bedrock). In the Detroit-Idanha sewer basin (Figure 7), soil favorability to infiltration is highest near the Santiam River, and becomes lower away from the Santiam River.

Table 1. Saturated Hydraulic Conductivities of Surficial Soils in the Valley-Filling Alluvium.

K_{sat} Grouping	Soil Name	K_{sat}
	Gates-Mill City Sewer Basin [1]	
> 10 in/hr	Ad – Alluvial Land	60 in/hr
	Ca – Camas Gravelly Sandy Loam	19.35 in/hr
	18 – Camas Gravelly Sandy Loam	14.88 in/hr
	92 – Sifton Variant Gravelly Loam	13.33 in/hr
5 – 10 in/hr	64 – Malabon Variant Loam	8.9 in/hr
	73 – Newberg Fine Sandy Loam	6.55 in/hr
	HSC – Horeb Gravelly Silt Loam	6.26 in/hr
0.5 – 5 in/hr	Nu – Newbery Fine Sandy Loam	4.0 in/hr
	HSE – Horeb Gravelly Silt Loam	1.86 in/hr
	21 – Chehalis Silt Clay Loam	1.30 in/hr
	67 – McBee Silty Clay Loam	1.30 in/hr
	Mb – McBee Silty Clay Loam	1.30 in/hr
	17C, 17E – Bull Run Silt Loam	1.30 in/hr
	66B – McAlpin Silty Clay Loam	0.56 in/hr
	32D – Cumley Silty Clay Loam	0.53 in/hr
< 0.5 in/hr	23 – Clackamas Gravelly Silt Loam	0.46 in/hr
	36D – Dupee Silt Loam	0.42 in/hr
	98 – Waldo Silty Clay Loam	0.13 in/hr
	Detroit-Idanha Sewer Basin	
> 10 in/hr	--	--
5 – 10 in/hr	7003 – Jimbo Medial Silt Loam	8.52 in/hr
	7004 – Aschoff Gravelly Medial Loam	6.95 in/hr
0.5 – 5 in/hr	8221 – Coffin-Coolcamp Hummocky Complex	4.05 in/hr
	7001 – Saturn Clay Loam	2.73 in/hr
	8210 – Browder, Hummocky-Ramcreek Complex	2.63 in/hr
	7101 – Kinney Gravelly Medial Loam	2.22 in/hr
< 0.5 in/hr	-	--

Notes

in/hr = inches per hour

(1) Soils 74H (Ochrepts, very steep) and 39 (Fluvents-Fluvaquents Complex, nearly level) are present in the Gates-Mill City sewer basin (see gray polygons in Figure 6), but are not listed on the table because the USDA does not provide values of saturated hydraulic conductivity for the soils.

3. Methods for Evaluating Infiltration Potential at Ten Sites

This section presents the methods used to evaluate infiltration potential at ten sites in the North Santiam Canyon. The methods included an initial site selection meeting with stakeholders to choose ten sites for evaluation (Section 3.1), and compilation and evaluation of geologic, hydrogeologic, and soil characteristics at each site (Section 3.2).

3.1 Stakeholder Meeting for Site Selection

On September 4, 2020, GSI and Keller met with representatives from the communities of Mill City, Gates, Idanha, and Detroit to identify ten sites for a focused desktop evaluation of infiltration potential. The sites were selected according to the following criteria:

- Outside of 100 year floodplain,
- Relatively level topography,
- Favorable property ownership, and
- Infiltration favorability of surficial soils is “Marginal,” “Good,” or “Excellent” [see Figures 6 and 7].

The properties that were selected for a desktop evaluation of infiltration potential are listed in Table 2, and are shown in Figure 6 (Gates-Mill City sewer basin) and Figure 7 (Detroit-Idanha sewer basin).

Table 2. Properties Included in the Desktop Study of Infiltration Potential.

Site	Tax Lot(s)	Site-Scale Drawing
Gates-Mill City Sewer Basin		
Tom Fencl	01003	Figure A.1
Hazelnut Property	03000	Figure A.2
WWTP 2	00300	Figure A.3
Rock Creek	00200	Figure A.4
Blaylock	02100 and 02101	Figure A.5
Power Easement	00100	Figure A.6
Detroit-Idanha Sewer Basin		
Freres	01000	Figure A.7
Bark Flat West	01300	Figure A.8
Frank	00902	Figure A.9
Upper Deck	00100	Figure A.10

3.2 Scoring and Ranking Criteria

The following sections present the criteria that GSI used to rank the sites for infiltration potential. Criteria included: (1) level of effort to develop the project (Section 3.2.1), (2) permitting challenges (Section 3.2.2), (3) a planning-level estimate of the volume of water that can be infiltrated (Section 3.2.3), (4) surficial soil permeability reported by the USDA (Section 3.2.4) and (5) the width of valley-filling alluvium (Section 3.2.5). For each criteria, GSI assigned a score for the favorability of infiltration on a scale of 1 (less favorable for implementing infiltration at the site) to 4 (more favorable for implementing infiltration at the site).

3.2.1 Development Effort

Keller Associates (Keller) rated the level of effort to develop an infiltration basin at each of the 10 sites. Factors influencing the potential effort to develop the property include the following items:

- Proximity to roadway network,
- Proximity to existing utility network (power, gas, water),
- Vegetation and growth on property,
- Site topography,
- Current ownership,
- Current land use,
- Environmental permitting requirements,
- WTP potential,
- Expandability, and
- Public acceptance (NIMBY, odor, optics).

At each site, the development cost was scored on a scale ranging from 1 (highest effort to develop) to 4 (lowest effort to develop):

- 1 – Development effort is estimated to be the highest.
- 2 – Development effort is estimated to be relatively high.
- 3 – Development effort is estimated to be relatively low.
- 4 – Development effort is estimated to be the lowest.

Documentation of the methods and assumptions used by Keller to estimate planning-level development costs are provided in Attachment B.

3.2.2 Permitting Challenges

Oregon law requires that wastewater discharge systems are authorized by a permit from the Department of Environmental Quality (DEQ). There are two options for permitting a wastewater discharge with DEQ: (1) an NPDES permit or (2) a Water Pollution Control Facility (WPCF) permit. The type of permit that DEQ will require depends fundamentally on whether or not the wastewater is to be discharged to surface water (directly or indirectly).

- NPDES permits are required for discharges of pollutants to surface waters, whether done so *directly* via an outfall, or *indirectly* via infiltration and transport by groundwater.
- WPCF permits are required for the discharge of wastewater to the ground; discharge to surface water is prohibited.

The type of permit that DEQ requires is an important criteria for ranking properties because the communities of Mill City, Gates, Detroit, and Idanha are located in the North Santiam River Subbasin, which is subject to the the State of Oregon's Three Basin Rule[8]. The rule prohibits new or increased wastewater discharges that require an NPDES permit[9], but allows a discharge requiring a WPCF permit *if the discharge is a domestic sewage treatment facility that does not discharge waste to surface water*[10]*.* Therefore, we developed a score for each of the 10 sites that accounts for the likelihood of an NPDES permit being required and the likelihood of waste reaching surface water. Sites located within the Quaternary Alluvium of the Santiam River geologic unit or within 0.25 miles of the Santiam River and/or Rock Creek will likely require an NPDES permit because they will be considered by DEQ to be an indirect discharge [see the DEQ (2007) Internal Management

[8] OAR 340-041-0350(1)(c)
[9] OAR 340-041-0350(8)(a)
[10] OAR 340-041-0350(8)(c)

Directive for Indirect Discharge] that reaches the Santiam River[11]. For the purpose of site ranking, we assumed that sites located more than 0.25 miles from the Santiam River will need a WPCF permit, and that the likelihood of waste from the facility reaching surface water will be reduced with greater thickness of unsaturated soil between the bottom of the infiltration facility and the groundwater table (called the "unsaturated zone" in this technical memorandum)[12]. For each of the ten sites, we assigned a score that ranged from 1 (most significant permitting challenges) to 4 (least significant permitting challenges):

- 1 –NPDES permit required because infiltration is considered an indirect discharge by DEQ; site located within 0.25 miles of the Santiam River/Rock Creek, or within the Alluvium of the Santiam River.
- 2 – WPCF permit likely required; site located more than 0.25 miles from the Santiam River and Rock Creek, *AND* unsaturated zone is less than 30 feet thick.
- 3 – WPCF permit likely required, site located more than 0.25 miles from the Santiam River and Rock Creek, *AND* unsaturated zone is 30 to 40 feet thick.
- 4 – WPCF permit likely required, site located more than 0.25 miles from the Santiam River and Rock Creek, *AND* unsaturated zone is over 40 feet thick.

Depth to groundwater was estimated from water well logs located near each site, available online from the Oregon Water Resources Department (OWRD, 2020) (see Attachment A).

It should be noted that, due to uncertainties related to a recent (April 2020) U.S. Supreme Court decision[13], DEQ no longer uses setbacks between an infiltration facility and surface water to determine the type of permit that will be required. In this technical memorandum, we are using a setback distance of 0.25 miles as a planning-level criteria to develop the relative likelihood of whether DEQ will require an NPDES permit or a WPCF permit. Ultimately, DEQ will make a final permitting determination (i.e., NPDES or WPCF) for the site based on site-specific hydrologic conditions, hydrogeologic conditions, and the overall physical setting of the site for the infiltration system, and it will be necessary for the project team to proactively engage DEQ to reduce uncertainty related to permitting challenges.

In addition, note that this analysis of permitting-related challenges does not consider the distance between the infiltration facility and minor drainages (e.g., Snake Creek, Turnridge Creek, Mad Creek). As shown in the Figure 4 cross section, these minor drainages are generally perched above the regional water table, and would be unlikely to receive waste discharges even if significant mounding of the water table occurs during infiltration. For example, water wells L61041 and L60307, located adjacent to Snake Creek, have a depth to groundwater of 50 feet and 67 feet, respectively. DEQ will likely require site-specific data to demonstrate the lack of a hydraulic connection between the regional water table and minor drainages during infiltration.

3.2.3 Hantush (1967) Estimated Infiltration Volume

Infiltrated wastewater will migrate downwards from the infiltration basin through unsaturated soils until reaching groundwater. The inflow of water into the aquifer causes the groundwater table to rise, forming a mound. If the mound reaches the bottom of the infiltration basin, the rate of infiltration out of the basin decreases substantially. Therefore, the volume of water that can be infiltrated at a site is a function of the thickness of unsaturated soils to accommodate a water table mound, and the ability of the aquifer to dissipate the mound (which is based on aquifer properties including hydraulic conductivity, aquifer thickness,

[11] Rock Creek, which flows into the Santiam River between Mill City and Gates, is likely a gaining stream, meaning that groundwater flows into the stream. Therefore, infiltration facilities near Rock Creek will likely be considered to indirectly discharge to Rock Creek and, eventually, the Santiam River.

[12] The likelihood of waste reaching the Santiam River will also depend on the horizontal distance between the infiltration facility and the river. However, we are focusing the ranking on vertical separation from groundwater because increased vertical separation from groundwater reduces other permitting-related challenges (i.e., meeting DEQ's antidegradation standard and impacting water supply wells).

[13] *County of Maui, Hawaii v. Hawaii Wildlife Fund*

and specific yield) (Carleton, 2010). The permeability of surficial soils (as measured by saturated hydraulic conductivity) may also limit the infiltration volume and is discussed in Section 3.2.4.

We used the Hantush (1967) equation to estimate the infiltration rate that could be achieved at each site if the water table mound were to be brought to within ten feet of ground surface. The Hantush (1967) calculations were based on the following input parameters:

- A site-specific aquifer thickness and unsaturated zone thickness, based on water levels and soil logs from well driller logs located near each site (OWRD, 2020),
- A site-specific infiltration basin size, based on developing conceptual infiltration basins on each site (see Attachment A, and note that the infiltration basins in the attachment were selected with the objective of maximizing infiltration volume at the site in order to determine relative infiltration potential, and will need to be changed during facility design to accommodate regulatory and other requirements),
- A specific yield (0.10 for glacial till or 0.19 for the Alluvium of the Santiam River), aquifer hydraulic conductivity (20.77 feet per day for glacial till or 50 feet per day for the Alluvium of the Santiam River), and infiltration period duration (365 days) assumed to be the same at all sites.

Technical documentation of input parameters and Hantush (1967) equation calculations are provided in Attachment A. At each of the 10 sites, we scored the infiltration volume on a scale ranging from 1 (lower infiltration volume) to 4 (higher infiltration volume):

- 1 – Infiltration Potential of less than 0.5 million gallons per day (MGD).
- 2 – Infiltration Potential of 0.5 to 1.0 MGD
- 3 – Infiltration Potential of 1.0 to 1.5 MGD
- 4 – Infiltration Potential of more than 1.5 MGD

It should be noted that the infiltration volumes calculated by Hantush (1967) are planning-level estimates developed based on approximate values of infiltration basin dimensions, aquifer dimensions (saturated zone thickness and unsaturated zone thickness), horizontal hydraulic conductivity, specific yield, and the duration of the infiltration period (see Attachment A). The estimates are helpful for comparing the relative infiltration potential between the ten properties. We recommend collecting site-specific data to develop reliable estimates of the actual infiltration volume that can be achieved at a site.

3.2.4 USDA Surficial Soil Permeability

The Hantush (1967) equation evaluates infiltration potential based on the response of the aquifer to infiltration; it does not capture the favorability of surficial (i.e., the upper 6 feet) soils to infiltration[14]. At each of the ten sites, we scored the favorability of surficial soils to infiltration using the USDA saturated hydraulic conductivities on a scale of 1 (lowest saturated hydraulic conductivity) to 4 (highest saturated hydraulic conductivity):

- 1 – Saturated hydraulic conductivity of < 0.5 inches per hour.
- 2 – Saturated hydraulic conductivity of 0.5 to 5 inches per hour.
- 3 – Saturated hydraulic conductivity of 5 to 10 inches per hour.
- 4 – Saturated hydraulic conductivity of > 10 inches per hour.

If an infiltration basin covered more than one zone of saturated hydraulic conductivity, we assigned the score based on the most common hydraulic conductivity zone within the basin footprint. It should be noted that the saturated hydraulic conductivities reported by the USDA are planning-level estimates that are from regional-

[14] Note that we did verify that the Hantush-calculated infiltration rates were feasible given the saturated hydraulic conductivities of surficial soil reported by the USDA.

scale studies of soil properties. We recommend collecting site-specific data to develop reliable estimates of the saturated hydraulic conductivity at a site.

3.2.5 Width of Valley-Filling Alluvium

Because the Hantush (1967) equation assumes the aquifer is infinite in aerial extent, it does not capture the potential for infiltration volume to be reduced due to the limited extent of an aquifer. Specifically, the groundwater mound created by infiltration will be more pronounced in areas where the valley-filling alluvium have been deposited in a narrow canyon, because the canyon walls are low-permeability boundaries that inhibit dissipation of the mound. At each of the ten sites, we scored the ability of the aquifer to dissipate the groundwater mound based on aquifer extent on a scale of 1 (least ability to dissipate the groundwater mound) to 4 (most ability to dissipate the groundwater mound):

- 1 – Valley-filling alluvium is < 0.5 miles wide.
- 2 – Valley-filling alluvium is 0.5 to 1.0 miles wide.
- 3 – Valley-filling alluvium is 1.0 to 1.5 miles wide.
- 4 – Valley-filling alluvium is > 1.5 miles wide.

Note that, due to the fact that the Santiam Canyon in the Gates-Mill City sewer basin is wider than in the Detroit-Idanha sewer basin, all potential infiltration sites in the Detroit-Idanha sewer basin received a score of “1” and all of the potential infiltration sites in the Mill City and Gates area received a score of “2” or “3.”

4. Results of Infiltration Site Ranking

Table 3 presents the data that were used to develop scores for each of the ten sites. The data in Table 3 are color-coded according to the following color scheme:

- Data results in a site score of 1 (least favorable to infiltration)
- Data results in a site score of 2
- Data results in a site score of 3
- Data results in a site score of 4 (most favorable to infiltration)

Table 3. Data Used to Assign Infiltration Potential Scores.

Property	Development Effort	Distance from River / Depth to Groundwater	Hantush (1967) Estimated Infiltration Volume	USDA Surficial Soil Permeability	Width of Valley-Filling Alluvium
Tom Fencl	3	> 0.25 mi. / 50 feet	1.95 MGD	8.9 in/hr	1.1 mi.
Hazelnut Property	2	> 0.25 mi. / 51 feet	2.30 MGD	8.9 in/hr	1.1 mi.
WWTP 2	3	< 0.25 mi. / 46 feet	1.21 MGD	6.6 in/hr	1.1 mi.
Rock Creek	3	< 0.25 mi. / 40 feet	1.14 MGD	13.3 in/hr	1.2 mi.
Blaylock	4	> 0.25 mi. / 17 feet	0.19 MGD	1.3 in/hr	1.4 mi.
Power Easement	1	> 0.25 mi. / 48 feet	1.47 MGD	1.3 in/hr	0.9 mi.
Freres	4	< 0.25 mi / 14 feet	0.30 MGD	8.5 in/hr	0.50 mi.
Bark Flat West	4	< 0.25 mi / 20 feet	0.30 MGD	8.5 in/hr	0.39 mi.
Frank	1	< 0.25 mi / 45 feet	0.59 MGD	8.5 in/hr	0.46 mi.
Upper Deck	3	< 0.25 mi / 13 feet	0.04 MGD	8.5 in/hr	0.47 mi.

Notes

in/hr = inches per hour   mi = miles   MGD = Million gallons per day   USDA = U.S. Department of Agriculture

Table 4 presents the scores, ranging from 1 (less favorable for implementing infiltration at the site) to 4 (more favorable for implementing infiltration at the site), that were assigned to each site for the criteria in Table 3, and an overall score for infiltration potential at each site. Note that the overall score is a weighted average of the criteria in Table 3, with the weighting shown in Table 4. Permitting challenges are weighted the highest (30%) and the width of the valley-filling alluvium is weighted the lowest (5%). Sites are organized from highest to lowest overall score for implementation of an advanced treated (Class A) wastewater infiltration project.

The green-highlighted text in Table 4 are the sites that will be chosen for infiltration testing. Note that the highest-ranking sites were not selected for infiltration testing because:

- A goal of this analysis was to select two sites from the Gates-Mill City sewer basin and two sites from the Detroit-Idanha sewer basin (see Section 1). As such, the Tom Fencl and Rock Creek sites were chosen from the Gates-Mill City sewer basin, and the Freres and Bark Flat West sites were chosen from the Detroit-Idanha sewer basin.
- The Hazelnut property is characterized by a high overall score for infiltration. However, the property was not chosen for infiltration testing because it is located within the drinking water protection area for at least one of the City of Mill City Kingwood wells (DEQ, 2020), which is considered a potential fatal flaw to a wastewater infiltration project. While the other properties in Table 4 may also be too close to drinking water wells, proximity to water wells has not yet been confirmed (a door-to-door survey is necessary to accurately locate water wells) and it may be possible to provide an alternative source of water to the properties from the Mill City Kingwood wells. Note that DEQ permits will require that the wastewater infiltration facility not degrade groundwater quality per Oregon's groundwater protection rules[15].

Table 4. Ranking of Ten Sites by Potential for Implemenation of an Advanced Treated (Class A) Wastewater Infiltration Project.

Rank	Property	Development Effort	Permitting Challenges	Hantush (1967) Estimated Infiltration Volume	USDA Surficial Soil Permeability	Width of Valley-Filling Alluvium	Overall Score
	Weight	*25%*	*30%*	*20%*	*20%*	*5%*	--
1	Tom Fencl	3	4	4	3	3	3.50
2	Hazelnut Property	2	4	4	3	3	3.25
3	Rock Creek	3	1	3	4	3	2.60
4	Power Easement	1	4	3	2	2	2.55
5	WWTP 2	3	1	3	3	3	2.40
6	Blaylock	4	2	1	2	3	2.35
7	Freres	4	1	1	3	2	2.20
8	Bark Flat West	4	1	1	3	1	2.15
9	Upper Deck	3	1	1	3	1	1.90
10	Frank	1	1	2	3	1	1.60

[15] OAR 340-040

5. Conclusions and Recommendations

This desktop evaluation of the relative potential for infiltration of advanced treated (Class A) wastewater at ten sites in the North Santiam Canyon indicates that, in general, the Gates-Mill City sewer basin has the highest potential for the infiltration of advanced treated (Class A) wastewater because:

- The valley-filling alluvium (specifically glacial till) in the Gates-Mill City sewer basin is wider, which promotes faster dissipation of the groundwater mound that is created during infiltration, and can potentially avoid permitting challenges related to the Three Basin Rule because the infiltration facility can be located over 0.25 miles from the Santiam River.

- The water table in the Gates-Mill City sewer basin is deeper, which allows more room for unsaturated soils to accommodate the groundwater mound that is created during infiltration, resulting in higher infiltration volumes and fewer permitting challenges.

Based on the results of this analysis, we have developed the following recommendations to evaluate individual site infiltration characteristics to assess site-specific feasibility:

- Engagement with the Department of Environmental Quality. DEQ determinations will affect the feasibility of implementing the infiltration project in at least two ways. First, DEQ will make a determination of the type of permit (NPDES or WPCF) that is required for the facility. As discussed in Section 3.2.2, the type of permit that DEQ requires for the infiltration facility is important because the communities of Mill City, Gates, Detroit, and Idanha are located in the North Santiam River Subbasin, and are subject to the State of Oregon's Three Basin Rule[16]. Under the current rule, a new domestic sewage treatment and infiltration facility can be permitted only with a WPCF permit, and *only if the discharge does not discharge waste to surface water*[17]. Second, DEQ will make a determination about whether wastewater infiltration is protective of drinking water wells (in accordance with DEQ's groundwater protection rules).

  Ultimately, DEQ will make a final decision about whether the facility discharges waste to surface water and is protective of drinking water wells based on site-specific hydrologic conditions, hydrogeologic conditions, and the overall physical setting of the site for the infiltration system. We recommend engaging DEQ to understand the site-specific data that should be collected, and the evaluations that will be needed (e.g., modeling, groundwater quality data, water well locations) to make a demonstration that waste from the facility will not reach surface water or drinking water wells.

- Site-Specific Data Collection. As discussed above, DEQ will require that the project team collect site-specific aquifer and soil property data and, based on the data, assess whether wastes from the infiltration facility reach drinking water wells. Development of an accurate inventory of all water wells in the study area is not possible using publically-available databases, and because of this uncertainty, we did not include proximity of the sites to water wells in our scoring. Note that of the sites recommended for infiltration testing, the Tom Fencl site and the Freres site are located adjacent to a known water well (see Figure 2). However, we still recommend conducting infiltration tests at these sites because the Tom Fencl site is relatively large and offers flexibility for locating infiltration basins on the property such that potential impacts to water wells could be eliminated. The water well at the Freres site is located in the northwest corner of the property, and the infiltration basin may be able to be located such that the well is upgradient of the basin (i.e., infiltrated water flows away from the

[16] OAR 340-041-0350(1)(c)
[17] OAR 340-041-0350(8)(c)

well)[18]. Ultimately, site-specific data and modeling, and a door-to-door survey to accurately locate water wells, will be necessary to determine if the nearby water wells are a fatal flaw to wastewater infiltration at a site.

- **Infiltration Tests.** Infiltration tests measure the permeability of surficial soils, and are necessary to check and refine the surficial soil permeability estimates from the USDA. We recommend excavating test pits and conducting infiltration tests at the Tom Fencl, Rock Creek, Freres and Bark Flat West sites in soils that will be the target for infiltration, which will usually be native soils (as opposed to artificial fill). The infiltration tests are included in this scope of work for master planning.

- **Aquifer Tests.** Testing of the Glacial Fluvial Sediment aquifer in Mill City will provide reliable estimates of aquifer properties, which are necessary to refine estimates of infiltration volumes in Table 3. For example, the Mill City can test a city well located north of the Hazelnut Site. Specifically, the City can pump the Kingwood No. 2 well for 72 hours at a constant rate, and measure drawdown in vicinity observation wells [e.g., the Kingwood No. 1 well (located about 300 feet west of the Kingwood No. 2 well), LINN 2588 (located about 600 feet south of the Kingwood No. 2 well), and LINN 3496 (located about 850 feet south of the Kingwood No. 2 well). The observation wells should be equipped with down-hole pressure transducers and data loggers to continuously monitor water levels during the test. We also recommend collecting a groundwater quality sample at the end of the aquifer test, and analyzing the sample for an analyte list that will be developed with input from DEQ. The aquifer tests are not included in this current scope of work, and can be performed during a stretch of dry weather.

[18] Note that the drainage basin footprints shown in Attachment A are only used to evaluate the *relative, maximum* infiltration potential at the ten sites, and are not intended for design purposes. Therefore, the drainage basin sizes and locations in Attachment A can be changed as a part of the design process.

6. References

Beaulieu, J. D., Hughes, P. W., and R. K. Mathiot. 1974. Environmental Geology of Western Linn County, Oregon. State of Oregon Department of Geology and Mineral Industries Bulletin 84. 145 pp.

Carleton, G. B. 2010. Simulation of Groundwater Mounding Beneath Hypothetical Stormwater Infiltration Basins: U.S. Geological Survey Scientific Investigations Report 2010-5102. 64 pp.

DEQ. 2007. Disposal of Municipal Wastewater Treatment Plant Effluent by Indirect Discharge to Surface Water via Groundwater or Hyporheic Water. Internal Management Directive. September.

DEQ. 2020. DEQ Facility Profiler Lite Permitted Sites. Accessed by GSI in October 2020. Available online at: https://hdcgcx1.deq.state.or.us/Html5viewer291/?viewer=FacilityProfilerLite.

Fetter, C. W. 1994. Applied Hydrogeology. 3rd Ed. Prentice Hall, Upper Saddle River, New Jersey. 691 pp.

Hantush, M. S. 1967. Growth and Decay of Groundwater Mounds in Response to Uniform Percolation. Water Resources Research (3): 227-234.

James, L. A. 2003. Late Pleistocene Glaciations in the Northwestern Sierra Nevada, Field Trip Guide and Road Log. XVI INQUA Congress, International Quaternary Association from Reno, Nevada. July 27. Available online at: https://people.cas.sc.edu/ajames/Research/Pubs/03.INQUA.Log.pdf.

Keller Associates. 2017. North Santiam Canyon Regional Wastewater Analysis.

Molina, B. F. 2004. Glossary of Glacier Terminology: A Glossary Providing the Vocabulary Necessary to Understand the Modern Glacier Environment. U.S. Geological Survey Open-File Report 2004-2016.

OWRD. 2020. Online Well Report Query. Available online at: https://apps.wrd.state.or.us/apps/gw/well_log/. Accessed by GSI in September 2020.

Priest, G. R., Woller, N. M. and M. L. Ferns. 1987. Geologic Map of the Breitenbush River Area, Linn and Marion Counties, Oregon. Oregon Department of Geology and Mineral Industries GMS-46.

Thayer, T. P. 1934. The General Geology of the North Santiam River Section of the Oregon Cascades. P.h. D. Thesis, California Institute of Technology. 170 pp.

Thayer, T. P. 1939. Geology of the Salem Hills and the North Santiam River Basin, Oregon. State of Oregon Department of Geology and Mineral Industries Bulletin No. 15. 51 pp.

Walker, G. W. and R. A. Duncan. 1989. Geologic Map of the Salem 1 degree by 2 degree Quadrangle, Western Oregon. U.S. Geological Survey Miscellaneous Investigations Series Map I-1893.

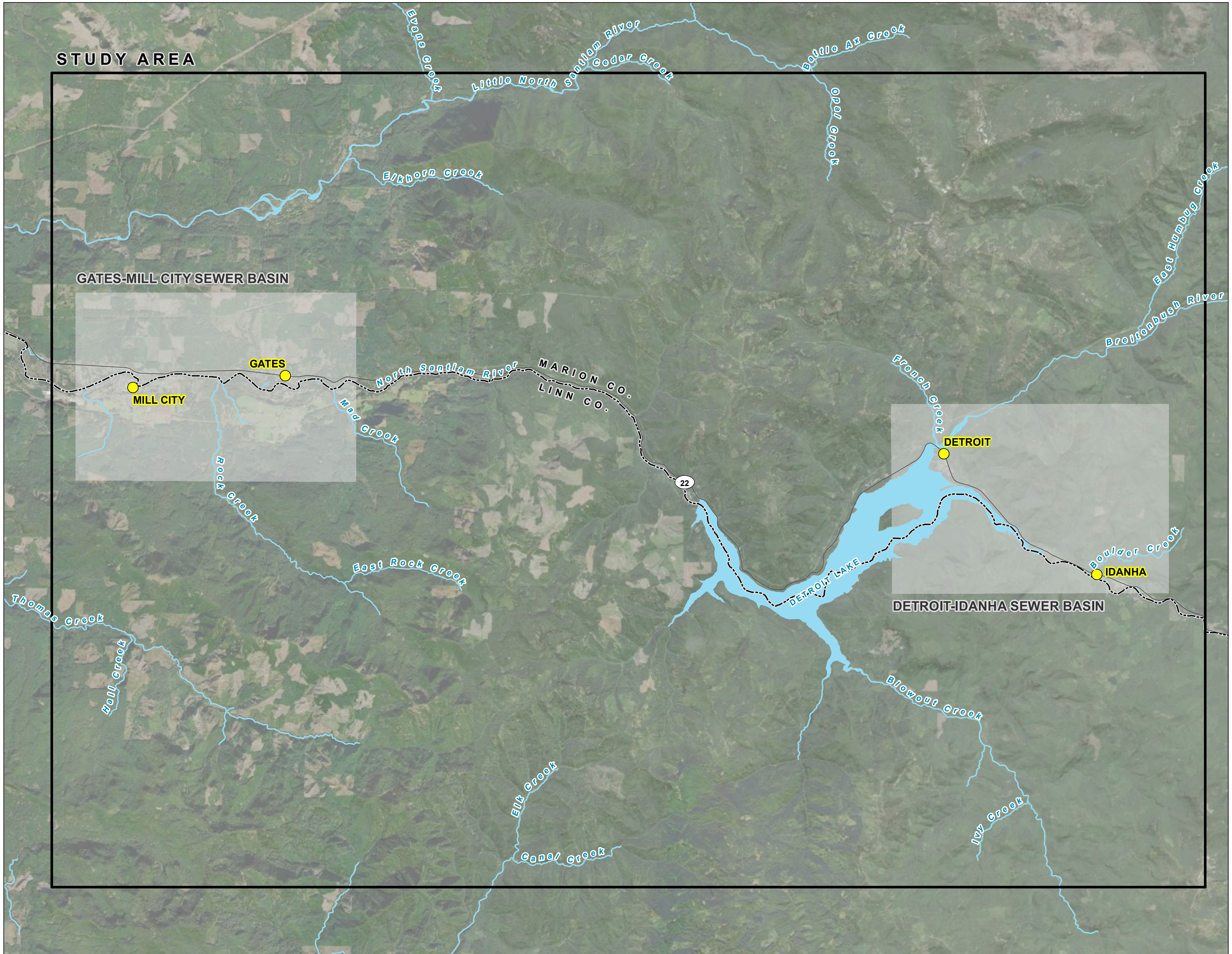


FIGURE 1

Study Area Location Map

North Santiam Canyon
Infiltration Analysis

LEGEND

- City
- Sewer Basin
- Study Area
- County Boundary
- Major Road
- Watercourse
- Waterbody

N

0 5,000 10,000 15,000
Feet

Date: September 24, 2020
Data Sources: USGS, FEMA, WSS, OSIP Imagery 2018.

GSI Water Solutions, Inc.

Document Path: Y:\0464_Keller_Assoc\Source_Figures\010_North_Santiam_Sewer\NSC_Infiltration_Analysis\Figure1_Study_Area.mxd, abarry

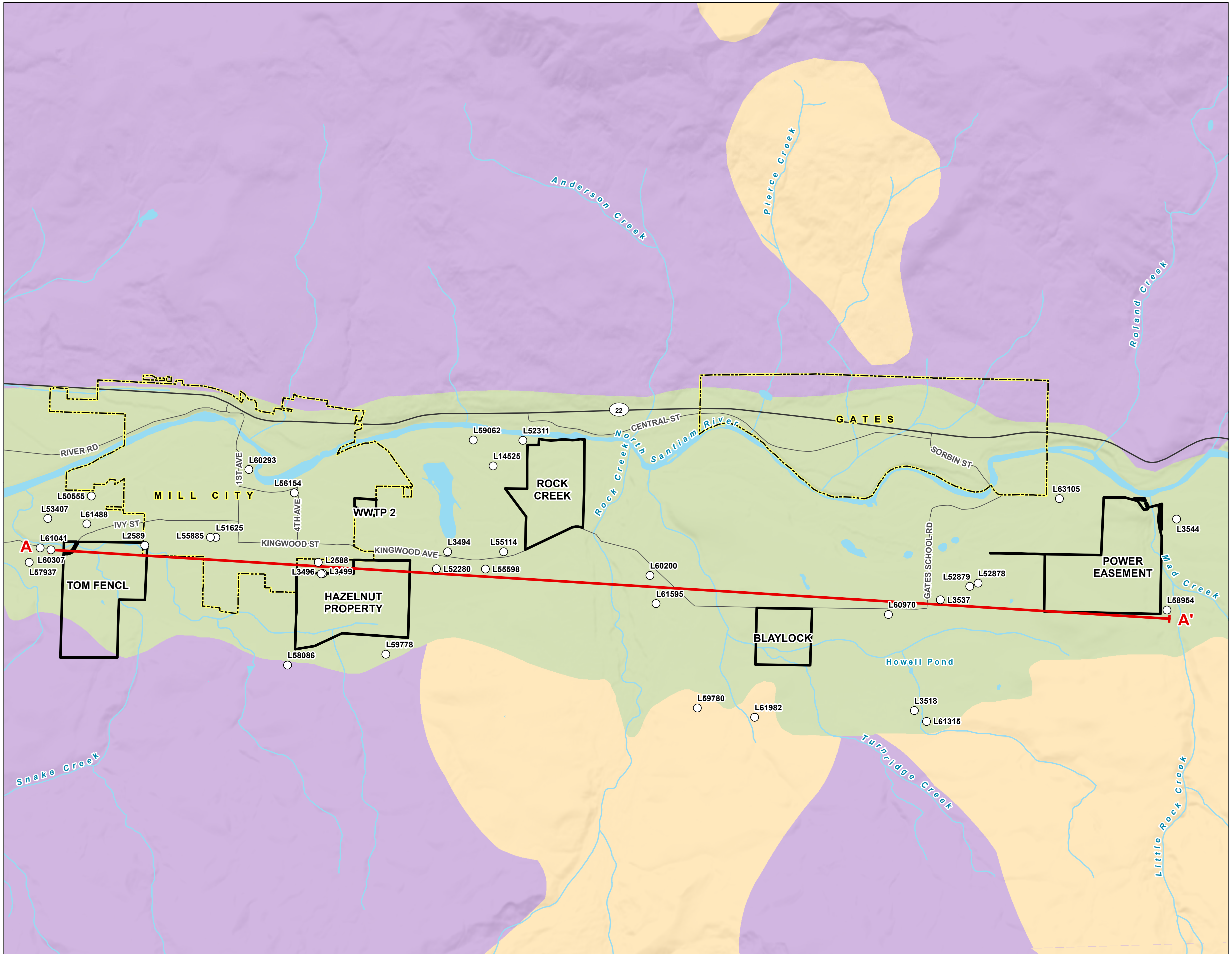


FIGURE 2

Surficial Geology in the Gates-Mill City Sewer Basin

North Santiam Canyon Infiltration Analysis

LEGEND

- Water Well
- Cross Section Line
- Focused Evalution Property

Geology

Quaternary Unconsolidated Deposits

- Glacial Fluvial Deposits (Glacial Till) (Qtm)
- Landslide Debris (Qls)

Tertiary Volcanic and Sedimentary Rocks

- Tuffaceous Sediments and Basalt Flows and Tuffs (Tu)
- Major Road
- City Boundary
- Watercourse
- Waterbody

NOTES

1. Geology is generally based on Walker and Duncan (1989) and Beaulieu et al. (1974).
2. Tuffaceous Sediments and Basalt (Tu) is from Walker and Duncan (1989) and includes the Sardine Formation and Little Butte Formation as mapped by Walker (1989).
3. Landslide Deposits (Qls) are from Walker and Duncan (1989)

N

0 1,100 2,200 3,300
Feet

Date: September 24, 2020
Data Sources: USGS, FEMA, WSS, OSIP Imagery 2018.

GSI Water Solutions, Inc.

Document Path: Y:\0464_Keller_Assoc\Source_Figures\010_North_Santiam_Sewer\NSC_Infiltration_Analysis\Figure2_MillCity_Gates_Geology.mxd, abarry

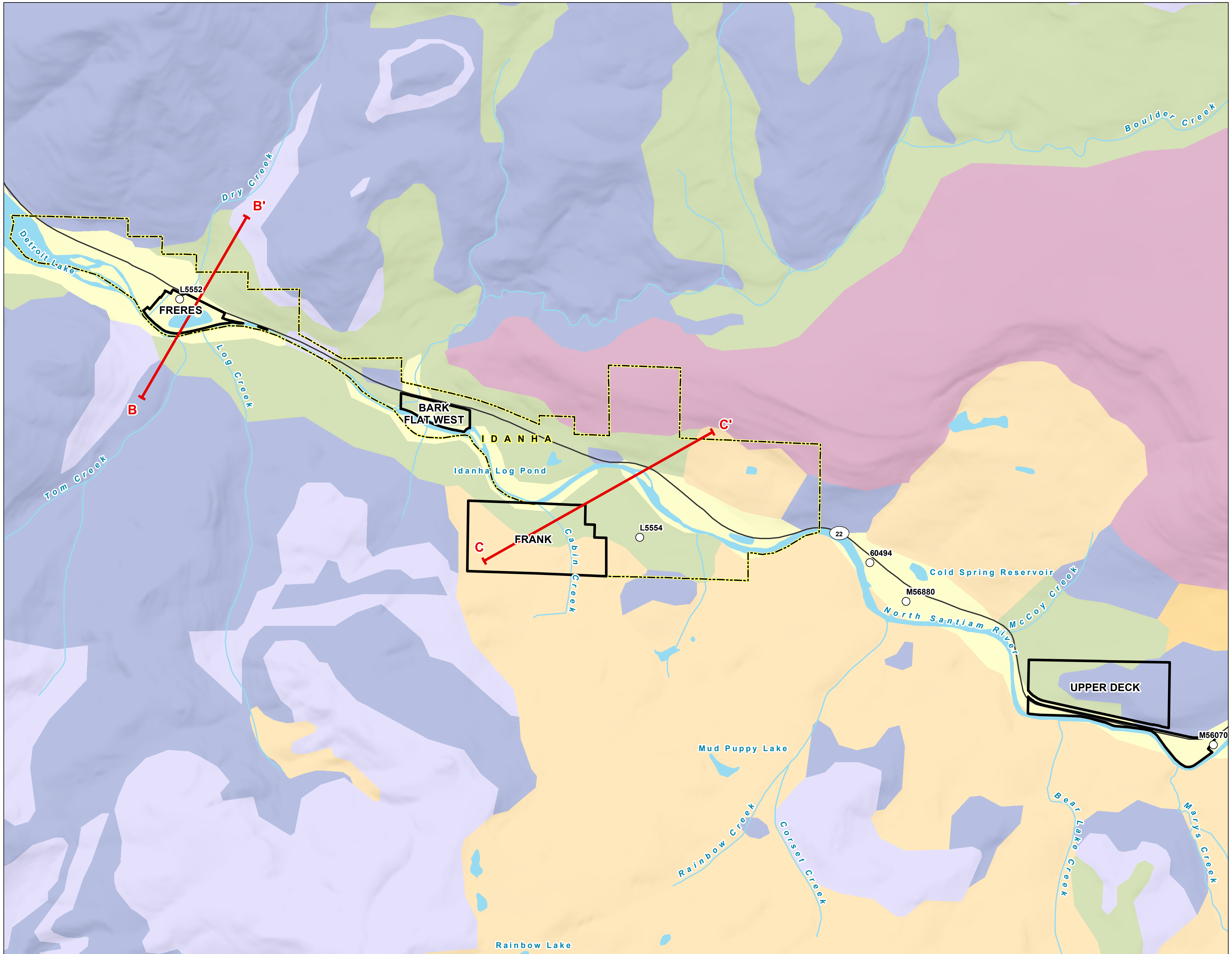


FIGURE 3

Surficial Geology in the Detroit-Idanha Sewer Basin

North Santiam Canyon Infiltration Analysis

LEGEND

- Water Well
- Cross Section Line
- Focused Evalution Property

Geology

Quaternary Unconsolidated Deposits

- Alluvium (Qal)
- Colluvium (Qc)
- Landslide Debris (Qls)
- Glacial-fluvial Deposits (Glacial Till)(Qgf)

Volcanic and Sedimentary Rocks

- Quarternary Basalt and Andesite (QTb)
- Tertiary Tuff (Tb)
- Tertiary Andesite (Ts)

All Other Features

- Railroad
- Major Road
- City Boundary

NOTES

1. Geology is generally based on Priest et al. (1987).
2. Tertiary Tuff includes the Quartz-bearing ash-flow tuff (Tbq), Breitenbush Tuff (Tb), Volcanic and volcaniclastic rocks of the lower part of the Breitenbush tuff (Tbl), Welded Pyroxene-bearing ash flow tuff (Tbp), Hornblende-bearing nonwelded ash-flow tuff (Tbh), Possible intracaldera landslide deposits (Tbv), Volcanic and volcaniclastic rocks of the upper part of the Breitenbush tuff (Tbu), and Possible intracaldera landslide deposits (Tbv) of Priest et al. (1987).
3. Tertiary Andesite includes the Lower andesite sequence (Tla), Lavas of Scorpion Mountain (Ts), and Andesite dikes, plugs, and sills (Tis) of Priest et al. (1987).

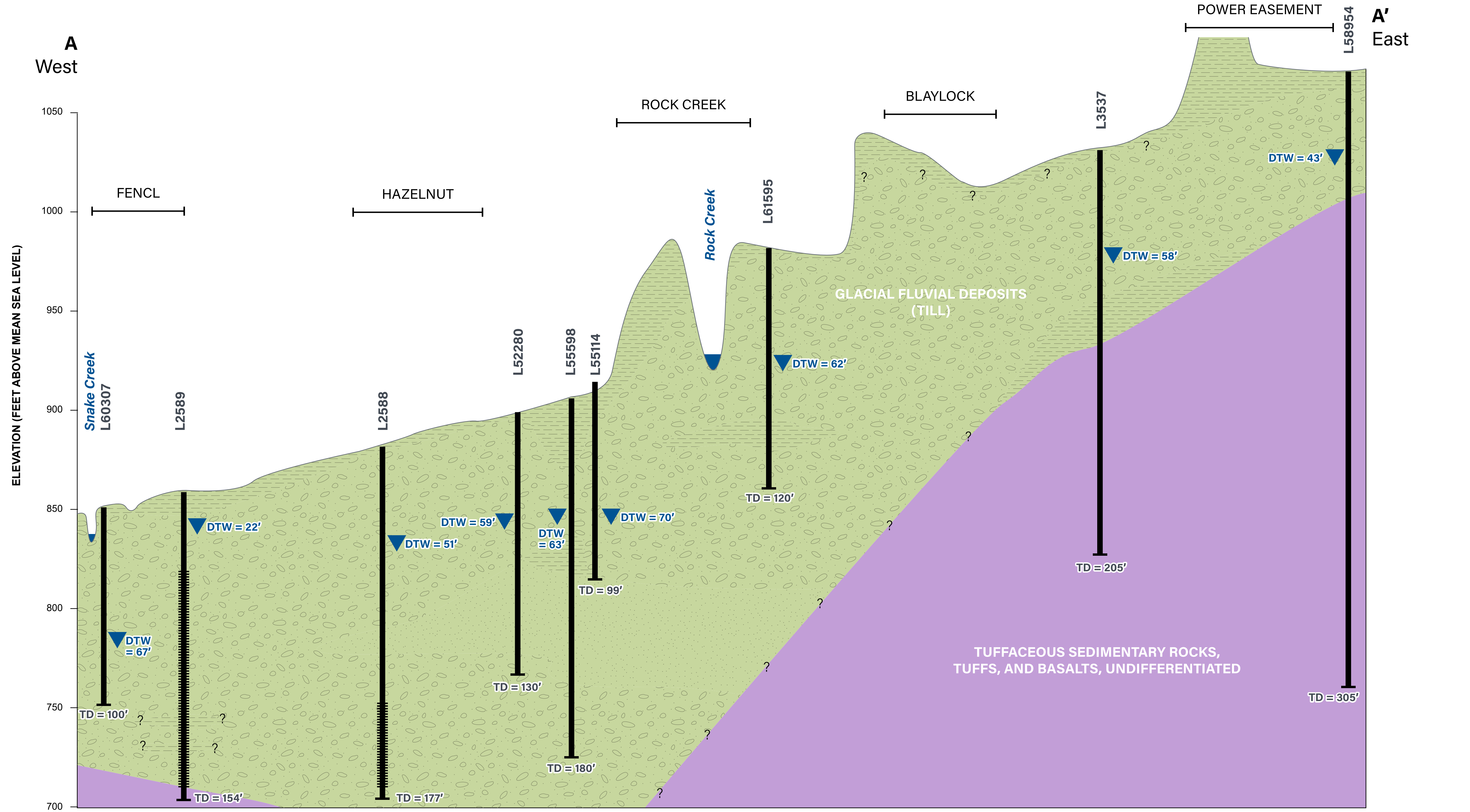
N

0 1,000 2,000 3,000
Feet

Date: September 24, 2020
Data Sources: USGS, FEMA, WSS, OSIP Imagery 2018.

GSI Water Solutions, Inc.

Document Path: Y:\0464_Keller_Assoc\Source_Figures\010_North_Santiam_Sewer\NSC_Infiltration_Analysis\Figure3_Idanha_Geology.mxd, abarry



LEGEND

Geology

Quaternary Unconsolidated Deposits

Glacial Fluvial Deposits (Glacial Till) (Qtm)

Clay

Gravel

Sand

Tertiary Volcanic and Sedimentary Rocks

Tuffaceous Sediments and Basalt Flows and Tuffs (Tu)

NOTES

Horizontal Scale is 1 inch = 2,000 feet
Vertical Scale is 1 inch = 50 feet
Vertical Exaggeration = 40X

FIGURE 4

Cross Section A, Gates-Mill City Sewer Basin

North Santiam Canyon Infiltration Analysis

GSI Water Solutions, Inc.

Y:\0464_Keller_Assoc\Figures\010_North_Santiam_Sewer\Focused_Eval_Sites

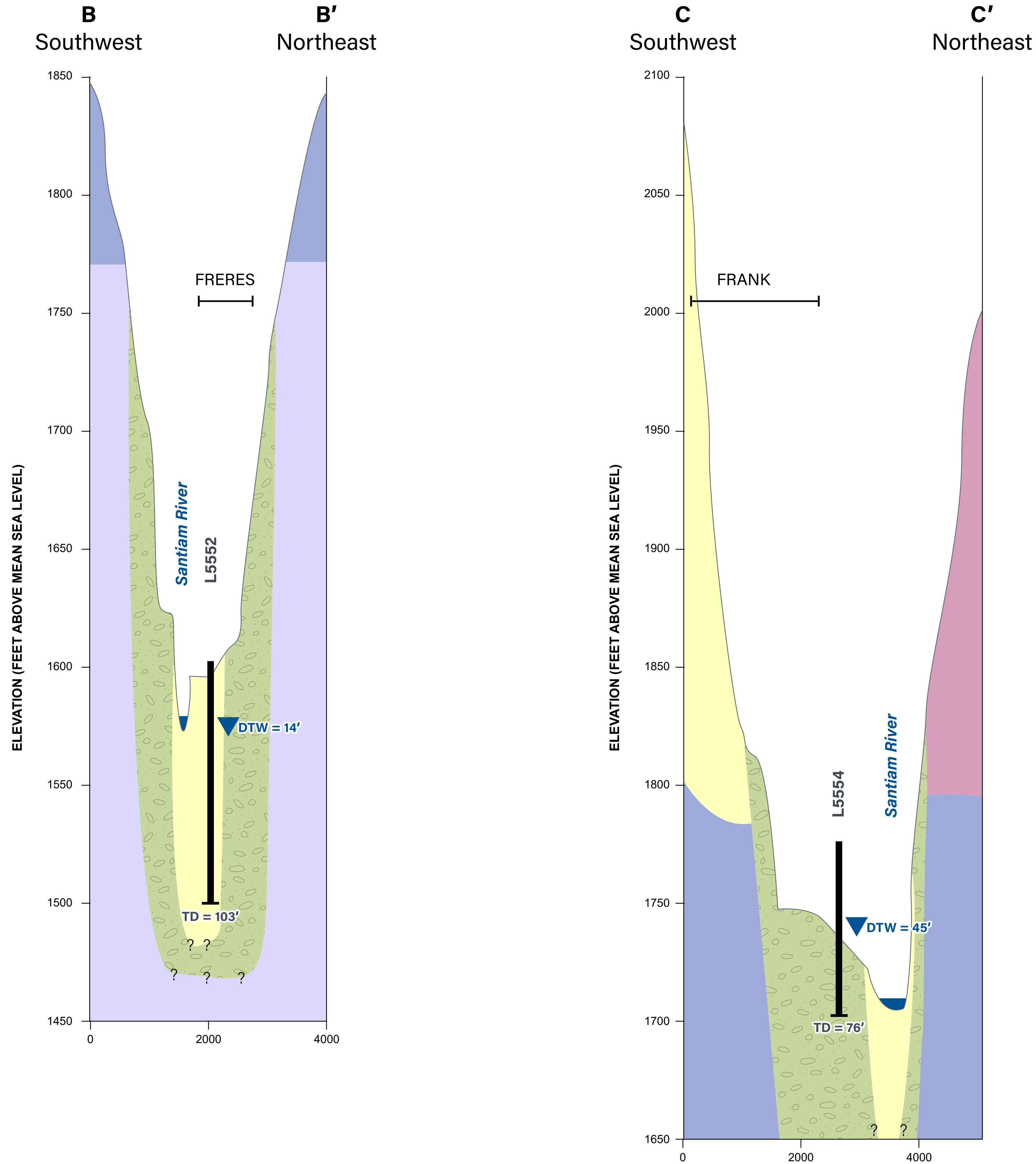


FIGURE 5

Cross Sections B and C, Detroit-Idanha Sewer Basin

North Santiam Canyon Infiltration Analysis

LEGEND

Geology

Quaternary Unconsolidated Deposits

- Alluvium (Qal)
- Glacial Fluvial Deposits (Glacial Till) (Qtm)

Volcanic and Sedimentary Rocks

- Quaternary Basalt and Andesite (QTb)
- Tertiary Tuff (Tb)
- Tertiary Andesite (Ts)

NOTES

Horizontal Scale is 1 inch = 2,000 feet
Vertical Scale is 1 inch = 50 feet
Vertical Exaggeration = 40X

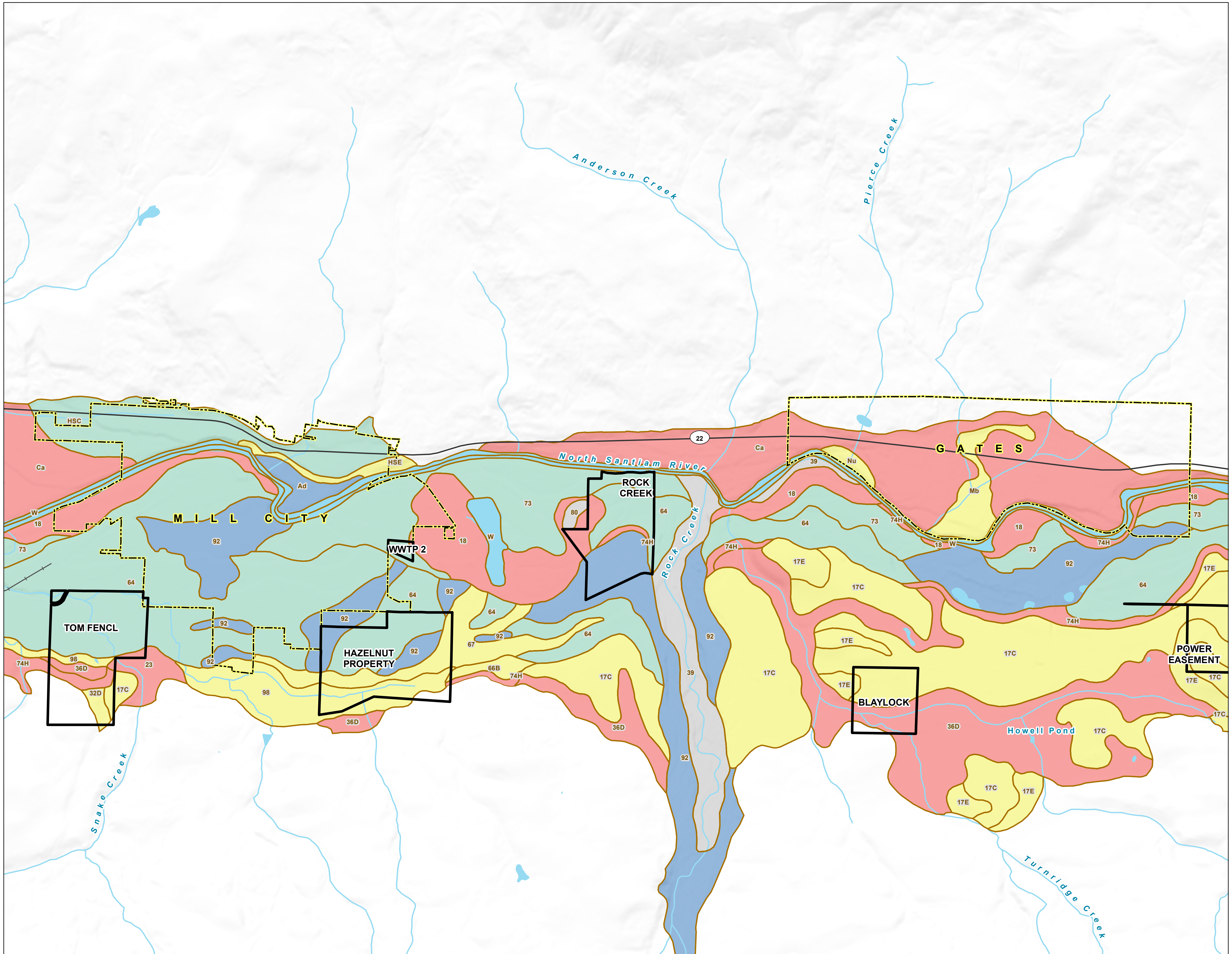
GSI Water Solutions, Inc.

Y:\0464_Keller_Assoc\Figures\010_North_Santiam_Sewer\Focused_Eval_Sites

FIGURE 6

Favorability of Shallow Soils to Infiltration in the Gates-Mill City Sewer Basin

North Santiam Canyon Infiltration Analysis



LEGEND

Focused Evalution Property

Shallow Soil Favorability to Infiltration

- Poor (<0.5 in/hr, >30% slope, restrictive layer present)
- Marginal (0.5 to 5 in/hr, <30% slope, no restrictive layer)
- Good (5 to 10 in/hr, <30% slope, no restrictive layer)
- Excellent (>10 in/hr, <30% slope, no restrictive layer)
- No Data

All Other Features

- Railroad
- Major Road
- City Boundary
- Watercourse
- Waterbody

NOTES

1. Soils have "Poor" favorability if the a slope is greater than 30%, a restrictive layer is present within 72 inches of ground surface, or Ksat is less than 0.5 inches per hour.
2. Soils have a "Marginal" or "Good" favorability to infiltration is the slope is less than 30%, no restrictive layer is present within 72 inches of ground surface, and Ksat is greater than 0.5 inches per hour.

N

0 950 1,900 2,850
Feet

Date: September 24, 2020
Data Sources: USGS, FEMA, WSS, OSIP Imagery 2018.

GSI Water Solutions, Inc.

Document Path: Y:\0464_Keller_Assoc\Source_Figures\010_North_Santiam_Sewer\NSC_Infiltration_Analysis\Figure6_Favorability_of_Shallow_Soils_to_Infiltration_Gates_and_Mills_City.mxd, abarry

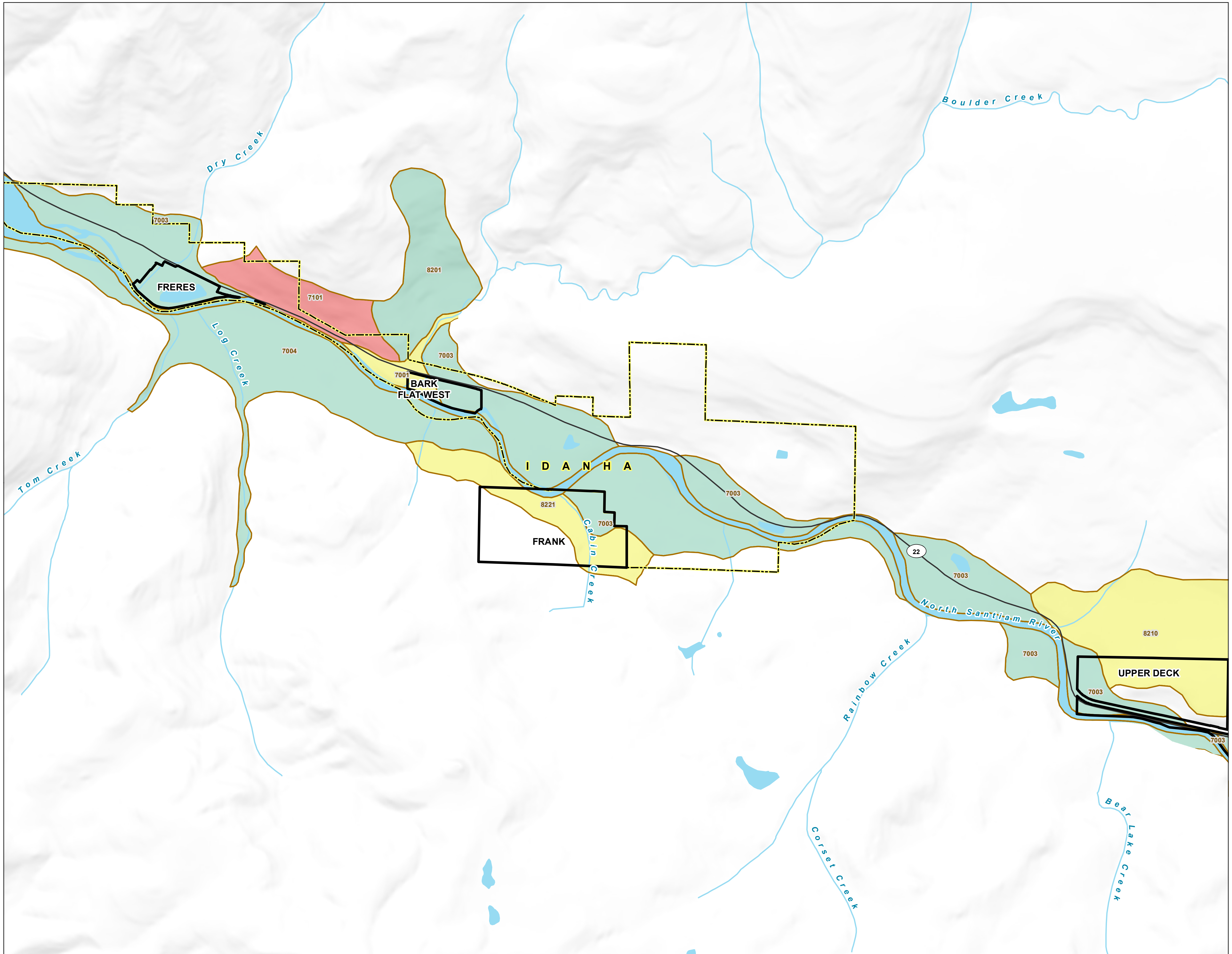


FIGURE 7

Favorability of Shallow Soils to Infiltration in the Detroit-Idanha Sewer Basin

North Santiam Canyon
Infiltration Analysis

LEGEND

Focused Evalution Property

Shallow Soil Favorability to Infiltration

Poor
(<0.5 in/hr, >30% slope, restrictive layer present)

Marginal
(0.5 to 5 in/hr, <30% slope, no restrictive layer)

Good
(5 to 10 in/hr, <30% slope, no restrictive layer)

All Other Features

Major Road

City Boundary

Watercourse

Waterbody

NOTES

1. Soils have "Poor" favorability if the a slope is greater than 30%, a restrictive layer is present within 72 inches of ground surface, or Ksat is less than 0.5 inches per hour.
2. Soils have a "Marginal" or "Good" favorability to infiltration is the slope is less than 30%, no restrictive layer is present within 72 inches of ground surface, and Ksat is greater than 0.5 inches per hour.

N

0 850 1,700 2,550
Feet

Date: September 24, 2020
Data Sources: USGS, FEMA, WSS, OSIP Imagery 2018.

GSI Water Solutions, Inc.

Document Path: Y:\0464_Keller_Assoc\Source_Figures\010_North_Santiam_Sewer\NSC_Infiltration_Analysis\Figure7_Favorability_of_Shallow_Soils_to_Infiltration_Idanha.mxd, abarry

DRAFT

North Santiam Canyon Wastewater Infiltration Evaluation

Attachment A. Technical Background Information for Hantush (1967) Infiltration Volume Calculations

September 2020

Prepared by:
GSI Water Solutions, Inc.
55 SW Yamhill St., Suite 300, Portland, OR, 97204

This page intentionally left blank.

Contents

Tables

1. Background

This attachment provides a detailed technical discussion of the Hantush (1967) calculations that were used to estimate the infiltration rate and resulting volume of water that can be infiltrated at each of the ten candidate sites. The 1967 Hantush equation describes the magnitude and radius of groundwater mounding that may occur beneath an infiltration basin for a given infiltration rate and set of aquifer properties, from which an infiltration volume can be determined.

1.1 Hantush (1967) Equation

The Hantush equation is an analytical solution to the general two-dimensional groundwater flow equation. Hantush (1967) derived a solvable integral through assumptions that create boundary conditions that allow the use of a Laplace transform with respect to time, and the Fourier cosine transform with respect to x then y (Carleton, 2010 and Hantush 1967). Assumptions include an aquifer of infinite extent, finite thickness, and a horizontal impermeable base; horizontal groundwater flow; and a negligible change in transmissivity with change in head (Carleton, 2010 and Hantush 1967). The 1967 Hantush equation also neglects storage and delayed yield from the unsaturated zone. The governing equation is shown below.

$$h^2 - h_i^2 = \left(\frac{w}{2k}\right)(vt)\left\{S*\left(\frac{l+x}{\sqrt{4vt}},\frac{a+y}{\sqrt{4vt}}\right) + S*\left(\frac{l+x}{\sqrt{4vt}},\frac{a-y}{\sqrt{4vt}}\right) + S*\left(\frac{l-x}{\sqrt{4vt}},\frac{a+y}{\sqrt{4vt}}\right) + S*\left(\frac{l-x}{\sqrt{4vt}},\frac{a-y}{\sqrt{4vt}}\right)\right\}$$

$$\text{where, } S*(\alpha,\beta) = \int_0^1 erf\left(\frac{\alpha}{\sqrt{\tau}}\right)erf\left(\frac{\beta}{\sqrt{\tau}}\right)d\tau$$

and,

h = head at a given time after recharge begins;
h_i = initial head (height of the water table above the base of the aquifer);
w = recharge (infiltration) rate;
k = horizontal hydraulic conductivity;
b = average aquifer thickness;
S_y = specific yield;
l = half-length of the recharge basin;
a = half-width of the recharge basin;
v = diffusivity, where $v = kb/S_y$;
t = time elapsed since recharge began;
x = distance from the center of the recharge basin in the x direction;
y = distance from the center of the recharge basin in the y direction;
$\alpha = \frac{l+x}{\sqrt{4vt}}$ or $\frac{l-x}{\sqrt{4vt}}$;
$\beta = \frac{a+y}{\sqrt{4vt}}$ or $\frac{a-y}{\sqrt{4vt}}$;
τ = dummy variable of integration; and
erf = error function.

Because the Hantush (1967) equation cannot be solved explicitly, it is solved using iterative numerical methods. GSI utilized a Microsoft Excel spreadsheet developed by the U.S. Geological Survey (USGS) to solve the equation and calculate the amount of groundwater mounding likely to occur at each evaluation site. The USGS Excel spreadsheet solves the Hantush (1967) equation numerically using Simpson's Rule and the Trapezoidal Rule integration techniques (Chapra and Canale, 1998 and Carleton, 2010). The calculation begins by estimating a water level, then uses a macro and the "Goal Seek" excel function to converge on a solution where estimated and calculated water levels are within 0.00001 (Carleton 2010). The required input parameters are discussed in Section 1.2, below.

1.2 Input Parameters

Table A-1 provides a summary of the input parameters and physical characteristics of the 10 sites for infiltration. The methods used to develop the input parameters are discussed in the following sections.

Table A-1. Input Parameters and Physical Site Characteristics for the Hantush (1967) Equation.

Property	Specific Yield (dimensionless)	Hydraulic Conductivity (ft/d)	Drainage Basin Length (feet)	Drainage Basin Width (feet)	Infiltration Period Duration (days)	Saturated Zone Thickness (feet)	Unsaturated Zone Thickness (feet)
Tom Fencl	0.10	20.77	922.3	589.7	365	129	50
Hazelnut Property	0.10	20.77	1155.1	1155.1	365	126	51
WWTP 2	0.10	20.77	372.8	372.8	365	100	46
Rock Creek	0.10	20.77	852.7	852.7	365	90	40
Blaylock	0.10	20.77	981.2	981.2	365	60	17
Power Easement	0.10	20.77	1080.5	1080.5	365	75	48
Freres	0.19	50	676.0	676.0	365	92	14
Bark Flat West	0.10	20.77	633.0	330.0	365	92	20
Frank	0.10	20.77	506.5	506.5	365	31	45
Upper Deck	0.10	20.77	713.0	713.0	365	30	13

Notes
ft/d = feet per day
WWTP = Wastewater Treatment Plant

1.2.1 Specific Yield

Specific yield is the percentage of water in a saturated soil or aquifer that will drain under the influence of gravity (i.e. a measure of the pore space that is available for groundwater flow). A specific yield of 0.10 was chosen for sites mapped as glacial till, which is typical of unconsolidated sediments in a semi-confined aquifer. The Freres site is the only site located on Alluvium of the Santiam River, so this site utilized a specific yield of 0.19, as reported by Heath (1983) for a gravel for an unconfined aquifer.

1.2.2 Hydraulic Conductivity

Horizontal hydraulic conductivity (k) for the glacial till was estimated from aquifer tests reported on well logs for wells completed in the glacial sediments in the vicinity of Gates, Mill City, and Idanha (OWRD, 2020). Only pumping tests longer than 1 hour that reported both a pumping rate and drawdown were used to estimate hydraulic conductivity. The below equation from Driscoll (1986) was used to solve for transmissivity, from which hydraulic conductivity can be determined.

$$\frac{Q}{s} = \frac{T}{264 * \log(\frac{0.3Tt}{r^2 S})}$$

Where,

s = drawdown in the well, in feet;
Q = yield of the well, in gallons per minute (gpm);
T = transmissivity of the well, in gallons per day per foot (gpd/ft);
t = pumping duration, in days;
r = radius of the well, in feet; and
S = storage coefficient of the aquifer (unitless)

From the transmissivity, the hydraulic conductivity of the aquifer can be calculated by dividing the transmissivity by the aquifer thickness (the thickness of the saturated zone, see section 1.2.5). The resulting hydraulic conductivities ranged from 12.62 to 29.8 feet per day (ft/day). For wells which reported multiple aquifer tests, the hydraulic conductivities resulting from each test were averaged together to determine a mean hydraulic conductivity for the well. The resulting hydraulic conductivities from each well were then averaged using an arithmetic mean to obtain a single hydraulic conductivity value of 20.77 ft/day for the glacial sediments.

Due to the limited pumping data for the Alluvium of the Santiam River, a hydraulic conductivity could not be calculated based on available well log information. Instead, a hydraulic conductivity of 50 ft/day was assumed for the alluvial aquifer, based on typical hydraulic conductivity for a coarse sand compiled by Anderson and Woessner (1992). The hydraulic conductivity of a coarse sand was used to estimate the permeability of the Alluvium of the Santiam River because we assume that the unit is a matrix-supported gravel, and the sand matrix likely governs groundwater flow characteristics.

The hydraulic conductivity values used in the Hantush (1967) equation are study-area-wide averages and approximations. Hydraulic conductivity is likely to vary locally at each site as grain size, the degree of cementation, and other physical properties of the aquifer vary. As described by the Hantush (1967) equation, assuming a lower hydraulic conductivity results in a greater degree of mounding beneath an infiltration site (and lower infiltration volume), while a higher hydraulic conductivity results in a lesser degree of mounding beneath an infiltration site (and higher infiltration volume).

1.2.3 Drainage Basin Dimensions (Length and Width)

Rectangular drainage basins were located on each site, shown on Figures A.1 to A.10. Basin locations targeted areas where ground slope is less than ten percent and the average vertical hydraulic conductivity of surface soils are high. Basin locations cover the maximum area of the site possible, and do not necessarily reserve areas for siting of wastewater infiltration facilities. At sites with only one basin (Tom Fencl, Bark Flat West), half the basin length and half the basin width are used as inputs for the Hantush (1967) equation. At sites with multiple infiltration basins, a half-length and half-width for input into the Hantush (1967) equation were determined from the total area covered by infiltration basins using the equation below.

$$l \; or \; w = 0.5 * \sqrt{\sum a_n}$$

Where,

$l \; or \; w$ = half the basin length or width, in feet; and

a_n= the area of each basin in the evaluation site, in square feet

See table A-1 for resulting dimensions. The shape of the infiltration basin (rectangle vs square) does not impact the height of the groundwater mound or amount of water infiltrated when the resulting area is the same.

1.2.4 Infiltration Period Duration

An infiltration period of 365 days was used to calculate groundwater mound height at each evaluation site. This is a conservative assumption because, in practice, infiltration will not occur every day of the year so estimates generated using 365 days provide a maximum estimate of groundwater mound height and yearly infiltrated volume.

1.2.5 Saturated Zone Thickness

The thickness of the saturated zone at each site was estimated from nearby well logs from the Oregon Water Resources Department (OWRD, 2020). The saturated zone thickness can be determined from a well log by subtracting the reported depth to groundwater from the depth to the bottom of the aquifer. However, many wells do not fully penetrate the alluvial or glacial aquifers. In this case, a minimum saturated zone thickness was determined by subtracting the depth to groundwater from the total depth of the well. Where possible, estimates of the thickness of the saturated zone were taken from well logs which fully penetrate the aquifer in the vicinity of the site. When no nearby wells recorded the full depth of the aquifer, an average of the minimum saturated zone thicknesses from nearby wells was used instead. See Table A-1 for resulting inputs. A thinner saturated zone results in a greater degree of mounding because the aquifer has less ability to transmit water away from the infiltration source (USGS, 2010). As a result, using a thinner saturated zone results in a higher groundwater mound, lower possible recharge rate, and more conservative volume estimate.

1.2.6 Unsaturated Zone Thickness

The unsaturated zone thickness was determined at each evaluation site by averaging the depth to static water level found in nearby well logs. While the 1967 Hantush equation does not directly account for the thickness of the unsaturated zone, it should be noted that a greater degree of mounding and more unsaturated zone storage is possible in areas where the depth to the saturated zone is greater. The thickness of the saturated zone, minus a safety factor of 10 ft, dictated the magnitude of groundwater mounding acceptable at each site evaluated for this study.

1.2.7 Recharge Rate

Recharge rates at each site were calculated to provide the maximum groundwater mound height possible while remaining at least 10 ft below the ground surface. The resulting recharge rates were in reasonable agreement of the vertical saturated hydraulic conductivity values estimated for local soils by the NRCS. These recharge rates were multiplied by the basin area and infiltration duration to determine the volume of infiltrated water at each site.

2. Results

Table A-2 shows the volume of water that can be infiltrated at each of the 10 candidate infiltration sites, assuming that the groundwater mound is brought to within 10 feet of ground surface.

Table A-2. Infiltration Volume at the Ten Sites, Estimated by the Hantush (1967) Equation.

Property	Recharge Rate (feet/day)	Area of Drainage Basin (ft^2)	Length of Infiltration (days)	Infiltration Volume (MGY)
Tom Fencl	0.48	543,913	365	713
Hazelnut Property	0.223	1,334,243	365	838
WWTP 2	1.16	138,956	365	440
Rock Creek	0.21	727,016	365	417
Blaylock	0.03	962,676	365	68.3
Power Easement	0.17	1,167,408	365	536
Freres	0.09	456,944	365	109
Bark Flat West	0.19	208,890	365	108
Frank	0.31	256,568	365	216
Upper Deck	0.01	508,345	365	14.6

Notes
MGY = million gallons per year
ft^2 = square feet

3. References

Anderson, M. P. and W. W. Woessner. 1992. Applied Groundwater Modeling: Simulation of Flow and Advective Transport. Academic Press, San Diego, CA. 381 pp.

Carleton, G. B. (2010). Simulation of groundwater mounding beneath hypothetical stormwater infiltration basins. U. S. Geological Survey; Prepared in cooperation with the New Jersey Department of Environmental Protection.

Chapra, S.C., and Canale, R.P. (1998). Numerical methods for engineers (3d ed.): Boston, Mass., WCB/McGraw-Hill, 924 p.

Driscoll, F. G. (1986). Groundwater and wells: St. Paul, Minnesota, Johnson Screens., 1089p.

Hantush, M. S. (1967). Growth and decay of groundwater-mounds in response to uniform percolation. Water Resources Research, 3(1), p. 227-234.

Heath, R. C. (1983). Basic Groundwater Hydrology: US Geological Survey Water Supply Paper 2220; prepared in cooperation with the North Carolina Department of Natural Resources and Community Development.

OWRD. 2020. Online Well Report Query. Available online at: https://apps.wrd.state.or.us/apps/gw/well_log/. Accessed by GSI in September 2020.

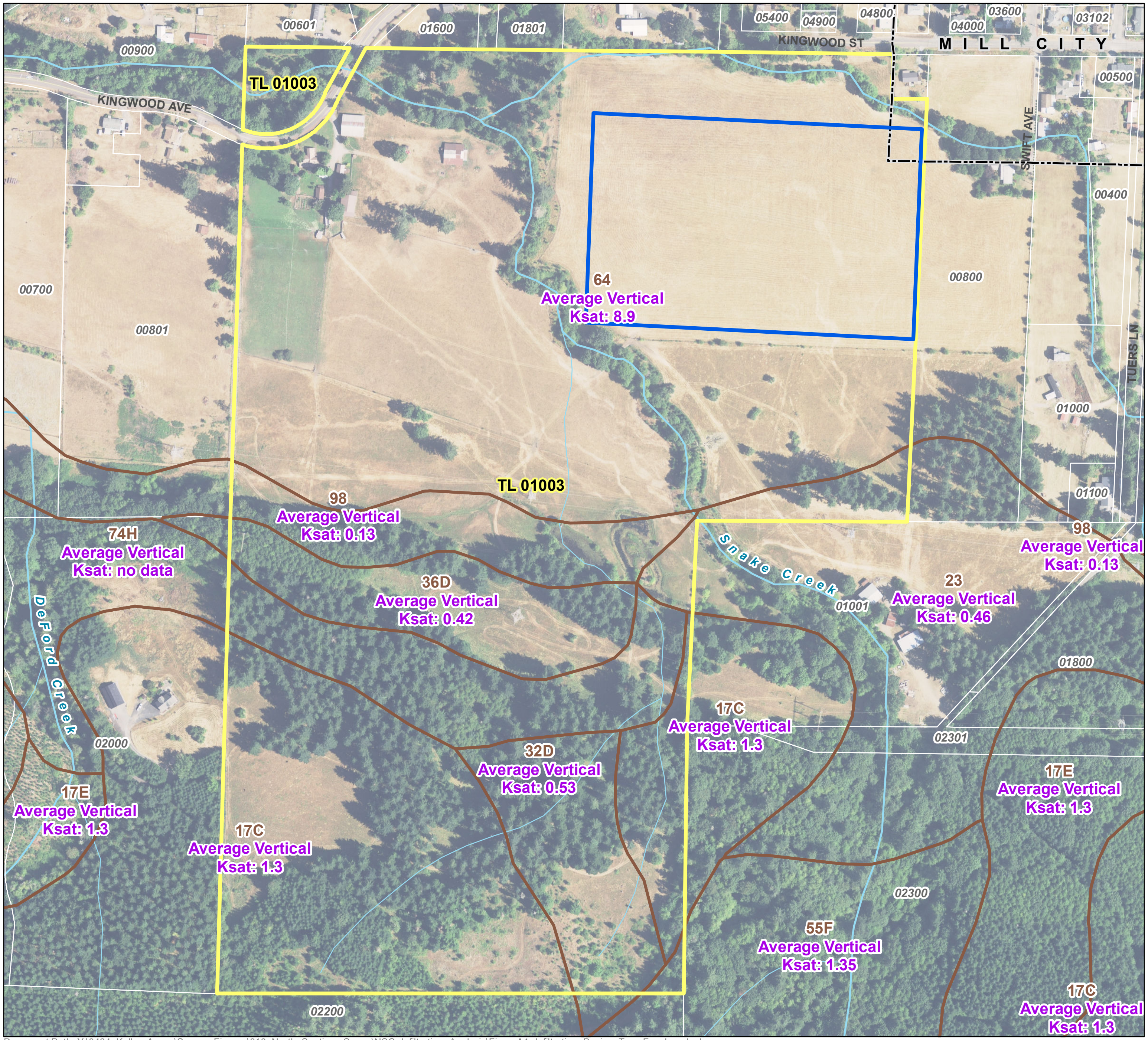


FIGURE A.1

Intiltration Basin at Tom Fencl Site

North Santiam Canyon Infiltration Analysis

Mill City, Oregon

LEGEND

- Potential Infiltration Basin (12.46 ac.)
- Tom Fencl Property
- Soil Type
- City Boundary
- Watercourse

NOTES

1. Infiltration basin footprint(s) are designed to maximize infiltration volume (i.e., to maximize the area of the site where infiltration occurs). As a part of facility design, the basin footprint(s)may need to be adjusted to accommodate structures and/or parking areas or meet regulatory requirements (e.g., setbacks).
2. Average Saturated Hydraulic Conductivity (Ksat) is in units of in/hr.

N

0 200 400
Feet

Date: September 25, 2020
Data Sources: USDA, USGS, Linn Co., Marion Co., OSIP imagery 2018.

GSI Water Solutions, Inc.

Document Path: Y:\0464_Keller_Assoc\Source_Figures\010_North_Santiam_Sewer\NSC_Infiltration_Analysis\FigureA1_Infiltration_Basins_Tom_Fencl.mxd, abarry

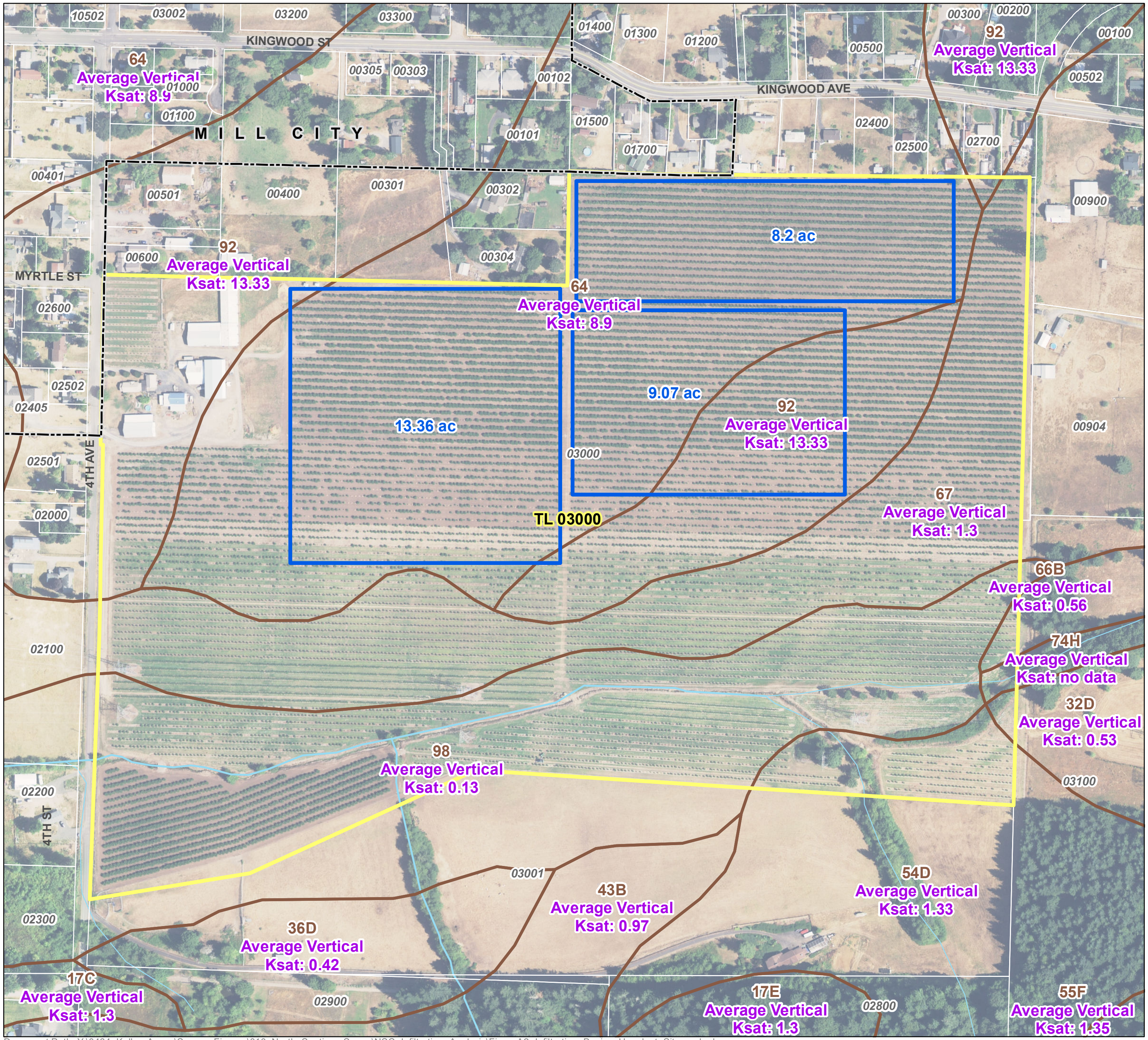


FIGURE A.2

Infiltration Basins at Hazelnut Site

North Santiam Canyon Infiltration Analysis

Mill City, Oregon

LEGEND

- Potential Infiltration Basin
- Hazelnut Property
- Soil Type
- City Boundary
- Watercourse

NOTES

1. Infiltration basin footprint(s) are designed to maximize infiltration volume (i.e., to maximize the area of the site where infiltration occurs). As a part of facility design, the basin footprint(s)may need to be adjusted to accommodate structures and/or parking areas or meet regulatory requirements (e.g., setbacks).
2. Average Saturated Hydraulic Conductivity (Ksat) is in units of in/hr.

N

0 200 400
Feet

Date: September 25, 2020
Data Sources: USDA, USGS, Linn Co., Marion Co., OSIP imagery 2018.

GSI Water Solutions, Inc.

Document Path: Y:\0464_Keller_Assoc\Source_Figures\010_North_Santiam_Sewer\NSC_Infiltration_Analysis\FigureA2_Infiltration_Basins_Hazelnut_Site.mxd, abarry

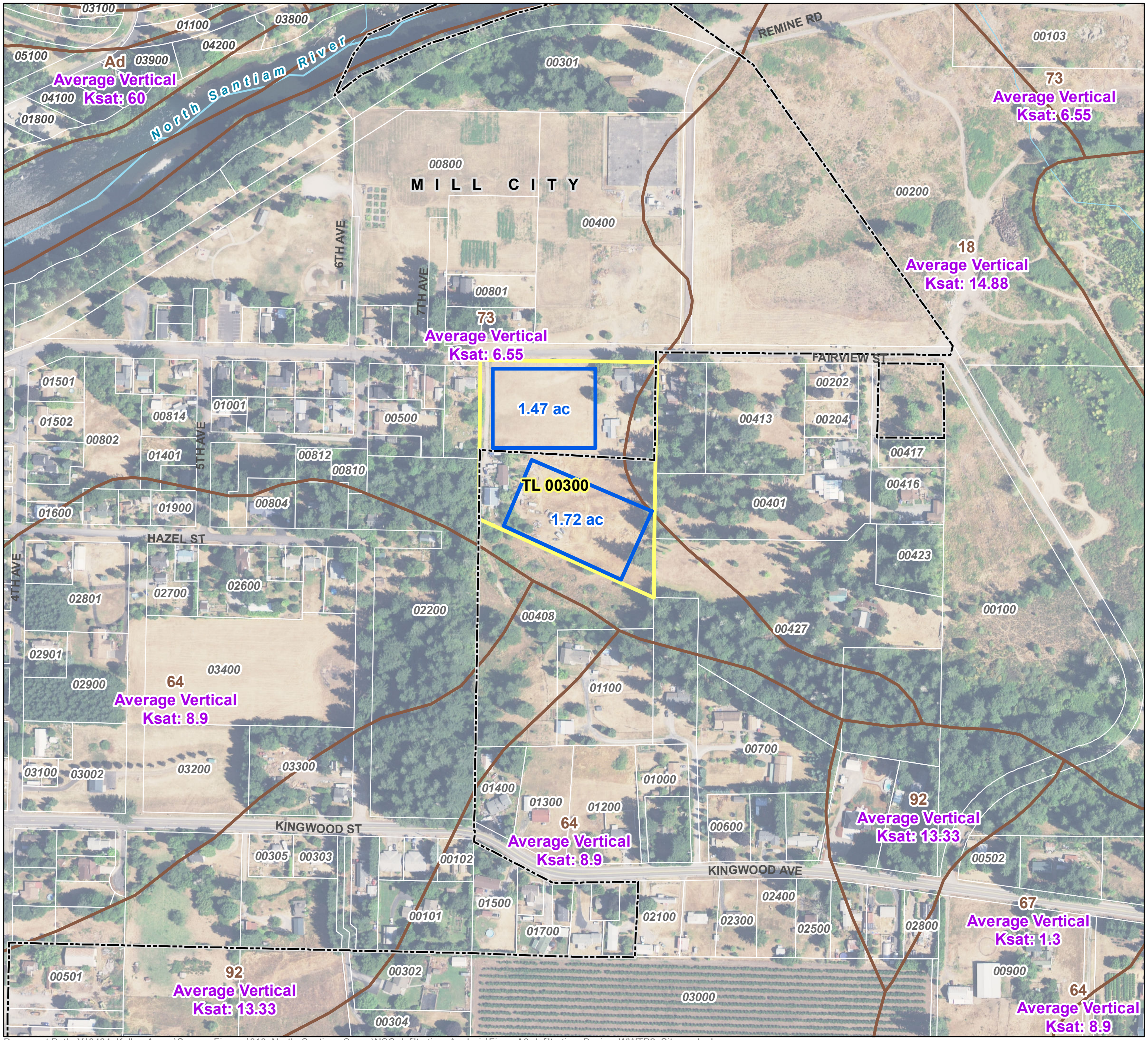


FIGURE A.3

Infiltration Basins at WWTP 2 Site

North Santiam Canyon Infiltration Analysis

Mill City, Oregon

LEGEND

- Potential Infiltration Basin
- WWTP 2 Site
- Soil Type
- City Boundary
- Watercourse

NOTES

1. Infiltration basin footprint(s) are designed to maximize infiltration volume (i.e., to maximize the area of the site where infiltration occurs). As a part of facility design, the basin footprint(s)may need to be adjusted to accommodate structures and/or parking areas or meet regulatory requirements (e.g., setbacks).
2. Average Saturated Hydraulic Conductivity (Ksat) is in units of in/hr.

WWTP: Waste Water Treatment Plant

N

0 200 400
Feet

Date: September 25, 2020
Data Sources: USDA, USGS, Linn Co., Marion Co., OSIP imagery 2018.

GSI Water Solutions, Inc.

Document Path: Y:\0464_Keller_Assoc\Source_Figures\010_North_Santiam_Sewer\NSC_Infiltration_Analysis\FigureA3_Infiltration_Basins_WWTP2_Site.mxd, abarry

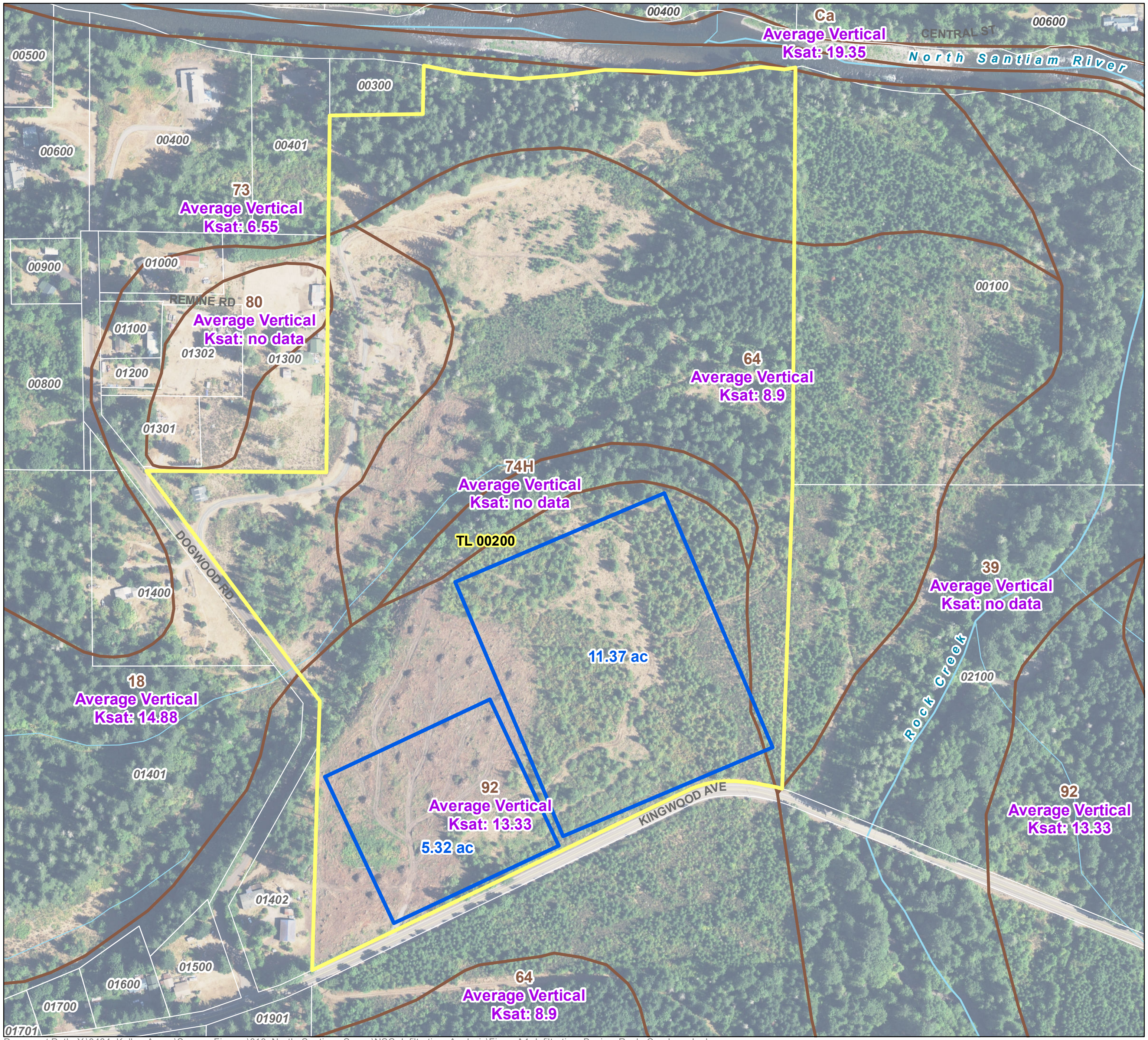


FIGURE A.4

Infiltration Basins at Rock Creek Site

North Santiam Canyon Infiltration Analysis

Mill City, Oregon

LEGEND

- Potential Infiltration Basin
- Rock Creek Site
- Soil Type
- Watercourse

NOTES

1. Infiltration basin footprint(s) are designed to maximize infiltration volume (i.e., to maximize the area of the site where infiltration occurs). As a part of facility design, the basin footprint(s)may need to be adjusted to accommodate structures and/or parking areas or meet regulatory requirements (e.g., setbacks).
2. Average Saturated Hydraulic Conductivity (Ksat) is in units of in/hr.

N

0 200 400
Feet

Date: September 25, 2020
Data Sources: USDA, USGS, Linn Co., Marion Co., OSIP imagery 2018.

GSI Water Solutions, Inc.

Document Path: Y:\0464_Keller_Assoc\Source_Figures\010_North_Santiam_Sewer\NSC_Infiltration_Analysis\FigureA4_Infiltration_Basins_Rock_Creek.mxd, abarry

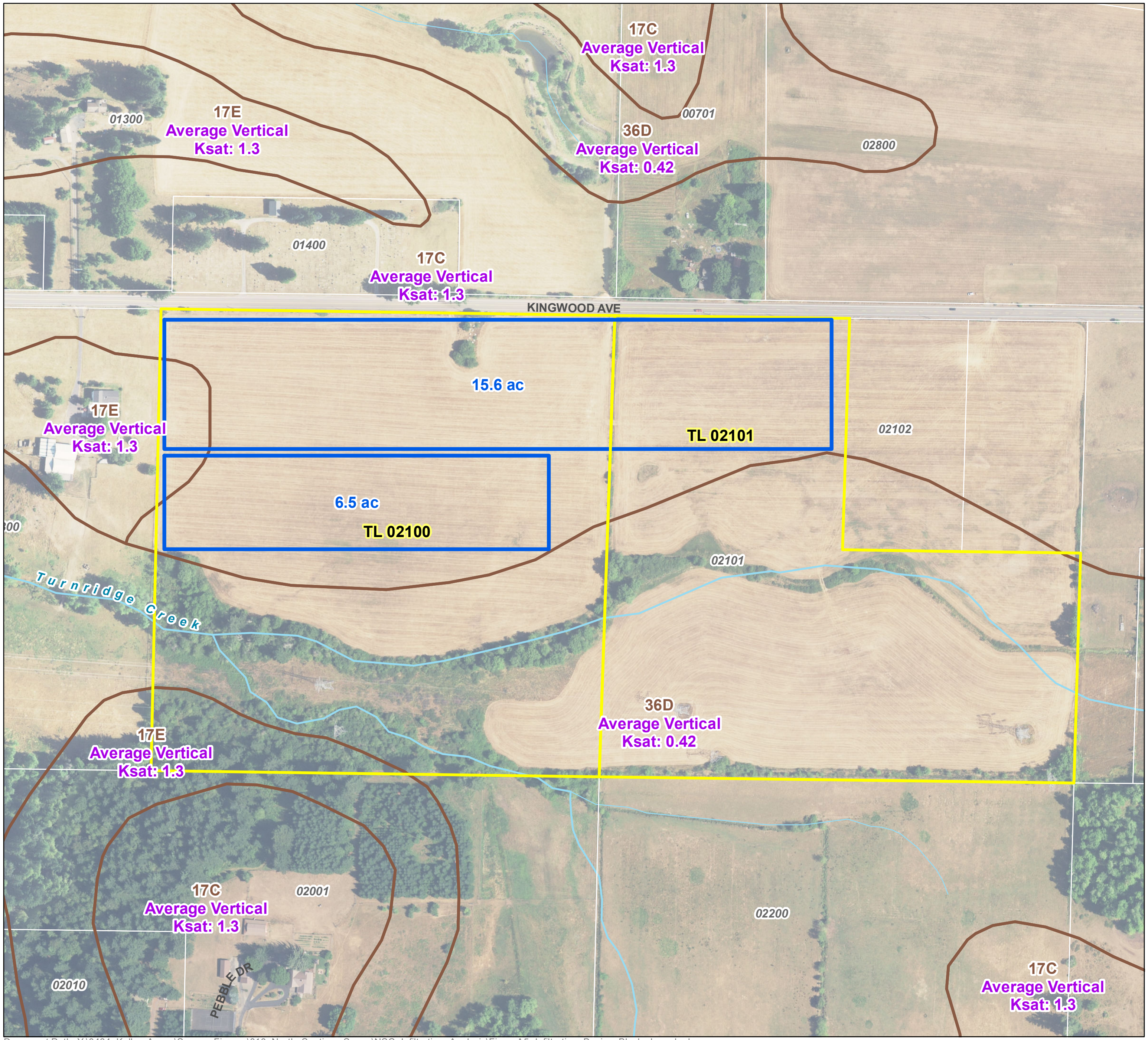


FIGURE A.5

Infiltration Basins at Blaylock Site

North Santiam Canyon Infiltration Analysis

Gates, Oregon

LEGEND

- Potential Infiltration Basin
- Blaylock Site
- Soil Type
- Watercourse

NOTES

1. Infiltration basin footprint(s) are designed to maximize infiltration volume (i.e., to maximize the area of the site where infiltration occurs). As a part of facility design, the basin footprint(s)may need to be adjusted to accommodate structures and/or parking areas or meet regulatory requirements (e.g., setbacks).
2. Average Saturated Hydraulic Conductivity (Ksat) is in units of in/hr.

N

0 200 400

Feet

Date: September 25, 2020
Data Sources: USDA, USGS, Linn Co., Marion Co., OSIP imagery 2018.

GSI Water Solutions, Inc.

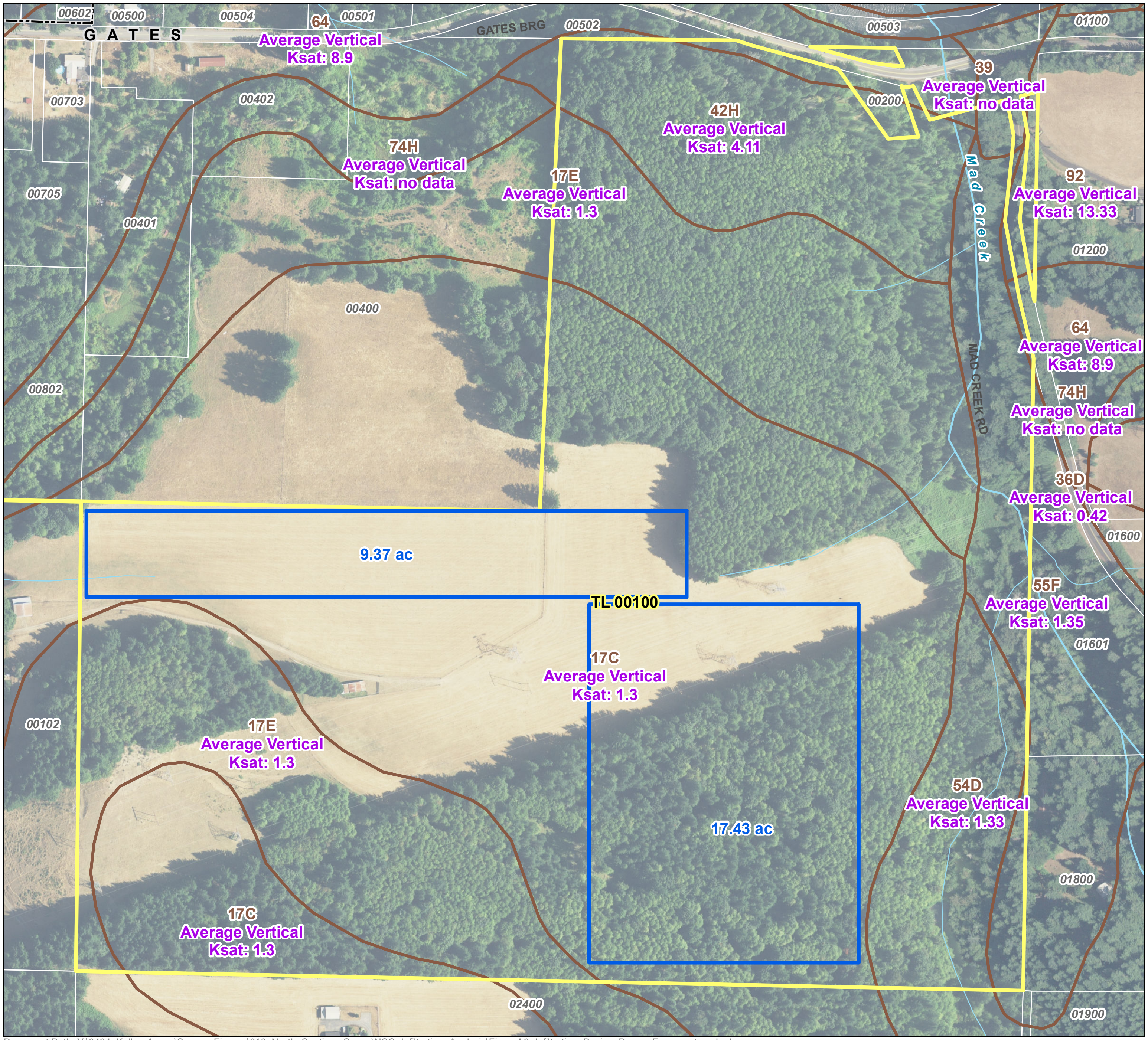


FIGURE A.6

Infiltration Basins at Power Easement Site

North Santiam Canyon Infiltration Analysis

Gates, Oregon

LEGEND

- Potential Infiltration Basin
- Power Easement Site
- Soil Type
- City Boundary
- Watercourse

NOTES

1. Infiltration basin footprint(s) are designed to maximize infiltration volume (i.e., to maximize the area of the site where infiltration occurs). As a part of facility design, the basin footprint(s)may need to be adjusted to accommodate structures and/or parking areas or meet regulatory requirements (e.g., setbacks).
2. Average Saturated Hydraulic Conductivity (Ksat) is in units of in/hr.

WWTP: Waste Water Treatment Plant

N

0 200 400
Feet

Date: September 25, 2020
Data Sources: USDA, USGS, Linn Co., Marion Co., OSIP imagery 2018.

GSI Water Solutions, Inc.

Document Path: Y:\0464_Keller_Assoc\Source_Figures\010_North_Santiam_Sewer\NSC_Infiltration_Analysis\FigureA6_Infiltration_Basins_Power_Easement.mxd, abarry

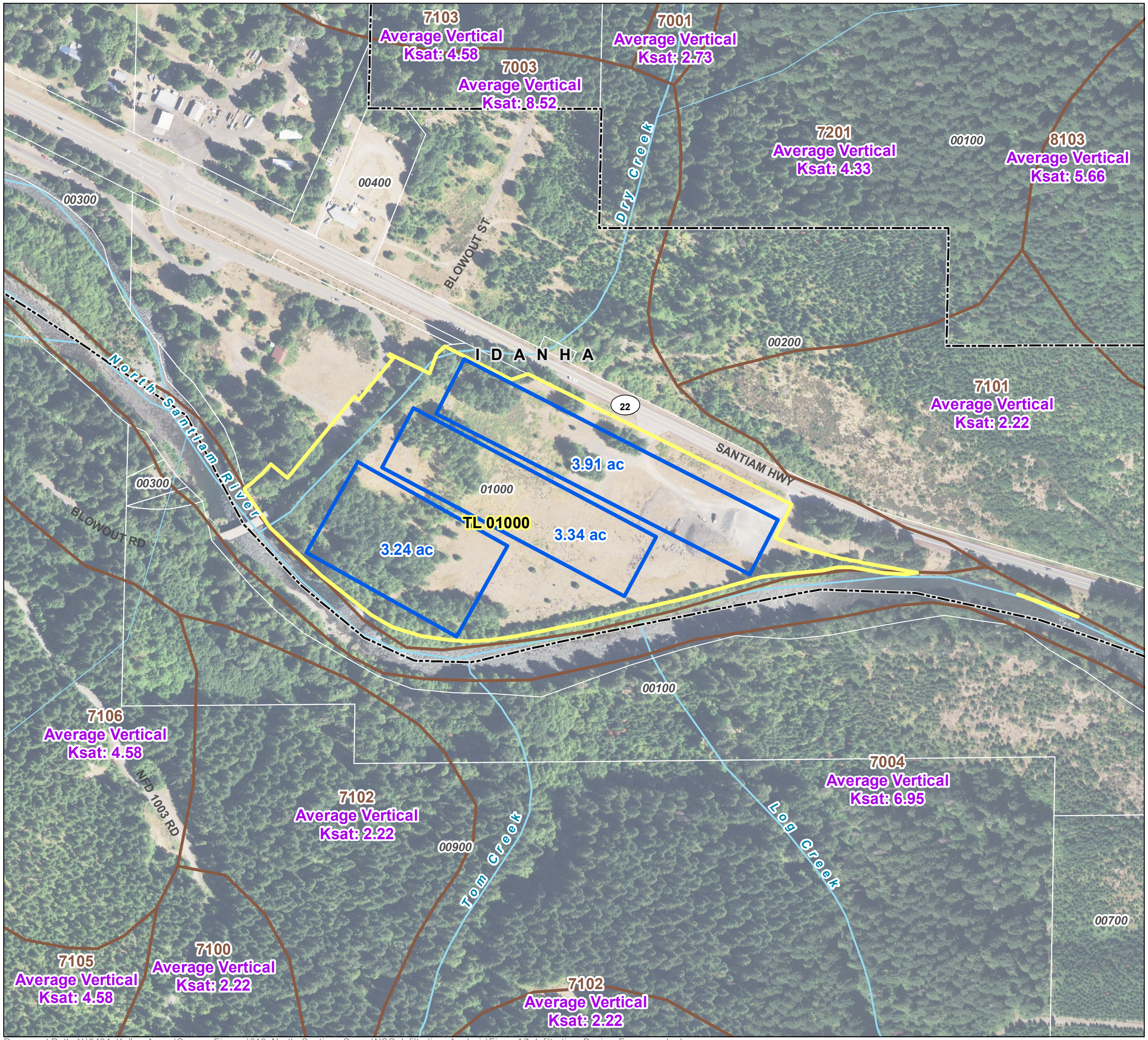


FIGURE A.7

Infiltration Basins at Freres Site

North Santiam Canyon Infiltration Analysis

Idanha, Oregon

LEGEND

- Potential Infiltration Basin
- Freres Site
- Soil Type
- City Boundary
- Watercourse

NOTES

1. Infiltration basin footprint(s) are designed to maximize infiltration volume (i.e., to maximize the area of the site where infiltration occurs). As a part of facility design, the basin footprint(s)may need to be adjusted to accommodate structures and/or parking areas or meet regulatory requirements (e.g., setbacks).
2. Average Saturated Hydraulic Conductivity (Ksat) is in units of in/hr.

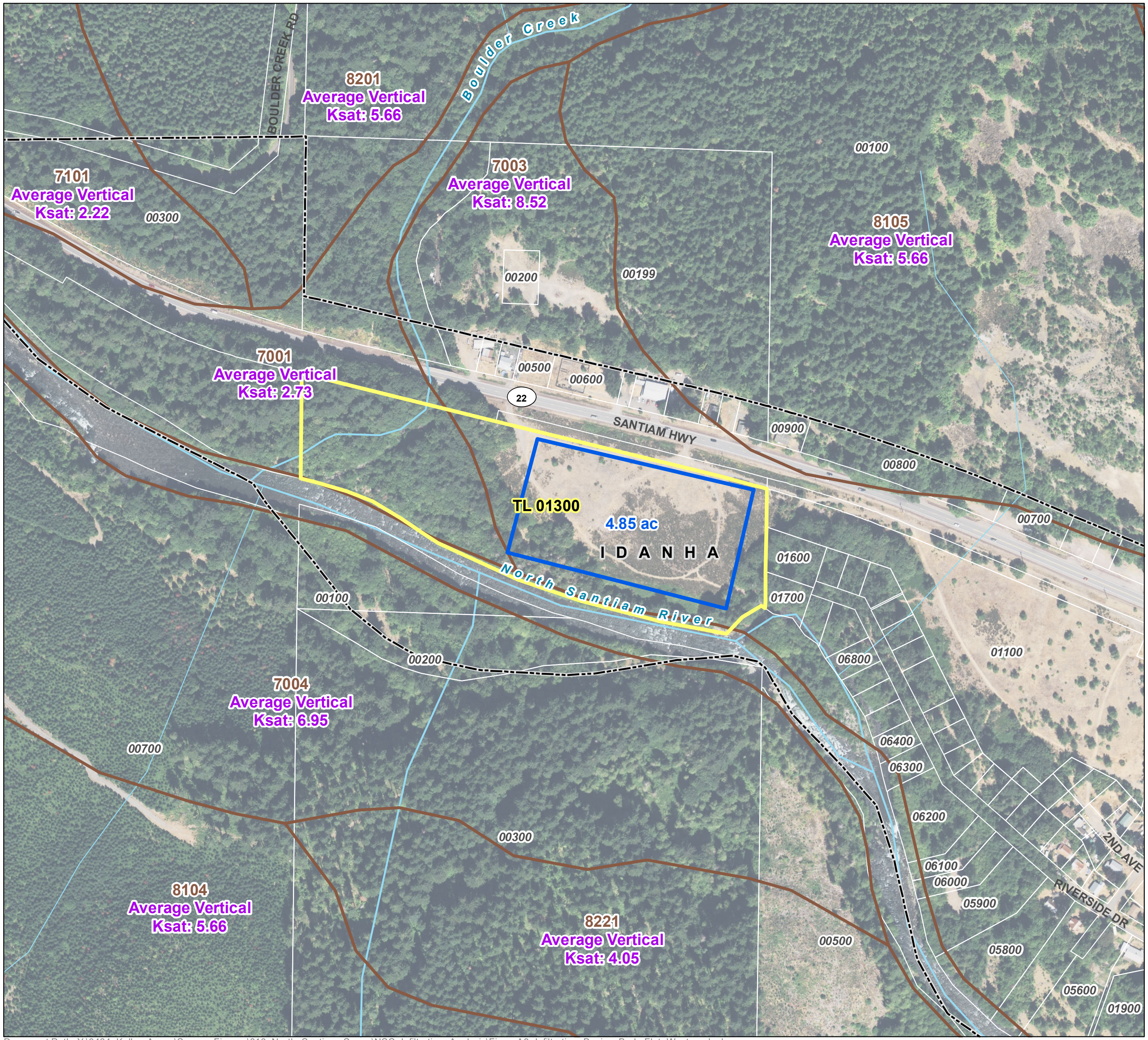
N

0 200 400
Feet

Date: September 25, 2020
Data Sources: USDA, USGS, Linn Co., Marion Co., OSIP imagery 2018.

GSI Water Solutions, Inc.

Document Path: Y:\0464_Keller_Assoc\Source_Figures\010_North_Santiam_Sewer\NSC_Infiltration_Analysis\FigureA7_Infiltration_Basins_Freres.mxd, abarry



Document Path: Y:\0464_Keller_Assoc\Source_Figures\010_North_Santiam_Sewer\NSC_Infiltration_Analysis\FigureA8_Infiltration_Basins_Bark_Flat_West.mxd, abarry

FIGURE A.8

Infiltration Basin at
Bark Flat West Site
North Santiam Canyon
Infiltration Analysis
Idanha, Oregon

LEGEND

- Potential Infiltration Basin
- Bark Flat West Site
- Soil Type
- City Boundary
- Watercourse

NOTES

1. Infiltration basin footprint(s) are designed to maximize infiltration volume (i.e., to maximize the area of the site where infiltration occurs). As a part of facility design, the basin footprint(s)may need to be adjusted to accommodate structures and/or parking areas or meet regulatory requirements (e.g., setbacks).
2. Average Saturated Hydraulic Conductivity (Ksat) is in units of in/hr.

N

0 200 400
Feet

Date: September 25, 2020
Data Sources: USDA, USGS, Linn Co., Marion Co., OSIP imagery 2018.

Water Solutions, Inc.

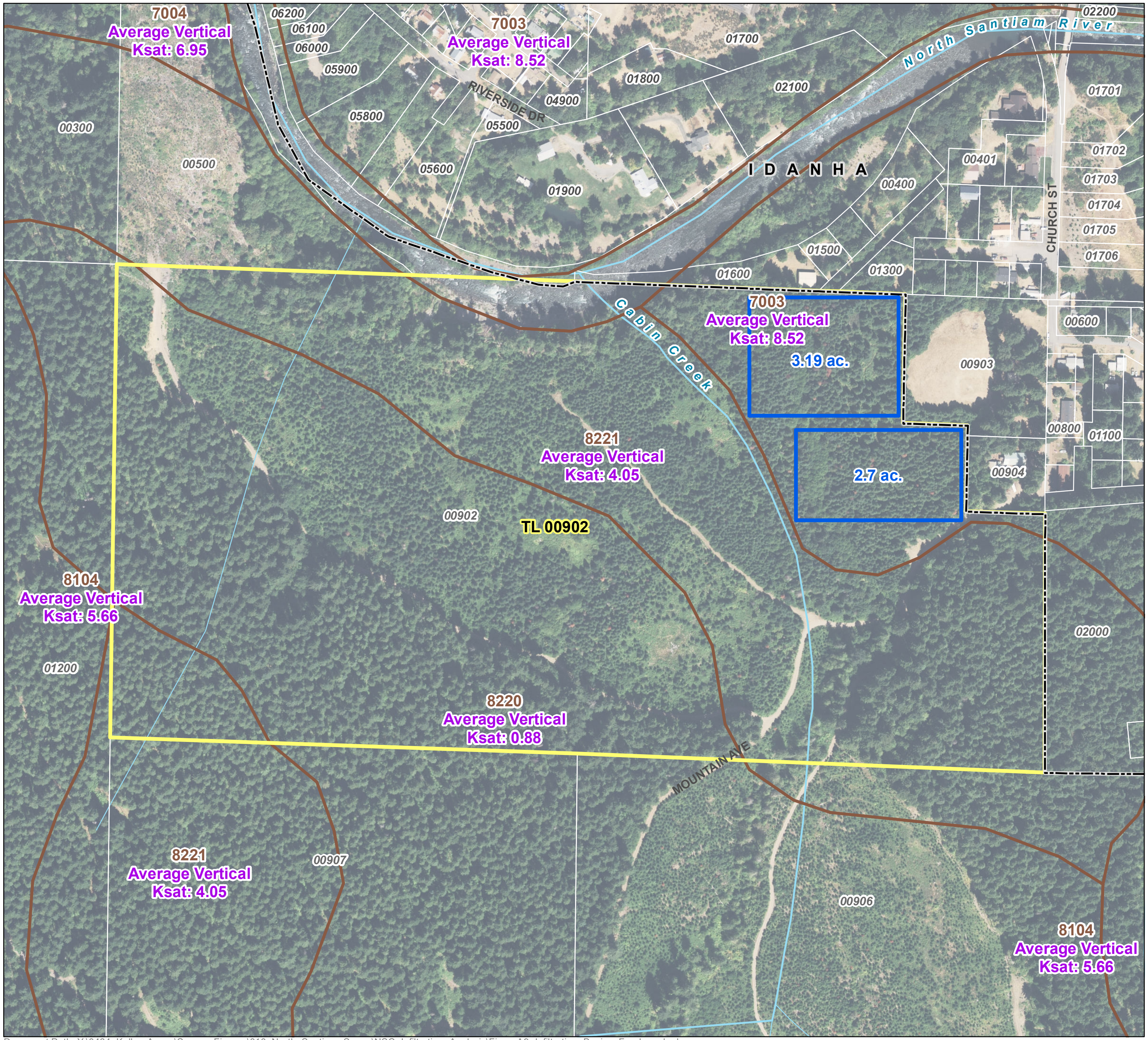


FIGURE A.9

Infiltration Basins at Frank Site

North Santiam Canyon Infiltration Analysis

Idanha, Oregon

LEGEND

- Potential Infiltration Basin
- Frank Site
- Soil Type
- City Boundary
- Watercourse

NOTES

1. Infiltration basin footprint(s) are designed to maximize infiltration volume (i.e., to maximize the area of the site where infiltration occurs). As a part of facility design, the basin footprint(s)may need to be adjusted to accommodate structures and/or parking areas or meet regulatory requirements (e.g., setbacks).
2. Average Saturated Hydraulic Conductivity (Ksat) is in units of in/hr.

N

0 200 400
Feet

Date: September 25, 2020
Data Sources: USDA, USGS, Linn Co., Marion Co., OSIP imagery 2018.

GSI Water Solutions, Inc.

Document Path: Y:\0464_Keller_Assoc\Source_Figures\010_North_Santiam_Sewer\NSC_Infiltration_Analysis\FigureA9_Infiltration_Basins_Frank.mxd, abarry

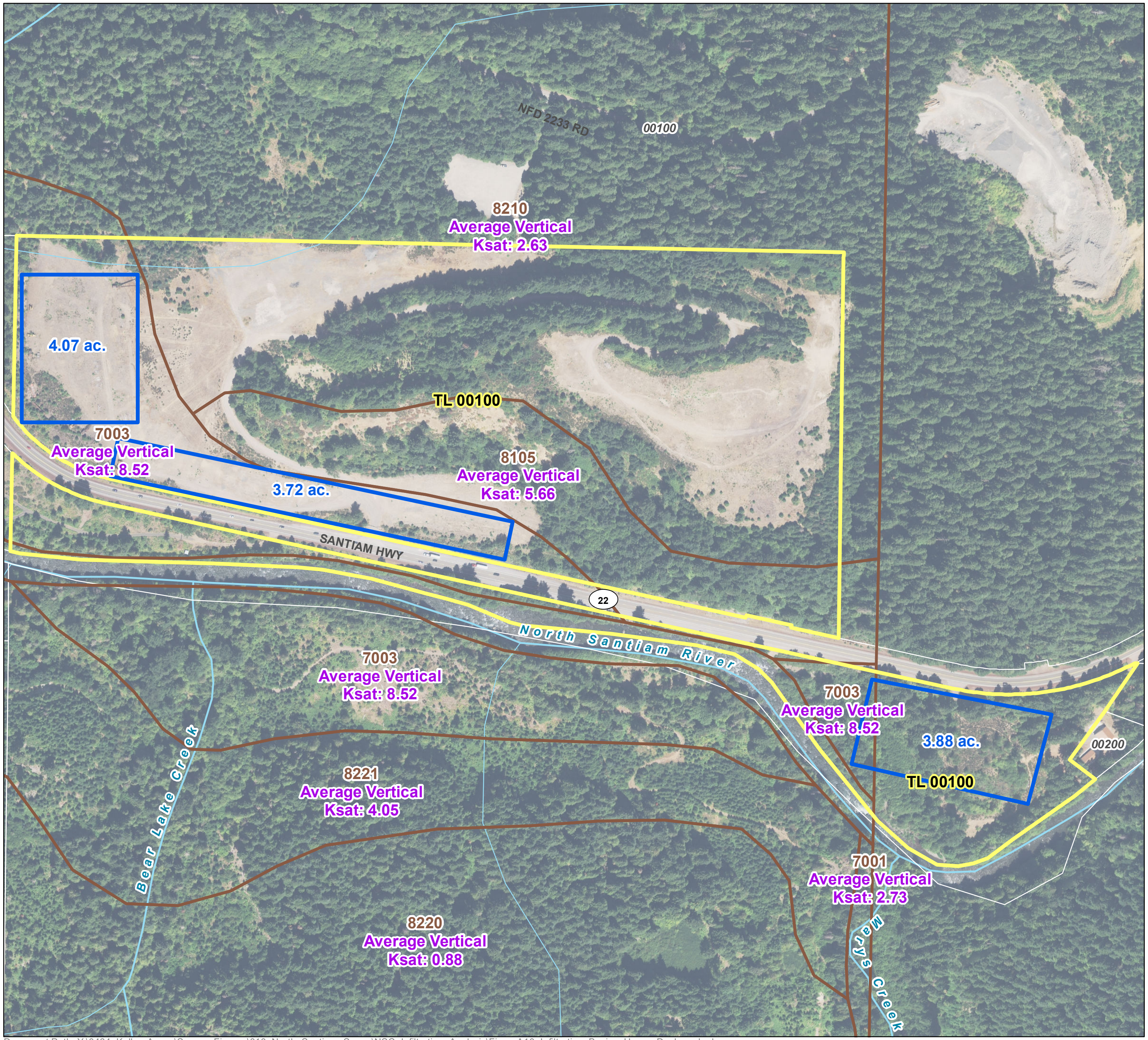


FIGURE A.10

Infiltration Basin at Upper Deck Site

North Santiam Canyon Infiltration Analysis

Idanha, Oregon

LEGEND

- Potential Infiltration Basin
- Upper Deck Site
- Soil Type
- City Boundary
- Watercourse

NOTES

1. Infiltration basin footprint(s) are designed to maximize infiltration volume (i.e., to maximize the area of the site where infiltration occurs). As a part of facility design, the basin footprint(s)may need to be adjusted to accommodate structures and/or parking areas or meet regulatory requirements (e.g., setbacks).
2. Average Saturated Hydraulic Conductivity (Ksat) is in units of in/hr.

N

0 200 400
Feet

Date: September 25, 2020
Data Sources: USDA, USGS, Linn Co., Marion Co., OSIP imagery 2018.

GSI Water Solutions, Inc.

Document Path: Y:\0464_Keller_Assoc\Source_Figures\010_North_Santiam_Sewer\NSC_Infiltration_Analysis\FigureA10_Infiltration_Basins_Upper_Deck.mxd, abarry

DRAFT

North Santiam Canyon Wastewater Infiltration Evaluation

Attachment B. Keller Engineers Estimated Development Effort for the Ten Sites.

September 2020

Prepared by:
GSI Water Solutions, Inc.
55 SW Yamhill St., Suite 300, Portland, OR, 97204

ATTACHMENT B: DEVELOPMENT EFFORT											
Criteria / Site	Weighting	1 (Tom Fencl)	2 (Hazelnut Property)	3 (WWTP 2)	4 (Rock Creek)	5 (Blaylock)	6 (Power Easement)	7 (Freres)	8 (Bark Flat West)	9 (Frank)	10 (Upper Deck)
Proximity to roadway network	15	8	10	13	15	15	1	15	15	3	15
Proximity to utility network	15	10	12	13	7	7	1	15	15	7	12
Vegetation and growth	15	15	5	13	3	15	5	10	12	1	10
Site topography	7	7	7	7	7	7	5	7	7	7	7
Ownership	10	10	2	4	10	8	8	10	10	8	10
Land use	8	8	5	6	8	8	8	8	8	8	8
Environmental Permitting	10	6	10	10	10	10	10	5	5	8	5
WTP potential	10	5	6	10	10	9	6	10	5	3	1
Expandability	5	4	5	1	3	4	3	1	1	1	1
Public acceptance	5	2	3	1	5	5	5	5	5	5	5
Total	100	75	65	78	78	88	52	86	83	51	74
Evaluation Score	**-**	**3**	**2**	**4**	**3**	**4**	**1**	**4**	**4**	**1**	**3**

Legend	
1	50 to 59
2	60 to 69
3	69 to 78
4	79 to 88