Geotechnical Engineering Report
Wastewater Pump Station No. 12 Rehabilitation
Redmond, Washington

April 30, 2020

Prepared for
BHC Consultants, LLC
1601 Fifth Avenue, Suite 500
Seattle, Washington 98101
Geotechnical Engineering Report
Wastewater Pump Station No. 12 Rehabilitation
Redmond, Washington

This document was prepared by, or under the direct supervision of, the undersigned, whose seal is affixed below.

Name: Daniel Simpson
Washington No. 54753

Date: April 30, 2020

Document prepared by: Daniel Simpson, PE
Primary Author

Document reviewed by: Calvin McCaughan, PE
Quality Reviewer
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LIST OF ABBREVIATIONS AND ACRONYMS

ASTM ............................................................ASTM International
bgs ............................................................ below ground surface
BHC ............................................................ BHC Consultants, LLC
btoc ........................................................... below top of casing
CDF ............................................................ controlled density fill
City ............................................................ City of Redmond
ft .............................................................. foot/feet
ft/day ....................................................... foot/feet per day
GMHA ........................................................ground motion hazard analysis
H:V ........................................................... horizontal to vertical
IBC ............................................................ International Building Code
KGS ........................................................... Kansas Geological Survey
LAI ............................................................ Landau Associates, Inc.
NAVD88 ..................................................North America Vertical Datum of 1988
pcf ............................................................ pounds per cubic foot
psf ............................................................ pounds per square foot
RMC ..........................................................Redmond Municipal Code
STN 7A .................................................... Stormwater Technical Notebook Issue 7A
WAC .......................................................... Washington Administrative Code
WSDOT ..................................................... Washington State Department of Transportation
1.0 INTRODUCTION

This report summarizes the results of geotechnical engineering services provided by Landau Associates, Inc. (LAI) in support of the City of Redmond’s (City’s) proposed Wastewater Pump Station No. 12 Rehabilitation project. The project is located north of a recently constructed residential building (AM Apartments, LLC), near 6117 East Lake Sammamish Parkway Northeast in Redmond, Washington (site; Figure 1).

This report has been prepared based on discussions with, and information provided by, representatives of BHC Consultants, LLC (BHC) and the City; data collected during the field exploration and laboratory testing programs; our familiarity with geologic conditions in the vicinity of the site; and our experience with similar projects.

1.1 Project Understanding

The site is located in a landscaped area approximately 500 feet (ft) north of existing Pump Station No. 12. To support redevelopment of the area, the City plans to increase sanitary sewer flow capacity by constructing a new submersible pump station and utility lines (influent and effluent lines). An above-grade generator and control panel will also be constructed. The replacement pump station will have a maximum depth of 25 ft below ground surface (bgs). The influent/effluent lines will likely be located at 15 ft bgs or shallower.

Because the improvements will be constructed in a high-permeability aquifer with a nearby contaminant plume, dewatering must be limited to reduce the likelihood of contaminant transport.

1.2 Scope of Services

Geotechnical services have been provided in accordance with the scope outlined in the Subconsultant Services Agreement, authorized by BHC on November 9, 2018. The objective of our services was to develop geotechnical recommendations in support of the proposed improvements by exploring subsurface soil and groundwater conditions at the site. Our scope of services included the following tasks:

- Reviewed available geotechnical reports for the site as well as published geologic data for the site and the surrounding area.
- Contacted the Washington Utilities Coordinating Council’s “One Call” service to locate utilities in the project area, and subcontracted a private utility-locating service.
- Explored subsurface soil and groundwater conditions at the site by advancing one hollow-stem auger boring (MW-1) to 46.5 ft bgs.
- Installed a 2-inch-diameter, flush-mounted groundwater monitoring well in the soil boring adjacent to the proposed pump station location.
- Performed geotechnical laboratory testing on select samples obtained from the boring. Testing included gradation and moisture content determinations.
• Performed geotechnical engineering analyses to support project design.
• Prepared this geotechnical engineering report, summarizing the results of the field investigation and laboratory testing and providing conclusions and recommendations to support design of the proposed improvements.
2.0 SITE CONDITIONS

The following sections describe the geologic setting of the project area and the surface and subsurface conditions observed during the field investigation. Interpretations of site conditions are based on review of available geologic and geotechnical information and on the results of LAI’s site reconnaissance, subsurface explorations, and laboratory testing.

2.1 Geologic Setting

Geologic information for the site and the surrounding area was obtained from the Geologic Map of the Redmond Quadrangle, King County, Washington (Minard et al. 1988). Near-surface site soil is mapped as young alluvium (Qyal), a material consisting of moderately to well-sorted gravel, sand, and silt with cobbles and boulders. Alluvium typically exhibits high permeability and low to medium shear strength, depending on the degree of consolidation. The soil observed in LAI’s November 2018 exploratory borings was consistent with the mapped geology.

The City of Redmond Wellhead Protection Report (Parametric 1997) indicates that subsurface conditions in the vicinity of the site consist of alluvium overlying glacial recessional outwash and Olympia Beds (sands and gravels in the vicinity of the site). For the purposes of this report, no distinction is made between alluvium, recessional outwash, or Olympia Beds sands and gravels, as the materials are similar from a geotechnical standpoint. The documented geologic conditions are consistent with those observed in LAI’s explorations.

2.2 Surface Conditions

Located north of a multi-story residential building, the site consists of an open, landscaped area, approximately 65 by 75 ft. An asphalt parking lot and road surround the site, with a 2- to 5-ft retaining wall to the east and west. Site topography slopes down at 2 to 3 percent grade to the north. A flat asphalt parking lot extends from the western retaining wall to existing Pump Station No. 12.

2.3 Subsurface Explorations

Subsurface conditions at the site were explored on November 8, 2018 by advancing one hollow-stem auger boring (MW-1) 46.5 ft bgs. The boring was advanced at the approximate location shown on Figure 2. A monitoring well was installed with the well screen intersecting the groundwater table observed at the time of drilling. The well was developed for continued use. Select soil samples obtained from the borings were tested in LAI’s geotechnical laboratory to measure grain size distribution and moisture content.

The following sections summarize the subsurface soil and groundwater conditions observed in the explorations. More detailed information, including summary exploration logs, is provided in Appendix B. Details of geotechnical laboratory testing are provided in Appendix C.
2.3.1 Soil Conditions

The material observed underlying existing surface conditions (i.e., topsoil or gravel base course for pavement) generally consisted of loose to very dense, coarse-grained soil (sands and gravels) with approximately 0 to 9 percent fines. The soils exhibited alternating well- and poorly graded, stratified layers typical of alluvial or water-deposited soils.

Although cobbles and boulders are too large to be observed in the 1.5-inch inside-diameter, split-spoon sampler, they are often found in alluvial soils and Olympia Beds, and could be present throughout the site. Though not observed in LAI’s November 2018 explorations, glacial till or glacially consolidated material likely underlies the alluvium. Nearby borings advanced by others indicate that the depth to glacial soil is approximately 80 to 100 ft (Golder 2018).

2.3.2 Groundwater Conditions

During the November 2018 field investigation, groundwater was observed at 11 ft bgs (33 ft North America Vertical Datum of 1988 [NAVD88]) in boring MW-1. The monitoring well was checked on December 13, 2018 and groundwater was 12.2 ft bgs (31.8 ft NAVD88). Based on data obtained from nearby monitoring wells, groundwater levels at the monitoring well MW-1 location could rise to approximately 36.2 ft NAVD88 during an average wet season. A slug test was performed in MW-1 to measure additional aquifer characteristics. Details of the slug test are provided in Appendix D.

Groundwater conditions reported herein and on the exploration logs are for the specific date and location indicated, and may not be representative of other locations and/or times. Groundwater conditions will vary depending on local subsurface conditions, weather conditions, and other factors, with maximum groundwater levels occurring during late winter and early spring.
3.0 SEISMIC DESIGN CONSIDERATIONS

The following sections provide seismic design considerations, including seismic design parameters and liquefaction susceptibility and consequences.

3.1 Seismic Design Parameters

Seismic design will be performed using the 2018 International Building Code (IBC) standards (ICC 2017). The parameters in Table 1 can be used to compute seismic forces. The site conditions at Pump Stations 12 and 13 are similar (same site class), and the parameters in Table 1 are based on the ground motion hazard analysis (GMHA) performed for Pump Station 13 (LAI 2019). Because a site-specific GMHA has been performed, use of the conservative methods in Section 11.4.8 of *Minimum Design Loads and Associated Criteria for Buildings and Other Structures* (ASCE 2016) is not required to determine the design coefficient $C_s$.

Table 1. 2018 International Building Code Seismic Design Parameters

<table>
<thead>
<tr>
<th>Parameter Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design short-period spectral acceleration, $S_{DS}$</td>
<td>0.922g</td>
</tr>
<tr>
<td>Design 1-second spectral acceleration, $S_D$</td>
<td>0.718g</td>
</tr>
<tr>
<td>MCE short-period spectral acceleration, $S_{MS}$</td>
<td>1.383g</td>
</tr>
<tr>
<td>MCE 1-second spectral acceleration, $S_{M1}$</td>
<td>1.077g</td>
</tr>
</tbody>
</table>

$g =$ force of gravity
MCE = risk-targeted, maximum considered earthquake

Based on the IBC seismic design parameters and seismic information from the U.S. Geological Survey's National Seismic Hazard Mapping Project (USGS; accessed December 18, 2018), the parameters in Table 2 were selected for liquefaction analyses.

Table 2. 2018 International Building Code Seismic Design Parameters (Liquefaction)

<table>
<thead>
<tr>
<th>Parameter Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak ground acceleration, site class D (PGA$_{M}$)</td>
<td>0.595g</td>
</tr>
<tr>
<td>Earthquake magnitude (M)</td>
<td>7.1</td>
</tr>
</tbody>
</table>

$g =$ force of gravity

3.2 Liquefaction

Liquefaction is defined as a significant rise in pore water pressure within a soil mass caused by earthquake-induced cyclic shaking. The increase in pore water pressure causes a loss in soil shear strength during and immediately after long-duration earthquakes, which can result in significant and widespread structural damage if not properly mitigated.
The risk of soil liquefaction was assessed using the simplified method proposed by Boulanger and Idriss (2014). Analyses indicate that several soil layers are at risk for liquefaction during the design earthquake. Based on the results of LAI’s analysis, soils most at risk for liquefaction are located approximately 11 to 17 ft bgs and 25 to 35 ft bgs. Additional liquefaction considerations are discussed in Section 4.2.
4.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the conditions observed in our November 2018 exploration, site soils are suitable for the proposed improvements, provided the following recommendations are incorporated into the project design. Saturated sands and gravels at the site must be shored during excavation and dewatering must be limited. Shoring recommendations for Pump Station No. 12 will be finalized following discussion of shoring options for nearby Pump Station No. 13. The contractor should be made aware of the retaining walls that surround the site to the east and west, and the complications they could cause during construction.

4.1 Pump Station Excavation Shoring

The proposed pump station will be constructed in a wet/dry well approximately 8 ft in diameter and 25 ft deep. Saturated granular soil is present throughout the site, and an excavation shoring system will be required to construct the pump station. City requirements limit groundwater extraction and widespread dewatering, therefore an impermeable shoring system will likely be required.

The following shoring types appear feasible: braced sheet pile walls, soil freezing, and drilled caissons. If sheet pile walls are allowed, project specifications must include significant vibration and settlement monitoring requirements due to proximity of existing Pump Station No. 12 and the adjacent buildings. The City, BHC, and LAI should discuss applicable shoring methods prior to finalization of this report. Information collected during Pump Station No. 13 design and from Pump Station No. 2 contractor submittals will inform this decision.

The drilled caisson method involves the use of a solid-stem auger drill rig with a casing advancer (similar to a drilled shaft-installation drill rig) to remove soil while simultaneously advancing a temporary steel casing. Drilling can be done in the wet to limit the amount of dewatering required, and the groundwater head inside the excavation can be used to resist excavation heave or piping. The casing is advanced to the bottom of the tremie seal elevation, where concrete slurry is tremied to the bottom of the excavation before the interior of the excavation is dewatered. Once dewatered, the permanent pump station structure can be placed, and the temporary steel caisson removed.

Actual excavation configurations and maintenance of safe working conditions, including temporary excavation stability, should be the responsibility of the contractor. All applicable local, state, and federal safety codes should be followed. Temporary excavations in excess of 4 ft should be shored or sloped in accordance with Safety Standards for Construction Work Part N, Washington Administrative Code (WAC) 296-155-657.


4.2 Pump Station Design Considerations

Selection of an applicable shoring method(s) will inform final design considerations and design parameters for the dry/wet well structure. For planning purposes, the following engineering data are provided:

- **Lateral Earth Pressures.** LAI recommends designing the dry/wet well structure for at-rest earth pressures. An equivalent fluid density of 58 pounds per cubic foot (pcf) above groundwater and 29 pcf below groundwater can be used. Hydrostatic pressures should be added to these values, and a design groundwater depth of 5 ft bgs is recommended (this depth should also be used for above- and below-groundwater at-rest pressures). Seismic earth pressures should be calculated with a uniform lateral pressure of 11H pounds per square foot, where H is the height of the structure in feet with unbalanced earth pressure. The seismic earth pressure should be refined during final design.

- **Bearing and Vertical Resistance.** Vertical compression (downward) loads can be resisted with an allowable end bearing value of 2,500 pounds per square foot (psf) and an average allowable side friction of 200 psf (assumes precast or cast-in-place concrete on soil friction).

- **Uplift.** Uplift from groundwater buoyancy is resisted by side friction (see above) and the weight of the structure. If the tremie seal is tied to the pump station structure, the weight of the seal may be used to resist buoyancy. When calculating buoyancy uplift forces, groundwater should be assumed at ground surface.

  **Tremie Seal.** The estimated tremie seal thickness for temporary excavation support only is approximately 16 ft. This assumes groundwater is 5 ft bgs, bottom of the well is 25 ft bgs, 140 pcf controlled density fill (CDF) is used for the tremie seal, and the seal’s self-weight solely is used to resist buoyancy.

- **Liquefication Considerations.** Liquefaction is estimated to occur between 11 and 17 ft bgs and 25 and 35 ft bgs, resulting in 2 to 3 inches of ground surface settlement. Additionally, buried structures can move up or down in liquefied soil with buoyancy or bearing failure, respectively. LAI recommends that the project team considers installing the tremie seal bottom below 37 ft bgs to provide vertical bearing resistance during liquefaction, reducing the potential for structure settlement caused by liquefaction. Alternatively, the team should consider using flexible utility connections at the pump station structure to accommodate seismic settlement.

4.3 Earthwork and Linear Utilities

LAI anticipates that project earthwork will include excavating and backfilling linear utilities and subsurface structures. All earthwork practices and materials should comply with the Washington State Department of Transportation’s *2020 Standard Specifications for Road, Bridge, and Municipal Construction (2020 WSDOT Standard Specifications)*, as modified, amended, or deleted by the City’s *2020 Standard Specifications and Details (City of Redmond 2020)*.
4.3.1 General Earthwork Considerations

The following general recommendations are provided for earthwork:

- The soils observed in LAI’s November 2018 exploration generally consisted of clean sands and gravel to sand and gravel with fines. This material may be reused as structural fill; however, the contractor should be prepared to remove deleterious material and material more than 4 inches in diameter. In general, onsite soils encountered in the borings contained less than 7 to 9 percent fines, though some soils contained more than 9 percent fines. Soils with more than 7 to 9 percent fines can be moisture sensitive and difficult to compact during wet weather.

- Utility trenches should be backfilled in accordance with 2020 City Standard Detail 201. Structural fill, placed and compacted in accordance with 2020 City Standard Detail 201, may be used to backfill above-pipe bedding zones in trenches beneath pavement (City of Redmond 2020).

- Pipe bedding material will require import. Pipe bedding material should meet the requirements for Crushed Surfacing Top Course set forth in Section 9-03.9(3) of the 2020 WSDOT Standard Specifications, per 2020 City Standard Detail 201 (City of Redmond 2020).

- If required, backfill around the pump station excavation should consist of structural fill or CDF. Structural fill should be placed in accordance with Method C, Section 2-03.3(14)C of the 2020 WSDOT Standard Specifications.

- If used, CDF should comply with Section 2-09.3(1)E of the 2020 WSDOT Standard Specifications.

4.3.2 Linear Utility Excavation and Dewatering

LAI understands that approximately 300 ft of linear utility excavation will be required for this project. Linear utilities will be installed in granular soils with excavation depths of approximately 20 ft bgs or less. If excavation is performed during the low-groundwater season, a portion of the excavation may be above groundwater.

Granular soils will require shoring or sloping to maintain stability. For linear utilities, the most practical solution may be use of a rigid trench box or steel sheets, spanned by expandable hydraulic jacks. These shoring methods are likely to provide adequate excavation stability, but can result in ground deformation (and possible pavement cracking) near the excavation. Excavation safety and stability are the responsibilities of the contractor; excavations should conform to Section 269-155 of the WAC.

Dewatering may be required for portions of the linear utility excavation. Where possible, dewatering should be limited to minimize the potential for contaminated groundwater transport. Based on discussions with BHC, LAI understands that localized trench dewatering, with less than a 3-ft decrease in piezometric head, will be acceptable to the City. Dewatering approximately 3 ft will likely yield considerable quantities of water. Dewatering water should be disposed of at the City’s direction. Additional dewatering information is provided in Appendix A.
4.3.3 Linear Utility Subgrade Preparation

The subgrade should be free of standing water and compacted to a firm condition prior to placement of pipe bedding. Subgrades that cannot be prepared to a firm condition should be overexcavated and replaced with Class A Foundation Material, per Section 9-03.17 of the 2020 WSDOT Standard Specifications. To minimize dewatering, Class A Foundation Material may be placed in the wet in 4-inch loose lifts and tamped or vibrated with an excavator.

4.4 At-Grade Structure Foundations

A small structure, such as a prefabricated metal building with a slab-on-grade, will likely be used in the vicinity of boring MW-1 to house pump-control equipment. The subgrade for the slab-on-grade foundation should be prepared as follows:

- Remove and dispose of the top 6 to 12 inches of organic-rich topsoil.
- Overexcavate and recompact 18 inches of native soil, per Method C, Section 2-03.3(14)C of the 2018 WSDOT Standard Specifications. Extend the overexcavation area 2 ft beyond the edge of the slab.
- Have a qualified civil engineer observe the subgrade prior to performing additional work. Subgrade inspection could reveal areas that require additional overexcavation and recompaction.

A slab-on-grade foundation can be designed with a modulus of subgrade reaction of 200 pounds per cubic inch, assuming the subgrade is prepared as outlined above. If the slab elevation is above the bottom of the nearby wall elevation, the edge of the slab should be offset away from existing retaining walls to avoid increasing loading on the walls. The offset should be at least 1.0H, where H is the height of the retaining wall.

4.5 Infiltration

Soil infiltration capacity was estimated in accordance with grain size methods in the Washington State Department of Ecology's 2012 Stormwater Management Manual for Western Washington, As Amended in December 2014. Methods were modified in accordance with the City’s Stormwater Technical Notebook Issue 7A (STN 7A). Recommended short-term (for construction dewatering disposal) and long-term (for stormwater disposal) infiltration rates are provided in Table 3. The short- and long-term infiltration rates were calculated identically with a biofouling correction factor of 0.9 for short-term infiltration.

Per STN 7A, at least 5 ft of vertical separation must be included between the bases of infiltration facilities and the seasonal high groundwater table. This 5-ft separation was observed when estimating the rates in Table 3. The average seasonal high groundwater at the site is estimated at elevation 36 ft NAVD88, based on data collected from monitoring well MW-1 and nearby City monitoring wells (MW047/MW048, MW333, and MW334). Based on the groundwater monitoring data, 5 ft of vertical
separation may not be maintained at lower elevations of the site. If needed, a groundwater mounding analysis can be performed to reduce vertical separation to 3 ft. Per STN 7A, permanent infiltration facilities cannot be used to dispose of construction-generated water.

Table 3. Recommended Infiltration Rates (Inches Per Hour)

<table>
<thead>
<tr>
<th>Infiltration Type</th>
<th>MW-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short-term (construction dewatering discharge)</td>
<td>7</td>
</tr>
<tr>
<td>Long-term (stormwater)</td>
<td>5</td>
</tr>
</tbody>
</table>

Notes: The following correction factors were used to calculate infiltration rates:
- Site variability and number of locations test ($CF_v$) = 0.6.
- Uncertainty of test method ($CF_t$) = 0.40.
- Degree of influent control to prevent siltation and bio-buildup ($CF_m$) = 0.9 (long term), 1.0 (short term).
5.0 FINAL DESIGN AND CONSTRUCTION SUPPORT

LAI recommends that monitoring, testing, and consultation are provided during construction to confirm that the conditions encountered are consistent with those observed in the exploration; to provide expedient recommendations should conditions be revealed during construction that differ from those anticipated; and to evaluate whether geotechnical construction activities comply with project plans, specifications, and the recommendations contained in this report. Such activities include installation of the dewatering and shoring systems, placement and compaction of backfill material, and other earthwork activities. LAI would be pleased to provide these services for you.
6.0 USE OF THIS REPORT

Landau Associates, Inc. (LAI) has prepared this technical memorandum for the exclusive use of BHC Consultants, LLC and the project design team for specific application to the Wastewater Pump Station No. 12 Rehabilitation project in Redmond, Washington. No other party is entitled to rely on the information, conclusions, and recommendations included in this document without the express written consent of LAI. Reuse of the information, conclusions, and recommendations provided herein for extensions of the project or for any other project, without review and authorization by LAI, shall be at the user’s sole risk. LAI warrants that, within the limitations of scope, schedule, and budget, its services have been provided in a manner consistent with that level of skill and care ordinarily exercised by members of the profession currently practicing in the same locality under similar conditions as this project. LAI makes no other warranty, either express or implied.
7.0 REFERENCES


Legend
MW-1  Monitoring Well Location and Designation

Note
1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

New Pump Station No. 12 Location

Source: Google Earth Pro 2018
City Dewatering Requirements
APPENDIX A
CITY DEWATERING REQUIREMENTS

Redmond Municipal Code (RMC) 13.25.060 and 13.25.070 require site-specific geotechnical information for development projects that will include construction dewatering. The required geotechnical information has been summarized in the following sections, and should be used in conjunction with the main text of this report.

LAI understands that the City has retained GSI Water Solutions, Inc. (GSI) as the City’s hydrogeological consultant and that the City can obtain supplemental dewatering related information from GSI, as discussed below.

Geotechnical Information for Temporary Construction Dewatering Feasibility Study (RMC 13.25.060)

A. Stratigraphy generally consisted of loose to very dense, coarse-grained soil (sands and gravels) with approximately 0 to 10 percent fines. Material interpreted as alluvium, recessional outwash, or Olympia Beds sand and gravel extended to the maximum depth explored (46.5 feet (ft) below ground surface [bgs]). The bottom of the deepest excavation is approximately 40 ft bgs assuming a tremie seal is used.

B. The primary aquifer appears to be unconfined, and measures 80 to 100 ft thick (the thickness of alluvium, which appears to overlie the glacially overconsolidated soils). LAI understands that GSI can provide additional information about the aquifer.

C. On average, seasonal groundwater fluctuates by approximately 6 ft. The seasonal high groundwater table is approximately 6 ft bgs, and the seasonal low is approximately 12 ft bgs. A more detailed understanding of the site groundwater fluctuation can be made after the site elevation is known. Survey information was outstanding at the time of this draft report.

D. A slug test was performed within the monitoring well installed in boring MW-1. Details of the slug test are provided in Appendix D. Based on the hydraulic conductivity measured in the slug test and the thickness of the soil stratum in which the well is situated, Landau Associates, Inc. (LAI) estimates a transmissivity of $1.8 \times 10^4$ ft$^2$/day. LAI understands that GSI can provide additional aquifer characteristics.

E. Sump pumps within utility trenches will likely be employed. LAI understands that GSI can estimate pumping rates, if needed.

F. The results of a similar drawdown analysis, performed for the Pump Station 13 Replacement project, were included in a 2019 GSI report titled Evaluation of Potential Effects on Former Super Rent Facility Groundwater Contamination from Construction Dewatering Operations for Pump Station 13 Sewer Line (City of Redmond, Washington). LAI understands that, for the Pump Station 12 Rehabilitation project, GSI may estimate drawdown that results from dewatering of utility trenches.

G. LAI understands that groundwater in the vicinity of the site is not contaminated. However, a plume of contaminated groundwater is present at the former Super Rent Property (Washington State Department of Ecology Facility Site ID 58128821), near the site. LAI also understands, based on preliminary modelling by GSI, that short-term dewatering of 3 ft or less is unlikely to cause contaminated groundwater migration.
Geotechnical Information for Temporary Construction Dewatering Plan (RMC 13.25.070)

A. Subsurface work will include installation of an estimated 8-ft-diameter sewer pump station well approximately 25 ft below grade. The excavation required for the pump station may be as large as 12 ft in diameter and 35 to 40 ft deep. The shoring method will be a drilled steel caisson or similar. Because the shoring method is impermeable, dewatering will be limited to the volume of water in the soil pore space within the excavated mass.

Subsurface work will also consist of excavating utility trenches and installing gravity and force main sewer pipes. Trenches will be excavated just below the groundwater elevation (pipe inverts up to 20 ft bgs, elevation 25 ft North American Vertical Datum of 1988). Up to 6 ft of dewatering may be required within the trench during periods of low groundwater.

B. Stratigraphy generally consisted of loose to very dense coarse-grained soil (sands and gravels) with approximately 0 to 10 percent fines. Material interpreted as alluvium, recessional outwash, or Olympia Beds sand and gravel extended to the maximum depth explored (46.5 ft bgs). The bottom of the deepest excavation is approximately 40 ft bgs assuming a tremie seal is used.

C. LAI understands that GSI can provide detailed hydrogeological information, if needed. Appendix D contains the results of a slug test performed by LAI. The gravelly layer in which the slug test was performed showed permeability on the order of 200 ft/day by the slug test method.

D. Historical groundwater data were provided by the City (City monitoring wells MW333, MW334, and MW047/048) which indicates a typical seasonal variation of about 6 ft.

E. Peak wet-season groundwater depth at the pump station is estimated to be about 9 ft bgs. The seasonal high groundwater depth was determined by comparing the seasonal fluctuation in the City’s data to monitored groundwater depth in well MW-1.
Field Explorations
APPENDIX B
FIELD EXPLORATIONS

Subsurface conditions at the site were explored by advancing one hollow-stem auger boring (MW-1) 46.5 feet (ft) below ground surface. The boring was advanced using a track-mounted drill rig, operated by Holocene Drilling, Inc. of Puyallup, Washington, under subcontract to Landau Associates, Inc. (LAI). The approximate location of the exploration is shown on Figure 2.

The geotechnical field investigation was coordinated and monitored by LAI personnel, who also obtained representative soil samples from the borings, maintained a detailed record of subsurface soil and groundwater conditions, and described the soil observed by visual and textural examination. Each representative soil type observed was described using the soil classification system shown on Figure B-1, in general accordance with ASTM International test method D2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). A log of the conditions observed in boring MW-1 is presented on Figure B-2. The stratigraphic contacts shown on this log represent the approximate boundaries between soil types; actual transitions may be more gradual. The soil and groundwater conditions depicted are for the specific date and location reported, and are not necessarily representative of other locations and times.

Disturbed soil samples were obtained from the boring at frequent intervals using a 1.5-inch inside-diameter, standard penetration test, split-spoon sampler. The sampler was driven 18 inches (or a portion thereof) into the undisturbed soil ahead of the auger bit, with a 140-pound automatic hammer falling a distance of approximately 30 inches. The number of blows required to drive the sampler for the final 12 inches (or a portion thereof) of soil penetration is noted on the boring log, adjacent to the appropriate sample notation. Samples were taken to LAI’s soils laboratory for further examination and testing.

A 2-inch monitoring well was installed in boring MW-1. The well was screened with a pre-packed filter from approximately 10 to 20 ft bgs.

Upon completion of drilling and sampling, the borehole was decommissioned in general accordance with the requirements of Washington Administrative Code 173-160.
### Soil Classification System

#### MAJOR DIVISIONS

<table>
<thead>
<tr>
<th>GRAVEL AND GRAVELLY SOIL</th>
<th>CLEAN GRAVEL</th>
<th>USCS LETTER</th>
<th>TYPICAL DESCRIPTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Fine-grained soil)</td>
<td>(Little or no fines)</td>
<td>GW</td>
<td>Well-graded gravel; gravel/sand/mixture(s); little or no fines</td>
</tr>
<tr>
<td></td>
<td>(Appreciable amount of fines)</td>
<td>GM</td>
<td>Silty gravel; gravel/sand/silt/mixture(s)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GC</td>
<td>Clayey gravel; gravel/sand/clay/mixture(s)</td>
</tr>
<tr>
<td>SAND AND SANDY SOIL</td>
<td>CLEAN SAND</td>
<td>SW</td>
<td>Well-graded sand; gravelly sand; little or no fines</td>
</tr>
<tr>
<td>(Coarse-grained soil)</td>
<td>(Little or no fines)</td>
<td>SP</td>
<td>Poorly graded sand; gravelly sand; little or no fines</td>
</tr>
<tr>
<td></td>
<td>(Appreciable amount of fines)</td>
<td>SM</td>
<td>Silty sand; sand/silt/mixture(s)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SC</td>
<td>Clayey sand; sand/clay mixture(s)</td>
</tr>
<tr>
<td>FINE-GRAINED SOIL</td>
<td>SAND WITH FINES</td>
<td>OL</td>
<td>Inorganic silt; organic, silty clay of low plasticity</td>
</tr>
<tr>
<td>(More than 50% of coarse fraction passed through No. 4 sieve)</td>
<td></td>
<td>ML</td>
<td>Inorganic silt and very fine sand; rock flour; silty or clayey fine sand or clayey silt with slight plasticity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CL</td>
<td>Inorganic clay of low to medium plasticity; gravelly sandy clay; silty clay; lean clay</td>
</tr>
<tr>
<td></td>
<td></td>
<td>OH</td>
<td>Organic clay of medium to high plasticity; organic silt</td>
</tr>
<tr>
<td>WATER-Borne ORGANIC SOIL</td>
<td></td>
<td>PT</td>
<td>Peat; humus; swamp soil with high organic content</td>
</tr>
</tbody>
</table>

#### OTHER MATERIALS

<table>
<thead>
<tr>
<th>GRAPHIC SYMBOL</th>
<th>LETTER SYMBOL</th>
<th>TYPICAL DESCRIPTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC or PC</td>
<td></td>
<td>Asphalt concrete pavement or Portland cement pavement</td>
</tr>
<tr>
<td>RK</td>
<td></td>
<td>Rock (See Rock Classification)</td>
</tr>
<tr>
<td>WD</td>
<td></td>
<td>Wood, lumber, wood chips</td>
</tr>
<tr>
<td>DB</td>
<td></td>
<td>Construction debris, garbage</td>
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</tbody>
</table>

### Drilling and Sampling Key

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Sample Number &amp; Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>3.25-inch O.D., 2.42-inch I.D. Split Spoon</td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>2.00-inch O.D., 1.50-inch I.D. Split Spoon</td>
<td></td>
</tr>
<tr>
<td>c</td>
<td>Shelby Tube</td>
<td></td>
</tr>
<tr>
<td>d</td>
<td>Grab Sample</td>
<td></td>
</tr>
<tr>
<td>e</td>
<td>Single-Tube Core Barrel</td>
<td></td>
</tr>
<tr>
<td>f</td>
<td>Double-Tube Core Barrel</td>
<td></td>
</tr>
<tr>
<td>g</td>
<td>2.50-inch O.D., 2.00-inch I.D. WSDOT</td>
<td></td>
</tr>
<tr>
<td>h</td>
<td>3.00-inch O.D., 2.375-inch I.D. Mod. California</td>
<td></td>
</tr>
<tr>
<td>i</td>
<td>300-lb Hammer, 30-inch Drop</td>
<td></td>
</tr>
<tr>
<td>j</td>
<td>140-lb Hammer, 30-inch Drop</td>
<td></td>
</tr>
<tr>
<td>k</td>
<td>Pushed</td>
<td></td>
</tr>
<tr>
<td>l</td>
<td>Vibrocore (Rotasonic/Geoprobe)</td>
<td></td>
</tr>
<tr>
<td>m</td>
<td>Other - See text if applicable</td>
<td></td>
</tr>
</tbody>
</table>

**Sample Identification Number**

- **Recovery Depth Interval**
- **Sample Depth Interval**
- **Portion of Sample Retained for Archive or Analysis**

### Field and Lab Test Data

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Sample Number &amp; Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP</td>
<td>Pocket Penetrometer, tsf</td>
<td></td>
</tr>
<tr>
<td>TV</td>
<td>Torvane, tsf</td>
<td></td>
</tr>
<tr>
<td>PID</td>
<td>Photoionization Detector VOC screening, ppm</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Dry Density, pcf</td>
<td></td>
</tr>
<tr>
<td>AL</td>
<td>Atterberg Limits - See separate figure for data</td>
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</tr>
<tr>
<td>GT</td>
<td>Other Geotechnical Testing</td>
<td></td>
</tr>
<tr>
<td>CA</td>
<td>Chemical Analysis</td>
<td></td>
</tr>
</tbody>
</table>

### Groundwater

- Approximate water level at time of drilling (ATD)
- Approximate water level at time after drilling/excavation/well

---

**Notes:**
1. USCS letter symbols correspond to symbols used by the Unified Soil Classification System and ASTM classification methods. Dual letter symbols (e.g., SP-SM for sand or gravel) indicate soil with an estimated 5-15% fines. Multiple letter symbols (e.g., ML/CL) indicate borderline or multiple soil classifications.
2. Soil descriptions are based on the general approach presented in the Standard Practice for Description and Identification of Soils (Visual-Manual Procedure), outlined in ASTM D 2488. Where laboratory index testing has been conducted, soil classifications are based on the Standard Test Method for Classification of Soils for Engineering Purposes, as outlined in ASTM D 2487.
3. Soil description terminology is based on visual estimates (in the absence of laboratory test data) of the percentages of each soil type and is defined as follows:
   - **Primary Constituent:** > 50% - "GRAVEL," "SAND," "SILT," "CLAY," etc.
   - **Secondary Constituents:** > 30% and < 50% - "very gravelly," "very sandy," "very silty," etc.
   - **Additional Constituents:** > 15% and < 30% - "gravelly," "sandy," "silty," etc.
   - **Additional Constituents:** > 5% and < 15% - "with gravel," "with sand," "with silt," etc.
   
4. Soil density or consistency descriptions are based on judgement using a combination of sampler penetration blow counts, drilling or excavating conditions, field tests, and laboratory tests, as appropriate.

---

**Wastewater Pump Station**
No. 12 Rehabilitation
Redmond, Washington

**Soil Classification System and Key**

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**Figure B-1**
Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
### WELL DETAIL

**Drilling Method:** Hollow-Stem Auger  
**Ground Elevation (ft):** Not Measured  
**Logged By:** BJM  
**Date:** 11/08/18

**Moisture Content (%):**

<table>
<thead>
<tr>
<th>Moisture Content (%)</th>
<th>20</th>
<th>40</th>
<th>60</th>
<th>80</th>
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<tr>
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<td></td>
</tr>
<tr>
<td></td>
<td>▲</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Fines Content (%):**

<table>
<thead>
<tr>
<th>Fines Content (%)</th>
<th>20</th>
<th>40</th>
<th>60</th>
<th>80</th>
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</thead>
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</tr>
<tr>
<td></td>
<td>▲</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Graphic Symbol:** SP-SM  
**Notation:** Gray, fine to coarse SAND with gravel and silt (medium dense, wet)  
- Grades to dense

---

**Notes:**

1. Stratigraphic contacts are based on field interpretations and are approximate.  
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.  
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

---

**SAMPLE DATA**

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Sample Number &amp; Interval</th>
<th>Sampler Type</th>
<th>Blows/Foot</th>
<th>Test Data</th>
<th>Graphic Symbol</th>
<th>USCS Symbol</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-13</td>
<td>b2 32</td>
<td></td>
<td></td>
<td></td>
<td>SP-SM</td>
<td></td>
<td></td>
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<tr>
<td>S-14</td>
<td>b2 39</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-15</td>
<td>b2 42</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tbody>
</table>

Boring Completed 11/08/18  
Total Depth of Boring = 46.5 ft.
APPENDIX C
LABORATORY TESTING

To facilitate soil classification, natural moisture content determinations and grain size analyses were performed on select samples obtained from the boring. Laboratory testing was performed in general accordance with the ASTM International (ASTM) standard test methods described below. The field log descriptions were checked against the samples, and updated where appropriate in general accordance with ASTM standard test method D2487, *Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System).*

Natural Moisture Content

Natural moisture content determinations were performed on select soil samples in accordance with ASTM standard test method D2216, *Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass.* The natural moisture content is shown as \( W = xx \) (i.e., percent of dry weight) in the column labeled “Test Data” on the summary boring log in Appendix B.

Grain Size Analysis

To provide an indication of the grain size distribution of site soil, sieve analyses were conducted on representative soil samples in accordance with ASTM standard test method D422, *Standard Test Method for Particle-Size Analysis of Soils.* Samples selected for grain size analyses are designated with a “GS” in the column labeled “Test Data” on the summary boring log in Appendix B. The results of the grain size analyses are presented on Figures C-1 and C-2 in this appendix.
U.S. Sieve Opening in Inches | U.S. Sieve Numbers | Hydrometer
--- | --- | ---
6 | 4 | 3
3 | 2 | 1
1 | 3/4 | 1
1/2 | 1/4 | 1
1/4 | 1/8 | 1
1/8 | 1/16 | 1
1/16 | 1/32 | 1
1/32 | 1/64 | 1
1/64 | 1/128 | 1
1/128 | 1/256 | 1
1/256 | 1/512 | 1
1/512 | 1/1024 | 1
1/1024 | 1/2048 | 1
1/2048 | 1/4096 | 1
1/4096 | 1/8192 | 1
1/8192 | 1/16384 | 1
1/16384 | 1/32768 | 1
1/32768 | 1/65536 | 1
1/65536 | 1/131072 | 1
1/131072 | 1/262144 | 1
1/262144 | 1/524288 | 1
1/524288 | 1/1048576 | 1
1/1048576 | 1/2097152 | 1
1/2097152 | 1/4194304 | 1
1/4194304 | 1/8388608 | 1
1/8388608 | 1/16777216 | 1
1/16777216 | 1/33554432 | 1
1/33554432 | 1/67108864 | 1
1/67108864 | 1/134217728 | 1
1/134217728 | 1/268435456 | 1
1/268435456 | 1/536870912 | 1
1/536870912 | 1/1073741824 | 1

<table>
<thead>
<tr>
<th>Cobble</th>
<th>Gravel</th>
<th>Sand</th>
<th>Silt or Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse</td>
<td>Fine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coarse</td>
<td>Medium</td>
<td>Fine</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Exploration Number</th>
<th>Sample Number</th>
<th>Depth (ft)</th>
<th>Natural Moisture (%)</th>
<th>Soil Description</th>
<th>Unified Soil Classification</th>
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</thead>
<tbody>
<tr>
<td>●</td>
<td>MW-1</td>
<td>S-3</td>
<td>7.5</td>
<td>4</td>
<td>Very sandy, fine to coarse GRAVEL</td>
<td>GP</td>
</tr>
<tr>
<td>□</td>
<td>MW-1</td>
<td>S-5</td>
<td>12.5</td>
<td>7</td>
<td>Very sandy, fine to coarse GRAVEL</td>
<td>GP</td>
</tr>
<tr>
<td>▲</td>
<td>MW-1</td>
<td>S-7</td>
<td>17.5</td>
<td>8</td>
<td>Very gravelly, fine to coarse SAND</td>
<td>SP</td>
</tr>
<tr>
<td>★</td>
<td>MW-1</td>
<td>S-8</td>
<td>20.0</td>
<td>11</td>
<td>Very gravelly, fine to coarse SAND</td>
<td>SP</td>
</tr>
<tr>
<td>○</td>
<td>MW-1</td>
<td>S-11</td>
<td>27.5</td>
<td>17</td>
<td>Fine to coarse SAND with gravel and silt</td>
<td>SP-SM</td>
</tr>
</tbody>
</table>

Wastewater Pump Station
No. 12 Rehabilitation
Redmond, Washington

Grain Size Distribution

Figure C-1
Wastewater Pump Station
No. 12 Rehabilitation
Redmond, Washington

Grain Size Distribution

Figure C-2
APPENDIX D
SLUG TESTING

During the November 2018 field explorations, shallow groundwater was observed in the vicinity of proposed Pump Stations 12 and 13. Temporary construction dewatering will likely be necessary during excavation of the pump stations. City of Redmond Municipal Code (RMC) Sections 13.25.060 and 13.25.070 outline the geotechnical information that must be provided if temporary construction dewatering is required for a development project.

The required information includes an estimate of aquifer characteristics (e.g., transmissivity) in the vicinity of the temporary construction dewatering. The transmissivity of a hydrogeologic unit can be estimated directly or indirectly. Direct estimates involve performing a pumping test on a well, and indirect estimates involve multiplying the estimated hydraulic conductivity (K) by the saturated thickness of the unit.\(^1\) K can be estimated using soil descriptions and/or aquifer testing (e.g., slug testing).

The November 2018 explorations encountered highly permeable alluvial deposits of gravelly, fine to coarse sand and sandy, fine to coarse gravel. Geologic data for the project area indicate that similarly coarse-grained soils extend from ground surface to 80 to 100 feet (ft) below ground surface (bgs). The soils are underlain by glacial till (Golder 2018). K values for coarse-grained material range from 100 to 2,800 feet per day (ft/day; Freeze and Cherry 1979; Fetter 2001; Schwartz and Zhang 2003). Grain size distribution estimates of K (e.g., Hazen's D\(_{10}\) correlation) indicate hydraulic conductivities on the order of 1×10\(^1\) ft/day to 9×10\(^3\) ft/day. To refine the estimate, slug tests were performed in monitoring wells installed at the proposed pump station locations.

Slug tests are performed by artificially perturbing the water level in a well and observing the recovery to static conditions over time. Perturbation can be accomplished by adding or removing a discrete volume (water or a solid of known volume) to or from the well or by pneumatic methods (pressurized air). Following perturbation, the water-level response curve can be analyzed to estimate the hydraulic conductivity of the soil immediately surrounding the well screen. To estimate transmissivity, the estimated K value can be multiplied by an assumed (or observed) saturated thickness of similar soil material at that location.

METHODOLOGY

Slug tests were performed in Pump Station 12 and 13 monitoring wells using a 43-inch-long, 1.5-inch-diameter solid slug. Each monitoring well was constructed with 2-inch schedule, 40 polyvinyl chloride and a 10-ft screen. Static water level (i.e., depth to water) was measured manually with a Solinst Model 101 electronic water-level indicator. Water-level response and recovery during the slug tests

1 Transmissivity (T) equals hydraulic conductivity (K) times saturated thickness (b), or T = K*b.
were measured using a Solinst Model 3001 pressure transducer set to record at a uniform ¼-second interval.

Pump Station 12 was screened from 9.55 to 19.55 ft below top of casing (btoc; or approximately 9.8 to 19.8 ft bgs), and the static water level was measured at 12.15 ft btoc (within the screen interval). Pump Station 13 was screened from 15.00 to 25.00 ft btoc (or approximately 15.5 to 25.5 ft bgs), and the static water level was measured at 14.25 ft btoc (just above the screen interval). Both wells include an artificial sand pack, consisting of 20/40 silica sand (Pump Station 12) or 10/20 silica sand (Pump Station 13), in the 2-inch annular space between the well screen and the borehole wall. Both wells were developed by surging and pumping the screen interval until discharge became clear.

The Pump Station 12 screen was only partially saturated at the time of testing, and during preliminary testing, a significant oscillatory response was observed in well water levels upon submergence of the slug (commonly seen during slug tests in wells screened in high K material). As such, only rising head tests were performed and analyzed. Rising head slug tests were performed by submerging the slug until the top was level with the static water level, waiting for the water level to return to static conditions (as observed by real-time view of data logger data), and removing the slug from the well. The result was an initial drop in water level and a subsequent rising water-level recovery. Given the high K material, water levels were recovered in a matter of seconds. Water-level data from three representative rising head tests were retained for analysis. Criteria used to select data included observed initial displacement, relative to theoretical initial displacement, and overall smoothness of the recovery curve.

Water-level response to the slug tests was analyzed using the Aqtesolv (Duffield 2007) aquifer test analysis software program with the following semi- or fully analytical models:

- Hvorslev 1951.
- Bouwer-Rice 1976.

All three models were developed or adapted by Aqtesolv for use in unconfined aquifer conditions. The Hvorslev and Bouwer-Rice models are steady-state, straight-line methods. Hvorslev is often used as a first-cut estimate of K values, and Bouwer-Rice is an improvement on the Hvorslev model. The KGS model is a transient, curve-matching model with multiple parameters, and is generally considered more robust than the straight-line methods.

---

2 Given the dimensions of the slug and well casing, a theoretical initial displacement of approximately 2.0 ft is expected with full submergence and removal of the slug. Given the high K material and the rapidity of the water-level response, even the ¼-second interval water-level recordings may not have captured the full extent of the initial observed displacement. Professional judgment was used to select tests based on the magnitude of the initial displacement recorded by the data logger.
RESULTS
The following sections describe the results of slug testing at the proposed pump station locations.

Pump Station 12 Monitoring Well
Results of the Aqtesolv analyses for the three rising head slug tests performed in Pump Station 12 are shown on Figures D-1a through D-1c, and summarized in Table D-1. Based on the results, the K value of shallow subsurface soils in the vicinity of Pump Station 12 is estimated at 200 feet per day (within, but on the low end of, the range of expected values for similar material). Assuming a saturated thickness of approximately 90 ft, the transmissivity of the soil beneath proposed Pump Station 12 is estimated at approximately 18,000 square feet per day (or 135,000 gallons per day per foot). The artificial sand pack of the well (20/40 silica sand) may have affected the water-level response during the slug tests. If so, the hydraulic conductivity (and therefore, the transmissivity) of the native material may be higher than that estimated by the slug test analyses.

Pump Station 13 Monitoring Well
Results of the Aqtesolv analyses for the three rising head slug tests performed in Pump Station 13 are shown on Figures D-2a through D-2c, and summarized in Table D-2. Based on the results, the K value of shallow subsurface soils in the vicinity of Pump Station 13 is estimated at approximately 500 feet per day (within, but on the low end of, the range of expected values for similar material). Assuming a saturated thickness of approximately 90 ft, the transmissivity of the soil beneath proposed Pump Station 13 is estimated at approximately 45,000 square feet per day (or 335,000 gallons per day per foot). The artificial sand pack of the well (10/20 silica sand) may have affected the water-level response during the slug tests. If so, the hydraulic conductivity (and therefore, the transmissivity) of the native material may be higher than that estimated by the slug test analyses.

3 20/40 silica sand is a fine to medium sand with an effective grain size (i.e., d_{10}) of approximately 0.42 millimeter. Applying the Hazen (1911) equation with a “C” coefficient of 60 to 80 (appropriate for fine to medium sand; Fetter 2001) yields an estimated K value of 300 to 400 ft/day for the Pump Station 12 sand pack. The actual hydraulic conductivity of the sand pack may vary.

4 10/20 silica sand is a medium sand with an effective grain size (i.e., d_{10}) of approximately 0.84 millimeter. Applying the Hazen (1911) equation with a “C” coefficient of 80 to 120 (appropriate for medium sand; Fetter 2001) yields an estimated K value of 2,400 to 3,000 ft/day for the Pump Station 13 sand pack. The actual hydraulic conductivity of the sand pack may vary.
Hvorslev (1951)

Bouwer-Rice (1976)

KGS Model (Hyder et al. 1994)
Figure D-1b

PS-12 Slug Test 2 Results

Hvorslev (1951)

Bouwer-Rice (1976)

KGS Model (Hyder et al. 1994)
Hvorslev (1951)

Bouwer-Rice (1976)

KGS Model Hyder et al. (1994)
Figure D-2a

PS-13 Slug Test 1 Results

Hvorslev (1951)

Bouwer-Rice (1976)

KGS Model Hyder et al. (1994)
Hvorslev (1951)

Bouwer-Rice (1976)

KGS Model Hyder et al. (1994)
Table D-1
PS-12 Slug Test Results

PS-12 Slug Test Analysis Summary - Hydraulic Conductivity

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<th></th>
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<th>Bouwer-Rice</th>
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<th>Average</th>
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<tbody>
<tr>
<td>Test 1</td>
<td>168.0</td>
<td>189.1</td>
<td>159.2</td>
<td>172</td>
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<tr>
<td>Test 2</td>
<td>212.4</td>
<td>156.5</td>
<td>216.2</td>
<td>195</td>
</tr>
<tr>
<td>Test 3</td>
<td>240.8</td>
<td>170.2</td>
<td>214.6</td>
<td>209</td>
</tr>
</tbody>
</table>

Avg: 200

*All hydraulic conductivity (K) values in units of feet/day.
*Average K value is rounded.
<table>
<thead>
<tr>
<th></th>
<th>Hvorslev</th>
<th>Bouwer-Rice</th>
<th>KGS</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td>586.3</td>
<td>318.6</td>
<td>446.3</td>
<td>450</td>
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<td>Test 2</td>
<td>573.2</td>
<td>379.7</td>
<td>535.9</td>
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<tr>
<td>Test 3</td>
<td>722.4</td>
<td>459.1</td>
<td>457.7</td>
<td>546</td>
</tr>
</tbody>
</table>

**Avg:** 500

*All hydraulic conductivity (K) values in units of feet/day.*

*Average K value is rounded.*