RhinoOne GEOTECHNICAL

August 9, 2022

Brown and Caldwell
Jonathan R. Holland, P.E.
Vice President
6500 SW Macadam Avenue, Suite 200
Portland, Oregon 97239

RE: Geotechnical Technical Memorandum
Raw Water Pipeline Alternatives from Lusted Road to Filtration Facility
Portland Water Bureau - Bull Run Treatment Program
Rhino One Project No. BAC-2020-004

Dear Mr. Holland:

Rhino One Geotechnical Engineering (ROG) has prepared this Geotechnical Technical Memorandum (GTM) in support of the selected alternative for the raw water pipeline alignment. The proposed tunnel under exclusive farm use (EFU) land provides the necessary connection between the existing supply pipelines in Lusted Road and the planned filtration facility on Carpenter Lane. To serve the project objectives, this connection must pass below land zoned EFU for technical and engineering feasibility reasons.

For the review of technical and engineering feasibility factors, the geography and zoning context in the area is relevant. Geographically, the filtration site is surrounded on two sides by EFU zoned lands: to the east by EFU land along Dodge Park Boulevard in Multnomah County, and to the south by EFU lands in Clackamas County (Figure 1).

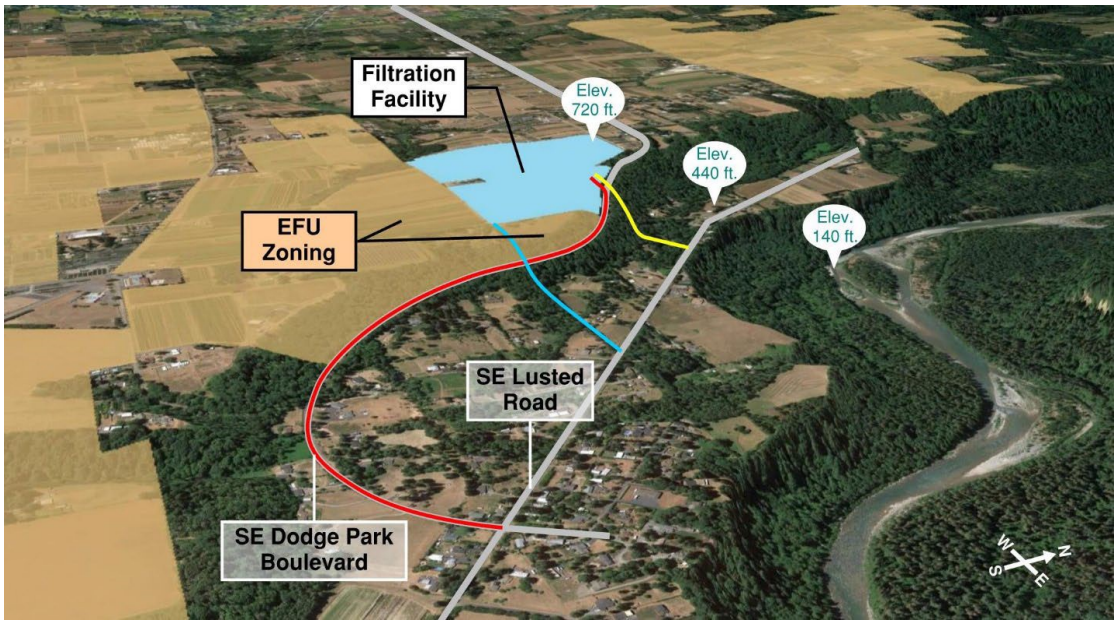

Figure 1: Birds eye view of Sandy River bluffs (scarps) showing Alt. 2 (red), Alt. 4 (yellow), and proposed Alt. (blue)

Pipeline alignment and construction alternatives were evaluated and refined over the course of a year. Six Raw Water pipeline alternatives were studied including alignments within and outside of EFU lands (Figure 2). The RW Alternative 4 (orange) was a non-EFU alignment connecting to the site from the northeast. Another alignment, RW Alternative 2 (red), followed the right of way at the edge of the EFU zone, also connecting to the site from the northeast. All other alternatives require crossing of EFU lands.

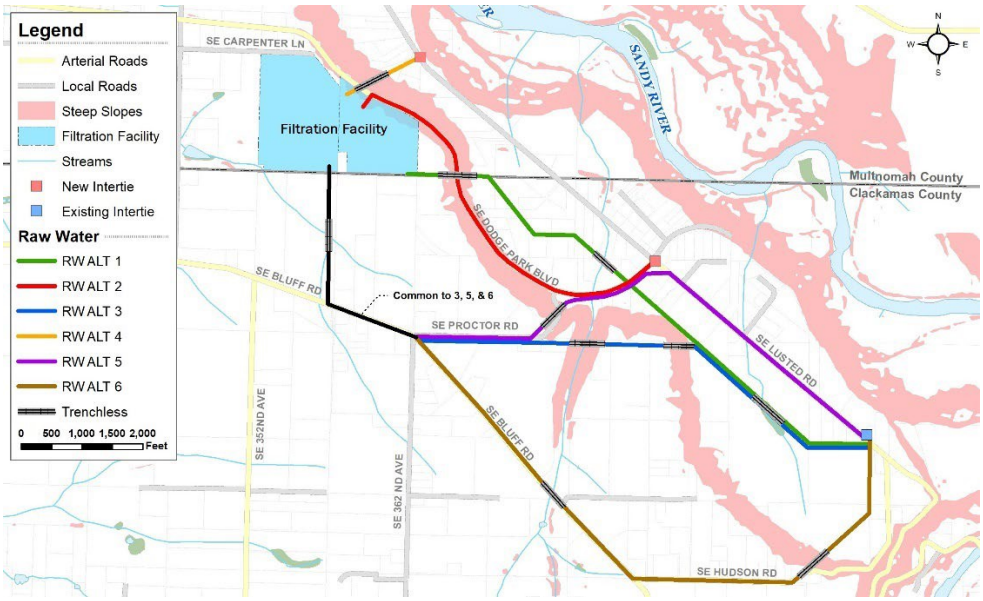

Figure 2: Raw Water Alternative Alignments

ROG assembled and led a Geotechnical Technical Advisory Committee (GTAC) to provide further geotechnical and seismic guidance for the Bull Run Filtration Project. The GTAC consisted of regional subject matter experts that include geologists and geotechnical engineers. The GTAC members and their brief qualifications are summarized below:

- Rajiv Ali, PhD, PE, GE (OR): ROG, Lead Geotechnical Engineer for PWB program management team
  Dr. Ali has more than 26 years of experience involving soil mechanics, earthquake hazard evaluations, seismic design, foundation design, static and dynamic loading analysis, and slope-stability analysis in support of various projects. These include transportation infrastructure; water and wastewater facilities and pipelines; government, commercial, and industrial facilities; land development; soil and rock stability; and ground support.

- Dr. Scott Burns, Professor, Portland State University
  Dr. Burns has been a professor at PSU since 1990 with a teaching career spanning over 40 years. He has published over 100 peer-reviewed papers and has over 25 research grants. He earned the Distinguished Practice Award from the Geological Society of America (GSA) in 2012, Top Engineering Geologist from GSA and the Association of Environmental and Engineering Geologists in 2011 and Outstanding Scientist from Oregon in 2014.

- Stephen Dickenson, Ph.D., PE, D. PE, New Albion Geotechnical
  Dr. Dickenson has been active in geotechnical engineering research, education, and professional practice since 1985. Dr. Dickenson actively participates on professional committees charged with developing seismic guidelines for port waterfront structures and lifelines infrastructure, with incorporation of performance-based design principles. Dr. Dickenson has published over 50 per-

reviewed technical papers and has contributed to development of several codes and practice manuals.

- Dr. Sunil Sharma, Ph.D., PE, M. ASCE, Professor of Civil Engineering, University of Idaho
  Dr. Sharma teaches Earthquake Engineering, Soil Dynamics, Seepage and Earth Dams, and other courses in geotechnical engineering. Dr. Sharma is the author of the popular slope stability computer program, XSTABL which is used by many highway agencies and consultants. His research interests and publications for the last 20 years have been focused on earthquake engineering, slope stability, foundation engineering, groundwater seepage, and computer software design and development.

- Mr. Bill Perkins, PE, LEG, Vice President, Earthquake Engineering Services Group Leader, Shannon & Wilson
  Mr. Perkins manages traditional geotechnical/geologic engineering projects as well as seismic design and retrofit projects/tasks. His technical experience includes probabilistic seismic hazard analysis (PSHAs), bridge seismic evaluation/retrofit projects, seismic evaluation contracts for the General Services Administration, seismic tasks on major structures, and transportation and infrastructure projects.

The GTAC met on several occasions in 2019 to review results of geotechnical investigations and provide guidance on how to avoid and/or mitigate project hazards and risks, including for pipeline alternatives. The rationale for eliminating from further consideration the raw water pipeline routes that avoid EFU lands is provided below.

RW Alt 2 Alignment Along Dodge Park Boulevard: The RW Alt 2 (red) alignment is located within the narrow roadway of Dodge Park Boulevard. The GTAC recommended that it not be considered further due to geologic and seismic hazards and challenging constructability requirements.

Slope stability analysis, guided by GTAC input, was based on low blow count materials observed in geotechnical borings, soil characterizations, water table levels, and historic landslide records. The GTAC noted the history of shallow slope failures between the upper terrace (where the filtration facility will be located) and the lower terrace (where the new raw water pipeline will connect to the existing supply lines in Lusted Road). These shallow/surficial slope failures (5 to 10 feet deep) are mapped and were also identified in geotechnical explorations on Dodge Park Boulevard, as the road begins to gain elevation near the county line.

The GTAC also noted that likely soil liquefaction and lateral spreading on this steep slope during a Cascadia Subduction Zone earthquake is a significant hazard. Installing the pipeline transverse to the slope (the failure plane of these hazards) would pose high risks due to soil movement and resulting stresses on the pipeline.

In addition, major constructability issues were also identified and were complicated by the compact work zone within the narrow roadway to avoid the adjacent steep slopes.

The GTAC concluded that these risks cannot be mitigated with reasonable certainty and should be avoided by selecting an alternative alignment.

RW Alt 4 Alignment Along Dodge Park Boulevard:
The RW Alternative 4 (orange) is a non-EFU alignment connecting to the site from the northeast from Lusted Road. A fatal flaw screening analysis was conducted using recommendations provided by the GTAC. Based on field explorations and historical knowledge of the region, the GTAC concluded that RW Alt 4 was fatally flawed because of “very high” seismic hazard risks where Lusted Road approaches the steep scarp above the Sandy River, as shown on Figure 1. Catastrophic slope failures are anticipated during the Cascadia Subduction Event in this area. In addition, the estimated shaft depth required for a

trenchless crossing at the filtration facility site was deemed to be too deep to be considered feasible. Lastly, there is not enough room within the existing right-of-way of Lusted Road to provide a reasonable setback to the top of the slope to minimize or avoid the hazard. This alignment is therefore considered fatally flawed and was eliminated.

RW1 Alignment:
The proposed alternative (RW Alt 1) avoids the steep scarp along Lusted Road and hazards associated with the Dodge Park Boulevard alignment. It provides a direct route between the existing conduits in Lusted Road and the filtration facility. For purposes of seismic resiliency and technical feasibility, the GTAC determined that tunneling under the upper slope at the proposed depths (147 feet to 217 feet below ground surface) provides the greatest protection of the pipeline in the event of an earthquake or landslide. This alignment meets the seismic resiliency goals in accordance with the Oregon Resiliency Plan.

As demonstrated based on technical and engineering feasibility factors, reasonable alternatives have been considered and the facility must be sited in an EFU zone to meet the project objectives.

We appreciate this opportunity to submit this GTM to you. Please contact me of if you have any questions or wish to further discuss our recommendations.

Sincerely,

Rajiv Ali, Ph D, PE, GE
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