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GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

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August 17, 2016

Mr. Allen Hendy, PE
Otak, Inc.
700 Washington Street, Suite 401
Vancouver, Washington 98660

RE: DRAFT PRELIMINARY GEOTECHNICAL NARRATIVE
BOONES FERRY ROAD TO BROWN ROAD
EAST-WEST CONNECTOR CORRIDOR PLAN
WILSONVILLE, OREGON

Dear Mr. Hendy:

This letter report presents the results of our preliminary review and conceptual geotechnical recommendations for use in planning the proposed Boones Ferry Road to Brown Road Connector Corridor project in Wilsonville, Oregon. The locations of the proposed alignment alternatives are shown on Figure 1, Site Plan. Our services are being performed under a Subconsultant Agreement between Otak, Inc. (Otak), and Shannon & Wilson, Inc. (S&W), dated June 6, 2016.

SCOPE OF SERVICES

At the request of the City of Wilsonville, the Otak team is performing an alternative selection process and providing a final recommendation for the preferred alignment of an extension of Brown Road to either Bailey Street or 5th Street. The new roadway will cross Coffee Lake Creek. Shannon & Wilson's task is to summarize general soil conditions in the project area and provide conceptual foundation recommendations for the creek crossing structure.

EXISTING INFORMATION REVIEW

Regional Geology

The project site is located in the Willamette Lowland, at the northern end of the Central Willamette Valley (Gannett and Caldwell, 1998). The Willamette Lowland is a structural depression created by complex faulting and folding of Miocene (approximately 17 to 6 million

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years old) Columbia River Basalt Group (CRBG) basalt flows and older underlying basement rock.

In the Willamette Valley, the CRBG is generally overlain by Upper Miocene (approximately 10 to 5 million years old) deposits consisting of fine-grained micaceous fluvial and lacustrine sediments derived from the Columbia and Willamette Rivers that are collectively termed the Sandy River Mudstone (Orr and Orr, 2000). The Sandy River Mudstone is described by Gannett and Caldwell as a micaceous arkosic siltstone, mudstone, and claystone. Overlying the Sandy River Mudstone is the Pliocene (approximately 5 to 1.8 million years old) Troutdale Formation, which is described as a quartzite-bearing basaltic conglomerate, vitric sandstone, and micaceous sandstone (Gannett and Caldwell, 1998). Composition and thicknesses of the two units vary with location. Mapping at the project location by Schlicker and others (1967) includes the Sandy River Mudstone with the Troutdale Formation and describes the overall unit as poorly indurated silt, clay, and silty sand with occasional pebble conglomerate beds. Locally, the Troutdale Formation is concealed beneath younger sediments and is exposed only in the bottom of steep ravines.

During the late stages of the last great ice age, between about 18,000 and 15,000 years ago, a lobe of the continental ice sheet repeatedly blocked and dammed the Clark Fork River in western Montana, which then formed an immense glacial lake called Lake Missoula. The lake grew until its depth was sufficient to buoyantly lift and rupture the ice dam, which allowed the entire massive lake to empty catastrophically. Once the lake had emptied, the ice sheet again gradually dammed the Clark Fork Valley and the lake refilled, leading to 40 or more repetitive outburst floods at intervals of decades (Allen and others, 2009). These repeated floods are collectively referred to as the Missoula Floods. During each short-lived Missoula Flood episode, floodwaters washed across the Idaho panhandle, through eastern Washington's scablands, and through the Columbia River Gorge. When the floodwater emerged from the western end of the gorge, it spread out over the Portland Basin and pooled to elevations of about 400 feet, depositing a tremendous load of sediment. Boulders, cobbles, and gravel were deposited nearest the mouth of the gorge and along the main channel of the Columbia River. Cobble-gravel bars reached westward across the basin, grading to thick blankets of micaceous sand and silt (Allen and others, 2009). Ma and others (2012) divided the Missoula Flood Deposits into four groups:

- Silt Colluvium consisting of sand and silt colluvium, generally along stream channels
- Fine-Grained Deposits consisting of sand and silt

- Coarse-Grained Deposits consisting mostly of gravel with cobbles and boulders
- Channel Deposits consisting of interlayered and variable silt, sand, and gravel

The Tonquin Scablands Channels, north of the Wilsonville area, constricted flows from the Missoula Floods, creating a high-energy water surge from the Tualatin Basin in the north emptying into the Central Willamette Valley to the south. The high-velocity water flowing through the gap entrained coarse gravels, cobbles, and boulders that were dropped out of suspension when the surge lost energy opening up into the Central Willamette Valley near the I-5 Boone Bridge in Wilsonville (Thompson, 2012). As a result, much of the Wilsonville area is underlain by coarse-grained Missoula Flood Deposits. In more recent times, rivers and streams, such as the Willamette River and Coffee Lake Creek, have deposited alluvial sediments in and along their channels and floodplains (Ma and others, 2012; Smith and Roe, 2015).

Seismic Setting

Earthquakes in the Pacific Northwest occur largely as a result of the collision between the Juan de Fuca plate and the North American plate. These two tectonic plates meet along a mega thrust fault called the Cascadia Subduction Zone (CSZ). The CSZ runs approximately parallel to the coastline from northern California to southern British Columbia. The compressional forces that exist between these two colliding plates cause the denser oceanic plate to descend, or subduct, beneath the continental plate at a rate of about 1.5 inches per year. This process leads to volcanism and contortion and faulting of both crustal plates throughout much of the western regions of southern British Columbia, Washington, Oregon, and northern California. Stress built up between the colliding plates is periodically relieved through great earthquakes at the plate interface (CSZ) (Goldfinger and others, 2012).

Within our present understanding of the regional tectonic framework and historical seismicity, three broad earthquake (seismogenic) sources have been identified. These three types of earthquakes and their maximum plausible magnitudes are as follows.

- **Subduction Zone Interface Earthquakes** originate along the CSZ, which is located 25 miles beneath the coastline. Paleoseismic evidence and historic tsunami studies indicate that the most recent subduction zone thrust fault event occurred in the year 1700, probably ruptured the full length of the CSZ, and may have reached magnitude 9.
- **Deep-Focus, Intraplate Earthquakes** originate from within the subducting Juan de Fuca oceanic plate as a result of the downward bending and contortion of the plate in the CSZ.

These earthquakes typically occur at a depth of 28 to 38 miles. Such events could be as large as magnitude 7.5. Examples of this type of earthquake include the 1949 magnitude 7.1 Olympia earthquake, the 1965 magnitude 6.5 earthquake between Tacoma and Seattle, and the 2001 magnitude 6.8 Nisqually earthquake. The highest rates of CSZ intraslab activity are beneath the Puget Sound area, with much lower rates observed beneath western Oregon.

- **Shallow-Focus Crustal Earthquakes** are typically located within the upper 12 miles of the continental crust. The relative plate movements along the CSZ cause not only east-west compressive strain, but dextral shear, clockwise rotation, and north-south compression of the leading edge of the North American Plate (Wells and others, 1998), which is the cause of much of the shallow crustal seismicity of engineering significance in the region. The largest known crustal earthquake in the Pacific Northwest is the 1872 North Cascades earthquake with an estimated magnitude of about 7. Other examples include the 1993 magnitude 5.6 Scotts Mill earthquake and 1993 magnitude 6 Klamath Falls earthquake.

Shallow crustal faults and folds throughout Oregon and Washington have been located and characterized by the United States Geological Survey (USGS). Mapped fault locations and detailed descriptions can be found in the USGS Quaternary Fault and Fold Database (USGS, 2006). The database defines four categories of faults, Classes A through D, based on evidence of tectonic movement known or presumed to be associated with large earthquakes during Quaternary time (less than 1.8 million years ago). For Classes A and B, there is geologic evidence that demonstrates the existence of Quaternary deformation. However, for Class B faults, evidence of Quaternary faulting or slip is more equivocal or may not extend deep enough to be a source of significant earthquakes.

According to the USGS Fault and Fold database, the closest Class A fault to the project site is the Canby-Molalla Fault. It is mapped approximately 4.5 miles east of the site and is believed to have deformed within the past 15,000 years. Additionally, the Newberg fault is mapped about 8.5 miles west of the site and the Mount Angel Fault is mapped about 11 miles southwest. The Newberg fault is believed to have deformed within the past 1.6 million years and the Mount Angel Fault within the past 15,000 years. The CSZ itself is approximately 130 miles west of the site, with a slip rate of approximately 40 millimeters (1.5 inches) per year and the most recent deformation occurring about 300 years ago (Personius and Nelson, 2006). Based on the mapped

fault locations from the USGS database, the potential for fault rupture or near-fault effects at the site is low.

ANTICIPATED SUBSURFACE CONDITIONS

We reviewed published geologic maps and logs of explorations completed for previous projects in the vicinity of the proposed alignments. The locations of the past projects and the proposed alignments are shown on a geologic map in Figure 1. Based on this information, we expect that the western ends of the alignments will be underlain by at least 25 feet of Fine-Grained Missoula Flood Deposits consisting of nonplastic to low plasticity silt to fine silty sand. Moving east from the western end, we expect that this layer of fine-grained deposits will thin and that the majority of both alignments, including the crossing of Coffee Lake Creek, will be underlain by near-surface Coarse-Grained Missoula Flood Deposits. All explorations for previous projects that encountered Coarse-Grained Missoula Flood Deposits in this vicinity noted cobbles and/or boulders with a maximum reported dimension of 18 inches. The eastern ends of the alignments are mapped in or near either Missoula Flood Deposits, Channel Deposits (Ma and others, 2012) or Alluvium of Smaller Streams (Smith and Roe, 2015). Based on the logs for previous nearby test pits and borings, we anticipate that at the eastern ends of the alignments Coarse-Grained Missoula Flood Deposits will be overlain by a relatively thin (about 5 to 10 feet) layer of sandy silt and that cobbles and boulders will be encountered below this layer.

GEOLOGIC AND SEISMIC HAZARDS

Slope Stability

Based on a review of available LiDAR data for the project vicinity, about 300 linear feet of the proposed Alignment Alternative 2 east of SW Morey Lane appears to be at or near the top of the slope above Arrowhead Creek. We expect that this portion will be underlain by Fine-Grained Missoula Flood Deposits and that the static and seismic stability of the slope above the creek will be a concern.

Liquefaction and Lateral Spread

We expect that the fine-grained sand and silt near the western ends of the alignments will be susceptible to wide-spread liquefaction and liquefaction-induced settlement. We also anticipate

that there may be layers of liquefaction-susceptible sand and silt interbedded with the Coarse-Grained and Channel Deposits.

Evaluations for lateral spread will be required for the slopes above Arrowhead Creek and Coffee Lake Creek. We expect that the fine-grained material along Arrowhead Creek will be more susceptible to lateral spread than the coarse-grained material along Coffee Lake Creek.

CONCEPTUAL GEOTECHNICAL OPINIONS

Northern light blue route to either Bailey or 5th Street

Based on the local geology and anticipated subsurface conditions described above, Alignment 1 (A and B) is preferred from a geotechnical perspective because the alignment is further away from Arrowhead Creek and also because the majority of the alignment is within the area mapped as Coarse-Grained Missoula Flood Deposits.

We understand that the project may involve the construction of two new bridges: one for the SW Kinsman Road extension overcrossing Coffee Lake Creek, the other for the proposed Brown Road extension overcrossing Coffee Lake Creek. We have considered three foundation alternatives: spread footings, driven piles, and drilled shafts. The spread footing alternative may not be preferred because the spread footing construction may require overexcavation of near-surface fine-grained soil, dewatering, and temporary shoring, which may be more expensive than deep foundation construction costs. The bridges can be supported by deep foundations, including driven piles or drilled shafts. Due to the anticipated presence of shallow Coarse-Grained Missoula Flood Deposits, the deep foundations would be designed as end-bearing piles or shafts. The bearing resistances of the deep foundations are dependent on the pile or shaft diameters and embedment depths. In our current opinion, driven pile foundations may be the most cost-effective foundation alternative.

LIMITATIONS

The conclusions and recommendations contained in this letter are based on the site conditions as they reportedly exist and assume that the subsurface conditions are not significantly different from those inferred from the published maps and previous explorations.

This letter report is prepared for the exclusive use of the Boones Ferry Road to Brown Road Connector Corridor project team. It should be made available for information of factual data only, and not as a warranty of subsurface conditions, such as those interpreted from published

maps and reports for nearby projects, and discussions of subsurface conditions included in this letter.

Please note that our scope of services did not include any environmental assessment or evaluation regarding the presence or absence of hazardous or toxic materials in the soil, surface water, groundwater, or air, on or below the site.

Shannon & Wilson has prepared the attached, "Important Information About Your Geotechnical/Environmental Report," to assist you and others in understanding the use and limitations of our reports.

Sincerely,

SHANNON & WILSON, INC.

Aimee E. Holmes, PE, CEG
Senior Engineer / Engineering Geologist

Risheng (Park) Piao, PE, GE
Vice President

AEH:RPP/

Enc: Figure 1 – Site Plan
Important Information About Your Geotechnical/Environmental Report

REFERENCES

Allen, J.E., Burns, M., and Burns, S., 2009, Cataclysms on the Columbia: The Great Missoula Floods (2nd ed.): Portland, Oreg., Ooligan Press, 204 p.

Burns, W.J. and Watzig, R.J., 2014, Statewide Landslide Information Database for Oregon, release 3 (SLIDO-3): Oregon Department of Geology and Mineral Industries.

Gannett, G.W. and Caldwell, R.R, 1998; Geologic Framework of the Willamette Lowland Aquifer System, Oregon and Washington: U.S. Geological Survey Professional Paper 1424-A, 32 p., 8 pls.

Goldfinger, C. and others, 2012, Turbidite Event History – Methods and Implications for Holocene Paleoseismicity of the Cascadia Subduction Zone: U.S. Geological Survey Professional Paper 1661-F, 184 p.

Ma, Lina, Madin, I.P., Duplantis, S., and Williams, K.J., 2012, Lidar-Based Surficial Geologic Map of the Greater Portland Area: Clackamas, Columbia, Marion, Multnomah, Washington, and Yamhill Counties, Oregon and Clark County, Washington: Oregon Department of Geology and Mineral Industries, Open-File Report O-12-02, scale 1:63,360.

Orr, Elizabeth L. and Orr, William N., 2000, Geology of Oregon: Fifth Edition: Dubuque, Iowa, Kendall/Hunt.

Personius, S.F., and Nelson, A.R., compilers, 2006, Fault number 781, Cascadia subduction zone, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed May 18, 2015.

Schlicker, H.G. and Deacon, R.J., 1967, Engineering Geology of the Tualatin Valley region, Oregon: Oregon Department of Geology and Mineral Industries Bulletin B-60, 103 p., 5 app., 45 figs., 5 tables, 4 pls. incl. 1 geologic-hazards map and 1 depth-to-basalt map [all 1:48,000].

Shannon & Wilson, Inc.,1972, Subsurface Investigation, Proposed Relocation Oregon Electric Railway Bridge OE 43.4, Wilsonville, Oregon: Report prepared by Shannon & Wilson, Inc., Portland, Oreg., O-639, for Burlington Northern, Portland, Oreg., August, 27 p.

Shannon & Wilson, Inc., 1988, Geotechnical Investigation, Wilsonville School Addition, Wilsonville, Oregon: Report prepared by Shannon & Wilson, Inc., Portland, Oreg., O-2010-01, for West Linn School District 3J, West Linn, Oreg., February, 6 p.

Shannon & Wilson, Inc., 1988, Pavement Investigation, Wilsonville School, Wilsonville, Oregon: Report prepared by Shannon & Wilson, Inc., Portland, Oreg., O-2018-01, for West Linn School District 3J, West Linn, Oreg., February, 5 p.

Shannon & Wilson, Inc., 2010, Final Updated Geotechnical Design Report, I-5: Wilsonville Road Interchange, Wilsonville, Oregon: Report prepared by Shannon & Wilson, Inc., Lake Oswego, Oreg., 24-1-03528-002, for Otak, Inc., Lake Oswego, Oreg., May, 40 p.

Shannon & Wilson, Inc., 2015, Draft Geotechnical Report, Willamette River Water Treatment Plant 2015 Master Plan Update, Wilsonville, Oregon: Report prepared by Shannon & Wilson, Inc., Lake Oswego, Oreg., 24-1-03928-005, for Carollo Engineers, Inc., Portland, Oreg., October, 36 p.

Smith, Rachel L. and Roe, Warren P., 2015, Oregon Geologic Data Compilation Release 6 (OGDC-6): Oregon Department of Geology and Mineral Industries.

Squier Associates, "Project Memorandum, Wilsonville Water Treatment Plant (WWTP), Assessment of Boulders Encountered at Finished Water Pipeline Undercrossing," Prepared for Montgomery/Watson, 2001.

Squier Associates, "Project Memorandum, Wilsonville Water Treatment Plant (WWTP), Geotechnical Analyses and Recommendations in Support of 30 Percent Design Effort," Prepared for Montgomery/Watson, 2000.

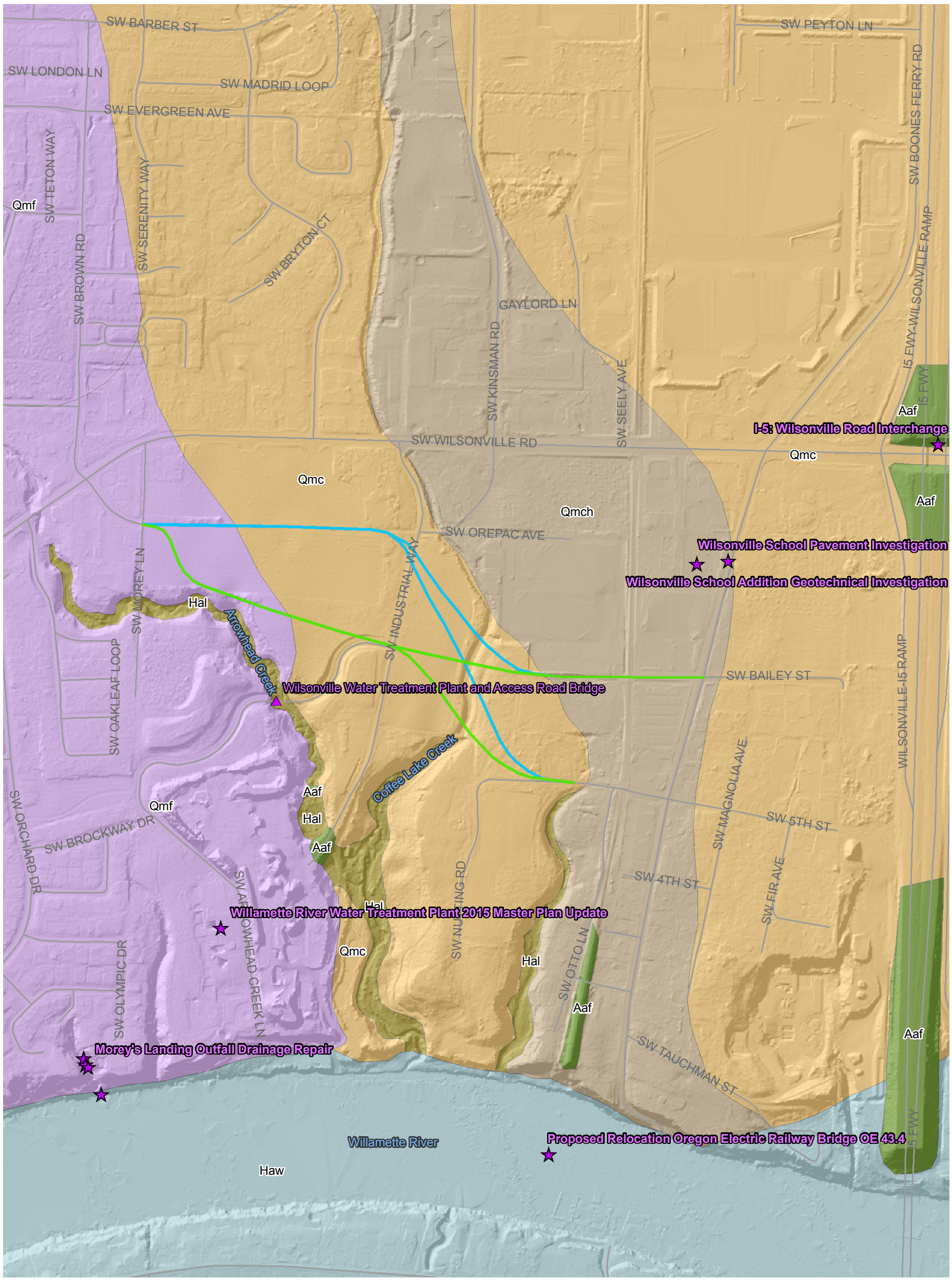
Squier Associates, "Project Memorandum, Wilsonville Water Treatment Plant (WWTP), Evaluation and Recommendations of East Abutment Foundations in Support of 30 Percent Design Effort of Entrance Road Bridge," Prepared for Montgomery/Watson, 2000.

Thompson, Rick, 2012, The Tualatin and Yamhill Valleys in Northwest Oregon: The Pleistocene Post, Newsletter of the Ice Age Floods Institute, Spring 2012, p. 6-11.

U.S. Geological Survey, 2006, Quaternary fault and fold database for the United States, accessed April, 23, 2014, from USGS web site: http//earthquake.usgs.gov/hazards/qfaults/.

Wells, R. E., Weaver, C. S., and Blakely, R. J., 1998, Fore arc migration in Cascadia and its neotectonic significance; Geology, v. 26, p. 759-762.

Filename: T:\Projects\24-1\4041_East West Connector\Avmxd\SitePlan.mxd Date: 8/15/2016 Login: aeh



LEGEND

- General Location of Previous Shannon & Wilson Project
- General Location of Previous Squier Associates Project
- Alignment Alternative 1A (North)
- Alignment Alternative 1B (South)
- Alignment Alternative 2A (North)
- Alignment Alternative 2B (South)

Hal	Alluvium of lowland streams
Haw	Alluvium of the Willamette River
Aaf	Artificial fill
Qmch	Missoula flood deposits, channel facies
Qmc	Missoula flood deposits, coarse-grained facies
Qmf	Missoula flood deposits, fine-grained

0 250 500 1,000
Scale in Feet

NOTES

1. Geologic mapping from Open-File Report O-12-02 by DOGAMI.

Boones Ferry Road to Brown Road
East-West Connector Corridor Plan
Wilsonville, Oregon

SITE PLAN

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FIG. 1

FIG. 1