**Washington State**
**Department of Transportation**

MEMORANDUM

June 23, 2008

TO: Bijan Khaleghi /Mark Anderson
Bridge and Structures, MS 47340

FROM: Tony M. Allen/Donald A. Williams
E&EP Geotechnical Division, MS 47365

SUBJECT: SR-520, MP 12.73, XL-2028
West Lake Sammamish Parkway to SR-202
Bridge 520/46 – Pier 2 Shaft Option
Addendum to the Geotechnical Design Recommendations

As requested, we are supplying foundation recommendations for a drilled shaft option for the widening of Bridges 520/ 46 Pier 2. The new spread footing foundation at Pier 2 may encroach on an existing 42 inch metro sewer that lies just north of Pier 2. Therefore, a drilled shaft may be required to avoid the sewer line. It is our understanding that the sewer line can not be relocated.

**Liquefaction**

The liquefaction potential of saturated soils is evaluated mainly on soil gradation, density, and the depth of the deposit. The potential for liquefaction is highest for loose, fine to medium grained sands and silty sands. Increasing fines content along with increasing plasticity (i.e., silt and clay) decreases the potential for liquefaction. Conversely, clean coarse grained granular soils are less susceptible to liquefaction due to their high permeability. The potential for liquefaction also decreases with increasing density and depth.

We have evaluated the potential for liquefaction of the project soils based on the SPT data obtained from the field explorations and the percentages of silt. Our analysis indicates that there are lenses of liquefiable layers along the alignment. Therefore, the potential for liquefaction varies from pier to pier at these structures. Estimated liquefaction-induced ground settlement is shown in Table 1.

Table 1: Estimate of Liquefaction-Induced Settlement at Bridge 520/46.

| Pier No. | Approximate Elevation of Liquefiable Layers (feet) | Estimated Maximum Ground Settlement (inches) |
|---|---|---|
| 1 | 29 ft to 24 ft<br>-5 ft to -7 ft | 1.5 |
| 2, 3 & 4 | 9 ft to 4 ft<br>-4 ft to -12 ft | 3.0 |
| 5 | 25 ft to 24 ft<br>-15 ft to -16 ft | Less than 0.5 |
| 6 | No Liquefaction expected | NA |

## Liquefaction Induced Lateral Spreading

In general, we expect that the zones of liquefiable layers will not induce global instability at pier sites due to their depth, discontinuous, lensed nature, and relatively flat terrain. Lateral spreading and slope stability analyses was performed on the near surface zone at Bridge 520/46. The near surface zone had adequate global stability under the seismic case. Therefore, the risk of lateral spreading is minimal.

## Drilled Shaft Recommendations for Pier 2

In Appendix D, we have provided drilled shaft resistance plots for various shaft diameters. At Pier 2, we provided plots for shaft diameters that range from 6.0 ft to 10.0 ft, shown in Figures D-42 through D-44. At a given depth on the figures, the factored resistance can be determined by adding the nominal skin friction multiplied by its resistance factor, and the nominal tip resistance multiplied by its resistance factor ($\phi_b$) as shown in the following equation:

$$R_R = R_P \times \phi_{qp} + R_s \times \phi_{qs}$$

For the service limit state, the settlement of the shaft foundations will be less than 1-inch. Settlement will occur as the loads are applied. Post-construction settlement should be negligible.

## Resistance Factors for Drilled Shaft Design

We recommend that the following resistance factors be used when evaluating the different limit states.

Table 2: Resistance Factors for Drilled Shafts

| Limit State | Resistance Factor $\phi$ | | |
|---|---|---|---|
| | Skin Friction, $R_s$ | End Bearing, $R_b$ | Group Uplift |
| Strength | 0.55 | 0.50 | 0.45 |
| Service | 1.00 | 1.00 | NA |
| Extreme | 1.00 | 1.00 | 0.80 |

**Group Effects**

Drilling a hole for a shaft less than 4.0 shaft diameters from an existing shaft reduces the effective stresses against both the side and base of the existing shaft. As a result, the axial resistances of the individual shafts within a group tend to be less than the corresponding resistances of isolated shafts. Since the drilled shafts on this project will likely be a single row or two rows, we recommend the nominal resistance of each shaft should be reduced as needed to account for group effects in accordance in Section 10.8.3.6.3 of the AASHTO LRFD Bridge Design Specifications.

**Lateral Load Analysis**

We understand that lateral analysis for drilled shafts will be evaluated using the DFSAP program. The soil parameters used for DFSAP input are included in Figure D-45 in Appendix D. The DFSAP parameters use the existing ground surface as a reference point.

**Downdrag**

Since no new fill will be added in the vicinity of Pier 2, the mechanism that can induce downdrag loads is the post liquefaction settlement of the foundation soils that can occur after the design seismic event. These loads will be applied to the foundation elements in the extreme event limit state. A loss of axial resistance will also occur in the liquefied soils. Downdrag loads and loss of axial resistance for the extreme event limit state are shown in Tables 3 and 4 below.

Table 3: Downdrag Loads for Extreme Limit State

| Location | Downdrag Load per shaft (kips) | | |
|---|---|---|---|
| | 6.0-Foot | 8.0-Foot | 10.0-Foot |
| Pier 2 | 1,717 | 2,290 | 2,860 |

Table 4: Loss of Axial Resistance for Extreme Limit State

| Location | Downdrag Load per shaft (kips) | | |
|---|---|---|---|
| | **6.0-Foot** | **8.0-Foot** | **10.0-Foot** |
| Pier 2 | 1,717 | 2,290 | 2,860 |

The load factor in Table 5 should be applied to the downdrag loads. It is important to note that downdrag loads from the various limit states should not be combined.

Table 5: 2008 AASHTO LRFD Bridge Design Downdrag Load Factors

| Limit State | Load Factor | |
|---|---|---|
| | **Min.** | **Max.** |
| Strength | 0.35 | 1.25 |
| Service | 1.0 | |
| Extreme Event | 1.0 | |

## Drilled Shaft Tip Elevations

At Pier 2, the liquefiable layers shown in Table 1 have a factor of safety between 1.0 and 1.1. From a geotechnical point of view, we estimate that there will be a volume change during the extreme event. Therefore, settlement during the extreme limit state should occur and downdrag will occur. Due to the depth of these layers, we recommend that the tips be placed below elevation -12 ft. Under no circumstances do we want to place the shaft tip in the liquefiable layers.

## Construction Considerations

The construction considerations are as follows:

1. We expect caving soils in both the recent alluvium soil unit and the outwash soil unit. Soil Unit 3 (outwash) consists of medium dense to very dense, well-graded gravel to poorly graded sand below the ground water table with relatively clean soil. Temporary casing may be needed to control the sides of the excavated shafts. However, the casing recommendations need to be reviewed per our agreement with the ADSC (Association of Drilled Shaft Contractors).
2. Ground water will be encountered in the drilled shafts and will require the shafts be constructed "in the wet" using a slurry construction method. For shafts constructed "in the wet", cross-hole sonic logging (CSL) will be required.

3. Since Bridge and Structures detail requires a construction joint approximately 11 ft below the ground surface for a single shaft and column design, we recommend the following casing recommendations be included into the contract:

## 3.03 Shaft Excavation

B. The Contractor shall furnish and install casings as follows:

| Wall Name or Bridge No. | Wall Station or Bridge Pier Number | Casing Type | Elev. Of Bottom of Required Casing (ft) | Upper And Lower Elevation Limits for Concurrent Casing Placement With Excavation |
|---|---|---|---|---|
| Bridge 520/42 | Pier 2 | Permanent | 32 ft | 43 ft to 32 ft |
| | Pier 2 | Temporary | Shaft Tip | 32 ft to shaft tip |

When installing required temporary or required permanent casings between the upper and lower elevation limits specified above, the casing shall be advanced prior to or concurrently with the excavation. Excavation in advance of the casing tip shall not exceed ***2*** feet.

To maintain stable excavations and to facilitate construction, the Contractor may furnish and install temporary casing in addition to the required casing specified above. The Contractor shall provide temporary casing at the site in sufficient quantities to meet the needs of the anticipated construction method.

We will submit our recommendations to the ADSC (Association of Drilled Shaft Contractors) for review. These recommendations are preliminary and may change depending on the ADSC review.

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Reviewed By: Jim Cuthbertson
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Approval Authority: Tony Allen
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# APPENDIX - D

## Bridge 520/46 Widening

SR-520 - SR 202 Bridge 520/46

Pier 2

Diameter = 6.0 feet
Shaft Type = Cased the Top 10 ft

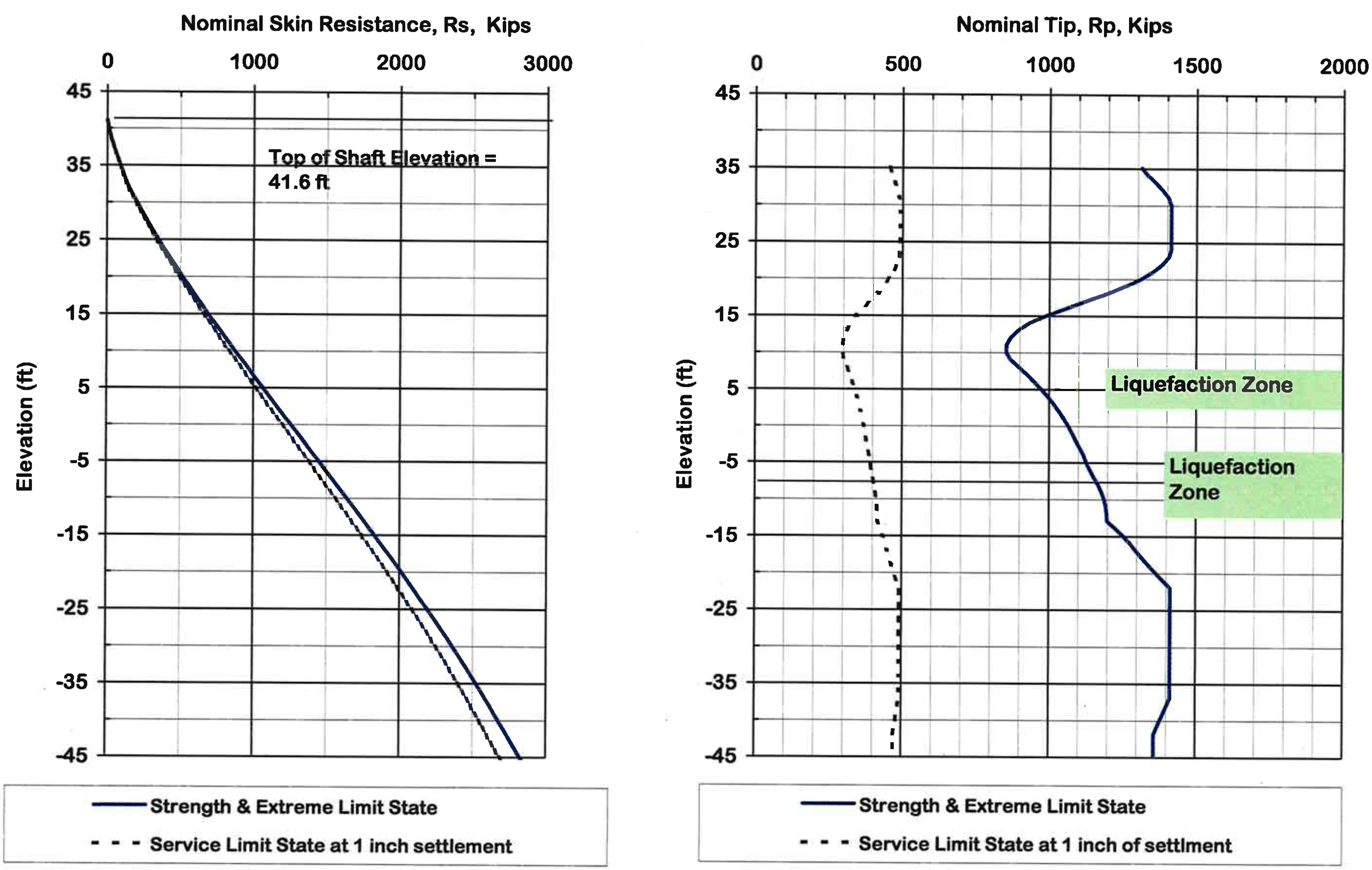
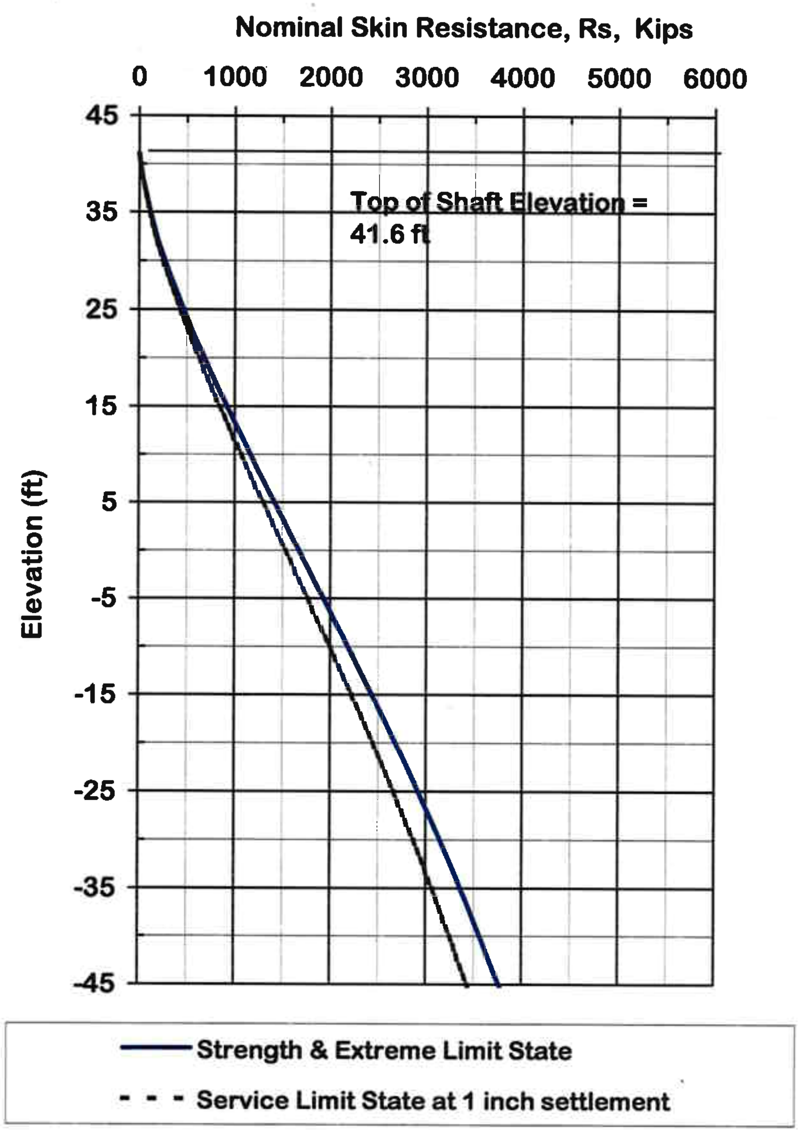



FIGURE D-42: Drilled Shaft Resistance Plot Bridge 520/46 - Pier 2

SR-520 - SR 202 Bridge 520/46

Pier 2

Diameter = 8.0 feet
Shaft Type = Cased the Top 10 ft



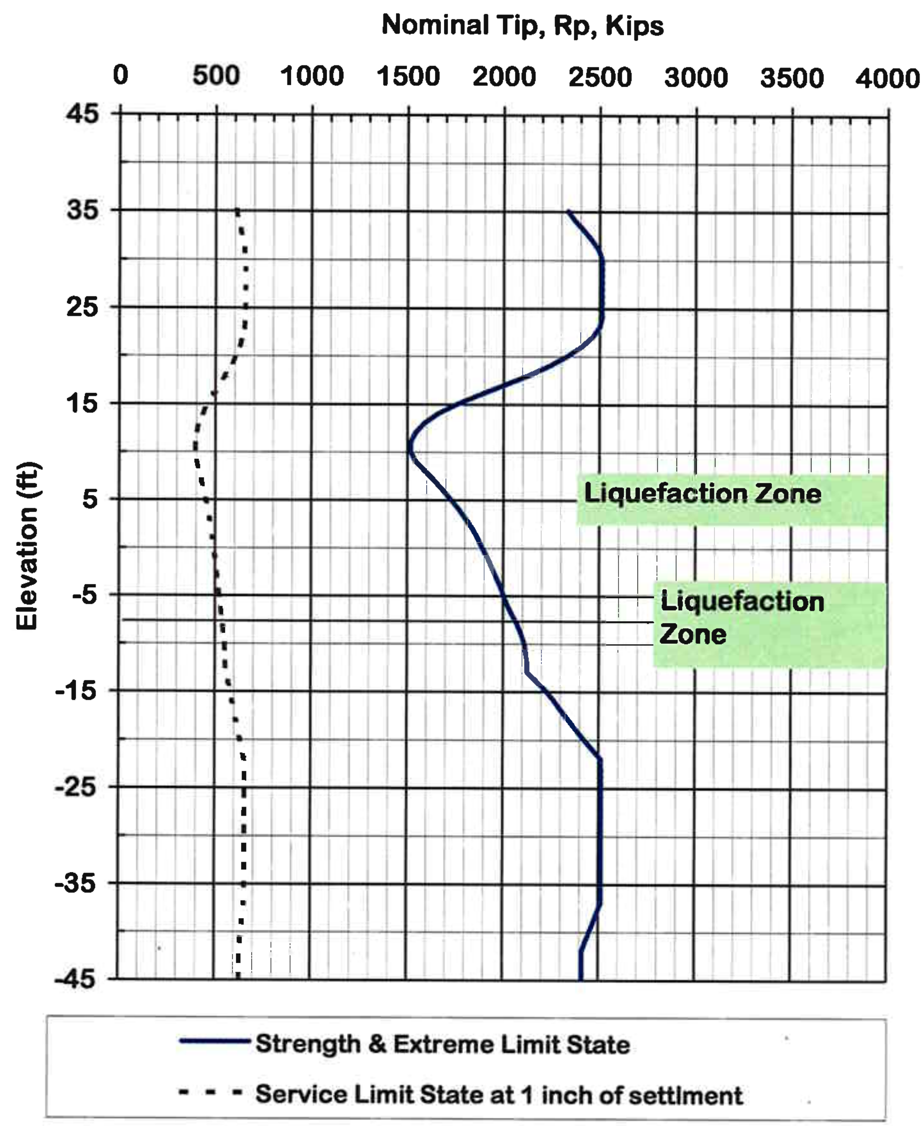
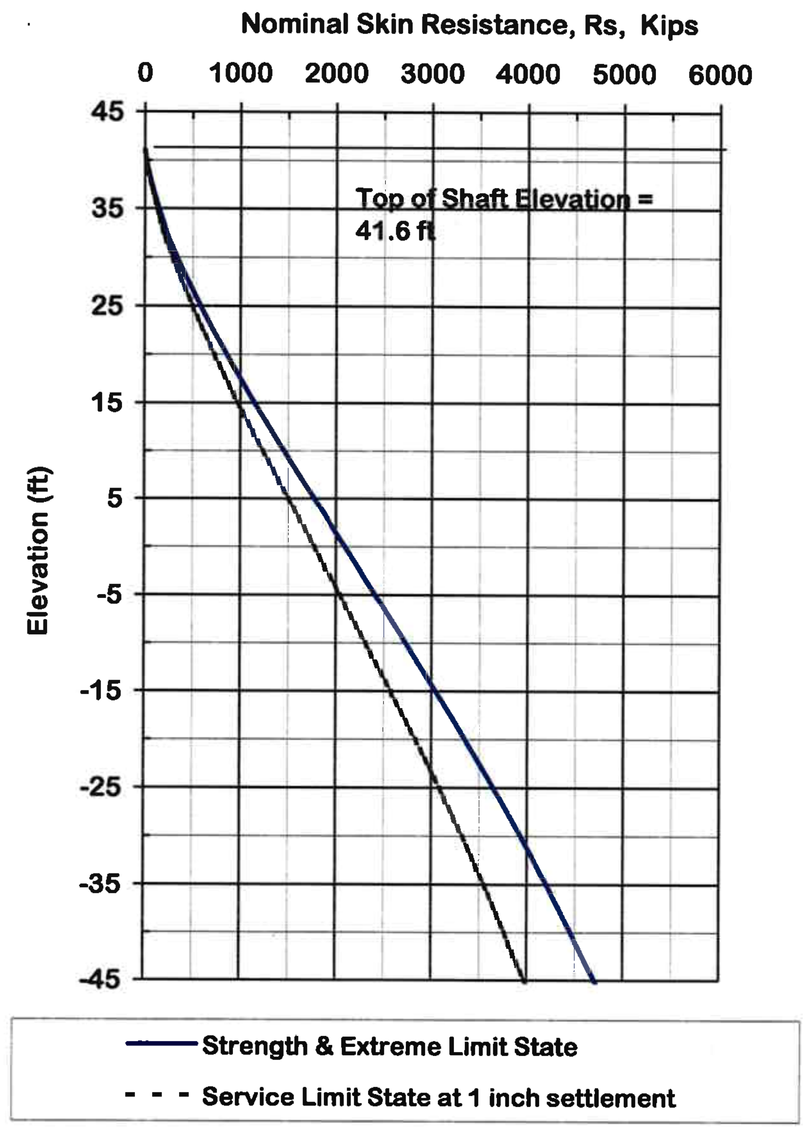




**FIGURE D-43: Drilled Shaft Resistance Plot Bridge 520/46 - Pier 2**

SR-520 - SR 202 Bridge 520/46

Pier 2

Diameter = 10.0 feet
Shaft Type = Cased the Top 10 ft



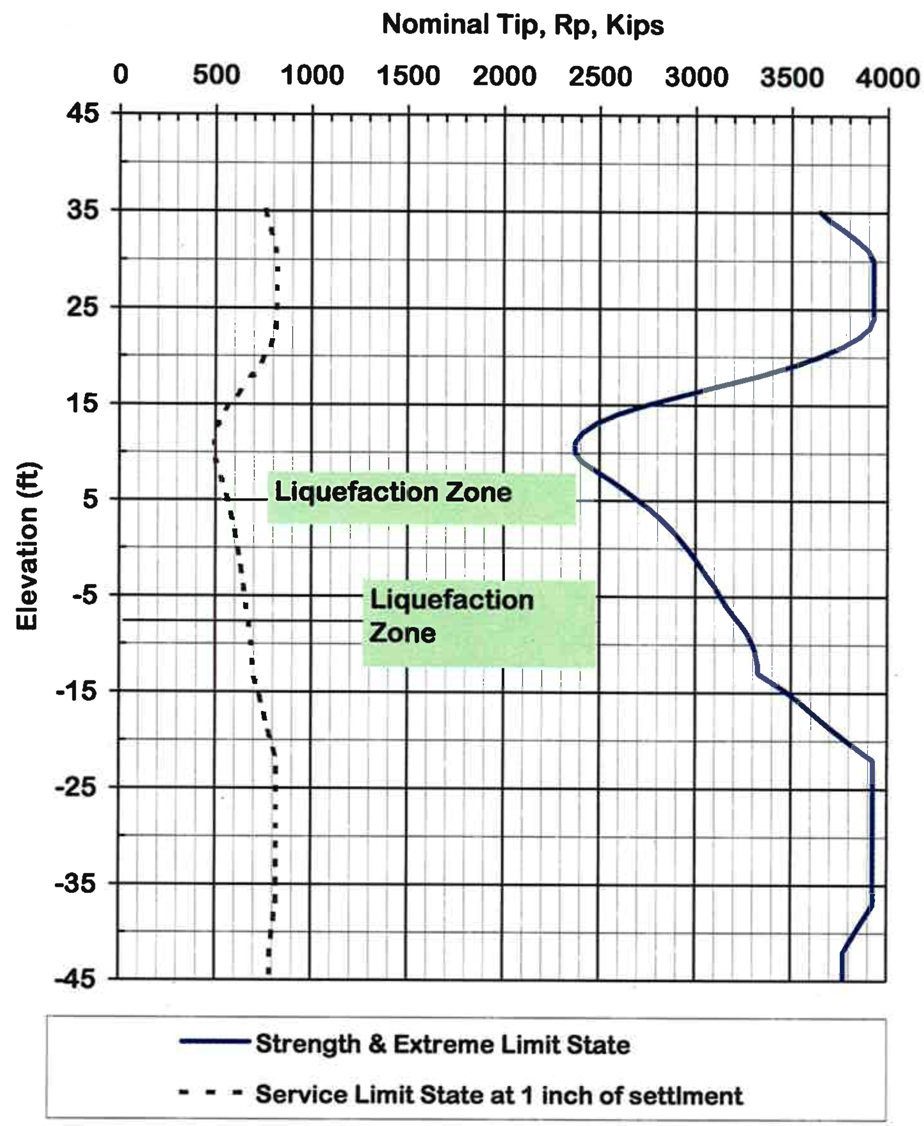




FIGURE D-44: Drilled Shaft Resistance Plot Bridge 520/46 - Pier 2

## SIL-Shaft Input Data

**Bridge No. or Name** West Lake Sammamish Parkway to SR-202 - Bridge 520/46
**Pier No(s).** 2
**Ground Surface Elevation** 45.0 (ft)

| Layer | Soil Type | Layer Thickness (ft) | Btm. Elev. (ft) | Effective Unit Weight (pcf) | Friction[1] Angle (deg) | $\varepsilon_{50}$ (%) | Liq. | Soil Cohesion (psf) | $s_u$ at Top of Layer (psf) | $s_u$ at Bottom of Layer (psf) | Rock Comp. Stgth (psf) | SPT Corrected Blowcounts (bpf) | Fines Content (%) | Angularity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Sand | 8.4 | 36.6 | 120 | 34 | 0.5 | No | | | | | | | |
| 2 | Sand | 28 | 8.9 | 68 | 39 | 0.4 | No | | | | | | | |
| 3 | Sand | 5 | 3.9 | 58 | 34 | 0.2 | Yes | | | | | 24 | 7 | Sub-Rounded |
| 4 | Sand | 8 | -4.1 | 58 | 36 | 0.5 | No | | | | | | | |
| 5 | Sand | 8 | -12.1 | 63 | 37 | 0.9 | Yes | | | | | 33 | 3 | Sub-Rounded |
| 6 | Sand | 24 | -36.1 | 65 | 38 | 0.3 | No | | | | | | | |
| 7 | Sand | 10 | -14.1 | 73 | 42 | 0.4 | No | | | | | | | |
| 8 | Sand | 5 | -17.1 | 63 | 39 | 1.2 | No | | | | | | | |
| 9 | Sand | 10 | -46.1 | 78 | 45 | 0.6 | No | | | | | | | |
| | | | | | | | | | | | | | | |

**Bridge No. or Name** West Lake Sammamish Parkway to SR-202 - Bridge 520/46
**Pier No(s).** 2
**Ground Surface Elevation** 45.0 (ft) Reduce Values for the Extreme Limit State Case

| Layer | Soil Type | Layer Thickness (ft) | Btm. Elev. (ft) | Effective Unit Weight (pcf) | Friction[1] Angle (deg) | $\varepsilon_{50}$ (%) | Liq. | Soil Cohesion (psf) | $s_u$ at Top of Layer (psf) | $s_u$ at Bottom of Layer (psf) | Rock Comp. Stgth (psf) | SPT Corrected Blowcounts (bpf) | Fines Content (%) | Angularity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Sand | 8.4 | 36.6 | 120 | 34 | 1.2 | No | | | | | | | |
| 2 | Sand | 28 | 8.9 | 68 | 39 | 1.5 | No | | | | | | | |
| 3 | Sand | 5 | 3.9 | 58 | 16 | 1.5 | No | | | | | | | |
| 4 | Sand | 8 | -4.1 | 58 | 36 | 0.4 | No | | | | | | | |
| 5 | Sand | 8 | -12.1 | 63 | 20 | 0.4 | No | | | | | | | |
| 6 | Sand | 24 | -36.1 | 65 | 38 | 1.5 | No | | | | | | | |
| 7 | Sand | 10 | -46.1 | 73 | 42 | 0.6 | No | | | | | | | |
| 8 | Sand | 5 | -51.1 | 63 | 39 | 0.5 | No | | | | | | | |
| 9 | Sand | 10 | -61.1 | 78 | 45 | 0.5 | No | | | | | | | |
| | | | | | | | | | | | | | | |

## FIGURE D-45: DFSAP Input Data - Bridge 520/46 Widening