Appendix D

Summary of Hydrogeologic Characteristics

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Appendix D – Summary of Hydrogeologic Characteristics

In this section, hydrogeologic information in support of the Terminal 4 hydrogeologic conceptual model (HCM) is presented and discussed. The HCM is based primarily on information provided from hydrogeologic cross sections developed from monitoring well boring logs and on groundwater elevation, river stage, and precipitation data. The HCM will be used in support of the engineering evaluation/cost analysis (EE/CA) to evaluate contaminant transport aspects of certain Removal Action alternatives, for example, sediment capping or placement in an onsite confined disposal facility (CDF).

D.1 Hydrogeologic Cross Sections

Three hydrogeologic cross sections were developed using information obtained from monitoring well boring logs. Locations of the hydrogeologic cross sections are shown on Figure D-1. Hydrogeologic cross-sections A-A', B-B', and C-C' (Figures D-2 through D-4) show the relative locations of the upland fill material, Unconsolidated Alluvial Deposits, and Troutdale Gravel geologic units. The upland fill material is composed of medium brown fine sands. Based on monitoring well boring logs (BBL, 2004) and from information provided in a previous upland investigation at Terminal 4 (Hart Crowser, 2000), the fine sands range in thickness from about 40 feet near the river to 5 feet in some upland portions of Terminal 4. The upland fill material was placed directly on top of the sediments that comprise the Unconsolidated Alluvial Deposits.

Near the river (monitoring well clusters T4-MW01, T4-MW04, and T4-MW06), the Unconsolidated Alluvial Deposits consist of dark grey to black, fine to medium sand that is about 160 feet in thickness. In the upland portions of Terminal 4 (monitoring well clusters T4-MW02, T4-MW03, and T4-MW05), the Unconsolidated Alluvial Deposits are primarily composed of interbedded layers of fine sand, silt, clayey silt, and silty clay. Sediments in the Unconsolidated Alluvial Deposits in the vicinity of Gatton's Slough (monitoring well clusters T4-MW02 and T4-MW03) are finer grained than are sediments in the Unconsolidated Alluvial Deposits in the vicinity of monitoring well cluster T4-MW05. The sediments of the Unconsolidated Alluvial Deposits are 120 to 150 feet in thickness in the upland portion of Terminal 4.

Gravel from the Troutdale formation was encountered at depths ranging from 142 to 200 feet below ground surface and at elevations ranging from -114 feet to -168 feet Columbia River Datum (CRD) at monitoring well T4-MW02D and monitoring well T4-MW06D, respectively (Figures D-2 through D-4). Gravel encountered in boring samples from monitoring well T4-MW05I likely is not associated with Troutdale Gravel given the higher elevation (-22.2 feet CRD) at which the monitoring well T4-MW05I gravels were encountered.

D.2 Groundwater Data

D.2.1 Groundwater Elevation Data

Depth to groundwater measurements were conducted approximately weekly from April 29, 2004 through June 3, 2004 and depth to groundwater values were converted to groundwater elevations (BBL, 2004). Weekly groundwater elevation data are presented on Figures 5-9 through 5-14 in BBL (2004) for monitoring well clusters T4-MW01 through T4-MW06, respectively.

During the study period, fluctuations in groundwater elevations greater than 4.0 feet were observed for shallow, intermediate, and deep groundwater at near-river monitoring well clusters T4-MW01, T4-MW04, and T4-MW06 and for deep groundwater at upland monitoring well clusters T4-MW02 and T4-MW03. The magnitude and direction of groundwater elevation fluctuations were similar for these wells (Figures 5-9 through 5-14 in BBL, 2004). The similarities in the magnitude and direction of groundwater elevation fluctuations indicate that a hydraulic connection exists between these depths and locations. As described in more detail in Section D.2.2, these groundwater elevation fluctuations appear to be correlated with river stage. Shallow and intermediate groundwater elevation fluctuations at upland monitoring well clusters T4-MW02, T4-MW03, and T4-MW05 were small (<1.0 foot) relative to the variations in groundwater elevations observed at the near-river monitoring well clusters. Hydraulic connectivity between shallow and intermediate groundwater at these locations may be impeded by layers of fine-grained materials within the Unconsolidated Alluvial Deposits and Gatton's Slough in the upland portion of Terminal 4.

Based on the weekly groundwater elevation data, downward vertical hydraulic gradients were observed between shallow and intermediate groundwater at monitoring well clusters T4-MW03, T4-MW04, and T4-MW05 and between intermediate and deep groundwater at monitoring well cluster T4-MW02 (Table 5-1 in BBL, 2004). Upward vertical hydraulic gradients were observed between shallow and intermediate groundwater at monitoring well cluster T4-MW02. Vertical hydraulic gradient reversals were observed between shallow and intermediate groundwater and between intermediate and deep groundwater at near-river monitoring well clusters T4-MW01 and T4-MW06 (Table 5-1 in BBL, 2004). These apparent reversals in vertical hydraulic gradient may be an artifact of the method in which depth to groundwater was measured. Time lapses of up to four hours but generally less than one hour, occurred between depth to groundwater measurements for individual monitoring wells at a monitoring well cluster. As described in Section D.2.2, tidally-induced changes in river stage cause rapid changes in groundwater elevations in near-shore monitoring wells. These changes could result in apparent gradient reversals between weekly measurement periods if the depth to groundwater measurements were not collected within a short time duration. Additional monitoring of groundwater elevations using pressure transducers deployed at monitoring well clusters T4-MW01 and T4-MW02 is currently underway. These additional data will be used to evaluate vertical hydraulic gradients in greater detail. The magnitude of the vertical hydraulic gradient was small to moderate (from less than 0.01 to 0.1 ft/ft) at near-river monitoring well clusters T4-MW01, T4-MW04, and T4-MW06 and was moderate to large (from 0.01 to greater than 0.1 ft/ft) at upland monitoring well clusters T4-MW02, T4-MW03, and T4-MW04.

These data indicate that vertical groundwater flow at Terminal 4 is dynamic and may be influenced by different factors, such as river stage or resistance to flow by fine-grained materials, at different locations. For example, variation in river stage may cause gradient reversals between hydrostratigraphic units at the near-river locations; however, at monitoring well cluster T4-MW02, horizontal groundwater flow in the Unconsolidated Alluvial Deposits may be hindered due to the confining nature of fine-grained materials located in downgradient Gatton's Slough.

Pressure transducers were used to "continuously" monitor groundwater pressure at 1-minute intervals at monitoring wells T4-MW06I and T4-MW06D. These pressure data were converted to groundwater elevations. In addition, a pressure transducer was used to continuously monitor Willamette River stage in Slip 3 at 10-minute intervals. Concurrent continuous groundwater elevation data and continuous stage data were available for a one-month period from April 17 to May 17, 2004 as shown on Figure 5-15 in BBL (2004). For illustrative purposes, weekly and continuous groundwater elevation data for monitoring well cluster T4-MW06 were compared with Willamette River stage and daily precipitation for a two-week period as shown on Figure D-5.

The Willamette River stage was tidally affected, and tidal stage fluctuations ranged from about 0.8 foot to 2.8 feet. Groundwater elevation also appeared to be tidally affected; daily groundwater elevation fluctuations ranged from about 0.7 foot to 2.2 feet and were less than river stage fluctuations. A strong relation between river stage and the elevation of intermediate ($R^2 = 0.987$, $p = 0$) and deep ($R^2 = 0.983$, $p = 0$) groundwater at monitoring wells T4-MW06I and T4-MW06D was observed during the monitoring period. When river stage changed, groundwater elevation at both monitoring wells changed in a similar manner (Figure D-5). This effect was observed for both tidally influenced changes in river stage as well as precipitation-induced changes in river stage. There was a time lag of about zero to 15 minutes between changes in the river stage and changes in the groundwater elevations at both monitoring wells, i.e., groundwater elevation changes lagged behind river stage changes by less than about 1/4 hour at this location.

Given the strong interaction between river stage and groundwater elevations at monitoring wells T4-MW06I and T4-MW06D demonstrated by the pressure transducer data, weekly groundwater elevation data can also be used to demonstrate tidal influence on groundwater elevation at other T4 monitoring wells. Based on weekly groundwater elevation data, the influence of change in river stage was also observed in shallow groundwater at monitoring wells T4-MW01S, T4-MW04S, and T4-MW06S in intermediate groundwater at monitoring wells T4-MW01D and T4-MW04I, and in deep groundwater at T4-MW01D, T4-MW02D, and T4-MW03I/D (Figures 5-9 through 5-14 in BBL, 2004). These observations indicated that in the upland fill material, Unconsolidated Alluvial Deposits, and Troutdale Gravel at nearshore locations (i.e., monitoring well clusters T4-MW01, T4-MW04, and T4-MW06), shallow, intermediate, and deep groundwater was hydraulically connected to and groundwater elevations were influenced by variations in stage in the Willamette River.

Tidal influences were not observed in shallow and intermediate groundwater at upland monitoring well clusters T4-MW02, T4-MW03, and T4-MW05. Finer-grained materials that are present in the upland portions of the Unconsolidated Alluvial Deposits (including Gatton's Slough) likely dampened the tidal pressure effect so that the tidal signal was no longer observed in shallow and intermediate groundwater at the upland monitoring well clusters. The elevation of the contact between the upland fill material and Unconsolidated Alluvial Deposits was greater than river stage at upland monitoring well clusters for the period of record (Figures 5-6 through 5-8 in BBL, 2004). Therefore, tidal fluctuation in river stage likely was not propagated through fine-grained Unconsolidated Alluvial Deposits to shallow groundwater at these upland locations. Tidal effects may be observed farther upland in shallow and intermediate groundwater during periods of higher river stage.

The magnitude and timing of variations in groundwater elevations at upland monitoring wells T4-MW02D and T4-MW03I/D were similar to the magnitude and timing of variations in groundwater elevations at near-river monitoring wells T4-MW01D and T4-MW06D (Figures 5-9, 5-10, 5-11, and 5-14 in BBL, 2004). Therefore, it is likely that fluctuations in river stage affected deep groundwater elevations as far upland as monitoring well cluster T4-MW02, indicating that river stage influences groundwater elevations farther upland within the Troutdale Gravel as compared with the upland fill material and Unconsolidated Alluvial Deposits. This tidal influence on deep groundwater at monitoring well clusters T4-MW02 and T4-MW03 suggests that the Troutdale Gravel is under semi-confined conditions due to the presence of fine-grained materials in the Unconsolidated Alluvial Deposits above the Troutdale Gravel in this portion of Terminal 4 (Fetter, 1994).

Tidal efficiency (TE) relates the amplitude of groundwater elevation fluctuations in an aquifer to the amplitude of fluctuation at the tidal boundary, which at Terminal 4 is the Willamette River. Tidal efficiency at monitoring well cluster T4-MW06 was estimated by dividing the change in groundwater elevation over a single tidal cycle by the change in river stage for the same tidal cycle. Tidal efficiency in intermediate and deep groundwater at monitoring well cluster T4-MW06 ranged from about 0.7 to 0.8 for the monitoring period. Because only weekly depth to groundwater measurements were performed at other monitoring well clusters, TEs were not calculated for other locations at Terminal 4. Tidal efficiency will be evaluated for groundwater at monitoring well clusters T4-MW01 and T4-MW02 once additional depth to groundwater data collection activities have been completed.

Relatively short-duration (i.e., 1-hour) hydraulic gradient reversals were observed between river stage and groundwater elevations at T4-MW06I during the monitoring period (BBL, 2004). However, since average groundwater elevation at T4-MW06I from April 27 through May 17, 2004 (5.13 feet CRD) was 0.1 feet greater than average river stage for this same period (5.03 feet CRD), there was a net discharge of groundwater from the Unconsolidated Alluvial Deposits to the river at this location for this time period. Average groundwater elevation at T4-MW06D (5.02 feet CRD) was 0.11 feet lower than average groundwater elevation at T4-MW06I (5.13 feet CRD) for the April 27 through May 17, 2004 time period. This difference of 0.11 feet indicates that there was a net potential for flow of water from the Unconsolidated Alluvial Deposits to the Troutdale Gravel at this location. The Troutdale Gravel aquifer is not directly connected with the Willamette River at T4.

D.2.2 Groundwater Elevation Contours

Groundwater elevation contour maps were developed for shallow, intermediate, and deep groundwater (Figures D-6 through D-8) based on river stage and depth to groundwater measurements performed on April 29, 2004. Since river stage is tidally affected and can vary by about 2 feet between low tide and high tide, the range of stage values for the time period during which groundwater elevation measurements were made was used for comparison with the groundwater elevations. For April 29, 2004, river stage ranged from 5.44 to 6.16 feet CRD during the 11:00 to 15:00 time period.

Shallow groundwater elevations ranged from 3.55 feet CRD at monitoring well T4-MW06S to 16.02 feet CRD at monitoring well T4-MW05S on April 29, 2004 (Figure D-6). As shown, the horizontal hydraulic gradient direction for shallow groundwater was toward the Willamette River. Horizontal hydraulic gradient in shallow groundwater ranged from approximately 0.0002 to 0.02 ft/ft depending upon location at Terminal 4. The average horizontal hydraulic conductivity was approximately 0.01 ft/ft. Based on groundwater elevation data presented in Hart Crowser (2000) and on groundwater elevation data from BBL (2004), groundwater horizontal hydraulic gradients were steepest at the eastern ends of Slip 1 and Slip 3.

Intermediate groundwater elevations ranged from 2.93 feet CRD at monitoring well T4-MW04I to 16.47 feet CRD at monitoring well T4-MW02I on April 29, 2004 (Figure D-7). As shown, the horizontal hydraulic gradient direction for intermediate groundwater was toward the Willamette River. Horizontal hydraulic gradient ranged from approximately 0.005 to 0.02 ft/ft depending upon location at Terminal 4. The average horizontal hydraulic gradient in intermediate groundwater was approximately 0.01 ft/ft.

Deep groundwater elevations ranged from 3.35 feet CRD at monitoring well T4-MW06D to 4.17 feet CRD at monitoring well T4-MW02D on April 29, 2004 (Figure D-8). As shown, the horizontal hydraulic gradient direction for deep groundwater was toward the Willamette River on April 29, 2004. The average horizontal hydraulic gradient in deep groundwater was approximately 0.0005 ft/ft on April 29, 2004.

D2.3 Groundwater Flow Parameters

Results of a pumping test conducted in 1994 suggested a horizontal hydraulic conductivity, K, of about 0.023 centimeters per second (cm/sec) (65 feet/day) for the upland fill material and upper Unconsolidated Alluvial Deposits near the head of Slip 3 (Hart Crowser, 2000). This K value falls within the expected range of hydraulic conductivity values of 10^{-3} to 10^{-1} cm/sec (2.8 to 280 feet/day) for clean sands (Freeze and Cherry, 1979). Given the similar grain sizes of the upland fill material and Unconsolidated Alluvial Deposits in the near-river portion of Terminal 4 at monitoring well clusters T4-MW01, T4-MW04, and T4-MW06 (Figures D-2 through D-4), the horizontal hydraulic conductivity value of 0.023 cm/sec likely is representative for the upland fill material and sandy layers of the Unconsolidated Alluvial Deposits.

Pumping tests have not been conducted at Terminal 4 monitoring wells completed in Troutdale Gravel or in finer-grained layers of the Unconsolidated Alluvial Deposits. Based on descriptions of soils from monitoring well boring logs (BBL, 2004), the expected range of horizontal hydraulic conductivities for finer-grained layers of the Unconsolidated Alluvial Deposits is 10^{-6} to 10^{-4} cm/sec for silt (0.0028 to 0.028 feet/day) (Freeze and Cherry, 1979). The expected range of horizontal hydraulic conductivities is 10^{-1} to 10 cm/sec for gravel (280 to 28,000 feet/day) (Freeze and Cherry, 1979,)

Groundwater flow velocity is estimated from the following equation:

$$v = Ki/\eta_e$$

where v is velocity, K is horizontal hydraulic conductivity, i is the horizontal hydraulic gradient, and η is the effective soil porosity.

The effective soil porosity, η_e, was not measured. For unconsolidated sediments, total porosity typically is 0.25 to 0.40 for gravel, 0.25 to 0.50 for sand, and 0.35 to 0.50 for silt (Freeze and Cheery, 1979). Effective soil porosity typically is less than total porosity. Assuming (1) the horizontal gradients discussed above in Section D1.3, (2) typical values for effective porosity for poorly sorted gravel (0.30), well-sorted sand (0.30), and silt (0.40), and (3) typical hydraulic conductivities for gravel (2,800 feet/day) and silt (0.0028 feet/day), horizontal groundwater velocities within the different geologic materials encountered in monitoring well borings at Terminal 4 may be approximately as follows:

Deposit	Horizontal Hydraulic Conductivity (feet/day)	Average Horizontal Hydraulic Gradient (ft/ft)	Effective Soil Porosity	Horizontal Groundwater Velocity (feet/day)
Gravel	2,800	0.0005	0.30	5
Sand	65	0.01	0.30	2
Silt	0.0028	0.01	0.40	10^{-4}

D.3 Hydrogeologic Conceptual Model

The hydrogeologic regime at Terminal 4 is complex due to the heterogeneous grain size and differences in lateral extent in the upland fill and alluvial deposits. In addition, there is a distinctly strong hydraulic connection to Willamette River stage variations within an area generally defined as west of the former shoreline and within the Troutdale Gravel. This hydraulic connection is dampened by the presence of interbedded fine-grained silt and clay layers within the natural deposits that are generally east of the former shoreline within the Unconsolidated Alluvial Deposits. Therefore, a generalized interpretation of the hydrogeologic conceptual model relative to groundwater flow and gradient behavior is made by defining two primary areas at Terminal 4 separated by the general location of the former shoreline, which is shown on Figure D-1. Upland fill material consisted primarily of well-sorted fine to medium sand; Unconsolidated Alluvial Deposits consisted of fine sand at near-river monitoring well cluster locations (T4-MW01, T4-MW04, and T4-MW06) and of interbedded layers of well sorted fine sand, silt, and clay at upland monitoring well cluster locations (T4-MW02, T4-MW03, and T4-MW05); and Troutdale Gravel consisted primarily of poorly sorted fine to medium gravel (Figures D-2 through D-4).

For the western portion of Terminal 4 (west of the former shoreline), the two geologic units of upland fill and Unconsolidated Alluvial Deposits combine as essentially one hydrostratigraphic unit that is above the underlying hydrostratigraphic unit of the Troutdale Gravel. The separation of the upland fill and Unconsolidated Alluvial Deposits from the Troutdale Gravel hydrostratigraphic unit in the nearshore portion of Terminal 4 is due to considerable differences in gradation and the resulting likelihood of order-of-magnitude differences in hydraulic conductivities between the upper sands and the Troutdale Gravel, but the hydraulic connection is evident based on groundwater level monitoring data. The similarity of grain size characteristics between the upland fill and underlying Unconsolidated Alluvial Deposits, which are both composed of fine to medium sand with less than 15% fines content and which are differentiated primarily by color, is a reasonable indicator that their similar transmissivity characteristics will cause the two units to function as a single hydrostratigraphic unit west of the historic shoreline.

For the eastern portion of Terminal 4 (east of the former shoreline), there are three hydrostratigraphic units, which include the sands of the upland fill material; the finer-grained sands, silts, and clays of the Unconsolidated Alluvial Deposits; and the gravels of the Troutdale Gravel. As described in Section D.2.1, the finer-grained materials of the Unconsolidated Alluvial Deposits act as a semi-confining unit above the Troutdale Gravel in this portion of Terminal 4.

Groundwater elevations varied across Terminal 4 and were higher in the upland portions of Terminal 4 (i.e., at monitoring well clusters T4-MW02, T4-MW03, and T4-MW05) than at near-river portions of Terminal 4 (i.e., at monitoring well clusters T4-MW01, T4-MW04, and T4-MW06). The net horizontal hydraulic gradient was toward the river for groundwater in upland fill material, Unconsolidated Alluvial Deposits, and Troutdale Gravel. However, short-duration (i.e., 1-hour) gradient reversals were recorded for the Unconsolidated Alluvial Deposits and Troutdale Gravel and were associated with tidal changes in the river.

Tidal fluctuations caused changes in groundwater elevations in the intermediate depth groundwater at monitoring well T4-MW06I. However, based on average river stage (5.036 feet CRD) and monitoring well T4-MW06I groundwater elevation (5.132 feet CRD) for the April 27 through May 17 time period, there was a net potential for discharge of groundwater to the river. Based on the similarity between shallow and intermediate groundwater elevations at monitoring well clusters T4-MW01, T4-MW04, and T4-MW06, shallow groundwater is expected to respond similarly to tidal variations in river stage, but net discharge will be to the river. At monitoring well T4-MW06D, average groundwater elevation (5.02 feet CRD) was about 0.1 feet less than average groundwater elevation at monitoring well T4-MW06I. There is a net downward vertical gradient between the Unconsolidated Alluvial Deposits and the Troutdale Gravel at this location. There is no direct connection between the Troutdale Gravel and the Willamette River at T4.

Vertical hydraulic gradients were primarily upward at some locations (e.g., intermediate to shallow groundwater at monitoring well cluster T4-MW02) and primarily downward at some locations (e.g., shallow to intermediate groundwater at monitoring well cluster T4-MW05 and intermediate to deep groundwater at monitoring well cluster T4-MW02), while vertical hydraulic gradient reversals were observed between shallow and intermediate groundwater and between intermediate and deep groundwater at monitoring well clusters T4-MW01 and T4-MW06. Variations in river stage may cause gradient reversals between hydrostratigraphic units at the near-river locations. At monitoring well cluster T4-MW02, horizontal groundwater flow in the Unconsolidated Alluvial Deposits may be hindered due to the confining nature of fine-grained materials located in downgradient Gatton's Slough, resulting in the observed upward vertical gradients from the Unconsolidated Alluvial Deposits to the upland fill material and downward vertical gradients from the Unconsolidated Alluvial Deposits to the Troutdale Gravel during the monitoring period.

As demonstrated by the correlation between Willamette River stage and intermediate and deep groundwater elevations at monitoring well cluster T4-MW06, tidal and precipitation-induced changes in the Willamette River stage caused changes in groundwater elevation that were similar in magnitude and direction for groundwater in the Unconsolidated Alluvial Deposits and Troutdale Gravel at this location. The TE for intermediate and deep groundwater at monitoring well cluster T4-MW06 was on the order of 0.7 to 0.8. Based on the magnitude of change in weekly groundwater elevations observed at monitoring well clusters T4-MW01 and T4-MW04 and at monitoring wells T4-MW02D and T4-MW03D, the TE is expected to be similar in magnitude to but slightly less than the TE at monitoring well cluster T4-MW06.

Based on weekly groundwater elevation data, river stage-induced groundwater elevation changes were also observed for shallow, intermediate, and deep groundwater at monitoring well cluster T4-MW01, for shallow and intermediate groundwater at monitoring well cluster T4-MW04, and for deep groundwater at monitoring well clusters T4-MW02 and T4-MW03. The observed tidal effects in deep groundwater at the upland well locations (monitoring well clusters T4-MW02 and T4-MW03) likely indicate that the Troutdale Aquifer is under semi-confining conditions due to the presence of finer-grained materials within the Unconsolidated Alluvial Deposits in the upland portion of Terminal 4.

D.4 References

Blasland, Bouck & Lee, Inc. (BBL), 2004. Characterization Report, Terminal 4 Early Action, Port of Portland, Oregon. September 17.

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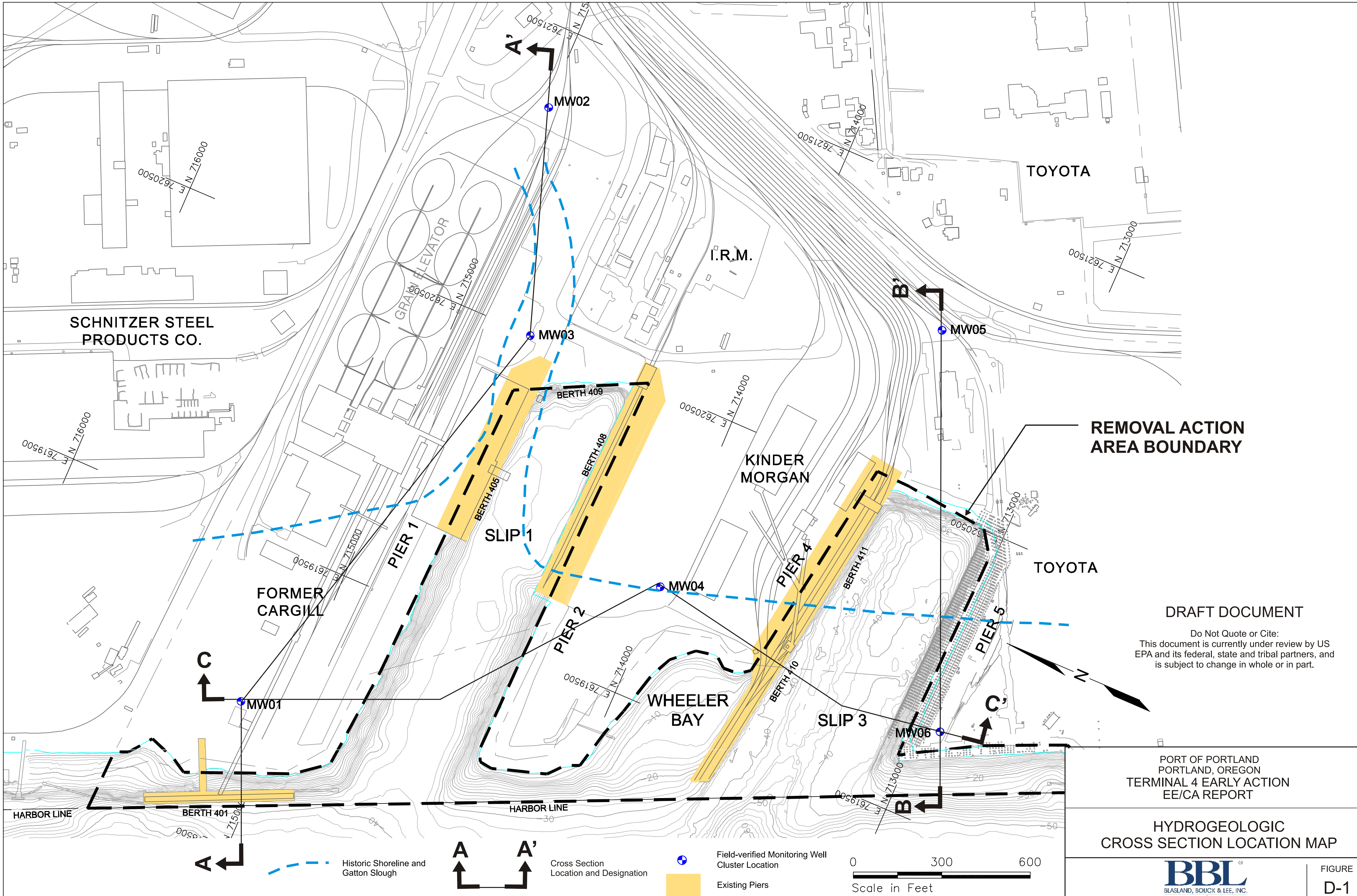
Freeze, R.A., and J.A. Cherry. 1979. Groundwater. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Hart Crowser, 2000. Remedial Investigation Report Terminal 4, Slip 3 Upland, Port of Portland, Portland, Oregon. January 2000.



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KINDER MORGAN
FORMER CARGILL
WHEELER BAY
TOYOTA
REMOVAL ACTION AREA BOUNDARY
SLIP 1
SLIP 3
PIER 1
PIER 2
PIER 4
PIER 5
BERTH 401
BERTH 405
BERTH 408
BERTH 409
BERTH 410
BERTH 411
HARBOR LINE
MW01
MW02
MW03
MW04
MW05
MW06
A
A'
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B'
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C'
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Historic Shoreline and Gatton Slough
Cross Section Location and Designation
Field-verified Monitoring Well Cluster Location
Existing Piers
0
300
600
Scale in Feet
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TERMINAL 4 EARLY ACTION
EE/CA REPORT
HYDROGEOLOGIC
CROSS SECTION LOCATION MAP
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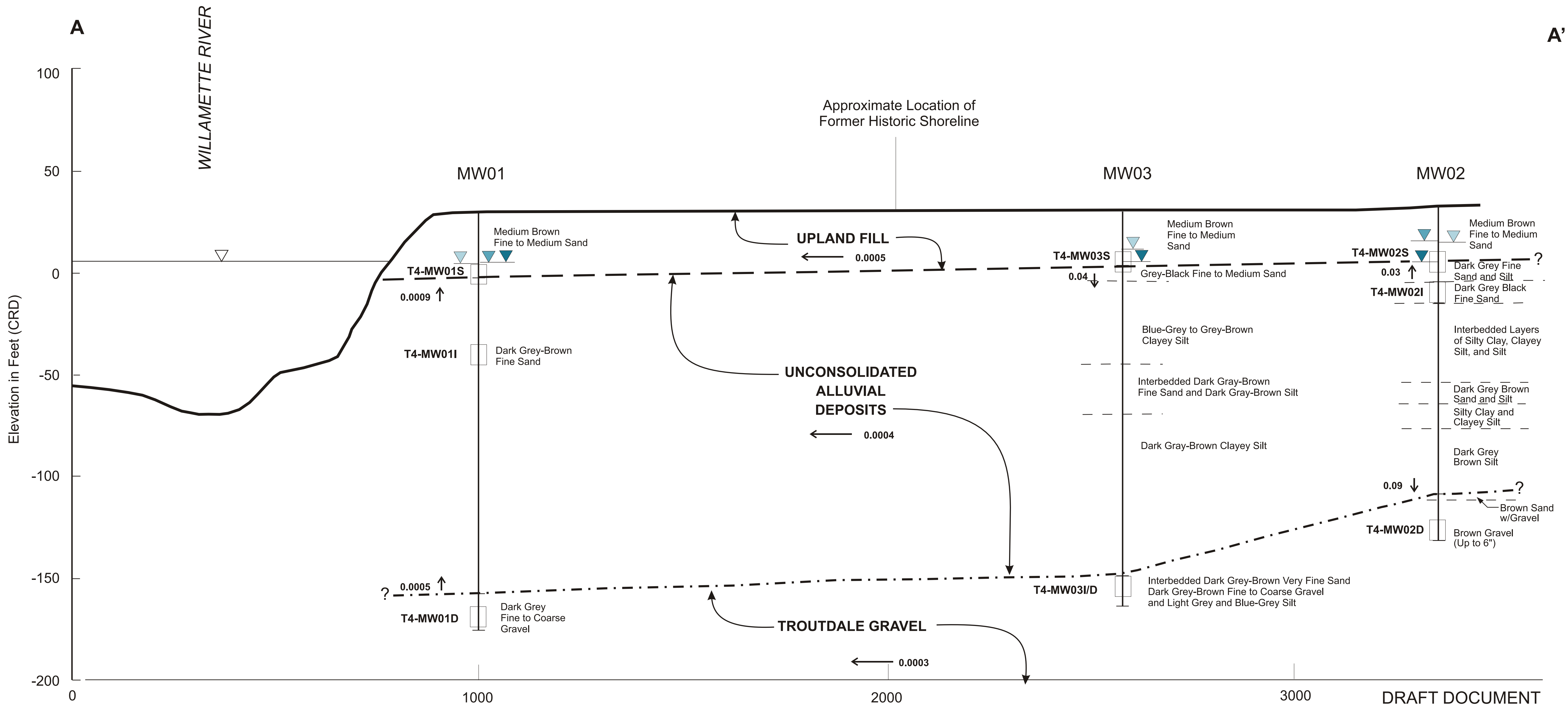
FIGURE
D-1



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Horizontal Scale in Feet

0 250 500

0 50 100

Vertical Scale in Feet

Vertical Exaggeration x 5

Notes:

1. Groundwater elevation data from 5/13/2004 monitoring event.
2. Geological data developed from monitoring well boring logs.

Legend:

MW01 Monitoring Well Cluster Designation

Monitoring Well Cluster Location

T4-MW01D Monitoring Well Designation

Monitoring Well Screened Interval

Shallow Groundwater Elevation (Ft CRD)

Intermediate Groundwater Elevation (Ft CRD)

Deep Groundwater Elevation (Ft CRD)

Willamette River Stage (Ft CRD)

Inferred Contact between Upland Fill and Unconsolidated Alluvial Deposits

Inferred Contact between Unconsolidated Alluvial Deposits and Troutdale Gravel

0.0009 Vertical Hydraulic Gradient (Ft/Ft) and Direction

0.0003 Horizontal Hydraulic Gradient (Ft/Ft) and Direction

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HYDROGEOLOGIC CROSS SECTION A-A'

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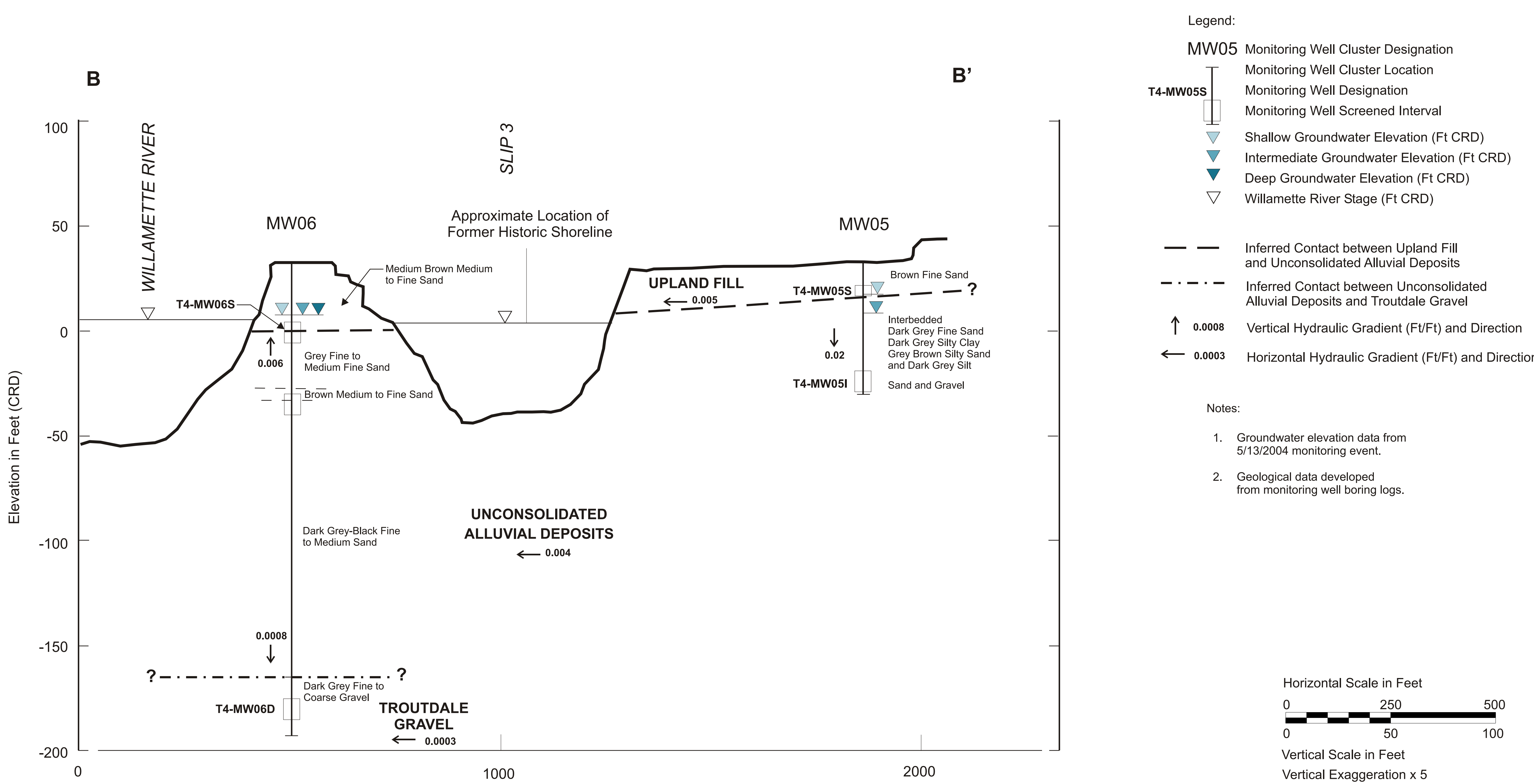
FIGURE
D-2



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HYDROGEOLOGIC CROSS SECTION B-B'

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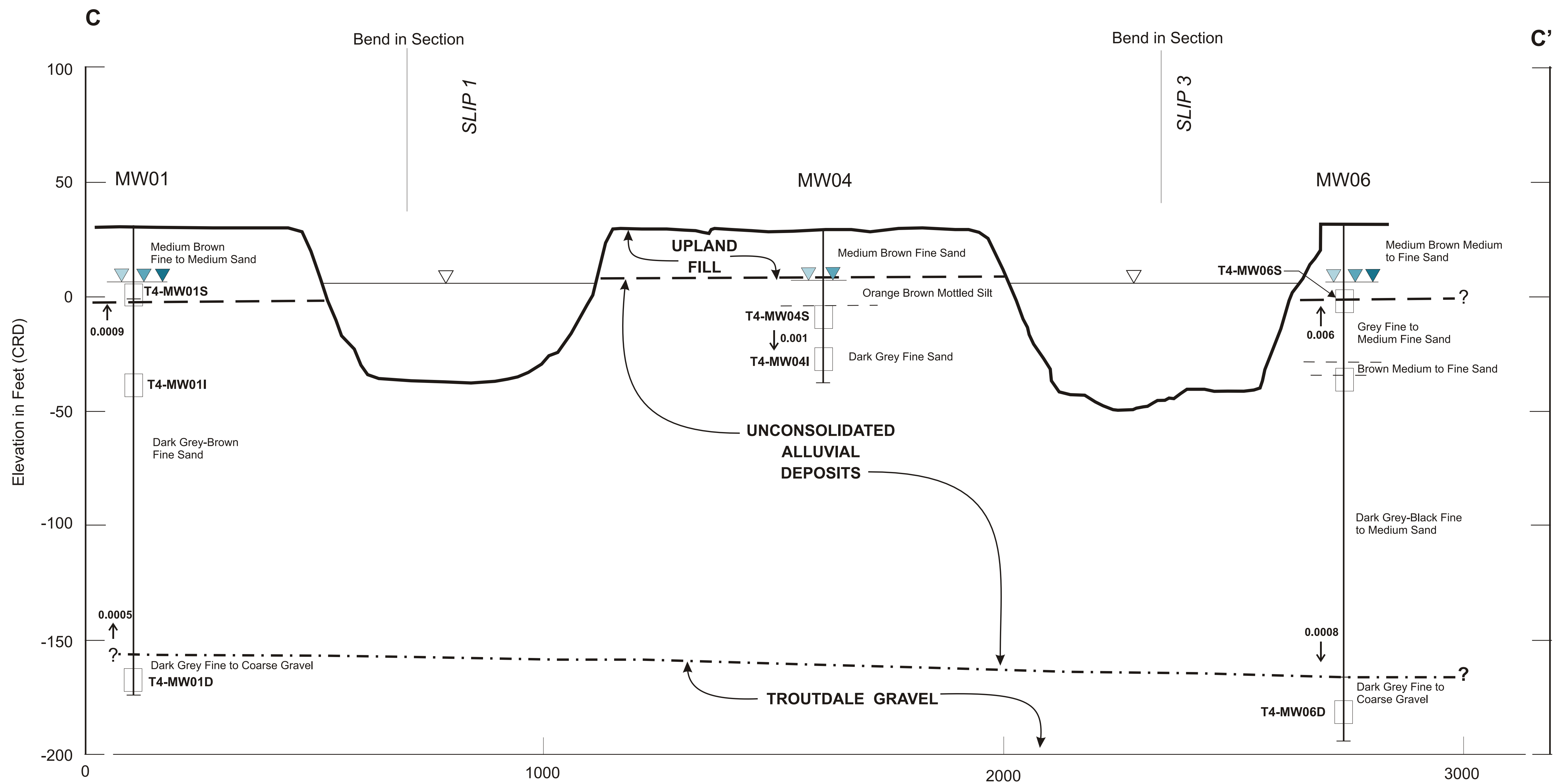
FIGURE
D-3



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Notes:

1. Groundwater elevation data from 5/13/2004 monitoring event.
2. Geological data developed from monitoring well boring logs.

Legend:

- MW01 — Monitoring Well Cluster Designation
- Monitoring Well Cluster Location
- T4-MW01D — Monitoring Well Designation
- Monitoring Well Screened Interval
- Shallow Groundwater Elevation (Ft CRD)
- Intermediate Groundwater Elevation (Ft CRD)
- Deep Groundwater Elevation (Ft CRD)
- Willamette River Stage (Ft CRD)
- Inferred Contact between Upland Fill and Unconsolidated Alluvial Deposits
- Inferred Contact between Unconsolidated Alluvial Deposits and Troutdale Gravel
- 0.0009 — Vertical Hydraulic Gradient (Ft/Ft) and Direction
- 0.0003 — Horizontal Hydraulic Gradient (Ft/Ft) and Direction

Horizontal Scale in Feet: 0 — 250 — 500

Vertical Scale in Feet: 0 — 50 — 100

Vertical Exaggeration x 5

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HYDROGEOLOGIC CROSS SECTION C-C'

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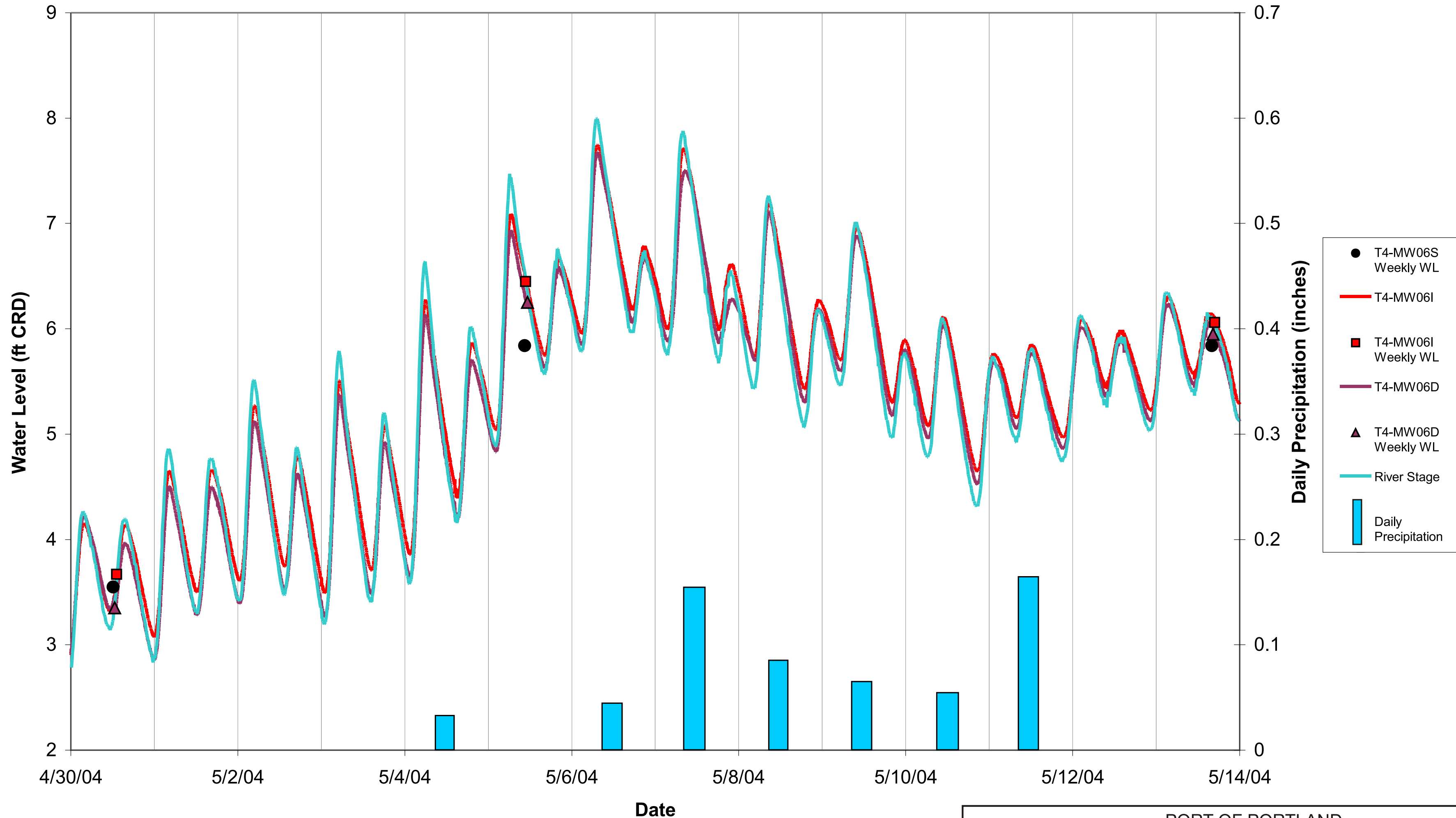
FIGURE D-4



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WILLAMETTE RIVER STAGE, PRECIPITATION, AND T4-MWO6 GROUNDWATER ELEVATIONS - 4/30/2004-5/13/2004

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FIGURE
D-5

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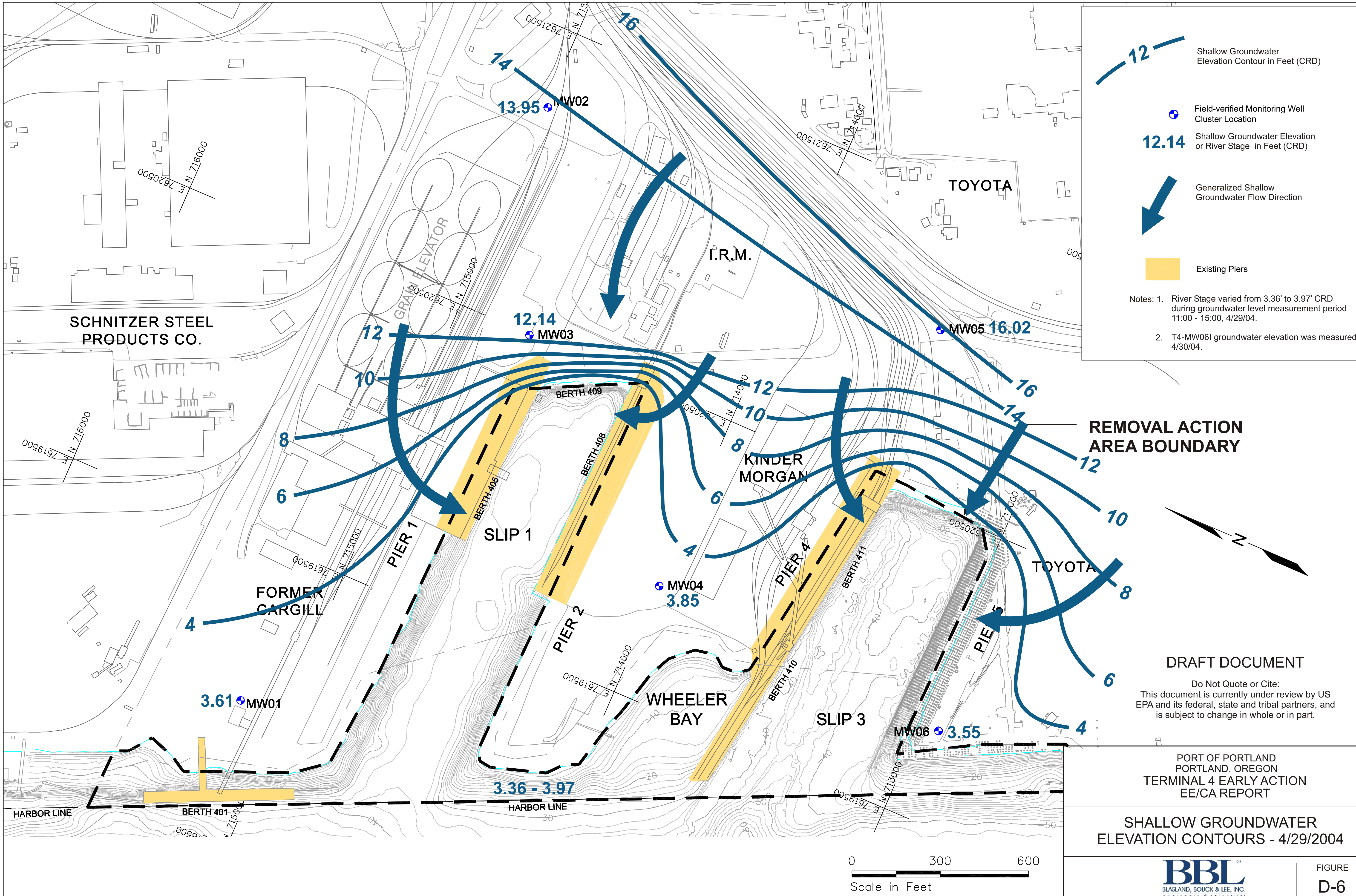

Shallow Groundwater Elevation Contour in Feet (CRD)
Field-verified Monitoring Well Cluster Location
12.14 Shallow Groundwater Elevation or River Stage in Feet (CRD)
Generalized Shallow Groundwater Flow Direction
Existing Piers
Notes: 1. River Stage varied from 3.36' to 3.97' CRD during groundwater level measurement period 11:00 - 15:00, 4/29/04.
2. T4-MW06I groundwater elevation was measured 4/30/04.
SCHNITZER STEEL PRODUCTS CO.
GRAIN ELEVATOR
I.R.M.
TOYOTA
KINDER MORGAN
FORMER CARGILL
REMOVAL ACTION AREA BOUNDARY
13.95 MW02
12.14 MW03
MW05 16.02
MW04 3.85
3.61 MW01
MW06 3.55
3.36 - 3.97
PIER 1
PIER 2
PIER 4
SLIP 1
SLIP 3
WHEELER BAY
BERTH 401
BERTH 405
BERTH 408
BERTH 409
BERTH 410
BERTH 411
HARBOR LINE
0 300 600
Scale in Feet
DRAFT DOCUMENT
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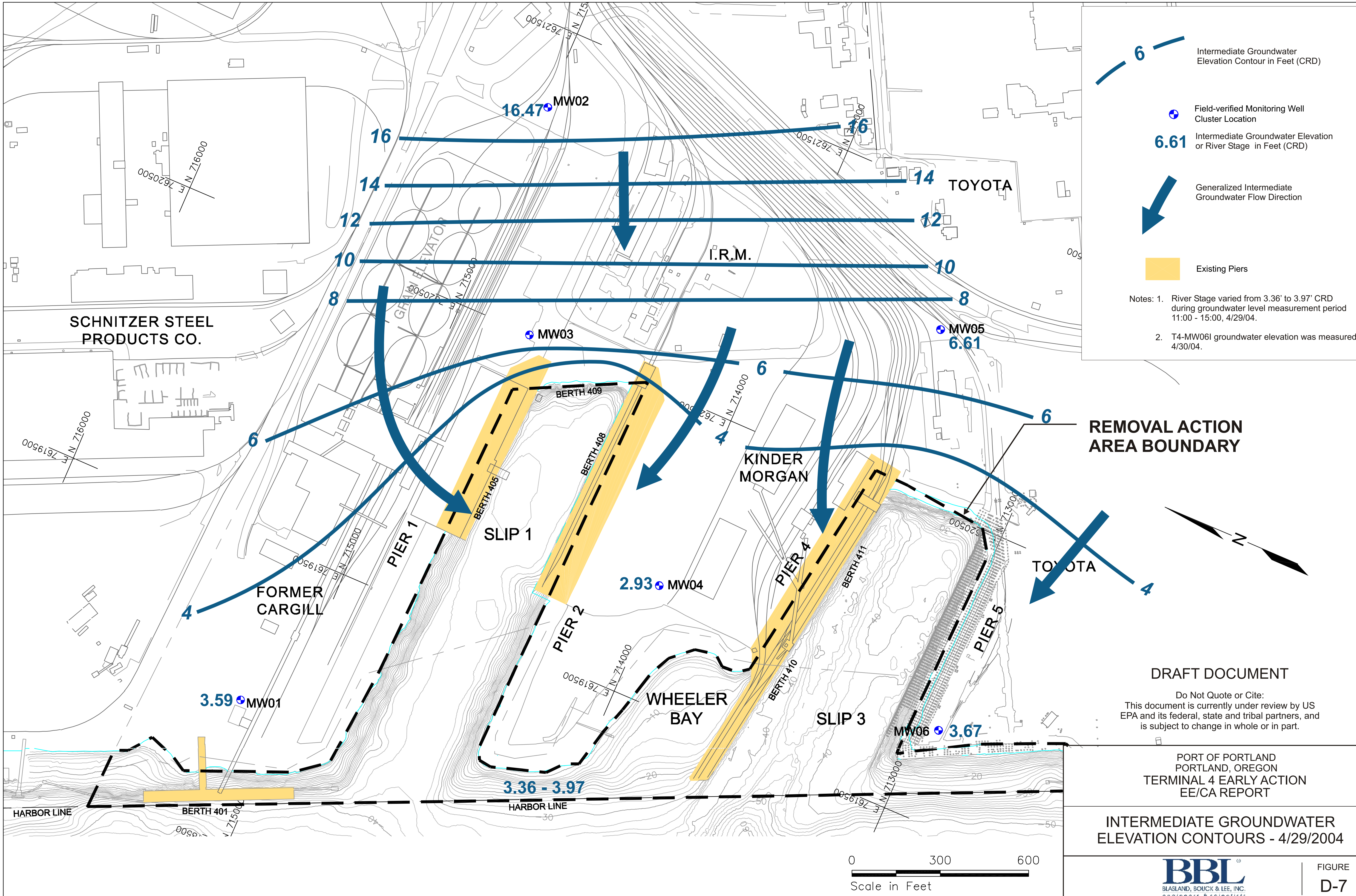
This document is currently under review by US EPA and its federal, state and tribal partners, and is subject to change in whole or in part.
PORT OF PORTLAND
PORTLAND, OREGON
TERMINAL 4 EARLY ACTION EE/CA REPORT
SHALLOW GROUNDWATER ELEVATION CONTOURS - 4/29/2004
BBL
BLASLAND, BOUCK & LEE, INC. engineers & scientists
FIGURE
D-6



DRAFT DOCUMENT

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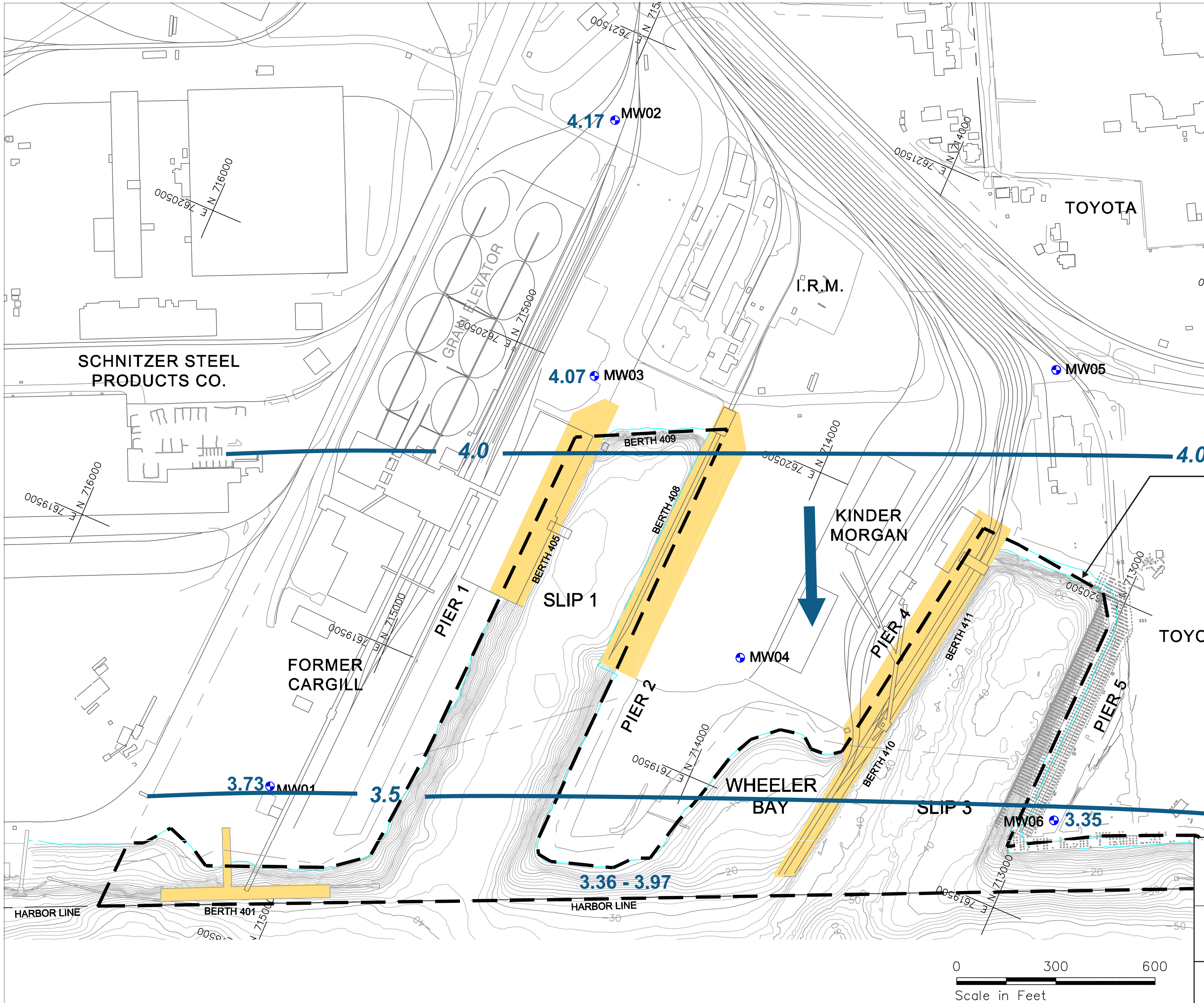
PORTLAND, OREGON
TERMINAL 4 EARLY ACTION
EE/CA REPORT

INTERMEDIATE GROUNDWATER ELEVATION CONTOURS - 4/29/2004

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE D-7



7.0 Deep Groundwater Elevation Contour in Feet (CRD)

Field-verified Monitoring Well Cluster Location

7.21 Deep Groundwater Elevation or River Stage in Feet (CRD)

Generalized Deep Groundwater Flow Direction

Existing Piers

Notes:
1. River Stage varied from 3.36' to 3.97' CRD during groundwater level measurement period 11:00 - 15:00, 4/29/04.
2. T4-MW06I groundwater elevation was measured 4/30/04.

DRAFT DOCUMENT

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EE/CA REPORT

DEEP GROUNDWATER
ELEVATION CONTOURS - 4/29/2004

BBL
BLASLAND, BOUCK & LEE, INC.
engineers & scientists

FIGURE
D-8