HYDRAULIC EVALUATION SUMMARY REPORT
SITE: FORMER BP HARBOR ISLAND TERMINAL
CLEANUP SITE ID: 4426
1652 SW LANDER STREET
SEATTLE, WASHINGTON

CONSENT DECREE NO. 00-2-05714-8SEA

FEBRUARY 2022

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Northwest Regional Office
3190 160th Avenue SE
Bellevue, Washington 98008-5452

Prepared for
TLP Management Services, LLC
1670 Broadway
Suite 3100
Denver, CO 80202

Prepared by
TechSolve Environmental, Inc.
7518 NE 169th Street
Kenmore, Washington 98028
www.techsolveinc.com

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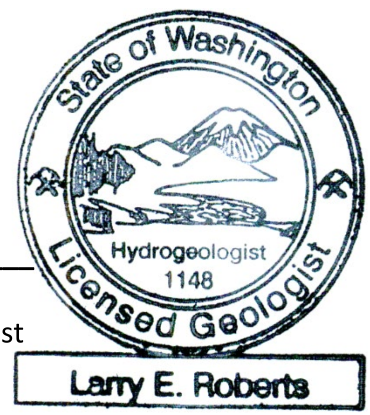
Scott K. Larsen, CHMM
Project Scientist/Project Manager
TechSolve Environmental, Inc.

Larry E. Roberts, LG, LHG
Principal, WA Licensed Geologist/Hydrogeologist
TechSolve Environmental, Inc.



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List of Abbreviations and Acronyms

ARCO	-	Atlantic Richfield Company
bgs	-	Below ground surface
BP	-	British Petroleum West Coast Products Company
CAP	-	Cleanup Action Plan
DAS	-	Diffused Air Stripper
Ecology	-	The Washington State Department of Ecology
EDR	-	Engineering Design Report
EPA	-	United States Environmental Protection Agency
ft/ft	-	Foot per Foot
GWCMCP	-	Groundwater Compliance Monitoring & Contingency Program
HASP	-	Health and Safety Plan
IHSs	-	Indicator Hazardous Substances
NAD83	-	North American Datum of 1983
NAVD88	-	North American Vertical Datum of 1988
OU	-	Operable Unit
O&M	-	Operation and Maintenance
RI	-	Remedial Investigation
RI/FS	-	Remedial Investigation and Feasibility Study
Seaport	-	Seaport Midstream Partners, LLC
TLP	-	TLP Management Services, LLC
TPH	-	Total Petroleum Hydrocarbons

Executive Summary

This report summarizes a study conducted in 2021 at the Former BP Harbor Island Terminal (the Site) located on Harbor Island, Seattle, Washington. The study was requested by the Washington State Department of Ecology (Ecology) to evaluate changes in Site hydrology due to the installation of a new seawall. The new seawall was installed in 2017 and 2018 along the northern half of the waterfront of Plant 1 to enhance the seismic stability of the Site. This study is based upon a work plan submitted to Ecology in 2018 and subsequently approved by Ecology in March 2021, with additional caveats detailed by Ecology. In addition to evaluating changes to Site hydrology, this study is intended to aide in determining if established conditional points of compliance remain appropriate and if continuation of, or revisions to, remedial actions are needed to meet cleanup objectives for Site closure.

Over the course of the study, water level and salinity data were collected from 23 separate groundwater monitoring wells and a surface water stilling well. The monitoring wells were selected with Ecology's input to include areas along the waterfront, upland areas of the Site, shallow and deeper groundwater, and eight nested well pairs (i.e., two adjacent wells with one screened in shallow and the other in deeper groundwater). The period of data collection occurred in the spring, as this typically represents the end of the annual period when groundwater to surface water gradients are highest. Water level and salinity data, which were collected for 23 days on 10-minute intervals, were evaluated and then compared to historical studies, including Remedial Investigations from the early 1990s. Due to highly dynamic conditions along the waterfront, which are driven by large daily tidal fluctuations in surface water, many of the evaluations were conducted using mean values computed from study data to evaluate overall flow patterns at the Site.

The results of this investigation showed some localized impacts of the new seawall on Site hydrology. Additionally, the study shows that some limited changes to hydrology, not related to seawall construction, may have occurred since the Remedial Investigation was completed in the early 1990s. While some change in flow mechanisms were observed, the results of this study were similar to historic studies that were the basis for selecting points of compliance at the Site. The findings of this investigation can be utilized to evaluate the applicability of established points of compliance and the need for continued remedial actions at the Site.

1. Introduction

TechSolve Environmental Inc. (TechSolve, formerly TechSolv Consulting Group, Inc.) has prepared this report on behalf of TLP Management Services, LLC (TLP) for the Former BP Harbor Island Site, currently the Seaport Seattle Terminal (formerly BP West Coast Products [BP] and Atlantic Richfield Company [ARCO]) (the Site) located on Harbor Island in Seattle, Washington. The report summarizes the evaluation of changes to Site hydrology due to the installation of a new seawall along the northern half of the Site bordering the West Duwamish Waterway (Figure 1), as formerly requested by Ecology (Ecology, 2015). This report is intended to satisfy Ecology's 2015 request and additional subsequent requests (Ecology, 2021). This report was prepared in accordance with the Hydraulic Evaluation Work Plan (TechSolve, 2019a) and the requirements of Consent Decree No. 00-2-05714-8SEA (Ecology, 2000), cooperatively entered into between ARCO and the Washington State Department of Ecology (Ecology).

This report is organized into six sections as follows:

- **Section 1. Introduction**: Provides a summary of the report format, sections, and drivers for conducting this evaluation.
- **Section 2. Site Description and History**: Provides descriptions of Site history, regulatory status, historical investigations, remedial actions, hydraulic conditions, and seawall construction activities that may have modified Site Conditions.
- **Section 3. Hydraulic Evaluation Activities**: Describes the elements of the evaluation, including:
  - Field activities conducted in support of the evaluation
  - Data collection activities, including descriptions of the well network, parameters, instrumentation, and the collection of measurements.
  - Data evaluation activities, including analyses of groundwater gradients in shallow and deeper soils, seawall impacts to groundwater flow and discharge to surface water, and observed changes in groundwater and surface water exchange from the Remedial Investigation (RI) (Geraghty & Miller, 1994).
- **Section 4. Results**: Details the results of the hydraulic evaluation.
- **Section 5. Summary and Findings**: Summarizes the information presented in this report and presents the pertinent findings of the hydraulic evaluation.
- **Section 6. Conclusions**: Presents the conclusions of the hydraulic evaluation.
- **Section 7. References**: Documents the references cited in this report.

2. Site Description and History

The Site is located on Harbor Island and consists of two separate bulk fuel storage plants, referred to as Plant 1 and Plant 2 (Figures 1 and 2). Harbor Island is a 455-acre man-made island that lies between the East and West Waterways of the Duwamish River. Plant 1 occupies about 12 acres on the western portion of the island, along the West Waterway of the Duwamish River. Plant 2 occupies about 3.5 acres in the north-central part of the island. Both plants were constructed in the 1930s and have operated as bulk fuel storage and transfer facilities under several owners since that time.

Harbor Island was created primarily from marine sediments dredged from the Duwamish River. Currently, about 95 percent of the island is covered with industrial buildings, paved roads, or other impervious surfaces. The island's pervious surfaces consist primarily of land located adjacent to aboveground storage tanks and by railroad tracks.

Harbor Island was placed on the National Priorities List in 1983 as a Superfund Site due to elevated levels of hazardous substances in soil, primarily lead. The United States Environmental Protection Agency (EPA) subsequently completed Remedial Investigation/Feasibility Studies (RI/FS) (Weston, 1993). A total of seven operable units (OUs) were established on the island. The Former BP Harbor Island Terminal Site is part of the Tank Farm OU, which includes the adjacent Shell (formerly Equiva Services, LLC, Equilon, and Texaco) and Kinder Morgan (formerly GATX and Shell) terminals. Ecology is the lead regulatory agency for the Tank Farm OU.

ARCO and Ecology cooperatively entered into Agreed Order No. DE 92 TC-N158 in 1992 (Ecology, 1992) to conduct Site characterization activities and develop remedial actions.

2.1. Remedial Investigation

Site-specific RI/FSs (Geraghty & Miller, 1994, 1996, and 1997) showed indicator hazardous substances (IHSs) present in shallow groundwater and soil at the Site were primarily highly weathered total petroleum hydrocarbons (TPH) as diesel (TPH-D), with lesser amounts of weathered gasoline (TPH-G) and heavier oil (TPH-O). The weathered TPH likely resulted from historic spills at the Site. The RI/FS showed the primary area of impact at the Site was a petroleum-based light non-aqueous phase liquid (LNAPL) plume located beneath the warehouse and loading rack area adjacent to the Duwamish Waterway at Plant 1. Secondary areas of concern included petroleum impacted soils located within the Plant 1 and Plant 2 tank farms (Figure 2). Site-specific cleanup alternatives for groundwater and soil were then developed to protect human health and the environment at the Site.

2.2. Conceptual Hydraulic Model

Flow characteristics observed at Plant 1 during the RI/FS, and confirmed during ongoing monitoring conducted to date (TechSolve, 2021), show that groundwater typically exists at a depth of 1 to 8 feet below ground surface (bgs). Groundwater flow directions at Plant 1 can vary seasonally but are generally west towards the waterway, and south to southwest along the southern property boundary. This flow pattern aligns with general island-wide groundwater flow directions, which typically flow radially outward from the island center and enter marine surface waters at the island's edge. Reversals in groundwater flow directions due to tidal or seasonal fluctuations have not been observed at the Site. Local groundwater is recharged primarily from precipitation and, possibly, leaking public underground utilities (e.g., public storm sewers and public water supply piping). Ecology and the EPA have determined that groundwater beneath Harbor Island is non-potable, due to the island's extensive industrial land usage.

Hydraulic gradients at the Site, measured during the RI/FS, were observed to be approximately 0.001 ft/ft. Downward gradients were observed throughout the Site, up to 0.45 ft/ft. Upward gradients were observed along the waterfront, up to 0.037 ft/ft. These vertical gradients were most pronounced along the waterfront.

A fresh/saltwater interface acts as an island wide vertical barrier to groundwater flow, due to fluid density differences. This interface is reported to be approximately 85 feet bls near the center of the island near Plant 2 (Weston 1993) and was observed to vary along the Plant 1 shoreline from 9 to 40 feet bls. Discontinuous silt layers at the base of the hydraulic fill unit may also act as a local barriers to vertical groundwater flow.

Groundwater flow is influenced locally along the waterfront by tidal effects, stratigraphy, and flow barriers. The RI/FS showed that the most efficient tidal response in groundwater to tidal changes in surface water occurred spatially in the wells located along the waterfront. Wells screened in deeper groundwater and in native deltaic sediments displayed greater efficiency to tides than wells screened in more shallow groundwater and in fill materials. Shallow wells screened in fill displayed little to no correlation to tidal effects. However, all deep wells screened in native deltaic sediments at Plant 1 displayed a correlation to tidal change. Greater tidal response of groundwater in deep wells versus shallow wells was explained by the hydrostratigraphic units in which the wells are screened. Deep wells are screened at a depth of approximately 35 to 40 feet BGS in the native deltaic sediments; the same depth as surrounding surface waters. These sediments have likely not been disturbed and therefore, maintain continuous layers providing a horizontally transmissive pathway to surface waters. Shallow wells mainly have screened intervals within 16 feet of ground surface in hydraulic fill. This fill does not have continuous horizontal stratification and does not maintain pathways to surface waters as transmissive as lower native sediments. Also, shallow wells are generally above surface-water level, therefore dampening the effects of changing tides. In addition, bulkheads and other barriers located along the waterfront have been shown to dampen the effects of tidal forces on groundwater.

2.2.1. Flow Barriers and New Seawall

Potential barriers of groundwater flow to surface water along the Plant 1 waterfront include the warehouse foundation, a two-tiered timber bulkhead dating to island construction in the early 1900s, and a new seawall installed along the northern portion of the Site in 2017 and 2018. These barriers act as “hanging walls” that likely dampen tidal forces on shallow groundwater. The relative position of these barriers are highlighted on Figure 3.

Historical construction drawings show the warehouse foundation consists of a 10-foot-deep concrete retaining wall overlying 12.5-foot-deep interlocking concrete sheet pilings. Concrete sheet pilings are made up of steel beams encased in concrete that were driven to approximately 22.5 feet below the floor of the warehouse. A concrete footer approximately 5 feet wide was poured on top of the sheet pilings. A concrete retaining wall was poured on top of the footing and extends to floor level. Figure 4 provides an east-west cross-sectional view of the warehouse foundation and timber bulkhead, from the A-A’ position highlighted on Figure 3. The tidal and groundwater elevation ranges recorded at the Site are highlighted on Figure 4.

In 2017 and 2018, a new seawall was installed waterward of a preexisting timber bulkhead along the waterfront at Plant 1. The new seawall is intended to provide long-term seismic protection along the northern half of the Site bordering the West Duwamish Waterway, from just north of the warehouse to the northern property boundary (Figure 3).

The new seawall was constructed waterward (approximately 3.5 feet on center) and parallel to the lower tier of the preexisting timber bulkhead that dated to island construction. Figure 5 provides oblique photos taken before and after seawall construction to highlight the changes along the waterfront. The replacement bulkhead consists of a single vertical combination steel sheet pile wall and a series of tieback ground anchors installed landward of the sheet pile wall. The replacement bulkhead extends from the north property line to approximately 16 feet north of the north end of the Warehouse building (Figure 3) (approximately 352 feet in length including return walls). Figure 6 provides an east-west cross-sectional view of the new seawall, from the B-B’ position highlighted on Figure 3. As-built drawings for the seawall were provided to Ecology in the work plan for this study (TechSolve, 2019b).

2.3. Remedies and Monitoring

ARCO entered into Consent Decree No. 00-2-05714-8SEA with Ecology in 2000 for implementing remedial actions at the Site. Separate cleanup actions for the Plant 1 Waterfront area and for the inland Plant 1 and 2 soils were developed and specified in the Cleanup Action Plan (CAP) (Ecology, 1999) and in the Engineering Design Report (EDR) (TechSolv and AG&M,

2000). Cleanup actions were selected from site-specific cleanup action alternatives developed as part of the Focused Feasibility Study (Geraghty & Miller, 1997). Cleanup actions have been ongoing since the Consent Decree was implemented as summarized in previous reports (e.g., TechSolve, 2021).

The achievement of cleanup criteria are measured at conditional points of compliance, which were established in the Groundwater Compliance Monitoring and Contingency Program (GWCMCP) (TechSolv, 1999b), Exhibit F of the Consent Decree.

2.3.1. Remedial Actions

While many of the remedial actions have been completed at Plant 1, a groundwater/LNAPL recovery system continues to be operated along the waterfront to depress groundwater and capture LNAPL and shallow groundwater containing dissolved hydrocarbons. Additionally, containment booms are monitored and maintained on the West Duwamish Waterway adjacent to Plant 1 to contain and capture occasional oil sheens that have historically appeared on surface water.

Monitoring results (TechSolve, 2021) show that ongoing and completed remedial actions have improved groundwater quality and soil conditions, and have been protective of surface water at Plant 1. These actions have reduced free LNAPL contained behind the subsurface warehouse foundation, provided hydraulic control and capture to reduce dissolved hydrocarbon concentrations in groundwater, and decreased the frequency of hydrocarbon sheens in the Duwamish Waterway.

Ongoing monitoring and the results of a 2019 probing investigation (TechSolve, 2020), show that associated performance criteria from the GWCMCP appear to have been met to discontinue groundwater/LNAPL recovery system operations. Negotiations with Ecology have been ongoing related to continued system operation.

2.3.2. Compliance Monitoring

Three types of compliance monitoring are required to be performed at the Site, as specified in the GWCMCP, to meet the monitoring program objectives. Compliance monitoring includes the following:

- Protection Monitoring. Protection monitoring is performed to confirm that human health and the environment are protected during the remedial action and is addressed in documents including a health and safety plan (HASP) and operation and maintenance (O&M) manual.

- Performance Monitoring. Performance Monitoring is performed to confirm that the remedial actions have attained cleanup standards and other performance standards.

While many of the performance monitoring criteria have been met at the Site, discussions are ongoing with Ecology related to the attainment of specific criteria dealing with sheen presence on surface water, LNAPL removal from groundwater, and dissolved TPH constituents in groundwater along the Plant 1 waterfront.

- Confirmation Monitoring. Confirmation Monitoring is performed at conditional points of compliance to confirm the long-term effectiveness of the remedial actions once performance monitoring standards have been attained. The conditional points of compliance were established in the GWCMCP at property boundaries and where groundwater and surface water exchange were shown to occur along the waterfront. Confirmation Monitoring Wells at Plant 1 include inland well AR-03 at the southern property boundary and five waterfront wells AMW-01, AMW-02, AMW-03, AMW-04, and AMW-05 (Figure 3).

Ecology has requested (Ecology, 2021) the results of the hydraulic evaluation described below be used to evaluate if the points of compliance established in the GWCMCP for compliance and confirmation monitoring along the waterfront remain appropriate.

3. Hydraulic Evaluation Activities

The supporting activities, data collection, and data evaluations conducted for the hydraulic evaluation are summarized in the following sections.

3.1. Supporting Activities

Activities conducted in support of the hydraulic evaluation included the installation of additional monitoring wells, the surveying of all wells for elevation and position consistency, and monitoring for impacts in the area of the groundwater/LNAPL recovery system during the study period. These activities are summarized in the following sections.

3.1.1. Well Installations

A total of three additional monitoring wells (GM-14D, HMW-01D, and HMW-01S) were agreed to be added to the Hydraulic Evaluation Well Network (Figure 3), as part of Ecology's approval (Ecology, 2021) to proceed with the evaluation. Well GM-14D created an additional monitoring point screened in deeper groundwater near the middle of the Site. Well GM-14D also created a nested well pair with the adjacent Well GM-14S, which is screened in shallow groundwater. Wells HMW-01D and HMW-01S created a shallow and deeper screened well pair at the northern tip of the new seawall, to provide increased resolution of groundwater flow mechanics around the seawall terminus.

The new wells were installed as close as practicable to previously proposed locations, and final placements are shown on Figure 3. Final well placements were determined based upon access and presence of subsurface structures and utilities. The three new wells were installed and developed in March and April of 2021, respectively. Boring logs for these new wells are included in Appendix A and well construction details are presented in Table 1.

3.1.2. Surveying

All wells included in the Hydraulic Evaluation Well Network (Figure 3) were surveyed for position and elevation by licensed surveyors. Well positions, or horizontal coordinates, were established to Washington State Plane Coordinate System, North Zone (2011) North American Datum of 1983 (NAD83) to within 0.1 foot. Elevations to the top of well casings were established to the North American Vertical Datum of 1988 (NAVD88) to within 0.01 foot. The horizontal coordinates for the three new wells (GM-14D, HMW-01D, and HMW-01S) were surveyed in May 2021. Horizontal coordinates for the remaining wells were established in earlier survey events from 2011, 2016, and 2018. The vertical coordinates for all wells included in the Hydraulic Evaluation were resurveyed in May 2021 to ensure consistency. Well locations and positions are presented in Table 1.

3.1.3. Impacts to Ongoing Waterfront Remedial Actions

The groundwater/LNAPL recovery system was shut down from April 20 to May 11, 2021 to allow groundwater levels to equilibrate to natural conditions during the study. Additional monitoring was conducted during this period of system shutdown to evaluate potential rebound of LNAPL in groundwater/LNAPL recovery wells (Table 2) and for sheen on surface water in areas where historical surface water impacts have been observed.

During the period of system shutdown, six accessible recovery wells (RW-1, RW-2, RW-4, RW-7, RW-8, and RW-9) (Figure 3) were monitored for LNAPL presence. The three remaining active recovery wells (RW-5, RW-6, RW-10) were used as part of the hydraulic evaluation well network and were inaccessible due to the presence of monitoring equipment (data loggers) in the wells. These three groundwater/LNAPL recovery wells resumed operation on May 17.

No measurable LNAPL was detected in any recovery well during the period of system shutdown. Additionally, no sheen on groundwater was detectable in three wells (RW-1, RW-7, RW-8). Slight and moderate sheens were detected in the first three monitoring events in wells RW-9 and RW-2. However, no sheen was detectable in wells RW-9 and RW-2 in the fourth and final monitoring event prior to system restart. An oily film, too thin to be measured, and a heavy sheen was detected in the first monitoring event in Well RW-4. An oil sorbent sock was subsequently placed in Well RW-4 throughout the study to recover the oily film. A heavy sheen and no oily film were detected in the next two monitoring events in RW-4. A slight sheen was detected in the final monitoring event in RW-4.

Overall, sheen and LNAPL presence in groundwater/LNAPL recovery wells appeared consistent with the recent results of monitoring conducted during periods of system operation (TechSolve, 2021). Lack of measurable LNAPL during the period of system shutdown and reductions in sheen strength in recovery wells in the final monitoring event prior to restart supports previous findings (TechSolve, 2020), which have shown that remaining petroleum impact along the Plant 1 waterfront are residual in nature and LNAPL appears to have been recovered to the extent practicable.

No sheen on surface water was observed during the period of system shutdown, or at any other time during the hydraulic evaluation.

3.2. Data Collection

The following sections summarize the data collection aspects of the hydraulic evaluation. The sections include summaries of the selected well network, the period during which the study occurred, the instrumentation used, the parameters that instruments measured, and how measurements were collected and verified.

3.2.1. Well Network

The well network utilized for the hydraulic evaluation (Figure 3) consisted of 23 groundwater wells and one surface water stilling well. As highlighted on Figure 3, the well network combined a variety of well types, including performance and confirmational monitoring wells, recovery wells, and piezometer wells to ensure adequate Site coverage and to meet project objectives. Well construction details are presented in Table 1 and boring logs are provided in Appendix A. The selected wells covered both deeper and shallower groundwater areas throughout the Site.

The surface water stilling well (SW-1) was located on a marine dock at the Site and was screened from approximately 2 feet to 7 feet above sediments, in the surface waters of the West Duwamish Waterway. The stilling well was included to provide tidal ranges from a surface water monitoring position directly waterward of the Site.

The groundwater wells unitized in the study included AMW-01 AMW-04, AMW-05, B-006, B-007, GM-10D, GM-10S, GM-11S, GM-12S, GM-13D, GM-13S, GM-14S, GM-14D, GM-15S, GM-16S, GM-17D, GM-17S, GM-18S, HMW-01D, HMW-01S, RW-5, RW-6, and RW-10.

Groundwater wells AMW-01 AMW-04, AMW-05, GM-10D, GM-13D, GM-14D GM-17D, and HMW-01D are screened in deeper groundwater, from 25 to 45 feet bgs. All other wells are screened in shallow groundwater, from about 5 to 15 feet BGS. Eight nested well pairs, consisting of the deeper screened wells and adjacent shallow screened wells, were selected to evaluate localized differences between shallow and deeper groundwater and vertical gradients at these locations.

Well network selection was based upon providing the following coverage:

- Wells HMW-01S, HMW-01D covered the area along the waterfront at the northern terminus of the new seawall.
- Wells GM-10S, GM-10D, B-007, AMW-05, AMW-04, and RW-5 covered areas along the waterfront directly inland of the new seawall.
- Well RW-6 covered the narrow gap along the waterfront located south of the new seawall and north of the warehouse foundation, where the timber bulkhead dating to island construction acts as the sole barrier between shallow groundwater and surface water.
- Wells GM-13D and GM-13S covered an area along the waterfront directly inland of the warehouse foundation
- Wells AMW-01, and RW-10 covered an area along the waterfront adjacent to the southern property boundary. This area is directly south of the warehouse foundation and inland of the timber bulkhead dating to island construction.
- Well B-006, GM-11S, GM-14S, GM-14D, GM-12S and GM-15S covered areas away from the waterfront and near the middle of the Site.
- Wells GM-18S, GM-17D, GM-17S, and GM-16S covered upland areas of the Site.

3.2.2. Study Period

The study period lasted from April 24 through May 17, 2021. The study period was conducted during the portion of the year when groundwater elevations have been shown (TechSolve, 2021) to be near their maximum. This period typically occurs in late winter through early spring and was conservatively selected as it represents the period when groundwater gradients towards surface water are typically highest.

The study period was also selected to include periods of large and small tidal ranges including a cycle of spring tides, which occurred from April 28 to 30, and neap tides, which occurred from May 6 to 8. Spring tides are not related to seasons and occur following a full moon, when the sun and moon are aligned, and tidal ranges are highest. Neap tides occur about one week following the spring tide, when the sun and moon are at right angles to each other, and tidal ranges are smallest.

The groundwater/LNAPL recovery system was offline from April 24 through noon on May 11 of the study period to allow for monitoring during a period of natural conditions. The recovery system was operated from May 11 through May 17 of the study period to evaluate the effects of system pumping on water levels, as previously requested by Ecology (Ecology, 2021).

3.2.3. Instrumentation and Parameters

In-Situ's Aqua TROLL 200 data loggers (Appendix B) were utilized to record water level, water pressure, temperature, conductivity, and salinity readings at regular intervals throughout the course of the study. The data loggers were selected at a range of 30-psig and in a vented configuration to compensate for barometric pressure changes. The data loggers directly measured and recorded water level, pressure, conductivity, and temperature data and provided salinity readings based upon calculations from actual conductivity and temperature readings.

3.2.4. Setup and Measurement Collection

The Aqua TROLL 200 data loggers were received from the manufacturer fully calibrated. All data loggers were bench tested prior to field deployment and following completion of the study, per manufacturer procedures and using calibration solutions preselected to be within known ranges of groundwater at the Site. All data loggers were pre-programmed prior to deployment for consistent measurement of parameters, parameter ranges, recording intervals of every 10-minutes, and a start time of 12:00 AM on April 24, 2021.

Data loggers were deployed in the stilling well and all monitoring wells April 22 and 23, 2021. All data loggers were connected to supplied vented cabling and desiccants during deployment, set at pre-determined depths, secured to well casings to prevent movement during the study, and then checked to ensure sensor functionality. Data loggers were set at depths that ensured full submergence throughout the study and near the middle of the screened interval of each well. The depth of the transducer was measured to top of well casing upon deployment, at the conclusion of the study, and at five separate intervals during the study with a maximum interval length of six days. Water levels were confirmed manually in the field at these intervals with the use of a calibrated water level meter. Sensor functionality was also confirmed at these intervals by connecting data loggers to an In-Situ Wireless TROLL Com device and directly downloading sensor readings using In-Situ's VuSitu and Win-Situ 5 software. All data were downloaded from the data loggers at the conclusion of the study using the In-Situ software and then exported to Excel worksheets for evaluation.

3.3. Data Evaluation

Data collected during the study were used to evaluate flow and flow barriers, to determine groundwater heads, gradients, tidal effects on water level ranges, and salinity distribution at the Site. The focus of the evaluation was to characterize the average conditions to provide an understanding of the movement of groundwater at the Site. Evaluations were also conducted related to ranges in conditions encountered at the Site. Data collected from past studies and the RI/FS were compared to study data to evaluate changes in Site hydrology and the impacts associated with the installation of the new seawall.

3.3.1. Groundwater Head Conditions and Gradients

Instantaneous heads and gradients in groundwater at the Site are chaotic in response to the hydraulic connection of groundwater to the adjacent, tidally influenced, surface water body. As such, the computation of average head conditions and gradients provides an estimation of how groundwater movement occurs over time at the Site. Numerous complete sinusoidal tidal cycles were included to increase precision in the computation of average heads and gradients. Average conditions were then compared to historical studies, including the RI/FS, to evaluate how conditions have changed at the Site over time.

The groundwater heads for all wells and associated hydrographs were calculated based on converting transducer pressure to effective freshwater head, allowing relative comparison of head to be made among wells with different groundwater densities. Surface water levels for stilling well SW-01 were converted to an actual water surface elevation using the average density recorded in the stilling well during the study of 1.021.

Average heads during the non-pumping period were computed from a data subset, extending from peak elevation on April 24 to peak elevation on May 11, approximately 17 days of continuous readings. Pressure data utilized in calculations spanned the entire 17-day period for all wells except one. Portions of data were excluded from Well B-006 following rainfall events that temporarily flooded the well, artificially and temporarily elevating static groundwater conditions in this well.

Head conditions were utilized to evaluate horizontal and vertical groundwater gradients at the Site. Horizontal gradients were evaluated in both shallow and deeper groundwater. Shallow and deep head data from the eight nested well pairs were utilized to calculate vertical gradients throughout the Site.

3.3.2. Tidal Effects

To gauge the effect of the new seawall on water levels and groundwater flow, comparisons were made between dynamic water level fluctuations in monitoring wells in response to tidal influences and comparing computed ranges from this study to historical ranges from past studies. This was done by computing the maximum range of water levels that occurred over specific time periods that have durations comparable to those for which historical data were available.

Additional comparisons to historical data were made by calculating tidal lag times. Groundwater and surface water level data were used to calculate tidal lag times, which are the difference in time between when a tidal maximum and minimum in surface water occurs and when a corresponding maximum and minimum in groundwater occurs. Tidal lag times along with corresponding ranges in groundwater elevation over the lag time periods are related to aquifer diffusivity (ratio of transmissivity to storage coefficient) and give an indication as to the connectivity of groundwater to surface water.

3.3.3. Salinity Distribution

The conceptual hydrogeologic models for Harbor Island detailed in the RI/FS is based on an oceanic island flow system (Fetter, 1988) consisting of a freshwater lens floating on a base of saltwater. The freshwater lens is thickest at the center of the island and thinnest at the island edge. The fresh/saltwater interface acts as a groundwater flow barrier due to fluid density differences. This interface has been reported to be approximately 85 feet bgs near the center of the island near Plant 2 (Weston, 1993) and was observed to vary along the Plant 1 shoreline from 9 to 40 feet bgs.

Near the island edge, tidal mixing occurs as freshwater physically mixes with saline surface water due to tidal fluctuations in surface water. Wells screened in the tidal mixing zone typically exhibit analogous fluctuations in water level elevation and salinity due to these tidal forces. These fluctuations attenuate inland with distance.

Salinity concentration data collected during this study were evaluated for range and spatial variability. Evaluating salinity fluctuations in groundwater in response to tidal stage is useful in evaluating the degree of tidal mixing and the connectivity of surface water to groundwater. Evaluating the spatial distribution of salinity concentrations in groundwater aids in determining the position of the fresh/saltwater interface.

Salinity concentrations were partially biased during the study in Wells HMW-01D, RW-10, and AMW-04. Well HMW-01D encountered temperature sensor drift, resulting in readings approximately 5-degrees Celsius lower than actual temperature. The conductivity sensors in Wells RW-10 and AMW-04 had intermittent sensor failure and sensor drift. Affected data from these wells were excluded to the extent practicable. Collected salinity values may also have been affected by elevated conductivity in groundwater in areas of remediation, as conductivity readings have been shown to be anomalously high in areas with LNAPL and hydrocarbon impacts (Cassidy, Werkema, Sauck, Atekwana, Rossbach Duris, 2001).

4. Results

The following sections summarize the results of the hydraulic evaluation. Most of the evaluations below were based upon the analysis of static conditions, which prevailed for approximately 17 ½ days, from 12:00 a.m. on April 24 to 12:30 p.m. on May 11, at which time operation of the groundwater/LNAPL recovery system was resumed. Section 4.5. below was included to evaluate potential changes to static conditions following system restart.

Water level measurement and salinity results detailed below are based upon data collection and analyses discussed in the previous section. Data downloaded from the individual In-Situ 200 Data Loggers are included in Appendix C.

4.1. Groundwater Head Conditions

Water level data from the static study period were used to compute the average head for each well. Table 3 shows the range of data that were used to support calculation of an average groundwater elevation for each well and for surface water elevation in Stilling Well SW-01. Note that the B-006 average incorporated five distinct and separate segments of data due to flooding events detailed in Section 3.3.1. The resulting average heads for each of the monitoring locations are shown on Table 3 and included on the individual hydrographs included in Appendix D. Table 3 separates water levels based upon position in shallow or deep groundwater, and for surface water in the stilling well.

4.2. Groundwater Gradients and Flow

As detailed in Section 2.1., general island-wide groundwater flow directions have been shown to be radially outward from the island center and entering the marine surface waters at the island's edge. The identified barriers to groundwater flow at the Site include both vertical and horizontal barriers. Vertical barriers include the island's freshwater/saltwater interface and the boundary between shallower structural fill and deeper native deltaic deposits. Horizontal flow barriers are predominantly found along the waterfront and include the original timber bulkhead, the warehouse foundation, and the new seawall (Section 2.1.1.). Groundwater flow directions and gradients are detailed in the following sections.

Groundwater contour Maps (Figures 7 and 8) were prepared from the average head data (Table 3) for both shallow and deeper groundwater. These figures illustrate lateral groundwater gradients at the Site. The average head differences and average vertical hydraulic gradients between shallow and deeper groundwater, as recorded from the eight nested well pairs (Section 3.2.1.), are presented in Table 4. The head differences were used to generate a contour map illustrating downward vertical gradients recorded during the study (Figure 9).

4.2.1. Shallow Groundwater Gradients

Shallow well data (Table 3 and Figure 7) show a predominantly westerly gradient with a slight northern component, with heads at the south end of the warehouse about half a foot higher than those just north of the loading rack. The higher head to the south could be an indication of somewhat tighter shallow sediments in that area, particularly with respect to vertical permeability.

4.2.2. Deeper Groundwater Gradients

Deep well data (Table 3 and Figure 8) show a predominantly westerly gradient. Slight mounding of groundwater inland of the new seawall, as shown by the contours on the figure, is possibly artificial due of the slightly higher screened elevations of Wells AMW-04 and AMW-05 (Table 4) when compared to other deep wells. Corresponding higher heads in these wells may be a result of these slight differences in screened elevations and not representative of deeper groundwater mounding.

4.2.3. Vertical Groundwater Gradients

Average head difference between the eight shallow and deep well pairs were used to evaluate vertical gradients throughout the Site. The average vertical head differences for the identified shallow and deep well pairs are presented in Table 4. Mean vertical hydraulic gradients were then calculated from the well pair data, which are included in Table 4 and illustrated on Figure 9. Vertical hydraulic gradients were calculated by subtracting the hydraulic head elevation in the deep well from the value in the shallow well and dividing the remainder by the vertical distance between the elevation of the midpoint of the deep well screen and the average groundwater elevation in the shallow well, as the screen lengths of shallow wells were not fully submerged. Positive hydraulic gradient values represent a downward gradient. The hydraulic gradients from this study were then compared to values listed in the RI (Geraghty & Miller, 1994) to evaluate changes over time.

Downward vertical gradients were observed in all wells. Slightly higher gradients were recorded inland and along the southern portion of the waterfront. The highest gradients were observed in the furthest inland well pair (GM-17D/GM-17D), with shallow water on average 2.32 feet higher than deeper water and a mean vertical hydraulic gradient of 0.074 ft/ft. Waterfront wells along the southern portion of the Site (GM-13D/GM-13S and AMW-01/RW-10) showed shallow water levels to be about two feet higher than the deep levels with vertical hydraulic gradients of 0.061 to 0.069 ft/ft. The difference in elevation between well pairs was about a foot and a half for waterfront wells extending north of the warehouse to the northern property line (AMW-04/RW-5, B-007/AMW-05, GM-10D/GM-10S and HMW-01D/HMW-01S), with mean vertical hydraulic gradients ranging from 0.046 to 0.061 ft/ft.

The mean vertical hydraulic gradients observed during the 1994 RI in well pairs GM-10S/GM-10D, and GM-17S/GM-17D were comparable to values recorded in 2021. The vertical hydraulic gradient in GM-13S/GM-13D have increased since the RI, showing a reduction in communication between shallow and deep groundwater in this area of the Site over time.

Differences in downward gradients along the waterfront could be the result of a variety of factors, such as tighter shallow sediments at the south end of the warehouse, or that the new seawall has created an added barrier to deeper groundwater migration along the northern portion of the waterfront.

4.2.4. Gradients Around New Seawall

Water level data from Wells HMW-01S, HMW-01D, GM-10S and GM-10D were used to investigate flow at the north end of the new seawall. Wells HMW-01S and HMW-01D were installed directly southeast of the northern terminus of the new seawall and to the east of Wells GM-10S and GM-10D (Figure 3). Wells GM-10S and GM-10D were potentially isolated behind the new seawall, which lies waterward of these wells to the west and to the north. Head differences between the shallow well pairs (HMW-01S and GM-10S) and deeper well pairs (HMW-01D and GM-10D) were evaluated to determine if localized groundwater mounding was occurring behind the new seawall. Table 5 shows a comparison of heads in those wells. The shallow pair of wells (HMW-01S and GM-10S) showed a negligible head decline to the east of just 0.007 ft, within the limits of measurement accuracy. However, deep wells (HMW-01D and GM-10D) showed a head decline of 0.131 ft from east to west.

Water level data from Wells RW-5 and RW-6 were used to investigate shallow groundwater flow at the south end of the new seawall. Well RW-6 is installed directly south of the new seawall and north of the warehouse foundation. Well RW-5 is located to the northeast of RW-6 and was potentially isolated by the new seawall located to the west. The comparison of heads between RW-6 and RW-5 showed a head decline of 0.055 feet from south to north.

The comparison of head results at the north and southern ends of the seawall did not indicate the presence of localized groundwater mounding behind the new wall, or that significant flux of groundwater, flowing around the end sections of the seawall, is occurring.

4.3. Tidal Effects

Dynamic groundwater level fluctuations due to tidal influences were compared to historical ranges to gauge the effect of the new seawall on water levels and groundwater flow. This was done by computing the maximum range of water levels that occurred over specific time periods that have durations similar to those for which historical data were available. Additional comparisons were made by calculating the range of tidal lag time response in wells and comparing these data to past studies. The results of these analyses are presented in the following sections.

4.3.1. Water Level Ranges

Dynamic water level fluctuations, which occur in response to tidal influences, were evaluated and compared to historical ranges to gauge the effect of the new seawall on water levels and groundwater flow. Anecdotal historical water level data were available from transducer studies that used limited numbers of wells, which were conducted over a 1-day period in August 2005, a 2-day period in April 1995, and a 2-day period in September 1993. Observed water level ranges from those periods were compared with three segments of the 2021 data, spanning intervals of 1 lunar day (approximately 24 hours 50 minutes, which captures a full tidal cycle), 2 lunar days, and 2 lunar days, respectively. To maximize comparison accuracy, periods of similar tidal fluctuation magnitude from the current study were selected that closely resembled those from the historical periods. Additionally, 2021 data segments were selected that closely matched the general appearance of the double-sinusoidal tidal response curve of the historical data. The periods used for comparison included the following:

- August 2005 data showed a tide elevation range of 11.58 feet. The period from the 2021 study showing similar tidal response, curve shape, and similar magnitude was a lunar day running from 11:00 on 5/10/21 to 11:50 on 5/11/21, during which the observed tidal range was 10.98 ft.

- April 1995 data showed a tide elevation range of 13.27 feet. The period from the 2021 study selected for comparison covered 2 lunar days from 18:00 on 5/1/21 to 19:40 on 5/3/21, during which the observed tidal range was 13.37 ft.

- September 1993 data showed a tide elevation range of 11.10 feet. The period from the 2021 study selected for comparison covered 2 lunar days from 7:00 on 5/9/21 to 8:40 on 5/11/21, during which the observed tidal range was 10.72 ft

Tidal effects in shallow groundwater over the 2021 periods in general were minimal, with a few hundredths or tenths of a foot of water level range observed in most shallow screened wells. Table 6 shows the tide induced water level ranges observed in the shallow wells for the three relevant periods from the current transducer study. The greatest fluctuations in shallow groundwater observed in the 2021 study were in Well RW-6 (ranges from the three periods of 1.99 to 3.61 feet). RW-6 is located between the warehouse foundation to the south and the new seawall to the north (Figure 3). The new seawall extends to an elevation of approximately -68 ft elevation (NAVD88) (Figure 6). Along the warehouse, the concrete foundation and underlying interlocking sheet piles extend to an estimated depth of approximately -14 ft (Figure 4). Between the southern terminus of the new seawall and the northern terminus of the warehouse foundation is a short section (approximately 15 feet north/south) where only the original timber bulkhead dating to island construction is present. While the actual base of the timber bulkhead is unknown, it is estimated that the timber lagging of the bulkhead extends to about -1 ft elevation. The next largest fluctuations observed in a shallow well occurred in RW-5 (ranges from 0.82 to 1.46 feet). While this well is behind the new seawall, it is located just 27 feet north-northeast of Well RW-6.

Near the south end of the warehouse, greater than average shallow groundwater fluctuations were observed in 2021 in Well RW-10 (ranges from 0.2 to 0.7 feet) and GM-13S (ranges from 0.23 to 0.5 feet). RW-10 lies beyond the southern limit of the warehouse in a similar setting to RW-6, wherein the only waterward barrier to shallow groundwater and surface water exchange appears to be the timber bulkhead dating to island construction. GM-13S is behind the warehouse foundation and underlying sheet pile wall, but is near the southern end of these structures, approximately 50 feet north of RW-10.

The remaining shallow screened wells are either inland (B-006, GM-14S, GM-15S, GM-16S, GM-17S, and GM-18S), located behind the new seawall (HMW-01S, B-007, GM-10S), or located behind the warehouse foundation and underlying sheet pile (GM-11S and GM-12S). These wells showed smaller tidal responses in 2021 (ranges from 0.01 to 0.36 feet) than the four shallow screened wells named above (RW-6, RW-5, RW-10 and GM-13S), likely muted by the presence of adjacent waterfront barriers or distance inland from the waterfront.

Tidal effects observed in deeper groundwater in 2021 were more pronounced than in shallower groundwater in all areas of the Site. Table 6 shows the tide induced water level ranges observed in the deep wells included in the study. All deeper screened wells, including inland wells (GM-14D and GM-17D), those behind the new seawall (HMW-01D, GM-10D, AMW-04 and AMW-05), or located behind the warehouse foundation and underlying sheet pile (GM-13D), showed significant tidal response. The lowest ranges observed in deeper groundwater were in well GM-17D (ranges from 1.33 to 1.69 feet). Well GM-17D is the furthest inland well, located 550 feet east of the waterway. The highest ranges observed in deeper groundwater were in the waterfront Well AMW-05 (ranges from 6.40 to 7.89 feet). Well AMW-05 is located directly adjacent to well RW-10, whose location is described above.

To help gauge the effect of the new seawall on hydrology, comparisons were made of current water level readings with the historically observed water level records, obtained from the Site prior to installation of the new seawall. The comparison of water level ranges from the 2021 study to a 2005 study, a 1995 study, and a 1993 study are presented in Table 6.

The magnitude in the tidal range observed in 2005 was 5.2% greater than in the current study and as such, the observed ranges from 2005 were reduced by a similar percentage for comparison. The fluctuation range in 2005 for well B-007, adjacent to where the new seawall was installed, were higher than the range recorded in 2021. The corrected range for B-007 was 1.66 ft in 2005 compared with just 0.09 ft in the 2021 study. An order of magnitude reduction in tidal range following seawall installation shows that the new seawall has dampened tidal fluctuations in shallow groundwater directly inland of the new wall near B-007. However, just beyond the new seawall Well RW-6 showed about the same response in 2021 as seen in 2005 data. The tidal response observed in Well RW-5 in 2021 was less than in 2005, but is still significant, likely due to its proximity to the area beyond the southern terminus of the new seawall, as measured at RW-6.

The 1995 tidal range values were adjusted upward by 0.75 percent to match the maximum tide range from 2021. Direct comparisons were only available for wells GM-12S and GM-13S, which show a decrease in GM-13S ranges from the 1995 to the 2021 study and a slight increase in GM-12S ranges from 1995 to 2021.

The 1993 tidal range values were adjusted downward by 3.4% to match the maximum tide range from 2021. The deeper screened inland Well GM-17D showed similar ranges in both 1993 and 2021. Shallow screened Well GM-10S, located directly inland of the new seawall, showed a significant attenuation of response, attributable to the new seawall. However, the adjacent deep screened well to GM-10S, Well GM-10D, showed large tidal responses both before and after installation of the new seawall. Shallow screened well GM-13S showed a substantial reduction in water level range from 1993 to 2021.

The results of the tidal range comparison show that tidal effects in shallow groundwater have been attenuated in shallow wells behind the seawall, but not those away from the seawall. Additionally, GM-13S showed a measurable decline in water level range compared to past results. The reduced tidal response in Well GM-13S is not due to changes in infrastructure, as nearby barriers to groundwater flow (e.g., the warehouse foundation) remain unchanged since 1993. It is theorized that biofouling, which has decreased pumping rates in nearby recovery wells, has affected the formation around GM-13S, reducing its communication with surface water.

The observed ranges in deeper groundwater were large historically and continue to be large today, showing negligible effect from the new seawall.

4.3.2. Tidal Lag Times

Groundwater and surface water level data were used to calculate tidal lag times, which are the difference in time between when a tidal maximum and minimum in surface water occurs and when a corresponding maximum and minimum in groundwater occurs. Tidal lag times along with corresponding ranges in groundwater elevation over the lag time periods are related to aquifer diffusivity (ratio of transmissivity to storage coefficient) and give an indication as to the connectivity of groundwater to surface water.

Tidal lag times were calculated for four different periods. Two periods following the High High and Low Low tides recorded on April 29 represent the Spring Tide and the maximum range in surface water (14.88 feet) recorded during the study. The other two periods follow the high and low tides recorded on May 6, which were during the neap tide period when relatively minimal range (5.35 feet) in surface water was observed. Table 7 presents a summary of tidal lag time data.

The shallow inland wells (B-006, GM-14S, GM-15S, GM-16S, GM-17S, and GM-18S) in general showed little to no tidal response, with groundwater ranges of less than 0.1 foot over both the spring and neap tidal period. These wells showed some of the longest tidal lag times (>2:00) if they could be accurately determined (i.e., if the range is too low lag times cannot be calculated). The shallow waterfront wells (B-007, GM-10S, GM-11S, GM-12S, GM-13S, HMW-01S, RW-5, and RW-10), apart from RW-6, showed groundwater ranges of less than 1.0 feet and tidal lag times more than an hour. RW-6 had the highest range of shallow groundwater (3.13 feet during the spring tide) as well as the shortest tidal lag times of all wells. Increased shallow groundwater/surface water exchange may be occurring directly south of the seawall and north of the warehouse foundation, as measured in RW-6.

The deeper screened inland wells (GM-14D and GM-17D) showed tidal ranges greater than 1.0 feet and lag times from 1:20 to 3:40. The deep waterfront wells (AMW-01, AMW-04, AMW-05, GM-13D, and HWM-01D) all showed the greatest ranges in groundwater elevation (>5') and the shortest tidal lag times recorded (0:10 to 1:30), apart from RW-6.

Lag times reported in the RI (Geraghty &Miller, 1994) ranged from 7:30 for GM-17D to approximately 0:40 to 0:50 for well pairs GM-10S/D and GM13S/D. Results from this study appear comparable with the RI, apart from GM-10S, which had significantly longer lag times of 4:10 to 5:40. These increases in tidal lag times in GM-10S from 1994 to 2021 shows that the addition of a new seawall may have further isolated shallow groundwater from surface water.

4.4. Salinity Distribution

Quantitative evaluations of salinity data were performed to illustrate spatial variability, salinity distribution, and to evaluate tidal mixing in conjunction with previously detailed water level data. Salinity concentrations were reported by the data loggers in practical salinity units (PSU), as defined by the Practical Salinity Scale 1978; Standard Methods 2520B. Note that one PSU unit is roughly equivalent to one part per thousand of salinity or 0.1 percent salt, as these units often appear in third-party and past studies at the Site, which are referenced in this report.

Salinity concentration data for groundwater wells and the stilling well are presented in Table 8, which provides the average values and ranges of salinity values for each well recorded over the course of the study. Figures 10 and 11 show the spatial distribution of salinity for shallow and deeper groundwater throughout the Site, respectively. Charts plotting salinity concentrations versus time over the course of the study in inland wells, shallow screened waterfront wells, and deeper screened waterfront wells are provided in Figure 12 through 14, respectively.

4.4.1. Surface Water Salinity

The average surface water salinity recorded in Stilling Well SW-01 was 27.6 PSU over the course of the study, with a maximum of 29.1 and a minimum of 15.4 PSU. Surface water salinity fluctuations recorded in Stilling Well SW-01 directly correlate to tidal stage, with salinity values falling at low tidal periods. Fluctuations in recorded surface water salinity are the result of the fixed vertical positioning of the data logger sensor, near the mouth of the Duwamish River, in a stratified estuary. This is a dynamic setting in which lighter fresh water originating upstream overlies a denser saltwater wedge originating from Elliott Bay, typified by a net upstream movement of the deepest salt water and a net downstream movement of the overlying fresh water (Pritchard, 1955). The positioning of the saltwater wedge oscillates daily upstream and downstream due to tidal effects, which are also affected by the degree of freshwater inflow. Average salinity values recorded during the study were comparable to those recorded at King County's Seattle Aquarium/Elliott Bay marine buoy (https://green2.kingcounty.gov/marine-buoy/default.aspx) over the same period, which averaged 25.6 PSU at 3.3 feet of submergence and 29.2 PSU at 32.8 feet of submergence. These data indicate SW-01's data logger was primarily in the saltwater wedge throughout the study and encountered overlying fresh water during low tidal periods when data logger submergence fell to as little as 1.4 feet.

4.4.2. Groundwater Salinity

Average salinity concentrations (Table 8) recorded from groundwater monitoring wells generally showed higher salinity concentrations along the waterfront, attenuating with distance inland (Figures 10 and 11). Salinity concentrations in deeper groundwater were typically higher than those observed in adjacent shallow groundwater, apart from in the waterfront area south of the new seawall and north of the warehouse foundation, as measured by shallow screened Wells RW-6, RW-5, and the deeper screened Well AMW-04. Daily sinusoidal fluctuation in salinity (Figures 12 through 14), which are tidal stage dependent, were observed in much of the deeper groundwater along the waterfront but were generally not observed in deeper inland groundwater or shallow groundwater, apart from well HMW-01S and RW-6.

4.4.2.1. Freshwater / Saltwater Interface

Salinity concentration data indicate that all inland shallow screened wells (B-006, GM-14S, GM-15S, GM-16S, GM-17S, and GM-18S) and deeper screened wells (GM-14D and GM-17D) used during this study were above the island's underlying freshwater/saltwater interface. Vertical salinity profiling performed as part of EPA's RI (Weston 1993) identified the saltwater/freshwater interface from 40 to >85 feet BGS on the island. The interface was defined as the distance between 2 ppt and 10 ppt salinity concentration isopleths, with the interface being as sharp as 10 feet in thickness. As all inland wells are screened to depths ≤40 feet bgs and average salinity concentrations did not exceed 1.02 PSU/PPT in any inland well, it is assumed that all inland wells were screened above the island's freshwater/saltwater interface during the study.

4.4.2.2. Tidal Mixing

Tidally driven fluctuations in groundwater salinity concentration provide an indication as to the presence and degree of tidal mixing occurring in an area, where fresh groundwater physically mixes with saline surface water due to tidal fluctuations in surface water.

All inland shallow screened wells (B-006, GM-14S, GM-15S, GM-16S, GM-17S, and GM-18S) and deeper screened wells (GM-14D and GM-17D) showed little to no change in salinity due to daily tidal fluctuations (Table 8 and Figure 12). Salinity fluctuations seen in well B-006 are attributed to rainfall events that flooded the well with fresh rainwater and are not tidally driven.

Salinity response to tidal fluctuations was limited in wells screened in shallow groundwater along the waterfront, except for in Wells HMW-01S and RW-6 (Figure 13). Well RW-6 had the highest salinity concentrations measured in shallow groundwater (average 16.1 PSU, Table 8). The gradual rise and fall of salinity concentrations in RW-6, shown on Figure 13, appears to be correlated to periods of higher and lower tidal elevation, with salinity values rising after a period of higher spring tides and falling during a period of lower neap tides. While Well HMW-01S had much lower salinity concentrations (average 0.21 PSU) than RW-6, it too showed tidally driven fluctuations in salinity. Salinity fluctuations in other shallow screened waterfront wells (e.g., Well GM-12S and RW-10) did not appear connected to tidal stage.

Tidally driven fluctuations in salinity were observed in all deeper screened waterfront wells (Figure 14). These data indicate that tidal mixing is limited to the waterfront area and is most pronounced in deeper groundwater wells, which are screened in native deltaic sediments. Some tidal mixing was observed in shallow groundwater just beyond the northern and southern terminus of the new seawall, as seen in wells RW-6 and HMW-01S.

To evaluate changes in salinity distribution at the Site over time, salinity concentrations recorded from 2007 through 2021 during quarterly groundwater monitoring events were reviewed. Salinity readings collected during this monitoring are based on converted conductivity and temperature readings, which are collected with field instruments following purging of wells and prior to sample collection. The average and range of salinity concentrations for the wells included in the monitoring program are presented in Table 9. The highest salinity concentrations and ranges were recorded in waterfront compliance wells AMW-01 through AMW-05, which are screened in deeper groundwater along the Plant 1 waterfront (Figure 3). The remaining wells subject to routine salinity monitoring (GM-14S, GM-15S, GM-16S, GM-17S, GM-24S, AR-03, MW-1-T9, MW-2-T9, and MW-3-T9) had low salinity concentration averages and ranges. These wells are all inland from the waterfront and screened in shallow groundwater. Lower ranges and concentrations in these wells indicate limited tidal mixing occurring and that the wells are screened above the underlying saltwater interface.

Evaluating temporal changes in salinity concentrations along the waterfront (as measured in Wells AMW-01 through AMW-05) show that the new seawall has reduced the degree of tidal mixing occurring locally directly inland of the southern portion of the new seawall. Reductions in salinity concentrations and ranges in waterfront compliance wells AMW-04 and AMW-05 are apparent (Table 10 and Figure 15) following completion of the new seawall in 2018. The salinity ranges and concentrations recorded in the remaining three waterfront wells (AMW-01, AMW-02, and AMW-03), which are all south of the new seawall, have remained consistent over time and within the ranges and concentrations recorded in the 2021 study.

4.5. Response to Groundwater/LNAPL Recovery System Restart

An evaluation was conducted to determine if the well network used in the study could show the effects of groundwater/LNAPL recovery system operation on overall Site hydrology. As a first step in the analysis, a hydrograph (Figure 16) was developed for the shallow groundwater wells located closest to adjacent groundwater/LNAPL recovery wells for the period directly preceding and following system restart. As shown on Figure 16, no discernable changes in water levels associated with groundwater drawdown were observed in these nearby monitoring wells following system restart. Reasons for lack of discernable drawdown are likely the result of a combination of the following:

- The spacing between pumping wells and monitoring wells was too great to observe the nuanced changes in groundwater elevation due to recovery system drawdown.
- The dynamic and chaotic conditions along the waterfront due to tidal influences drown out drawdown effects.
- Groundwater pumping during the study was limited as three of nine recovery wells (RW-5, RW-6, and RW-10) were included in the transducer study and were offline. Additionally, biofouling has affected the sand pack and formation surrounding the recovery wells, which has diminished capture and recovery.

While changes in site hydrology due to groundwater/LNAPL recovery system operation were not discernable during this study, controlled pumping tests with closely spaced background wells were historically used (TechSolve, 1999a) to measure drawdown and then model predicted capture (TechSolv and AG&M, 2000) from groundwater/LNAPL recovery. Several lines of evidence have recently been presented to Ecology (TechSolve, 2020, TechSolve, 2021, and Section 3.1.3 above) showing that the groundwater/LNAPL recovery system has met associated performance objectives established in the Consent Decree to discontinue system operation. As such, further testing of the groundwater/LNAPL recovery system's effect on Site hydrology does not appear to be warranted. The discontinuation of groundwater/LNAPL recovery system operation should be evaluated with Ecology following this study.

5. Summary of Findings

The major findings of the hydraulic evaluation include the following:

1. Groundwater Head and Gradients:
    a. Shallow groundwater has a predominately westerly gradient with a slight northern component.
    b. Higher heads along the southwestern portion of the Site bordering the waterfront indicate the presence of tighter shallow sediments in that area.
    c. Deeper groundwater has a predominately westerly gradient.
    d. Downward vertical gradients were observed in all wells. Slightly higher gradients were recorded inland and along the southern portion of the waterfront.
    e. Downward vertical gradients from the study were comparable to those recorded historically during the RI, except along the southwestern portion of the Site bordering the waterway, which again indicate the presence of tighter shallow sediments at the south end of the warehouse.
    f. Lower downward gradients directly inland of the new seawall indicate that the new seawall has created an additional barrier to deeper groundwater migration along the northern portion of the waterfront.
    g. Comparison of head results at the north and southern ends of the seawall did not show the presence of localized groundwater mounding behind the new wall, or that significant flux of groundwater, flowing around the end sections of the seawall, is occurring.

2. Tidal Effects:
    a. Tidal effects in shallow groundwater were minimal, with less than a few tenths of a foot of water level range observed in most shallow screened wells, including all inland wells and those behind barriers including the new seawall and the warehouse foundation.
    b. The greatest observed fluctuations in shallow groundwater were in Well RW-6, with ranges from 2 to 3.6 feet. RW-6 is directly inland of a waterfront area between the southern terminus of the new seawall and the northern terminus of the warehouse foundation, where the only physical barrier to surface water and groundwater exchange is the timber bulkhead dating to island construction. The reduced barriers to groundwater flow appear to have resulted in increased tidal effects in this area of the Site.
    c. Near the south end of the warehouse, greater than average shallow groundwater fluctuations were observed. The waterfront area south of the warehouse and beyond the southern property boundary resembles the area waterward of RW-6,

in that the timber bulkhead dating to island construction is the only apparent physical barrier to surface water and groundwater exchange, which makes tidal effects more pronounced.

d. Tidal effects were observed in deeper groundwater in all areas of the Site, including inland wells. Tidal effects were larger in deeper groundwater than in adjacent shallow groundwater throughout the Site, with tidally induced ranges from 1.3 to 7.9 feet in deeper screened wells.
e. Comparison of recorded tidal ranges to those from past studies show that tidal effects in shallow groundwater have been attenuated along the northwestern portion of the Site behind the new seawall. Along the southwestern portion of the waterfront, a decline in water level range was observed compared to past results in Well GM-13S, which indicates reduced communication in shallow groundwater directly inland of the warehouse foundation.
f. The observed ranges in deeper groundwater were large historically and continue to be large today, showing negligible effect from the new seawall.
g. Tidal lag times were shortest in deeper groundwater along the waterfront and in shallow groundwater directly inland of the waterfront area between the new seawall and warehouse foundation. Shorter tidal lag times indicate a greater connectivity of surface water to groundwater.
h. Increases in 2021 tidal lag times compared to those from 1994 indicate that the addition of a new seawall may have further isolated shallow groundwater from surface water. However increased groundwater/surface water exchange may be occurring directly south of the seawall and north of the warehouse foundation.

3. Salinity Distribution:
   a. The freshwater/saltwater interface in groundwater was too deep to be evaluated, as all inland wells (shallow and deeper wells) were screened above the island's freshwater/saltwater interface.
   b. Little to no change in salinity due to daily tidal fluctuations in any inland well indicates limited tidal mixing is occurring in areas inland from the waterfront.
   c. Along the waterfront, tidal mixing was observed in shallow groundwater just beyond the northern and southern terminus of the new seawall, but not in shallow groundwater directly inland of the new seawall or warehouse foundation.
   d. Tidally driven fluctuations in salinity were observed in all deeper screened waterfront wells.
   e. Salinity concentrations measured along the waterfront before and after installation of the new seawall showed marked reductions following seawall

construction directly inland of the wall, indicating that the new seawall has locally decreased tidal mixing.

4. Response to Groundwater/LNAPL Recovery System Restart:
    a. The effects of groundwater/LNAPL recovery system operation on overall Site hydrology could not be determined, as tidal effects were too dynamic to measure minute changes due to system pumping. Additionally, there were an insufficient number of closely spaced background wells adjacent to pumping wells to measure effects. Recent studies have shown that the groundwater/LNAPL recovery system has met associated performance objectives for system shutdown. The need for continued system operation should be evaluated with Ecology.

6. Conclusions

This hydraulic evaluation analyzed changes in Site hydrology that have occurred over time, with a primary focus on changes resulting from the installation of a new seawall. The new seawall was installed along the northern half of the Site bordering the waterfront in 2017 and 2018 for seismic protection.

Over the course of the study, water level and salinity data were collected from 23 separate groundwater monitoring wells and a surface water stilling well. The monitoring wells were selected with Ecology's input to include areas along the waterfront, upland areas of the Site, shallow and deeper groundwater, and eight nested well pairs (i.e., two adjacent wells with one screened in shallow and the other in deeper groundwater). The period of data collection was conservatively selected to occur in the spring, as this typically represents the end of the annual period when groundwater to surface water gradients are highest. Data collection occurred over both spring and neap tide periods when tidal forces are at their maximum and minimum, respectively, to ensure measurements covered a full range of realized tidal effects. Water level and salinity data, which were collected for 23 days on 10-minute intervals, were evaluated and then compared to historical studies, such as the RI/FS. Due to highly dynamic conditions along the waterfront, which are driven by large daily tidal fluctuations in surface water, many of the evaluations were conducted using mean values computed from study data to evaluate overall flow patterns at the Site.

The hydraulic evaluation showed the following:

- The new seawall does not appear to have altered groundwater gradients at the Site, which remain to the west and towards the waterway. While short lived and tidally driven reversals of groundwater flow may occur locally along the waterfront, these effects are attenuated inland, and overall flow is to the waterway. Flow characteristics observed in shallow and deeper groundwater in upland areas of the Site have not noticeably changed since the RI.
- Localized mounding of groundwater behind the new wall appeared minimal. Head conditions and average head differences observed during the study show a lack of head driven groundwater flow around the northern or southern toes of the new wall.
- The new seawall has locally attenuated both tidal response and surface water mixing in shallow groundwater directly inland of the new wall. Reduced water level ranges and salinity ranges and longer tidal lag times were observed in wells screened in shallow groundwater directly inland on the new seawall (Wells RW-5, B-007, and GM-10S) when compared to adjacent wells screened in deeper groundwater (Wells AMW-04, AMW-05,

and GM-10D), adjacent wells screened in shallow groundwater (HMW-01S and RW-6) just beyond the new wall, and from historical studies completed prior to seawall installation. These findings indicate the new seawall has further isolated shallow groundwater from surface water directly inland of the wall.

- Tidal response and surface water mixing in deeper groundwater directly inland of the new seawall appears more pronounced than in shallow groundwater described above. However, directly inland from the new seawall deeper groundwater has also been further isolated from surface water due to the seawall's location and construction. Wells directly inland of the seawall (AMW-04, AMW-05, and GM-10D) all showed lower water level ranges, lower salinity ranges, and longer tidal lag times when compared to other deeper screened waterfront wells (HMW-01D, AMW-01, and GM-13D). Also, an overall reduction in salinity concentrations measured in Wells AMW-04 and AMW-05 in the years following seawall construction points to reduced tidal mixing inland of the new seawall in deeper groundwater.

- Tidal response and surface water mixing in shallow groundwater along the waterfront appears to be most pronounced in the area near Well RW-6. This well is directly inland of a short area of the waterfront (approximately 15 feet north/south) located just beyond the southern terminus of the new seawall and the northern terminus of the warehouse foundation. The original timber bulkhead dating to island construction is the only apparent barrier to shallow groundwater and surface water exchange in this area. Higher salinity, water level ranges, and reduced tidal lag times all indicate greater communication of shallow groundwater with surface water in this area of the Site.

- The warehouse foundation remains an effective barrier to the migration of shallow groundwater to surface water and continues to function as a "hanging wall," which allows for greater deeper groundwater/surface water exchange below the foundation. Well GM-13S, which is screened in shallow groundwater directly inland of the warehouse foundation, showed lower water level ranges, salinity ranges, and salinity concentrations when compared to adjacent deeper groundwater measured in GM-13D. Wells screened in shallow groundwater further inland of the warehouse foundation (GM-11S and GM-12S) showed similar responses as observed in GM-13S. When comparing the results of this study to earlier investigations, surface water communication with shallow groundwater has reduced over time around GM-13S. As no infrastructure changes have been made in this area, changes are possibly related to increased biofouling observed in the formation, attributed to the long-term groundwater pumping (greater than 20 years) and remedial actions that have been conducted along the waterfront.

- In the area south of the warehouse foundation, groundwater/surface water mixing and tidal effects continue to appear more pronounced in deeper groundwater when compared to shallow groundwater, as shown in measurements collected from shallow screened well RW-10 and the adjacent deeper screened well AMW-01. However, shallow groundwater measured at RW-10 appears to be in better communication with surface water when compared to shallow groundwater to the north and behind the warehouse foundation, as measured in GM-13S. Site and shallow groundwater characteristics around RW-10 are similar to the area by RW-6, in that the original timber bulkhead dating to island construction is the only known waterward barrier between shallow groundwater and surface water. This timber bulkhead appears to be a less effective barrier of shallow groundwater migration to surface water than the new seawall or warehouse foundation. However, smaller water level ranges, smaller salinity ranges, lower salinity concentrations, and longer tidal lag times south of the warehouse (RW-10) when compared to north of the warehouse (RW-6) show lower communication of shallow groundwater with surface water in the area south of the warehouse foundation than directly north of the foundation.

This investigation was conducted in accordance with Ecology's request to evaluate how a new seawall, installed along the northern portion of the waterfront at the Site, has affected hydrology. The results of the investigation show that the new seawall has had limited overall effects on hydrology, primarily in reducing groundwater and surface water communication directly inland of the new seawall. The investigation also showed some limited changes to hydrology occurring along the waterfront since the RI/FS was conducted in the 1990s, possibly attributable to long term remedial actions involving pumping of shallow groundwater.

The results of this investigation support earlier studies and the conceptual Site model, which showed the bulk of surface water and groundwater exchange occurs along the waterfront in deeper sediments (i.e., deeper groundwater) and beneath shallower fill materials. These historical studies served as the basis for selecting waterfront wells screened in deeper groundwater as the agreed points of compliance at the Site. While surface water and groundwater exchange continues to appear greatest in deeper sediments, a few areas of higher exchange in shallow sediments (i.e., shallow groundwater) were observed when compared to adjacent shallow areas. These localized areas of higher surface water and shallow groundwater exchange appear tied to reduced waterward barriers.

This investigation supports recent studies and ongoing monitoring, indicating that remedial actions have been effective in protecting surface water and groundwater along the waterfront. These studies also show that remedial actions have met their intended remedial objectives. The findings of this investigation support the applicability of established points of compliance at the Site, which measure if performance and confirmational objectives have been met, and can be used to evaluate the appropriateness of any proposed modification to the compliance well network.

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TABLES

Table 1. Well Construction Details
Site: Former BP Harbor Island Terminal

Well Identification	Well Location Coordinate North (NAD 83)	Well Location Coordinate East (NAD 83)	Ground Surface Elevation (ft.) (NAVD 88)	Top of Casing Elevation (ft.) (NAVD 88)	Elevation Top of Screen (ft.) (NAVD 88)	Elevation Bottom of Screen (ft.) NAVD88)	Transducer Setpoint Elevation (ft.) (NAVD88)	Well Screen Length (feet)	Depth to Top of Screen (ft. BGS)	Depth to Bottom of Screen (ft. BGS)
AMW-01	215851.7	1264198.5	12.39	12.17	-17.61	-27.61	-22.75	10	30	40
AMW-04	216216.2	1264212.0	11.58	11.42	-13.42	-23.42	-18.51	10	25	35
AMW-05	216369.0	1264208.2	11.35	11.05	-13.65	-23.65	-18.85	10	25	35
GM-10S	216479.6	1264208.9	11.88	11.52	7.88	-2.12	2.69	10	4	14
GM-10D	216471.9	1264209.4	11.67	11.39	-23.33	-28.33	-26.27	5	35	40
GM-11S	216144.6	1264282.2	12.10	11.64	8.10	-1.90	2.79	10	4	14
GM-12S	215997.9	1264282.7	12.28	11.73	8.28	-1.72	2.79	10	4	14
GM-13S	215898.4	1264213.3	15.66	15.22	8.66	-6.34	0.78	15	7	22
GM-13D	215909.1	1264214.4	15.69	15.40	-24.31	-29.31	-27.07	5	40	45
GM-14S	216097.5	1264426.2	12.13	11.77	8.13	-1.87	2.89	10	4	14
GM-14D	216080.4	1264432.8	11.71	11.22	-23.29	-28.29	-26.20	5	35	40
GM-15S	215679.9	1264366.4	12.80	12.32	8.80	-1.20	3.33	10	4	14
GM-16S	215545.7	1264723.0	12.21	11.99	8.21	-1.79	3.12	10	4	14
GM-17S	215912.4	1264734.5	12.95	12.56	8.95	-1.05	3.71	10	4	14
GM-17D	215918.5	1264734.8	13.10	12.75	-20.90	-25.90	-23.70	5	34	39
GM-18S	216308.3	1264734.3	11.70	11.51	7.70	-2.30	2.66	10	4	14
HMW-01D	216489.2	1264227.8	12.25	11.82	-22.75	-27.75	-25.72	5	35	40
HMW-01-S	216484.5	1264228.7	12.15	11.78	8.15	-1.85	2.80	10	4	14
RW-5	216189.1	1264210.5	11.91	10.92	7.41	-2.59	1.48	10	4.5	14.5
RW-6	216164.3	1264198.8	12.37	12.03	7.87	-2.13	2.58	10	4.5	14.5
RW-10	215848.4	1264202.5	12.32	11.57	7.82	-2.18	2.20	10	4.5	14.5
B-006	216426.9	1264365.5	11.74	11.37	8.74	-1.26	3.23	10	3	13
B-007	216374.3	1264208.0	11.37	10.90	7.87	-2.13	2.40	10	3.5	13.5
SW-01	216142.6	1264110.5	19.58	19.58	-3.92	-8.92	-6.67	5	23'5' (7' above sediments)	28.5' BGS (2' above sediments)

Monitoring Wells		
Recovery Wells		
Piezometer Wells		
Stilling Well (in Duwamish Waterway)		

Definitions:
BGS - Below ground surface
ft. - Feet
NAD 83 - North American Datum of 1983
NAVD88 - North American Vertical Datum of 1988

Table 2. System Shutdown Groundwater/LNAPL Recovery Well Product Monitoring
April & May 2021
Site: Former BP Harbor Island Terminal

Well	Date	Measurable LNAPL (>0.01')	Sheen on Groundwater (No, SS, MS, HS)
RW-1	4/29/2021	No	No
RW-1	5/4/2021	No	No
RW-1	5/7/2021	No	No
RW-1	5/11/2021	No	No
RW-2	4/29/2021	No	**MS**
RW-2	5/4/2021	No	**MS**
RW-2	5/7/2021	No	**MS**
RW-2	5/11/2021	No	No
RW-4	4/29/2021	No*	**HS***
RW-4	5/4/2021	No*	**HS***
RW-4	5/7/2021	No*	**HS***
RW-4	5/11/2021	No*	**SS***
RW-5	Not Accessible. Well was part of hydraulic evaluation transducer study.		
RW-6	Not Accessible. Well was part of hydraulic evaluation transducer study.		
RW-7	4/29/2021	No	No
RW-7	5/4/2021	No	No
RW-7	5/7/2021	No	No
RW-7	5/11/2021	No	No
RW-8	4/29/2021	No	No
RW-8	5/4/2021	No	No
RW-8	5/7/2021	No	No
RW-8	5/11/2021	No	No
RW-9	4/29/2021	No	**SS**
RW-9	5/4/2021	No	**SS**
RW-9	5/7/2021	No	**SS**
RW-9	5/11/2021	No	No
RW-10	Not Accessible. Well was part of hydraulic evaluation transducer study.		
GM-11S	Not Accessible. Well was part of hydraulic evaluation transducer study.		
Cleanup Level		No	No[1]

Note: [1] The cleanup criterion for no sheen on groundwater is applicable at conditional points of compliance (CPoCs) only. Recovery wells are not CPoCs. Sheen detections in recovery wells do not represent an exceedance of the sheen criterion.

* Sorbent sock maintained in RW-4 during study due to presence of LNAPL film, which was too thin to measure (i.e., <0.01' thick).

SS Slight sheen observed on groundwater.

MS Meduim sheen obaserved on groundwater.

HS Heavy sheen observed on groundwater.

Table 3. Summary of Average Head Conditions
Site: Former BP Harbor Island Terminal

Location	Relative Position of Well Screen	Average Head Start Time	Average Head End Time	Average Water Level Elevation (ft NAVD88)
SW-01	Surface Water	4/24/21 3:40	5/11/21 4:50	4.186
HMW-01S	Shallow Groundwater	4/24/21 7:50	5/11/21 7:40	6.420
B-006 B-006 B-006 B-006 B-006	Shallow Groundwater	4/24/21 7:10 4/26/21 14:50 4/30/21 18:50 5/4/21 4:30 5/8/21 18:30	4/24/21 18:20 4/29/21 16:40 5/2/21 20:00 5/7/21 17:40 5/11/21 6:00	6.747
B-007	Shallow Groundwater	4/24/21 8:40	5/11/21 8:10	6.474
GM-10S	Shallow Groundwater	4/24/21 9:00	5/11/21 8:30	6.427
GM-11S	Shallow Groundwater	4/24/21 5:40	5/11/21 6:30	6.927
GM-12S	Shallow Groundwater	4/24/21 11:40	5/11/21 6:50	7.096
GM-13S	Shallow Groundwater	4/24/21 5:00	5/11/21 5:40	6.969
GM-14S	Shallow Groundwater	4/24/21 5:40	5/11/21 6:40	7.42
GM-15S	Shallow Groundwater	4/24/21 5:30	5/11/21 6:30	7.088
GM-16S	Shallow Groundwater	4/24/21 5:30	5/11/21 6:30	7.198
GM-17S	Shallow Groundwater	4/24/21 5:30	5/11/21 6:30	7.881
GM-18S	Shallow Groundwater	4/24/21 5:30	5/11/21 6:30	7.624
RW-5	Shallow Groundwater	4/24/21 6:20	5/11/21 6:50	6.603
RW-6	Shallow Groundwater	4/24/21 4:10	5/11/21 5:30	6.658
RW-10	Shallow Groundwater	4/24/21 6:50	5/11/21 7:30	6.986
HMW-01D	Deep Groundwater	4/24/21 4:40	5/11/21 5:30	4.951
AMW-01	Deep Groundwater	4/24/21 4:30	5/11/21 5:30	4.950
AMW-04	Deep Groundwater	4/24/21 5:00	5/11/21 5:50	5.076
AMW-05	Deep Groundwater	4/24/21 5:20	5/11/21 6:00	5.087
GM-10D	Deep Groundwater	4/24/21 4:50	5/11/21 5:30	4.820
GM-13D	Deep Groundwater	4/24/21 4:30	5/11/21 5:20	4.929
GM-14D	Deep Groundwater	4/24/21 6:00	5/11/21 6:30	5.252
GM-17D	Deep Groundwater	4/24/21 7:10	5/11/21 7:30	5.559

Definitions:
ft. - Feet
NAVD88 - North American Vertical Datum of 1988

Table 4. Vertical Head Differences & Gradients of Nested Well Pairs
Site: Former BP Harbor Island Terminal

Shallow Screened Well	Shallow Well Average Water Level Elevation (ft NAVD88)	Deeper Screened Well	Deep Well Average Water Level Elevation (ft NAVD88)	Average Head Difference (Shallow Elevation - Deep Elevation) (ft)	Deep well Midpoint of Well Screen Elevation (ft NAVD88)	2021 Mean Vertical Hydraulic Gradient (ft/ft)	1994 RI Mean Vertical Hydraulic Gradient (ft/ft)
HMW-01S	6.42	HMW-01D	4.951	1.47	-25.25	0.046	NA
GM-10S	6.427	GM-10D	4.82	1.61	-25.83	0.050	0.064
B-007	6.474	AMW-05	5.087	1.39	-18.65	0.055	NA
RW-5	6.603	AMW-04	5.076	1.53	-18.42	0.061	NA
GM-13S	6.969	GM-13D	4.929	2.04	-26.81	0.061	0.037
RW-10	6.986	AMW-01	4.95	2.04	-22.61	0.069	NA
GM-14S	7.42	GM-14D	5.252	2.17	-25.79	0.065	NA
GM-17S	7.881	GM-17D	5.559	2.32	-23.4	0.074	0.066

Definitions:
ft. - Feet
ft/ft - Foot per foot
NAVD88 - North American Vertical Datum of 1988

Table 5. Average Head Conditions at Ends of New Seawall
Site: Former BP Harbor Island Terminal

Comparison Location	Well #1 - Well Positioned Behind New Seawall	Well #1 Average Water Level Elevation (ft NAVD88)	Well #2 - Well Positioned Beyond Listed End of New Seawall	Well # Average Water Level Elevation (ft NAVD88)	Average Head Difference (Elevation Well #1 - Elevation Well #2) (ft)	Inferred Flow Direction
Shallow Groundwater Northern Seawall End	GM-10S	6.427	HMW-01S	6.42	0.007	To the east
Deeper Groundwater Northern Seawall End	GM-10D	4.82	HMW-01D	4.951	-0.131	To the west
Shallow Groundwater Southern Seawall End	RW-5	6.603	RW-6	6.658	-0.055	To the north

Definitions:
ft. - Feet
NAVD88 - North American Vertical Datum of 1988

Table 6. Tidal Induced Water Level Ranges
Site: Former BP Harbor Island Terminal

Location	2021 Maximum Range (ft) 5/10 11:00 to 5/11 11:50 2005 Comparison	2005 Maximum Range (ft) Reduced by 5.2 Percent	2021 Maximum Range (ft) 5/1 18:00 to 5/3 19:40 1995 Comparison	1995 Maximum Range (ft) Increased by 0.75 Percent	2021 Maximum Range (ft) 5/9 7:00 to 5/11 8:40 1993 Comparison	1993 Maximum Range (ft) Reduced by 3.4 Percent
Surface Water Level Ranges						
SW-01	10.98	11.58*	13.37	13.27*	10.72	11.10*
Shallow Groundwater Level Ranges						
HMW-01S	0.13		0.32		0.15	
B-006	0.05		0.09		0.09	
B-007	0.09	1.66	0.27		0.12	
GM-10S	0.10		0.27		0.12	0.65
GM-11S	0.19		0.36		0.22	
GM-12S	0.06		0.35	0.11	0.10	
GM-13S	0.23		0.50	0.92	0.27	2.10
GM-14S	0.02		0.03		0.04	
GM-15S	0.03		0.04		0.04	
GM-16S	0.03		0.03		0.03	
GM-17S	0.03		0.03		0.04	
GM-18S	0.01		0.03		0.03	
RW-5	0.82	1.53	1.46		0.87	
RW-6	1.99	1.72	3.61		2.21	
RW-10	0.20		0.70		0.30	
Deeper Groundwater Level Ranges						
HMW-01D	5.59		6.73		5.50	
AMW-01	6.60		7.89		6.40	
AMW-04	4.65		5.68		4.65	
AMW-05	4.04		4.98		4.05	
GM-10D	5.05		6.13		5.01	7.65
GM-13D	6.26		7.50		6.09	6.93
GM-14D	3.09		3.71		3.09	
GM-17D	1.33		1.69		1.33	1.69

Definitions:
ft - Feet

Notes:
* - Historical water level ranges presented for the stilling well were not altered, and were used to compute increases or reductions in percentages used for groundwater range comparison.

Table 7. Tidal Lag Times
Site: Former BP Harbor Island Terminal

Well	Spring Tide (4/29/21) Time of Maximum Water Level	Spring Tide (4/29/21) Time of Minimum Water Level	Neap Tide (5/6/21) Time of Minimum Water Level	Neap Tide (5/6/21) Time of Maximum Water Level	High High Spring Tide Tidal Lag Time (Hours)	Low Low Spring Tide Tidal Lag Time (Hours)	High Neap Tide Tidal Lag Time (Hours)	Low Neap Tide Tidal Lag Time (Hours)	High High to Low Low Spring Tide Tidal Range (ft)	High to Low Neap Tide Tidal Range (ft)
Surface Water Tidal Data										
SW-01	6:10 AM	1:10 PM	9:10 AM	2:50 PM	0:00	0:00	0:00	0:00	14.88	5.35
Shallow Groundwater Tidal Lag Time Data										
HMW-01S	8:50 AM	6:10 PM	2:50 PM	2:50 PM	2:40	5:00	0:00	5:40	0.18	0.17
B-006	8:50 AM	4:50 PM	2:10 PM	2:50 PM	2:40	3:40	0:00	5:00	0.08	0.04
B-007	9:40 AM	7:00 PM	2:40 PM	2:50 PM	3:30	5:50	0:00	5:30	0.17	0.16
GM-10S	10:20 AM	6:50 PM	2:50 PM	2:50 PM	4:10	5:40	0:00	5:40	0.14	0.15
GM-11S	8:00 AM	4:00 PM	2:30 PM	3:20 PM	1:50	2:50	0:30	5:20	0.33	0.15
GM-12S	9:50 AM	6:00 PM	2:40 PM	3:00 PM	3:40	4:50	0:10	5:30	0.10	0.11
GM-13S	7:10 AM	4:00 PM	2:50 PM	3:20 PM	1:00	2:50	0:30	5:40	0.42	0.15
GM-14S	12:10 PM	6:50 PM	2:30 PM	4:40 PM	6:00	5:40	1:50	5:20	0.04	0.03
GM-15S	1:00 PM	8:40 PM	2:00 PM	2:50 PM	6:50	7:30	0:00	4:50	0.01	0.03
GM-16S	12:30 PM	3:50 PM	1:10 PM	4:40 PM	6:20	2:40	1:50	4:00	0.01	0.01
GM-17S	6:10 AM	8:10 PM	2:20 PM	4:00 PM	0:00	7:00	1:10	5:10	0.03	0.03
GM-18S	7:50 AM	2:20 PM	1:50 PM	3:10 PM	1:40	1:10	0:20	4:40	0.01	0.02
RW-5	8:20 AM	5:30 PM	2:40 PM	2:50 PM	2:10	4:20	0:00	5:30	0.92	0.58
RW-6	6:50 AM	4:50 PM	12:20 PM	3:10 PM	0:40	3:40	0:20	3:10	3.13	0.68
RW-10	8:20 AM	6:50 PM	2:50 PM	2:50 PM	2:10	5:40	0:00	5:40	0.58	0.32
Deeper Groundwater Tidal Lag Time Data										
HMW-01D	7:00 AM	2:20 PM	10:10 AM	3:20 PM	0:50	1:10	0:30	1:00	7.63	2.51
AMW-01	6:50 AM	1:50 PM	9:50 AM	3:00 PM	0:40	0:40	0:10	0:40	8.96	3.03
AMW-04	7:20 AM	2:30 PM	10:30 AM	3:30 PM	1:10	1:20	0:40	1:20	6.48	2.04
AMW-05	7:30 AM	2:40 PM	10:40 AM	3:30 PM	1:20	1:30	0:40	1:30	5.71	1.70
GM-10D	7:10 AM	2:20 PM	10:20 AM	3:30 PM	1:00	1:10	0:40	1:10	6.98	2.25
GM-13D	7:00 AM	2:00 PM	9:50 AM	3:00 PM	0:50	0:50	0:10	0:40	8.54	2.83
GM-14D	8:00 AM	3:20 PM	11:20 AM	4:10 PM	1:50	2:10	1:20	2:10	4.33	1.13
GM-17D	9:00 AM	4:50 PM	12:50 PM	5:20 PM	2:50	3:40	2:30	3:40	1.89	0.60

Definitions:

ft - Feet

Notes:

Tidal lag times are calucalted by subtracting the time when a high or low tide occurs in surface water from when a corresponding high or low water level occurs in groundwater.

Table 8. Salinity Averages and Ranges
Site: Former BP Harbor Island Terminal

Location	Average Groundwater Salinity (PSU) 4/24-5/11	Range Groundwater Salinity (PSU) 4/24-5/11	Average Salinity (PSU) over Spring Tide Period (4/28 5:10 - 4/30 6:50)	Range Salinity (PSU) over Spring Tide Period (4/28 5:10 - 4/30 6:50)	Average Salinity (PSU) over Neap Tide Period (5/5 20:20 - 5/7 22:00)	Range Salinity (PSU) over Neap Tide Period (5/5 20:20 - 5/7 22:00)
Surface Water Salinity Averages and Ranges						
SW-01	27.58	13.67	26.84	12.99	28.29	4.51
Shallow Groundwater Salinity Averages and Ranges						
HMW-01S	0.21	0.68	0.27	0.58	0.16	0.26
B-006	0.07	0.06	0.07	0.01	0.07	0.01
B-007	0.24	0.08	0.26	0.01	0.23	0.02
GM-10S	0.20	0.09	0.21	0.02	0.19	0.01
GM-11S	0.14	0.01	0.14	0.00	0.14	0.00
GM-12S	0.10	0.15	0.05	0.00	0.11	0.00
GM-13S	0.19	0.03	0.18	0.01	0.19	0.01
GM-14S	0.14	0.01	0.14	0.00	0.14	0.00
GM-15S	0.12	0.03	0.13	0.00	0.11	0.00
GM-16S	0.07	0.00	0.07	0.00	0.07	0.00
GM-17S	0.25	0.01	0.25	0.00	0.25	0.00
GM-18S	0.08	0.02	0.08	0.01	0.08	0.00
RW-5	1.71	0.80	1.69	0.05	1.85	0.01
RW-6	16.06	12.16	16.52	3.35	15.48	2.35
RW-10	1.19	1.57	NA	NA	1.71	0.30
Deeper Groundwater Salinity Averages and Ranges						
HMW-01D	10.56	4.51	10.54	4.51	10.57	2.15
AMW-01	2.00	1.21	1.96	1.19	2.07	0.91
AMW-04*	0.49	0.63	0.49	0.39	0.46	0.43
AMW-05*	1.03	0.71	1.00	0.65	1.04	0.53
GM-10D	11.94	0.66	11.93	0.57	11.94	0.47
GM-13D	5.66	3.95	5.55	2.82	5.86	2.71
GM-14D	0.46	0.06	0.46	0.03	0.47	0.02
GM-17D	1.02	0.10	1.01	0.09	1.02	0.01

NA - RW-10 salinity values could not be determined during Spring Tide Period due to sensor malfunction.

*Shallower screens than other wells

Table 9. Salinity Averages and Ranges from Historical Monitoring
Site: Former BP Harbor Island Terminal

Well	2007-2021 Average Salinity Concentration (PPT)	2007-2021 Salinity Concentration Range (PPT)
GM-14S	0.08	0.40
GM-15S	0.09	0.21
GM-16S	0.29	2.80
GM-17S	0.13	0.30
GM-24S	0.02	0.50
AR-03	0.07	0.30
MW-1-T9	0.26	1.00
MW-2-T9	0.04	0.11
MW-3-T9	0.12	1.50
AMW-01	2.72	8.20
AMW-02	0.91	5.00
AMW-03	1.33	11.80
AMW-04	7.24	33.60
AMW-05	9.17	29.70

Definitions:
PPT - Parts per thousand

Table 10. Salinity History Waterfront Compliance Wells
Site: Former BP Harbor Island Terminal

Date	Well AMW-01 Salinity (PPT)	Well AMW-02 Salinity (PPT)	Well AMW-03 Salinity (PPT)	Well AMW-04 Salinity (PPT)	Well AMW-05 Salinity (PPT)
12/18/2007	3	5	1	3	19
3/25/2008	4	2	1	8	10
6/25/2008	5	2	1	13	15
9/17/2008	5	3	2	11	15
12/16/2008	4	2	2	13	15
3/11/2009	4	2	2	12	18
6/10/2009	3	3	2	12	25
9/16/2009	3	1	2	11	18
12/16/2009	4	3	2	11	11
3/30/2010	3	2	2	9	18
6/9/2010	2	1	1	8	16
9/14/2010	3	1	1	12	11
12/14/2010	3	1	2	11	9
3/22/2011	2	0	1	7	10
6/22/2011	2	0	1	11	12
9/27/2011	2.9	0.5	1.4	11.6	16.9
12/20/2011	8.2	1.6	3.5	34.1	22.4
3/20/2012	2.6	0.6	1.2	11.7	14.6
6/21/2012	2.1	0.5	1.1	9.5	15.3
9/10/2012	2	1	1	10	11
12/19/2012	3	1	1	11	9
3/19/2013	1.9	0.6	1	8	10.3
6/25/2013	2.3	0.5	1	7.5	15.5
9/10/2013	3	1	1	11	10
12/10/2013	3.4	0.5	0.9	10.3	7.9
3/11/2014	4	1	1	11	12
6/10/2014	2.99	0.53	0.9	6.27	11.39
9/9/2014	3	1	1	9	14
12/9/2014	3	1	1	12	10
3/10/2015	2.5	0.6	0.9	8	10.1
6/9/2015	2	1	1	8	13
9/22/2015	3.2	0.6	0.9	10.8	11.3
12/15/2015	3.66	0.62	0.74	11.63	11.14
3/8/2016	1.7	0.3	6	5.1	8.4
6/8/2016	2	0.5	0.8	6	11.2
9/8/2016	2.9	0.6	0.8	7.9	9.6
12/6/2016	2.8	0.5	12.2	7.8	7.3
3/7/2017	2.1	0.5	0.9	6.2	8.6
6/6/2017	1.4	0.4	0.7	3.9	0.3
9/12/2017	2.2	0.4	0.7	4.8	5.6
12/5/2017	2.2	0.6	0.89	1.26	2.32
3/20/2018	1.97	0.39	0.57	0.59	0.75
6/19/2018	0.198	0.38	0.6	0.59	0.52
9/11/2018	2.1	0.4	0.8	0.6	0.5
12/11/2018	2.77	0.39	0.62	0.57	0.67
3/12/2019	2.25	0.42	0.65	0.59	0.85
6/18/2019	2.17	0.46	0.9	0.57	1.11

Table 10. Salinity History Waterfront Compliance Wells
Site: Former BP Harbor Island Terminal

Date	Well AMW-01 Salinity (PPT)	Well AMW-02 Salinity (PPT)	Well AMW-03 Salinity (PPT)	Well AMW-04 Salinity (PPT)	Well AMW-05 Salinity (PPT)
9/24/2019	2.84	0.49	0.68	0.56	1.41
12/17/2019	2.85	0.52	0.78	0.58	1.41
3/18/2020	2.03	0.52	0.94	0.6	1.12
6/10/2020	1.95	0.5	1.05	0.54	1.24
9/16/2020	2.37	0.59	1.07	0.62	1.71
12/16/2020	2.01	0.5	1.04	0.57	1.24
3/10/2021	1.9	0.54	1.1	0.69	1.26
6/17/2021	2	0.55	1.21	0.69	1.46
9/22/2021	2.37	0.53	1.01	0.75	1.54
Avg. Pre-Seawall:	3.04	1.15	1.67	10.01	12.65
Avg. Post-Seawall:	2.13	0.49	0.89	0.61	1.15

Notes:

Cells highlighted in blue represent salinity data collected pre-seawall installation.

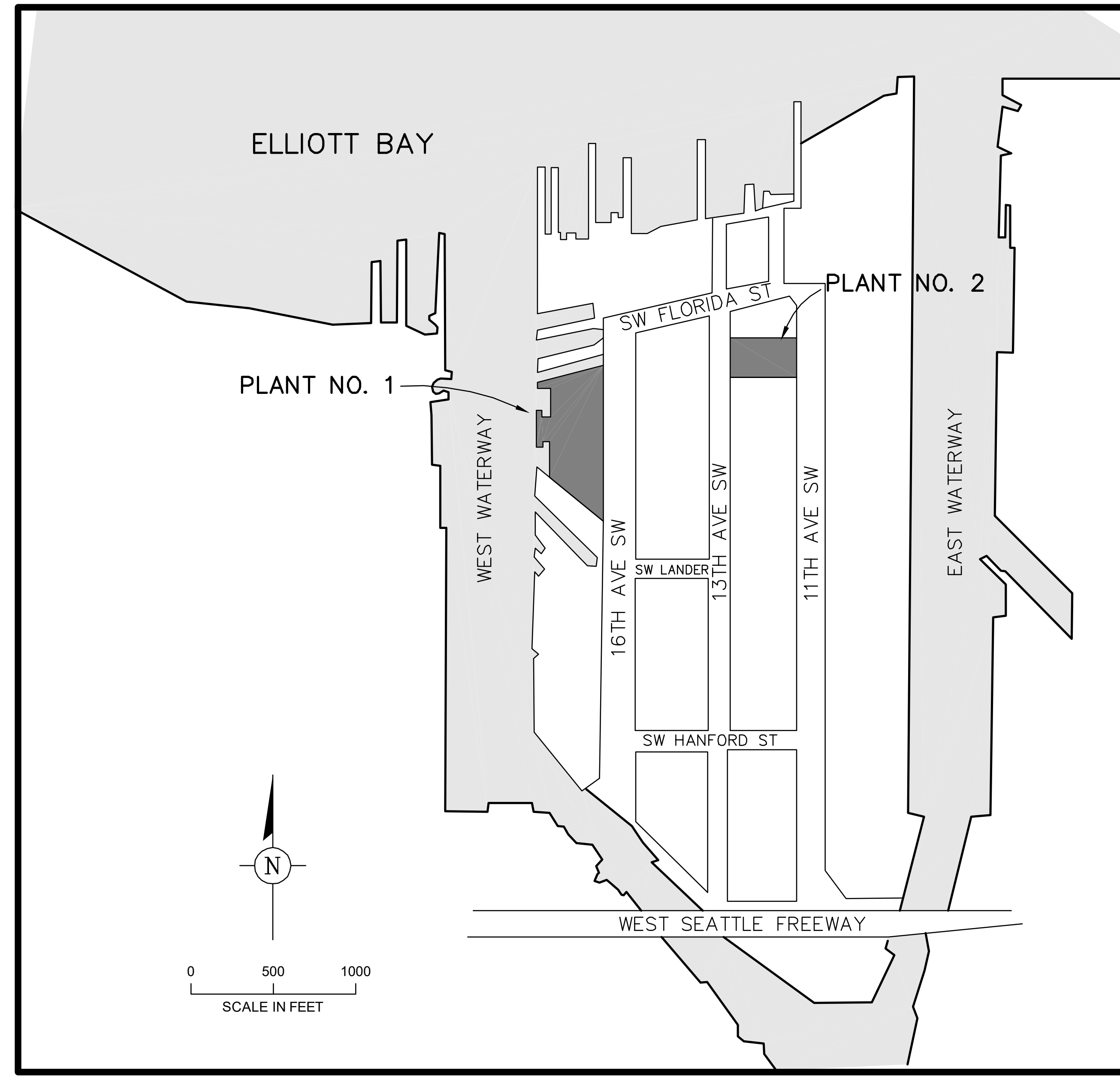
Cells highlighted in green represent salinity data collected post-seawall installation.

Averages for pre and post seawall construction exclude 9/12/17, 12/5/17, and 3/20/18 monitoring events, which were conducted during seawall construction.

PPT - Parts per thousand.

FIGURES

AREA PLAN



SITE PLAN

TECHSOLVE ENVIRONMENTAL
7518 NE 169th Street, Kenmore WA 98028
(425) 402-8277 FAX (425) 402-7917

Site Location Map

Site: Former BP Harbor Island Terminal
1652 Southwest Lander Street
Seattle, WA 98134

FIGURE 1

C:\DCS_PROJECTS\TechSolve PROJECTS\BP21T\ARCO 21T\dwg\MAP2.dwg JAN 13 2011 12:26:16

LEGEND

Plant 2 - Former BP Harbor Island Terminal

Plant 1 - Former BP Harbor Island Terminal

N

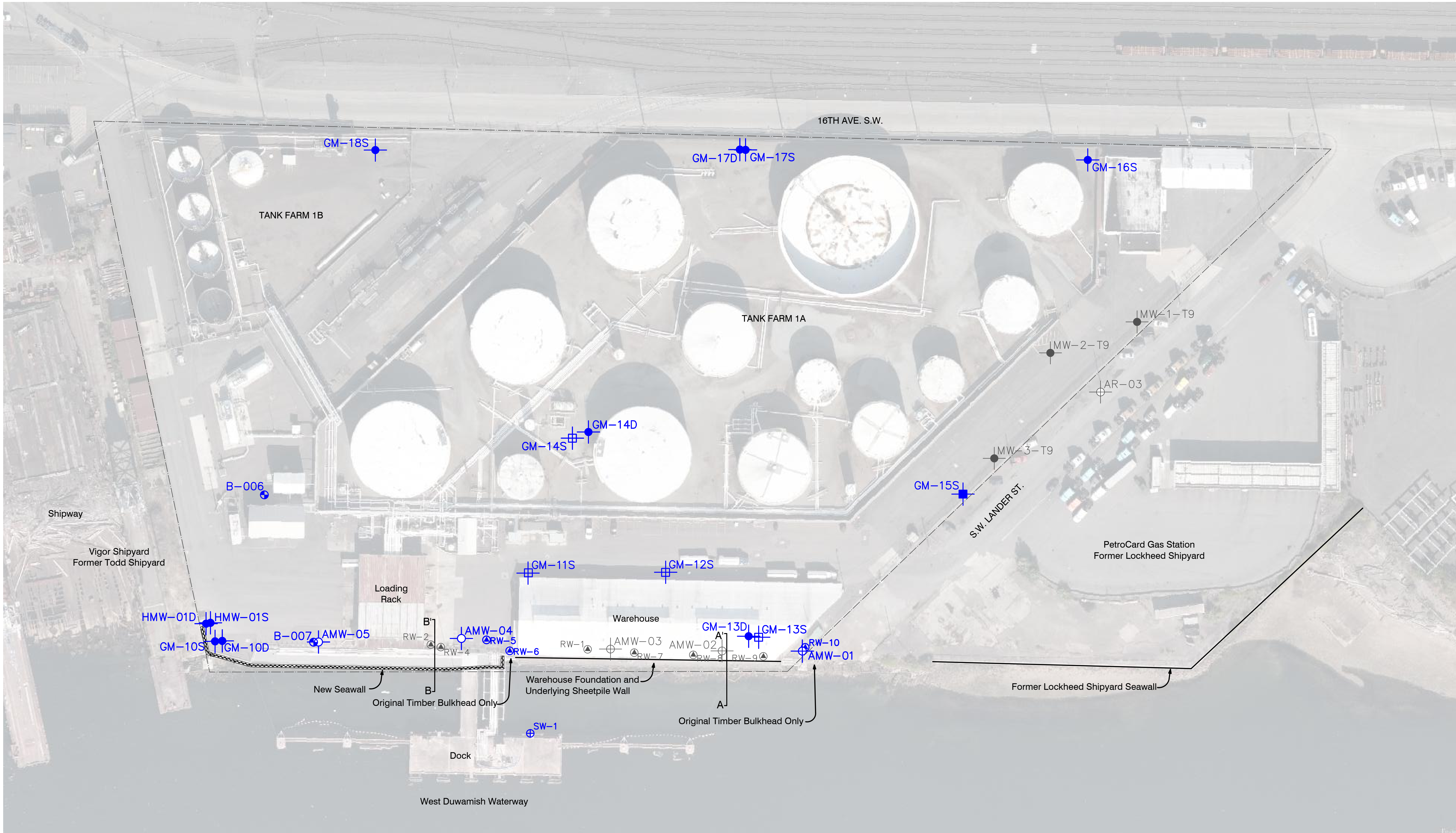
0 250 500
SCALE IN FEET

TECHSOLVE
ENVIRONMENTAL
7518 N.E. 169th Street
Kenmore, WA 98028
P:(425) 402-8277 F:(425) 402-7917

Harbor Island Site Map

Site: BP Harbor Island Terminal
1652 Southwest Lander Street
Seattle, WA 98134

FIGURE
2



LEGEND

GM−16S	Monitoring Well	RW−6	Recovery Well	A A'	Property Line
AMW−01	Performance/Confirmation Well	SW−1	Stilling Well		Reference to Cross−Section
GM−13D	Performance Well	B−006	Piezometer Well		
GM−13S	Product Performance Well	GM−16S	Study Well Highlighted in Blue		

N

0 50 100
SCALE IN FEET

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ENVIRONMENTAL
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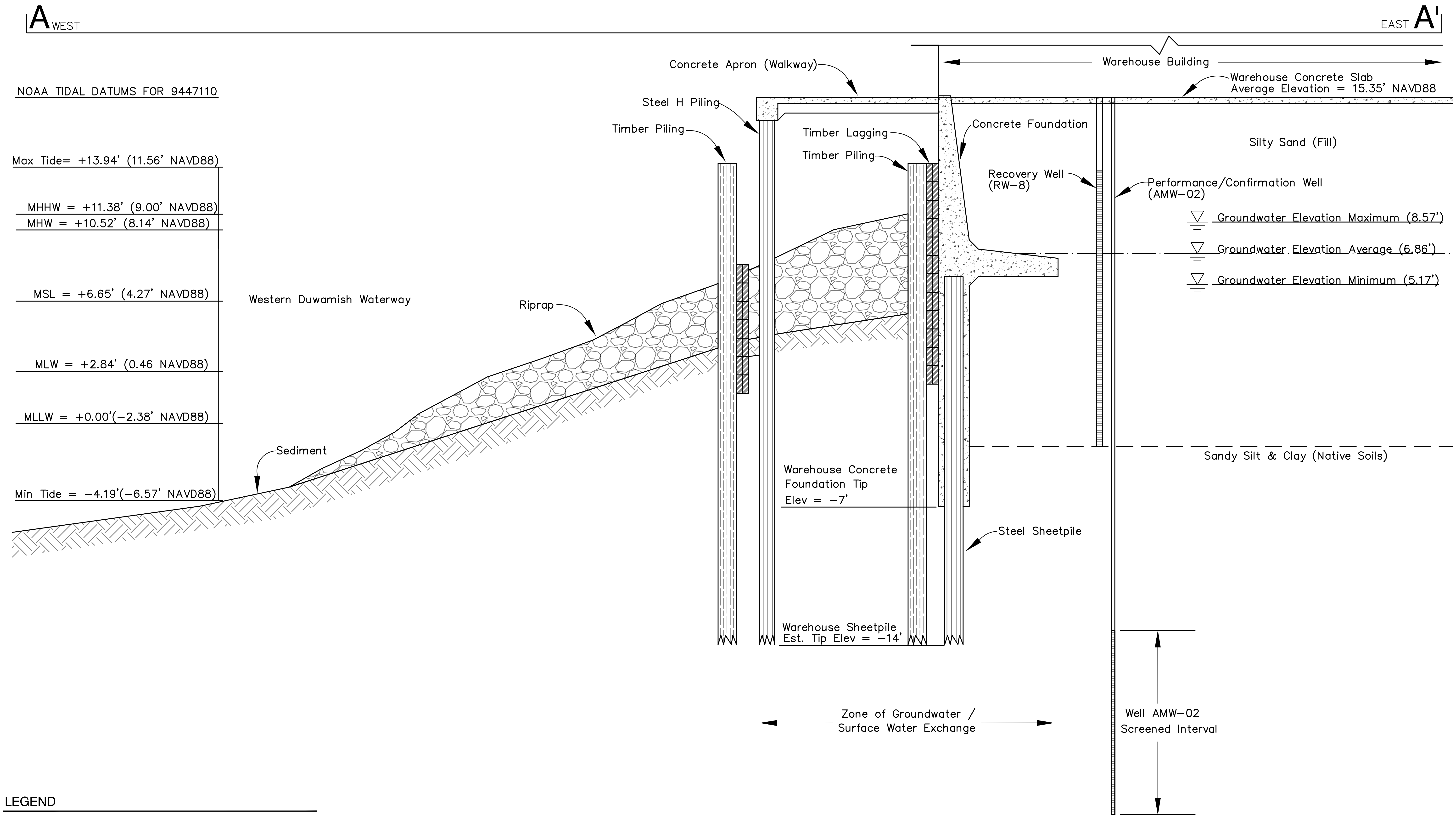
Kenmore, WA 98028
P:(425) 402-8277 F:(425) 402-7917

Plant 1 Hydraulic Evaluation
Transducer Study Wells

Site: BP Harbor Island Terminal
1652 Southwest Lander Street
Seattle, WA 98134

FIGURE
3



LEGEND

Average Groundwater Surface

Approximate Fill/Native Soil Interface

Groundwater Elevation Maximum, Average, and Minimum values are based upon 2000−2019 monthly gauging data (230 individual gauging events) collected from Monitoring Well GM−13S, which is screened in shallow groundwater.

NOAA Tidal Datums for Station 9447110 (Lockheed Shipyard, Harbor Island) are to Mean Low Low Water (MLLW). Subtract 2.38' from MLLW elevations to convert to North American Vertical Datum of 1988 (NAVD88).

W

0 2.5 5
SCALE IN FEET

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7518 N.E. 169th Street
Kenmore, WA 98028
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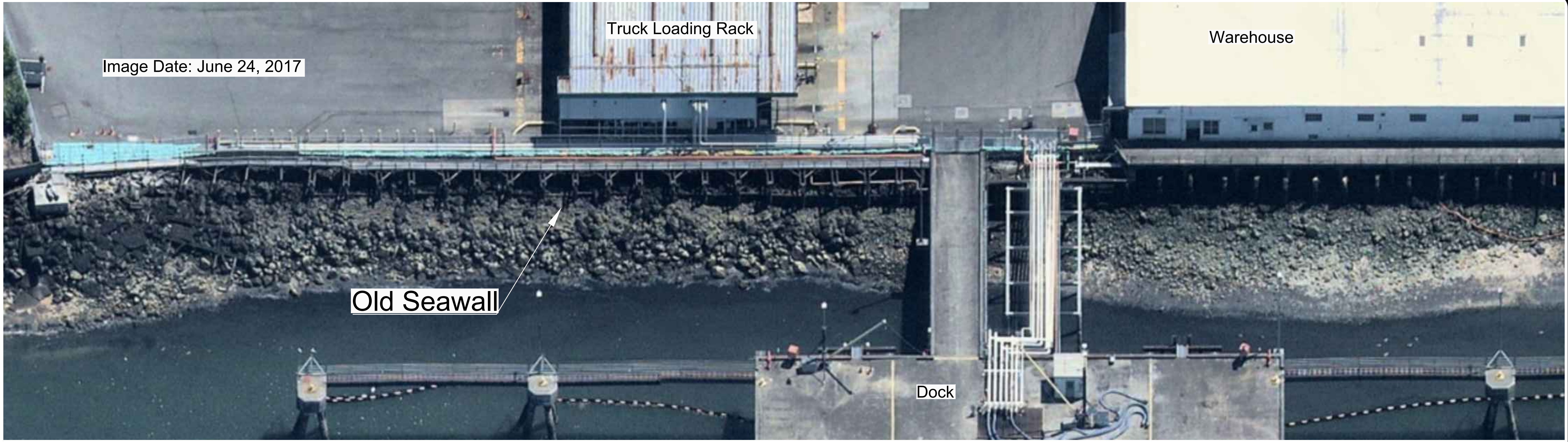
Plant 1 East/West Cross Section A-A'
Warehouse Construction & Waterway Details

BP West Coast Products Terminal 21T
1652 Southwest Lander Street
Seattle, WA 98134

FIGURE 4

\\server\ServerData\data\Aproject\ARCO 21T\Drawings and CAD files\Autocad files\Quarterly GWM Figures



LEGEND

Pre and post seawall installation imagery viewed from the west looking east.

Imagery provided by Nearmap.

0 15 30
APPROXIMATE SCALE IN FEET

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Kenmore, WA 98028
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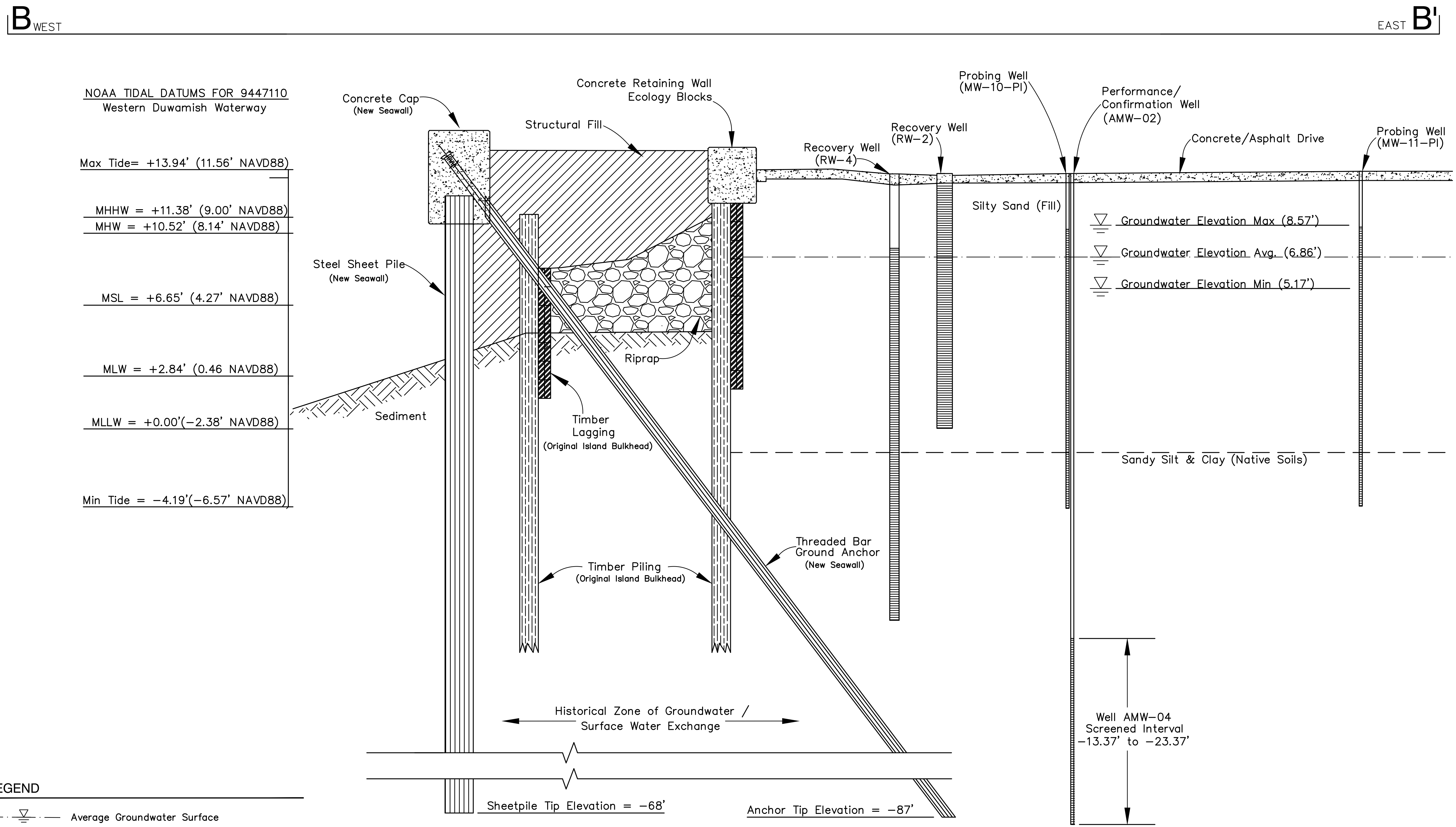
Pre & Post Seawall Installation Oblique Photos

Site: BP Harbor Island Terminal
1652 Southwest Lander Street
Seattle, WA 98134

FIGURE 5

\\SERVER\ServerData\data\Aproject\ARCO 21T\Drawings and CAD files\Autocad files\2021 Hyd Eval Figs: Plant 1 hyd eval Site Fig: Seawall Oblique (8/31/2021)



LEGEND

—·▽·—	Average Groundwater Surface
— — —	Approximate Fill/Native Soil Interface

Groundwater Elevation Maximum, Average, and Minimum values are based upon 2000−2019 monthly gauging data (230 individual gauging events) collected from Monitoring Well GM−13S, which is screened in shallow groundwater.

NOAA Tidal Datums for Station 9447110 (Lockheed Shipyard, Harbor Island) are to Mean Low Low Water (MLLW). Subtract 2.38' from MLLW to convert to North American Vertical Datum of 1988 (NAVD88). Assume elevations are to NAVD88 datum if no datum is listed next to the listed elevation in this figure.

W

0 2.5 5
SCALE IN FEET

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ENVIRONMENTAL
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Kenmore, WA 98028
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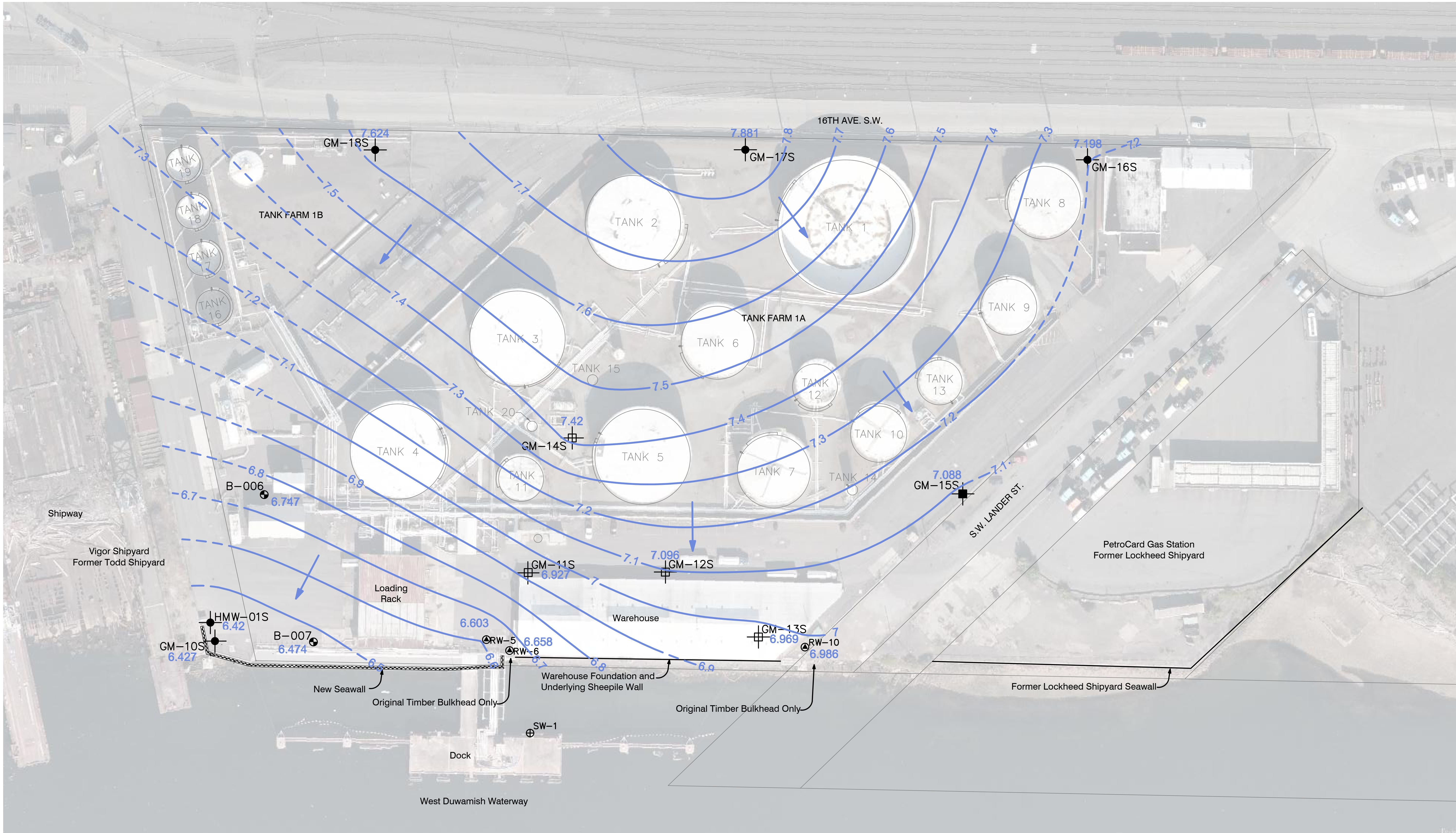
Plant 1 East/West Cross Section B-B'
New Seawall & Waterway Details

BP West Coast Products Terminal 21T
1652 Southwest Lander Street
Seattle, WA 98134

FIGURE
6



LEGEND

GM−16S Monitoring Well	RW−6 Recovery Well	Inferred Water Level
AMW−01 Performance/Confirmation Well	SW−1 Stilling Well	Groundwater Flow Direction
GM−13D Performance Well	B−006 Piezometer Well	
GM−13S Product Performance Well	Water Level Elevation (Feet NAVD88)	

N

0 50 100
SCALE IN FEET

TECHSOLVE ENVIRONMENTAL

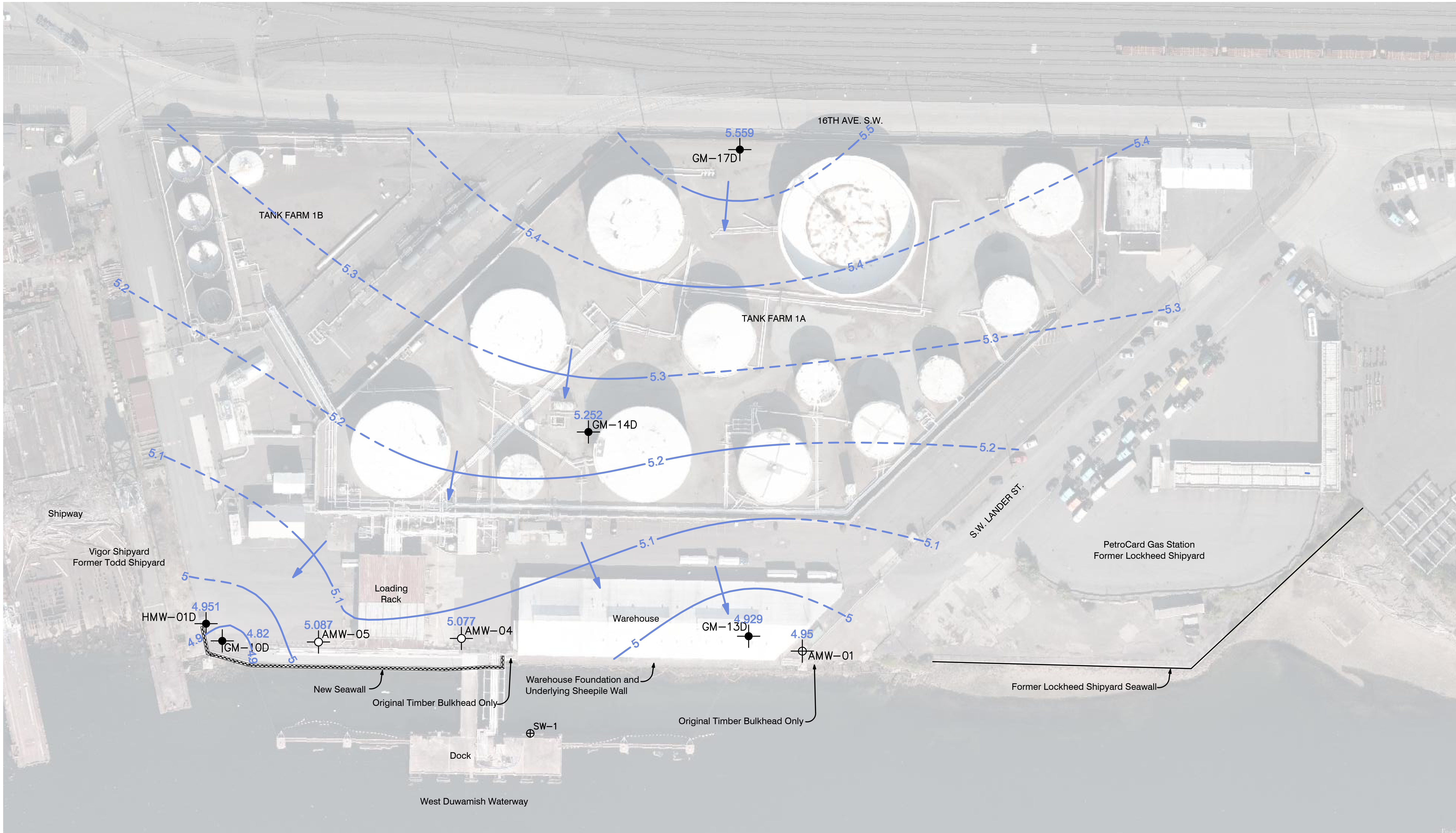
7518 N.E. 169th Street
Kenmore, WA 98028
P:(425) 402-8277 F:(425) 402-7917

Plant 1 Hydraulic Evaluation
Average Groundwater Level Shallow Wells

Site: Former BP Harbor Island Terminal
1652 Southwest Lander Street
Seattle, WA 98134

FIGURE
7

\\server\ServerData\data\project\ARCO 21T\Drawings and CAD files\Autocad files\2021 Hyd Eval Figs\Plant 1 Hyd eval contour figs: Shallow Avg GW Elev



LEGEND

GM-16S	Monitoring Well		Inferred Water Level
AMW-01	Performance/Confirmation Well		Groundwater Flow Direction
SW-1	Stilling Well		Water Level Elevation (Feet NAVD88)

N

0 50 100

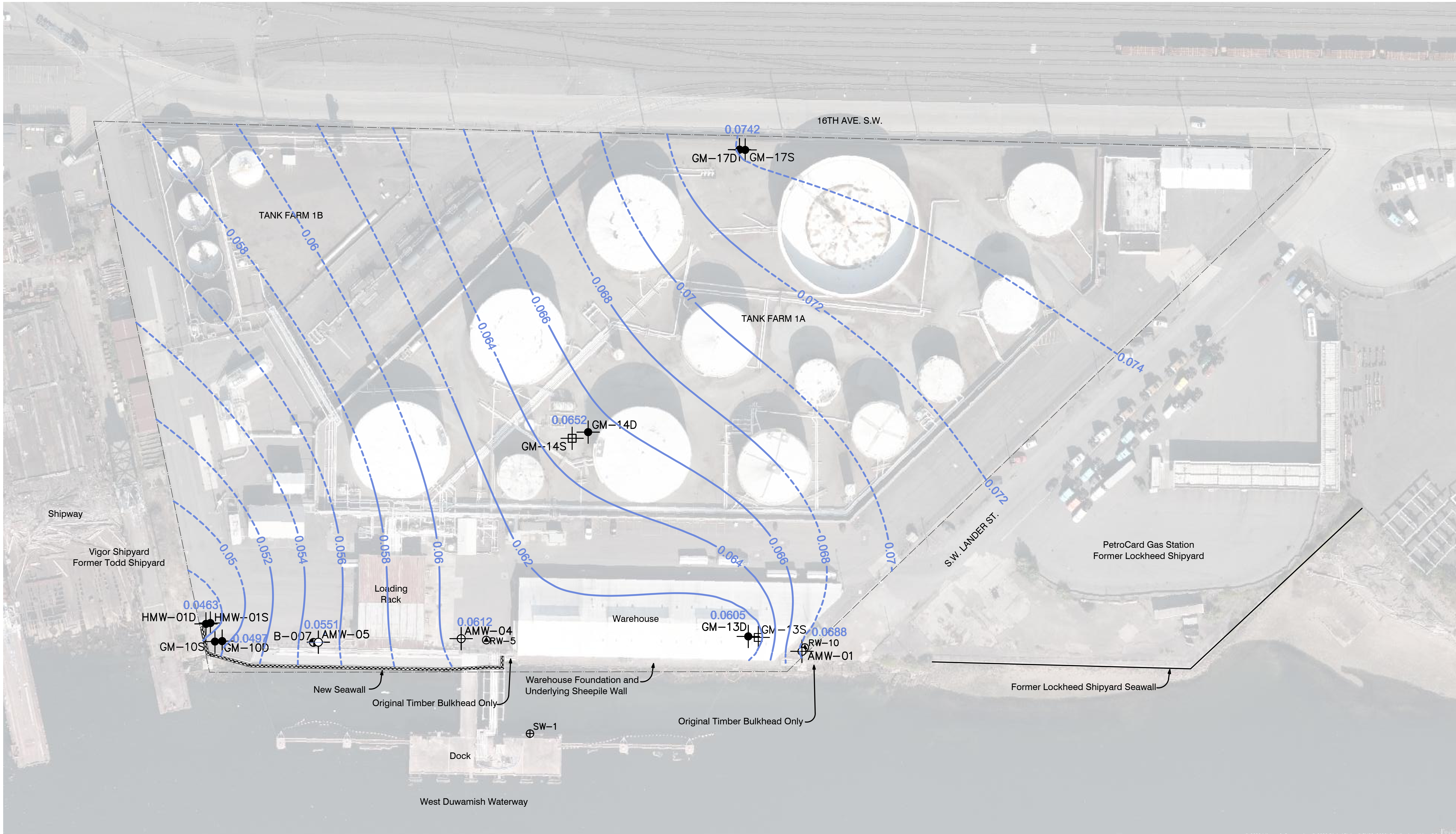
SCALE IN FEET

TECHSOLVE ENVIRONMENTAL
7518 N.E. 169th Street
Kenmore, WA 98028
P:(425) 402-8277 F:(425) 402-7917

Plant 1 Hydraulic Evaluation
Average Groundwater Level Deep Wells

Site: Former BP Harbor Island Terminal
1652 Southwest Lander Street
Seattle, WA 98134

FIGURE
8



LEGEND

GM–16S	MONITORING WELL
AMW–01	PERFORMANCE/CONFIRMATION WELL
GM–13D	PERFORMANCE WELL
GM–13S	PRODUCT PERFORMANCE WELL
RW–6	RECOVERY WELL
B–006	PIEZOMETER WELL
dashed line	Inferred Vertical Gradient
solid line	Vertical Gradient (ft/ft) Shallow Elevation to Deep Elevation

N

0 50 100
SCALE IN FEET

TECHSOLVE ENVIRONMENTAL

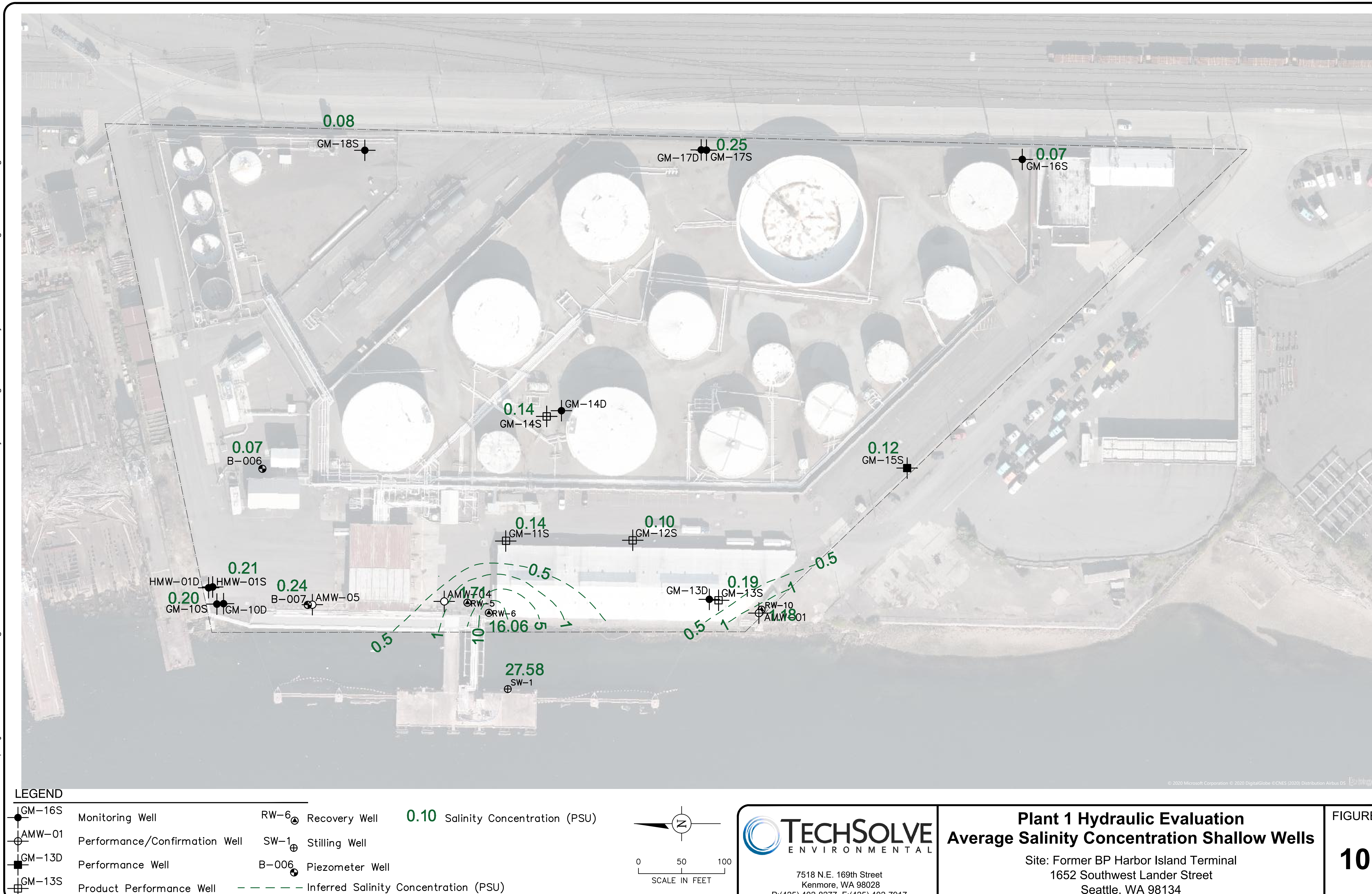
7518 N.E. 169th Street
Kenmore, WA 98028
P:(425) 402-8277 F:(425) 402-7917

Plant 1 Hydraulic Evaluation
Vertical Gradient Shallow to Deep Wells

Site: BP Harbor Island Terminal
1652 Southwest Lander Street
Seattle, WA 98134

FIGURE
9

\\server\ServerData\data\project\ARCO 21T\Drawings and CAD files\Autocad files\Quarterly GWM Figures: P1 Hyd Eval Wells Mods (6/29/21)



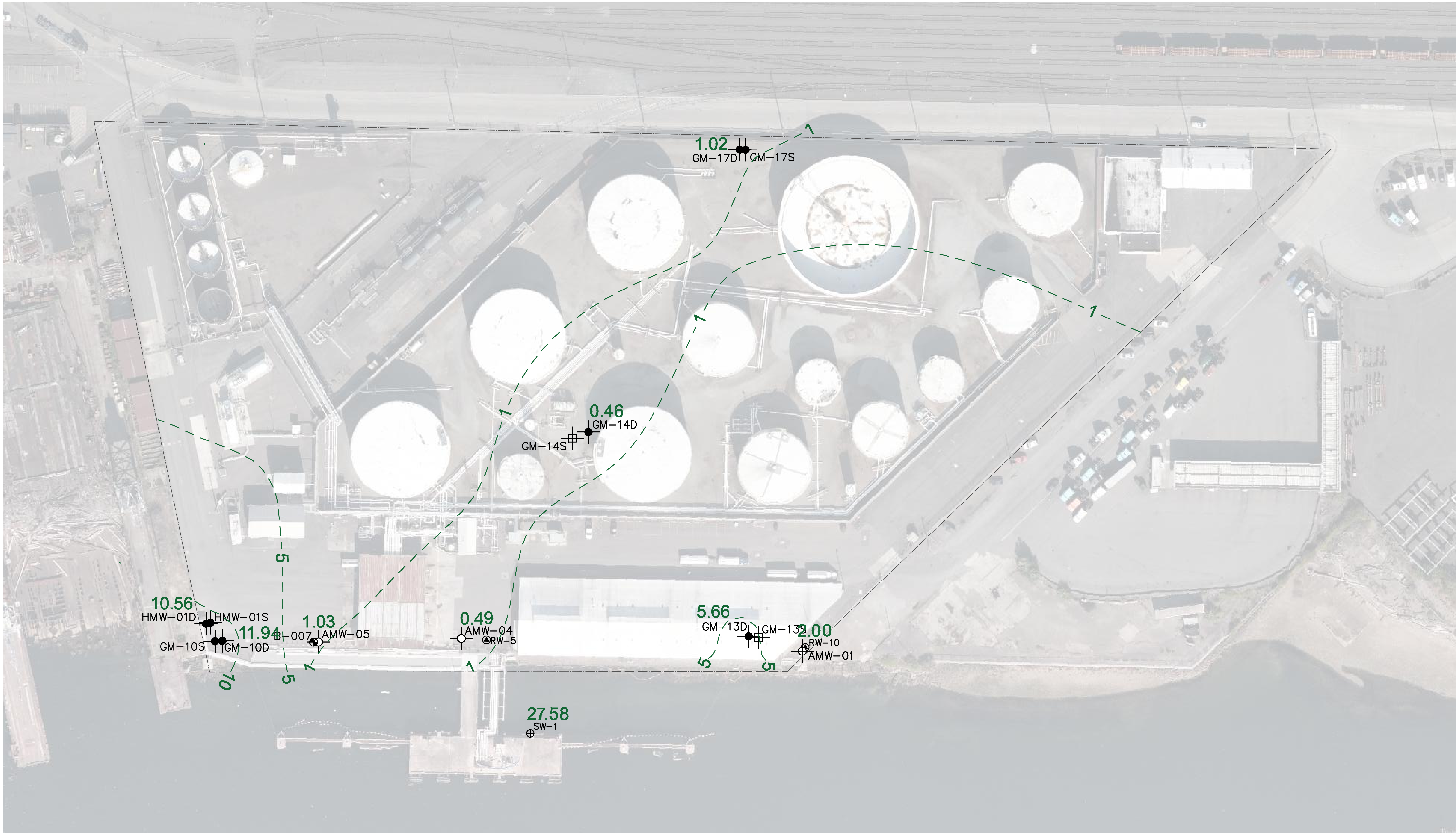
\\server\ServerData\data\project\ARCO 21T\Drawings and CAD files\Autocad files\2021 Hyd Eval Figs\Plant 1 Hyd eval contour figs: Shallow Avg GW Elev

TECHSOLVE ENVIRONMENTAL
7518 N.E. 169th Street
Kenmore, WA 98028
P:(425) 402-8277 F:(425) 402-7917

Plant 1 Hydraulic Evaluation
Average Salinity Concentration Shallow Wells

Site: Former BP Harbor Island Terminal
1652 Southwest Lander Street
Seattle, WA 98134

FIGURE **10**



LEGEND

GM−16S	Monitoring Well	RW−6	Recovery Well
AMW−01	Performance/Confirmation Well	SW−1	Stilling Well
GM−13D	Performance Well	B−006	Piezometer Well
GM−13S	Product Performance Well	— — —	Inferred Salinity Concentration (PSU)

0.10 Salinity Concentration (PSU)

N

0 50 100
SCALE IN FEET

TECHSOLVE ENVIRONMENTAL
7518 N.E. 169th Street
Kenmore, WA 98028
P:(425) 402-8277 F:(425) 402-7917

Plant 1 Hydraulic Evaluation
Average Salinity Concentration Deep Wells

Site: Former BP Harbor Island Terminal
1652 Southwest Lander Street
Seattle, WA 98134

FIGURE
11

\\server\ServerData\data\project\ARCO 21T\Drawings and CAD files\Autocad files\2021 Hyd Eval Figs\Plant 1 Hyd eval contour figs: Shallow Avg GW Elev

Figure 12. Inland Wells Salinity Concentration vs. Time
Site: Former BP Harbor Island Terminal

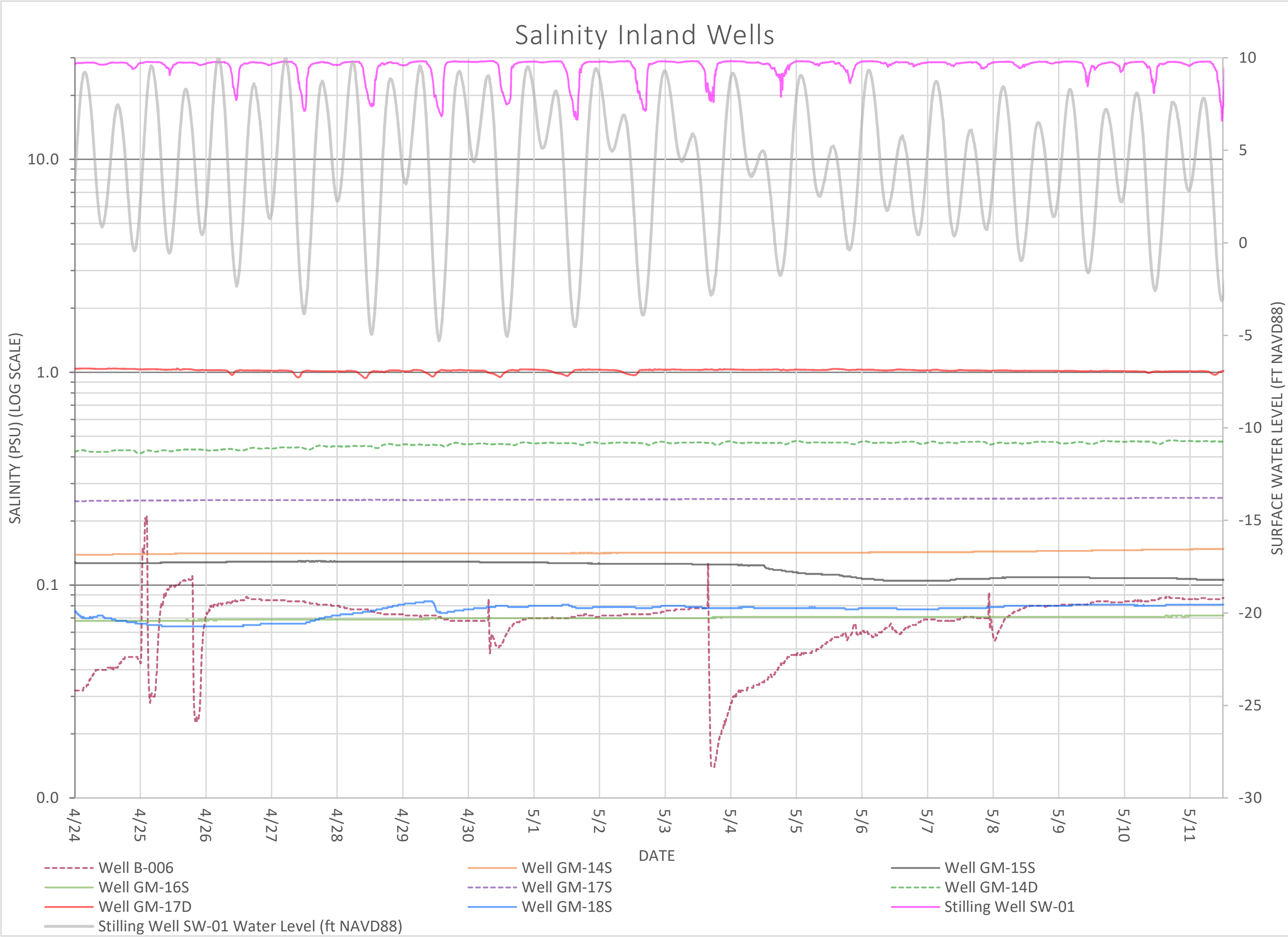


Figure 13. Shallow Waterfront Wells Salinity Concentration vs. Time
Site: Former BP Harbor Island Terminal

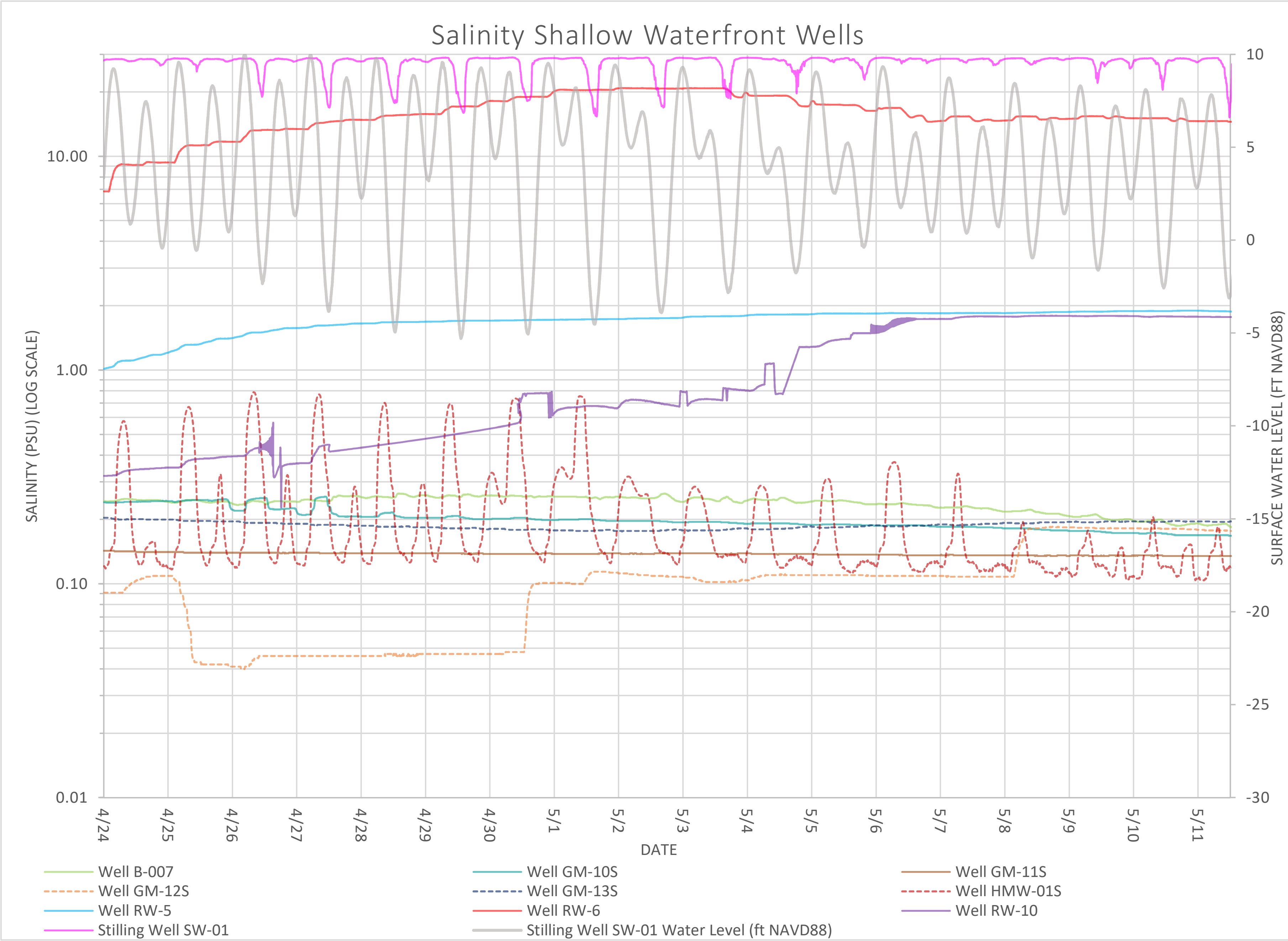


Figure 14. Deep Waterfront Wells Salinity Concentration vs. Time
Site: Former BP Harbor Island Terminal

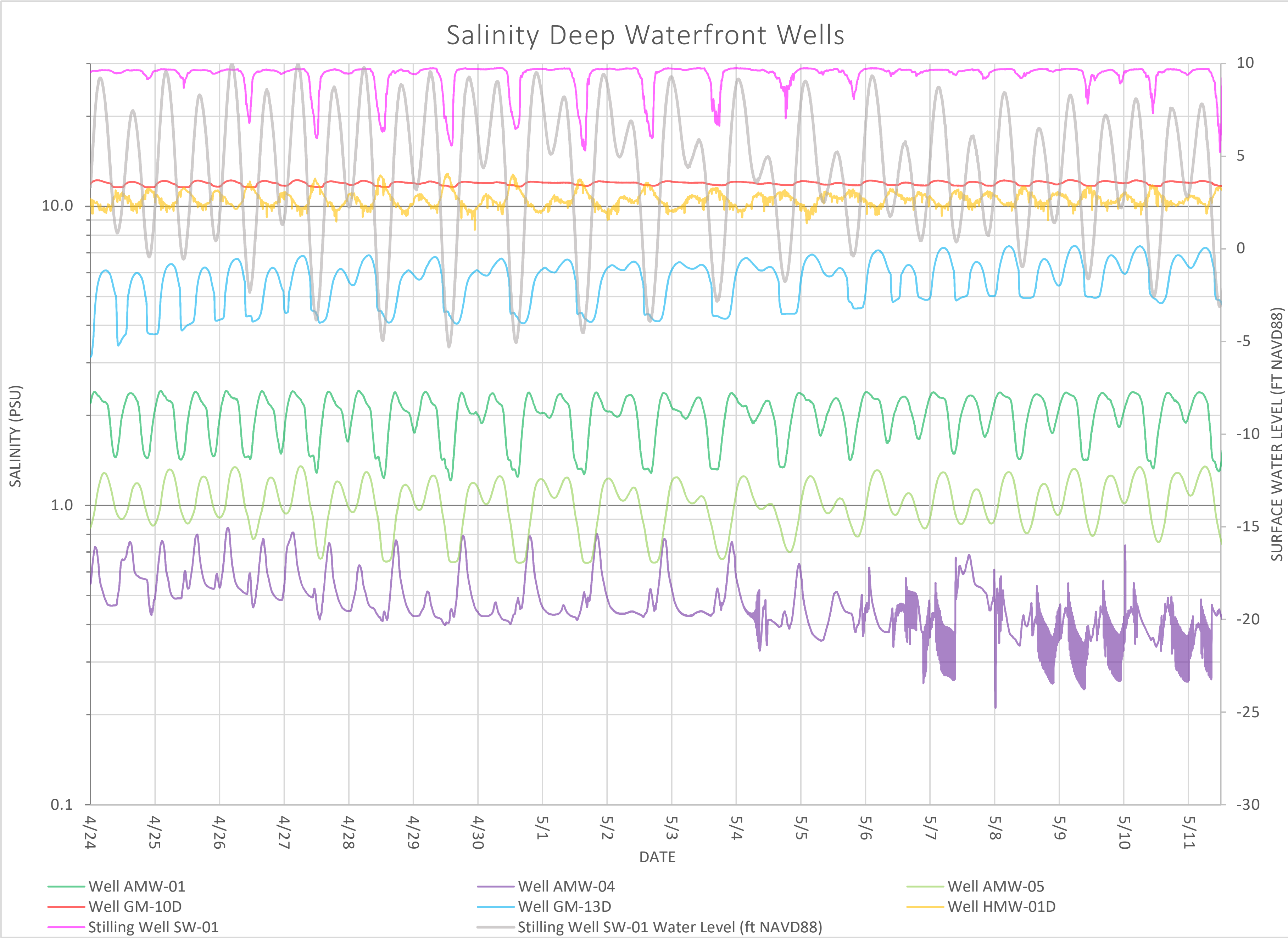


Figure 15. Waterfront Compliance Monitoring Salinity Concentration vs. Time
Site: Former BP Harbor Island Terminal

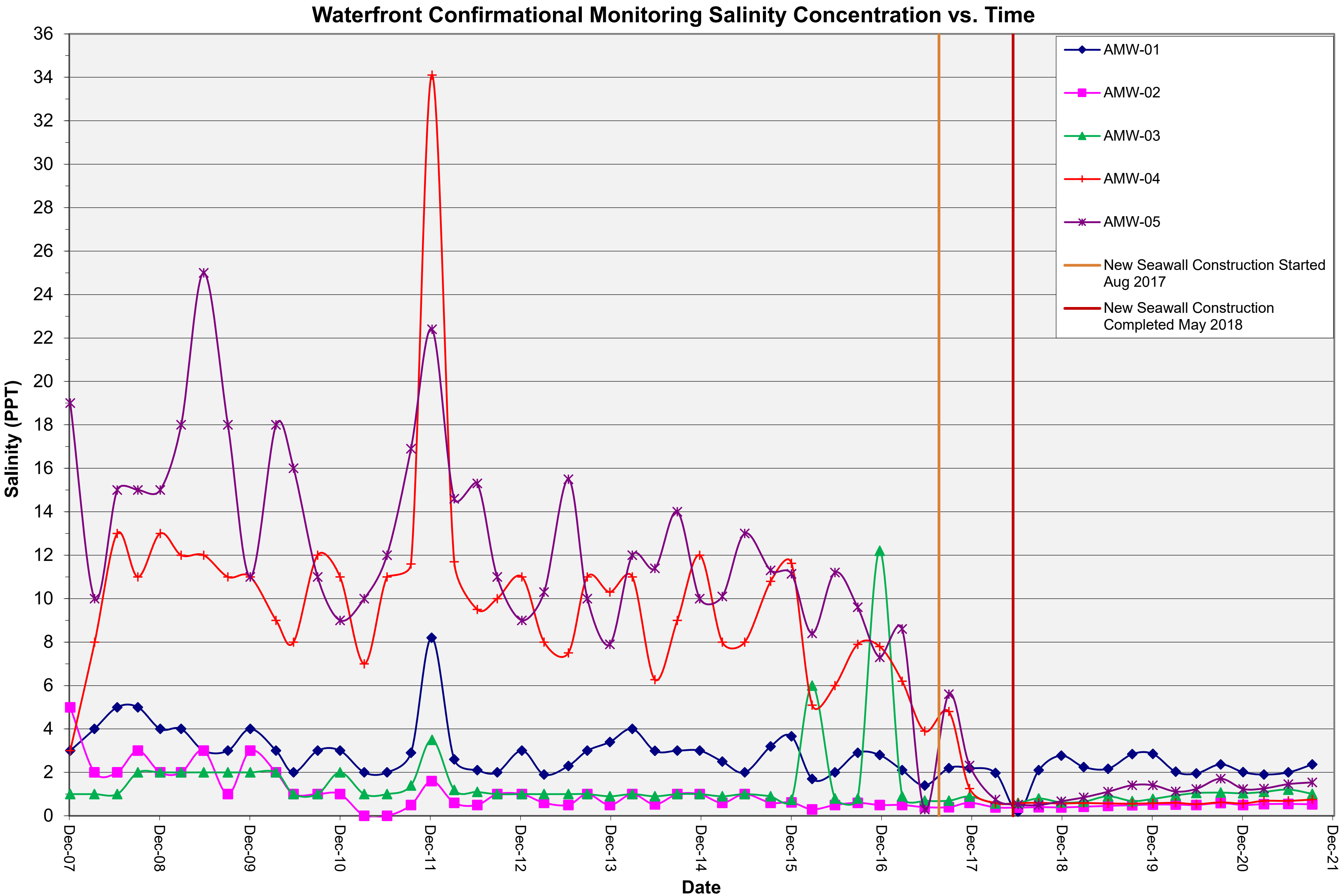
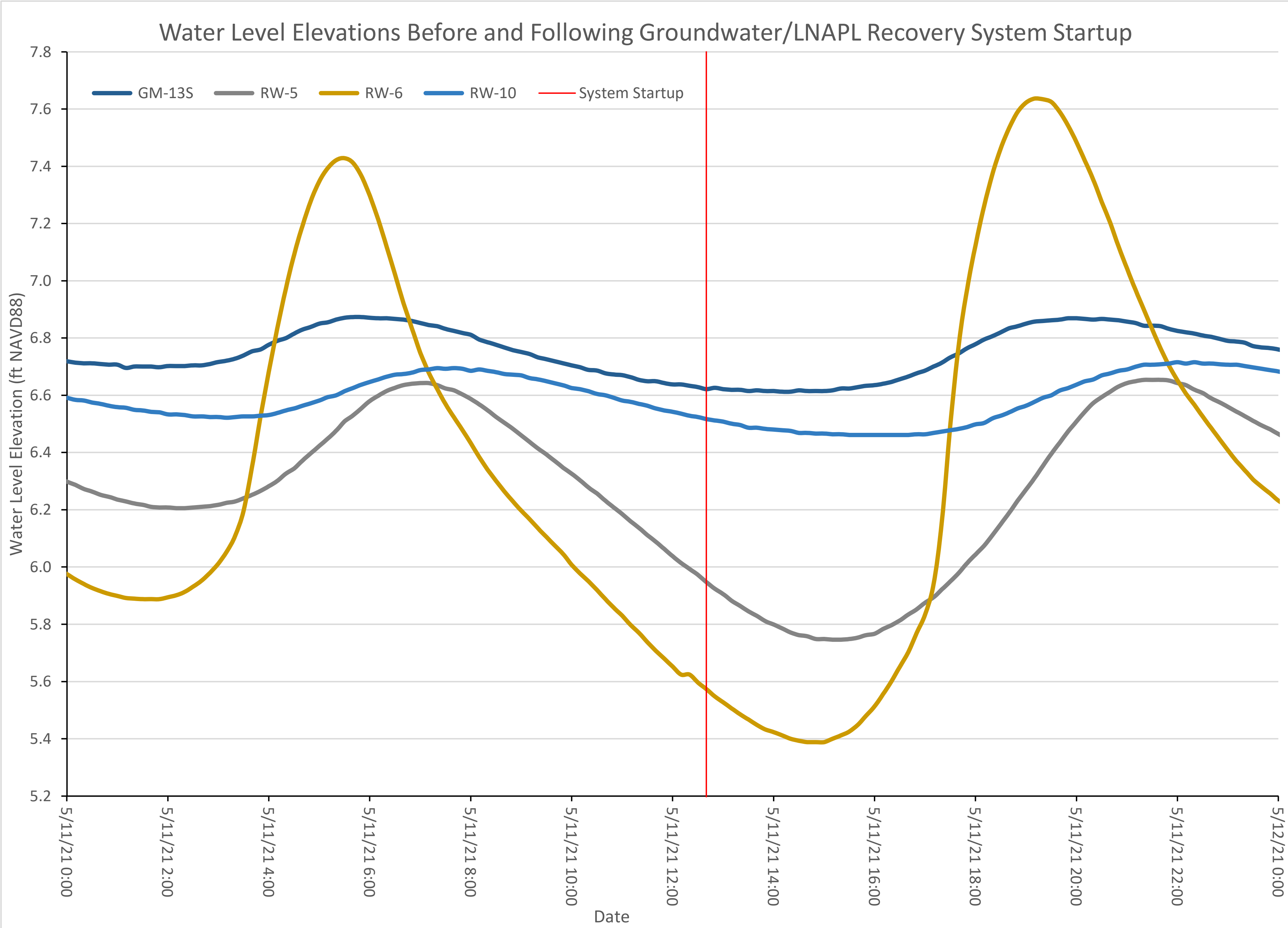


Figure 16. Pre and Post Recovery System Startup Hydrograph
Site: Former BP Harbor Island Terminal



APPENDIX A

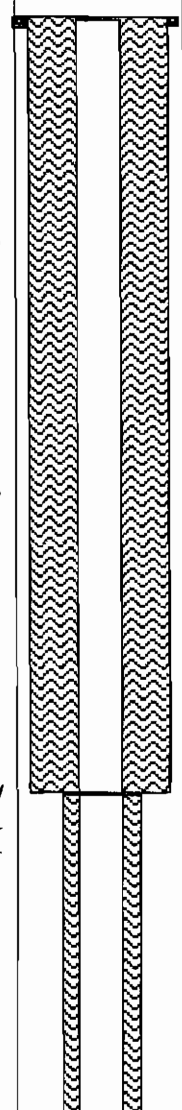
Boring Logs

TECH SOLV

TechSolv Consulting Group, Inc.
12930 NE 178th Street, Woodinville, WA 98072
(425) 402-8277 FAX (425) 402-7917

SOIL BORING LOG

Project Name and Location: ARCO 21T	**Boring Number:** AMW-01	**Page:** 1 of 2
	Contractor: Cascade Drilling, Inc.	**Drilling Method:** HSA
	Drill Crew: J. Goble	**Drill Rig:** CME-55
	Date Started: 12/5/00	**Date Finished:** 12/5/00
Surface Elevation:	**Logged by:** R. Honsberger	**Protective Cover:**
Top of Casing Elevation:		
Well Construction Information:		
Screened Interval (ft bgs): 40 to 30	**Screen:** 2" dia. 010 slot PVC	**Water Level While Drilling (ft bgs):** 6.5
Filter Pack Interval (ft bgs): 40 to 26	**Riser:** 2" dia. PVC	
Seal Interval (ft bgs): 26 to 21	**Seal Type:** bentonite	**Water Level at Completion (ft bgs):**
Grout Interval (ft bgs): 21 to 2	**Filter Pack:** 2/12 sand	

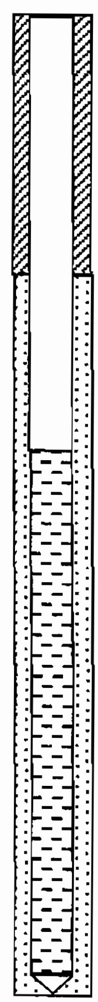
Depth (ft bgs)	Recov. (in.)	Blow Counts	Sample Interval	OVM / PID (ppm)	USCS Symbol	Well Construction	Sample Description
0							Asphalt 3" thick.
1							
2							
3							
4							
5	18	5/13/16	5/6.5	0.0	SP		Dark brown medium to fine sand moist with no hydrocarbon odor.
6							▽
7							
8							
9							
10	NM	15/16/30	10/11.5	NM	SP		Black medium to fine sand with few gravels saturated with water and has a strong hydrocarbon odor with a visible sheen on the sample.
11							
12							
13							
14							
15	NM	6/8/6	15/16.5	NM	SM/OH		Black silty clay saturated with water. 15.5 feet black medium to fine sand with rootlets slight hydrocarbon odor.
16							
17							
18							
19							
20	NR	16/16/15	20	NM			No recovery.

TECH SOLV

TechSolv Consulting Group, Inc.
12930 NE 178th Street, Woodinville, WA 98072
(425) 402-8277 FAX (425) 402-7917

SOIL BORING LOG

Project Name and Location: ARCO 21T	**Boring Number: AMW-01**	**Page: 2 of 2**
	Contractor: Cascade Drilling, Inc.	**Drilling Method: HSA**
	Drill Crew: J. Goble	**Drill Rig: CME-55**
	Date Started: 12/5/00	**Date Finished: 12/5/00**
Surface Elevation:	**Logged by: R. Honsberger**	**Protective Cover:**
Top of Casing Elevation:		
Well Construction Information:		
Screened Interval (ft bgs): 40 to 30	**Screen: 2" dia. 010 slot PVC**	**Water Level While Drilling (ft bgs): 6.5**
Filter Pack Interval (ft bgs): 40 to 26	**Riser: 2" dia. PVC**	
Seal Interval (ft bgs): 26 to 21	**Seal Type: bentonite**	**Water Level at Completion (ft bgs):**
Grout Interval (ft bgs): 21 to 2	**Filter Pack: 2/12 sand**	

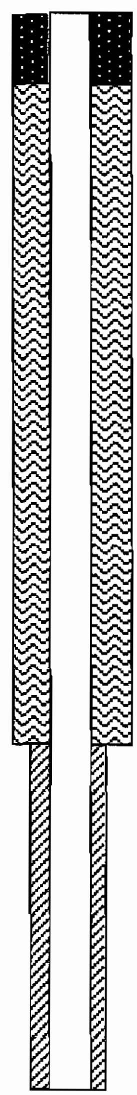
Depth (ft bgs)	Recov. (in.)	Blow Counts	Sample Interval	OVM / PID (ppm)	USCS Symbol	Well Construction	Sample Description
21	NR	19/ 24/25	25/ 26.5	NM			
22							
23							
24							
25	NR	19/ 24/25	25/ 26.5	NM			No recovery.
26							
27							
28							
29							
30	NR	15/17 /18	30/ 31.5	NM			No recovery.
31							
32							
33							
34							
35	NR	50 for2"	35/ 36.5	NM			No recovery.
36							
37							
38							
39							
40							
							End of boring at 40 feet.

TECHSOLV

TechSolv Consulting Group, Inc.
12930 NE 178th Street, Woodinville, WA 98072
(425) 402-8277 FAX (425) 402-7917

SOIL BORING LOG

Project Name and Location: ARCO 21T	**Boring Number:** AMW-04	**Page:** 1 of 2
	Contractor: Cascade Drilling, Inc.	**Drilling Method:** HSA
	Drill Crew: J. Goble	**Drill Rig:** CME-55
	Date Started: 12/8/00	**Date Finished:** 12/8/00
Surface Elevation:	**Logged by:** R. Honsberger/ C. Lybeer	**Protective Cover:**
Top of Casing Elevation:		
Well Construction Information:		
Screened Interval (ft bgs): 35 to 25	**Screen:** 2" dia. 010 slot PVC	**Water Level While Drilling (ft bgs):** 6.5
Filter Pack Interval (ft bgs): 35 to 21	**Riser:** 2" dia. PVC	
Seal Interval (ft bgs): 21 to 18	**Seal Type:** bentonite	**Water Level at Completion (ft bgs):**
Grout Interval (ft bgs): 18 to 5	**Filter Pack:** 2/12 sand	

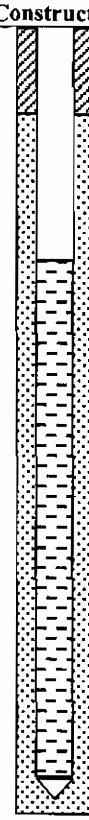
Depth (ft bgs)	Recov. (in.)	Blow Counts	Sample Interval	OVM / PID (ppm)	USCS Symbol	Well Construction	Sample Description
0							Asphalt 12 inches thick.
1							
2							
3							
4							
5	18	5/7/6	5/6.5	NM	SP		Brown medium to fine sand moist with strong hydrocarbon odor. ▽
6							
7							
8							
9							
10	18	6/5/8	10/ 11.5	NM	SP		Black medium to fine sand with a very strong hydrocarbon odor and a visible sheen on the sample.
11							
12							
13							
14							
15	18	6/9/ 10	15/ 16.5	NM	SM/ OH		Black to gray silty clay saturated with water and has a slight hydrocarbon odor.
16							Black fine to medium sand with rootlets saturated with water and has a slight hydrocarbon odor.
17							
18							
19							

T E C H S O L V

TechSolv Consulting Group, Inc.
12930 NE 178th Street, Woodinville, WA 98072
(425) 402-8277 FAX (425) 402-7917

SOIL BORING LOG

Project Name and Location: ARCO 21T	**Boring Number:** AMW-04	**Page:** 2 of 2
	Contractor: Cascade Drilling, Inc.	**Drilling Method:** HSA
	Drill Crew: J. Goble	**Drill Rig:** CME-55
	Date Started: 12/8/00	**Date Finished:** 12/8/00
Surface Elevation:	**Logged by:** R. Honsberger/ C. Lybeer	**Protective Cover:**
Top of Casing Elevation:		
Well Construction Information:		
Screened Interval (ft bgs): 35 to 25	**Screen:** 2" dia. 010 slot PVC	**Water Level While Drilling (ft bgs):** 6.5
Filter Pack Interval (ft bgs): 35 to 21	**Riser:** 2" dia. PVC	
Seal Interval (ft bgs): 21 to 18	**Seal Type:** bentonite	**Water Level at Completion (ft bgs):**
Grout Interval (ft bgs): 18 to 5	**Filter Pack:** 2/12 sand	

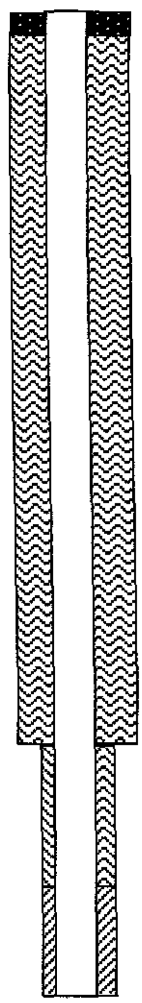
Depth (ft bgs)	Recov. (in.)	Blow Counts	Sample Interval	OVM / PID (ppm)	USCS Symbol	Well Construction	Sample Description
20							
21							
22							
23							
24							
25	NR	6/9/ 10	25/ 26.5	NM			No recovery.
26							
27							
28							
29							
30	NR	NR	30/ 31.5	NM			No recovery
31							
32							
33							
34							
35							End of Boring at 35 feet.

TECHSOLV

TechSolv Consulting Group, Inc.
12930 NE 178th Street, Woodinville, WA 98072
(425) 402-8277 FAX (425) 402-7917

SOIL BORING LOG

Project Name and Location: ARCO 21T	**Boring Number:** AMW-05	**Page:** 1 of 2
	Contractor: Cascade Drilling, Inc.	**Drilling Method:** HSA
	Drill Crew: J. Goble	**Drill Rig:** CME-55
	Date Started: 12/6/00	**Date Finished:** 12/6/00
Surface Elevation:	**Logged by:** R. Honsberger	**Protective Cover:**
Top of Casing Elevation:		
Well Construction Information:		
Screened Interval (ft bgs): 35 to 25	**Screen:** 2" dia. 010 slot PVC	**Water Level While Drilling (ft bgs):** 7.5
Filter Pack Interval (ft bgs): 35 to 21	**Riser:** 2" dia. PVC	
Seal Interval (ft bgs): 21 to 17	**Seal Type:** bentonite	**Water Level at Completion (ft bgs):**
Grout Interval (ft bgs): 17 to 4	**Filter Pack:** 2/12 sand	

Depth (ft bgs)	Recov. (in.)	Blow Counts	Sample Interval	OVM / PID (ppm)	USCS Symbol	Well Construction	Sample Description
0							Asphalt 7 inches thick.
1							
2							
3							
4							
5	12	10/10 /8	5/6	340	SP		Black medium to fine sand damp with slight hydrocarbon odor.
6							
7							▽
8							
9							
10	14	5/7/6	10/ 11.2	69	SP		Black medium to fine sand with few gravels, saturated with water and has a hydrocarbon odor.
11							
12							
13							
14							
15	18	5/5/6	15/ 16.5	4.6	SM/ OH		Black to gray silty clay saturated with water with a slight hydrocarbon odor. .
16							
17							
18							
19							

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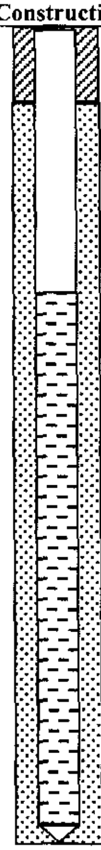
TechSolv Consulting Group, Inc.
12930 NE 178th Street, Woodinville, WA 98072
(425) 402-8277 FAX (425) 402-7917

SOIL BORING LOG

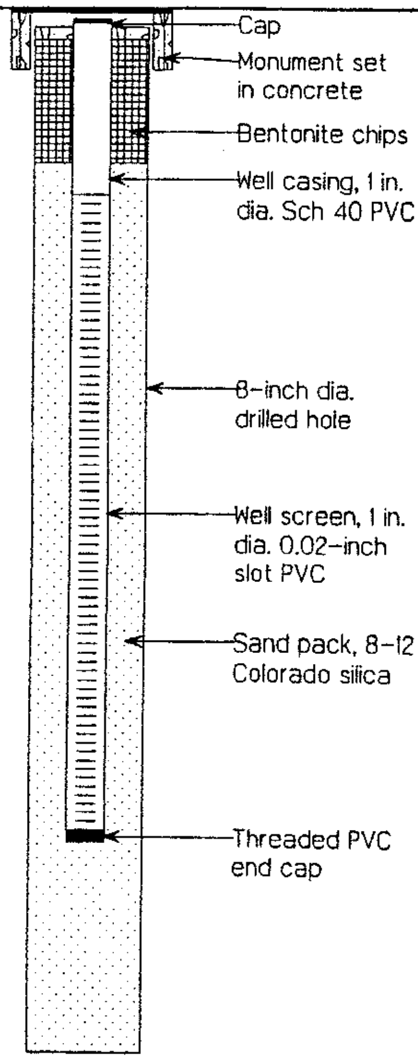
Project Name and Location: ARCO 21T	**Boring Number:** AMW-05	**Page:** 2 of 2
	Contractor: Cascade Drilling, Inc.	**Drilling Method:** HSA
	Drill Crew: J. Goble	**Drill Rig:** CME-55
	Date Started: 12/6/00	**Date Finished:** 12/6/00
Surface Elevation:	**Logged by:** R. Honsberger	**Protective Cover:**
Top of Casing Elevation:		
Well Construction Information:		
Screened Interval (ft bgs): 35 to 25	**Screen:** 2" dia. 010 slot PVC	**Water Level While Drilling (ft bgs):** 7.5
Filter Pack Interval (ft bgs): 35 to 21	**Riser:** 2" dia. PVC	
Seal Interval (ft bgs): 21 to 17	**Seal Type:** bentonite	**Water Level at Completion (ft bgs):**
Grout Interval (ft bgs): 17 to 4	**Filter Pack:** 2/12 sand	

Depth (ft bgs)	Recov. (in.)	Blow Counts	Sample Interval	OVM / PID (ppm)	USCS Symbol	Well Construction	Sample Description
20	18	5/5/6	20/ 21.5	0.0	SM		Black fine to medium sand saturated with water with no hydrocarbon odor.
21							
22							
23							
24							
25	NR	50 for 6	25/ 26.5	NM			No recovery.
26							
27							
28							
29							
30	NR	12/50	30/ 31.5	NM			No recovery.
31							
32							
33							
34							
35							End of boring at 35feet.

PROJECT NAME: ARCO TERMINAL NO. 21T
PROJECT NO: WA254.01

CLIENT NAME: ARCO PRODUCTS COMPANY
PROJECT LOCATION: SEATTLE, WASHINGTON
DATE STARTED: 23-FEB-93
DATE COMPLETED: 23-FEB-93
LOGGED BY: J. STRUTHERS
CHECKED BY: L. ROBERTS

SURFACE ELEV: 8.38feet
DATUM: NGVD (1929)
DRILL COMPANY: CASCADE DRILLING, INC.
DRILLER: SCOTT KRUEGER
DRILL METHOD: HOLLOW-STEM AUGER
SAMPLING METHOD: SPLIT SPOON (140-lb. hammer)

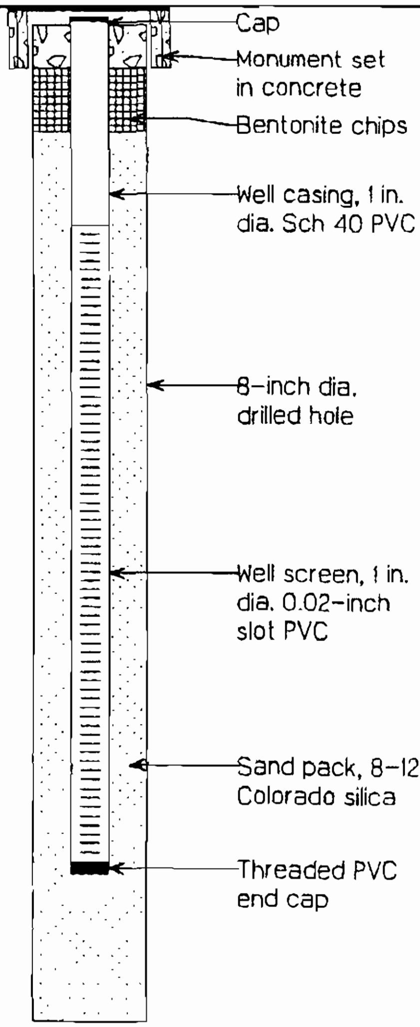
WELL CONSTRUCTION	DEPTH (feet)	BLOWS PER SIX IN.	SAMPLES AND GRAPHIC LOG	MATERIALS DESCRIPTION
				ASPHALT (2 inches).
				WELL-GRADED GRAVEL (GW) - Crushed gravel.
	3	NA		POORLY GRADED SAND (SP) - Brown to black, moist, medium-grained sand, little fine-grained sand, (no hydrocarbon odor, PID = 0.2 ppm).
		NA		
	6	11 13 15		As above, (no hydrocarbon odor, PID = 0.3 ppm). Ground water encountered during hand augering and sampling at 4.5 feet below land surface (bls).
				As above, wet, medium-grained sand, little fine gravel, medium dense, (strong hydrocarbon odor). Poor sample recovery due to fine gravels.
	9			Product sheen observed on hydropunch sampler. No hydropunch water sample collected.
		10 15 18		As above, wet, medium-grained sand, (poor recovery due to gravels, hydropunch screen).
	12			
	15	8 8 16		As above, wet, medium-grained sand, (strong hydrocarbon odor).
	18			Borehole terminated at 16.5 feet bls. Ground water encountered during drilling at 4.5 feet bls. No hydropunch water sample collected due to product sheen observed in sampler. Note: Blow counts taken below 4.5 feet bls using a 2.5-inch diameter split-spoon sampler driven with a 140-pound hammer falling 30 inches. Blow counts recorded for evaluating relative soil density only and are not appropriate for construction or structural design purposes. purposes.
	21			

PROJECT NAME: ARCO TERMINAL NO. 21T
PROJECT NO: WA254.01

CLIENT NAME: ARCO PRODUCTS COMPANY
PROJECT LOCATION: SEATTLE, WASHINGTON
DATE STARTED: 3-MAR-93
DATE COMPLETED: 3-MAR-93
LOGGED BY: A. AMR
CHECKED BY: L. ROBERTS

SURFACE ELEV: 8.47 feet
DATUM: NGVD (1929)
DRILL COMPANY: CASCADE DRILLING, INC.
DRILLER: ROY DRENNON
DRILL METHOD: HOLLOW-STEM AUGER
SAMPLING METHOD: SPLIT SPOON (140-lb. hammer)

WELL CONSTRUCTION



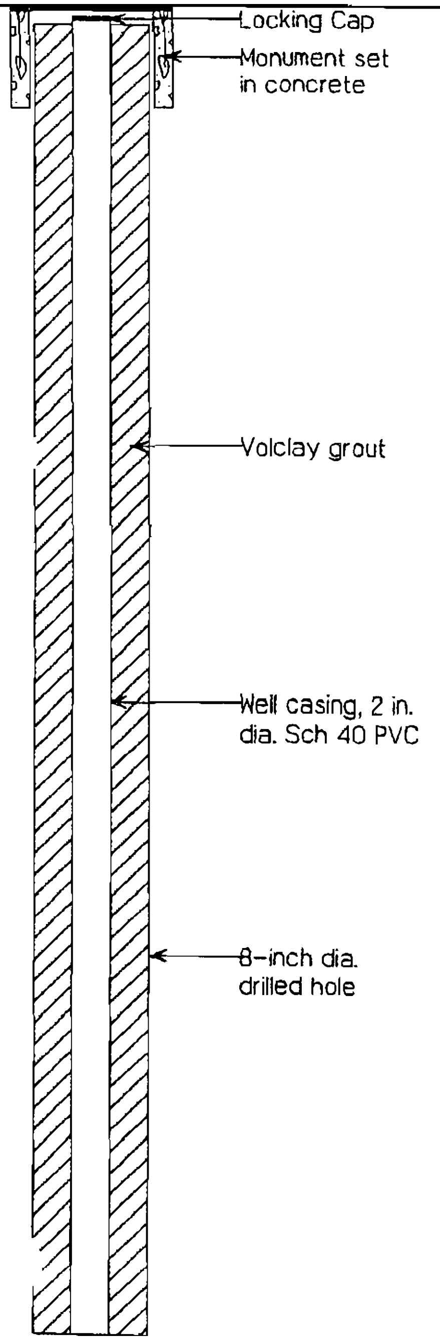
DEPTH (feet)	BLOWS PER SIX IN.	MATERIALS DESCRIPTION
		ASPHALT with crushed rock (4 inches).
	NA	POORLY GRADED SAND (SP) - Black, moist, medium-grained sand, trace fine-grained sand, trace silt, (no hydrocarbon odor, PID = 4 ppm).
3	NA	As above, (moderate hydrocarbon odor, PID = 9 ppm).
		Saturated soils, strong hydrocarbon odor at 4.5 to 5.0 feet below land surface (bls).
		Ground water encountered at 5 feet bls during hand augering and sampling to 5 feet bls.
6		As above, wet, (strong hydrocarbon odor).
		Hydropunch water sample collected from 6 to 9 feet bls during drilling (14.5 parts per thousand salinity).
9	15 19 25	POORLY GRADED SAND (PS) - Black, wet, medium-grained sand, trace fine gravel, trace silt, dense, (strong hydrocarbon odor).
12		
15	8 5 4	As above, wet, (15.0 parts per thousand salinity).
18		Borehole terminated at 16 feet bls. Ground water encountered during hand augering at 5 feet bls. Hydropunch water sample collected to 9 feet bls during drilling.
21		Note: Blow counts taken below 5 feet bls using a 2.5-inch diameter split-spoon sampler driven with a 140-pound hammer falling 30 inches. Blow counts recorded for evaluating relative soil density only and are not appropriate for construction or structural design purposes.

PROJECT NAME: ARCO TERMINAL NO. 21T
IECT NO: WA0254.002

CLIENT NAME: ARCO PRODUCTS COMPANY
PROJECT LOCATION: SEATTLE, WASHINGTON
DATE STARTED: 24-JUNE-93
DATE COMPLETED: 24-JUNE-93
LOGGED BY: G. STOYKA
CHECKED BY: L. ROBERTS

SURFACE ELEV: 8.55feet
DATUM: NGVD (1929)
DRILL COMPANY: CASCADE DRILLING, INC.
DRILLER: STEVE BUTLER
DRILL METHOD: HOLLOW-STEM AUGER
SAMPLING METHOD: SPLIT SPOON (140-lb. hammer)

WELL CONSTRUCTION

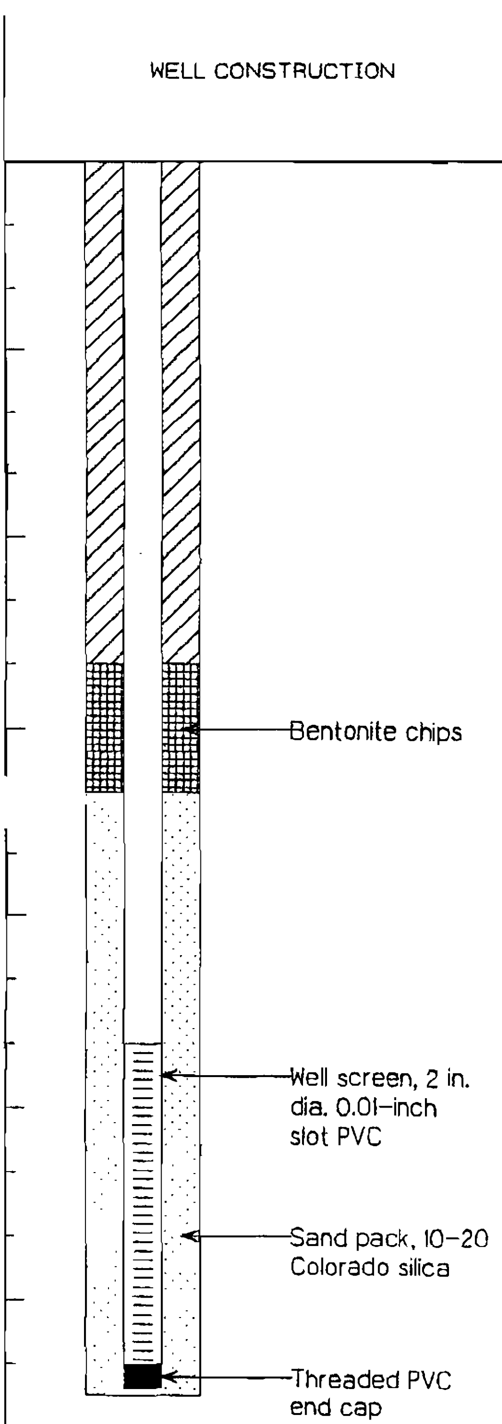


DEPTH (feet)	BLOWS PER SIX IN.	MATERIALS DESCRIPTION
		ASPHALT (3 inches)
		Cobbles, bricks, gravel and sand, (FILL).
	NA	POORLY GRADED SAND (SP) - Brown to black, slightly moist, fine- to medium-grained sand, (no hydrocarbon odor, PID = 1.7 ppm).
3		
	NA	As above, (PID = 1.1 ppm).
6		⊻ Hand augered and sampled to 6.25 feet below land surface (bls). Groundwater encountered at 6.25 feet bls.
		As above, wet.
9		
	8 10 12	As above, wet, medium-dense, trace silt, (marine odor).
12	4 6 11	As above, wet, medium dense, fine-grained sand (90%), medium-grained sand (10%).
		SILTY SAND (SM) - Grey, wet, medium-dense, fine-grained sand, silt, rootlets, (marine odor).
15	3 5 7	As above, silt lenses, wood chips and roots
	3	As above, (strong sulfur odor).
18	11 12	SILT with sand (ML) - Grey to black, wet, medium stiff, silt, with fine-grained sand, rootlets, wood fragments, (strong sulfur odor).
	6 11	POORLY GRADED SAND (SP) - Black to dark brown, wet, medium-dense, fine- to medium-grained sand, abundant shell and grass fragments, (weak marine odor).
21	15	

PROJECT NAME: ARCO TERMINAL NO. 21T

JECT NO: WA0254.002

LOG OF GM-10D



DEPTH (feet)	BLOWS PER SIX IN.	MATERIALS DESCRIPTION
		As above, black to dark grey, fine-grained sand, with silt, (strong sulfur odor).
	3 6 9	As above, brown to black, fine- to medium-grained sand, shell and wood fragments, (no hydrocarbon odor).
24		
	4 5 9	As above, abundant shell and wood fragments, (slight marine odor).
		As above, fine- to medium-grained sand, with silt.
27		
	5 12 14	As above.
30	9 15 19	As above, (weak marine odor).
	4	As above.
33	4 7	
		SILTY SAND (SM) - Grey to black, wet, medium-dense, fine-grained sand, silt, abundant wood fragments, (weak marine odor).
	4 5	POORLY GRADED SAND (SP) - Grey to black, wet, medium-dense, fine- to medium-grained sand, abundant shell fragments, (no hydrocarbon odor). Collected sample for grain-size analyis.
36	16	
	5 7 10	As above, few shell fragments.
39		
		Borehole terminated at 40.5 feet bls. Groundwater encountered during drilling at 6.25 feet bls.
42		Note: Blow counts taken below 6.25 feet bls using a 2.5-inch diameter split-spoon sampler driven with a 140-pound hammer falling 30 inches. Blow counts recorded for evaluating relative soil density only and are not appropriate for construction or structural design purposes.
45		

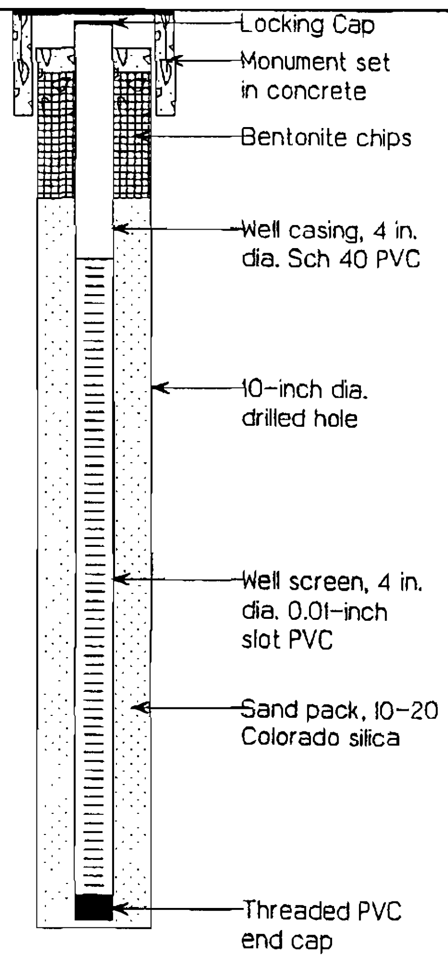
PROJECT NAME: ARCO TERMINAL NO. 21T
PROJECT NO: WA0254.002

LOG OF GM-10S
Page 1 of 1

CLIENT NAME: ARCO PRODUCTS COMPANY
PROJECT LOCATION: SEATTLE, WASHINGTON
DATE STARTED: 24-JUNE-93
DATE COMPLETED: 24-JUNE-93
LOGGED BY: G. STOYKA
CHECKED BY: L. ROBERTS

SURFACE ELEV: 8.71feet
DATUM: NGVD (1929)
DRILL COMPANY: CASCADE DRILLING, INC.
DRILLER: STEVE BUTLER
DRILL METHOD: HOLLOW-STEM AUGER
SAMPLING METHOD: SPLIT SPOON (140-lb. hammer)

WELL CONSTRUCTION



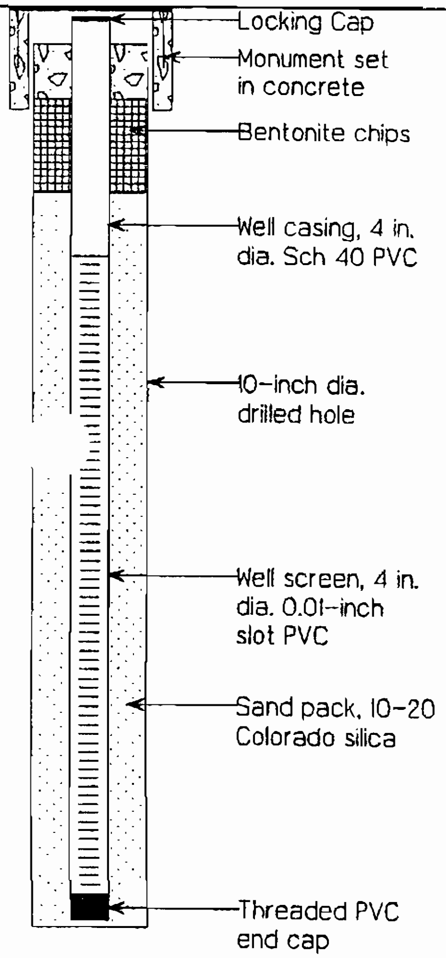
DEPTH (feet)	BLOWS PER SIX IN.	MATERIALS DESCRIPTION
0		ASPHALT (3-inches)
		Cobbles, bricks, gravel and sand, (FILL).
	NA	POORLY GRADED SAND (SP) - Brown to black, slightly moist, fine- to medium-grained sand, (no hydrocarbon odor, PID = 1.5 ppm).
3	NA, NA	As above, (PID = 4 ppm). Hand augered and sampled to 5 feet below land surface (bls).
6		⊻ Groundwater encountered at 6.25 feet bls.
9	8, 10, 6	As above, wet, medium-dense, trace silt, wood fragments, (marine odor). Collected sample for grain-size analysis.
12	4, 6, 11	As above, wet, more silt, (no hydrocarbon odor).
15		Borehole terminated at 14.5 feet bls. Groundwater encountered during drilling at 6.25 feet bls.
18		Note: Blow counts taken below 6.25 feet bls using a 2.5-inch diameter split-spoon sampler driven with a 140-pound hammer falling 30 inches. Blow counts recorded for evaluating relative soil density only and are not appropriate for construction or structural design purposes.
21		

PROJECT NAME: ARCO TERMINAL NO. 21T
T NO: WA0254.002

CLIENT NAME: ARCO PRODUCTS COMPANY
PROJECT LOCATION: SEATTLE, WASHINGTON
DATE STARTED: 28-JUNE-93
DATE COMPLETED: 28-JUNE-93
LOGGED BY: J. SADLER
CHECKED BY: L. ROBERTS

SURFACE ELEV: 8.51feet
DATUM: NGVD (1929)
DRILL COMPANY: CASCADE DRILLING, INC.
DRILLER: STEVE BUTLER
DRILL METHOD: HOLLOW-STEM AUGER
SAMPLING METHOD: SPLIT SPOON (140-lb. hammer)

WELL CONSTRUCTION



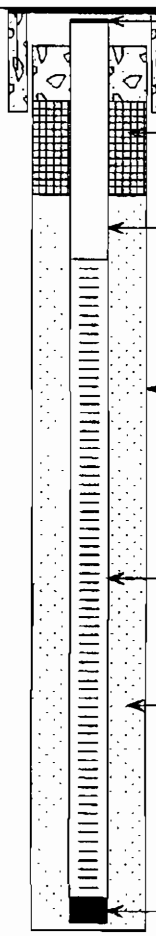
DEPTH (feet)	BLOWS PER SIX IN.	MATERIALS DESCRIPTION
		ASPHALT (3-inches)
		Gravel, gray to green, (FILL).
	NA	POORLY GRADED SAND (SP) - Dark brown, moist, fine- to medium-grained sand, (hydrocarbon odor, PID = 58 ppm).
3	NA	As above, dark gray to black, (hydrocarbon odor, PID = 416 ppm).
6		Hand augered and sampled to 6 feet below land surface (bls). Groundwater encountered at 6 feet bls.
	6 6 6	As above, wet, medium-dense, (diesel odor).
9		
	2 2 5	As above, loose, (slight diesel odor). Collected sample for grain-size analysis.
12	2 3 6	As above, fine-grained sand with silt layer (2-inches), trace fibrous organics.
		As above, no silt, no fibrous organics.
15		Borehole terminated at 14.5 feet bls. Groundwater encountered during drilling at 6 feet bls.
		Note: Blow counts taken below 6 feet bls using a 2.5-inch diameter split-spoon sampler driven with a 140-pound hammer falling 30 inches. Blow counts recorded for evaluating relative soil density only and are not appropriate for construction or structural design purposes.
18		
21		

PROJECT NAME: ARCO TERMINAL NO. 21T
PROJECT NO: WA0254.002

CLIENT NAME: ARCO PRODUCTS COMPANY
PROJECT LOCATION: SEATTLE, WASHINGTON
DATE STARTED: 28-JUNE-93
DATE COMPLETED: 28-JUNE-93
LOGGED BY: J. SADLER
CHECKED BY: L. ROBERTS

SURFACE ELEV: 8.60feet
DATUM: NGVD (1929)
DRILL COMPANY: CASCADE DRILLING, INC.
DRILLER: STEVE BUTLER
DRILL METHOD: HOLLOW-STEM AUGER
SAMPLING METHOD: SPLIT SPOON (140-lb. hammer)

WELL CONSTRUCTION



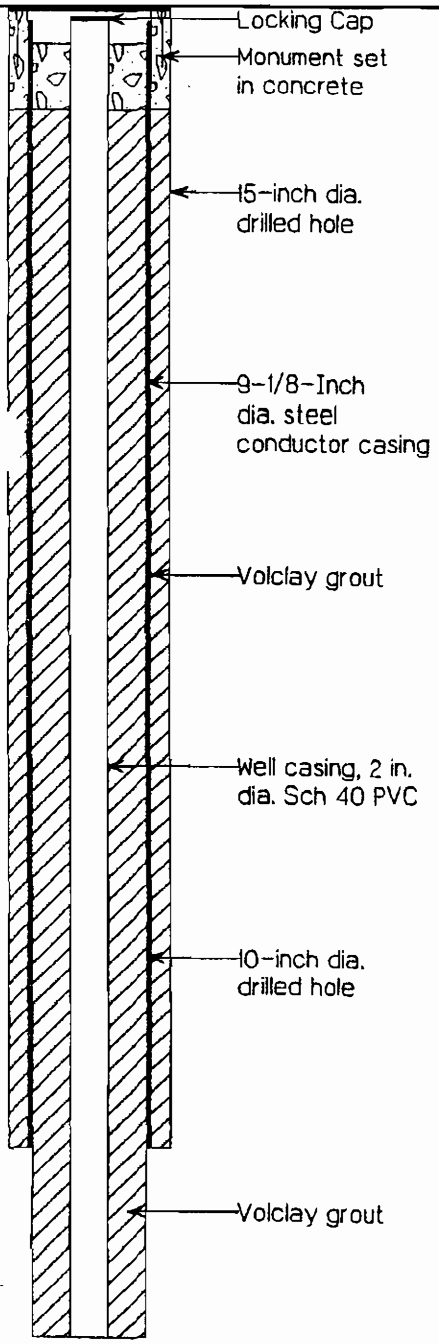
DEPTH (feet)	BLOWS PER SIX IN.	MATERIALS DESCRIPTION
0		ASPHALT (3-inches)
	NA	SILTY SAND with gravel (SM) - Damp to moist, sand, silt and gravel, (no hydrocarbon odor, PID = 2 ppm).
3	NA	POORLY GRADED SAND (SP) - Gray to brown, moist to wet, fine- to medium-grained sand, (slight hydrocarbon odor, PID = 7 ppm).
6		Hand augered and sampled to 6 feet below land surface (bls). Groundwater encountered at 6 feet bls.
	4 4 4	As above, black, wet, loose, (diesel odor).
9		
	4 40 6	As above, dense, (slight diesel odor). Collected sample for grain-size analysis.
12		
	2 2 8	As above, gray, medium-dense, fine-grained sand with silt layer (2-inches thick) with fibrous organics, (no hydrocarbon odor).
		As above, no silt, no organics.
15		Borehole terminated at 14.5 feet bls. Groundwater encountered during drilling at 6 feet bls.
		Note: Blow counts taken below 6 feet bls using a 2.5-inch diameter split-spoon sampler driven with a 140-pound hammer falling 30 inches. Blow counts recorded for evaluating relative soil density only and are not appropriate for construction or structural design purposes.
18		
21		

PROJECT NAME: ARCO TERMINAL NO. 21T
[PRO]JECT NO: WA0254.002

CLIENT NAME: ARCO PRODUCTS COMPANY
PROJECT LOCATION: SEATTLE, WASHINGTON
DATE STARTED: 2-JULY-93
DATE COMPLETED: 12-JULY-93
LOGGED BY: G. STOYKA/D. BRADLEY
CHECKED BY: L. ROBERTS

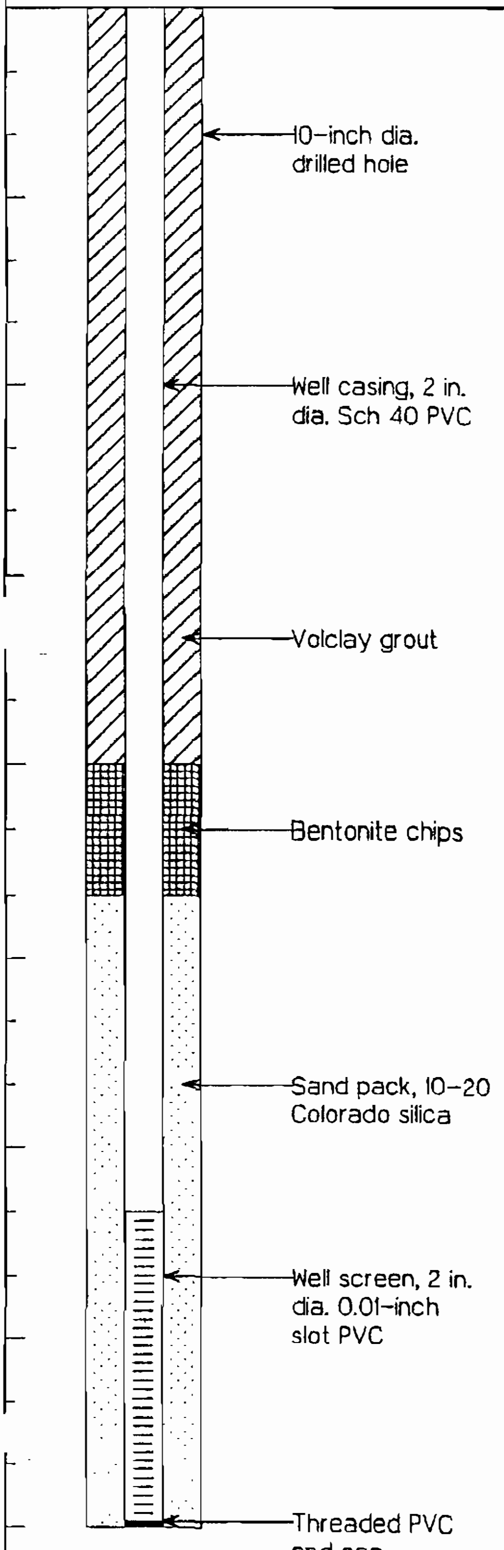
SURFACE ELEV: 12.32feet
DATUM: NGVD (1929)
DRILL COMPANY: CASCADE DRILLING, INC.
DRILLER: DON MINER
DRILL METHOD: HOLLOW-STEM AUGER
SAMPLING METHOD: SPLIT SPOON (140-lb. hammer)

WELL CONSTRUCTION



DEPTH (feet)	BLOWS PER SIX IN.	MATERIALS DESCRIPTION
		CONCRETE (5-Inches).
	NA	POORLY GRADED SAND (SP) - Brown to black, slightly moist, fine- to medium-grained sand, (no hydrocarbon odor).
3		
	NA	As above.
6		
9		
12	NA	▽ As above, gray to black. Free product (0.01 feet) measured on water-table using an acrylic bailer. Hand augered to 12 feet below land surface (bls). Ground water encountered at 12 feet bls.
15	8 4 6	As above, wet, medium-dense.
18		
21	5 3 2	As above.

WELL CONSTRUCTION



DEPTH (feet)	BLOWS PER SIX IN.	MATERIALS DESCRIPTION
		SILTY SAND (SM) - Brown to black, wet, loose, sand, silt, some clay of low plasticity (less than 5 %), (diesel odor).
	14, 12, 13	POORLY GRADED SAND (SP) - Brown to black, wet, medium-dense, sand, some silt, non-plastic, (diesel odor).
24		
	8, 7, 5	As above, no silt.
27	12, 37, 50	As above, very dense.
30	8, 14, 21	As above, dense, some silt.
33	21, 32, 35	As above, very dense, no silt.
36	15, 20, 25	As above, dense.
	8, 10, 12	As above, medium-dense, (slight diesel odor).
39	12, 25, 22	As above, dense, (no hydrocarbon odor).
42	13, 17, 21	As above. Collected sample for grain-size analysis.
45		

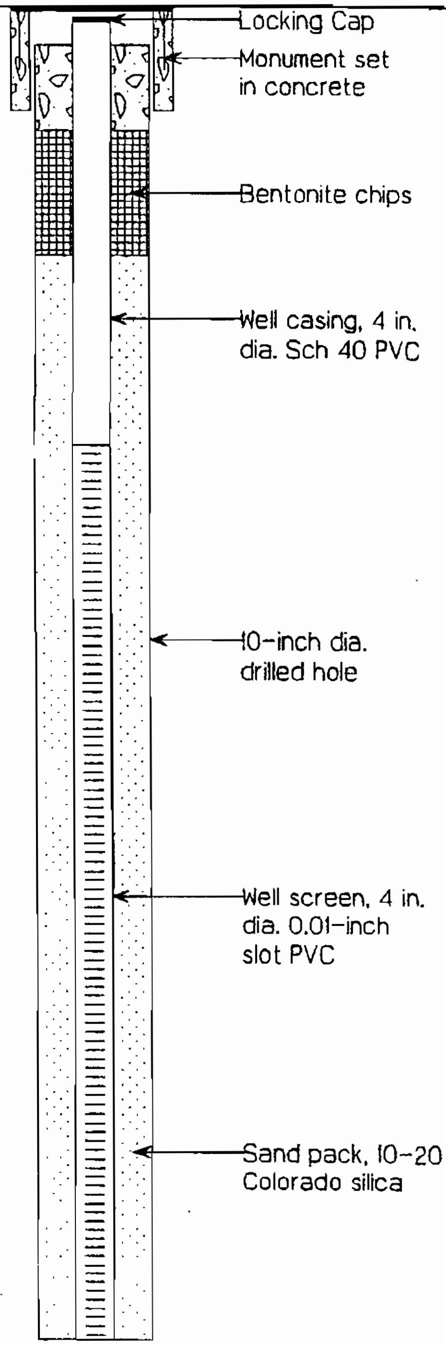
Borehole terminated at 45.5 feet bls. Groundwater encountered during drilling at 12 feet bls. Blow counts taken below 12 feet bls using a 2.5-inch diameter split-spoon split-spoon sampler driven with a 140-pound hammerfalling 30 inches. Blow counts recorded for evaluating relative soil density only and are not appropriate for construction or structural design purposes.

PROJECT NAME: ARCO TERMINAL NO. 21T
'ECT NO: WA0254.002

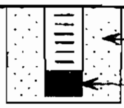
CLIENT NAME: ARCO PRODUCTS COMPANY
PROJECT LOCATION: SEATTLE, WASHINGTON
DATE STARTED: 30-JUNE-93
DATE COMPLETED: 30-JUNE-93
LOGGED BY: G. STOYKA
CHECKED BY: L. ROBERTS

SURFACE ELEV: 12.35feet
DATUM: NGVD (1929)
DRILL COMPANY: CASCADE DRILLING, INC.
DRILLER: DON MINER
DRILL METHOD: HOLLOW-STEM AUGER
SAMPLING METHOD: SPLIT SPOON (140-lb. hammer)

WELL CONSTRUCTION



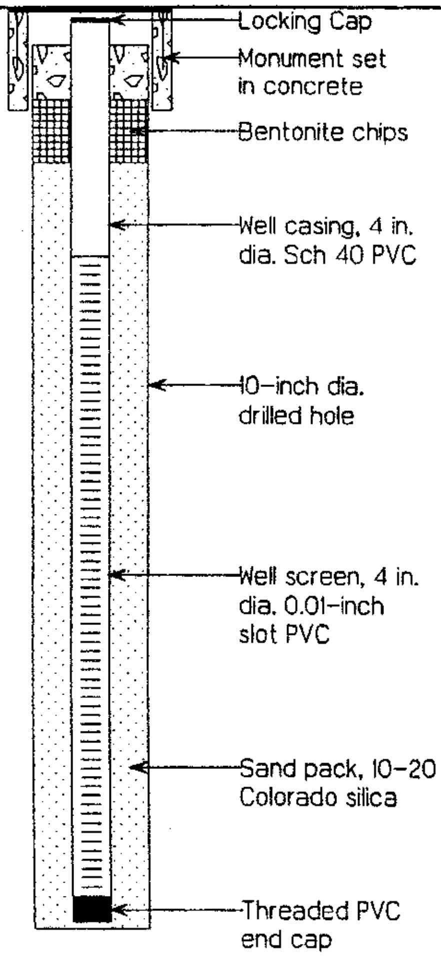
DEPTH (feet)	BLOWS PER SIX IN.	MATERIALS DESCRIPTION
		CONCRETE (5-Inches).
	NA	POORLY GRADED SAND (SP) - Brown to black, slightly moist, fine- to medium-grained sand, abundant shell fragments (1-inch diameter), (no hydrocarbon odor, PID = 2 ppm).
3		
	NA	As above.
6		
9		
	NA	As above, gray to black, sheen observed on disposable bailer, (strong hydrocarbon odor, PID = 229 ppm).
12		Hand augered to 12 feet below land surface (bls). Groundwater encountered at 12 feet bls.
15	2 4 12	As above, medium-dense, no shells.
18	4 4 5	As above, loose. Collected sample for grain-size analysis.
21	4 5 7	As above, medium-dense, trace silt, (moderate hydrocarbon odor).

WELL CONSTRUCTION	DEPTH (feet)	BLOWS PER SIX IN.	SAMPLES AND GRAPHIC LOG	MATERIALS DESCRIPTION
				SILT with sand (ML) - Gray, wet, stiff, silt, fine-grained sand, trace clay, (weak hydrocarbon odor).
				Borehole terminated at 22.5 feet bls. Groundwater encountered during drilling at 12 feet bls. Note: Blow counts taken below 12 feet bls using a 2.5-inch diameter split-spoon sampler driven with a 140-pound hammer falling 30 inches. Blow counts recorded for evaluating relative soil density only and are not appropriate for construction or structural design purposes.
	24			
	27			
	30			
	33			
	36			
	39			
	42			
	45			

PROJECT NAME: ARCO TERMINAL NO. 21T
PROJECT NO: WA0254.002

CLIENT NAME: ARCO PRODUCTS COMPANY	SURFACE ELEV: 8.64feet
PROJECT LOCATION: SEATTLE, WASHINGTON	DATUM: NGVD (1929)
DATE STARTED: 2-JULY-93	DRILL COMPANY: CASCADE DRILLING, INC.
DATE COMPLETED: 2-JULY-93	DRILLER: DON MINER
LOGGED BY: G. STOYKA	DRILL METHOD: HOLLOW-STEM AUGER
CHECKED BY: L. ROBERTS	SAMPLING METHOD: SPLIT SPOON (140-lb. hammer)

WELL CONSTRUCTION

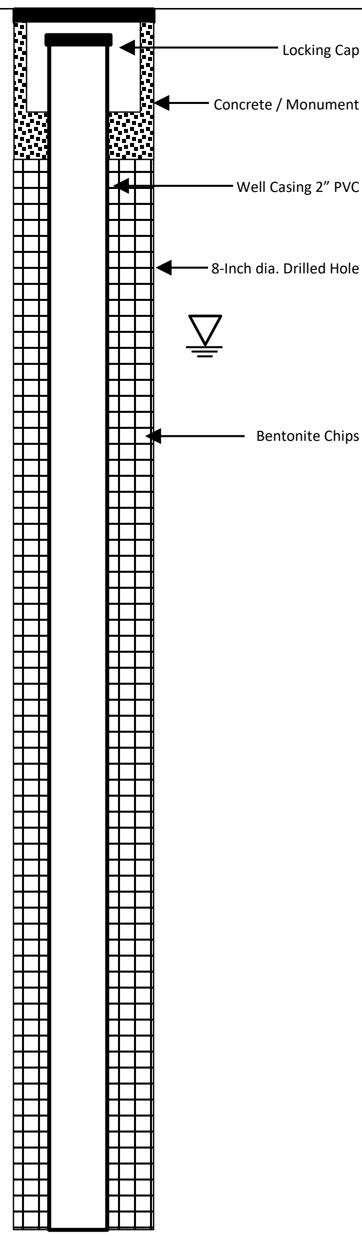


DEPTH (feet)	BLOWS PER SIX IN.	MATERIALS DESCRIPTION
	NA	POORLY GRADED SAND (SP) - Brown to black, slightly moist, fine- to medium-grained sand, with gravel, (no hydrocarbon odor, PID = 0.2 ppm). (FILL).
		WELL-GRADED GRAVEL - Light to dark brown, slightly moist, gravel, fine- to medium-grained sand, (no hydrocarbon odor).
3	NA	POORLY GRADED SAND (SP) - Gray to black, slightly moist, fine- to medium-grained sand, (hydrocarbon odor, PID = 248 ppm).
		As above, (strong hydrocarbon odor).
6		Hand augered and sampled to 5.5 feet below land surface (bls). Groundwater encountered at 5.5 feet bls.
	8 7 13	SILT with sand (ML) - Gray to black with red streaks, wet, very stiff, silt, fine-grained sand, (strong hydrocarbon odor).
9	1 2 1	POORLY GRADED SAND (SP) - Gray to black, wet, medium-dense, fine-to medium-grained sand, (strong hydrocarbon odor).
		As above, very loose. Collected sample for grain-size analysis.
12	4 6 5	As above, (moderate hydrocarbon odor).
		SILT with sand (ML) - Gray, wet, stiff, silt, fine-grained sand, wood fragments, (moderate hydrocarbon odor).
15		Borehole terminated at 14.5 feet bls. Groundwater encountered during drilling at 5.5 feet bls.
18		Note: Blow counts taken below 5.5 feet bls using a 2.5-inch diameter split-spoon sampler driven with a 140-pound hammer falling 30 inches. Blow counts recorded for evaluating relative soil density only and are not appropriate for construction or structural design purposes.
21		

Soil Boring Log

Project Name and Location: **Former BP Harbor Island Terminal, Plant 1** **1652 SW Lander Street, Seattle, WA 98134**	Boring Number: **GM-14D**	Page: 1 of 2
	Contractor: **Cascade Drilling**	Drilling Method: **Hollow Stem Auger**
	Drill Crew: **J. Goble, C. Jones**	Drill Rig: **CME-75**
	Date Started: **3/26/2021**	Date Completed: **3/26/2021**
Surface Elevation: **11.71 feet (NAVD88)**	Logged by: **E. Lottsfeldt**	Protective Cover: **8" Morris Flush Mount Monument**
Top of Casing Elevation: **11.22 feet (NAVD88)**		
Surveyed Coordinates (NAD 83): Northing: **216080.4**	Easting: **1264432.8**	
Screened Interval (ft bgs): **35 - 40**	Screen: **5' - 2" dia. 010 Slot PVC**	Water Level While Drilling (ft bgs): **6'**
Filter Pack Interval (ft bgs): **33 - 41.5**	Riser: **35' - 2" dia. PVC**	
Seal Interval (ft bgs): **3 - 33**	Seal Type: **Bentonite Chips**	Water Level at Completion (ft bgs): **6'**
Grout Interval (ft bgs): **NA**	Filter Pack: **2/12 Sand**	

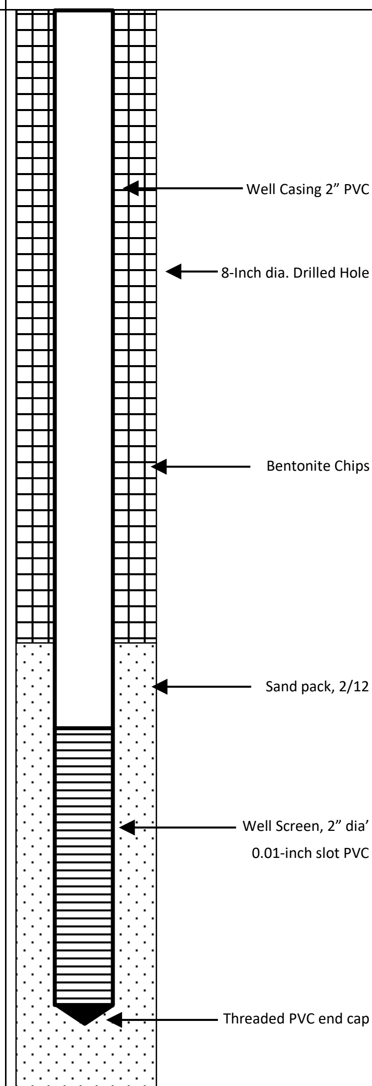
Depth (ft bgs)	Recovery(in.)	Blow Counts	Sample Interval	OVM/PID (ppm)	Sheen Test: NS: none, SS: slight, MS: moderate, HS: heavy	USCS Symbol	Well Construction	Sample Description: Lithology, color, constituents, density, moisture, other features, (interpretation)
								Crushed gravel, 6 inches.
1								
2								Soft clear with vacuum truck to 6 feet.
3								
4								
5		3				SP		SAND (SP), dark gray, 100% fine to medium sand, Loose, wet, moderate hydrocarbon odor, (fill)
6	18"	3		12	HS	SP		
		3				SP		
7								
8								
9								
10		3				SP		Same as above, mild hydrocarbon odor.
11	18"	4		70	HS	SP		
		5				SP		
12								
13								
14								
15		5				SP		Same as above, mild hydrocarbon odor.
16	18"	6		34	MS	SP		
		7				SP		
17								
18								
19								
20		6				SP		Same as above, mild hydrocarbon odor (native)
21	18"	7		5	SS	SP		
		7				SP		
22								



Project Name and Location: **Former BP Harbor Island Terminal, Plant 1** **1652 SW Lander Street, Seattle, WA 98134**	Boring Number: **GM-14D**	Page: 2 of 2

Depth (ft bgs)	Recovery(in.)	Blow Counts	Sample Interval	OVM/PID (ppm)	Sheen Test: NS: none, SS: slight, MS: moderate, HS: heavy	USCS Symbol	Sample Description: Lithology, color, constituents, density, moisture, other features, (interpretation)
23							
24							
25		7	25–26.5			SP	Same as above, very dark gray to black sand,
26	18"	7		0	NS	SP	trace shell fragments, slight hydrogen sulfide
		7				SP	odor, (native)
27							
28							
29							
30		7	30–31.5			SP	Same as above, trace shell fragments, no odor.
31	18"	8		0	NS	SP	
		8				SP	
32							
33							
34							
35		6	35–36.5			SP	Same as above, slight hydrogen sulfide odor.
36	18"	8		0	NS	SP	
		8				SP	
37							
38							
39							
40		6	40–41.5			SP	Same as above, trace shell fragments, no odor.
41	18"	7		0	NS	SP	
		6				SP	
42							
43							
44							
45							

Well Construction



Bottom of hole at 41.5 feet below ground surface surface (bgs). Groundwater at 6 feet bgs.

Blow counts taken using a 2.5-inch diameter split-spoon sampler driven with a 140-pound hammer falling from 30 inches.

Sampling method: Split Spoon.

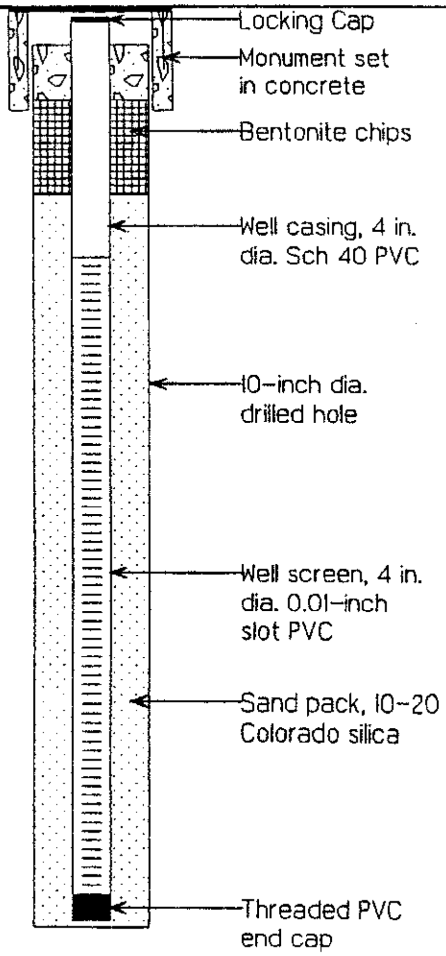
TechSolve Environmental, Inc.
7518 NE 169th St
Kenmore, WA 98028
425-402-8277
Email: info@techsolveinc.com

PROJECT NAME: ARCO TERMINAL NO. 21T
[illegible]JECT NO: WA0254.002

CLIENT NAME: ARCO PRODUCTS COMPANY
PROJECT LOCATION: SEATTLE, WASHINGTON
DATE STARTED: 28-JUNE-93
DATE COMPLETED: 28-JUNE-93
LOGGED BY: G. STOYKA
CHECKED BY: L. ROBERTS

SURFACE ELEV: 9.16feet
DATUM: NGVD (1929)
DRILL COMPANY: CASCADE DRILLING, INC.
DRILLER: STEVE BUTLER
DRILL METHOD: HOLLOW-STEM AUGER
SAMPLING METHOD: SPLIT SPOON (140-lb. hammer)

WELL CONSTRUCTION



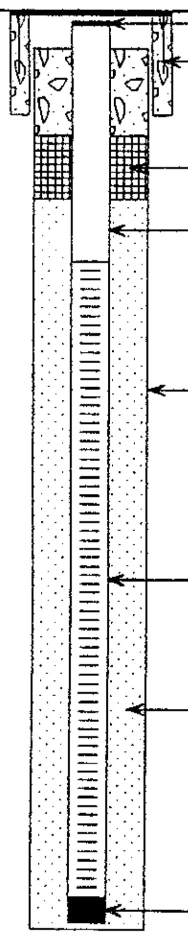
DEPTH (feet)	BLOWS PER SIX IN.	MATERIALS DESCRIPTION
		ASPHALT (3-inches)
		Cobbles, asphalt, and sand, (FILL).
	NA	POORLY GRADED SAND (SP) - Black, fine- to medium-grained sand, (strong hydrocarbon odor, PID = 2 ppm).
3	NA	As above, saturated with old diesel, plastic, (strong diesel odor, PID = 20 ppm).
		As above, brown to black.
6		Hand augered and sampled to 6 feet below land surface (bls). Groundwater encountered at 6 feet bls.
	8, 7, 5	As above, rust-brown to dark brown, wet, medium-dense, (slight hydrocarbon odor).
9		
	3, 8, 12	As above. Collected sample for grain-size analysis.
12	6, 8, 6	As above, gray to dark gray, fine-grained sand, with silt, trace organics (wood fragments), (slight hydrocarbon odor).
15		Borehole terminated at 14.5 feet bls. Groundwater encountered during drilling at 6 feet bls.
		Note: Blow counts taken below 6 feet bls using a 2.5-inch diameter split-spoon sampler driven with a 140-pound hammer falling 30 inches. Blow counts recorded for evaluating relative soil density only and are not appropriate for construction or structural design purposes.
18		
21		

PROJECT NAME: ARCO TERMINAL NO. 21T
ᵔJECT NO: WA0254.002

CᴗIENT NAME: ARCO PRODUCTS COMPANY
PROJECT LOCATION: SEATTLE, WASHINGTON
DATE STARTED: 25-JUNE-93
DATE COMPLETED: 25-JUNE-93
LOGGED BY: G. STOYKA
CHECKED BY: L. ROBERTS

SURFACE ELEV: 8.65feet
DATUM: NGVD (1929)
DRILL COMPANY: CASCADE DRILLING, INC.
DRILLER: STEVE BUTLER
DRILL METHOD: HOLLOW-STEM AUGER
SAMPLING METHOD: SPLIT SPOON (140-lb. hammer)

WELL CONSTRUCTION



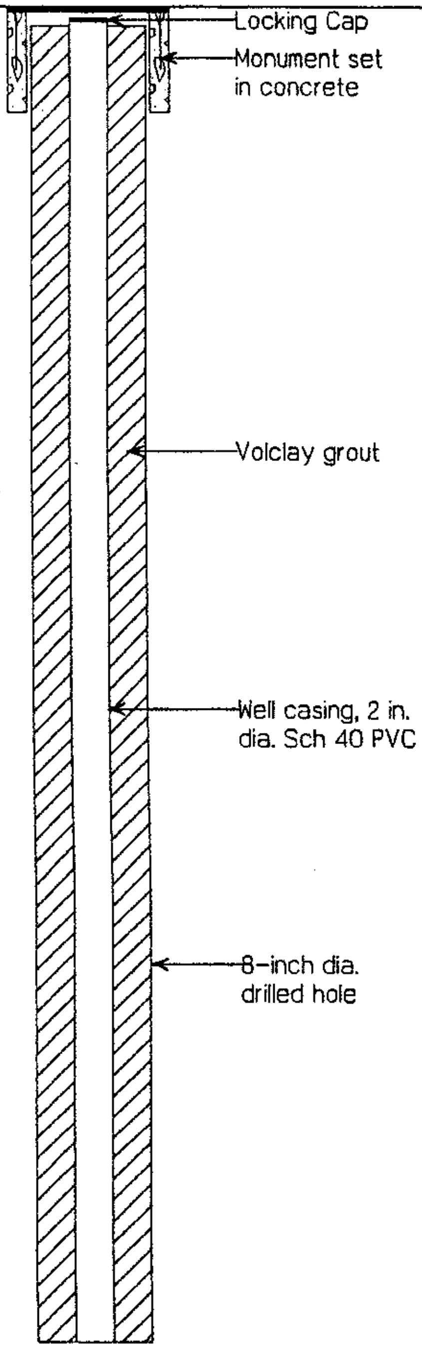
DEPTH (feet)	BLOWS PER SIX IN.	MATERIALS DESCRIPTION
	NA	POORLY GRADED SAND (SP) - Brown to black, slightly moist, fine- to medium-grained sand, (no hydrocarbon odor, PID = 1 ppm).
3	NA	As above, (no hydrocarbon odor, PID = 0.4 ppm).
6		⊽ Hand augered and sampled to 5.5 feet below land surface (bls). Groundwater encountered at 5.5 feet bls.
	3 5 3	As above, wet, loose.
9	5 6 8	As above, wet, medium-dense, (weak marine odor). Collected sample for grain-size analysis.
12	1 3 1	
		SILT with sand (ML) - Gray, wet, medium-stiff, silt, fine-grained sand, abundant wood fragments, (moderate marine odor).
15		Borehole terminated at 14.5 feet bls. Groundwater encountered during drilling at 5.5 feet bls.
18		Note: Blow counts taken below 5.5 feet bls using a 2.5-inch diameter split-spoon sampler driven with a 140-pound hammer falling 30 inches. Blow counts recorded for evaluating relative soil density only and are not appropriate for construction or structural design purposes.
21		

PROJECT NAME: ARCO TERMINAL NO. 21T
JECT NO: WA0254.002

CLIENT NAME: ARCO PRODUCTS COMPANY
PROJECT LOCATION: SEATTLE, WASHINGTON
DATE STARTED: 25-JUNE-93
DATE COMPLETED: 28-JUNE-93
LOGGED BY: G. STOYKA
CHECKED BY: L. ROBERTS

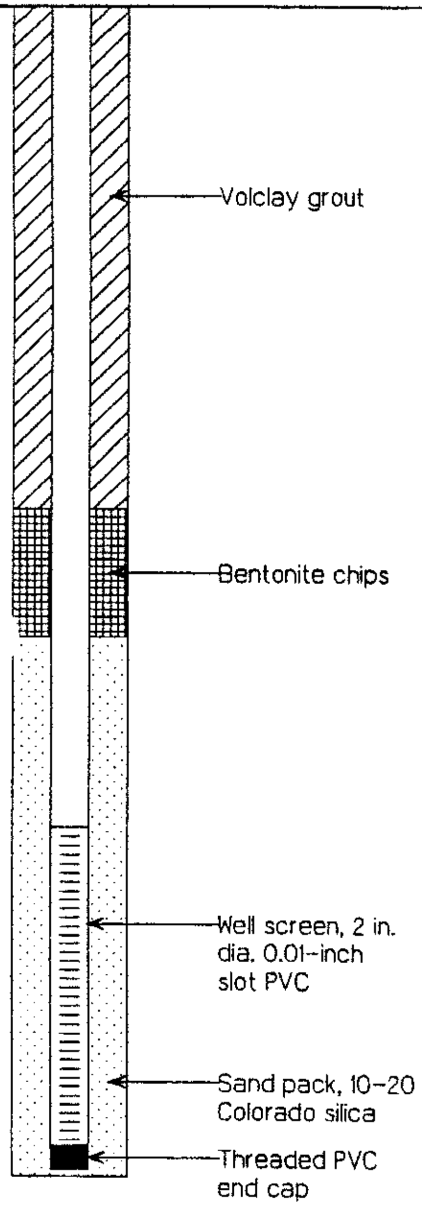
SURFACE ELEV: 9.5feet
DATUM: NGVD (1929)
DRILL COMPANY: CASCADE DRILLING, INC.
DRILLER: STEVE BUTLER
DRILL METHOD: HOLLOW-STEM AUGER
SAMPLING METHOD: SPLIT SPOON (140-lb. hammer)

WELL CONSTRUCTION



DEPTH (feet)	BLOWS PER SIX IN.	MATERIALS DESCRIPTION
	NA	WELL-GRADED SAND (SW) - Yellow to brown, sand, fine to coarse gravel (20 %), 0.25- to 6-inch diameter, (no hydrocarbon odor, PID = 0.6 ppm).
	NA	POORLY GRADED SAND (SP) - Brown to black, slightly moist, sand, (no hydrocarbon odor, PID = 0.6 ppm).
3		
6		As above, wet, free-product (0.01 feet) measured on water-table using and acrylic bailer. Hand augered and sampled to 5.5 feet below land surface (bls). Groundwater encountered at 5.5 feet bls.
	2 6 9	As above, medium-dense.
9	4 7 10	As above, trace silt, trace wood fragments, (diesel odor).
12	4 7 10	As above.
15	3 3 5	As above, loose.
		SILT with sand (ML) - Gray, wet, medium-stiff, silt, fine-grained sand, shell fragments, (diesel odor).
18	2 5 6	POORLY GRADED SAND (SP) - Brown to black, wet, medium-dense, fine- to medium-grained sand, shell fragments, (diesel odor).
21	4 7 10	As above, no shell fragments, (weak diesel odor).

WELL CONSTRUCTION



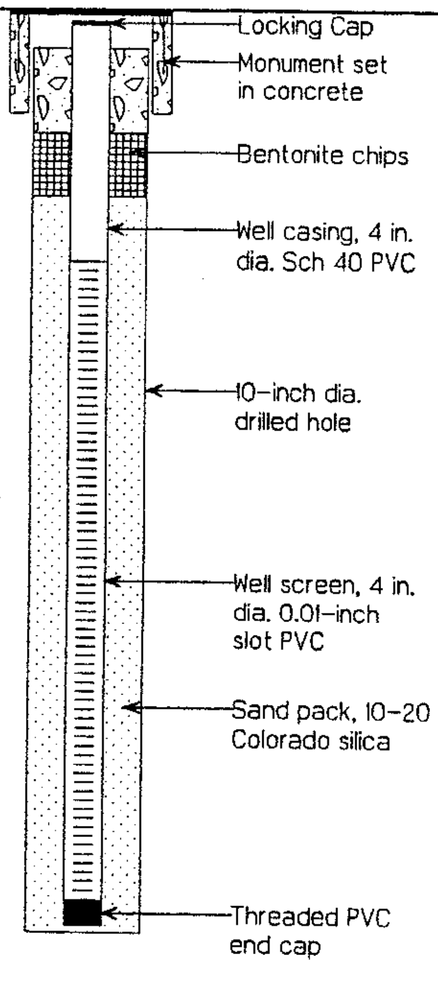
DEPTH (feet)	BLOWS PER SIX IN.	MATERIALS DESCRIPTION
24	5, 7, 12	As above, medium-dense, trace silt, no wood fragments, (no diesel odor).
	5, 7, 9	As above, some fragments.
27	16, 19, 21	As above, dense, abundant shell fragments.
30	10, 14, 19	As above, few shell fragments, no wood fragments, (weak marine odor).
33	6, 9, 28	As above, (diesel odor).
36	12, 34, 33	As above, very dense. Collected sample for grain-size analysis.
39	13, 21, 32	As above, (no hydrocarbon odor).
		SILT with sand (ML) - Gray, hard, wet, silt, with fine-grained sand, abundant wood fragments, (no hydrocarbon odor).
		POORLY GRADED SAND (SP) - Brown to black, very dense, wet, sand, trace silt, wood fragments, (no hydrocarbon odor).
42		Borehole terminated at 39.5 feet bls. Groundwater encountered during drilling at 5.5 feet bls.
45		Note: Blow counts taken below 4 feet bls using a 2.5-inch diameter split-spoon sampler driven with a 140-pound hammer falling 30 inches. Blow counts recorded for evaluating relative soil density only and are not appropriate for construction or structural design purposes.

PROJECT NAME: ARCO TERMINAL NO. 21T
PROJECT NO: WA0254.002

CLIENT NAME: ARCO PRODUCTS COMPANY
PROJECT LOCATION: SEATTLE, WASHINGTON
DATE STARTED: 25-JUNE-93
DATE COMPLETED: 25-JUNE-93
LOGGED BY: G. STOYKA
CHECKED BY: L. ROBERTS

SURFACE ELEV: 9.40feet
DATUM: NGVD (1929)
DRILL COMPANY: CASCADE DRILLING, INC.
DRILLER: STEVE BUTLER
DRILL METHOD: HOLLOW-STEM AUGER
SAMPLING METHOD: SPLIT SPOON (140-lb. hammer)

WELL CONSTRUCTION



BLOWS PER SIX IN.	MATERIALS DESCRIPTION
NA	Cobbles, gravels, brown, (FILL).
	POORLY GRADED SAND (SP) - Brown to black, slightly moist, fine- to medium-grained sand, (weak diesel odor, PID = 1 ppm).
NA	As above, (PID = 1 ppm).
	As above, gray, sheen on water-table, (strong diesel odor). Hand augered and sampled to 5.25 feet below land surface (bls). Groundwater encountered at 5.25 feet bls.
5 5 4	As above, wet, loose.
5 9 15	As above, brown to black, wet, medium-dense, (weak diesel odor). Collected sample for grain-size analysis.
2 5 7	As above, silt-rich lenses (0.25-inch thick), (no hydrocarbon odor).
	Borehole terminated at 14.5 feet bls. Groundwater encountered during drilling at 5.25 feet bls.

Note: Blow counts taken below 5.25 feet bls using a 2.5-inch diameter split-spoon sampler driven with a 140-pound hammer falling 30 inches. Blow counts recorded for evaluating relative soil density only and are not appropriate for construction or structural design purposes.

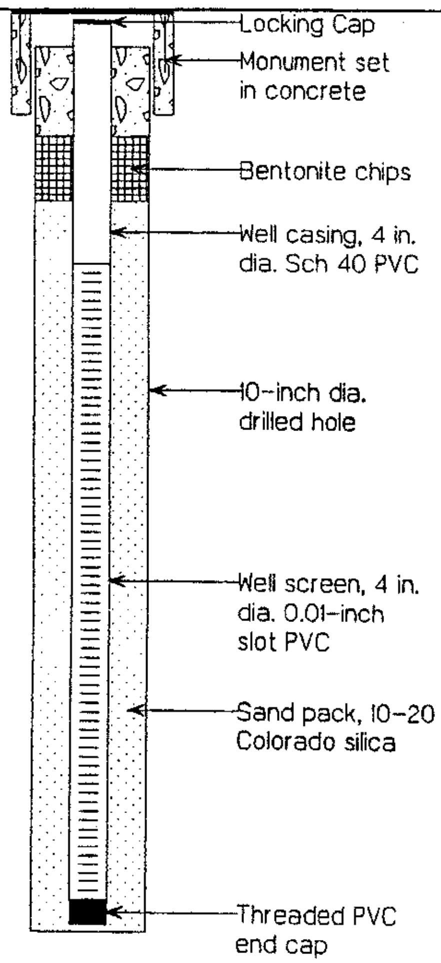
PROJECT NAME: ARCO TERMINAL NO. 21T
PROJECT NO: WA0254.002

LOG OF GM-18S

CLIENT NAME: ARCO PRODUCTS COMPANY
PROJECT LOCATION: SEATTLE, WASHINGTON
DATE STARTED: 29-JUNE-93
DATE COMPLETED: 29-JUNE-93
LOGGED BY: G. STOYKA
CHECKED BY: L. ROBERTS

SURFACE ELEV: 8.14feet
DATUM: NGVD (1929)
DRILL COMPANY: CASCADE DRILLING, INC.
DRILLER: STEVE BUTLER
DRILL METHOD: HOLLOW-STEM AUGER
SAMPLING METHOD: SPLIT SPOON (140-lb. hammer)

WELL CONSTRUCTION



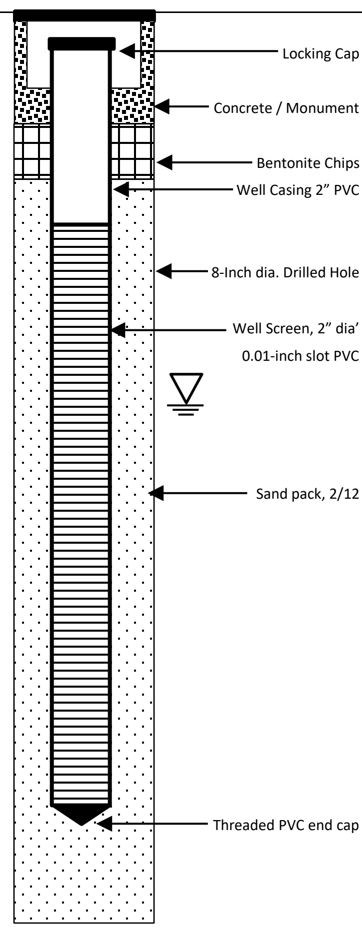
DEPTH (feet)	BLOWS PER SIX IN.	MATERIALS DESCRIPTION
	NA	FILL – Asphalt chunks.
		POORLY GRADED SAND (SP) – Brown to black, slightly moist, fine- to medium-grained sand, (weak hydrocarbon odor, PID = 0.1 ppm).
3	NA	As above, (PID = 0.2 ppm).
		Hand augered to 4 feet below land surface (bls). Groundwater encountered at 4 feet bls.
6		
	2 2 2	As above, loose, (no hydrocarbon odor).
9		
	4 6 4	As above, medium-dense. Collected sample for grain-size analysis.
12	6 5 4	
		SILT with sand (ML) – Gray to brown, wet, stiff, silt, fine-grained sand, trace medium-grained sand, trace clay, trace roots, (no hydrocarbon odor).
15		Borehole terminated at 14.5 feet bls. Groundwater encountered during drilling at 4 feet bls.
		Note: Blow counts taken below 4 feet bls using a 2.5-inch diameter split-spoon sampler driven with a 140-pound hammer falling 30 inches. Blow counts recorded for evaluating relative soil density only and are not appropriate for construction or structural design purposes.
18		
21		

TECHSOLVE ENVIRONMENTAL

Soil Boring Log

Project Name and Location: **Former BP Harbor Island Terminal, Plant 1 1652 SW Lander Street, Seattle, WA 98134**	Boring Number: **HMW-01S**	Page: 1 of 1
	Contractor: **Cascade Drilling**	Drilling Method: **Hollow Stem Auger**
	Drill Crew: **J. Goble, C. Jones**	Drill Rig: **CME-75**
	Date Started: **3/25/2021**	Date Completed: **3/25/2021**
Surface Elevation: **12.15 feet (NAVD88)**	Logged by: **E. Lottsfeldt**	Protective Cover: **12" HD Morrison Flush Mount Monument**
Top of Casing Elevation: **11.78 feet (NAVD88)**		
Surveyed Coordinates (NAD 83): Northing: **216484.5**	Easting: **1264228.7**	
Screened Interval (ft bgs): **4-14**	Screen: **10' – 2" dia. 010 Slot PVC**	Water Level While Drilling (ft bgs): **7'**
Filter Pack Interval (ft bgs): **3-14**	Riser: **4' – 2" dia. PVC**	
Seal Interval (ft bgs): **2-3**	Seal Type: **Bentonite Chips**	Water Level at Completion (ft bgs): **7'**
Grout Interval (ft bgs): **NA**	Filter Pack: **2/12 Sand**	

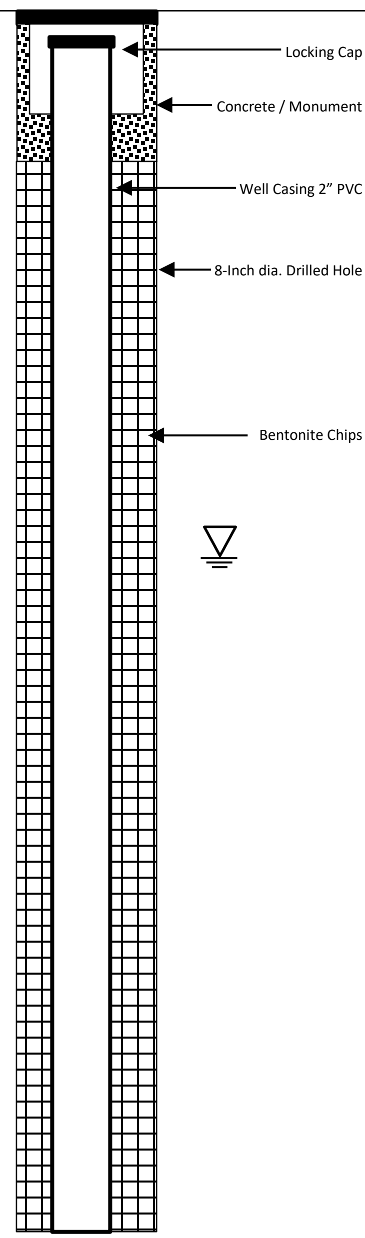
Depth (ft bgs)	Recovery(in.)	Blow Counts	Sample Interval	OVM/PID (ppm)	Sheen Test: NS: none, SS: slight, MS: moderate, HS: heavy	USCS Symbol	Well Construction	Sample Description: Lithology, (USCS), color, constituents, density, moisture, other features, (interpretation)
1								Asphalt (12 inches)
2								Soft clear with vacuum truck to 7 feet.
3								
4								
5		2		0	NS	SP		SAND (SP), dark gray, 100% fine to medium poorly graded sand, loose, wet, interbedded silt lens, (fill)
6	18"	2		0	NS	SP		
		3		0	NS	SP		
7								
8								
9								
10		6		0	NS	SP		Same as above, transition to medium sand, trace shell fragments at 11 feet, (native)
11	18"	7		0	NS	SP		
		7		0	NS	SP		
12								
13								
14								
15		7		0	NS	SP		Same as above, fine to medium sand, trace wood and shell fragments, ½ inch silt lens.
16	18"	9		0	NS	SP		
		9		0	NS	SP		
17								Bottom of hole at 16.5 feet below ground surface surface (bgs). Groundwater encountered at 7 feet bgs.
18								
19								Blow counts taken using a 2.5-inch diameter split-spoon sampler driven with a 140-pound hammer falling from 30 inches
20								
21								Sampling method: Split Spoon.
22								



TECHSOLVE ENVIRONMENTAL

Project Name and Location: **Former BP Harbor Island Terminal, Plant 1 1652 SW Lander Street, Seattle, WA 98134**	Boring Number: **HMW-01D**	Page: **1** of **2**
	Contractor: **Cascade Drilling**	Drilling Method: **Hollow Stem Auger**
	Drill Crew: **J. Goble, C. Jones**	Drill Rig: **CME-75**
	Date Started: **3/25/2021**	Date Completed: **3/25/2021**
Surface Elevation: **12.25 feet (NAVD88)**	Logged by: **E. Lottsfeldt**	Protective Cover: **12" HD Morrison Flush Mount Monument**
Top of Casing Elevation: **11.82 feet (NAVD88)**		
Surveyed Coordinates (NAD 83): Northing: **216489.2**	Easting: **1264227.8**	
Screened Interval (ft bgs): **35 - 40**	Screen: **5' - 2" dia. 010 Slot PVC**	Water Level While Drilling (ft bgs): **10'**
Filter Pack Interval (ft bgs): **33 - 41.5**	Riser: **35' - 2" dia. PVC**	
Seal Interval (ft bgs): **2 - 33**	Seal Type: **Bentonite Chips**	Water Level at Completion (ft bgs): **10'**
Grout Interval (ft bgs): **NA**	Filter Pack: **2/12 Sand**	

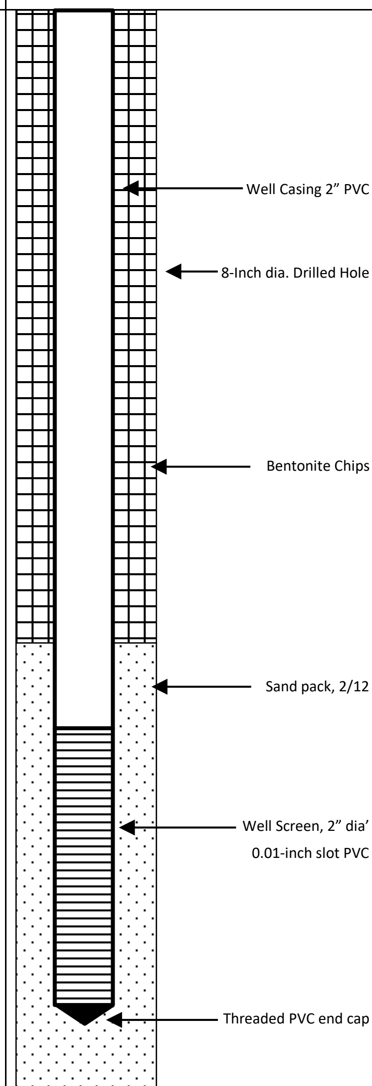
Depth (ft bgs)	Recovery(in.)	Blow Counts	Sample Interval	OVM/PID (ppm)	Sheen Test: NS: none, SS: slight, MS: moderate, HS: heavy	USCS Symbol	Well Construction	Sample Description: Lithology, color, constituents, density, moisture, other features, (interpretation)
1								Asphalt (12 inches)
2								Soft clear with vacuum truck to 6.5 feet. Large rocks and riprap drilled through to 10 feet.
3								
4								
5								
6								
7								
8								
9								
10		6		0	NS	SP		SAND (SP), dark gray, 95% fine to medium sand, 5% rounded gravel, medium dense, wet, no odor, (fill)
11	18"	7		0	NS	SP		
		6		0	NS	SP		
12								
13								
14								
15		9		0	NS	SP		Same as above, 100% medium sand, 1" silt interbed, trace wood fragments, slight hydrogen sulfide odor, (native)
16	18"	10		0	NS	SP		
		10		0	NS	SP		
17								
18								
19								
20		8		0	NS	SP		Same as above, trace shell fragments, moderate hydrogen sulfide odor.
21	18"	11		0	NS	SP		
		11		0	NS	SP		
22								



Project Name and Location: **Former BP Harbor Island Terminal, Plant 1 1652 SW Lander Street, Seattle, WA 98134**	Boring Number: **HMW-01D**	Page: 2 of 2

Depth (ft bgs)	Recovery(in.)	Blow Counts	Sample Interval	OVM/PID (ppm)	Sheen Test: NS: none, SS: slight, MS: moderate, HS: heavy	USCS Symbol	Sample Description: Lithology, color, constituents, density, moisture, other features, (interpretation)
23							
24							
25		8		0	NS	SP	Same as above, dark gray sand, 3" silt interbed, trace shell fragments, strong hydrogen sulfide odor.
26	18"	11		0	NS	SP	
		11		0	NS	SP	
27							
28							
29							
30		10		0	NS	SP	Same as above, dark gray, 100% fine to medium sand, no shells, no odor
31	18"	12		0	NS	SP	
		14		0	NS	SP	
32							
33							
34							
35		11		0	NS	SP	Same as above, dark gray to black, 100% fine to medium sand.
36	18"	13		0	NS	SP	
		15		0	NS	SP	
37							
38							
39							
40		12		0	NS	SP	Same as above, 3" silt interbed.
41	18"	15		0	NS	SP	
		15		0	NS	SP	
42							
43							
44							
45							

Well Construction



Bottom of hole at 41.5 feet below ground surface surface (bgs). Groundwater at 10 feet bgs.

Blow counts taken using a 2.5-inch diameter split-spoon sampler driven with a 140-pound hammer falling from 30 inches.

Sampling method: Split Spoon.

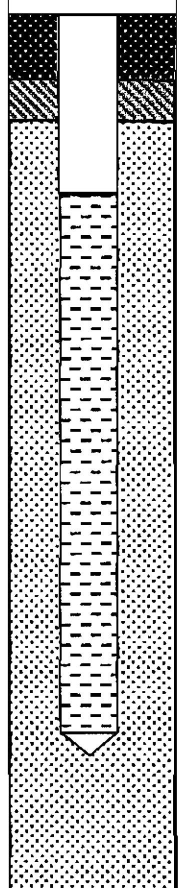
TechSolve Environmental, Inc.
7518 NE 169th St
Kenmore, WA 98028
425-402-8277
Email: info@techsolveinc.com

TECH SOLV

TechSolv Consulting Group, Inc.
12930 NE 178th Street, Woodinville, WA 98072
(425) 402-8277 FAX (425) 402-7917

SOIL BORING LOG

Project Name and Location: ARCO 21T	**Boring Number:** RW-5	**Page:** 1 of 1
	Contractor: Cascade Drilling, Inc.	**Drilling Method:** HSA
	Drill Crew: J. Goble	**Drill Rig:** CME-55
	Date Started: 12/7/00	**Date Finished:** 12/7/00
Surface Elevation:	**Logged by:** R. Honsberger	**Protective Cover:**
Top of Casing Elevation:		
Well Construction Information:		
Screened Interval (ft bgs): 14.5 to 4.5	**Screen:** 4" dia. 020 slot PVC	**Water Level While Drilling (ft bgs):** 6.5
Filter Pack Interval (ft bgs): 14.5 to 2	**Riser:** 4" dia. PVC	
Seal Interval (ft bgs): 2 to 1	**Seal Type:** bentonite	**Water Level at Completion (ft bgs):**
Grout Interval (ft bgs):	**Filter Pack:** 2/12 sand	

Depth (ft bgs)	Recov. (in.)	Blow Counts	Sample Interval	OVM / PID (ppm)	USCS Symbol	Well Construction	Sample Description
0							Asphalt 18 inches thick.
1							
2							
3							
4							
5	18	12/16 /14	5/6.5	209	SP		Brown medium to fine sand moist with slight hydrocarbon odor.
6							▽
7							
8							
9							
10	12	9/12/ 15	10/11	330	SP		Black medium to fine sand saturated with water and has a strong hydrocarbon odor.
11							
12							
13							
14	18	7/9/9	14.5/ 16	410	SP		Black medium to fine sand. Sheen on the soil with hydrocarbon odor and saturated with water.
15					SM/ OH		Gray to black silty clay. Sheen on the soil.
16							End of boring at 16 feet

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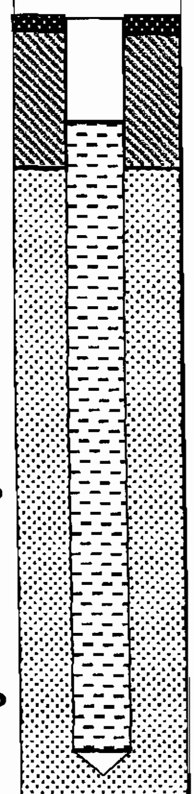
SOIL BORING LOG

Project Name and Location: ARCO 21T	**Boring Number:** RW-6	**Page:** 1 of 1
	Contractor: Cascade Drilling, Inc.	**Drilling Method:** HSA
	Drill Crew: J. Goble	**Drill Rig:** CME-55
	Date Started: 12/11/00	**Date Finished:** 12/11/00
Surface Elevation:	**Logged by:** R. Honsberger	**Protective Cover:**
Top of Casing Elevation:		
Well Construction Information:		
Screened Interval (ft bgs): 14.5 to 4.5	**Screen:** 4" dia. 020 slot PVC	**Water Level While Drilling (ft bgs):** 6.5
Filter Pack Interval (ft bgs): 14.5 to 3	**Riser:** 4" dia. PVC	
Seal Interval (ft bgs): 3 to 1	**Seal Type:** bentonite	**Water Level at Completion (ft bgs):**
Grout Interval (ft bgs):	**Filter Pack:** 2/12 sand	

Depth (ft bgs)	Recov. (in.)	Blow Counts	Sample Interval	OVM / PID (ppm)	USCS Symbol	Well Construction	Sample Description
0							Concrete 5 inches thick.
1							
2							
3							
4							
5	18	9/21/20	5/6.5	NM	SP		Brown medium to fine sand moist with no hydrocarbon odor.
6							
7							
8							
9							
10	18	50	10/11.5	NM	SP		Black medium to fine sand with saturated with water and has a slight hydrocarbon odor.
11							
12							
13							
14	6	12/15/18	14.5/15	NM	SP		Black to gray silty clay saturated with water and has a slight hydrocarbon odor.
15							End of boring at 15 feet.

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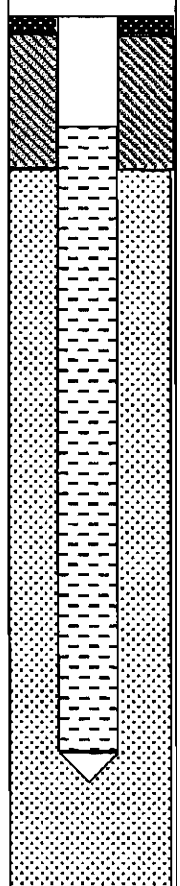
(425) 402-8277 FAX (425) 402-7917

SOIL BORING LOG

Project Name and Location: ARCO 21T	**Boring Number:** RW-10	**Page:** 1 of 1
	Contractor: Cascade Drilling, Inc.	**Drilling Method:** HSA
	Drill Crew: J. Goble	**Drill Rig:** CME-55
	Date Started: 12/5/00	**Date Finished:** 12/5/00
Surface Elevation:	**Logged by:** R. Honsberger	**Protective Cover:**
Top of Casing Elevation:		
Well Construction Information:		
Screened Interval (ft bgs): 14.5 to 4.5	**Screen:** 2" dia. 020 slot PVC	**Water Level While Drilling (ft bgs):** 6.5
Filter Pack Interval (ft bgs): 14.5 to 3	**Riser:** 2" dia. PVC	
Seal Interval (ft bgs): 3 to 1	**Seal Type:** bentonite	**Water Level at Completion (ft bgs):**
Grout Interval (ft bgs):	**Filter Pack:** 2/12 sand	

Depth (ft bgs)	Recov. (in.)	Blow Counts	Sample Interval	OVM / PID (ppm)	USCS Symbol	Well Construction	Sample Description
0							Concrete 5 inches thick.
1							
2							
3							
4							
5	12	10/9/9	5/6	NM	SP		Brown medium to fine sand damp with no hydrocarbon odor. ⊽
6							
7							
8							
9							
10	12	6/6/7	10/11	NM	SP		Brown medium to fine grained sand with few fine gravels saturated with water and has a strong hydrocarbon odor.
11							
12							
13							
14		14/16/10	14.5/16	NM	SP		Black medium to fine sand saturated with water and has a slight hydrocarbon odor.
15					OH		15.5 to ~16 gray to black slity clay with a very slight hydrocarbon odor.
16					SM		16 feet black fine to medium sand with few rootlets. End of boring at 16 feet.

APPENDIX B

Data Logger Specifications - In-Situ Aqua TROLL 200

YOUR EYES IN THE FIELD

Aqua TROLL® CTD Data Loggers

CONDUCTIVITY, TEMPERATURE, PLUS WATER LEVEL LOGGING

MEASURE AND RECORD WATER LEVEL, WATER PRESSURE, CONDUCTIVITY, AND TEMPERATURE WITH THE AQUA TROLL 200, OR ONLY CONDUCTIVITY AND TEMPERATURE WITH THE AQUA TROLL 100. UNIQUE CONDUCTIVITY CELL ALLOWS FOR A WIDE, ACCURATE MEASUREMENT RANGE IN A NARROW DIAMETER INSTRUMENT (SUB-1 INCH).

ACCURATE RESULTS

- **Use dynamic density compensation** to collect accurate water level data in environments where salinity values may vary.
- **Receive 3D factory calibrated instruments** that are validated with NIST®-traceable standards.
- **Deploy for long-term monitoring**. Instruments operate with very low drift.

FLEXIBLE COMMUNICATIONS

- **Streamline data management:** Use the VuSitu Mobile App to consolidate all site information on your smartphone, and tag data with site photos and GPS coordinates. Simply connect the instrument to a Wireless TROLL Com or power pack, launch the mobile app, and start reading results. Simplify instrument setup, reduce log errors and get the most out of your data with Log Setup Assistant and Panoramic Live Data. Log data to your smartphone and download results in a Universal Data File.
- **Integrate into telemetry and SCADA systems and HydroVu™ Data Services** for real-time data and automatic event alerts. Outputs include standard Modbus/RS485, SDI-12, and 4-20 mA.
- **Streamline data collection and analysis.** Simplify instrument setup, automate site management, and generate reports with user-friendly VuSitu Mobile and Win-Situ® PC Software.

RUGGED, COMPACT DESIGN

- **Use in harsh environments** such as coastal, remediation, and mine water monitoring projects. Titanium construction resists fouling and is chemical- and corrosion-resistant.
- **Sub-1 inch design** fits narrow diameter, 1-inch wells.
- **Use RuggedCable® Systems** with titanium twist-lock connectors for quick, reliable connections. Integrate with the Rugged Cable Splitter to attach multiple In-Situ Shared Ecosystem instruments in a single water column with a single connector, allowing you to measure multiple parameters at various depths and simultaneously.

TOTAL FIELD SUPPORT

- **One-stop-shop for purchasing and support.**
- **Total Field Support**
- **24/7/365 technical support is just a phone call away.**
- **Guaranteed 7-day service for maintenance (U.S.A. only).**

Applications:

- **AQUIFER STORAGE AND RECOVERY SYSTEMS**
- **COASTAL DEPLOYMENTS–SALTWATER INTRUSION MONITORING, STORM SURGE ANALYSIS, AND ESTUARY/WETLAND RESEARCH**
- **REMEDIATION SITE AND MINE WATER MONITORING**
- **STORMWATER MONITORING PROGRAMS**

www.in-situ.com

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1-970-498-1500 (U.S.A. and international)

In-Situ®
YOUR EYES IN THE FIELD

Aqua TROLL® 100 and 200 Data Loggers

VUSITU MOBILE APP

Use the VuSitu Mobile App to access and manage data on your Android™ smartphone or tablet. Intuitive, free mobile app is an all-in-one software package that provides auto-configuration, simplified calibration, guided log setup, directed data analysis, automated report creation, Panoramic Live Data, Calibration Assistant and Log Setup Assistant. Tag data with site photos and GPS coordinates. View results in the field and email data on the spot. Download through the Google Play Store.

HYDROVU DATA SERVICES

Get decision-quality data anywhere, anytime, with cloud-based HydroVu Data Services. Integrate with In-Situ instruments and telemetry systems for real-time feedback on all your remote water monitoring sites.

AQUA TROLL 100 AND 200 INSTRUMENTS	
TEMPERATURE RANGES[1]	Operational: -5 to 50° C (23 to 122° F) Storage: -40 to 65° C (-40 to 149° F) Calibrated: 0 to 50° C (32 to 122° F)
DIMENSIONS & WEIGHT	Diameter (OD): 1.83 cm (0.72 in.) Length: 31.5 cm (12.4 in.) Weight: 188 g (0.41 lb)
MATERIALS	Titanium body and sensors, Delrin® nose cone, and PVC conductivity cell
OUTPUT OPTIONS	Modbus/RS485, SDI-12, and 4-20 mA
BATTERY TYPE & LIFE[2]	3.6V lithium. 5 years or 200,000 readings3
EXTERNAL POWER	8-36 VDC; Measurement current: 15 mA; Sleep current: 40 µA
MEMORY Data records[4] Data logs	4.0 MB 190,000 50
LOG TYPES[5]	Linear, Linear Average, and Event
FASTEST LOGGING RATE	Linear: 1 per minute. Linear Average: 1 per minute. Event: 1 per second
FASTEST OUTPUT RATE	1 per second
ENVIRONMENTAL RATING	IP 68 with cable attached IP 67 without cable attached

CONDUCTIVITY SENSOR – TYPE: Balanced 4-electrode cell		
METHODS	EPA Method 120.1; Standard Methods 2510	
RANGE, ACCURACY, & RESOLUTION	Range: 0 to 100,000 µS/cm Accuracy: ± 0.5% of reading + 1 µS/cm when reading less than 80,000 µS/cm ± 1.0% of reading when reading above 80,000 µS/cm Resolution: 0.1 µS/cm)	
PARAMETERS SUPPORTED[6]	Range	Units
Actual conductivity	0 to 100,000 µS/cm	µS/cm, mS/cm
Specific conductivity[7]	0 to 100,000 µS/cm	µS/cm, mS/cm
Salinity[8]	0 to 42 PSU	PSU
Total dissolved solids	0 to 82 ppt	ppt, ppm
Resistivity	10 to 200,000 Ohms-cm	Ohms-cm
Density (water salinity)	0.98 to 1.14 g/cm3	g/cm3

PRESSURE/LEVEL/SENSOR[9] – TYPE: Piezoresistive. Pressure/level are available only on the Aqua TROLL 200 Instrument.		
RANGE	Absolute (non-vented) 30 psia: 11 m (35 ft) 100 psia: 60 m (197 ft) 300 psia: 200 m (658 ft)	Gauged (vented) 5 psig: 3.5 m (11.5 ft) 15 psig: 11 m (35 ft) 30 psig: 21 m (69 ft) 100 psig: 70 m (231 ft) 300 psig: 210 m (692 ft)
BURST PRESSURE	Maximum 2x range; burst > 3x range	
MAX PRESSURE FOR AQUA TROLL 100	300 psi (692 ft))	
ACCURACY & RESOLUTION[10]	Accuracy: ±0.05%FS or better; Resolution: ±0.01%FS or better	
LONG-TERM STABILITY[12]	<0.1% FS	
UNITS OF MEASURE	Pressure: psi, kPa, bar, mbar, mmHg, inHg, cmH20, inH20. Level: in, ft, mm, cm, m	

TEMPERATURE SENSOR[13]	
METHOD	EPA Method 170.1
ACCURACY & RESOLUTION	Accuracy: ±0.1° C. Resolution: 0.01° C or better
UNITS OF MEASURE	Celsius or Fahrenheit
WARRANTY	2 years. Up to 5-year (total) extended warranties available.

1 Temperature range for non-freezing liquids
2 Typical battery life when used within the factory-calibrated temperature range, dependent on site conditions
3 1 reading = date/time plus all available parameters polled or logged from device
4 1 data record = date/time plus 3 parameters logged (no wrapping) from device
5 External power or battery pack is recommended when using Linear Average or Event logging modes.
6 Parameters derived from temperature at 25° C and actual conductivity range of 0 to 100,000 µS/cm with a ±0.5% + 1 µS/cm accuracy
7 Derived from Standard Methods 2510B
8 Defined by the Practical Salinity Scale 1978; Standard Methods 2520B
9 Real-time level compensation based on water density
10 Accuracy with 4-20 mA output option: ±0.25% FS
11 Includes linearity and hysteresis over 1 year.
12 Temperature response varies by temperature change and environmental conditions. Under typical field conditions, T95<5 min.

CE FC

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1-970-498-1500 (U.S.A. and international)

221 East Lincoln Avenue, Fort Collins, CO 80524 USA

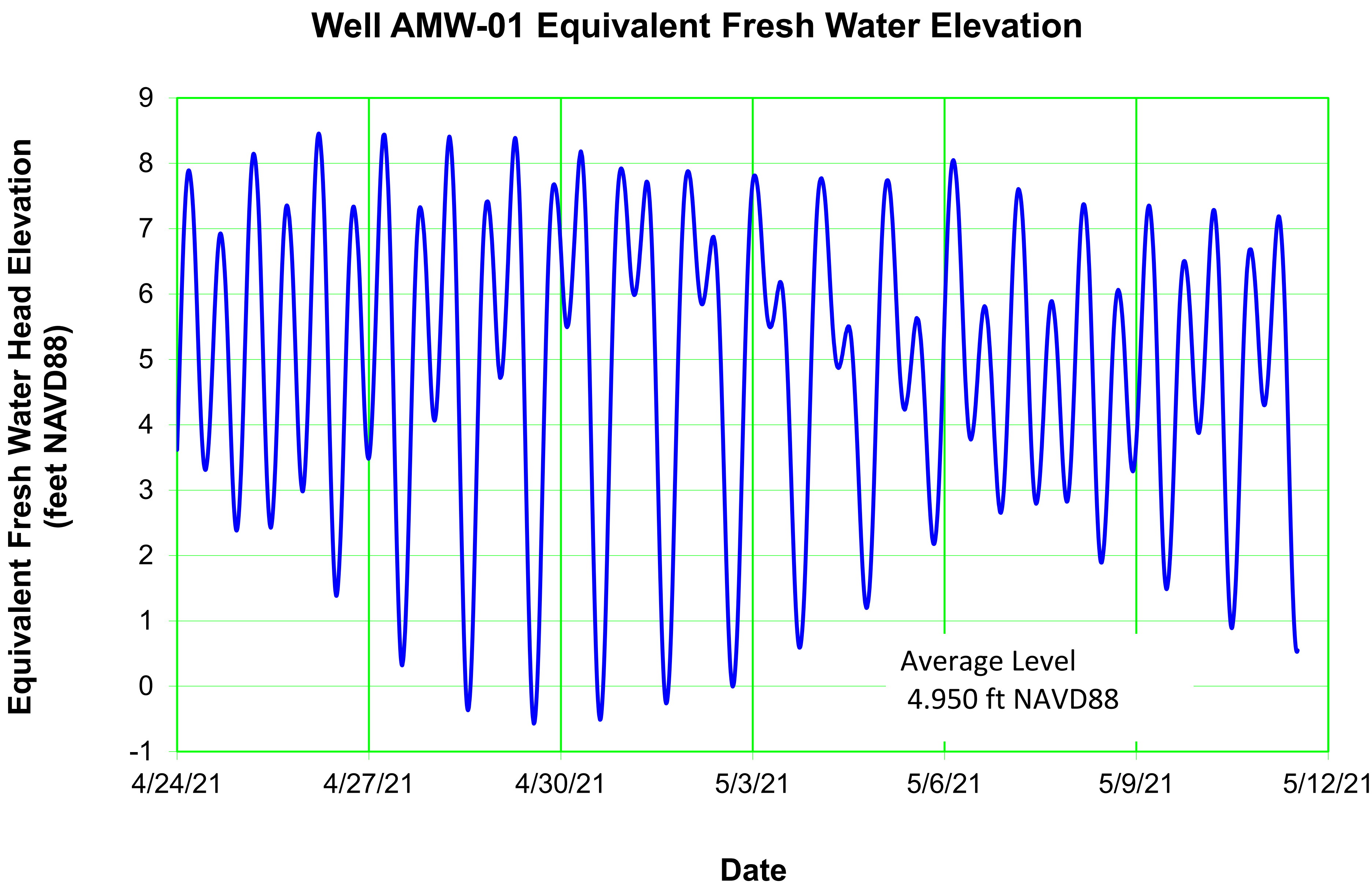
APPENDIX C

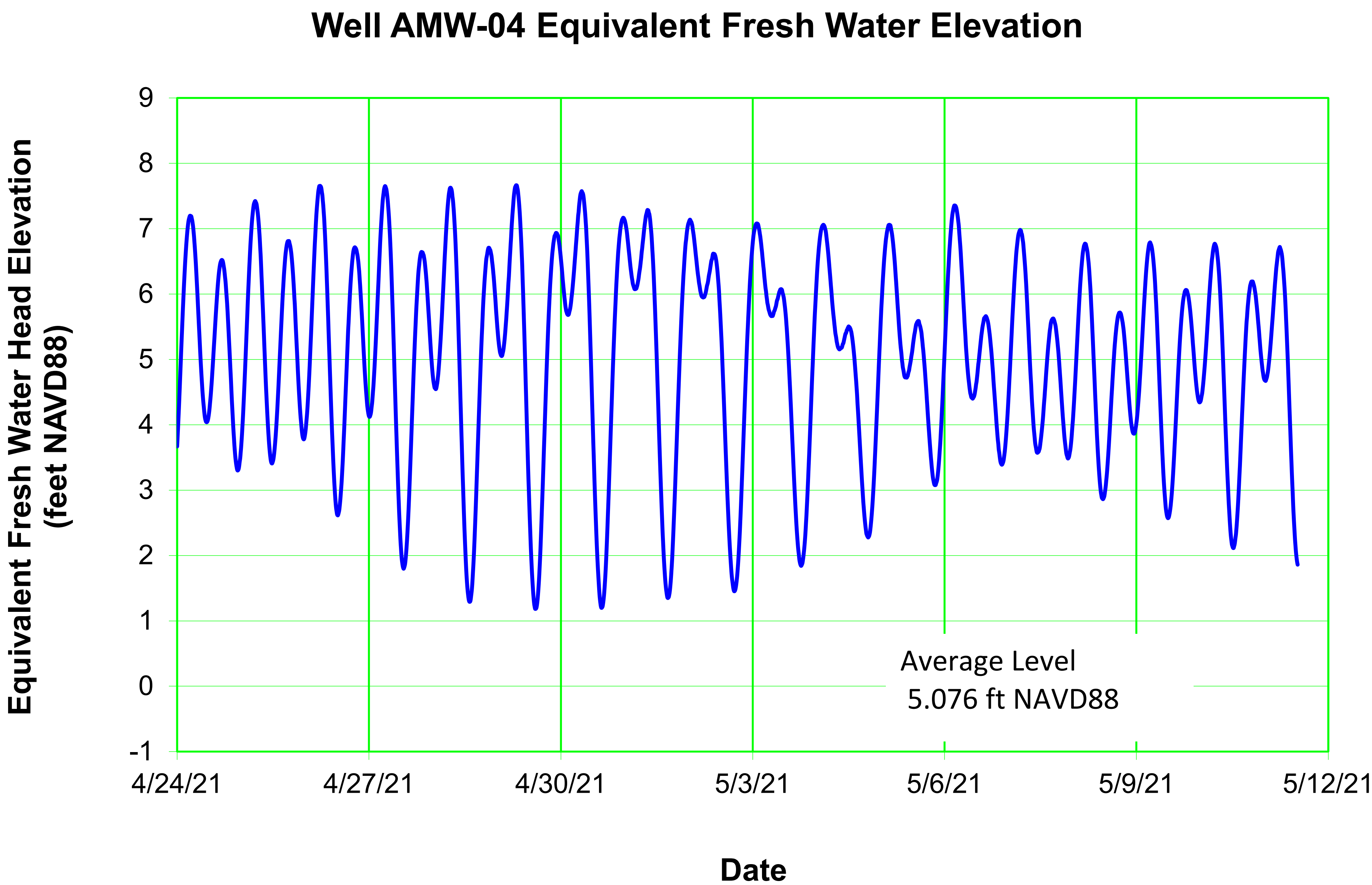
Hydraulic Investigation Data Files

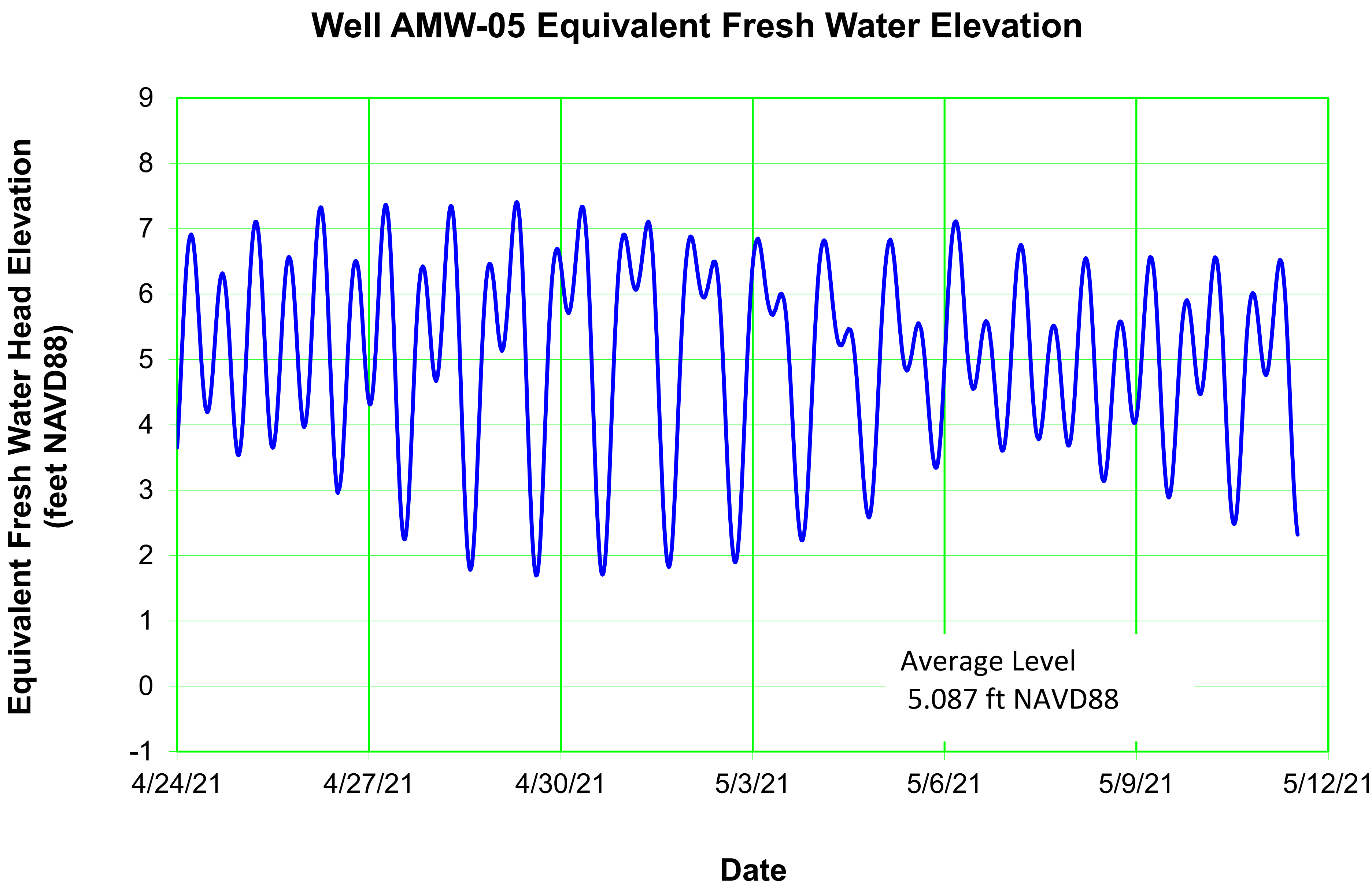
See Attached Excel File: App C - Hyd Eval Data Files.xlsx

APPENDIX D

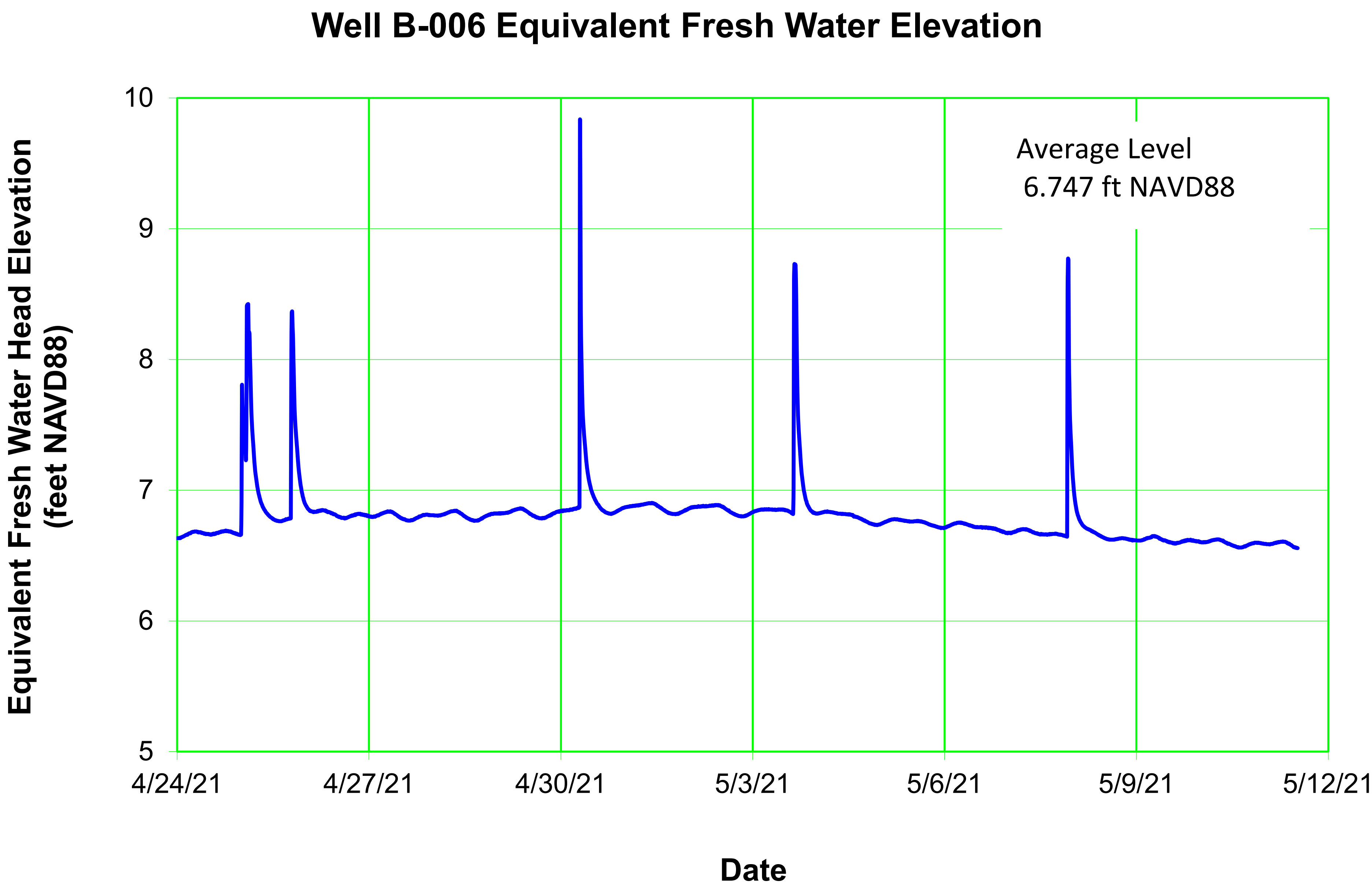
Hydrographs From Static Monitoring Period

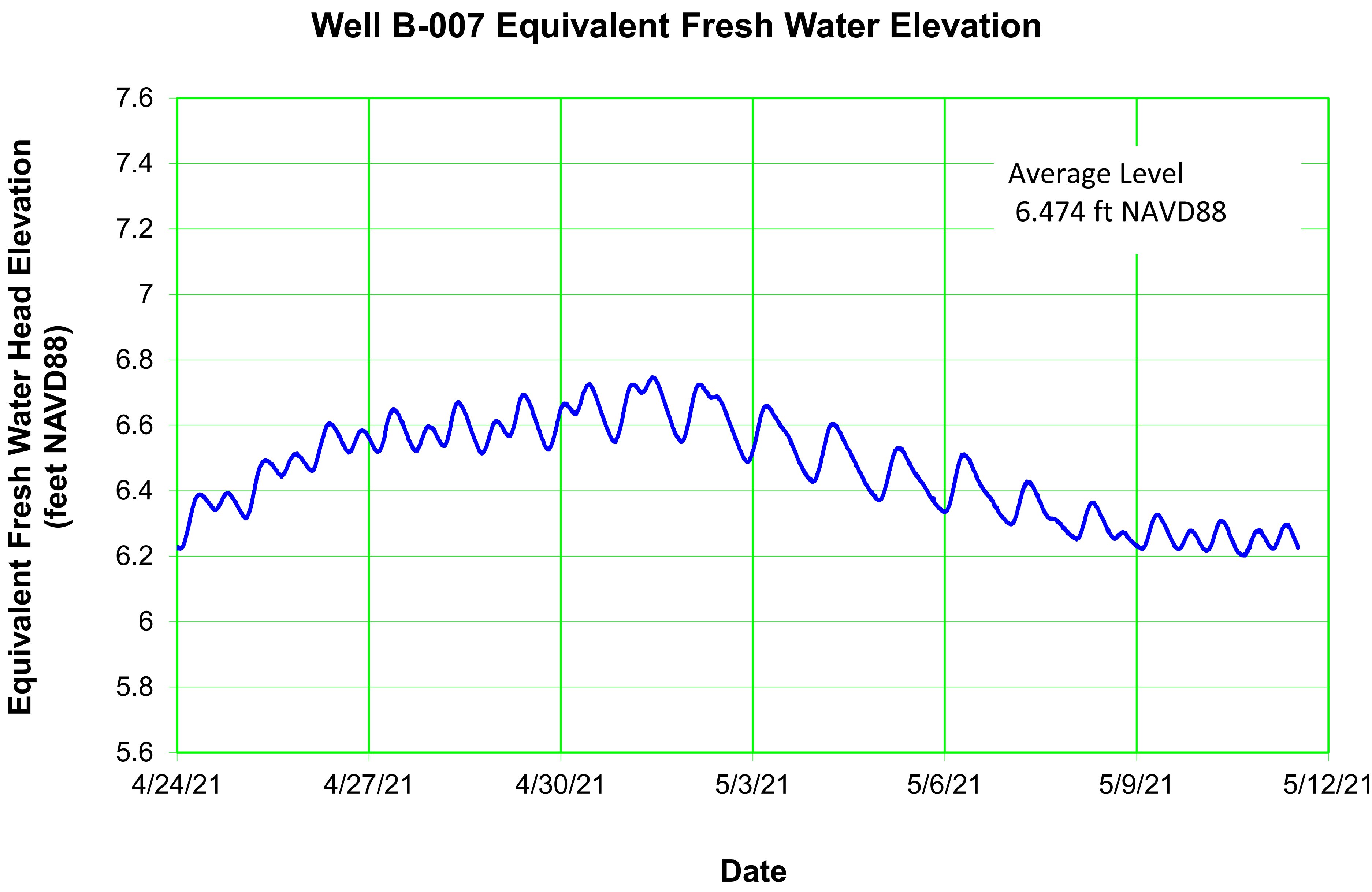

Well AMW-01 Equivalent Fresh Water Elevation
Equivalent Fresh Water Head Elevation (feet NAVD88)
9
8
7
6
5
4
3
2
1
0
-1
4/24/21
4/27/21
4/30/21
5/3/21
5/6/21
5/9/21
5/12/21
Date
Average Level
4.950 ft NAVD88

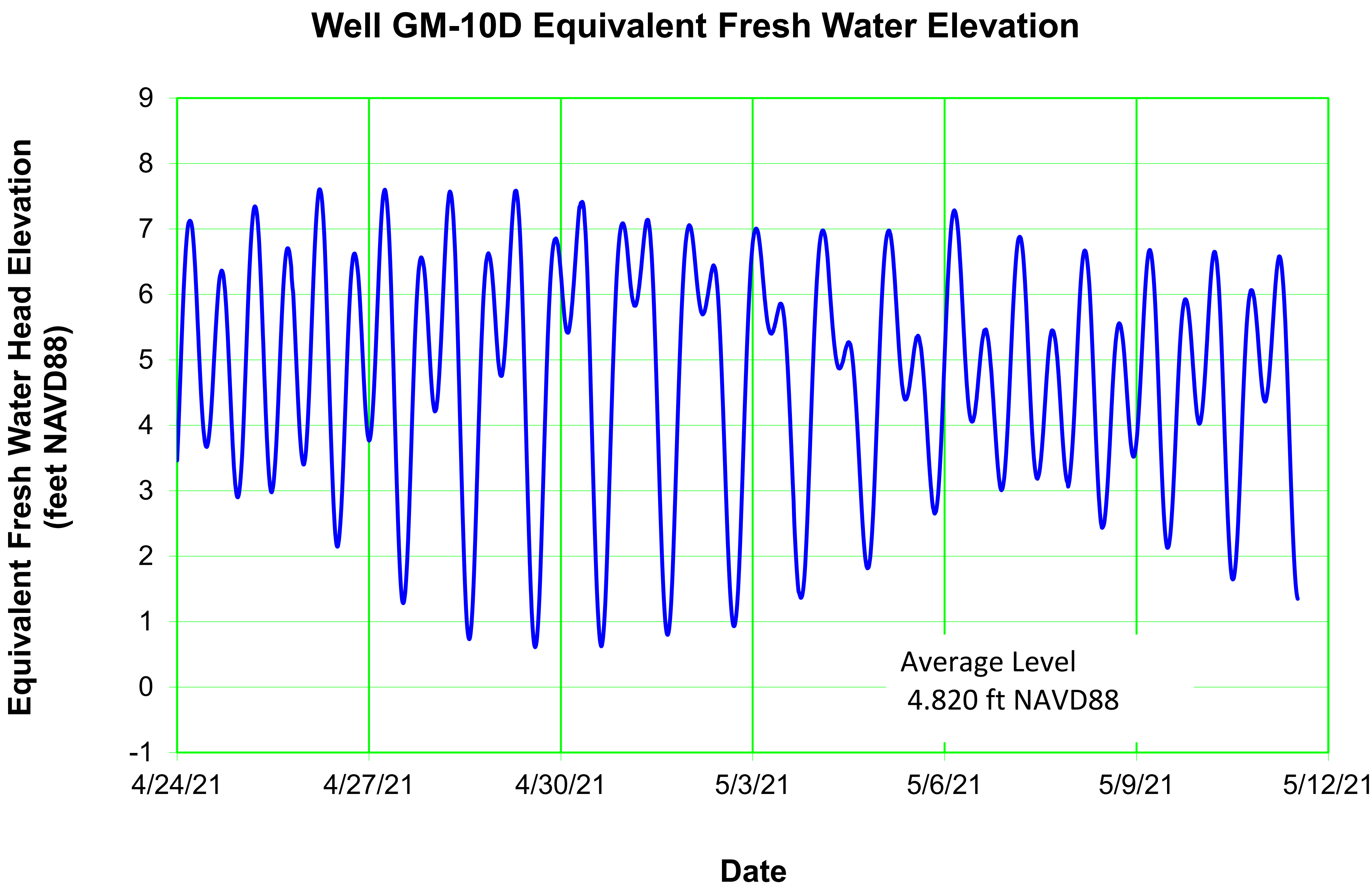

Well AMW-04 Equivalent Fresh Water Elevation
Equivalent Fresh Water Head Elevation (feet NAVD88)
9
8
7
6
5
4
3
2
1
0
-1
4/24/21
4/27/21
4/30/21
5/3/21
5/6/21
5/9/21
5/12/21
Date
Average Level
5.076 ft NAVD88



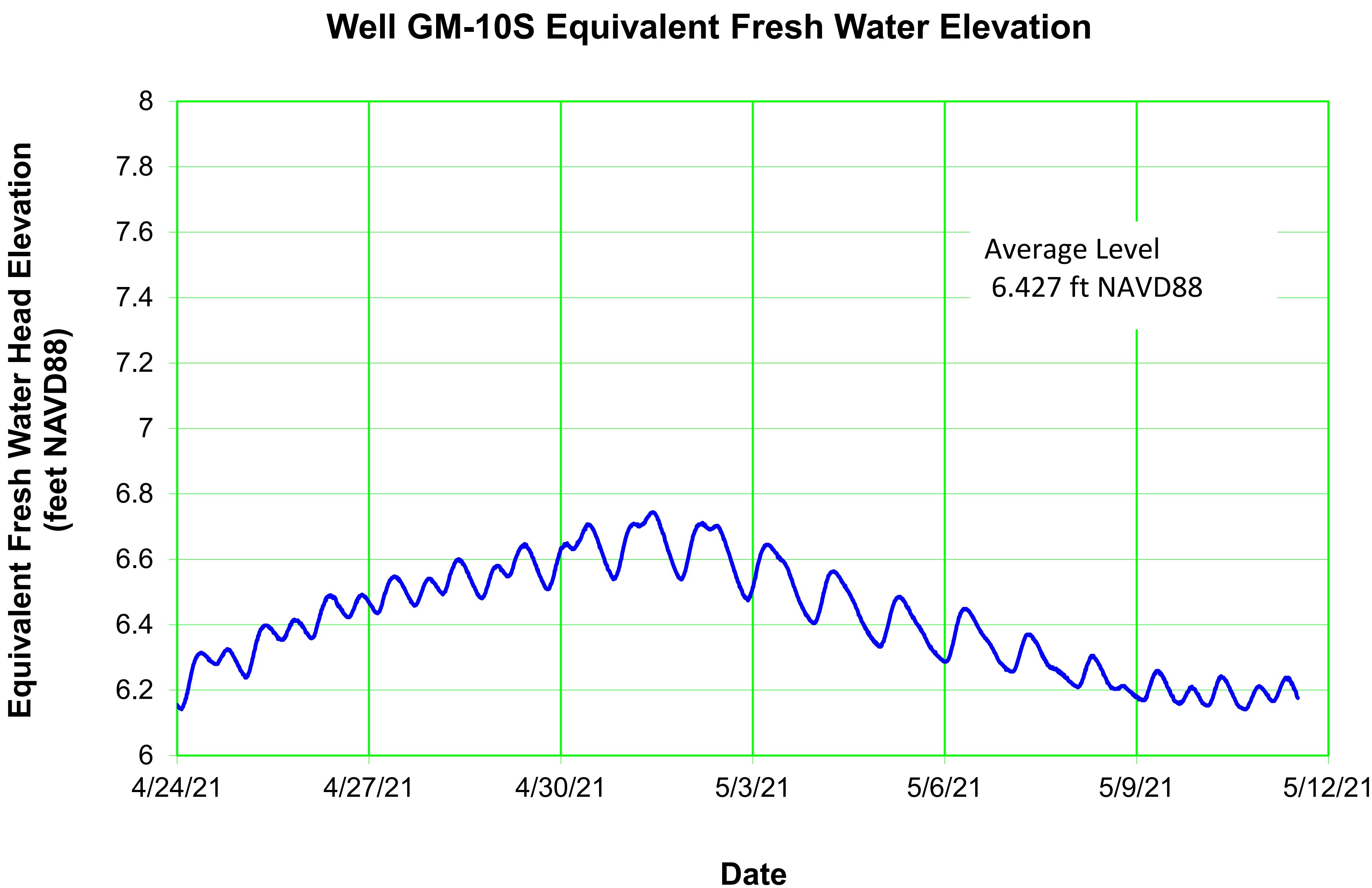
Well AMW-05 Equivalent Fresh Water Elevation
Equivalent Fresh Water Head Elevation (feet NAVD88)
9
8
7
6
5
4
3
2
1
0
-1
4/24/21
4/27/21
4/30/21
5/3/21
5/6/21
5/9/21
5/12/21
Date
Average Level
5.087 ft NAVD88


Well B-006 Equivalent Fresh Water Elevation
Equivalent Fresh Water Head Elevation (feet NAVD88)
10
9
8
7
6
5
Average Level
6.747 ft NAVD88
4/24/21
4/27/21
4/30/21
5/3/21
5/6/21
5/9/21
5/12/21
Date

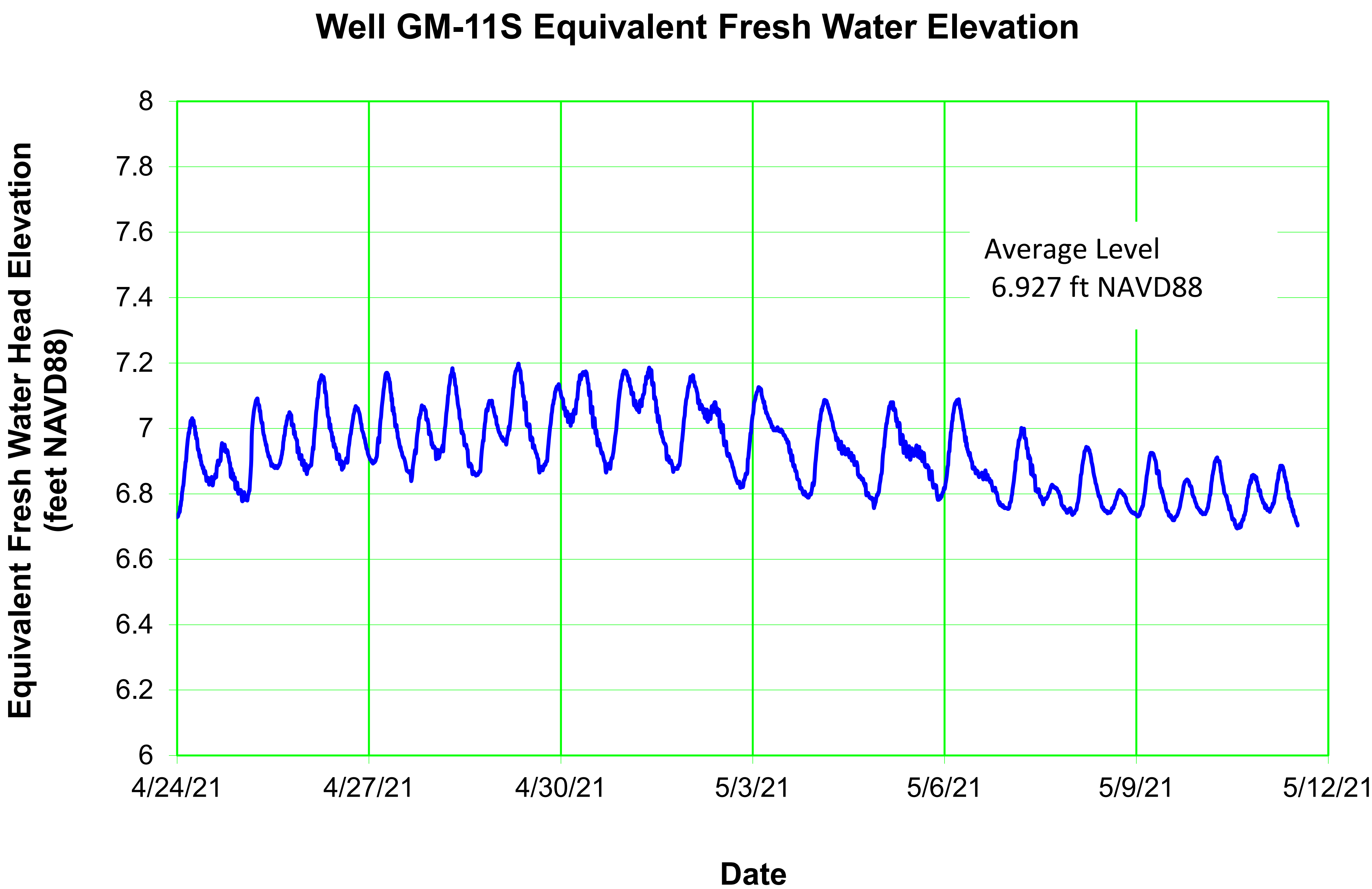

Well B-007 Equivalent Fresh Water Elevation
Equivalent Fresh Water Head Elevation
(feet NAVD88)
7.6
7.4
7.2
7
6.8
6.6
6.4
6.2
6
5.8
5.6
4/24/21
4/27/21
4/30/21
5/3/21
5/6/21
5/9/21
5/12/21
Date
Average Level
6.474 ft NAVD88



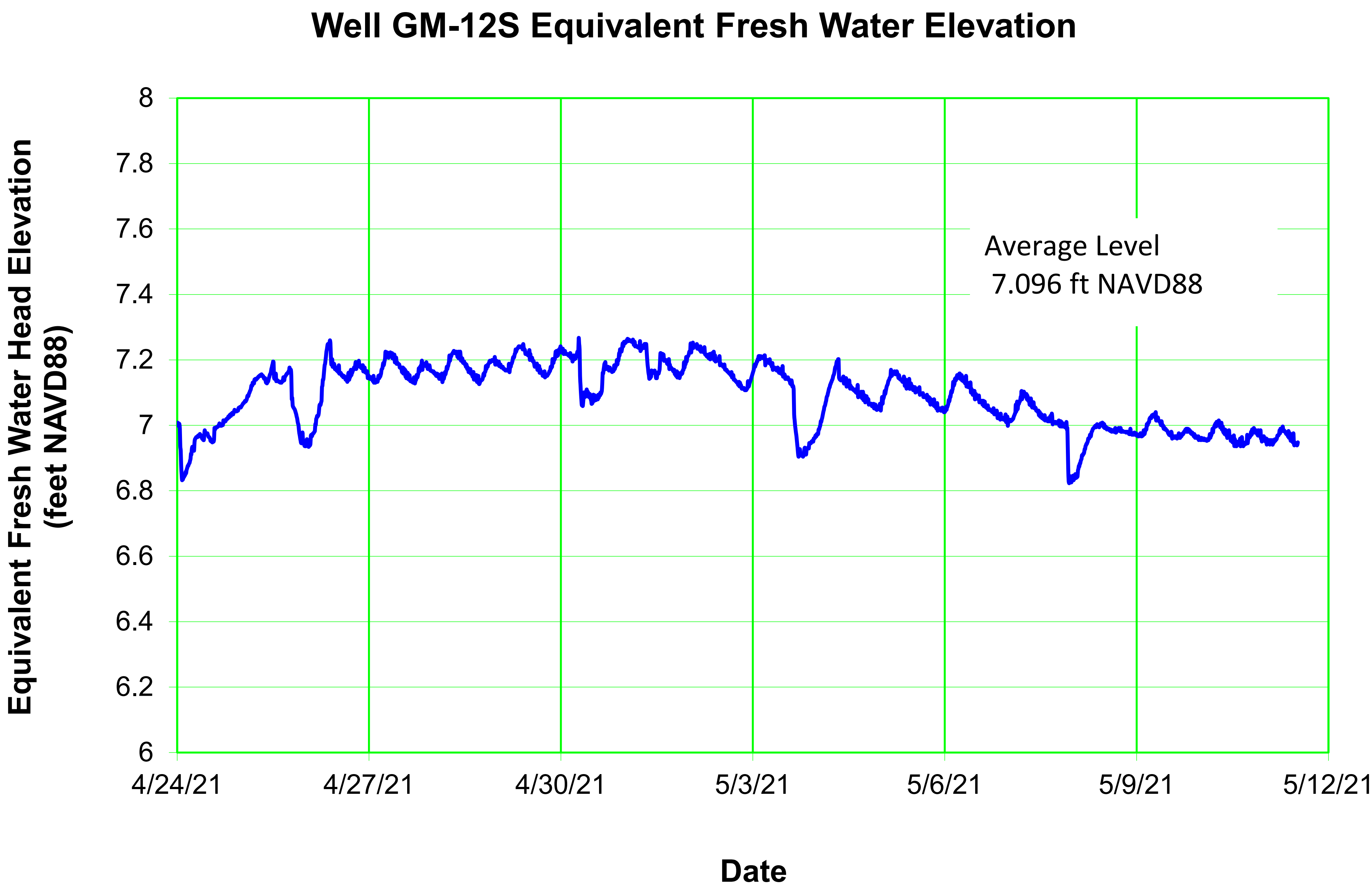
Well GM-10D Equivalent Fresh Water Elevation
Equivalent Fresh Water Head Elevation (feet NAVD88)
9
8
7
6
5
4
3
2
1
0
-1
4/24/21
4/27/21
4/30/21
5/3/21
5/6/21
5/9/21
5/12/21
Date
Average Level
4.820 ft NAVD88



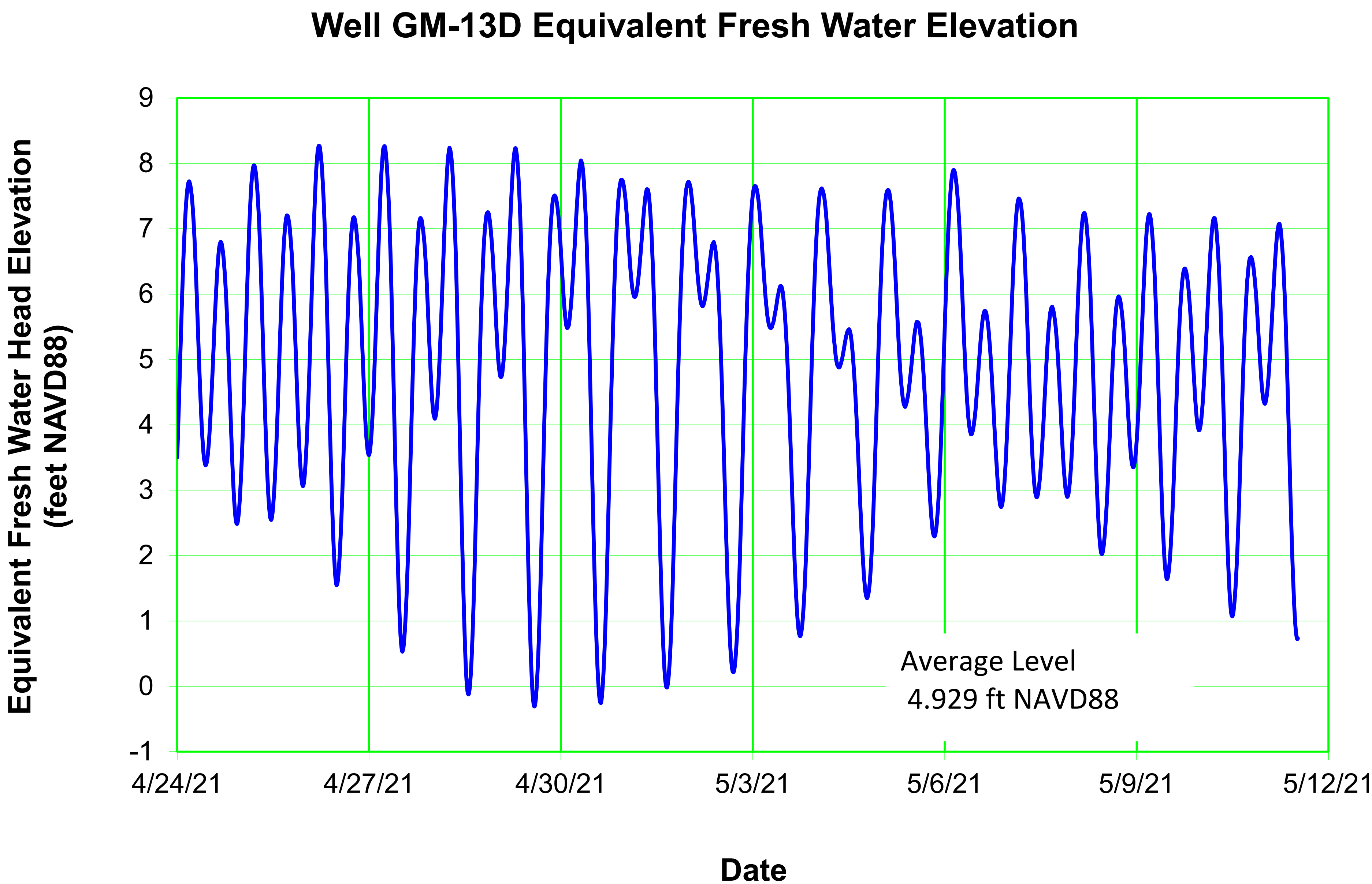
Well GM-10S Equivalent Fresh Water Elevation
Equivalent Fresh Water Head Elevation (feet NAVD88)
8
7.8
7.6
7.4
7.2
7
6.8
6.6
6.4
6.2
6
4/24/21
4/27/21
4/30/21
5/3/21
5/6/21
5/9/21
5/12/21
Date
Average Level
6.427 ft NAVD88



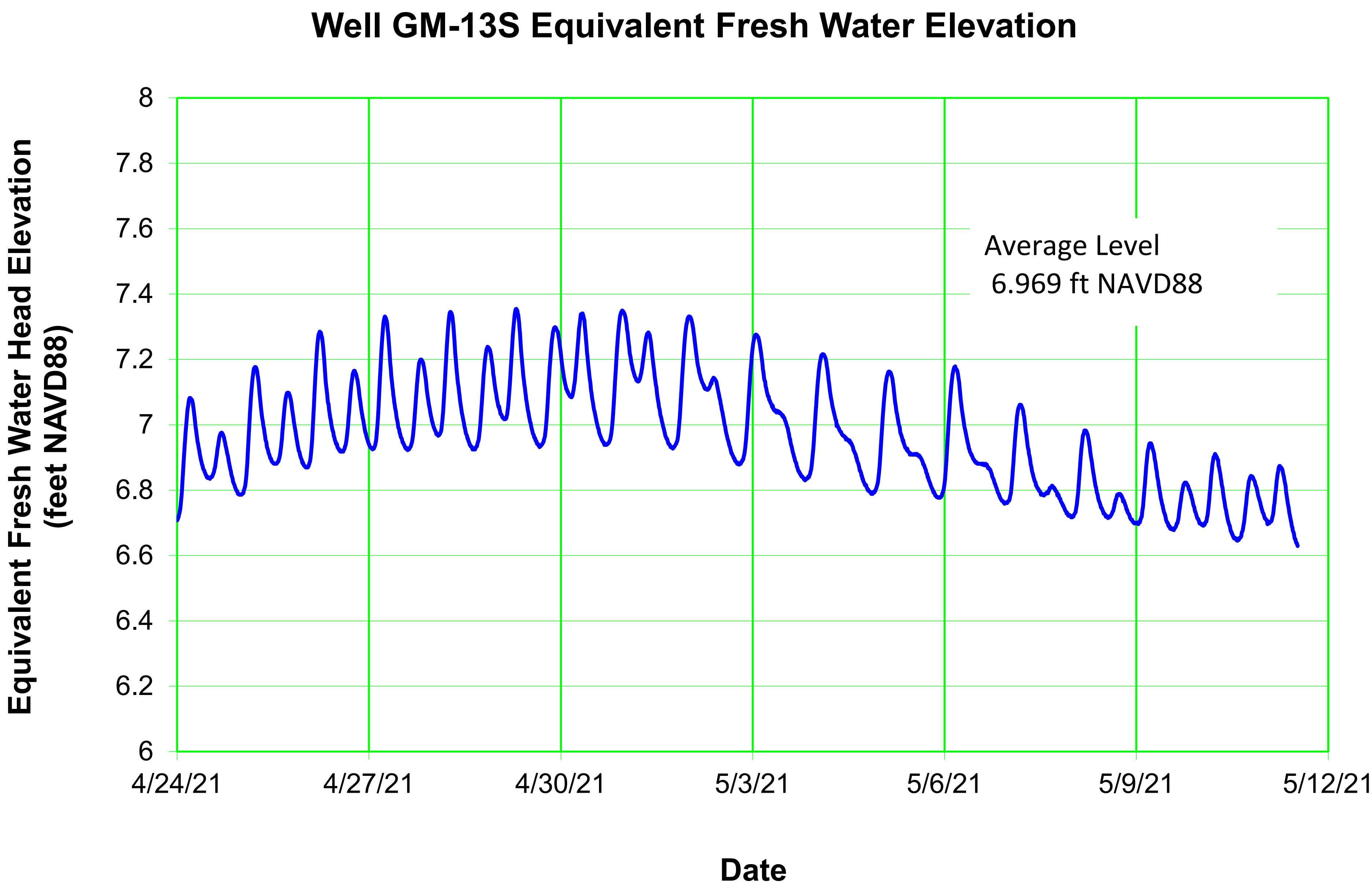
Well GM-11S Equivalent Fresh Water Elevation
Equivalent Fresh Water Head Elevation (feet NAVD88)
8
7.8
7.6
7.4
7.2
7
6.8
6.6
6.4
6.2
6
4/24/21
4/27/21
4/30/21
5/3/21
5/6/21
5/9/21
5/12/21
Date
Average Level
6.927 ft NAVD88



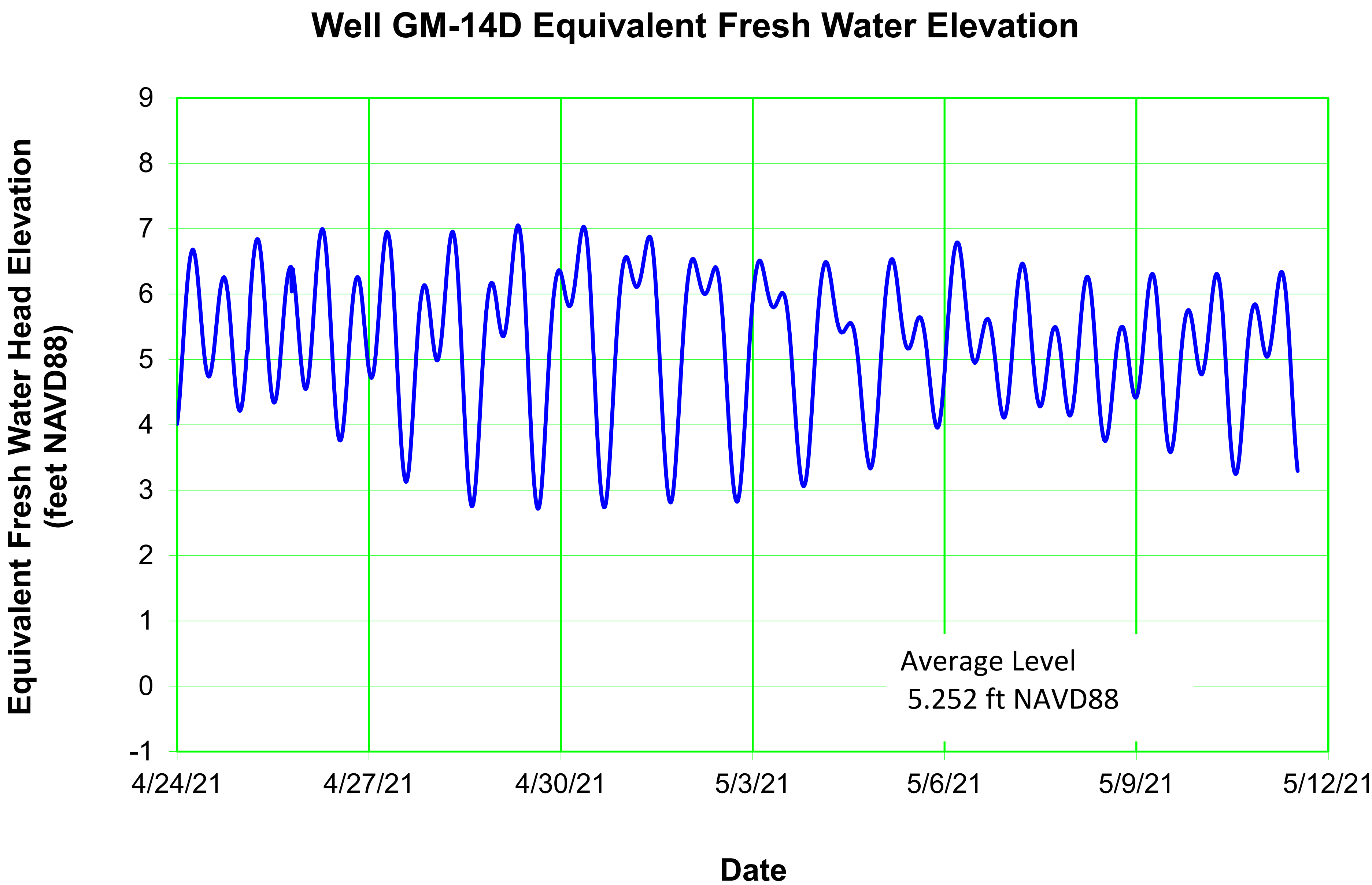
Well GM-12S Equivalent Fresh Water Elevation
Equivalent Fresh Water Head Elevation (feet NAVD88)
8
7.8
7.6
7.4
7.2
7
6.8
6.6
6.4
6.2
6
4/24/21
4/27/21
4/30/21
5/3/21
5/6/21
5/9/21
5/12/21
Date
Average Level
7.096 ft NAVD88



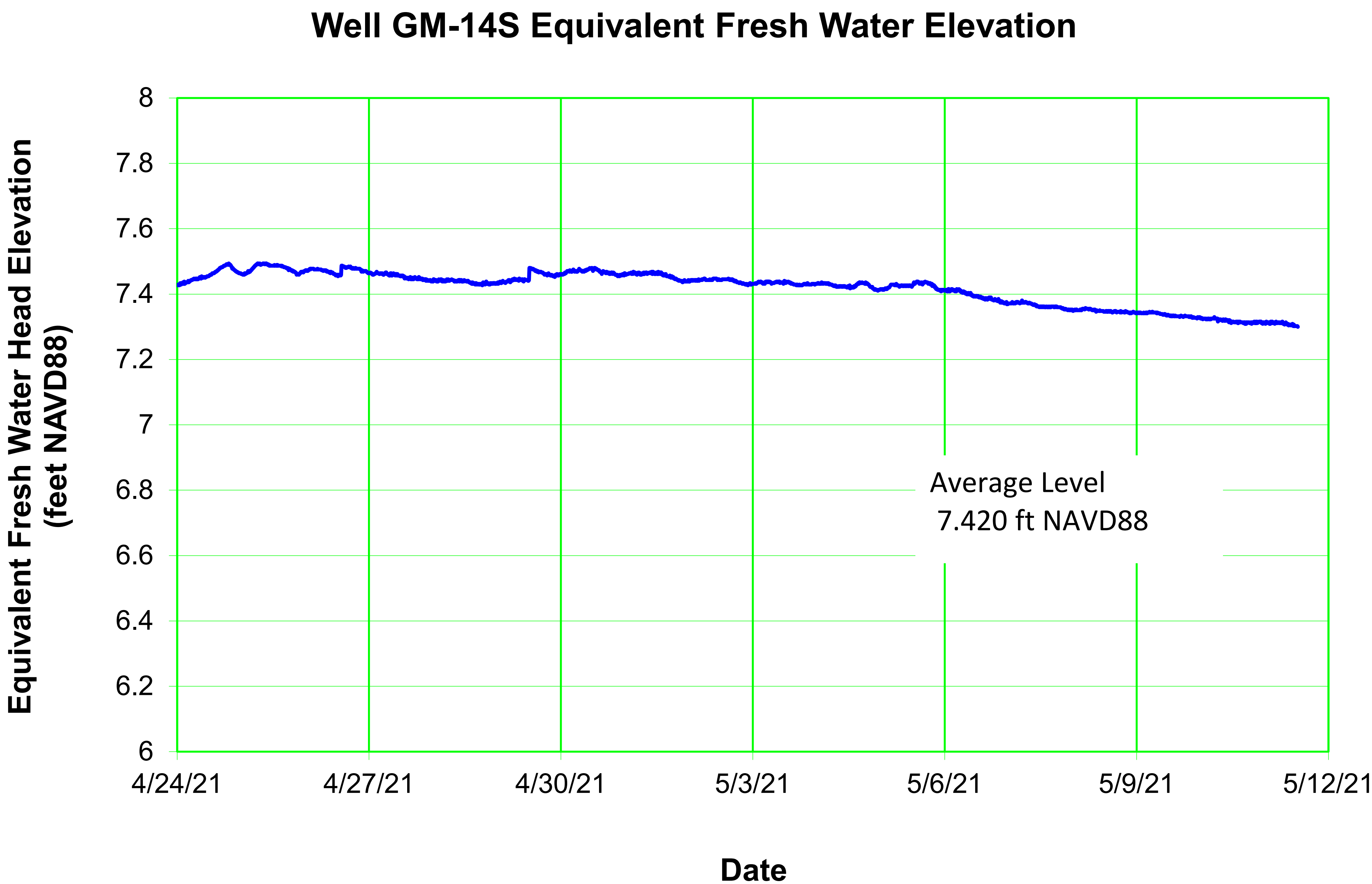
Well GM-13D Equivalent Fresh Water Elevation
Equivalent Fresh Water Head Elevation (feet NAVD88)
9
8
7
6
5
4
3
2
1
0
-1
4/24/21
4/27/21
4/30/21
5/3/21
5/6/21
5/9/21
5/12/21
Date
Average Level
4.929 ft NAVD88

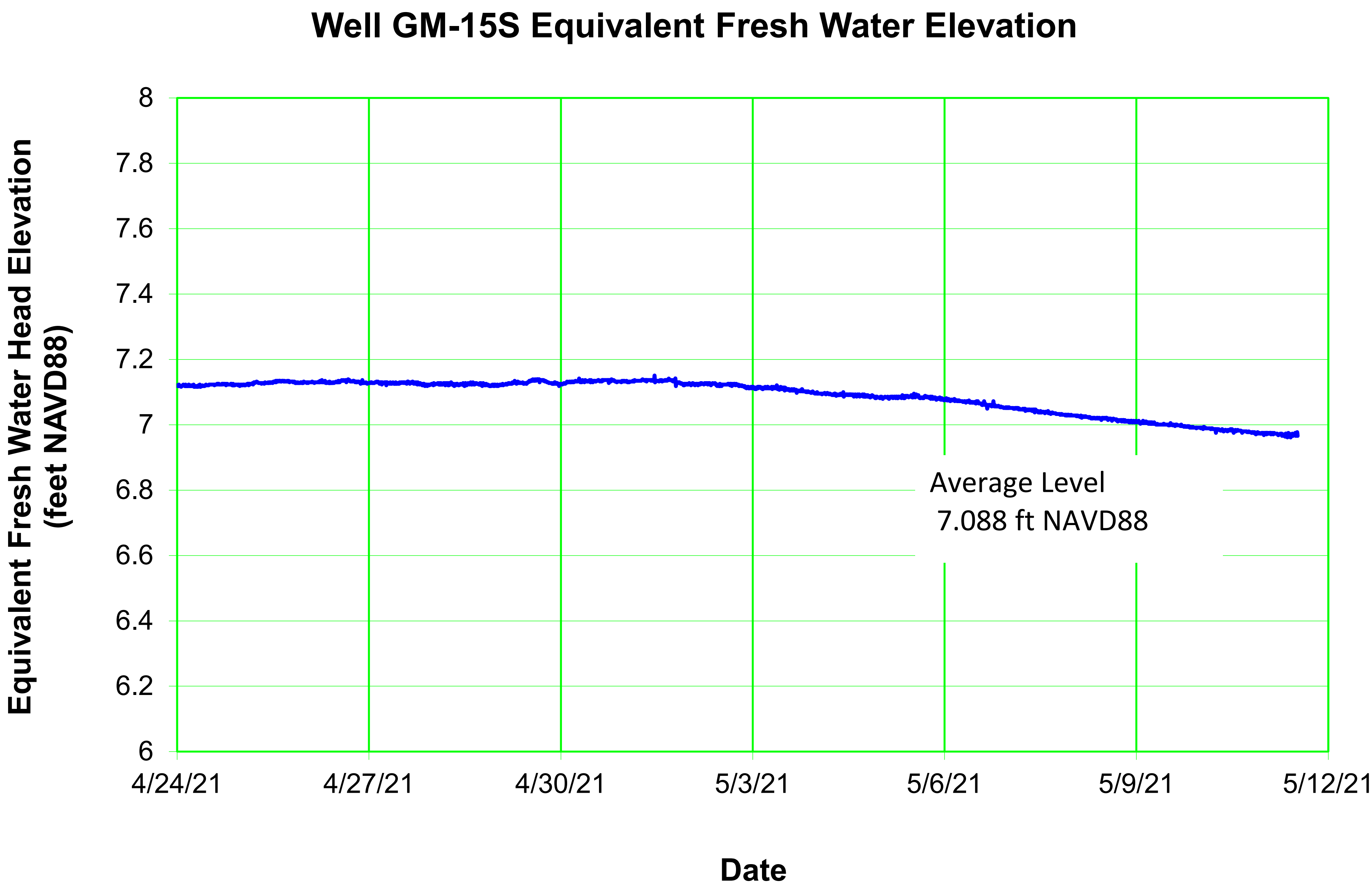


Well GM-13S Equivalent Fresh Water Elevation
Equivalent Fresh Water Head Elevation (feet NAVD88)
8
7.8
7.6
7.4
7.2
7
6.8
6.6
6.4
6.2
6
4/24/21
4/27/21
4/30/21
5/3/21
5/6/21
5/9/21
5/12/21
Date
Average Level
6.969 ft NAVD88

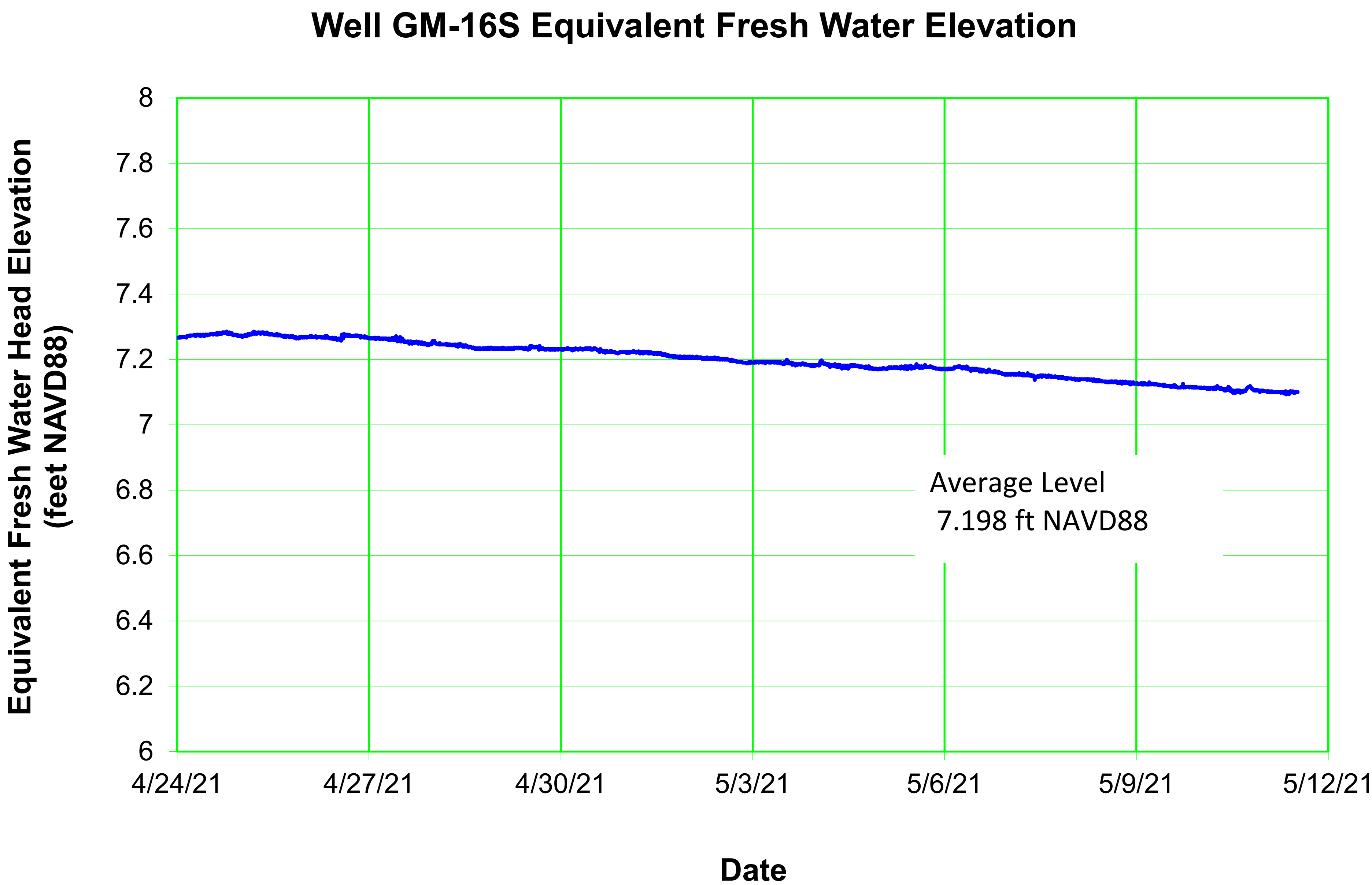


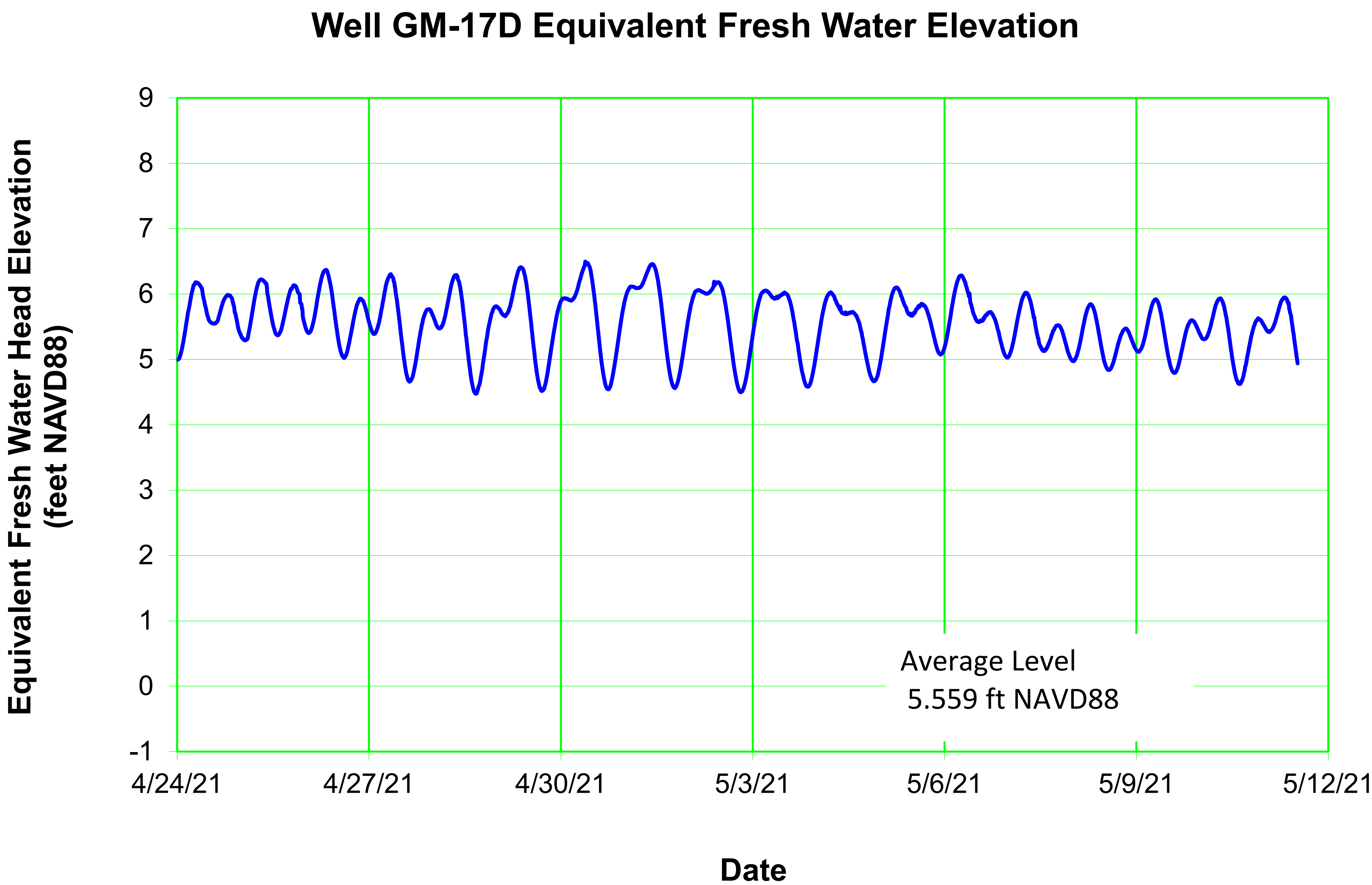
Well GM-14D Equivalent Fresh Water Elevation
Equivalent Fresh Water Head Elevation (feet NAVD88)
9
8
7
6
5
4
3
2
1
0
-1
4/24/21
4/27/21
4/30/21
5/3/21
5/6/21
5/9/21
5/12/21
Date
Average Level
5.252 ft NAVD88


Well GM-14S Equivalent Fresh Water Elevation
Equivalent Fresh Water Head Elevation (feet NAVD88)
8
7.8
7.6
7.4
7.2
7
6.8
6.6
6.4
6.2
6
4/24/21
4/27/21
4/30/21
5/3/21
5/6/21
5/9/21
5/12/21
Date
Average Level
7.420 ft NAVD88

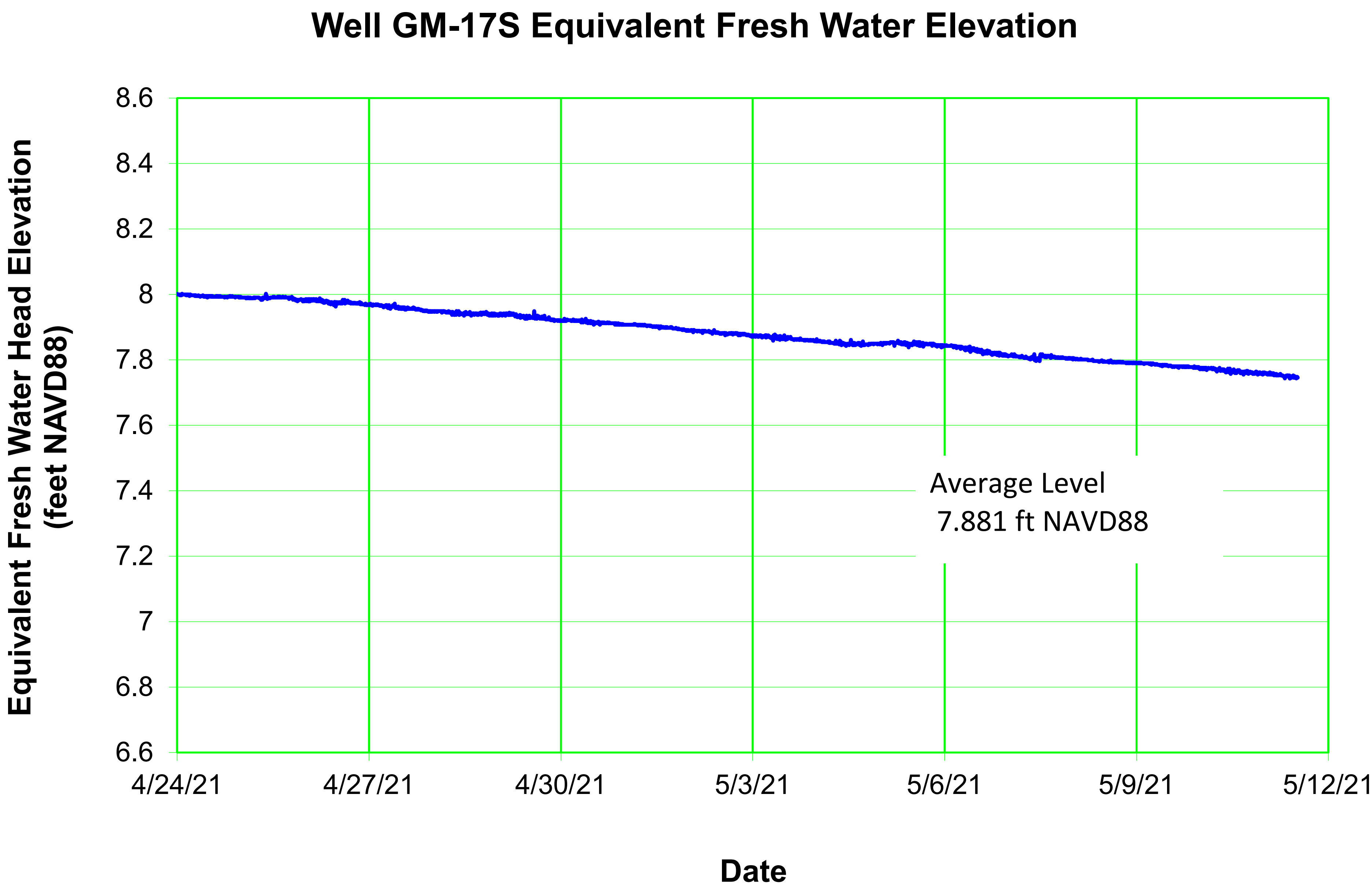


Well GM-15S Equivalent Fresh Water Elevation
Equivalent Fresh Water Head Elevation (feet NAVD88)
8
7.8
7.6
7.4
7.2
7
6.8
6.6
6.4
6.2
6
4/24/21
4/27/21
4/30/21
5/3/21
5/6/21
5/9/21
5/12/21
Date
Average Level
7.088 ft NAVD88

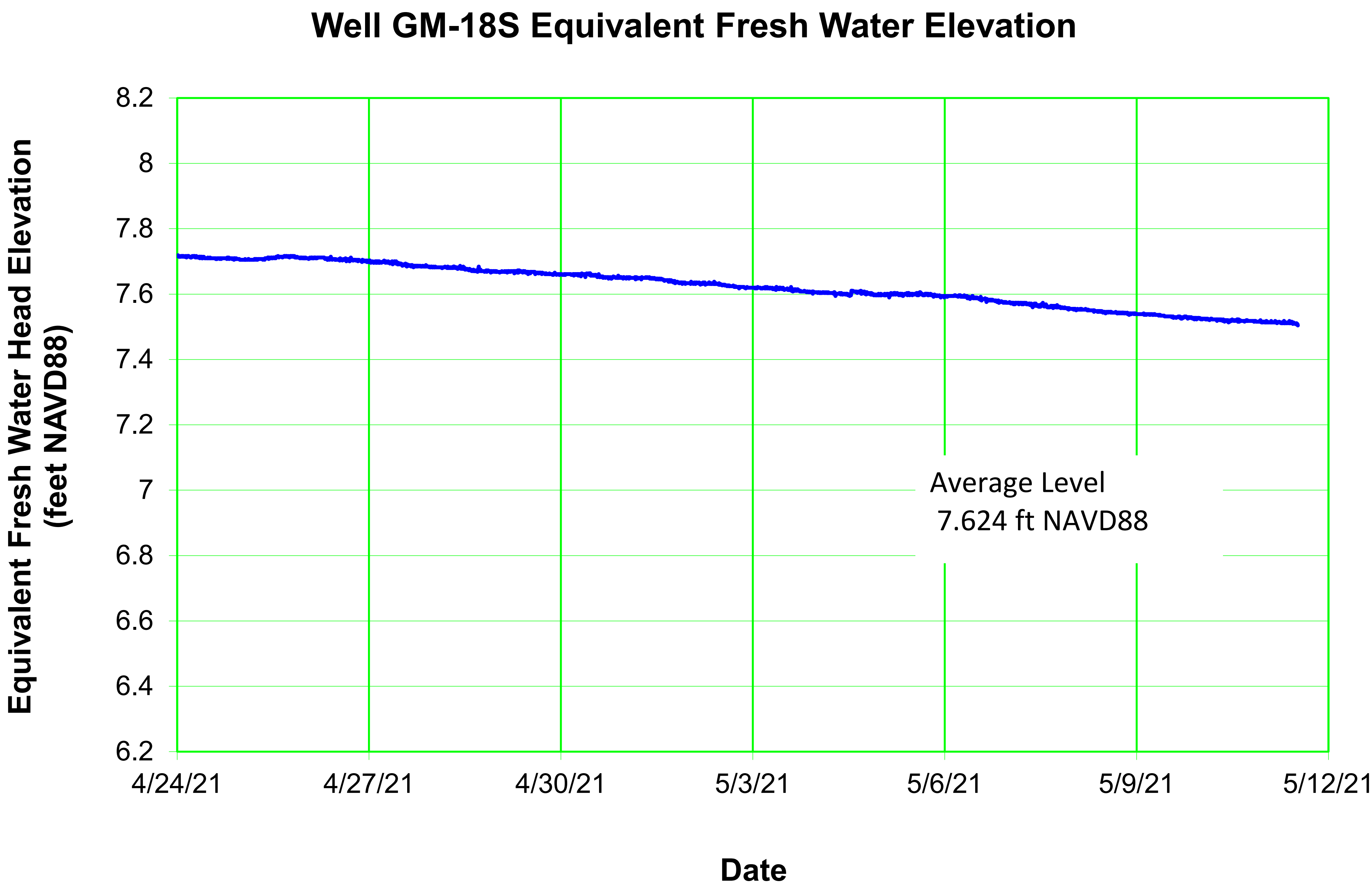

Well GM-16S Equivalent Fresh Water Elevation
Equivalent Fresh Water Head Elevation (feet NAVD88)
8
7.8
7.6
7.4
7.2
7
6.8
6.6
6.4
6.2
6
Average Level
7.198 ft NAVD88
4/24/21
4/27/21
4/30/21
5/3/21
5/6/21
5/9/21
5/12/21
Date



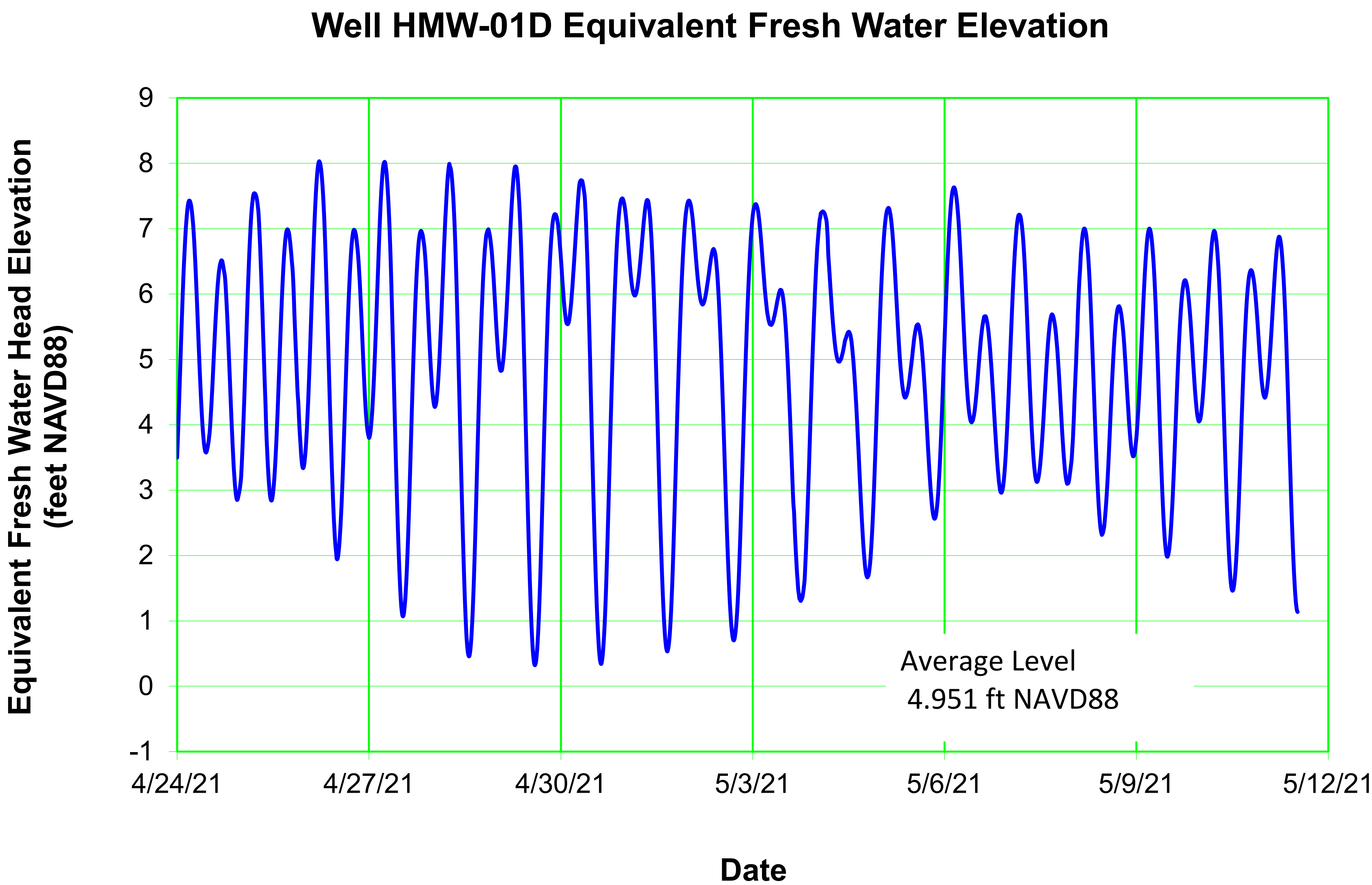
Well GM-17D Equivalent Fresh Water Elevation
Equivalent Fresh Water Head Elevation
(feet NAVD88)
9
8
7
6
5
4
3
2
1
0
-1
4/24/21
4/27/21
4/30/21
5/3/21
5/6/21
5/9/21
5/12/21
Date
Average Level
5.559 ft NAVD88



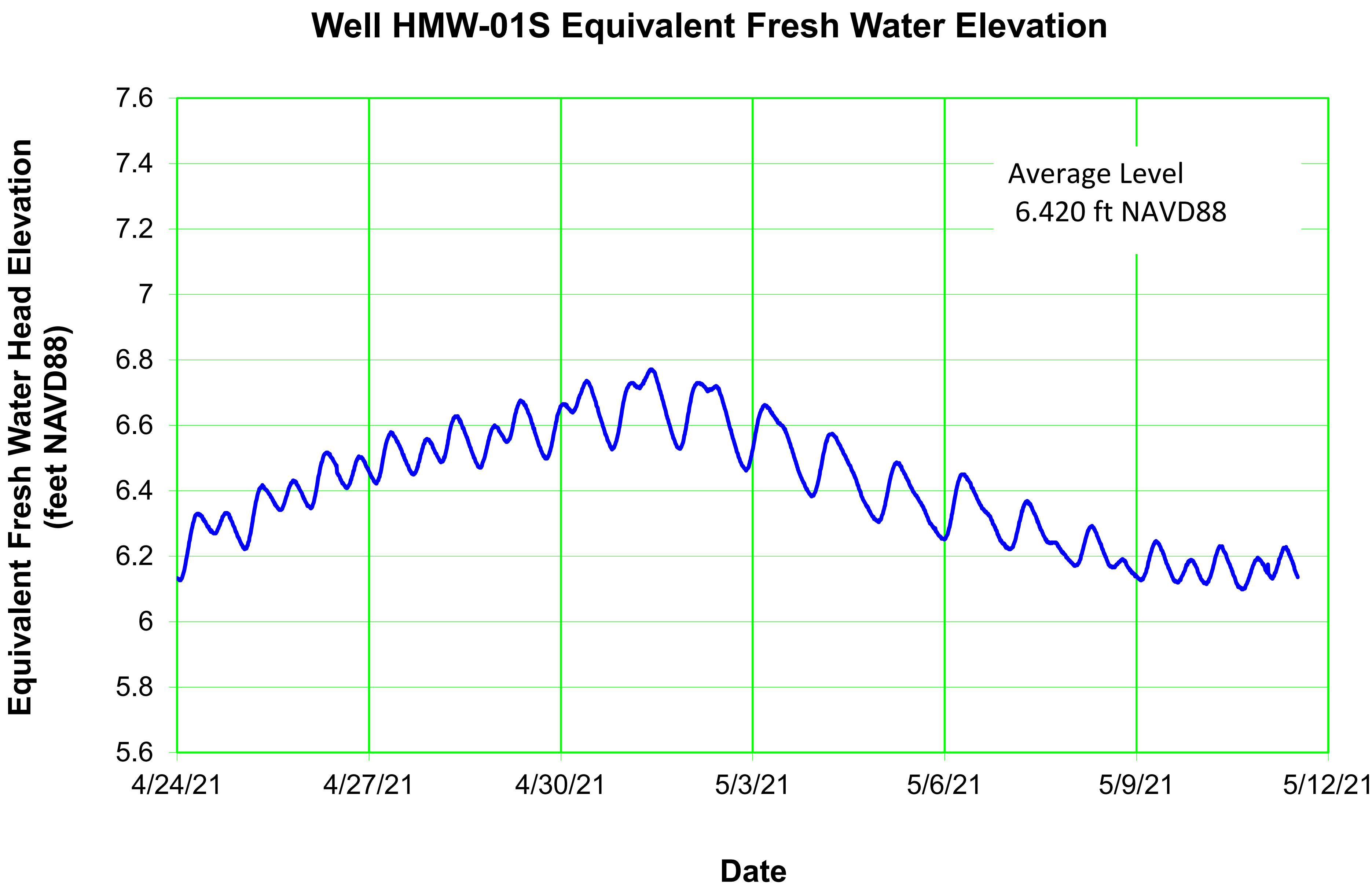
Well GM-17S Equivalent Fresh Water Elevation
Equivalent Fresh Water Head Elevation (feet NAVD88)
8.6
8.4
8.2
8
7.8
7.6
7.4
7.2
7
6.8
6.6
4/24/21
4/27/21
4/30/21
5/3/21
5/6/21
5/9/21
5/12/21
Date
Average Level
7.881 ft NAVD88



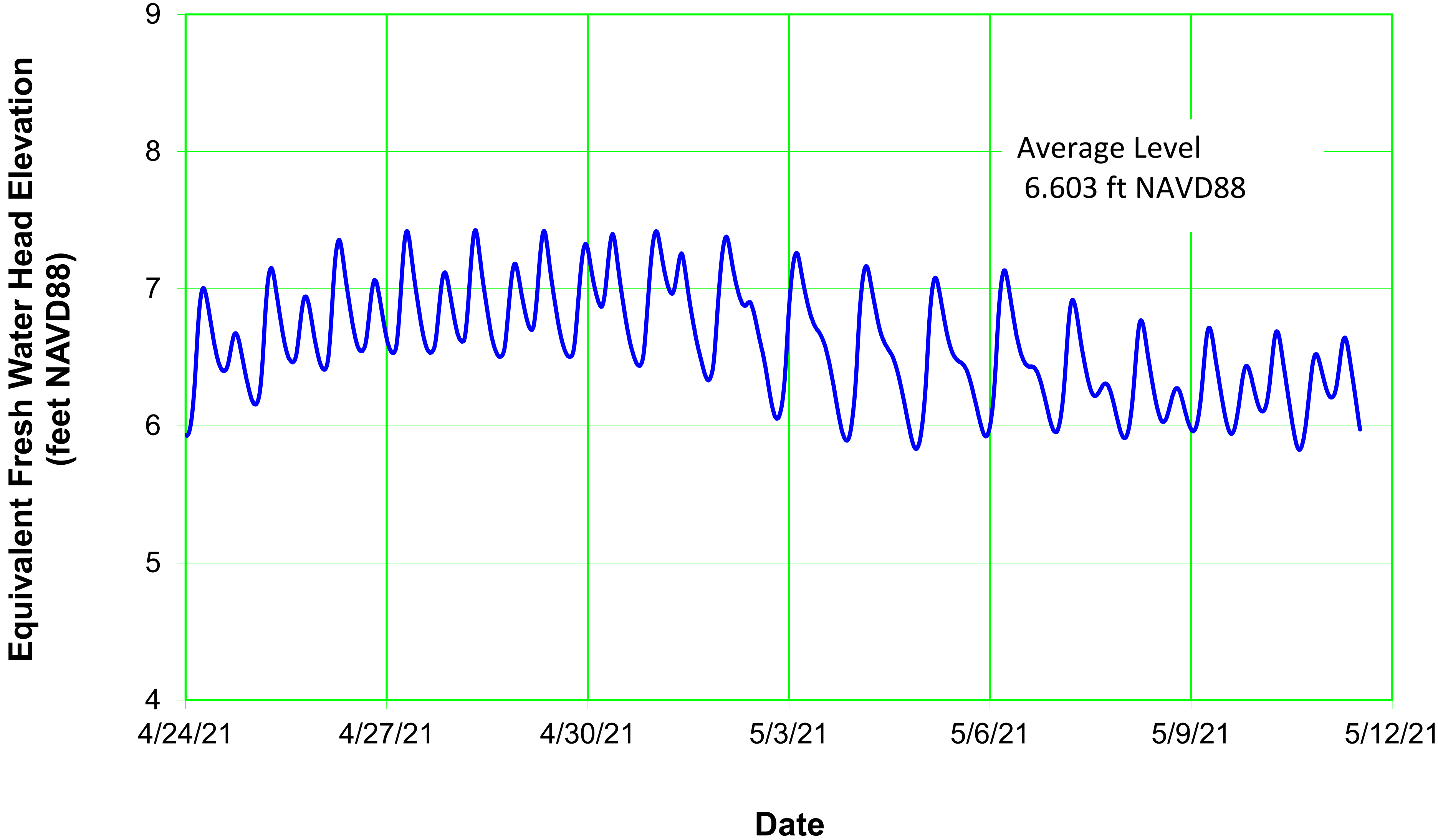
Well GM-18S Equivalent Fresh Water Elevation
Equivalent Fresh Water Head Elevation (feet NAVD88)
8.2
8
7.8
7.6
7.4
7.2
7
6.8
6.6
6.4
6.2
4/24/21
4/27/21
4/30/21
5/3/21
5/6/21
5/9/21
5/12/21
Date
Average Level
7.624 ft NAVD88

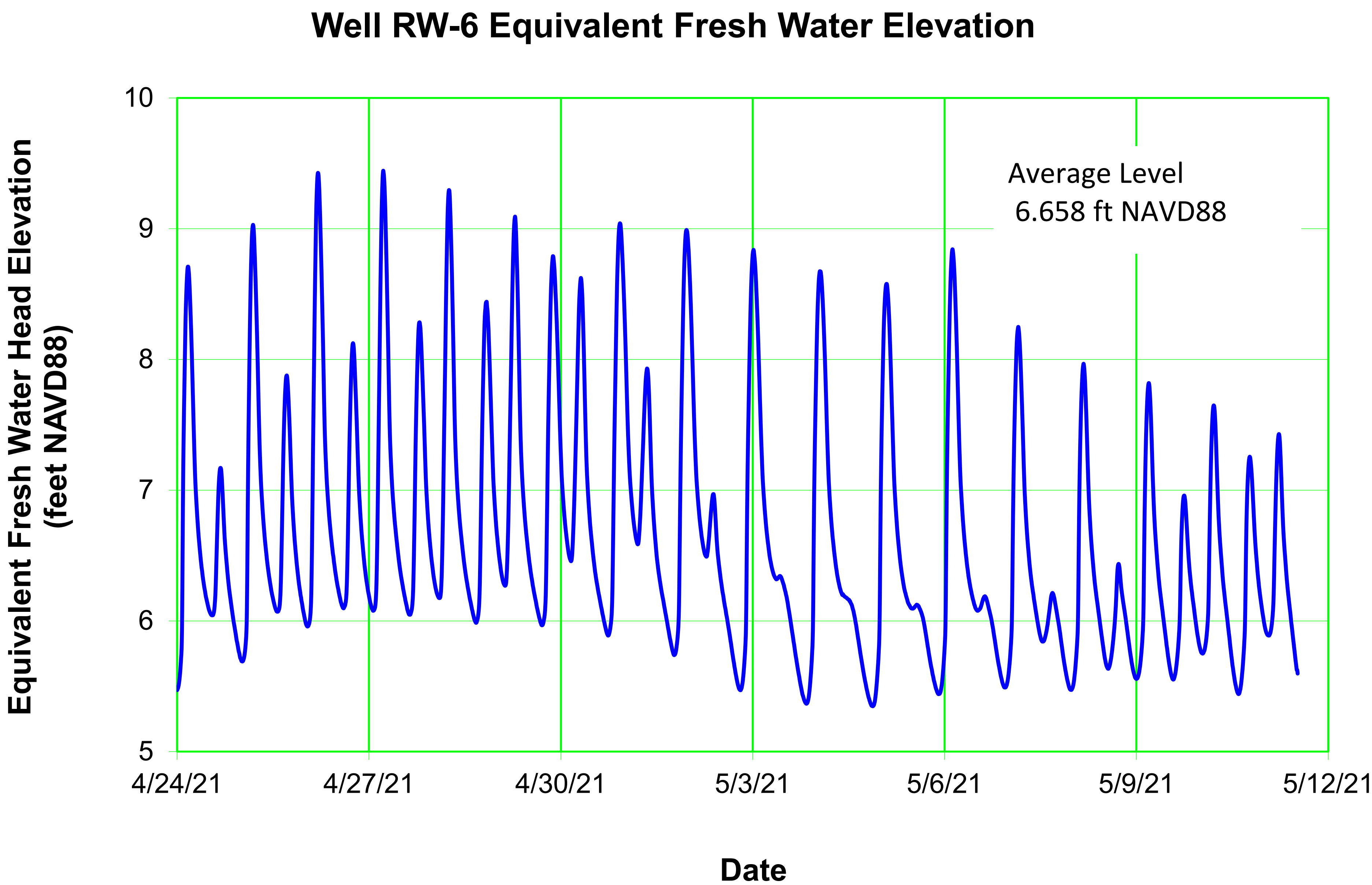


Well HMW-01D Equivalent Fresh Water Elevation
Equivalent Fresh Water Head Elevation (feet NAVD88)
9
8
7
6
5
4
3
2
1
0
-1
4/24/21
4/27/21
4/30/21
5/3/21
5/6/21
5/9/21
5/12/21
Date
Average Level
4.951 ft NAVD88


Well HMW-01S Equivalent Fresh Water Elevation
Equivalent Fresh Water Head Elevation (feet NAVD88)
7.6
7.4
7.2
7
6.8
6.6
6.4
6.2
6
5.8
5.6
Average Level
6.420 ft NAVD88
4/24/21
4/27/21
4/30/21
5/3/21
5/6/21
5/9/21
5/12/21
Date

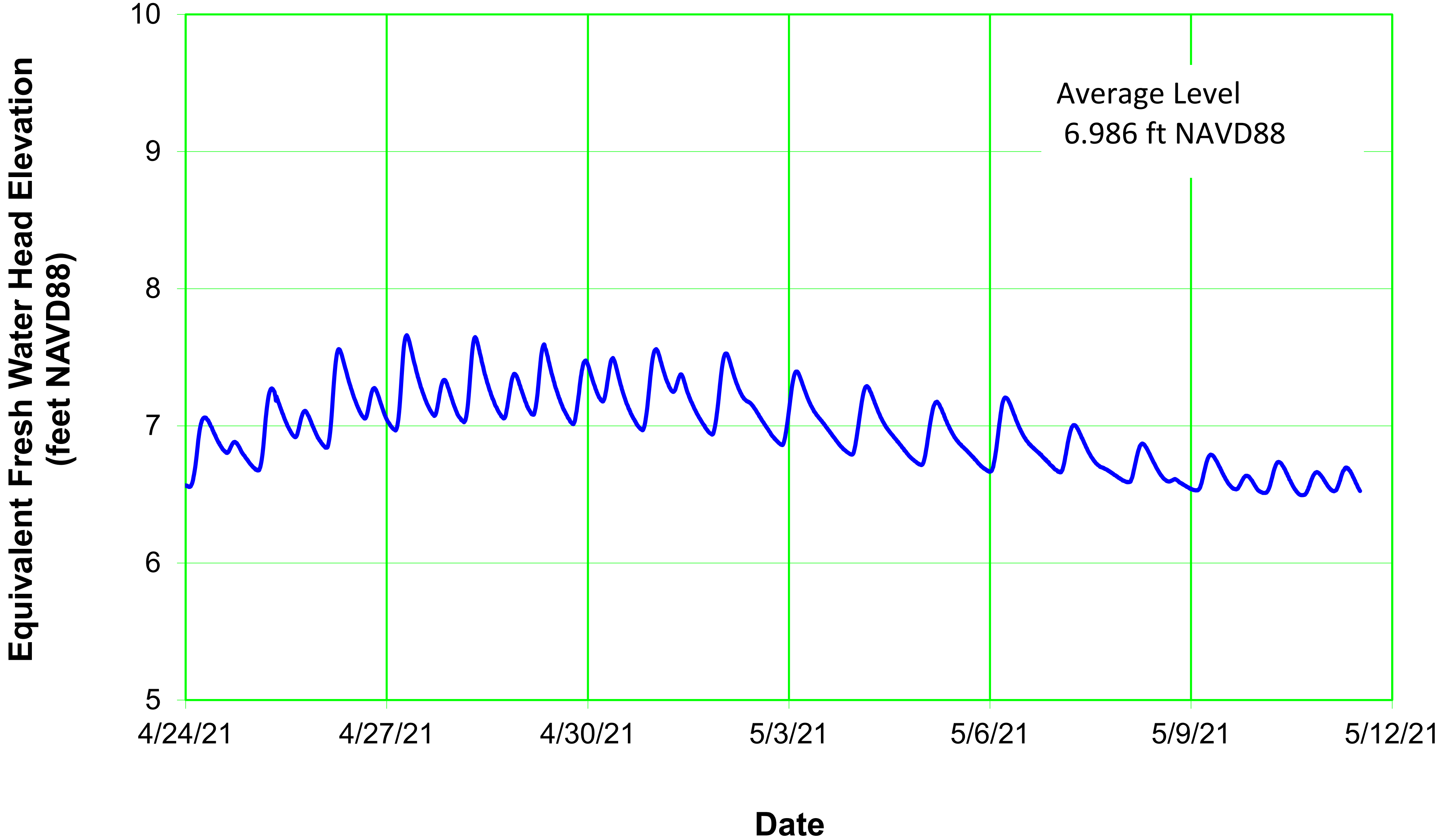
Well RW-5 Equivalent Fresh Water Elevation

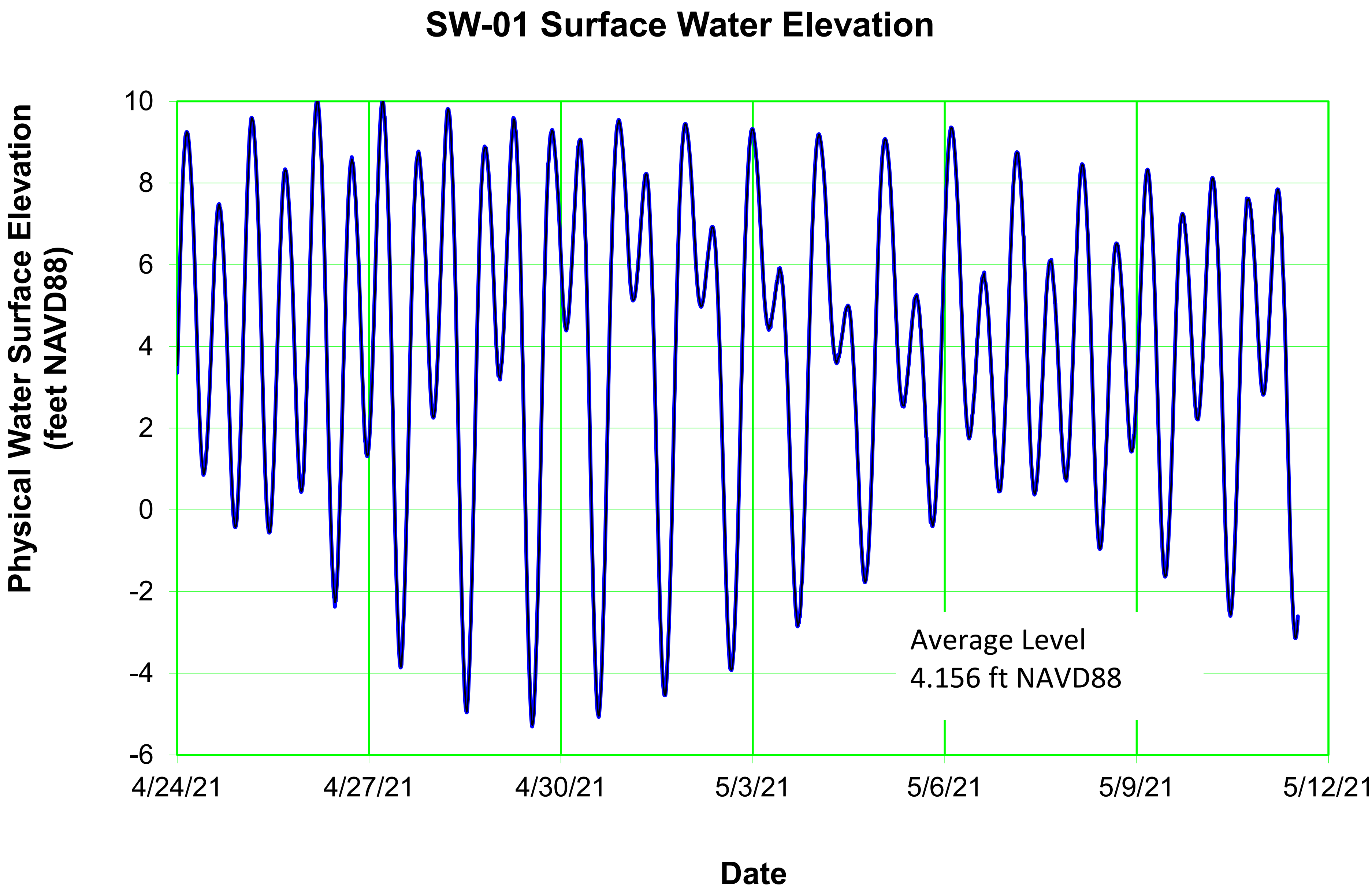




Well RW-6 Equivalent Fresh Water Elevation
Equivalent Fresh Water Head Elevation (feet NAVD88)
10
9
8
7
6
5
4/24/21
4/27/21
4/30/21
5/3/21
5/6/21
5/9/21
5/12/21
Date
Average Level
6.658 ft NAVD88

Well RW-10 Equivalent Fresh Water Elevation




SW-01 Surface Water Elevation
Physical Water Surface Elevation (feet NAVD88)
10
8
6
4
2
0
-2
-4
-6
4/24/21
4/27/21
4/30/21
5/3/21
5/6/21
5/9/21
5/12/21
Date
Average Level
4.156 ft NAVD88