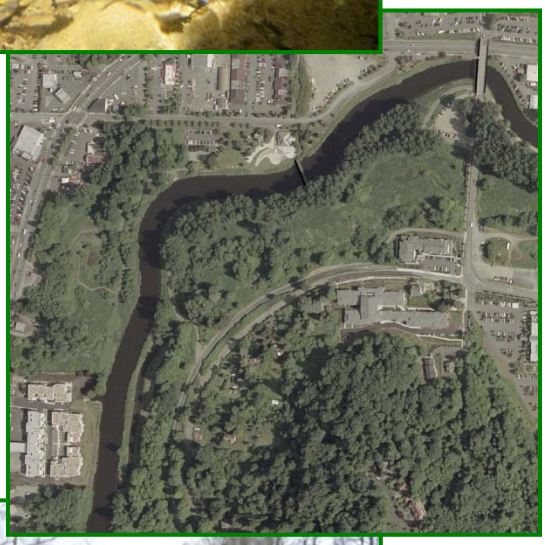
- FINAL -
Sammamish River Off-Channel Thermal Refuge Rearing Habitat Restoration Preliminary Design Report



Prepared for:

City of Bothell

Prepared by:

R2 Resource Consultants, Inc.
15250 N.E. 95th Street
Redmond, Washington 98052

October 10, 2014

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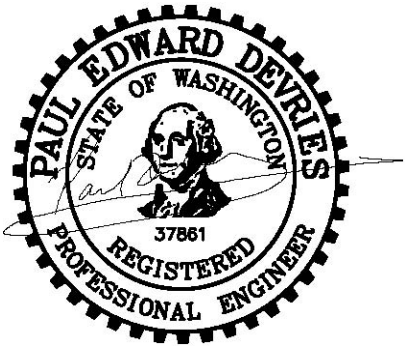

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CONTENTS

1. INTRODUCTION 1
2. EXISTING CONDITIONS 2
   2.1 SITE HYDROLOGY AND WATER LEVELS 2
3. PRELIMINARY DESIGN ALTERNATIVES 7
4. PREFERRED ALTERNATIVE AND RELEVANT DESIGN CONSIDERATIONS 9
5. DESIGN ANALYSES 10
   5.1 CULVERT DESIGN 10
      5.1.1 Inlet and Outlet Control Elevations 11
      5.1.2 Culvert Width 14
      5.1.3 Culvert Height 15
      5.1.4 Culvert Outlet/Apron Design 15
      5.1.5 Foundation/Backfill Design 17
   5.2 CHANNEL DESIGN 19
      5.2.1 Channel Planform Layout and Pool Locations 19
      5.2.2 Channel Invert Elevation/Water Depth 19
      5.2.3 Channel Width and Cross-Section Profile 20
      5.2.4 Instream Habitat Complexity (Large Woody Debris) 21
   5.3 VEGETATION RESTORATION DESIGN 22
      5.3.1 Vegetation Restoration Background 22
      5.3.2 Vegetation Restoration Design 26
         5.3.2.1 Reed Canarygrass Floodplain: Below 100-Year Floodplain Elevation 28
         5.3.2.2 Reed Canarygrass Floodplain: Above 100-Year Floodplain Elevation 28
         5.3.2.3 Blackberry Island and Blackberry Hillslope Restoration Plantings 29
         5.3.2.4 Reed Canarygrass Forest Inclusion 30
         5.3.2.5 Existing Riparian Forest Enhancement 31

5.3.2.6 Excavated Channel – Streambank Riparian Restoration Area Planting 31

6. COST ESTIMATE....33

7. REFERENCES 40

APPENDIX A: Flow Duration Percentiles for Gages Evaluated in the Hydrologic Analysis
APPENDIX B: Zipper Geo Associates LLC Geotechnical Engineering Report
APPENDIX C: Preliminary Design Drawings

FIGURES

Figure 1. Location of Sammamish River Off-Channel Habitat Restoration Project site, approximate disturbance limits for construction (yellow dashed line), and relevant landmarks. 3

Figure 2. Duration of Lake Washington water levels by month. Data from USACE Dataquery website, Station LKW, period=1991-2014. 4

Figure 3. Locations of major tributaries and stream gaging stations considered in the hydrologic analysis. Image from King County Hydrologic Information Center Webpage....5

Figure 4. Basis for selecting 18.5 ft as the inlet culvert invert elevation in terms of duration of water levels at the proposed channel inlet location in the months when outmigration occurs (April-June)and when elevated water temperatures are a concern (July-September)....13

Figure 5. Comparison of seasonal variation in frequencies that water level exceeds 18.5 ft NAVD88 at the proposed side channel inlet (1991-2014), monthly mean water temperatures in the Sammamish River (2005-14), and WDFW smolt trap run size estimates at Bear Creek (2009-12)....14

Figure 6. Floodplain elevation-storage volume curve (top) and comparison of required and potential flow rates through a single 5 ft wide culvert. Storage volume was summed east and west of 102nd Ave NE. 16

Figure 7. Scour calculation worksheet for designing culvert apron substrate depth and length....18

Figure 8. Image from Bothell Historical Museum showing flooding in the Project Area in the early 1900s. The 102nd Street bridge is near the center of the photograph. 23

Figure 9. Image from Bothell Historical Museum circa 1905. The 102nd Street bridge is shown near the center of the photograph with Sammamish River and floodplain of the Project Area west of the bridge. 23

Figure 10. Image from Bothell Historical Museum circa 1908. The 102nd Street bridge is on the far right side of photo. The proposed project area is inundated....24

TABLES

Table 1. List of stream gaging stations used to establish project hydrology. 4

Table 2. Duration characteristics of water levels in Lake Washington and flows in the Sammamish River at the project location. 6

Table 3. Flood flows estimated for the Sammamish River at the Project site (source: NHC 2010)....7

Table 4. Duration characteristics of water levels in Sammamish River at the Inlet. 12

Table 5. Partial listing of vascular plant species observed at the Project Area. Species identifications and taxonomic nomenclature follow Flora of the Pacific Northwest (Hitchcock and Cronquist 1990) and the PLANTS database (USDA and NRCS 2014), wetland indicator status follow National List of Plant Species that Occur in Wetlands: Northwest (Region 9) (Lichvar et al. 2014). 25

Table 6. Mature plant height estimated at 20 years with maximum height, if different, shown in parentheses. 27

Table 7. Planting specifications for reed canarygrass floodplain below 100-year floodplain. 28

Table 8. Planting specifications for reed canarygrass meadow above 100-year floodplain elevation. 29

Table 9. Planting specifications for Blackberry Island and Blackberry Hillslope Restoration. 30

Table 10. Planting specifications for reed canarygrass forest inclusions. 31

Table 11. Planting specifications for Existing Riparian Forest Enhancement. 32

Table 12. Planting specifications for excavated channel - streambank riparian restoration area....32

Table 13. Summary of Engineer's Opinion of Probable Cost: Sammamish River Off Channel Habitat & Floodplain Restoration - Preliminary Design. 33

Table 14. Estimated Unit Costs Used in Developing Cost Estimate for Preliminary Design. 34

Table 15. Estimated Unit Costs Associated with Culvert Installation, Preliminary Design. 36

Table 16. Estimated Unit Costs Associated With Vegetation Restoration, Maintenance. 37

1. INTRODUCTION

The City of Bothell (COB) Public Works Department (PWD) desires to reconnect and restore ~1,100 ft of an old remnant channel and floodplain of the Sammamish River within the City of Bothell limits. Funding has been obtained via SRFB grant #13-1133, and thus the project is subject to SRFB Manual 18 requirements. Project goals include: increasing juvenile salmon habitat quantity and quality in a critical reach of the Sammamish River; restoring floodplain plant community diversity and structure; restoring floodplain and channel connectivity and function; and developing opportunities for public involvement and education. The presently undeveloped project site is owned primarily by COB and King County and is zoned Public Park Open Space on land located to the west of 102nd Ave NE.

The proposed action was identified as a key project of the 2002 Sammamish River Corridor Action Plan and responds directly to the 2005 WRIA 08 Chinook Recovery Plan which identified the need to increase off-channel rearing habitat for salmonids throughout the river basin (King County Department of Natural Resources 2005). A key goal is to hydraulically reconnect the restored area at both ends to the Sammamish River to make the project accessible as off-channel rearing habitat for salmonids, with an emphasis on Chinook and coho salmon. The site is located within a reach of the Sammamish where there are cold water springs, and a feasibility study prepared by R2/PGG (2013) for the COB concluded that a feasible restoration project could be designed that provides critical cool water refuge during summer months, while minimizing access by predatory fish during the warmest summer months.

This report:

- Summarizes the findings of the feasibility report, which included identifying and evaluating alternatives.
- Documents the technical decisions that informed the development of the selected project design.
- Provides a determination of quantities and construction cost based on the preliminary design.

Most of the details presented will be also relevant to the final design. Any changes to the final design will be documented in a final design technical addendum to this report.

2. EXISTING CONDITIONS

The Project area is depicted in Figure 1. The presently undeveloped project site is owned primarily by COB and King County and is zoned Public Park Open Space. All disturbances will occur on COB owned land, including the trail, although King County as trail manager will also be a stakeholder.

The Project site is a former low elevation floodplain that was hydrologically abandoned when the US Army Corps of Engineers (USACE) constructed the Lake Washington Ship Canal and consequently lowered the level of Lake Washington below its pre-development level by approximately 9 ft (Chrzastowski 1983), effectively decoupling the floodplain from the Sammamish River. There is evidence of relic channels on site, although much of the area was swampy prior to lowering of the lake level, reflecting long term deposition of fine grained sediments in what appears to have been a shallow water wetland complex at the head of the lake based on site ground elevations. Well boring logs from R2's feasibility study are consistent with this, showing a mix of sand and silt substrates in much of the upper soil horizons (R2/PGG 2013). Historically, the floodplain area was inundated frequently by Lake Washington and is estimated to have been under 2 feet of water typically (Tetra Tech 2002). The USACE straightened much of the river in the 1910s and channelized the river in the vicinity of the project site ca. 1964 (Williams et al. 1975). A portion of the project reach was straightened at that time, as evidenced in comparisons of the 1953 USGS 7.5 minute topographic map and a photogrammetric survey map prepared for the USACE in 1961 with later maps and aerial photographs. Because flood flows were able to disperse over a low elevation floodplain, it is likely that the historic Sammamish River channel was smaller than at present.

2.1 SITE HYDROLOGY AND WATER LEVELS

Water levels in the Sammamish River vary seasonally in the vicinity of the proposed inlet and outlet locations in ways that are unique to the project site. Although the site is located between river miles 3 and 4, the location is under strong backwater control from Lake Washington. HEC-RAS modeling indicates that at most of the lower to mid-flow range, the lake level is approximately 0.2 ft lower than the river stage at the site. Importantly, lake level management has a strong influence on water levels most of the year and causes them to fall within a relatively narrow range compared with other rivers. This is because the lake level is managed by the USACE at the Hiram M. Chittenden Locks to be around 17 feet (NAVD88) over the winter when river flows are high, and is ~2 feet higher during the summer when river flows are lowest (Figure 2).

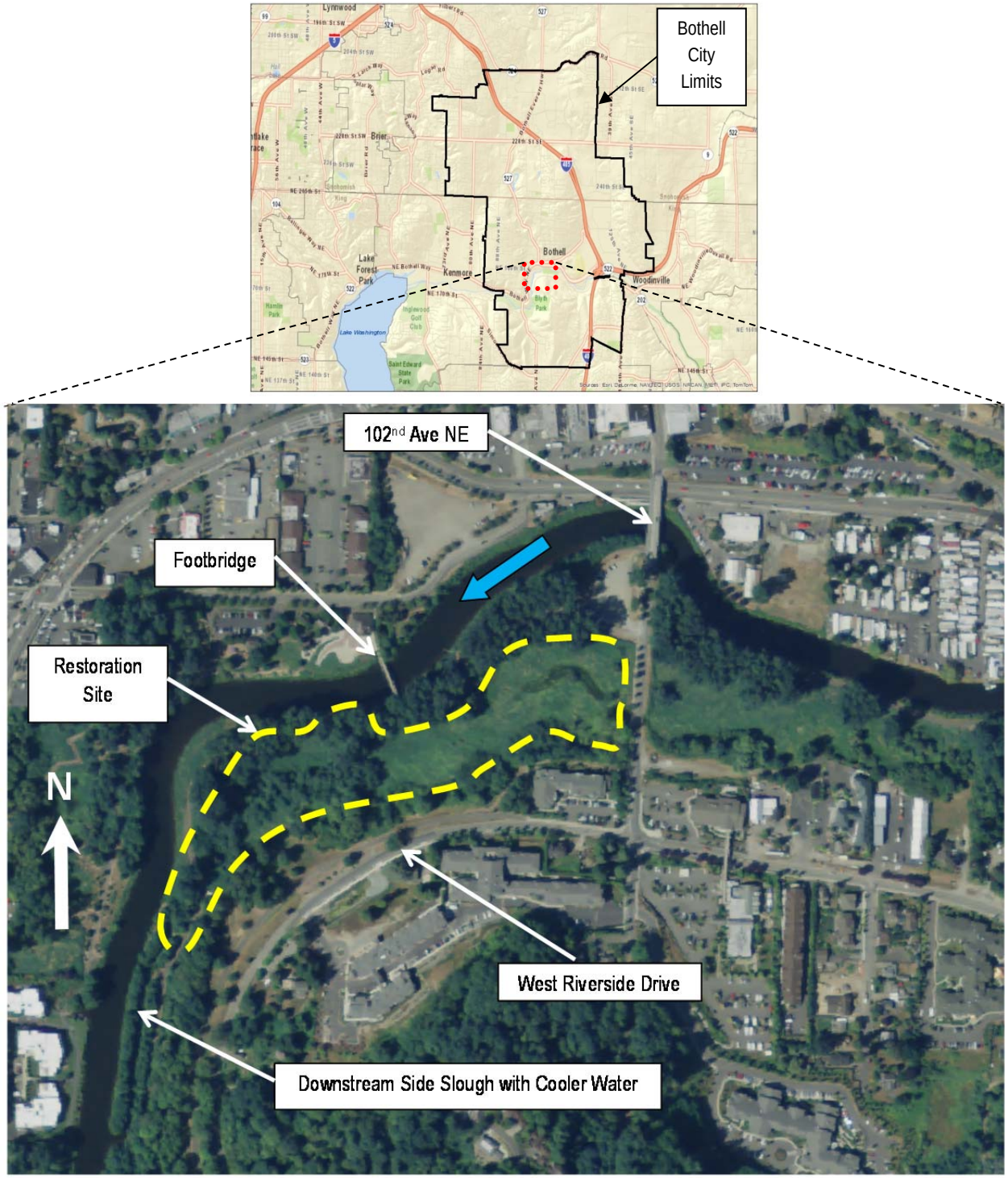


Figure 1. Location of Sammamish River Off-Channel Habitat Restoration Project site, approximate disturbance limits for construction (yellow dashed line), and relevant landmarks.

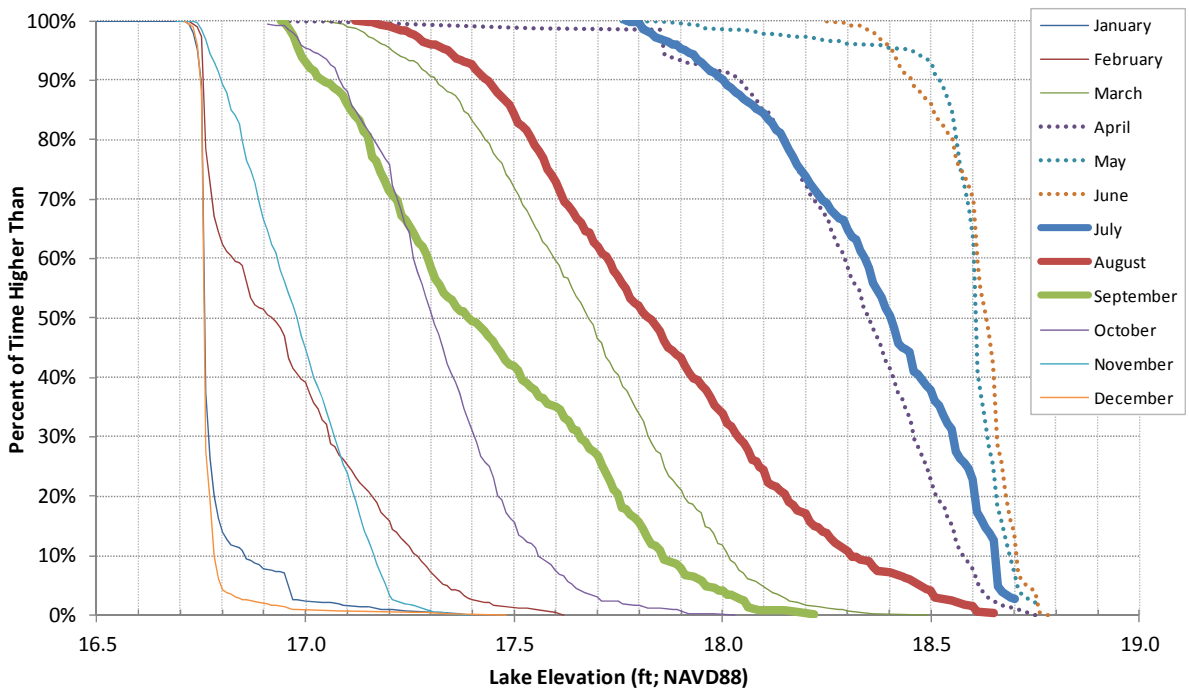


Figure 2. Duration of Lake Washington water levels by month. Data from USACE Dataquery website, Station LKW, period=1991-2014.

There has been relatively good stream gaging in the basin (Table 1; Figure 3; Appendix A). Flow has been measured in the Sammamish River upstream at the NE 116th St gage, as well as in Little Bear Creek, North Creek, and Swamp Creek. Flows at Swamp Creek do not influence water levels at the project site because the stream discharges near the mouth of the Sammamish River, in a section that is deeper than upstream and effectively is part of the lake water body. The only other stream of any size between the site and the mainstem gage is Gold Creek (drainage area ~ 0.4 mi^2), which has been measured as part of this and a previous study performed by R2 to contribute a discharge around 3 cfs or less during the summer.

Table 1. List of stream gaging stations used to establish project hydrology.

				Drainage Area (mi^2)	
Stream, Location	**Operator**	**Station ID**	**Period of Record**	**At Gage**	**At Mouth**
Sammamish River @ 116th	USGS	12125000	Oct 87 - Jun 06	150	240
	King County	51T	Jun 05 - Present	150	240
Little Bear Creek @ 228th	Snohomish County	Bc	Mar 00 - Nov 12	11.4	15.6
North Creek @ County Line	Snohomish County	Nc	May 88 - May 11	26.6	28.5

Figure 3. Locations of major tributaries and stream gaging stations considered in the hydrologic analysis. Image from King County Hydrologic Information Center Webpage.

Flow at the site was estimated as the sum of flow at the mainstem gage plus flow at the North Creek and Little Bear Creek gages. Between 3 and 10 cfs was added to the sum to account for seasonal variation in Gold Creek inflows. While the gages in North and Little Bear Creek are not located close to their mouths, flow data collected by R2 indicates that there is relatively little flow accretion downstream such that the available records may be used in the preliminary design. Additional flow data collected this summer and fall will be used to refine the final design hydrology to account for flow accretion, and determine if the change in hydrology is significant enough to warrant fine-tuning of design elevations. Given the strong backwater control by Lake Washington, however, underestimation errors inherent in the sum of gage flows are generally not discernible in predicted water surface elevations at the project channel inlet, and small changes in the design hydrology resulting from more detailed analysis is not expected to change the design (but this will be checked). Table 2 presents the resulting estimated hydrology of the Sammamish River at the project site used for the preliminary design, where for simplicity flow percentiles at each gage were assumed to match (e.g., the 50% exceedance flow at the site was approximated as the sum of the 50 % exceedance flows at each gage).

Table 2. Duration characteristics of water levels in Lake Washington and flows in the Sammamish River at the project location.

Percent Exceed-ance	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						Lake Level (ft NAVD88)						
95%	16.7	16.8	17.2	17.9	18.5	18.4	17.9	17.3	17.0	17.0	16.8	16.7
80%	16.8	16.8	17.4	18.2	18.6	18.6	18.1	17.5	17.2	17.2	16.8	16.8
50%	16.8	16.9	17.7	18.4	18.6	18.6	18.4	17.8	17.4	17.3	17.0	16.8
20%	16.8	17.2	17.9	18.5	18.7	18.7	18.6	18.2	17.8	17.5	17.1	16.8
5%	17.0	17.3	18.1	18.6	18.7	18.7	18.7	18.5	18.0	17.6	17.2	16.8
						Flow (cfs)						
95%	292	270	239	223	153	114	66	50	52	68	126	223
80%	393	348	322	305	201	153	85	66	73	87	185	296
50%	619	513	498	412	275	211	123	83	86	128	330	513
20%	1062	828	761	588	379	324	174	108	118	212	613	978
5%	1752	1235	1235	883	536	537	268	157	179	370	1189	1469

Peak flows were taken from a floodplain mapping assessment performed by Northwest Hydraulics Consultants for King County (NHC 2010). Magnitudes of the 1.5 and 5 year floods were derived on log-probability paper by extrapolating back from the flood flows reported for the 10, 50, and 100 year floods. The flows were used for evaluating culvert design height and in the riparian and channel profile design, and for comparing hydraulic modeling predictions of water level with the official FEMA map of the 100 year floodplain. Table 3 lists the corresponding estimated flood flows at the project site. The present phase design was developed to avoid changing the extent of the mapped FEMA floodplain, thus the flood flows taken from the NHC (2010) assessment sufficed for our design purposes (i.e., there was no need to perform a new hydrologic analysis addressing FEMA requirements because there was no intent to change the FEMA flood map with this project).

Table 3. Flood flows estimated for the Sammamish River at the Project site (source: NHC 2010).

Recurrence Interval (years)	Flow (cfs)
1.5	2200
5	3000
10	3347
50	4090
100	4374

3. PRELIMINARY DESIGN ALTERNATIVES

The site is located within a reach of the Sammamish where there are cold water springs. The feasibility study (R2/PGG 2013) concluded it was possible through appropriate site investigation to develop a feasible restoration project that provides critical cool water refuge during summer months. Identification and evaluation of alternatives are described in greater detail in the feasibility report. Alternatives considered excavating and enhancing portions or all of a remnant side channel and adjacent seasonally inundated wetlands. Restoration and enhancement measures considered included:

1. Hydraulically reconnecting the relic channel and floodplain to the Sammamish River at both upper and lower ends making the project site accessible as off-channel rearing habitat for salmonids, with an emphasis on Chinook (*Oncorhynchus tshawytscha*) and coho (*O. kisutch*) salmon;

2. Enhancing the reed canarygrass (*Phalaris arundinaceae*) dominated relic floodplain wetlands with extensive plantings of native wetland shrubs;
3. Removing Himalayan blackberry (*Rubus armeniacus*) dominated wetland/upland border and planting native floodplain trees and shrubs; and
4. Utilizing the channel cut spoils material to create slightly elevated floodplain areas suitable for tree plantings, thereby enhancing the wetland forest habitat structure for birds.

The evaluation of alternatives and their feasibility was based on assessing primarily:

- Accessibility for fish, where the frequency and duration of different flow levels in the Sammamish River influenced the temporal availability of side channel habitat and provided an initial indication of the design of side channel invert elevations at the inlet, outlet, and in-between.
- Habitat suitability for juvenile salmon that may spend a year or more in freshwater, and for piscine predators during the summer in terms of water temperature and other water quality characteristics influenced by groundwater and river inflow. This included mapping groundwater hydraulic gradients and flow paths, estimating an average inflow rate using piezometers, and measuring groundwater temperatures, dissolved oxygen, and pH to assess the potential for providing cooler off-channel refuge habitat during the warmer parts of the year. The information was used to identify where the channel and pools might be located optimally In addition, the potential was considered for creating instream habitat complexity through instream structure, riparian enhancement, and interactions with potential beaver activity.
- Access for construction equipment onto and within the site, and for staging.
- The spatial extent of existing natural and enhanced wetlands and riparian vegetation were considered in formulating alternatives.
- The potential for sedimentation and infilling of constructed off-channel habitat.
- Cost vs. Benefit, where lower cost of less extensive construction activities was compared relative to identifying locations where groundwater cooling effects would be greatest.
- Potential for permitting difficulties, where some alternatives require more extensive permitting-related analysis/reporting and thus cost, involving the jurisdiction of the USACE (e.g., where an existing wetland mitigation site would be affected) and FEMA (where a letter of map revision might be required).

Three alternatives with variations based on inlet control elevation were identified in addition to the no-action alternative:

- Alternative 1: Long channel extending from East of 102nd Ave NE and running along margins of an existing wetland mitigation site, through an existing culvert (which would need to be retrofitted) under 102nd Ave NE, and along the course of an existing floodplain swale downstream to connect with an existing cooler water backwater slough.
- Alternative 2: Medium length channel, with the same inlet and channel location as the upper 2/3rd length of Alternative 1 but with an outlet that connects with the river a short distance downstream of the existing footbridge located to the west of 102nd Ave NE, at approximately where the river channel was located prior to straightening by the USACE.
- Alternative 3: Connecting Lower Segments of Alternatives 1 and 2.

4. PREFERRED ALTERNATIVE AND RELEVANT DESIGN CONSIDERATIONS

Alternative 3 was selected as the best alternative on the basis of (i) lowest cost in terms of design, construction and permitting, and (ii) greatest potential for groundwater cooling benefits. Another channel could be added in the future to include the upper end of Alternatives 1 and 2 pending monitoring results. The rationale for selecting this alternative is provided in greater detail in R2 (2012). The preferred alternative design involved the following elements and design features:

1. Construction of two concrete box culverts to connect the river with the channel, with culvert type and material, width, height, length, invert control elevation, aprons, and safety features reflecting:
    a. Seasonal and stochastic variation in surface water levels in Lake Washington and the lower Sammamish River, and groundwater levels
    b. Juvenile salmonid life history timing (downstream migration, summer rearing, winter refuge)
    c. Predatory fish access
    d. Attraction/passage of fish
    e. Flood Levels and floodplain storage
    f. Scour potential at culvert edges
    g. Sammamish River trail elevation, types of use, and public safety
    h. Cost and constructability
2. Excavation of a channel with planform, width, depth, slope, cross-section profile, and instream habitat complexity reflecting:

a. Topography of site with relic channel swales
b. Elevation of river and groundwater
c. Vegetative overhang width providing shade (for reed canarygrass control and summer temperature moderation), insulation (for summer temperature moderation), and insect drop
d. Presence and control of reed canarygrass growth in the channel
e. Potentially concentrated fish use of pools with temperature stratification during summer
f. Characteristic water levels in river at inlet and outlet
g. Presence of beaver in area
h. Desire to create a small floodplain terrace
i. Public safety

3. Developing a native vegetation restoration earthwork and planting plan on the reed canarygrass dominated floodplain and along the constructed channel margins.

5. DESIGN ANALYSES

The preliminary design development process was iterative. It involved interactions between engineering, fisheries, fluvial geomorphology, wetland/riparian ecology, and recreational disciplines.

A topographic elevation contour map was developed in CAD from LiDAR data and the contours were adjusted using ground-truth data surveyed with a total station. Data were collected in 2012 and 2014. A licensed PLS firm (Axis Surveying, Inc.) was contracted to establish two control monuments that R2 was then able to tie in to. The contour map was used as a base map for design drawings, for laying out the channel and culverts, and for determining earthwork quantities.

5.1 CULVERT DESIGN

The first choice for providing flow connectivity to off-channel habitat under the Sammamish River trail was whether to install culverts or bridges. We opted for culverts to minimize distractions on the trail while allowing for a safe, wide corridor over the inlet and outlet locations, and to reduce the potential for ingress to the channel by humans and dogs on either

side of the trail. Noting that the covered length of channel would need to be about the same for either option, fish would negotiate similar lengths of darkened channel in the daytime.

A concrete rectangular box culvert was selected for the design to maximize the entrance width at each culvert at low flow depths. The width, control elevation, height, and soffit thickness of the culvert reflected the predicted range of water surface elevations at low flow and during floods up to the 100 year recurrence interval event (see section 5.1.1), and matching the Sammamish River trail elevation after placing a crushed rock topped with asphalt. A concrete box culvert can bear the required load on the path. In addition, they are modular and relatively inexpensive to install. A rectangular bottom was preferred to maximize the entrance width at low flow for fish access. Passage depth will be provided by suitable design of the bottom elevation and design of a low flow notch that backs up water in the culvert and allows fish passage, which will be a subject of final design pending input from fisheries management stakeholders. Box culverts meeting load and size criteria are readily available in 10 ft long sections, and joining three sections together to form a 30 ft long culvert overall at the inlet and outlet locations provides a safety buffer of 9 ft on either side of the approximately 12 ft wide trail. This was considered necessary given the speed of many aggressive bicyclists on the trail and associated risk of injury to them and pedestrians at any narrowed choke point on the trail.

Two utility locates were performed, one for the surveyor, and the second for the driller. Neither effort found any buried utilities, thus there are no utility constraints for the design.

5.1.1 Inlet and Outlet Control Elevations

The key hydrologic and hydraulic design parameter for this project is water level at the inlet location, because it controls accessibility for juvenile salmon (desirable) and predatory fish (undesirable), and the ability for warm water to flow into off-channel thermal refuge habitat during the warmest time of the year (also undesirable). In addition, water levels were confirmed through surveying and modeling to be typically around 0.01-0.02 ft lower at the outlet location during the summer, less than 0.1 ft lower during moderate spring and fall flows, and greater than that during winter flows. While these head differences are relatively low, it was decided to base the inlet control elevation on the HEC-RAS modeling results, and make the outlet elevation the same so that there would be relatively little head drop along the channel during the summer, and this would also reduce the likelihood of beaver constructing a dam at either culvert if there was negligible head drop across the project site. It should be noted that when the channel is connected to the river, it is the upstream-downstream head difference that drives flow through the channel, with peak velocities in the channel predicted to be on the order of 2 ft/s and less during the 100 year flood. Most of the time, velocities in the channel are expected to be well

under 1 ft/s based on steady state inflow rate and channel cross-section area. Because of the generally low head drop from inlet to outlet location in the river, it is not feasible to design for a significant attraction velocity, thus ingress by fish is expected to occur primarily during times they are actively outmigrating, seeking food, and/or moving to new habitats.

A 2010 version of King County's flood insurance study HEC-RAS model was used for design. The model was recalibrated to low flow using stage data surveyed at the inlet and outlet and flow data collected in North Creek, Little Bear Creek, and Gold Creek combined with real time flow data from King County's gage on the Sammamish River. The model was then used to predict water levels at the inlet and outlet locations for a range of flow percentiles estimated for each month of the year (Table 4). All elevations were specified to NAVD88 vertical datum.

Table 4. Duration characteristics of water levels in Sammamish River at the Inlet.

Percent Exceed-ance	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						Inlet WSE (ft NAVD88)						
95%	17.12	17.10	17.50	18.09	18.64	18.58	18.10	17.54	17.20	17.24	17.01	17.05
80%	17.25	17.19	17.76	18.42	18.75	18.74	18.33	17.74	17.36	17.38	17.12	17.13
50%	17.60	17.54	18.14	18.67	18.82	18.83	18.59	18.02	17.60	17.53	17.37	17.42
20%	18.44	18.21	18.63	18.94	18.92	18.92	18.79	18.34	17.96	17.72	17.84	18.27
5%	19.81	19.02	19.41	19.31	19.07	19.09	18.87	18.64	18.17	17.99	18.86	19.23

The culvert inlet invert elevation controls the minimum flow at which connectivity between the river and off-channel habitat occurs. The control elevation was determined using the data in Table 4, which were plotted for the primary months when juvenile salmon and steelhead outmigration occurs (April, May and June; Kiyohara and Zimmerman 2011a, 2011b, 2012, 2013) and the months when temperatures are highest in the Sammamish River (July, August and September; R2 2010). A value of 18.5 ft (NAVD88) was selected as a good design compromise between providing connectivity for juveniles and preventing warmer river water from entering the off-channel habitat during the summer. Figures 4 and 5 show that this elevation allows passage of fish during all of May and June, and most of April. In addition, the channel is accessible during fall and winter high water events when residualizing juvenile salmonids may be seeking refuge habitat. Based on annual hydrograph timing, the time in April depicted in

Figure 4 when passage is not possible corresponds to earlier in April when outmigration numbers are relatively low (cf. Figure 5). Conversely, the river is generally lower than 18.5 ft in part of July, most of August and all of September. Importantly, the connection between the river and the channel in July typically occurs earlier in the month when temperatures are lower, and the August water level exceeds 18.5 ft only about ten percent of the time. Thus, the 18.5 elevation appears to be about the optimal level that facilitates meeting the two key biological goals of providing accessibility and thermal refuge most of the time when it matters.

The data in Table 4 indicate that an inlet control elevation of 18.5 ft results in the off-channel habitat being disconnected from the river most of the time in late fall, winter, and early spring months. Connectivity during the October-March period may not occur in some years except during storm runoff events.

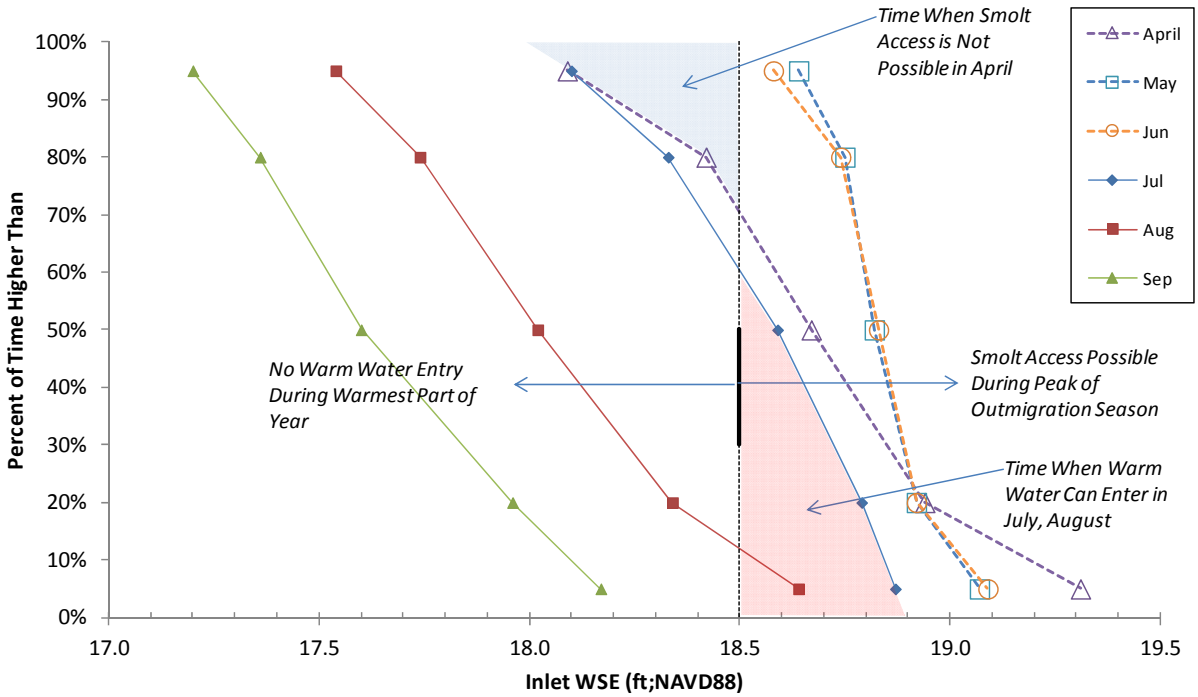


Figure 4. Basis for selecting 18.5 ft as the inlet culvert invert elevation in terms of duration of water levels at the proposed channel inlet location in the months when outmigration occurs (April-June)and when elevated water temperatures are a concern (July-September).

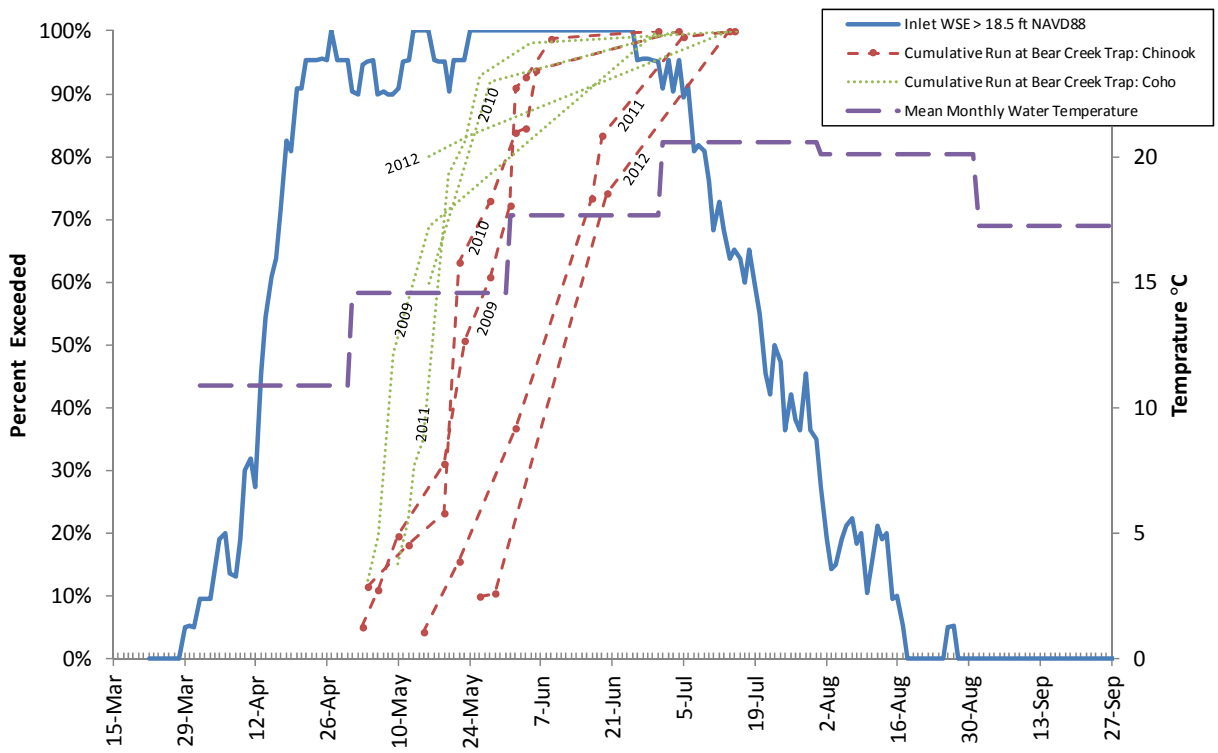


Figure 5. Comparison of seasonal variation in frequencies that water level exceeds 18.5 ft NAVD88 at the proposed side channel inlet (1991-2014), monthly mean water temperatures in the Sammamish River (2005-14), and WDFW smolt trap run size estimates at Bear Creek (2009-12).

5.1.2 Culvert Width

The design width of the culvert reflected primarily a balance between fish access (wider entrance increases probability fish will find it), minimizing head difference across the culvert during the rising stage of a storm hydrograph (wider opening allows quicker filling of the floodplain, thereby reducing head difference, flow velocity, and thus scour potential on culvert apron), and cost (wider is more expensive to construct). A 10 ft wide culvert was evaluated initially and compared with a 5 ft wide culvert. Narrower and wider culverts were not evaluated on the basis of more limited fish accessibility and greater construction cost, respectively.

The analysis focused on predicting flow rate through a single culvert associated with a worst case hourly rise in stage during a flood event. Knowing the associated flow rate permitted calculation of velocity in the culvert and scour potential at the culvert exit. To calculate flow rate through the culvert, a HEC-RAS model was created of a culvert with wide storage areas upstream and downstream, and the simulation flow varied to identify the flow associated with

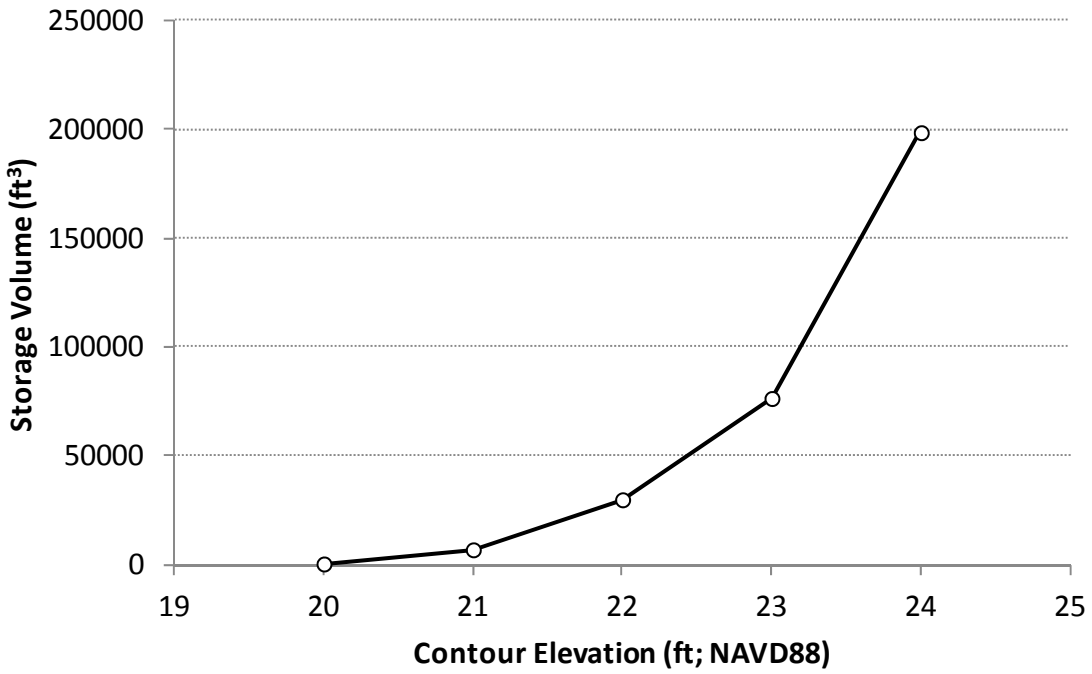
the head drop. The worst case head drop was assumed to occur over an hour period. Hourly stage data from the Sammamish River gage were analyzed for discrete flood events, including the January 2009 and December 2007 events. The maximum rate of increase in stage was calculated for each event and assumed to equate to the worst case head difference across the culvert. This design approach provided two levels of safety towards a conservative design: (i) if the rise is stage is matched by floodplain fill rate in less time, the actual head drop across the culvert will be less, and (ii) by sizing to one culvert but installing two, the head drop across each culvert will be even less. The greatest rate of change was calculated for the 2007 event, equaling a rise of 0.46 ft/hr. A storage volume-elevation curve was derived for the floodplain using the ground-truthed DEM (Figure 6, upper graph). The flow rate calculated for the culvert head drop was compared to that required to fill the floodplain (Figure 6, lower graph). Both the 10 ft wide and 5 ft wide culvert were found to not limit the floodplain fill rate. The 5 ft wide culvert was selected on the basis of reduced construction cost compared with the 10 ft wide culvert.

5.1.3 Culvert Height

As high a culvert as possible was desired to increase light penetration inside and minimize potential for pressure flow (i.e., flowing full). The primary constraint was not significantly changing the trail elevation while ensuring enough thickness for a crushed rock base and asphalt cover. A 4 ft high culvert was found to the largest standard size meeting these constraints.

5.1.4 Culvert Outlet/Apron Design

The possibility was considered that some scour could occur outside the culvert openings during inflow to and outflow from the floodplain, and that the scour could undermine the foundation base material of the culvert without appropriate countermeasures. Scour is typically associated with transition from the hard surface of a culvert to a deformable bed downstream. It was decided that a cobble apron would be constructed on each side of each culvert opening to accommodate the potential for scour and at the same time reduce the potential for vegetation encroachment by reed canarygrass which would otherwise occur with an earthen substrate. To minimize potential for beaver interest in constructing a dam (albeit unlikely given that inlet and outlet control elevations are identical and the upstream-downstream gradient in the river is sufficiently low that no significant ponding behind and dam overflow could occur), a level cobble apron was specified extending out and away from the culvert.



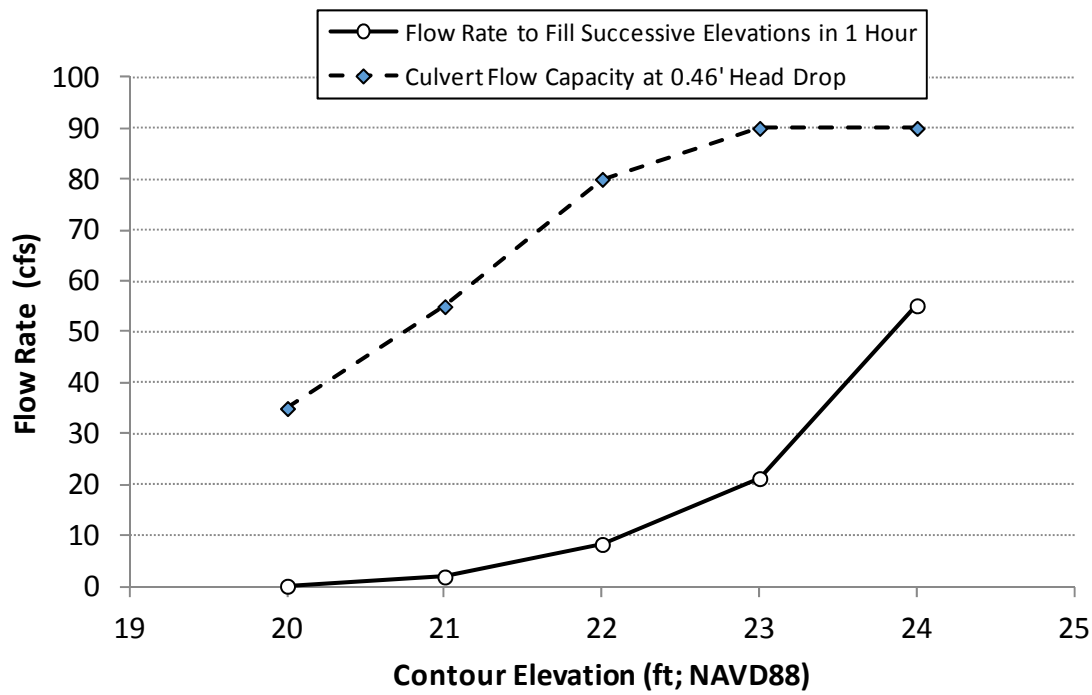


Figure 6. Floodplain elevation-storage volume curve (top) and comparison of required and potential flow rates through a single 5 ft wide culvert. Storage volume was summed east and west of 102nd Ave NE.

A variety of sill scour equations considering substrate size were evaluated to design the depth of the apron substrate, using the velocities calculated from the culvert HEC-RAS analysis, resulting in a range of predicted scour hole depth and length dimensions (Figure 7). A standard WSDOT specification for 8" cobble was selected based on engineering judgment. Most scour equations predicted a scour hole depth less than 1 ft for a 0.46 ft head drop across the culvert. The largest predictions were for equations developed from steeper mountain streams. A design target scour depth of 1 ft was selected that enveloped most of the scour depth predictions. To provide a pavement at the base of the scour hole, a 1.5 ft deep layer of cobble was accordingly specified for the apron thickness.

The length of the apron was designed to be 10 ft, and to end at a set of western red cedar logs stacked vertically with crest elevation equal to the culvert control elevation. The 10 ft length is slightly shorter than the maximum anticipated scour hole length (~12 ft; Figure 7) and reflects a compromise between having a smaller area paved with cobble and accommodating scour. The logs are specified to be stacked down to a depth below the target grade of the constructed channel, and act as a wall preventing the apron material and culvert backfill and foundation base material from being eroded into. This sudden depth transition also precludes having a sloping bottom (from the culvert apron to the excavated channel invert) on which reed canarygrass could become established (see section 5.2 re. corresponding rationale for design depth of the channel). The upper log will be exposed for part of the year in most years, but the lower logs will remain submerged based on river levels in Table 4 and groundwater inflow from the adjacent hill slope. Thus, even if the upper log eventually rots, the lower logs should remain in sufficient condition to maintain a stable grade away from the culvert opening. A small notch will be cut into the top log for fish passage.

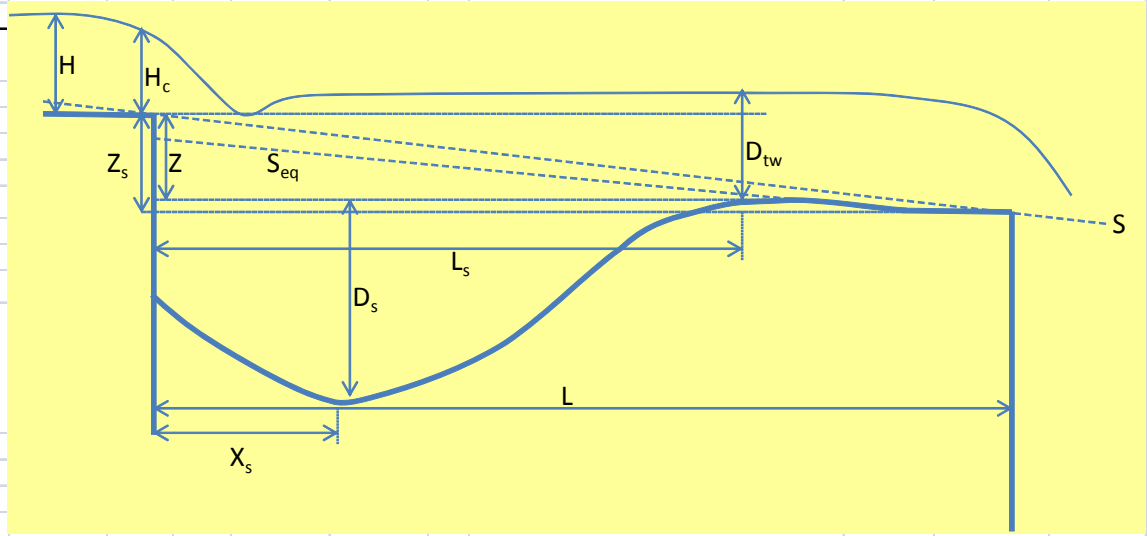
5.1.5 Foundation/Backfill Design

Zipper Geo Associates prepared a geotechnical engineering report based on drill borings performed at each culvert location (Appendix B). They provided recommendations for excavation elevations, foundation materials and preparation, fill placement and compaction, and temporary construction shoring and dewatering approaches. The preliminary design implements their key recommendations accordingly, including excavating down to firmer alluvial deposits approximately 10-11 feet below the existing ground surface, and placing appropriate quarry spalls and crushed rock fill materials for the culvert foundations.

SCOUR DOWNSTREAM OF WEIRS/SILLS

Sammamish Side Channel Culvert

Input			Source
Q=	50	cfs	Associated w/ 0.46' head drop
WEIR Width W=	5	ft	design variable
CHANNEL WIDTH =	8	ft	design variable
Weir Streamwise Length=	30	ft	
Tau*cr=	0.045		
Tailwater depth D_{tw}=	3.6	ft	HECRAS input
Step Spacing L=	15	ft	design variable
Channel Slope S=	0.00001		Culvert bottom
Submerged spec grav (S_s-1)=	1.65		
D16=	25	mm	WSDOT Spec 9-03.11(2), 8" Cobbles
D50 =	76	mm	
D84=	127	mm	
D90=	152	mm	
D95=	180	mm	
Weir Ht above bed Dp (z)=	0.1	ft	design variable
face angle from horiz=	90	deg	design variable
Upstream Head=	4.00	ft	HECRAS Output



Miscellaneous Calculated

weir crest depth H_c =	2.2	ft
weir crest velocity Vo=	4.6	fps

Lenzi et al. (2003): Minimum Sill Distance to Maximize Scour Depth

L_{min}= 4 ft

Summary	Scour Depth Ds (ft)	Scour Hole Length Ls (ft)	Scour hole slope S
Lenzi et al. (2002) a1=z	1.1	16	0.068
Gaudio & Marion low gradient a1=z	0.8	12	
Marion et al. (2004) a1=z	0.7	10	
Comiti et al (2006)	0.3	5	
Italians, Max|(a1=(S-Seq)L)	0.9	12	
D'agostino & Ferro (2004)	2.0	30	

Figure 7. Scour calculation worksheet for designing culvert apron substrate depth and length.

5.2 CHANNEL DESIGN

The excavated channel will have a level bottom punctuated by five deeper pools. Because of the low gradient, low head-drop and thus low through-flow rate, and target design depth to prevent reed canarygrass growth in the channel, velocities will be sufficiently low in the channel over the entire design flow range such that scour and erosion will not be significant issues, if at all. Hence, the primary design features are planform and location of the channel, channel depth, channel width and cross-section profile, and habitat complexity. The vegetation restoration plan will focus on species that can provide 100% canopy cover over the channel to provide thermal insulation.

5.2.1 Channel Planform Layout and Pool Locations

The planform of the excavated channel generally follows a relic swale on the floodplain to minimize excavation volume (cost consideration) and elevation difference between pool bottom and top of floodplain (public safety consideration). In addition, the surrounding ground elevations are near the 2-year flood elevation such that riparian restoration will occur faster than at higher elevation locations. The centerline of the channel was shifted a little at a few locations to run between significant trees without removing them, which would then provide habitat complexity through their roots protruding into the excavated channel.

There are five bathymetric depressions in the design, with an arbitrary 50 foot length to spread out fish during summer months when they may concentrate near the bottom if and when water temperature stratification occurs. All of the depressions are located proximal to the steeper groundwater gradient measured coming off the hill slope in the feasibility study (R2/PGG 2013). The depressions are also located where construction activities will not disturb existing significant trees, the locations of which were surveyed by R2 with a total station.

5.2.2 Channel Invert Elevation/Water Depth

There were three design criteria concerning channel depth:

1. Providing sufficient depth for juvenile salmonids during the summer months. In general, presently unpublished habitat suitability criteria data collected by R2 recently for juvenile salmonids in quiescent Alaskan off-channel habitats indicate a minimum design depth of 2 ft. Suitability drops off at depths below about 1.5 ft. This is generally consistent with standard instream flow habitat suitability criteria for juveniles in flowing water (e.g., Bovee 1978; Beecher and Caldwell 2013).

2. Keeping the depth in the channel sufficient year round to prevent reed canarygrass growth. A minimum depth of 1 ft has been recommended (e.g., WRCGMWG 2009), but it has been our experience that a persistent inundation depth of 2 ft is better at preventing growth long term.
3. Having deeper bathymetric depressions distributed along the length of the channel portion abutting the southern hill slope to allow concentration of cooler groundwater and facilitate daytime vertical temperature stratification in the water column, with cooler groundwater pooling near the bottom of the depressions.

The design bathymetric depression depth reflects a professional judgment balance between increasing the potential for thermal stratification and habitat volume versus considering safety by keeping the channel wadeable. We opted for a maximum depth of 4 ft in the depressions during the summer. For an inlet and outlet control elevation equal to 18.5 ft (NAVD88), this corresponds to a pool bottom elevation equal to 14.5 ft (NAVD88).

The remaining design parameter to identify was then the depth of the rest of the channel. Table 4 indicates that during summer months, the river water surface elevation is above 17.2 ft (NAVD88) nearly all of the time. A channel bottom elevation equal to 15.2 ft would meet the 2 ft habitat suitability and reed canarygrass control criteria most of the time. However, this equates to a minimum 'residual depth' (i.e., if the channel were to drain, which is not possible given groundwater levels) equal to 0.7 ft. We are not aware of firm criteria for residual depths in a setting such as the project site where the channel will never run dry, but it is our judgment that a deeper residual depth would be associated with greater potential for thermal stratification to occur in the pools. Therefore, a bottom elevation of 15.5 ft (NAVD88) was selected for the design as a compromise. This level ensures the water depth is still generally well above the absolute minimum reed canarygrass control criterion (1 ft of inundation) part of the year, and above the 2 ft habitat criterion most of the time; the pools will always be above the 2 ft habitat suitability criterion, thus having a 15.5 ft invert elevation (and thus water depth around 1.7 ft or less) may encourage fish to move into thermal refuge pools during the summer in years when water levels are lowest and water temperatures the highest.

5.2.3 Channel Width and Cross-Section Profile

A rectangular channel was selected as a balance between constructability (function of excavator bucket shape), reed canarygrass control (sloped banks easier for grass colonization and sedimentation/ ecological succession, which is not desired), and fish habitat quality/quantity (vertical undercut banks held together by willows and some reed canarygrass will have a higher

carrying capacity for juvenile salmonids than a more exposed sloping bank, and rectangular channel has greater volume than a triangular one).

A width of 8 ft was selected initially based on professional judgment considering spatial overhang distance of willow and dogwood shrubs. This value was verified to result in an excavated spoils ('cut') materials volume that could be distributed in a 1.5 ft thick layer over open areas where reed canarygrass elimination is a goal, where estimated cut and fill volumes balance out such that no export of material is required. In addition, an 8 ft wide channel could be laid out between existing significant trees without requiring their removal. There was thus no reason to not continue with the 8 ft width in the design.

The original design concept called for a 'mini-floodplain' terrace on either side of the channel. The design parameters then became terrace width and elevation. The wider the terrace, the greater the excavation volume and more spoils that need to be disposed of. A 3 ft wide level terrace was selected, on which willow shrubs could become established. The landward side of the terrace was then specified to be excavated at a 3H:1V side slope up to existing ground surface elevation, with warping of the slope cut as needed. The elevation of the terrace was set at 19.5 ft (NAVD88), which is approximately halfway between the inlet control elevation (18.5 ft NAVD88) and the 1.5 year flood elevation (~20.5 ft NAVD88). This elevation is highly suitable for willow growth on the terrace without chronic inundation (cf. Table 4).

5.2.4 Instream Habitat Complexity (Large Woody Debris)

The question was raised whether or not to include large woody debris in the constructed channel. Unpublished data collected by R2 in North Creek before and after restoration indicated that sections of channel with overhanging banks associated with reed canarygrass had greater carrying capacity for juvenile salmon and trout than large pools associated with large woody debris where a small number of large, dominant cutthroat trout exhibit territoriality behavior that may limit carrying capacity. In addition, larger cutthroat trout, which are often found in relatively large numbers in urbanized or urbanizing area streams, will eat smaller salmonids (Wydoski and Whitney 2003). The results of fish sampling performed by R2 (Jeanes and Hilgert 2002) in the Sammamish river indicates that large cutthroat trout occur in the vicinity of the project site, and thus they should be expected to enter the off-channel habitat at one time or another. Hence, the design question distils to: with large cutthroat trout present, which is better, not having large wood complexity in the pools that adult cutthroat and potentially smallmouth bass (*Micropterus salmoides*) can hide within to prey on juveniles, or having complexity with many hiding spots making it more difficult for predation? Our consensus in consulting with

other fisheries biologist colleagues is that not having wood would limit carrying capacity in the pools, whereas having wood might provide hiding places for predators but also for juveniles.

The design accordingly involves placing large woody debris rootwads in the bathymetric depressions. Rootwads provide greater habitat complexity than logs. No rootwads are specified for placement between the depressions because there should be plenty of cover along the vertical banks provided by undercut banks, overhanging vegetation and tree roots. In addition, adult cutthroat are more likely to reside in the depression areas during the summer. The design selected is where a single Douglas fir log with rootwad is installed in a trench with most of the log buried to keep it from dislodging and moving because of buoyancy. The weight of soil above the log was used as the design parameter, assuming submerged specific gravity of both wood and soil, and ignoring log-soil and soil-soil friction forces, and resistance provided by root systems that would act to keep the wood in place (which thereby provides a safety factor against log pullout in the design). For a 12" diameter, 15 ft long log with rootwad, where only a 1 ft length of the log plus rootwad protrudes into the channel, this equates to an estimated minimum soil depth of 0.5 ft above the log (assuming soil porosity = 40%, log specific gravity = 0.5, and soil specific gravity = 2.5). However, this would result in placing the log too high in the water column, thus an installation depth of about 2.5 ft of soil above the log would result in essentially full submersion during the summer and provide a large safety factor (SF >>2.5) against pullout.

5.3 VEGETATION RESTORATION DESIGN

5.3.1 Vegetation Restoration Background

The project area is located on a relic floodplain of the Sammamish River. Photographs from the early 1900s show hydrologic connection of the floodplain with the Sammamish River and suggest seasonal to perennial inundation throughout the proposed Project Area (Figures 8-10). The project area is no longer flooded regularly due to construction of the Hiram Chittenden Locks which lowered the water elevation in Lake Washington and subsequent dredging of the Sammamish River. Hydrologically, the project area has a seasonally high water table and seepage areas are found along the toe of the adjacent north/northwest-facing hillslope. Relic meander sloughs are seasonally flooded and the lowest elevations have surface water throughout much or all of most years supporting wetland marsh vegetation. The soil profile is saturated to within several inches of the surface across the floodplain throughout most of the year.

Figure 8. Image from Bothell Historical Museum showing flooding in the Project Area in the early 1900s. The 102nd Street bridge is near the center of the photograph.

Figure 9. Image from Bothell Historical Museum circa 1905. The 102nd Street bridge is shown near the center of the photograph with Sammamish River and floodplain of the Project Area west of the bridge.

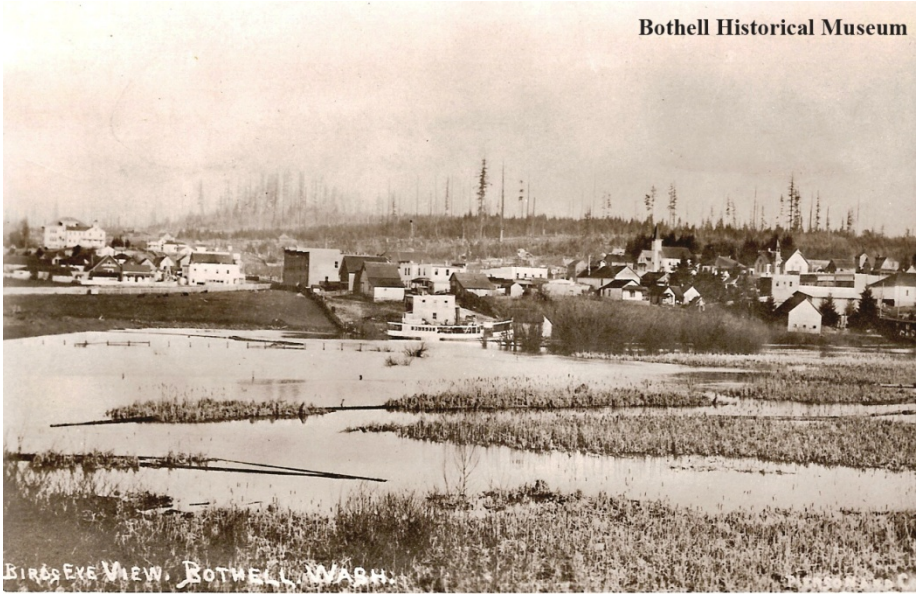


Figure 10. Image from Bothell Historical Museum circa 1908. The 102nd Street bridge is on the far right side of photo. The proposed project area is inundated.

Site disturbances include historic land clearing, road construction and other urbanizing activities in the vicinity over the past century and a half. The floodplain forests in this vicinity were cleared prior to 1900 and were colonized by an emergent plant community. Prior to and in the absence of clearing, the plant community would have been primarily forested with Western red cedar, black cottonwood, big leaf maple, and red alder with patches of scrub-shrub and emergent vegetation.

Currently, vegetation in the project area is a mosaic of native and non-native forest, scrub-shrub, and emergent wetland communities. Relic floodplain within the project area is dominated by monotypic stands of reed canarygrass. Stands of Himalayan blackberry form a perimeter around the historic floodplain upland transition zone. Wetland shrubs and small trees (e.g., *Spiraea douglasii*, *Cornus sericea*, *Salix lucida* ssp. *lasiandra*, *S. sitchensis*) occur in patches along the margins of the reed canarygrass plain. Willows (*Salix* spp.) dominate the western portion of the project area where the proposed channel will be established. Mature stands of black cottonwood are growing in areas along the Sammamish River Trail on what is likely a relic natural levee of the Sammamish River channel. A partial listing of vascular plants observed in the project area during the wetland delineation and subsequent field surveys is provided in Table 5.

Table 5. Partial listing of vascular plant species observed at the Project Area. Species identifications and taxonomic nomenclature follow Flora of the Pacific Northwest (Hitchcock and Cronquist 1990) and the PLANTS database (USDA and NRCS 2014), wetland indicator status follow National List of Plant Species that Occur in Wetlands: Northwest (Region 9) (Lichvar et al. 2014).

Scientific Name	Common Name	Wetland Indicator Status[1]
Trees		
Alnus rubra	Red alder	FAC
Populus balsamifera ssp. *trichocarpa*	Black cottonwood	FAC
Thuja plicata	Western red cedar	FAC
Acer macrophyllum	Big leaf maple	FACU
Crataegus monogyna	Common hawthorn	FAC
Shrubs		
Lonicera involucarta	Black twinberry	FAC
Physocarpus capitatus	Pacific ninebark	FACW
Sambucus racemosa.	Elderberry	FACU
Rubus parviflorus	Thimbleberry	FACU
Rubus armeniacus	Himalayan blackberry	FACU
Rubus spectabilis	Salmonberry	FAC
Rubus laciniatus	Cut leaf blackberry	FACU
Salix lucida ssp. *lasiandra*	Pacific willow	FACW
Salix scouleriana	Scouler's willow	FAC
Salix sitchensis	Sitka willow	FACW
Cornus sericea	Redosier dogwood	FACW
Spiraea douglasii	Rose spirea	FACW
Viburnum edule	Squashberry	FACW
Herbs/Forbes/Grasses/Ferns		
Phalaris arundinacea	Reed canarygrass	FACW
Polysticum munitum	Swordfern	FACU
Ranunculus repens	Creeping buttercup	FACW
Tolmiea menziesii	Piggy back plant	FAC
Agrostis gigantea	Redtop	FAC
Urtica dioica	Stinging nettle	FAC
Tolmiea menziesii	Piggy-back plant	FAC
Prunella vulgaris	Self-heal	FACU
Unknown graminoids	lawn grass	-
Pteridium aquilinum	Bracken fern	FACU
Lythrum salicaria	Purple loosestrife	OBL
Typha latifolia	cattail	OBL
Equisetum arvense	Field horsetail	FAC

Notes: [1] USFWS wetland plant indicator status (Lichvar et al. 2014; FAC = Facultative; FACW = Facultative Wetland; FACU = Facultative Upland; OBL = Obligate Wetland).

5.3.2 Vegetation Restoration Design

The vegetation restoration plan has been developed to meet design objectives: (1) restoring floodplain wetlands presently dominated by reed canarygrass, (2) removing and replacing Himalayan blackberry stands, with native tree and shrub species increasing habitat complexity, vertical structure, and diversity, and (3) utilizing channel cut spoils on-site to enhance shrub and tree planting zones. The extent of jurisdictional waters of the U.S. including wetlands on the property and the FEMA 100-year floodplain (FEMA 2011) are mapped on Preliminary Design CAD Sheet 11. The vegetation restoration plan has been developed to avoid placement of any cut spoils within the 100 year floodplain and has been designed to facilitate transition of non-native (reed canarygrass) palustrine emergent wetlands to native palustrine scrub-shrub wetlands. Planting for all shrubs will be done in clusters arranged by species to create a complex mosaic of varying plant heights. Average plant heights for each species are provided in Table 6.

Reed canarygrass is a dominant species across much of the project site occurring as a monoculture over more than 3 acres. It is highly unlikely that complete eradication of reed canarygrass from the site will be possible. The design goal therefore is instead to reduce the areal cover of reed canarygrass such that it becomes a subordinate member of the plant community. Channel cut spoils, plant species selection, and planting densities are planned to strategically reduce the competitive vigor of reed canarygrass and facilitate development of wetland scrub-shrub and forested plant communities. Kim et al. (2006) recommend planting willow live stakes at 0.6 to 0.9 meter spacing to reduce reed canarygrass biomass within 1 to 2 years. It will be critical to quickly establish dense cover along the new excavated channel to reduce potential for reed canarygrass growth in and along the new channel. As described in Section 5.2, the channel excavation depth was selected to minimize risk of re-colonization by reed canarygrass within the channel proper.

Other invasive and/or noxious weed species (e.g., English ivy, Himalayan blackberry, Japanese knotweed, purple loosestrife, etc.) will be managed with removal prior to planting and then controlled during the scheduled two or more annual maintenance site visits. Monitoring protocols will be developed for on-going management of weed species.

Six plant community types were identified along the excavated channel and adjacent floodplain and associated upland areas. Each of these community types has a vegetation restoration strategy tailored to restore native habitat as described in the sections below:

1. Reed Canarygrass Floodplain: Below 100 year floodplain
2. Reed Canarygrass Floodplain: Above 100 year floodplain

3. Blackberry Island and Blackberry Hillslope Restoration Plantings
4. Reed Canarygrass Forest Inclusion
5. Excavated Channel – Streambank Riparian Restoration Area Planting
6. Existing Riparian Forest

Table 6. Mature plant height estimated at 20 years with maximum height, if different, shown in parentheses.

Scientific Name	**Common Name**	**Mature Plant Height At 20 Years (Maximum Height) (in feet)[1]**
Trees		
Fraxinus latifolia	Oregon ash	50 (80)
Picea sitchensis	Sitka spruce	40 (200)
Thuja plicata	Western red cedar	40 (150)
Alnus rubra	Red alder	50 (90)
Populus balsamifera ssp. *trichocarpa*	Black cottonwood	60 (100 +
Tsuga heterophylla	Western hemlock	40 (170)
Shrubs		
Salix lucida ssp. lasiandra	Pacific willow	50 (80)
Salix scouleriana	Scouler willow	6 (40)
Salix sitchensis	Sitka willow	23
Rubus spectabilis	Salmonberry	12
Corylus cornuta	Beaked hazelnut	15
Rosa nutkana	Nootka rose	6 (10)
Rosa pisocarpa	Cluster rose	6
Lonicera involucrata	Black twinberry	10
Spiraea douglasii	Western spirea	7
Sambucus racemosa	Red elderberry	10 (20)
Cornus sericea	Redosier dogwood	12
Oemleria cerasiformis	Indian plum	5-20

Notes: [1]: Mature plant heights as indicated by USDA and NRCS (2014).

It is important to note that due to the high volume of planting material needed, a lead time of 2 or more years may be necessary to acquire plants for this project.

5.3.2.1 Reed Canarygrass Floodplain: Below 100-Year Floodplain Elevation

No grading will occur for reed canarygrass floodplain vegetation restoration areas within the FEMA map 100-yr floodplain. Site preparation will include mowing twice the existing non-native vegetation prior to planting (primarily reed canarygrass with some Himalayan blackberry). Live stakes will be planted in dense patches (per Kim et al. 2006) with a goal of quickly establishing a shrub canopy layer. Regular maintenance will be required until shrub canopy cover is established, approximately three to five years; mowing shall occur two or more times throughout the growing season as necessary to control growth of non-native herbs and shrubs and to reduce competition with the live stake plantings. Live stakes will be installed on 2-foot center spacing in clusters by species (Table 7).

Table 7. Planting specifications for reed canarygrass floodplain below 100-year floodplain.

Scientific Name	Common Name	Wetland Indicator Status[1]	Plant Material	On-center Spacing
Shrubs				
Salix lasiandra	Pacific willow	FACW	live stakes	2', in clusters
Salix scouleriana	Scouler willow	FAC	live stakes	2', in clusters
Salix sitchensis	Sitka willow	FACW	live stakes	2', in clusters
Cornus sericea	Redosier dogwood	FACW	live stakes	2', in clusters

Notes: [1] USFWS wetland plant indicator status (Lichvar et al. 2014).

5.3.2.2 Reed Canarygrass Floodplain: Above 100-Year Floodplain Elevation

Restoration activities in this area will include first mowing the reed canarygrass and small isolated blackberry stands. As broad an area as possible will be covered with an approximately 1.5 ft thick layer of cut material spoils from the channel excavation. This strategy will effectively bury the existing non-native vegetation while ensuring that the hydrologic conditions will remain suitable for maintaining wetland vegetation and functions. The bare mineral soil will be planted densely with a suite of shrub species to rapidly recapture the site with native wetland shrubs before reed canarygrass can re-establish. Trees will be installed along the edge of this planting zone and at higher elevations as described in Section 5.3.2.3. Preliminary Design CAD sheets 10-12 depict plan views and cross-sections detailing placement of spoils to create suitable

planting zones within the restoration area. Table 8 provides planting specifications for the reed canarygrass meadow planting above the 100-year floodplain elevation.

Table 8. Planting specifications for reed canarygrass meadow above 100-year floodplain elevation.

Scientific Name	Common Name	Wetland Indicator Status[1]	Plant Material	On-center Spacing
Shrubs				
Salix lucida ssp. *lasiandra*	Pacific willow	FACW	live stakes	2', in clusters
Salix sitchensis	Sitka willow	FACW	live stakes	2', in clusters
Spiraea douglasii	Western spirea	FACW	1-gallon pots	3', in clusters
Rubus spectabilis	Salmonberry	FAC	1-gallon pots	3', in clusters
Rosa nutkana	Nootka rose	FAC	1-gallon pots	3', in clusters
Rosa pisocarpa	Cluster rose	FAC	1-gallon pots	3', in clusters
Lonicera involucrata	Black twinberry	FAC	1-gallon pots	3', in clusters
Frangula purshiana	Cascara	FAC	1-gallon pots	3', in clusters
Cornus sericea	Redosier dogwood	FACW	live stakes	3', in clusters
Physocarpus capitatus	Pacific ninebark	FACW	1-gallon pots	3', in clusters

Notes: [1] USFWS wetland plant indicator status (Lichvar et al. 2014).

5.3.2.3 Blackberry Island and Blackberry Hillslope Restoration Plantings

Two large inclusions or 'islands' of Himalayan blackberry thicket lie within the reed canarygrass floodplain (see Preliminary Design CAD Sheets 3 and 11). These areas currently support Himalayan blackberry, bracken fern (*Pteridium aquilinum*), and elderberry (*Sambucus racemosa*), which are all facultative upland species. The blackberry islands are slightly higher in elevation and slightly drier than adjacent areas of the floodplain. Channel excavated sediments will be placed within these inclusions raising the surface elevation to 3 feet above the existing surface. Raising the surface elevation will allow planting and survival of Facultative and Facultative Wet tree species (Table 9). In addition, there is another elevated, general area of blackberry growth between the trail parking area and the reed canarygrass floodplain that will be restored without placing spoils.

Table 9. Planting specifications for Blackberry Island and Blackberry Hillslope Restoration.

Scientific name	Common name	Wetland Indicator Status[1]	Plant material	On-center Spacing
Trees				
Fraxinus latifolia	Oregon ash	FACW	1-gallon pots	12 '
Picea sitchensis	Sitka spruce	FAC	1-gallon pots	12'
Thuja plicata	Western red cedar	FAC	1-gallon pots	12'
Alnus rubra	Red alder	FAC	1-gallon pots	12'
Populus balsamifera ssp. *trichocarpa*	Black cottonwood	FAC	1-gallon pots	12'
Shrubs				
Corylus cornuta	Beaked hazelnut	FACU	1-gallon pots	3', in clusters
Rubus spectabilis	Salmonberry	FAC	1-gallon pots	3', in clusters
Rosa nutkana	Nootka rose	FAC	1-gallon pots	3', in clusters
Rosa pisocarpa	Cluster rose	FAC	1-gallon pots	3', in clusters
Lonicera involucrata	Black twinberry	FAC	1-gallon pots	3', in clusters
Salix sitchensis	Sitka willow	FACW	Live stakes	3, in clusters
Sambucus racemosa	Red elderberry	FACU	1-gallon pots	3', in clusters
Cornus sericea	Redosier dogwood	FACW	1-gallon pots	3', in clusters

Notes: [1] USFWS wetland plant indicator status (Lichvar et al. 2014).

In both cases, a suite of wetland tree species will be installed to add structural complexity to the floodplain. This suite of forest species will also be installed along the edge of the reed canarygrass floodplain meadow at the transition to adjacent upland forest communities. The goal for these areas will be to develop patches of native wetland forest with a conifer component within the floodplain.

5.3.2.4 Reed Canarygrass Forest Inclusion

An inclusion of reed canarygrass occurs between the proposed channel and the trail (see Preliminary Design CAD Sheet 11). This area has partial tree canopy cover by black cottonwood and small patches of Himalayan blackberry. Site preparation will include mowing the existing non-native vegetation and installing tree and shrub species that tolerate partial shade conditions per specifications in Table 10. Regular maintenance mowing of reed canarygrass will be required.

Table 10. Planting specifications for reed canarygrass forest inclusions.

Scientific Name	Common Name	Wetland Indicator Status[1]	Plant Material	On-center Spacing
Trees				
Picea sitchensis	Sitka spruce	FAC	1-gallon pots	12'
Thuja plicata	Western red cedar	FAC	1-gallon pots	12'
Shrubs				
Oemleria cerasiformis	Indian plum	FACU	1-gallon pots	3', in clusters
Corylus cornuta	Beaked hazelnut	FACU	1-gallon pots	3', in clusters
Rubus spectabilis	Salmonberry	FAC	1-gallon pots	3', in clusters
Rosa pisocarpa	Cluster rose	FAC	1-gallon pots	3', in clusters
Rosa nutkana	Nootka rose	FAC	1-gallon pots	3', in clusters

Notes: [1] USFWS wetland plant indicator status (Lichvar et al. 2014).

5.3.2.5 Existing Riparian Forest Enhancement

The existing black cottonwood stand is approximately 60 years old. The trees will begin to senesce within fifty years as the life span of black cottonwood is on average 100-150 years. Some of these mature trees have been cut down already to minimize hazards along the trail and a need for additional tree removal is projected. There are few to no young understory trees to replace this stand. Table 11 provides planting specifications for enhancing the existing riparian forest. The goal of these plantings will be to enhance the existing forest community and develop a coniferous forest within the existing forest to promote long term forest replacement and regeneration. Under planting of conifer species will be done within the existing riparian black cottonwood forest.

5.3.2.6 Excavated Channel – Streambank Riparian Restoration Area Planting

Bare mineral soils exposed by excavation and grading for the new channel will be planted densely with live stakes of willow species and red-osier dogwood. Table 12 provides planting specifications for the streambank riparian restoration area. The goal of this strategy will be to develop shrub and tree canopy cover over the channel quickly. As part of this, the design calls for the restored channel area not be connected hydraulically to the river via the culverts for at least one year, and preferably two, which will be sufficient for root growth to occur to help hold the near vertical cut channel banks intact and preclude erosion. Restoration of native forest

vegetation over the channel will provide shade (for reed canarygrass control and summer temperature moderation), insulation (for summer temperature moderation), and insect drop.

Table 11. Planting specifications for Existing Riparian Forest Enhancement.

Scientific Name	Common Name	Indicator status	Plant Material	On-center Spacing
Trees				
Picea sitchensis	Sitka spruce	FAC	1-gallon pots	12'
Thuja plicata	Western red cedar	FAC	1-gallon pots	12'
Psuedotsuga menziesii	Douglas-fir	FACU	1-gallon pots	12'
Tsuga heterophylla	Western hemlock	FACU	1-gallon pots	12'

Notes: [1] USFWS wetland plant indicator status (Lichvar et al. 2014).

Table 12. Planting specifications for excavated channel - streambank riparian restoration area.

Scientific Name	Common Name	Indicator status	Plant Material	On-center Spacing
Shrubs				
Salix lasiandra	Pacific willow	FACW	live stakes	3', in clusters
Salix sitchensis	Sitka willow	FACW	live stakes	3', in clusters
Cornus sericea	Redosier dogwood	FACW	live stakes	3', in clusters
Herbs				
Wetland Grass/Sedge seed mix		FAC-FACW	Hydroseeding	N/A

Notes: [1] USFWS wetland plant indicator status (Lichvar et al. 2014).

6. COST ESTIMATE

Table 13 summarizes our Engineer's Opinion of Probable Cost for the CAD design as presented in Appendix C. Not shown in the drawings but included in the cost estimate include dewatering, trail management, TESC, and other measures needed to prevent environmental and public impacts. Tables 14 through 16 provide more detailed cost breakdowns on unit costs and quantities; costs from Tables 15 and 16 are included variously in Table 14.

Table 13. Summary of Engineer's Opinion of Probable Cost: Sammamish River Off Channel Habitat & Floodplain Restoration - Preliminary Design.

Group	Description	
1	Site Preparation, Mobilization	$95,220.00
2	Earthwork	$153,030.00
4	Culverts	$99,950.00
7	Log Work	$29,300.00
11	Specialties	$6,000.00
13	Planting, Site Restoration, Demobilization	$160,830.00
	Total Direct Costs	**$544,330.00**
Rate	**Markups**	
5.0%	Contractor Site Overhead/Mobilization	$27,216.50
	Subtotal	$571,546.50
4.0%	Contractor Mark-up	$22,861.86
	Subtotal	$594,408.36
7.0%	Contractor Home Office Overhead	$41,608.59
	Subtotal	$636,016.95
1.0%	Bond and Insurance	$6,360.17
	Total Contractor Cost	**$642,377.11**
9.5%	King County Sales Tax	$61,025.83
10.0%	Contingency	$64,237.71
	Total Owner Cost	**$767,640.00**

Table 14. Estimated Unit Costs Used in Developing Cost Estimate for Preliminary Design.

Group	Description	Qty	Units	Unit Cost	TOTAL DIRECT COST
1	**Site Preparation, Mobilization**				**$95,220.00**
	Mobilization	1	LS	$35,610.26	$35,610.26
	Clearing and Grubbing	2.0	ACRE	$6,000.00	$12,000.00
	Stabilized Construction Entrance (3 No.)	167	SY	$20.00	$3,340.00
	Access Road Prep (quarry spalls)	130	CY	$50.00	$6,500.00
	Staging Area Prep (quarry spalls)	222	CY	$50.00	$11,100.00
	Mowing Reed Canary Grass, Blackberry	3.0	ACRE	$256.00	$768.00
	Water Management	1	LS	$23,500.00	$23,500.00
	High Visibility Fence	400	LF	$4.00	$1,600.00
	Silt Fence	200	LF	$4.00	$800.00
2	**Earthwork**				**$153,030.00**
	Channel Excavation	2,800	CY	$30.00	$84,000.00
	Upland Spoils Haul, Fill, Spreading	2,800	CY	$6.25	$17,500.00
	Culvert Earthwork	1	LS	$47,204.70	$47,204.70
	River Cobble Apron	31	CY	$75.00	$2,325.00
	Survey Control	1	LS	$2,000.00	$2,000.00
4	**Culverts**				**$99,950.00**
	Culvert Install	1	LS	$68,304.80	$68,304.80
	Trail Bypass, Restoration	1	LS	$31,646.67	$31,646.67
7	**Log Work**				**$29,300.00**
	Habitat Logs w/ rootwads	35	EA	$500.00	$17,500.00
	Grade Control Logs at Culverts	12	EA	$300.00	$3,600.00
	Log w/ rootwad at U/S culvert inlet + boles	1	LS	$800.00	$800.00
	Labor & Equipment, Log Install	1	LS	$7,400.00	$7,400.00
11	**Specialties**				**$6,000.00**
	SPCC Plan	1	LS	$4,000.00	$4,000.00
	Stormwater Pollution Prevention Plan	1	LS	$2,000.00	$2,000.00

Table 14. Estimated Unit Costs Used in Developing Cost Estimate for Preliminary Design.

Group	Description	Qty	Units	Unit Cost	TOTAL DIRECT COST
13	**Planting, Site Restoration, Demobilization**				**$160,830.00**
	Seed Mix, hydroseeding disturbed areas	1	ACRE	$1,700.00	$1,700.00
	Reed Canary Grass Floodplain (Non-Fill Areas)	1	LS	$51,675.00	$51,675.00
	Reed Canary Grass Floodplain (Fill Area)	1	LS	$18,375.00	$18,375.00
	Blackberry Areas	1	LS	$33,805.00	$33,805.00
	Reed Canary Grass Forest Inclusions	1	LS	$29,631.00	$29,631.00
	Constructed Channel Riparian Zone	1	LS	$8,148.00	$8,148.00
	Riparian Forest Enhancement	1	LS	$7,492.00	$7,492.00
	Demobilization	1	LS	$10,000.00	$10,000.00

Table 15. Estimated Unit Costs Associated with Culvert Installation, Preliminary Design.

DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
General				
Temporary Sand Bag Cofferdams	100	LF	$10.00	$1,000
Water Handling - 200 gpm Pump	1	LS	$10,000.00	$10,000
Water Handling - 200 gpm Silt Bags	1	LS	$12,000.00	$12,000
Fish Rescue	1	LS	$500.00	$500
Earthwork				
Common Excavation	780	CY	$30.00	$23,400
Fill				
Quarry Spalls	140	CY	$58.00	$8,120
Crushed Rock Base Course	17	tons	$40.00	$660
Common Backfill	240	CY	$35.00	$8,400
Gravel Crushed Surfacing (1-1/4" Minus)	61	CY	$103.00	$6,283
Geotextile Fabric	67	SY	$5.10	$342
Box Culvert				
Precast Trench Split Culvert (Box Culvert)	60	LF	$450.00	$27,000
Precast Wing Walls	8	EA	$3,000.00	$24,000
Installation (12 ton - truck mounted crane)	4	DAY	$2,451.00	$9,805
Grouting	1	LS	$7,500.00	$7,500
Trail Work				
Asphalt	4	tons	$120.00	$480
Railing	60	LF	$100.00	$6,000
Traffic Control	1	LS	$10,000.00	$10,000
Remove, Dispose Asphalt	25	SY	$20.00	$500
Temporary Bypass Trail, Prism Fill	293	CY	$20.00	$5,852
Temporary Bypass Trail Crushed Rock, grading	56	tons	$40.00	$2,222
Temporary Bypass Trail Removal	330	CY	$20.00	$6,593

Table 16. Estimated Unit Costs Associated With Vegetation Restoration, Maintenance.

DESCRIPTION	SPECIES/DETAILS	QUANTITY	UNIT	UNIT PRICE	TOTAL
Reed Canarygrass floodplain (2.33 acres)					
Plant Material and Installation	*Salix lasiandra*	5709	stake	$2.00	$11,419
Plant Material and Installation	*Salix scouleriana*	5709	stake	$2.00	$11,419
Plant Material and Installation	*Salix sitchensis*	5709	stake	$2.00	$11,419
Plant Material and Installation	*Cornus sericea*	5709	stake	$2.00	$11,419
Labor - Planting Supervision		50	Hours	$120.00	$6,000
Total					**$51,675**
Reed Canarygrass meadow fill area above 100-year floodplain elevation (0.59 acres)					
Plant Material and Installation	*Salix lasiandra*	645	stake	$2.00	$1,290
Plant Material and Installation	*Salix sitchensis*	645	stake	$2.00	$1,290
Plant Material and Installation	*Spiraea douglasii*	129	1-gallon	$11.50	$1,484
Plant Material and Installation	*Rubus spectabilis*	77	1-gallon	$11.50	$890
Plant Material and Installation	*Rosa nutkana*	52	1-gallon	$11.50	$593
Plant Material and Installation	*Rosa pisocarpa*	52	1-gallon	$11.50	$593
Plant Material and Installation	*Lonicera involucrata*	258	1-gallon	$11.50	$2,967
Plant Material and Installation	*Frangula purshiana*	77	1-gallon	$11.50	$890
Plant Material and Installation	*Cornus sericea*	516	1-gallon	$11.50	$5,934
Plant Material and Installation	*Physocarpus capitatus*	129	1-gallon	$11.50	$1,484
Labor - Planting Supervision		8	Hours	$120.00	$960
Total					**$18,375**
Blackberry Island and Blackberry Hillslope Restoration (0.79 acres)					
Plant Material and Installation	*Fraxinus latifolia*	22	1-gallon	$11.50	$248
Plant Material and Installation	*Picea sitchensis*	54	1-gallon	$11.50	$621
Plant Material and Installation	*Thuja plicata*	54	1-gallon	$11.50	$621
Plant Material and Installation	*Populus balsamifera ssp. trichocarpa*	43	1-gallon	$11.50	$497
Plant Material and Installation	*Alnus rubra*	43	1-gallon	$11.50	$497
Plant Material and Installation	*Corylus cornuta*	11	1-gallon	$11.50	$124
Plant Material and Installation	*Rubus spectabilis*	11	1-gallon	$11.50	$124
Plant Material and Installation	*Rosa nutkana*	173	1-gallon	$11.50	$1,984
Plant Material and Installation	*Rosa pisocarpa*	173	1-gallon	$11.50	$1,984
Plant Material and Installation	*Lonicera involucrata*	690	1-gallon	$11.50	$7,935

Table 16. Estimated Unit Costs Associated With Vegetation Restoration, Maintenance.

DESCRIPTION	SPECIES/DETAILS	QUANTITY	UNIT	UNIT PRICE	TOTAL
Plant Material and Installation	*Salix sitchensis*	690	stake	$2.00	$1,380
Plant Material and Installation	*Sambucus racemosa*	690	1-gallon	$11.50	$7,935
Plant Material and Installation	*Cornus sericea*	690	1-gallon	$11.50	$7,935
Labor - Planting Supervision		16	Hours	$120.00	$1,920
Total					**$33,805**
Reed canarygrass forest inclusions (0.59 acres)					
Plant Material and Installation	*Picea sitchensis*	81	1-gallon	$11.50	$932
Plant Material and Installation	*Thuja plicata*	81	1-gallon	$11.50	$932
Plant Material and Installation	*Oemlaria cerasiformis*	777	1-gallon	$11.50	$8,936
Plant Material and Installation	*Corylus cornuta*	518	1-gallon	$11.50	$5,957
Plant Material and Installation	*Rubus spectabilis*	518	1-gallon	$11.50	$5,957
Plant Material and Installation	*Rosa pisocarpa*	259	1-gallon	$11.50	$2,979
Plant Material and Installation	*Rosa nutkana*	259	1-gallon	$11.50	$2,979
Labor - Planting Supervision		8	Hours	$120.00	$960
Total					**$29,631**
Existing Riparian Forest Enhancement (2.24 acres)					
Plant Material and Installation	*Picea sitchensis*	152	1-gallon	$11.50	$1,753
Plant Material and Installation	*Thuja plicata*	152	1-gallon	$11.50	$1,753
Plant Material and Installation	*Psuedotsuga menziesii*	152	1-gallon	$11.50	$1,753
Plant Material and Installation	*Tsuga heterophylla*	152	1-gallon	$11.50	$1,753
Labor - Planting Supervision		4	Hours	$120.00	$480
Total					**$7,492**
Excavated channel - streambank riparian restoration area (0.57 acres)					
Plant Material and Installation	*Salix lasiandra*	744	stake	$2.00	$1,488
Plant Material and Installation	*Salix sitchensis*	744	stake	$2.00	$1,488
Plant Material and Installation	*Cornus sericea*	992	stake	$2.00	$1,984
Plant Material and Installation	Wetland Grass/Sedge seed mix	0.57	acre	$4,750.00	$2,708
Labor - Planting Supervision		4	Hours	$120.00	$480
Total					**$8,148**
Plant Material and Installation Grand Total					**$149,126**

Table 16. Estimated Unit Costs Associated With Vegetation Restoration, Maintenance.

DESCRIPTION	SPECIES/DETAILS	QUANTITY	UNIT	UNIT PRICE	TOTAL
	Additional Costs				
Habitat Conservation Signs		6	EA	$100	$600
Annual Monitoring and Maintenance Supervision		10	Year	$5,500	$55,000
Annual Maintenance (Years 0-5)		5	Year	$3,200	$16,000
Annual Maintenance (Years 5-10)		5	Year	$1,600	$ 8,000
Plant replacement fund Estimate for 5 years		1	Contingency	$10,000	$10,000
Total					**$89,600**
Plant Related Costs 10 Year Grand Total					**$238,726**

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APPENDIX A

Flow Duration Percentiles for Gages Evaluated in the Hydrologic Analysis

Month	5% exceedance (cfs)	20% exceedance (cfs)	50% exceedance (cfs)	80% exceedance (cfs)	95% exceedance (cfs)
LittleBear@195th-KC (2013-2014)					
January	79.1	36.7	17.9	13.5	12.1
February	82.4	60.9	29.1	15.4	11.8
March	176.9	106.2	66.9	35.7	28.8
April	48.8	34.6	24.3	19.2	17.0
May	33.5	19.0	13.3	11.8	11.0
June	16.1	12.2	9.8	9.2	8.9
July	8.6	8.2	7.7	7.3	7.1
August	10.9	9.1	8.0	7.1	6.8
September	37.9	11.5	9.7	9.1	8.5
October	18.6	12.4	10.5	9.9	9.7
November	34.9	21.1	13.4	11.9	10.8
December	40.6	19.9	14.6	12.5	11.2
LittleBear@228th-KC (2003-2005)					
January	80.9	44.9	18.8	11.3	9.5
February	29.2	23.5	15.5	9.3	7.6
March	21.9	16.7	12.7	8.0	6.9
April	10.5	9.1	7.8	7.1	6.6
May	16.6	7.7	6.7	6.0	5.6
June	9.1	7.6	5.8	4.7	4.5
July	6.2	5.3	3.8	3.2	3.0
August	9.8	6.6	4.1	3.5	3.4
September	13.3	11.0	8.0	5.9	5.3
October	17.3	11.4	8.5	7.2	6.0
November	68.3	24.3	8.5	6.9	4.3
December	63.6	32.7	21.3	15.8	12.6

Month	5% exceedance (cfs)	20% exceedance (cfs)	50% exceedance (cfs)	80% exceedance (cfs)	95% exceedance (cfs)
LittleBear@228th-SC (2000-2012)					
January	82.7	42.6	21.7	13.1	9.4
February	39.9	22.7	15.3	10.8	7.7
March	48.5	28.4	17.1	11.7	8.2
April	34.2	21.3	14.6	10.0	7.5
May	20.2	13.3	9.9	6.6	5.6
June	18.8	11.1	8.0	5.6	4.5
July	8.7	7.1	5.5	4.0	3.4
August	7.9	6.2	5.2	4.0	3.4
September	10.1	7.9	6.0	5.2	4.3
October	21.8	12.8	9.2	6.4	5.3
November	82.5	30.6	15.0	9.6	7.0
December	82.6	39.2	17.0	10.6	8.5
NorthCr@CountyLine-SC (1988-2011)					
January	276.1	145.9	73.7	42.1	31.9
February	214.8	118.7	58.7	35.5	24.3
March	189.8	98.8	53.0	32.2	16.1
April	123.1	64.5	42.1	26.5	17.2
May	79.3	39.4	24.9	16.6	12.0
June	79.2	35.7	20.3	13.7	11.2
July	36.4	20.6	14.2	11.5	9.5
August	32.2	17.8	13.1	10.7	3.8
September	40.7	18.8	13.9	11.5	1.1
October	101.0	42.4	21.2	14.2	9.2
November	232.1	105.7	45.9	24.9	14.6
December	262.7	134.2	69.1	38.1	25.5

Month	5% exceedance (cfs)	20% exceedance (cfs)	50% exceedance (cfs)	80% exceedance (cfs)	95% exceedance (cfs)
Sammamish@116th-KC51T (2005-2014)					
January	1424.2	944.1	561.9	388.5	299.0
February	920.7	642.8	408.3	307.0	258.5
March	1152.6	670.6	438.8	303.2	246.9
April	757.8	558.6	391.6	299.1	244.5
May	441.3	360.7	255.1	191.5	154.7
June	488.4	277.6	184.3	134.1	103.5
July	206.9	149.2	106.0	66.0	51.9
August	97.0	71.6	58.9	48.2	42.5
September	117.1	80.7	59.5	51.3	45.2
October	237.4	152.7	104.0	66.1	50.3
November	860.5	541.3	315.9	187.3	125.7
December	1154.7	796.7	436.2	235.0	178.0
SammamishR@116th-USGS (1987-2006)					
January	1342.0	783.6	465.0	267.6	181.4
February	1020.0	709.8	449.0	276.2	196.6
March	821.6	577.4	398.0	234.0	162.4
April	684.6	435.2	309.0	227.8	142.5
May	421.4	282.4	216.0	155.0	106.4
June	380.1	266.2	172.0	123.8	84.0
July	232.3	138.0	94.0	68.0	48.0
August	130.0	89.6	64.0	49.0	37.0
September	134.1	96.2	67.0	54.8	42.0
October	246.6	150.0	82.0	56.0	46.0
November	879.0	401.6	212.0	103.0	73.9
December	1072.0	792.0	398.0	239.6	180.4

Month	5% exceedance (cfs)	20% exceedance (cfs)	50% exceedance (cfs)	80% exceedance (cfs)	95% exceedance (cfs)
SwampCr-KC (1999-2005)					
January	149.2	89.5	46.1	22.5	1.0
February	105.6	68.6	37.2	24.5	12.2
March	92.1	60.6	32.0	17.3	9.1
April	74.6	46.7	25.3	15.7	10.5
May	43.7	22.3	14.2	10.4	5.0
June	38.8	17.1	10.4	6.7	5.2
July	17.7	8.8	6.6	4.5	3.5
August	17.3	7.5	6.0	4.3	3.5
September	27.4	9.2	6.2	5.4	4.4
October	72.8	34.4	10.9	6.7	5.1
November	204.0	79.5	28.3	13.1	10.1
December	169.7	97.5	47.5	21.4	9.2

APPENDIX B

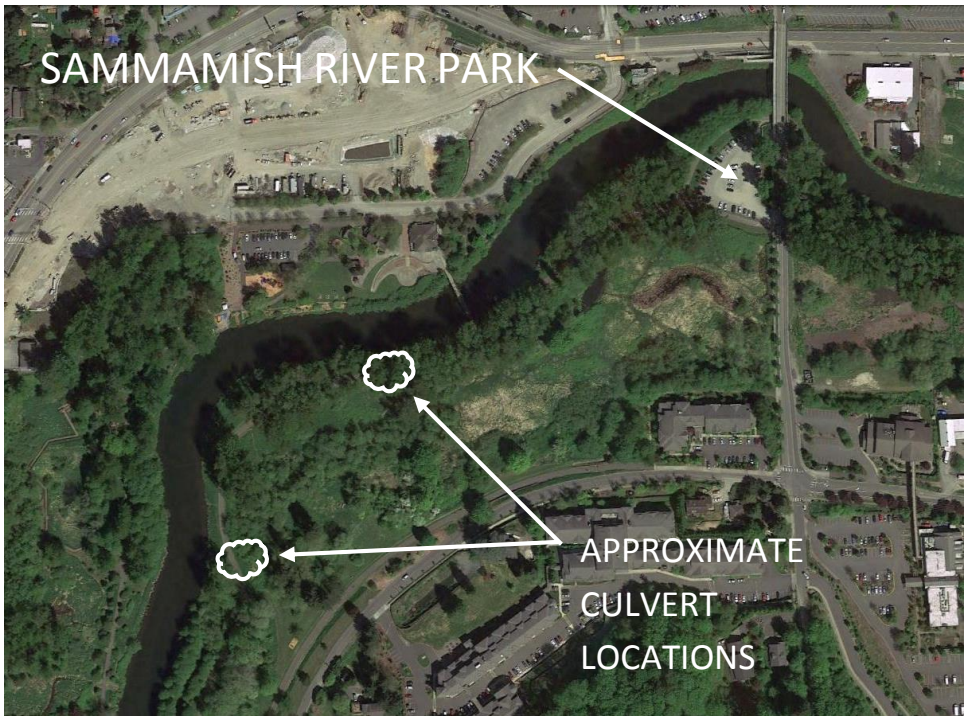
Zipper Geo Associates LLC Geotechnical Engineering Report

GEOTECHNICAL ENGINEERING REPORT

SAMMAMISH RIVER SIDE CHANNEL RESTORATION PROJECT
SAMMAMISH RIVER TRAIL CULVERTS
BOTHELL, WASHINGTON

Project No. 1313.01
September 19, 2014

Prepared for:
R2 Resource Consultants, Inc.



Prepared by:

Zipper Geo Associates, LLC
Geotechnical and Environmental Consultants
19023 36th Avenue W., Suite D
Lynnwood, WA 98036

Zipper Geo Associates, LLC
Geotechnical and Environmental Consulting

Project No. 1313.01
September 19, 2014

R2 Resource Consultants, Inc.
15250 NE 95th Street
Redmond, Washington 98052

Attention: Mr. Paul DeVries, P.E.

Subject: **Geotechnical Engineering Report**
Sammamish River Side Channel Restoration Project
Sammamish River Trail Culverts
Bothell, Washington

Dear Mr. Devries,

In accordance with your request and written authorization, Zipper Geo Associates, LLC (ZGA) has completed the subsurface explorations and geotechnical engineering evaluation for the two proposed Sammamish River Trail culverts in Bothell, Washington. This report presents the findings of the subsurface exploration and geotechnical recommendations for project design and construction. Written authorization to proceed was provided by R2 Consultants, Inc. in your Purchase Order-Subconsultant Agreement (Subcontract No. PO #C380-14) dated July 2, 2014. We appreciate the opportunity to be of service to you on this project. If you have any questions concerning this report, or if we may be of further service, please contact us.

Sincerely,
Zipper Geo Associates, LLC

State of Washington
9-19-14
Engineering Geologist
1783
Licensed Geologist
JAMES P. GEORGIS

JOHN E. ZIPPER
STATE OF WASHINGTON
9/19/14
22611
REGISTERED
PROFESSIONAL ENGINEER

James P. Georgis, L.E.G.
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Managing Principal

Copies: Addressee (1)

19023 36th Avenue West, Suite D **Lynnwood, WA 98036** **(425) 582-9928**

TABLE OF CONTENTS

Page

INTRODUCTION **1**
SITE AND PROJECT DESCRIPTION **1**
SUBSURFACE CONDITIONS **2**
- Regional Geology 2
- Soil Conditions 2
- Groundwater Conditions 3
- Summary of Laboratory Testing 4

CONCLUSIONS AND RECOMMENDATIONS **4**
- General 4
- Site Preparation 5
- Structural Fill Materials and Preparation 7
- Temporary and Permanent Slopes 9
- Temporary Shoring 10
- Culvert Foundations 11
- Temporary Construction Dewatering 12
- Foundation Embedment and Scour Considerations 13
- Seismic Considerations 13

CLOSURE **14**

FIGURES

Figure 1 – Vicinity Map
Figure 2 – Site and Exploration Plan
- Sheet 1 – Downstream Culvert
- Sheet 2 – Upstream Culvert
- Sheet 3 – Explorations Completed by Others

APPENDICES

Appendix A – Subsurface Exploration Procedures and Logs
Appendix B – Laboratory Testing Procedures and Results
Appendix C – Subsurface Exploration Logs Completed by Others

Cover Photo Credit: Google Earth 2014

GEOTECHNICAL ENGINEERING REPORT
SAMMAMISH RIVER SIDE CHANNEL RESTORATION PROJECT
SAMMAMISH RIVER TRAIL CULVERTS
BOTHELL, WASHINGTON

Project No. 1313.01

September 19, 2014

INTRODUCTION

This report documents the surface and subsurface conditions encountered at the site and our geotechnical engineering recommendations for the two proposed Sammamish River Trail culverts. The project description, site conditions, and our geotechnical conclusions and design recommendations are presented in the text of this report. Supporting data including detailed exploration logs and field exploration procedures, results of laboratory testing, and other supporting information are presented as appendices.

Our geotechnical engineering scope of services for the project included a literature review, site reconnaissance, subsurface exploration, laboratory testing, geotechnical engineering analysis, and preparation of this report. The subsurface evaluation consisted of completing 2 exploratory borings designated B-1 and B-2. The borings extended to a depth of approximately 18 to 21½ feet below existing grade.

SITE AND PROJECT DESCRIPTION

The Sammamish River Trail in the project vicinity and the proposed culverts are within a floodplain located along the south and southeast sides of the Sammamish River in the City of Bothell, Washington. The low elevation floodplain was hydraulically abandoned when the US Army Corps of Engineers constructed the Lake Washington Ship Canal and lowered the elevation of Lake Washington below its predevelopment level, effectively decupling the floodplain from the Sammamish River. We understand that the proposed project includes reconstructing and reconnecting an abandoned side channel to the Sammamish River in order to increase juvenile salmon habitat quantity and quality, restore flood plain plant communities, and increase opportunities for public involvement and education.

The side channel project includes new culvert crossings of the Sammamish River Trail near the downstream and upstream side channel to river connection locations. The Sammamish River Trail is about 12 feet wide near the culvert locations and is surfaced with asphalt pavement. The trail surface is generally 1 to 2 feet higher than the surrounding floodplain and appears to be constructed on a fill berm.

We understand the culverts will consist of pre-manufactured, closed bottom, concrete box culverts. The culverts are about 6½ feet tall (including the lid), 11½ feet wide, and 10 feet long. Three 10 foot long box

culvert sections will be used end-to-end to produce a total culvert length of about 30 feet at each culvert location. Preliminary plans indicate that both the downstream and upstream culverts will have invert elevations of about 18.4 feet and a bottom of culvert elevation of about 17.6 feet. We understand that these elevations are relative to NAVD88. The approximate location of the site and the downstream and upstream culverts are shown on the enclosed *Vicinity Map, Figure 1*. A more detailed view of the downstream and upstream culvert locations is shown on the enclosed *Site and Exploration Plan, Figure 2*.

SUBSURFACE CONDITIONS

Regional Geology

We assessed the geologic setting of the site and surrounding vicinity by reviewing the *Geologic Map of the Bothell Quadrangle, Snohomish and King Counties, Washington,* U.S. Geologic Survey, Map MF-1747, 1985. The geologic map indicates that the culvert sites are mantled by Quaternary age (Holocene) Alluvium (Qal). The alluvium is described as stratified, gray to gray brown clay, silt, and very fine to fine sand containing organic matter. Medium to coarse sand and gravel alluvial deposits are described as underlying much of the fine-grained floodplain alluvial deposits. Quaternary age Transitional Bed deposits (Qtb) are mapped along the south side of the abandoned floodplain. The Transitional Beds are described as glacially consolidated, thinly bedded clay, silt, and very fine sand deposited in still to slowly moving water.

Soil Conditions

The subsurface evaluation for this project included borings B-1 and B-2 completed near the downstream and upstream culvert locations, respectively. The borings extended to a depths of about 18 to 21½ feet below the ground surface. The approximate exploration locations are shown on the enclosed *Site and Exploration Plan, Figure 2, Sheets 1 and 2*.

Soils were visually classified in general accordance with the Unified Soil Classification System. Descriptive logs of the subsurface explorations completed for this project and the procedures utilized in the subsurface exploration program are presented in *Appendix A*. A generalized description of soil conditions encountered in the borings is presented below. Please refer to the boring logs in *Appendix A* for a more detailed description of the conditions encountered at the exploration locations.

Our evaluation of subsurface conditions also included a review of boring logs completed within the abandoned floodplain by Pacific Groundwater Group in July and August of 2012. The approximate exploration locations are shown on the enclosed *Site and Exploration Plan, Figure 2, Sheet 3*. Copies of the Pacific Groundwater Group boring logs are presented in Appendix C.

In general, ZGA borings B-1 and B-2 encountered a top down sequence consisting of fill soils over native alluvial deposits over Transitional Bed deposits. A more detailed description of the materials encountered at the exploration locations is presented below.

Boring B-1

Boring B-1 was completed near the downstream culvert about 3 feet west of the trail. Boring B-1 encountered about 6 feet of fill consisting of loose to medium dense sand with some silt and trace gravel. Rough drilling action was encountered at a depth of about 2 feet and could represent rocks, cobbles, or construction debris within the fill soils. Alluvial deposits were encountered below the fill and extended to a depth of about 20½ feet. The upper 3½ feet of the alluvium generally consisted of medium stiff silt and very loose silty sand with trace fine organic material. Below a depth of about 9½ feet, the alluvium generally consisted of medium dense sand with trace to some silt. Hard, silt with some clay was encountered below the alluvial deposits at a depth of about 20½ feet and extended to the total depth explored of 21½ feet below the ground surface. The hard silt is interpreted as glacial lacustrine deposits locally referred to as Transitional Beds.

Boring B-2

Boring B-2 was completed near the upstream culvert about 3 feet south of the trail. Boring B-2 encountered about 3 feet of fill consisting of loose to medium dense sand with some silt and trace to some gravel. Alluvial deposits were encountered below the fill and extended to a depth of about 11 feet. The upper 2 feet of the alluvium generally consisted of loose, finely bedded sand with some silt. Below a depth of about 5 feet, the alluvium generally consisted of very loose, silty sand with some gravel and trace fine organic material. Hard, silt with some clay was encountered below the alluvial deposits at a depth of about 11 feet and extended to the total depth explored of 18 feet below the ground surface. The hard silt is interpreted as glacial lacustrine deposits locally referred to as Transitional Beds.

Groundwater Conditions

Groundwater was encountered in borings B-1 and B-2 at the time of drilling. Groundwater in boring B-1 was observed at a depth of about 7.5 feet below the ground surface, which correlates to a site elevation of about 16.4 feet. Groundwater in boring B-2 was observed at a depth of about 7 feet below the ground surface, which correlates to a site elevation of about 17.3 feet. These observations represent approximate groundwater conditions at the time of the field exploration. Groundwater conditions should be expected to fluctuate due to changes in season, precipitation patterns, fluctuations in river level, site utilization, and other on- and off-site factors. It should be noted that borings B-1 and B-2 were completed in July of 2014 during an extended period of relatively dry weather, and likely characterize groundwater conditions within the lower portion of their seasonal fluctuation.

Pacific Groundwater Group installed groundwater monitoring wells in borings completed within the abandoned floodplain in July and August of 2012. The approximate exploration locations are presented on the enclosed *Site and Exploration Plan, Figure 2, Sheet 3*. Groundwater elevations recoded in the monitoring wells by Pacific Groundwater Group are presented in the table below.

SUMMARY OF PACIFIC GROUNDWATER GROUP GROUNDWATER OBSERVATIONS			
Exploration/Location	**9/14/2012 Groundwater Elevation [1] (ft)**	**11/4/2012 Groundwater Elevation [1] (ft)**	**11/17/2012 Groundwater Elevation [1] (ft)**
S-3	19.69	22.67	22.19
S-4	18.75	20.16	19.88
S-6	17.42	19.72	18.22
S-7	19.07	20.3	20.3
S-8	NA	18.62	19.83
S-10	24.45	NA	25.8
S-12	22.11	22.79	23.13
S-13	25.58	26.04	26.19
S-14	19.58	21.59	22.87
S-16	18.52	19.93	19.97
D-1	25.81	26.41	26.65
D-2	21.13	22.27	22.68
River Gauge	17.27	17.61	17.72

1. Groundwater elevations relative to NAVD88 vertical datum. NAVD88 groundwater elevations presented herein were obtained by subtracting 68.58 feet from the Local Datum used by Pacific Groundwater Group.

Summary of Laboratory Testing

Laboratory testing was completed on selected samples obtained from our borings. Testing completed included moisture content and grain size analyses. Moisture content testing indicates in-situ soil moisture contents ranging from about 4 to 38 percent for samples obtained within the upper 7½ feet of existing site grades. Grain size analysis testing was completed on two samples collected from depths of approximately 10 feet and indicate fines contents (silt and clay size particles passing a US No. 200 sieve) of about 7 and 36 percent. The results of moisture content testing are presented on the boring logs. The results of grain size analysis testing are presented in Appendix B.

CONCLUSIONS AND RECOMMENDATIONS

General

Based on our subsurface exploration program and geotechnical evaluation, we conclude that the upstream and downstream closed bottom concrete box culverts are feasible from a geotechnical perspective utilizing shallow foundation support, contingent on proper design and construction practices and implementation of the recommendations presented in this report.

Primary geotechnical considerations relative to design and construction of the culverts are related to the 3½ to 4¼ foot thick zone of medium stiff to very loose alluvium encountered below the planned culvert

bottom elevation of 17.6 feet, coupled with groundwater elevations of approximately 16.4 and 17.3 feet observed at the time of explorations. In our opinion, these medium stiff to very loose, wet to saturated soils will not provide a stable working surface during construction and could result in unacceptable levels of post construction settlement. We recommend that these soils be removed and that the culverts be supported on a zone of select structural fill placed on the underlying medium dense alluvium at the downstream culvert location and hard silt at the upstream culvert to provide a stable "working pad" for construction activities and limit post construction settlements. The excavation to remove and replace the 3½ to 4½ foot thick zone of unsuitable subgrade soils and create the "working pad" should extend out laterally from the edge of the culvert a distance equal to the excavation depth below the bottom of the culvert.

Geotechnical engineering recommendations for foundation support and other earthwork related phases of the project are outlined below. The recommendations contained in this report are based upon the results of field and laboratory testing (which are presented in *Appendices A and B*), engineering analyses, and our current understanding of the proposed project. ASTM and Washington State Department of Transportation (WSDOT) specification codes cited herein respectively refer to the current manual published by the American Society for Testing & Materials and the current edition of the *Standard Specifications for Road, Bridge, and Municipal Construction, (M41-10)*.

Site Preparation

Erosion Control Measures: Stripped surfaces and soil stockpiles are typically a source of runoff sediments. We recommend that silt fences, berms, straw wattles, and/or swales be installed around the downslope side of stripped areas and stockpiles in order to capture runoff water and sediment. If earthwork occurs during wet weather, we recommend that all stripped surfaces be covered with straw to reduce runoff erosion, whereas soil stockpiles should be protected with anchored plastic sheeting.

Temporary Drainage: Stripping, excavation, grading, and subgrade preparation should be performed in a manner and sequence that will provide drainage at all times and provide proper control of erosion. The site should be graded to prevent water from ponding in construction areas and/or flowing into and/or over excavations. Exposed grades should be crowned, sloped, and smooth-drum rolled at the end of each day to facilitate drainage if inclement weather is forecasted. Accumulated water must be removed from subgrades and work areas prior to performing further work in the area. Equipment access may be limited and the amount of soil rendered unfit for use as structural fill may be greatly increased if drainage efforts are not accomplished in a timely manner.

Clearing and Stripping: The existing trail is surfaced with asphalt concrete and the trail shoulders typically include about 2 inches of grass sod. As such, extensive clearing, grubbing, and topsoil stripping activities within the trail and shoulder areas are not anticipated. The floodplain south of the upstream culvert trail shoulder and east and west of the downstream culvert trail shoulder includes moderately dense blackberry shrubs and scattered trees. Thicker deposits of topsoil, root systems, or other organic rich soils

may be encountered beyond the trail shoulders and should be removed and utilized for non-structural landscape fill or be disposed of at a suitable off-site location. Any excavations that extend below finish grades below the trail and its shoulders should be backfilled with structural fill as outlined subsequently in this report.

Subgrade Preparation: Borings B-1 and B-2 encountered about 3½ to 4¼ feet of medium stiff to very loose alluvium below the planned culvert bottom elevation. These soils are not suitable for direct foundation support, in our opinion, and specific subgrade preparation and construction recommendations are presented in the *Culvert Foundations* section of this report. The following subgrade preparation recommendations have been developed for the new culvert trail approaches.

Based on our explorations, we anticipate that soils encountered in the upper 5 to 6 feet of the trail surface will consist of sand with some silt and trace to some gravel. Once site preparation is complete, areas that are at design subgrade elevation or areas that will receive new structural fill should be compacted to a firm and non-yielding condition and to a compaction level of at least 95 percent of the maximum laboratory density (per ASTM D 1557) within the upper 12 inches. Some moisture conditioning of site soils may be required to achieve an appropriate moisture content for compaction (typically ±2 percent of the soils laboratory optimum moisture content). Our laboratory testing indicates that, at the time our explorations were completed, in-situ moisture contents of soils ranged from about 4 to 6 percent for samples obtained within about 5 feet of the existing trail grade. These moisture contents are near to slightly below the estimated optimum moisture content of the near surface site soils. As a result, we expect that moisture conditioning of site soils during construction may be required to achieve suitable moisture contents (plus or minus two percent of optimum) for compaction.

Earthwork should be completed during drier periods of the year when soil moisture content can be controlled by aeration and drying if possible. If earthwork or construction activities take place during extended periods of wet weather, the existing site soils will become unstable or not be compactable. In the event the exposed subgrade becomes unstable, yielding, or unable to be compacted due to high moisture conditions, we recommend that the materials be removed to a sufficient depth in order to develop stable subgrade soils that can be compacted to the minimum recommended levels. The severity of construction problems will be dependent, in part, on the precautions that are taken by the contractor to protect the subgrade soils.

Once compacted, subgrades should be evaluated through density testing and, if possible, proof rolling with a loaded dump truck or heavy rubber-tired construction equipment to assess the subgrade adequacy and to detect soft and/or yielding soils. In the event that soft or yielding areas are detected during proof rolling, the upper 12 inches of subgrade should be scarified, moisture conditioned and re-compacted as necessary to obtain at least 95 percent of the maximum laboratory density (per ASTM D 557) and a firm, non-yielding condition. Those soils which are soft, yielding, or unable to be compacted to the specified

criteria should be over-excavated and replaced with suitable on-site or imported material as recommended in the *Structural Fill* section of this report.

Once subgrades are compacted, depending on the time of year, it may be desirable to protect prepared foundation and floor slab subgrades from wet weather. To protect stable subgrades, we recommend using crushed rock or crushed recycled concrete. The thickness of the protective layer should be determined at the time of construction and be based on the moisture condition of the soil and the amount of anticipated traffic.

Freezing Conditions: If earthwork takes place during freezing conditions, all exposed subgrades should be allowed to thaw and then be compacted prior to placing subsequent lifts of structural fill. Alternatively, the frozen material could be stripped from the subgrade to expose unfrozen soil prior to placing subsequent lifts of fill or foundation components. The frozen soil should not be reused as structural fill until allowed to thaw and adjusted to the proper moisture content, which may not be possible during winter months.

Structural Fill Materials and Preparation

Structural fill includes any material placed below foundations and pavement sections, within utility trenches, and behind retaining walls. Prior to the placement of structural fill, all surfaces to receive fill should be prepared as recommended in the *Site Preparation* and *Culvert Foundation* sections of this report.

Laboratory Testing: Representative samples of on-site and imported soils to be used as structural fill should be submitted for laboratory testing at least 4 days in advance of its intended use in order to complete the necessary Proctor tests.

Re-Use of Site Soils as Structural Fill: Field and laboratory test data indicates that the existing fill and native soils encountered to a depth of about 5 to 6 feet below existing trial grade at the exploration locations are suitable for reuse as general structural fill from a compositional standpoint provided the soil is placed and compacted in accordance with the compaction recommendations presented in this report. As indicated above, the upper 5 to 6 feet of the site soils at the time of our evaluation appeared to be near to slightly below of their estimated optimum moisture content. Soils encountered below a depth of about 5 to 6 feet typically contained a high fines content and were well above their optimum moisture content relative to compaction, or were located near or below the groundwater table and were wet to saturated. In our opinion, it would be extremely difficult to utilize these soils as structural fill without extensive moisture conditioning. For planning purposes we recommend that the native soils at depths greater than about 5 to 6 feet below trail grade be considered unsuitable for reuse as structural fill. Drying of over-optimum moisture soils may be achieved by scarifying or windrowing surficial materials during extended periods of dry weather. If encountered, soils which are dry of optimum may be moistened

through the application of water and thorough blending to facilitate a uniform moisture distribution in the soil prior to compaction.

We recommend that site soils used as structural fill have less than 4 percent organics by weight and have no woody debris greater than ½ inch in diameter. We recommend that all pieces of organic material greater than ½ inch in diameter be picked out of the fill before it is compacted. Any organic-rich soil derived from earthwork activities should be utilized in landscape areas or wasted from the site.

Imported Structural Fill: Imported structural fill may be required for raising site grades or as replacement fill for unsuitable site soils. The appropriate type of imported structural fill will depend on the prevailing weather conditions. During extended periods of dry weather, we recommend imported fill, at a minimum, meet the requirements of Common Borrow as specified in WSDOT Standard Specifications Section 9-03.14(3). During wet weather, higher-quality structural fill might be required, as Common Borrow may contain sufficient fines to be moisture sensitive. During wet weather we recommend that imported structural fill meet the requirements of Gravel Borrow as specified in Section 9-03.14(1) of the WSDOT Standard Specifications.

Import fill used to construct the "working pad" below the culverts should consist of Quarry Spalls conforming to WSDOT Standard Specification Section 9-13.9 and Crushed Surfacing Base Course conforming to WSDOT Standard Specification Section 9-03.9(3) as presented in the *Culvert Foundation* section of this report.

Trail Pavement Subgrade: Any structural fill used within the upper one foot below pavement sections should have a minimum California Bearing Ratio (CBR) of 15 when compacted to a minimum of 95 percent of the modified Proctor maximum dry density. A CBR value of 15 is representative of the on-site soils encountered to depths of about 5 to 6 feet below trail grade and Common Borrow import fill, in our opinion.

Moisture Content: The suitability of soil for use as structural fill will depend on the time of year, the moisture content of the soil, and the fines content (that portion passing the U.S. No. 200 sieve) of the soil. As the amount of fines increases, the soil becomes increasingly sensitive to small changes in moisture content. Soils containing more than about 5 percent fines (such as the near-surface on-site soils) cannot be consistently compacted to the appropriate levels when the moisture content is more than approximately 2 percent above or below the optimum moisture content (per ASTM D 1557). Optimum moisture content is that moisture content which results in the greatest compacted dry density with a specified compactive effort. Moisture content of fill at the time of placement should be within plus or minus 2 percent of optimum moisture content for compaction as determined by the ASTM D 1557 test method.

Fill Placement: Structural fill should be placed in horizontal lifts not exceeding 10 inches in loose thickness. Each lift of fill should be compacted using compaction equipment suitable for the soil type and lift thickness.

Compaction Criteria: Quarry Spalls and Crushed Surfacing Base Course import fill used to construct the "working pad" below the culverts should be compacted to a firm and non-yielding condition under the observation of a ZGA representative. In-situ density testing of Quarry Spalls is not feasible and reliable in-situ density testing of the relatively thin Crushed Surfacing Base Course would be very difficult, in our experience. The following compaction recommendations are provided for structural fill soils placed beyond the "working pad" envelope.

Each lift of fill should be compacted to the minimum levels recommended in the table below based on the maximum laboratory dry density as determined by the ASTM D 1557 Modified Proctor Compaction Test. We recommend that a geotechnical engineer be present during grading so that an adequate number of density tests may be conducted as structural fill placement occurs. In this way, the adequacy of the earthwork may be evaluated as it proceeds.

RECOMMENDED SOIL COMPACTION LEVELS	
Location	**Minimum Percent Compaction***
Stripped native subgrade soils, prior to fill placement (upper 12 inches)	95
Upper 1 feet of fill below pavements	95
Pavement fill below 1 foot	92
Upper 1 foot of utility trench backfill	95
Utility trenches below two feet	92
Landscape Areas	90
* *ASTM D 1557 Modified Proctor Maximum Dry Density*	

Temporary and Permanent Slopes

Temporary excavation slope stability is a function of many factors, including:

- The presence and abundance of groundwater;
- The type and density of the various soil strata;
- The depth of cut;
- Surcharge loadings adjacent to the excavation; and
- The length of time the excavation remains open.

As the cut is deepened, or as the length of time an excavation is open, the likelihood of bank failure increases; therefore, maintenance of safe slopes and worker safety should remain the responsibility of the contractor,

who is present at the site, able to observe changes in the soil conditions, and monitor the performance of the excavation.

It is exceedingly difficult under the variable circumstances to pre-establish a safe and "maintenance-free" temporary cut slope angle. Therefore, it should be the responsibility of the contractor to maintain safe temporary slope configurations since the contractor is continuously at the job site, able to observe the nature and condition of the cut slopes, and able to monitor the subsurface materials and groundwater conditions encountered. Unsupported vertical slopes or cuts deeper than 4 feet are not recommended if worker access is necessary. The cuts should be adequately sloped, shored, or supported to prevent injury to personnel from local sloughing and spalling. The excavation should conform to applicable Federal, State, and Local regulations.

According to Chapter 296-155 of the Washington Administrative Code (WAC), the contractor should make a determination of excavation side slopes based on classification of soils encountered at the time of excavation. Temporary cuts may need to be constructed at flatter angles based upon changes in soil moisture and groundwater conditions during construction. Adjustments to the slope angles should be determined by the contractor at that time.

We recommend that all permanent cut or fill slopes constructed in native soils or with imported structural fill be designed at a 2H: 1V (Horizontal: Vertical) inclination or flatter. All permanent cut and fill slopes should be adequately protected from erosion both temporarily and permanently. If the slopes are exposed to prolonged rainfall before vegetation becomes established, the surficial soils will be prone to erosion and possible shallow sloughing. We recommend covering permanent slopes with a rolled erosion protection material, such as Jute matting or Curlex II, if vegetation has not been established by the regional wet season (typically November through May).

Temporary Shoring

Given the very loose to medium dense nature of the site soils, the presence of existing fill within anticipated excavation depths, and impacts of groundwater seepage, we anticipate that temporary shoring may be considered to limit the extent of the excavation, particularly if the culverts are installed in sections in order to maintain trail traffic during construction. We typically recommend that temporary shoring systems be used where excavations will be located adjacent to property lines, roadways, or utilities, and might result in ground loss and damage to these facilities. A trench box is one type of support system which might be used. The zone between the trench box and the excavation face should be backfilled as necessary to limit ground movements. As an alternate, braced or unbraced shoring of various types could be considered.

The lateral soil pressures acting on temporary excavation support systems will depend on the ground surface configuration adjacent to the excavation, and the amount of lateral movement which can occur as the excavation is made. For support systems that are free to yield at the top at least one-thousandth

of the height of the excavation, soil pressures will be less than if movements are limited by such factors as wall stiffness or bracing.

We recommend that yielding shoring systems be designed using equivalent fluid densities of 35 and 85 pounds per cubic foot (pcf) for horizontal ground surfaces and ground surfaces inclined at 1.5H: 1V above the horizontal, respectively. For non-yielding systems, we recommend that the shoring be designed for a uniform lateral pressure of 25H in pounds per square foot (psf), where H is the depth of the planned excavation in feet below a level ground surface. Similarly, for a ground surface inclined at 1.5H: 1V, we recommend that non-yielding shoring be designed for a uniform lateral pressure of 55H.

The above recommended lateral soil pressures are based on a drained condition and do not include the effects of hydrostatic water pressures. In addition, the above values do not include the effects of surcharges (e.g., equipment loads, storage loads, traffic loads, or other surface loading). Hydrostatic water pressures and surcharge effects should be considered as appropriate.

Culvert Foundations

Based on our subsurface exploration program and geotechnical evaluation, we conclude that the upstream and downstream closed bottom concrete box culverts are feasible from a geotechnical perspective utilizing shallow foundation support provided the culvert subgrade conditions are prepared as recommended below.

Boring B-1 indicates that about 3½ feet of medium stiff to very loose silt and silty sand alluvium is present below the design culvert bottom elevation of 17.6 feet. Boring B-2 indicates that about 4½ feet of very loose silty sand alluvium is present below the design culvert bottom elevation of 17.6 feet. Groundwater was encountered at the downstream and upstream culvert locations at elevations of approximately 16.4 and 17.3 feet at the time of exploration, respectively. In our opinion, these medium stiff to very loose, wet to saturated soils will not provide a stable working surface during construction and could result in unacceptable levels of post construction settlement. We recommend that these soils be removed and that the culverts be supported on a zone of select structural fill placed on the underlying medium dense alluvium at the downstream culvert location and hard silt at the upstream culvert to provide a stable "working pad" for construction activities and limit post construction settlements. The excavation to remove and replace the 3½ to 4½ foot thick zone of unsuitable alluvial soils and create the "working pad" should extend out laterally from the edge of the culvert a distance equal to the excavation depth below the bottom of the culvert.

We recommend that the "working pad" consist of Quarry Spalls conforming to WSDOT Standard Specification Section 9-13.9. We recommend that the Quarry Spalls be completely enveloped in a geotextile meeting the requirements for Soil Stabilization as presented in Table 3 of WSDOT Standard Specification Section 9-33.2(1). The Quarry Spalls should extend down to medium dense alluvial sand

deposits encountered near elevation 14.4 in boring B-1 completed near the downstream culvert and down to hard silt deposits encountered near elevation 13.3 in boring B-2 completed near the upstream culvert.

Adequate fine grading of Quarry Spalls for precast foundations can be very difficult due to the coarse, angular nature of the material. A 4-inch thick layer of Crushed Surfacing Base Course conforming to WSDOT Standard Specification Section 9-03.9(3) may be placed above the geotextile enveloped layer of Quarry Spalls for fine grading considerations, provided that the Crushed Surfacing Base Course is above wet excavation conditions.

The Quarry Spalls and Crushed Surfacing Base Course should be compacted to a firm and non-yielding condition. In-situ density testing of Quarry Spalls is not feasible and reliable in-situ density testing of the relatively thin Crushed Surfacing Base Course would be very difficult, in our experience. We recommend that the excavation subgrade conditions, placement of the geotextile, and compaction of the "working pad" structural fill materials be monitored by a representative from ZGA.

Closed bottom concrete box culverts supported on new structural fill "working pads" placed and compacted in accordance with this report may be designed for a maximum allowable, net, bearing capacity of 2,000 psf. This allowable bearing pressure includes a 3.0 factor of safety.

Assuming the culvert foundation subgrade soils are prepared in accordance with recommendations presented herein, we estimate that static total and differential settlements will be less than 1 inch and ½ inch over a distance of about 30 feet, respectively. We anticipate that post construction static settlements would occur rapidly as loads are applied. Potential seismic settlements are discusses in the *Seismic Considerations* section of this report.

Temporary Construction Dewatering

Groundwater was encountered in borings B-1 (downstream culvert) and B-2 (upstream culvert) at approximately elevations 16.4 feet and 17.3 feet at the time of exploration, respectively. Based on the stratigraphy and groundwater conditions observed at the exploration locations, we anticipate that excavations to construct the structural fill "working pad" below the culverts will encounter groundwater seepage, and groundwater conditions may extend below the planned bottom of culvert elevation depending on groundwater levels at the time of construction.

The recommended Quarry Spall "working pad" was developed so that the excavation and placement of Quarry Spalls could be completed in the wet. However, as Quarry Spalls are placed, groundwater elevations in the excavation could rise substantially due to the volume of water displaced by the Quarry Spalls. In addition, the Crushed Surfacing Base Course levelling material cannot be adequately compacted in the wet. We therefore anticipate that some level of dewatering may be required, depending on

groundwater levels at the time of construction, the rate of Quarry Spall placement, and the size of the open excavation.

The contractor should be responsible for maintaining stable side slopes during excavation and backfilling. For excavation below groundwater level, side slopes flatter than 2H: 1V may be required, as determined by the contractor based on exposed soil and water conditions.

Possible dewatering measures include the use of sheet piles or other means to cut off flow from the river channel, ditches and sumps within the excavations and wells or well points outside of excavations. In our opinion, the contractor should be responsible for designing and installing appropriate dewatering systems to complete the work. The dewatering plan should include provisions for disposal of the collected water. We recommend that the contractor be required to submit the proposed dewatering plan to the engineer for review prior to start of construction. The specifications should require that the contractor provide sufficient dewatering to allow for (a) excavation to required depth without disturbing bearing soils and (b) placement and compaction of quarry spalls and crushed surfacing to a firm and non-yielding condition (c) avoid destabilizing the excavation side slopes.

We anticipate that river flows may have an impact on the amount of groundwater seepage encountered in culvert foundation excavation. We therefore recommend that the culvert portions of this project be completed during a period of low river stage, if possible. We understand that the US Army Corps of Engineers artificially controls the level of Lake Washington and that seasonal low lake levels are typically maintained during December through mid-February. We also recommend that the size of the culvert "working pad" excavation be limited to lengths that can be completed and backfilled in one day.

Foundation Embedment and Scour Considerations

Foundation design should include provisions for scour protection. For prefabricated box culverts, scour protection, when required at the end of the culverts, is often provided by establishing bottom of foundation elevations below anticipated scour depths, providing an adequate foundation setback from the river, providing "hard" or "soft" armoring at culvert inlet and outlet, or a combination of these methods. We recommend that provisions for scour protection be included in the project final design, as appropriate.

Seismic Considerations

We understand that the upstream and downstream trail crossings will be designed and permitted as culverts and that International Building Code (IBC) seismic design parameters and liquefaction analyses typically required for buildings and bridges are not required for this project and were not included in our scope of services. However, we completed a general review of the foundation support conditions for the culverts in order to provide a qualitative opinion regarding the potential for liquefaction and seismic settlement of the culverts considering a typical IBC seismic event in this area.

Based on our assessment, it is our opinion that the potential for liquefaction and significant seismic settlement of the upstream culvert is low since the culvert will be supported on a zone of compacted structural fill placed above hard, glacially consolidated silt deposits.

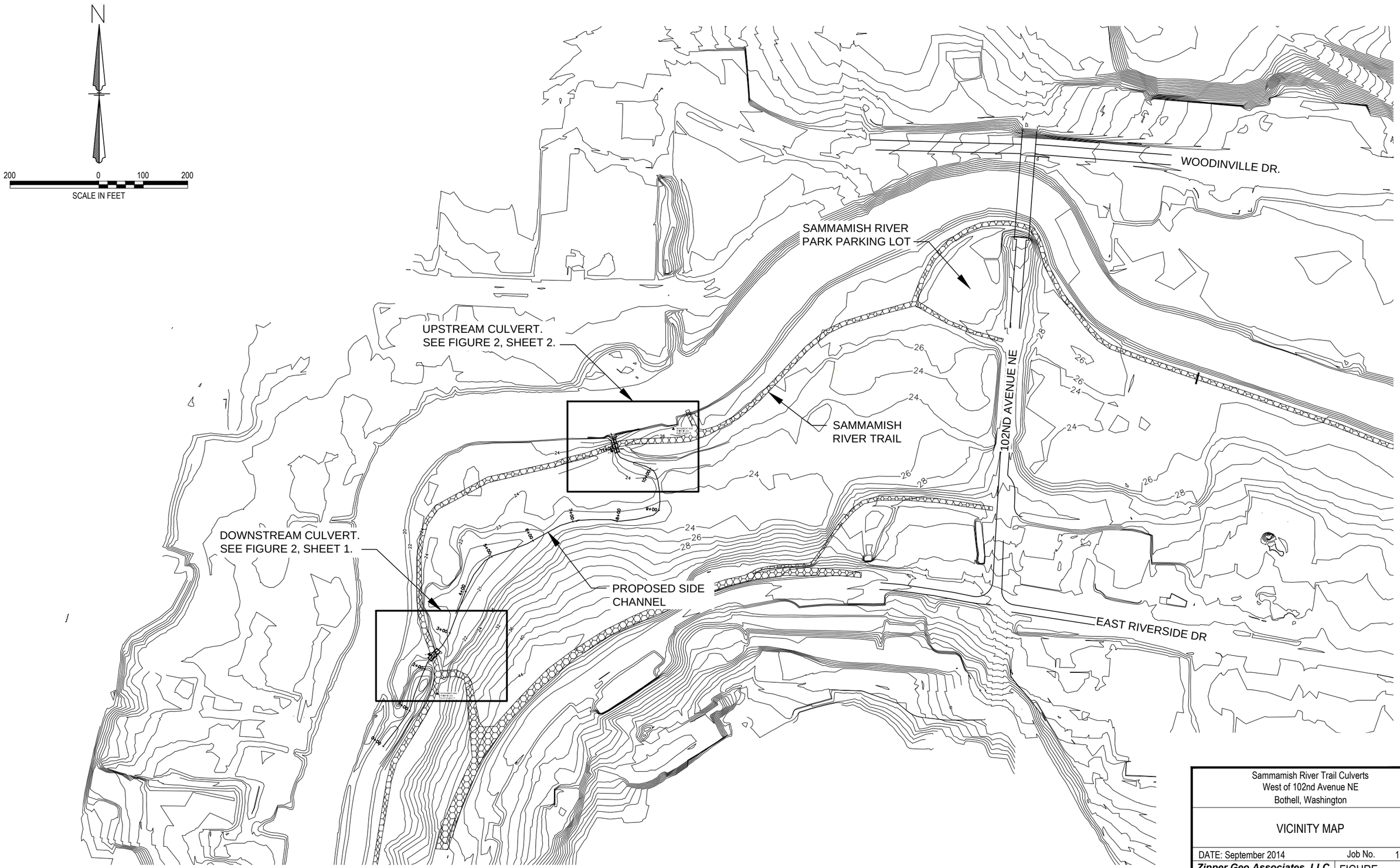
The downstream culvert location includes thicker deposits of alluvium than the upstream culvert and the proposed zone of structural fill will be underlain by about 11 feet of medium dense, saturated sand. This medium dense sand deposit will provide adequate support for the culvert under static loading conditions as outlined in the Foundation section of this report. However, it is our opinion that this medium dense sand deposit would have a moderate to high potential for liquefaction and seismic settlement during a typical IBC seismic design event. We anticipate that the adjacent sections of trail and floodplain would have a similar risk of liquefaction and seismic settlement, and that the differential settlement between the culvert and adjacent trail approaches would therefore be significantly lower than the total settlement.

CLOSURE

The analysis and recommendations presented in this report are based, in part, on the explorations completed for this study. The number, location, and depth of the explorations were completed within the constraints of budget and site access so as to yield the information to formulate our recommendations. Project plans were in the preliminary stage at the time this report was prepared. We therefore recommend Zipper Geo Associates, LLC be provided an opportunity to review the final plans and specifications when they become available in order to assess that the recommendations and design considerations presented in this report have been properly interpreted and implemented into the project design.

The performance of earthwork, structural fill, and foundations depend greatly on proper site preparation and construction procedures. We recommend that Zipper Geo Associates, LLC be retained to provide geotechnical engineering services during the earthwork and foundation construction phases of the project. If variations in subsurface conditions are observed at that time, a qualified geotechnical engineer could provide additional geotechnical recommendations to the contractor and design team in a timely manner as the project construction progresses.

This report has been prepared for the exclusive use of R2 Resource Consultants, and its agents, for specific application to the project discussed and has been prepared in accordance with generally accepted geotechnical engineering practices. No warranties, express or implied, are intended or made. Site safety, excavation support, and dewatering requirements are the responsibility of others. In the event that changes in the nature, design, or location of the project as outlined in this report are planned, the conclusions and recommendations contained in this report shall not be considered valid unless Zipper Geo Associates, LLC reviews the changes and either verifies or modifies the conclusions of this report in writing.



REFERENCE: UNDATED PRELIMINARY TOPOGRAPHIC BASE MAP PROVIDED BY R2 RESOURCE CONSULTANTS, INC. VERTICAL DATUM NAVD88.

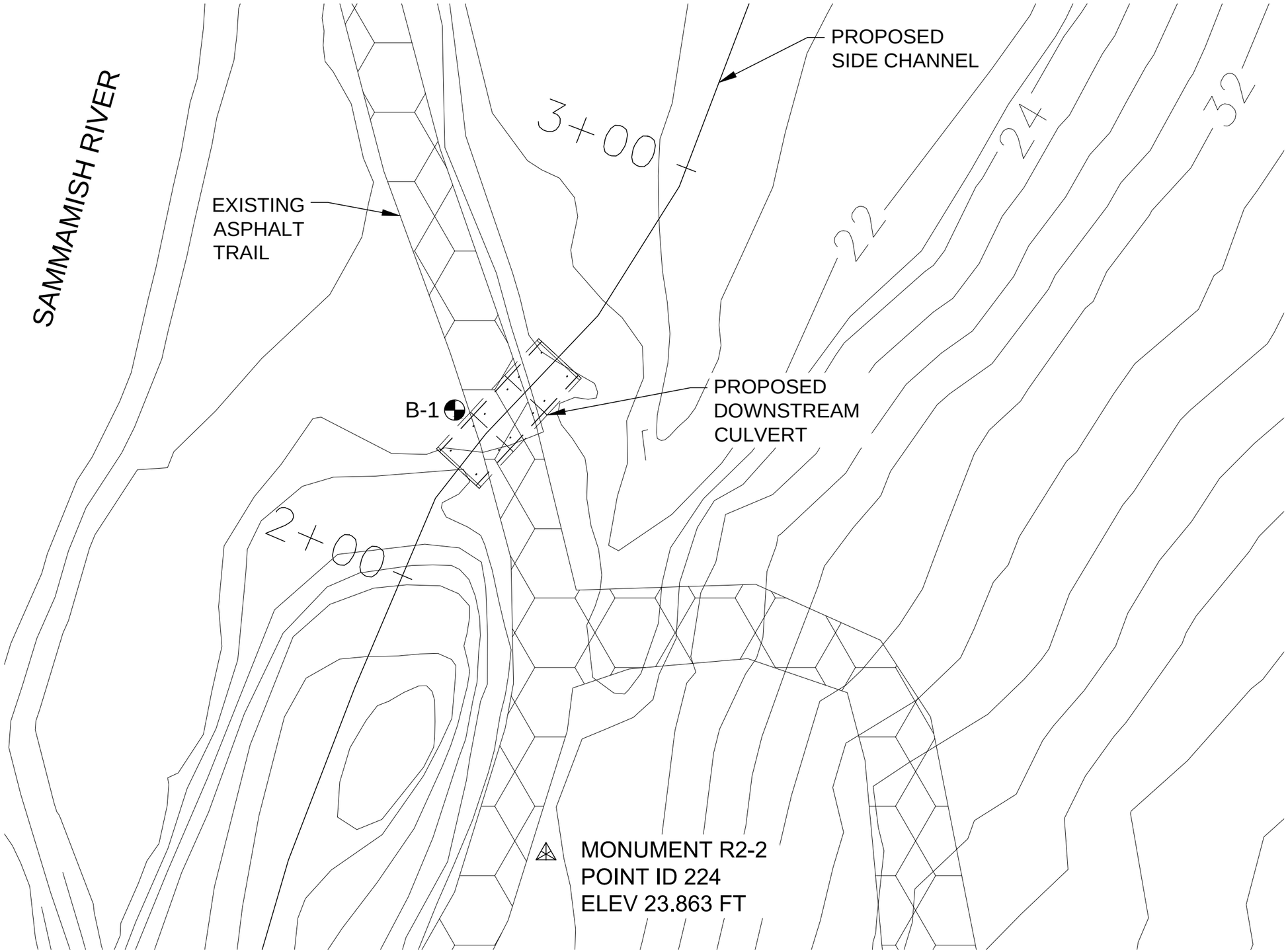
Sammamish River Trail Culverts
West of 102nd Avenue NE
Bothell, Washington

VICINITY MAP

DATE: September 2014 | Job No. 1313.01

Zipper Geo Associates, LLC
19023 36th Ave. W.,Suite D
Lynnwood, WA

FIGURE 1
SHT.1 of 1



LEGEND

B-1 BORING NUMBER AND APPROXIMATE LOCATION. COMPLETED BY ZIPPER GEO ASSOCIATES IN AUGUST 2014.

N

20 0 10 20

SCALE IN FEET

REFERENCE: UNDATED PRELIMINARY TOPOGRAPHIC BASE MAP PROVIDED BY R2 RESOURCE CONSULTANTS, INC. VERTICAL DATUM NAVD88.

Sammamish River Trail Culverts
West of 102nd Avenue NE
Bothell, Washington

SITE AND EXPLORATION PLAN
DOWNSTREAM CULVERT

DATE: September 2014 | Job No. 1313.01

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Lynnwood, WA

FIGURE 2

SHT. 1 of 3

LEGEND

B-1 BORING NUMBER AND APPROXIMATE LOCATION. COMPLETED BY ZIPPER GEO ASSOCIATES IN AUGUST 2014.

SAMMAMISH RIVER

MONUMENT R2-2
POINT ID 223
ELEV 25.563 FT

26

11+00

B-2

PROPOSED
UPSTREAM
CULVERT

EXISTING
ASPHALT
TRAIL

10+00

24

PROPOSED
SIDE CHANNEL

N

20 0 10 20
SCALE IN FEET

REFERENCE: UNDATED PRELIMINARY TOPOGRAPHIC BASE MAP PROVIDED BY R2 RESOURCE CONSULTANTS, INC. VERTICAL DATUM NAVD88.

Sammamish River Trail Culverts
West of 102nd Avenue NE
Bothell, Washington

SITE AND EXPLORATION PLAN
UPSTREAM CULVERT

DATE: September 2014 | Job No. 1313.01

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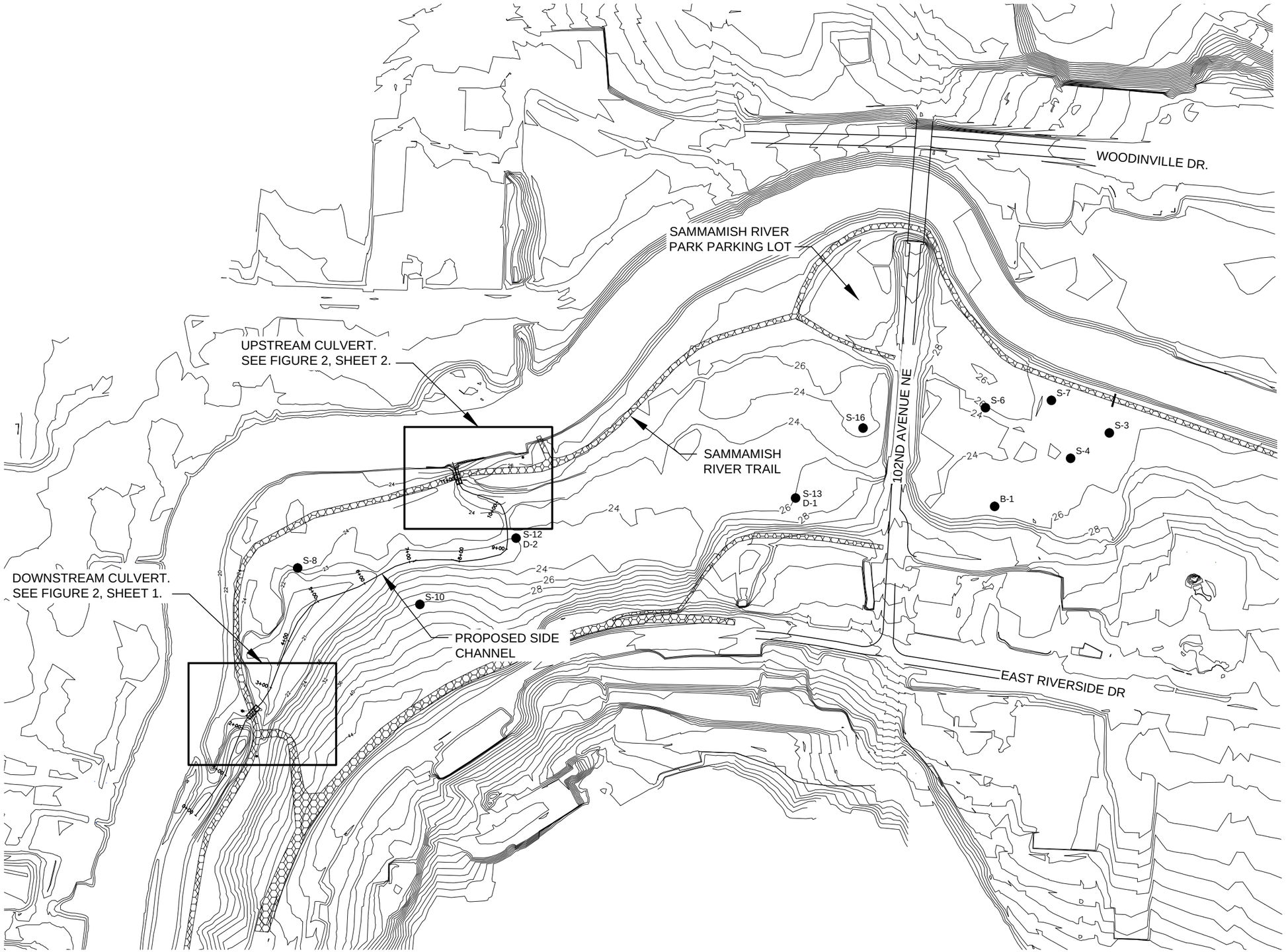
Lynnwood, WA

FIGURE 2
SHT.2 of 3



LEGEND

● B-1 BORING NUMBER AND APPROXIMATE LOCATION. COMPLETED BY PACIFIC GROUNDWATER GROUP IN JULY AND AUGUST 2012.

N

200 0 100 200

SCALE IN FEET

Sammamish River Trail Culverts
West of 102nd Avenue NE
Bothell, Washington

SITE AND EXPLORATION PLAN
EXPLORATIONS COMPLETED BY OTHES

DATE: September 2014 | Job No. 1313.01

Zipper Geo Associates, LLC
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Lynnwood, WA

FIGURE 2
SHT.3 of 3

REFERENCE: UNDATED PRELIMINARY TOPOGRAPHIC BASE MAP PROVIDED BY R2 RESOURCE CONSULTANTS, INC. VERTICAL DATUM NAVD88.

APPENDIX A

SUBSURFACE EXPLORATION PROCEDURES AND LOGS

APPENDIX A
SUBSURFACE EXPLORATION PROCEDURES AND LOGS

Field Exploration Description

Our field exploration for this project included two borings completed on August 6, 2014. The approximate exploration locations are shown on the enclosed *Site and Exploration Plan, Figure 2, Sheets 1 and 2*. The exploration locations were determined by measuring distances from two existing brass monuments and existing site features with a fiberglass tape relative to an undated preliminary topographic site plan provided by R2 Resource Consultants, Inc. Ground surface elevations at the exploration locations were interpolated from the topographic contour and spot elevation data presented on the preliminary site plan. As such, the exploration locations and elevations should be considered accurate only to the degree implied by the means and methods used to define them.

The borings were advanced using a limited access track-mounted drill rig operated by an independent drilling company (Boretec1, Inc.) working under subcontract to ZGA. The borings were advanced using hollow stem auger drilling methods. An engineering geologist from our firm continuously observed the borings, logged the subsurface conditions encountered, and obtained representative soil samples. All samples were stored in moisture-tight containers and transported to our laboratory for further evaluation and testing. Samples were obtained by means of the Standard Penetration Test and thin wall Shelby tube sampler at 2.5- to 5-foot intervals throughout the drilling operation.

The Standard Penetration Test (ASTM D 1586) procedure consists of driving a standard 2-inch outside diameter steel split spoon sampler 18 inches into the soil with a 140-pound hammer free falling 30 inches. The number of blows required to drive the sampler through each 6-inch interval is recorded, and the total number of blows struck during the final 12 inches is recorded as the Standard Penetration Resistance, or "blow count" (N value). If a total of 50 blows are struck within any 6-inch interval, the driving is stopped and the blow count is recorded as 50 blows for the actual penetration distance. The resulting Standard Penetration Resistance values indicate the relative density of granular soils and the relative consistency of cohesive soils.

The Shelby tube sampler (ASTM: D-1587) was used to collect relatively undisturbed soil samples for laboratory testing and consists of a 2.5 foot long, 3-inch outside diameter, thin wall steel tube. The tube is hydraulically pushed into and extracted from the soil, consequently no blow counts are recorded.

The enclosed boring logs describes the vertical sequence of soils and materials encountered in the borings, based primarily upon our field classifications. Where a soil contact was observed to be gradational, our logs indicate the average contact depth. Where a soil type changed between sample intervals, we inferred the contact depth. Our logs also graphically indicates the blow count, sample type, sample number, and approximate depth of each soil sample obtained from the borings. If groundwater was encountered, the approximate groundwater depth, and date of observation, are depicted on the logs.

Boring Location:	See Figure 1, Site and Exploration Plan	Drilling Company:	Boretec 1	Bore Hole Dia.:	6"	**B-1**
Top Elevation:	23.9 Feet	Drilling Method:	Hollow Stem Auger	Hammer Type:	Cat Head	
Date Drilled:	8/6/2014	Drill Rig:	Track	Logged by:	JPG	

Depth (ft)	SOIL DESCRIPTION	Sample Number	SAMPLES Recovery (inches)	Ground Water	PENETRATION RESISTANCE (blows/foot)	Blow Counts	Testing
	The stratification lines represent the approximate boundaries between soil types. The transition may be gradual. Refer to report text and appendices for additional information.				▲ Standard Penetration Test △ Hammer Weight and Drop: _____ 0 20 40 60		
0	2 inches grass sod over loose to medium dense, moist, brown, SAND, some silt, trace gravel (Fill)						
	(Rough, rocky drilling action observed at 2 feet)						
	(S-1 blow count overstated, sampler on rock)	S-1	6"			41	
5		S-2	12"			6	
	Medium stiff, wet, gray SILT, some fine sand, iron oxide staining (Alluvium)						
	Very loose, wet to saturated, gray-brown, silty SAND, trace fine organics with silty SAND interbeds (Alluvium)	S-3	14"	ATD		4	
10	Medium dense, saturated, gray SAND, trace to some silt, trace gravel (Alluvium)	S-4	8"			20	GSA
		S-5	16"			11	
15		S-6	16"			16	
		S-7	16"			22	
20	Hard, saturated, gray SILT, some clay, trace fine sand (Transitional Beds)	S-8	12			50/5"	
	Boring completed at approximately 21.5 feet on 8/6/14. Groundwater observed at approximately 7.5 feet at time of drilling.						
25							

SAMPLE LEGEND

- 2-inch O.D. split spoon sample
- 3-inch I.D. Shelby tube sample

GROUNDWATER LEGEND

- Clean Sand
- Bentonite
- Grout/Concrete
- Screened Casing
- Blank Casing
- ▼ Groundwater level at time of drilling (ATD) or on date of measurement. 11/2/12

◇ % Fines (<0.075 mm)

○ % Water (Moisture) Content

Plastic Limit ├──○──┤ Liquid Limit

Natural Water Content

TESTING KEY

GSA = Grain Size Analysis

200W = 200 Wash Analysis

Consol. = Consolidation Test

Att. = Atterberg Limits

Sammamish River Trail Culverts
West of 102nd Avenue NE
Bothell, WA

Date: 8/6/2014 Project No.: 1313.01

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Lynnwood, WA

BORING LOG: B-1

Boring Location:	See Figure 1, Site and Exploration Plan	Drilling Company:	Boretec 1	Bore Hole Dia.:	6"	**B-2**
Top Elevation:	24.3 Feet	Drilling Method:	Hollow Stem Auger	Hammer Type:	Cat Head	
Date Drilled:	8/6/2014	Drill Rig:	Track	Logged by:	JPG	

Depth (ft)	SOIL DESCRIPTION	Sample Number	SAMPLES Recovery (inches)	Ground Water	PENETRATION RESISTANCE (blows/foot)	Blow Counts	Testing
	The stratification lines represent the approximate boundaries between soil types. The transition may be gradual. Refer to report text and appendices for additional information.				▲ Standard Penetration Test △ Hammer Weight and Drop: _____ 0 20 40 60		
0	2 inches grass sod over loose to medium dense, moist, brown SAND, some silt, trace to some gravel (Fill)						
	Loose, moist, gray-brown, finely bedded SAND, some silt, trace fine gravel, slight iron oxide staining (Alluvium)	S-1	16"			7	
5	Very loose, wet, gray-brown, silty SAND, some gravel, trace fine organics (Alluvium)	S-2	6"	ATD		3	
		S-3	6"			2	
10	Hard, moist to wet, gray, SILT, some clay, trace fine sand (Transitional Beds)	S-4	12"			36	GSA
		S-5	12"			50/5"	
15		S-6	6"			50/1"	
		S-7	6"			50/6"	
	Boring completed at approximately 18 feet on 8/6/14. Groundwater observed at approximately 7 feet at time of drilling.						
20							
25							

SAMPLE LEGEND

- 2-inch O.D. split spoon sample
- 3-inch I.D. Shelby tube sample

GROUNDWATER LEGEND

- Clean Sand
- Bentonite
- Grout/Concrete
- Screened Casing
- Blank Casing
- ▼ Groundwater level at time of drilling (ATD) or on date of measurement. 11/2/12

◇ % Fines (<0.075 mm)

○ % Water (Moisture) Content

Plastic Limit ├──○──┤ Liquid Limit

Natural Water Content

TESTING KEY

GSA = Grain Size Analysis

200W = 200 Wash Analysis

Consol. = Consolidation Test

Att. = Atterberg Limits

Sammamish River Trail Culverts
West of 102nd Avenue NE
Bothell, WA

Date: 8/6/2014 Project No.: 1313.01

Zipper Geo Associates
19023 36th Ave. W, Suite D
Lynnwood, WA

BORING LOG: B-2

APPENDIX B

LABORATORY TESTING PROCEDURES AND RESULTS

APPENDIX B
LABORATORY TESTING PROCEDURES AND RESULTS

A series of laboratory tests were performed by ZGA during the course of this study to evaluate the index and geotechnical engineering properties of the subsurface soils. Descriptions of the types of tests performed by ZGA are given below.

Visual Classification

Samples recovered from the exploration locations were visually classified in the field during the exploration program. Representative portions of the samples were carefully packaged in moisture tight containers and transported to our laboratory where the field classifications were verified or modified as required. Visual classification was generally done in accordance with ASTM D 2488. Visual soil classification includes evaluation of color, relative moisture content, soil type based upon grain size, and accessory soil types included in the sample. Soil classifications are presented on the exploration logs in Appendix A.

Moisture Content Determinations

Moisture content determinations were performed on representative samples obtained from the explorations in order to aid in identification and correlation of soil types. The determinations were made in general accordance with the test procedures described in ASTM D 2216. Moisture contents are presented on the exploration logs in Appendix A.

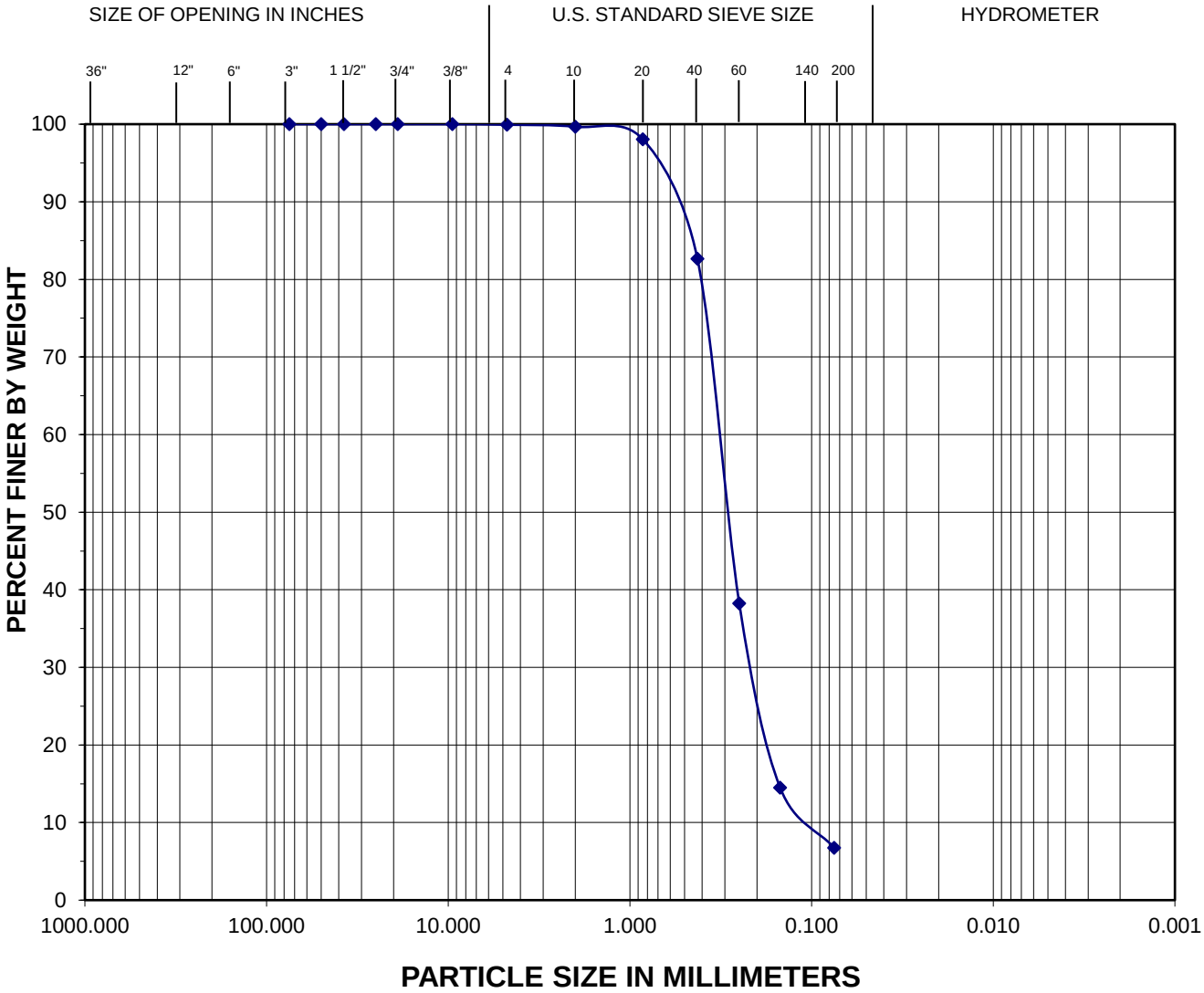
Grain Size Analysis

A grain size analysis indicates the range in diameter of soil particles included in a particular sample. Grain size analyses were performed on representative samples in general accordance with ASTM D 2487. The results of the grain size determinations for the samples were used in classification of the soils, and are presented in this appendix.

GRAIN SIZE ANALYSIS

Test Results Summary

ASTM D 422



		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
BOULDERS	COBBLES	GRAVEL		SAND			FINE GRAINED	

Comments: ASTM D 2487 Classification: SP-SM

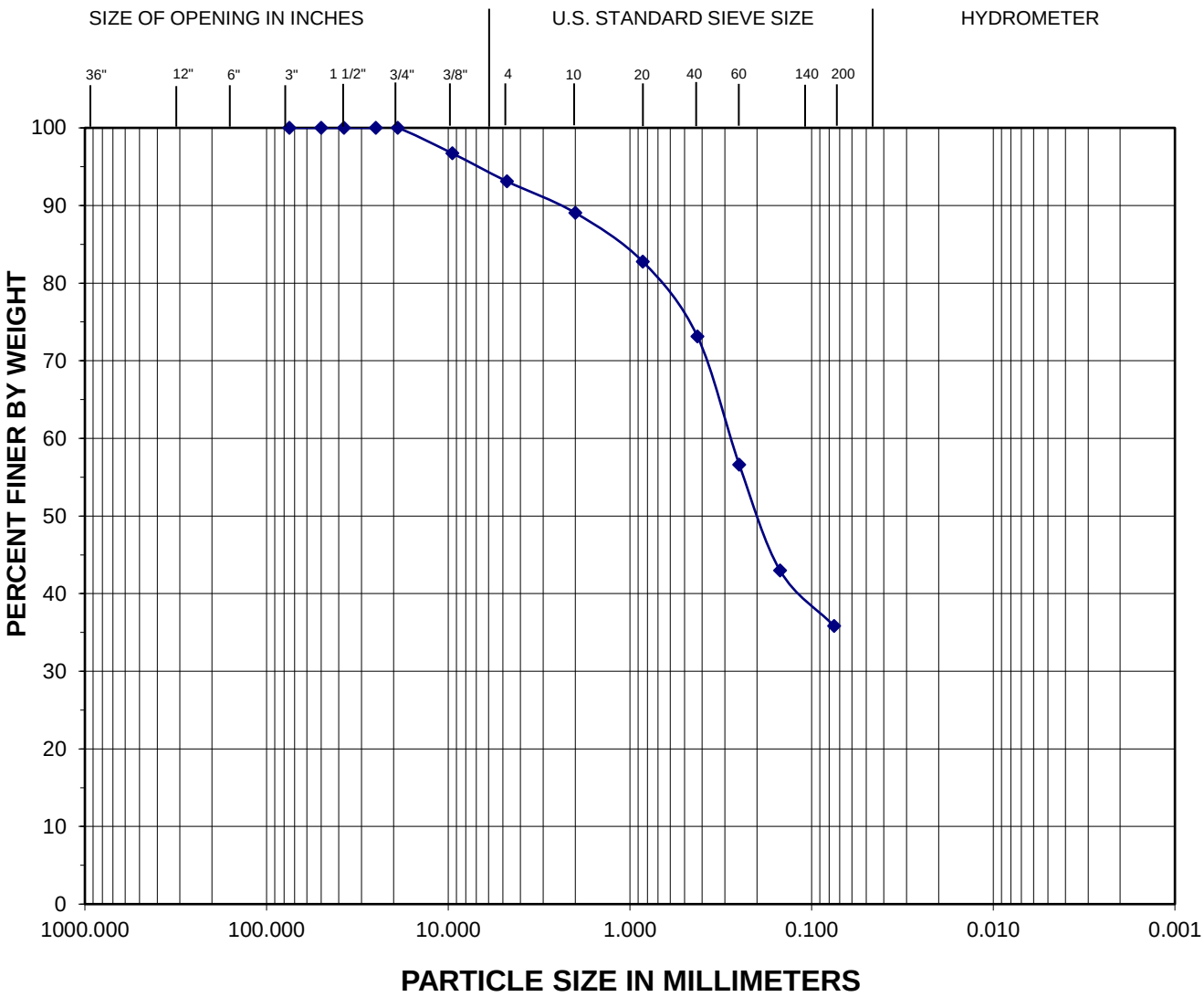
Exploration	Sample	Depth (feet)	Moisture (%)	Fines (%)	Description
B-1	S-4	10 ft.	23.5	6.8	poorly graded SAND some silt

Zipper Geo Associates, LLC Geotechnical and Environmental Consultants	Project No.: 1313.01 DATE OF TESTING: 8/7/2014	PROJECT NAME: Sammamish River Trail Culverts

GRAIN SIZE ANALYSIS

Test Results Summary

ASTM D 422



		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
BOULDERS	COBBLES	GRAVEL		SAND			FINE GRAINED	

Comments: ASTM D 2487 Classification: SM

Exploration	Sample	Depth (feet)	Moisture (%)	Fines (%)	Description
B-2	S-4	10 ft.	20.9	35.8	silty SAND some gravel

Zipper Geo Associates, LLC Geotechnical and Environmental Consultants	Project No.: 1313.01 DATE OF TESTING: 8/7/2014	PROJECT NAME: Sammamish River Trail Culverts

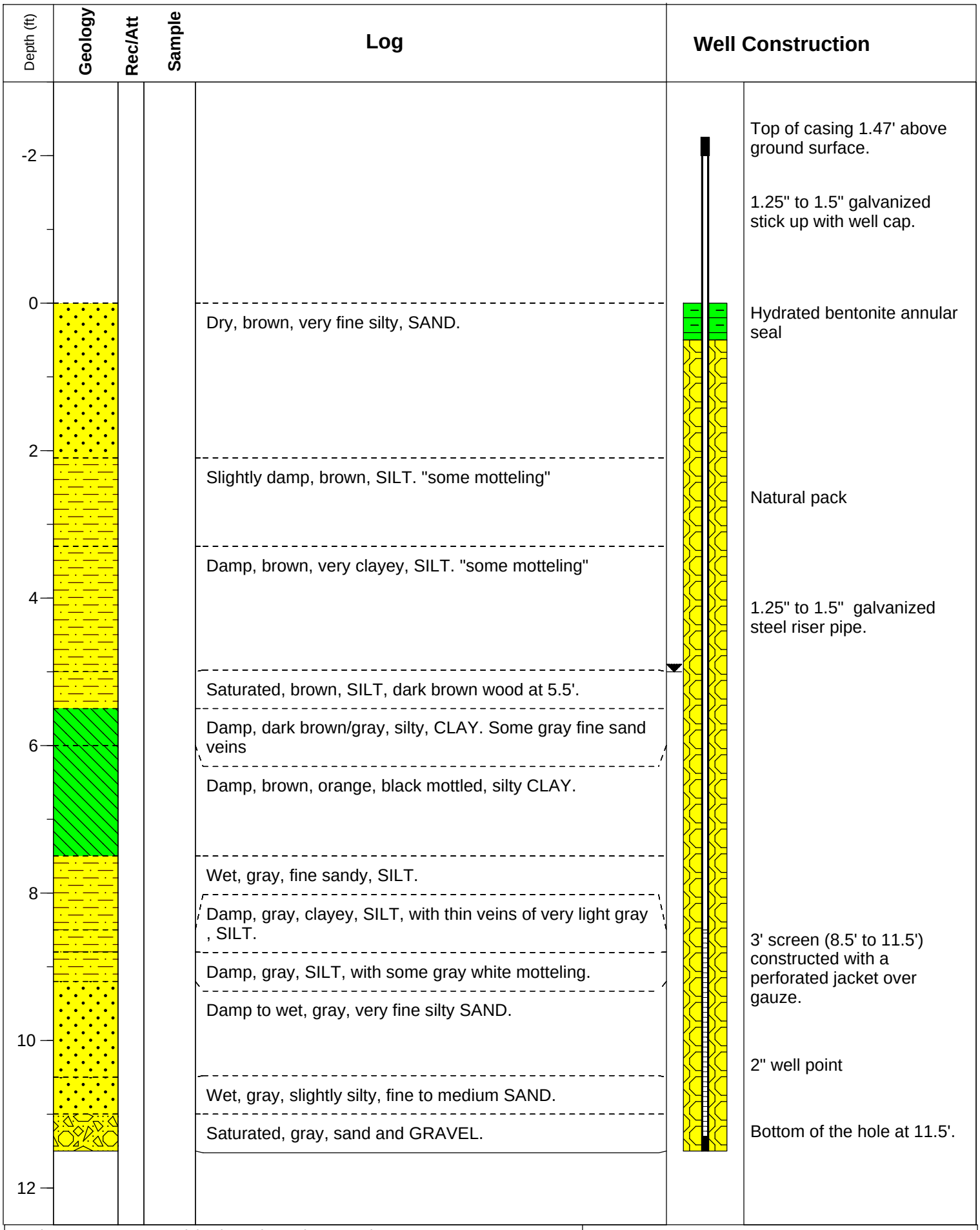
APPENDIX C

SUBSURFACE EXPLORATION LOGS COMPLETED BY OTHERS

APPENDIX C
SUBSURFACE EXPLORATION LOGS COMPLETED BY OTHERS

The following exploration logs were taken from the January 2013 *Draft Hydrogeologic Characterization, Sammamish River Side Channel Restoration, Phase 1 Design* report prepared by Pacific Groundwater Group without alteration. The explorations were reportedly completed in July and August of 2012. The approximate exploration locations are presented on the enclosed *Site and Exploration Plan, Figure 2, Sheet 3.* The approximate exploration locations shown on ZGA Figure 2, Sheet 3 were derived by overlaying Figure 1 contained within the referenced Pacific Groundwater Group report and the topographic base map provided to ZGA by R2 Resource Consultants, and should be considered accurate only to the degree implied by the means and methods used to define them.

- S-3
- S-4
- S-7
- B-1
- S-6
- S-16
- D-1
- S-13
- S-14
- D-2
- S-12
- S-8
- S-10

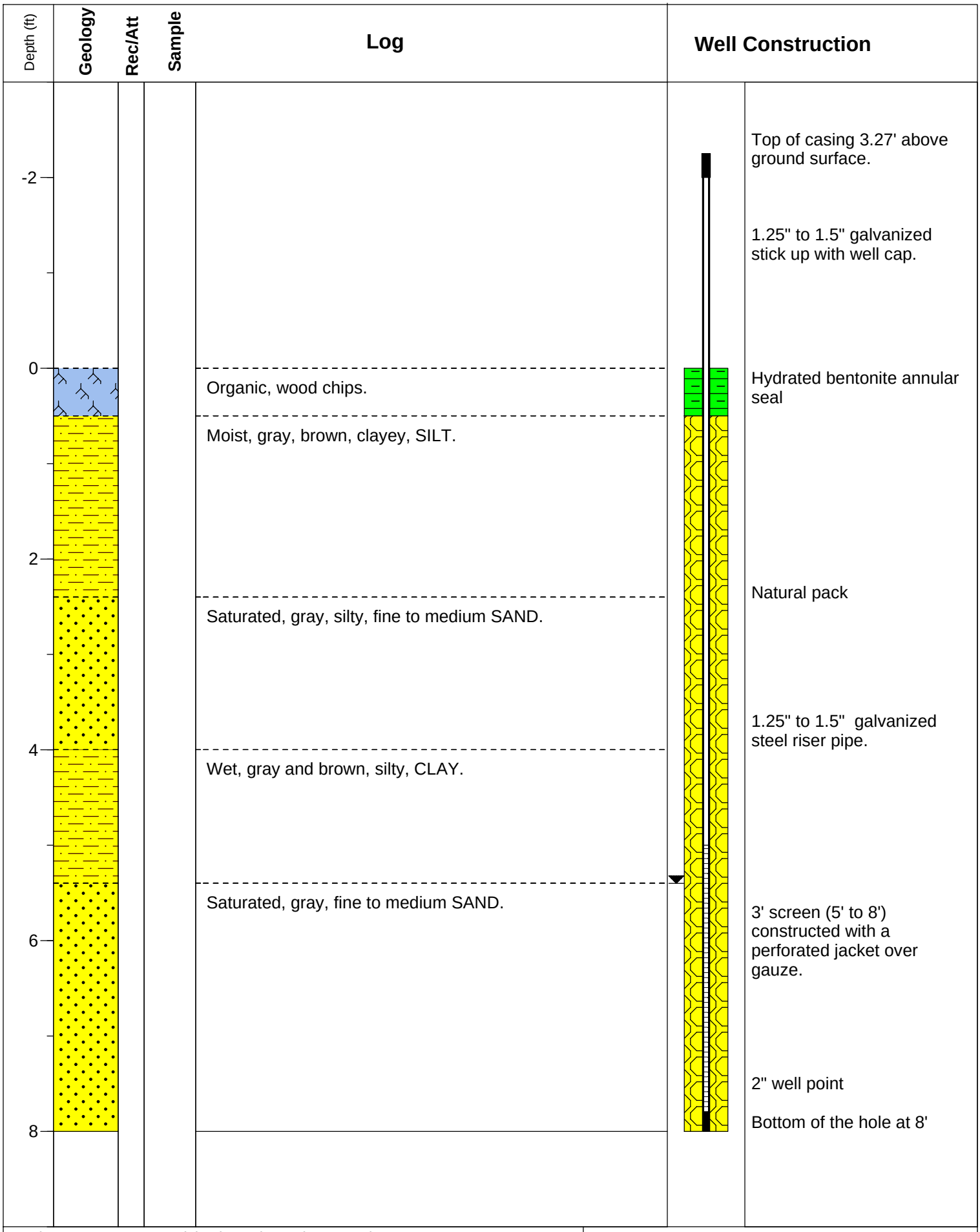


Project Name: Sammamish River Channel Restoration
Drilling Method: Hand Auger
Driller: Judy Oleson/Dawn Chapel
Firm: Pacific Groundwater Group
Consulting Firm: Pacific Groundwater Group
Logged by: Judy Oleson/Dawn Chapel

Borehole Name: S-3
Ecology ID: NA
MP Elevation: 95.6 (local datum)
Drilled: 7/25/2012
DTW: 5.0

FIGURE A-1
GEOLOGIC LOG AND AS-BUILT FOR BOREHOLE S-3
City of Bothell
Bothell, Washington
JS1204 7/25/2012

PgG

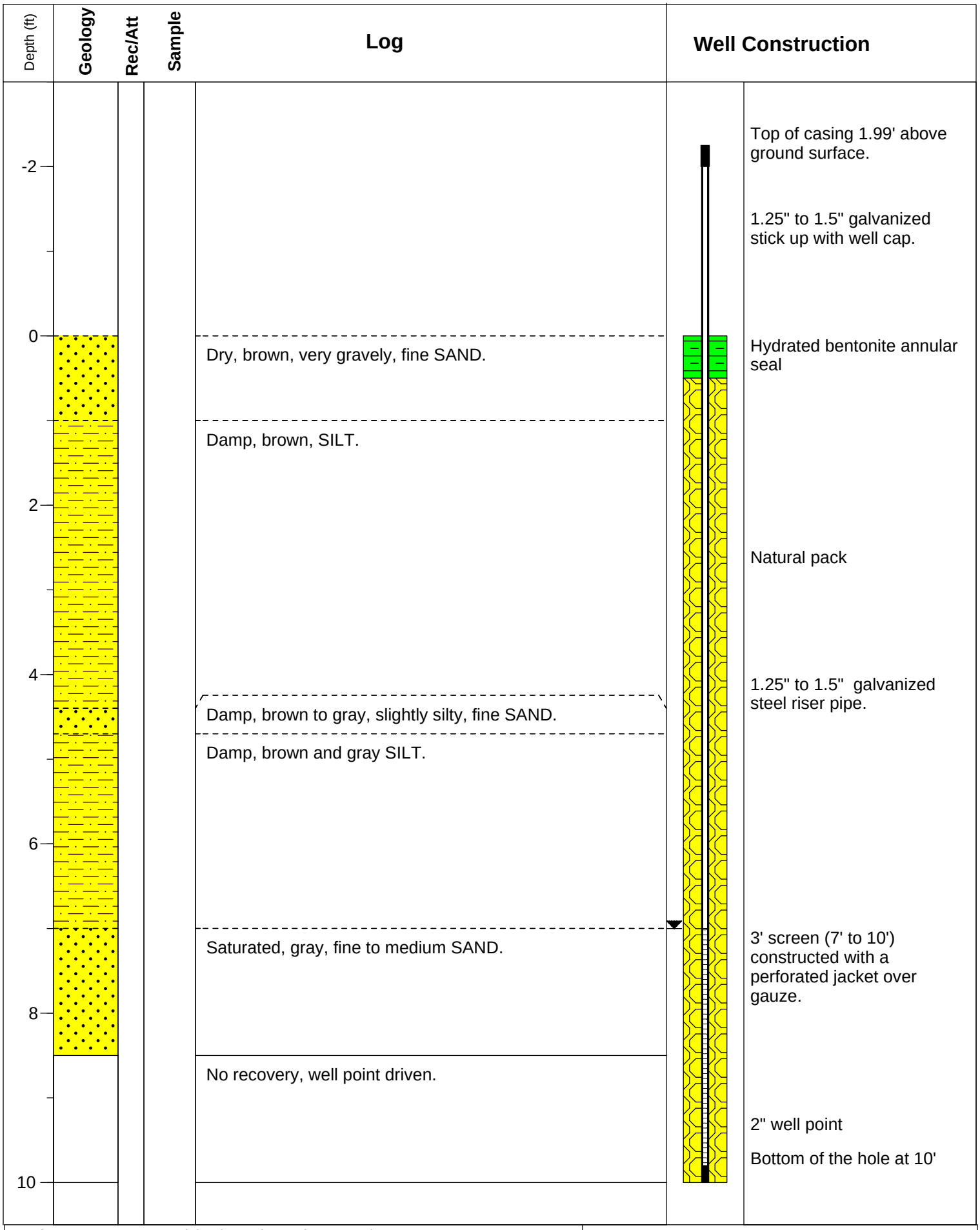


Project Name: Sammamish River Channel Restoration
Drilling Method: Hand Auger
Driller: Judy Oleson/Dawn Chapel
Firm: Pacific Groundwater Group
Consulting Firm: Pacific Groundwater Group
Logged by: Judy Oleson/Dawn Chapel

Borehole Name: S-4
Ecology ID: NA
MP Elevation: 96.42 (local datum)
Drilled: 7/25/2012
DTW: 5.4

FIGURE A-2
GEOLOGIC LOG AND AS-BUILT FOR BOREHOLE S-4
City of Bothell
Bothell, Washington
JS1204 7/25/2012

PgG

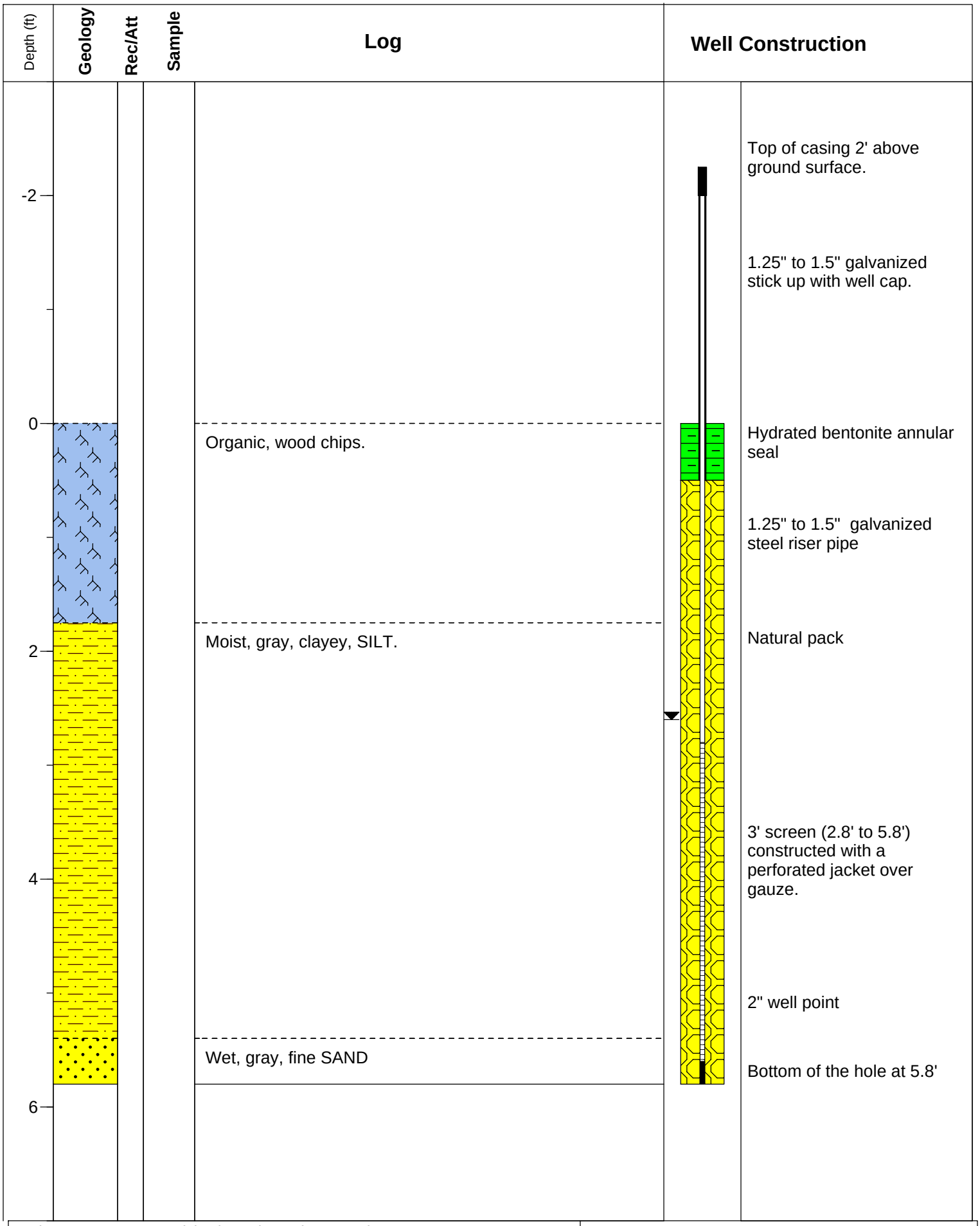


Project Name: Sammamish River Channel Restoration
Drilling Method: Hand Auger
Driller: Judy Oleson/Dawn Chapel
Firm: Pacific Groundwater Group
Consulting Firm: Pacific Groundwater Group
Logged by: Judy Oleson/Dawn Chapel

Borehole Name: S-7
Ecology ID: NA
MP Elevation: 96.03 (local datum)
Drilled: 7/25/2012
DTW: 7.0

FIGURE A-3
GEOLOGIC LOG AND AS-BUILT FOR BOREHOLE S-7
City of Bothell
Bothell, Washington
JS1204 7/25/2012

PgG



Project Name: Sammamish River Channel Restoration
Drilling Method: Hand Auger
Driller: Judy Oleson/Dawn Chapel
Firm: Pacific Groundwater Group
Consulting Firm: Pacific Groundwater Group
Logged by: Judy Oleson/Dawn Chapel

Borehole Name: B-1
Ecology ID: NA
MP Elevation: NA
Drilled: 7/24/2012
DTW: 2.6

FIGURE A-4
GEOLOGIC LOG AND AS-BUILT FOR BOREHOLE B-1
City of Bothell
Bothell, Washington
JS1204 7/24/2012

PgG

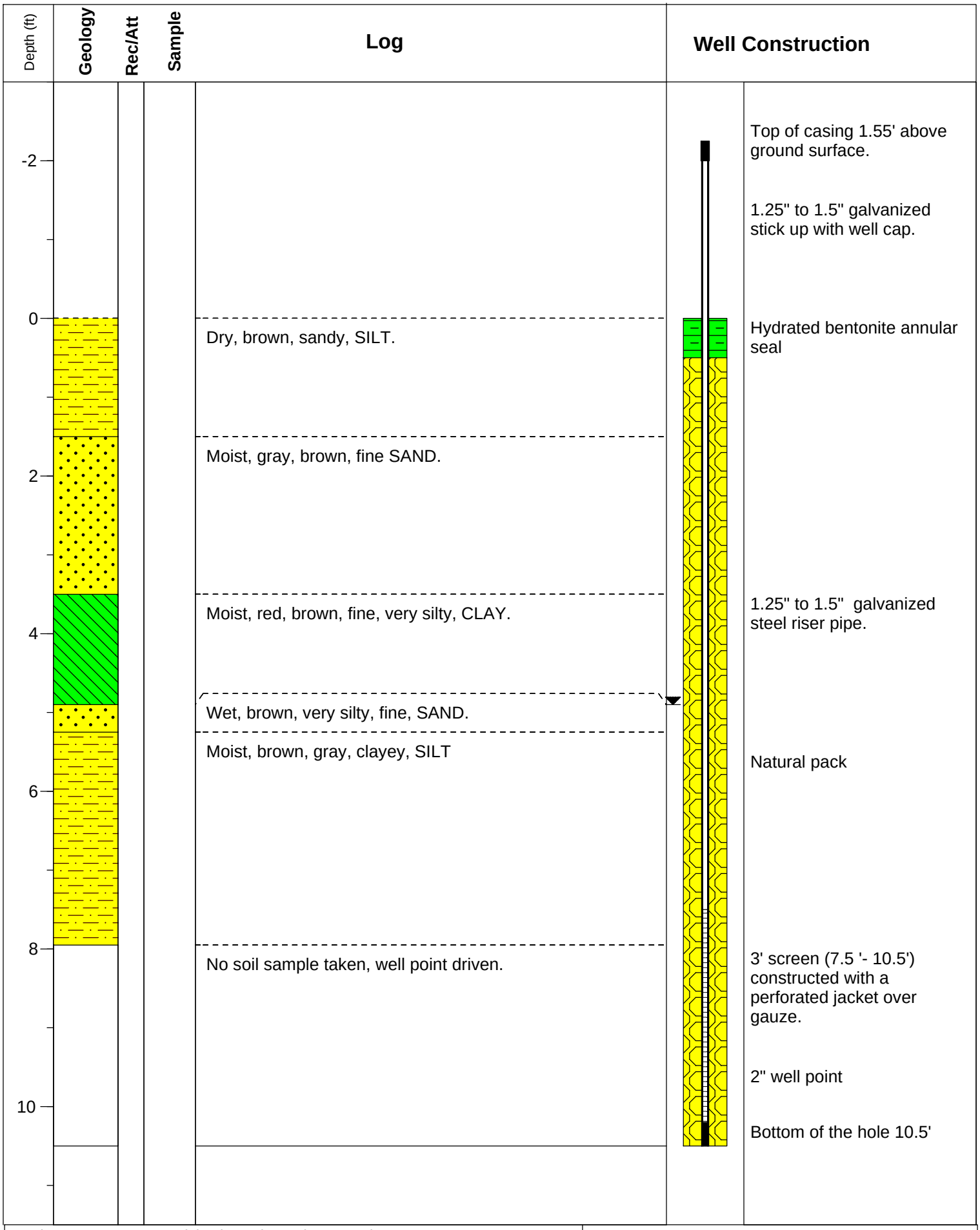
Depth (ft)	Geology	Rec/Att	Sample	Log	Well Construction
-2					Top of casing 1.15' above ground surface.
					1.25" to 1.5" galvanized stick up with well cap.
0				Damp, brown, fine, SILT.	Hydrated bentonite annular seal
				Brown, slightly clayey, SILT. (trace of pebbles)	
				Orange, brown mottled, slightly clayey, SILT. (trace of pebbles)	
2				Gray, brown, slightly clayey, SILT. (trace of motteling)	
				Gray, brown, clayey, SILT. (trace of roots, more damp)	Natural pack
				Brown, gray, slightly silty, fine SAND. (wet zone at 3.1' accompanied with H2S odor)	
4				Wet, clayey, fine SAND.	
				Damp, brown, gray, slightly clayey, fine, SAND.	
				Damp, brown, orange, mottled, SILT.	1.25" to 1.5" galvanized steel riser pipe.
				Brown. silty, fine SAND. (trace of pebbles)	
6					3' screen (6' to 9') constructed with a perforated jacket over gauze.
				Saturated, gray, fine SAND.	
8				No recovery, well point driven.	2" well point
					Bottom of the hole at 9'
10					

Project Name: Sammamish River Channel Restoration
Drilling Method: Hand Auger
Driller: Judy Oleson/Dawn Chapel
Firm: Pacific Groundwater Group
Consulting Firm: Pacific Groundwater Group
Logged by: Judy Oleson/Dawn Chapel

Borehole Name: S-6
Ecology ID: NA
MP Elevation: 93.98 (local datum)
Drilled: 7/25/2012
DTW: 3.8

FIGURE A-5
GEOLOGIC LOG AND AS-BUILT FOR BOREHOLE S-6
City of Bothell
Bothell, Washington
JS1204 7/25/2012

PgG

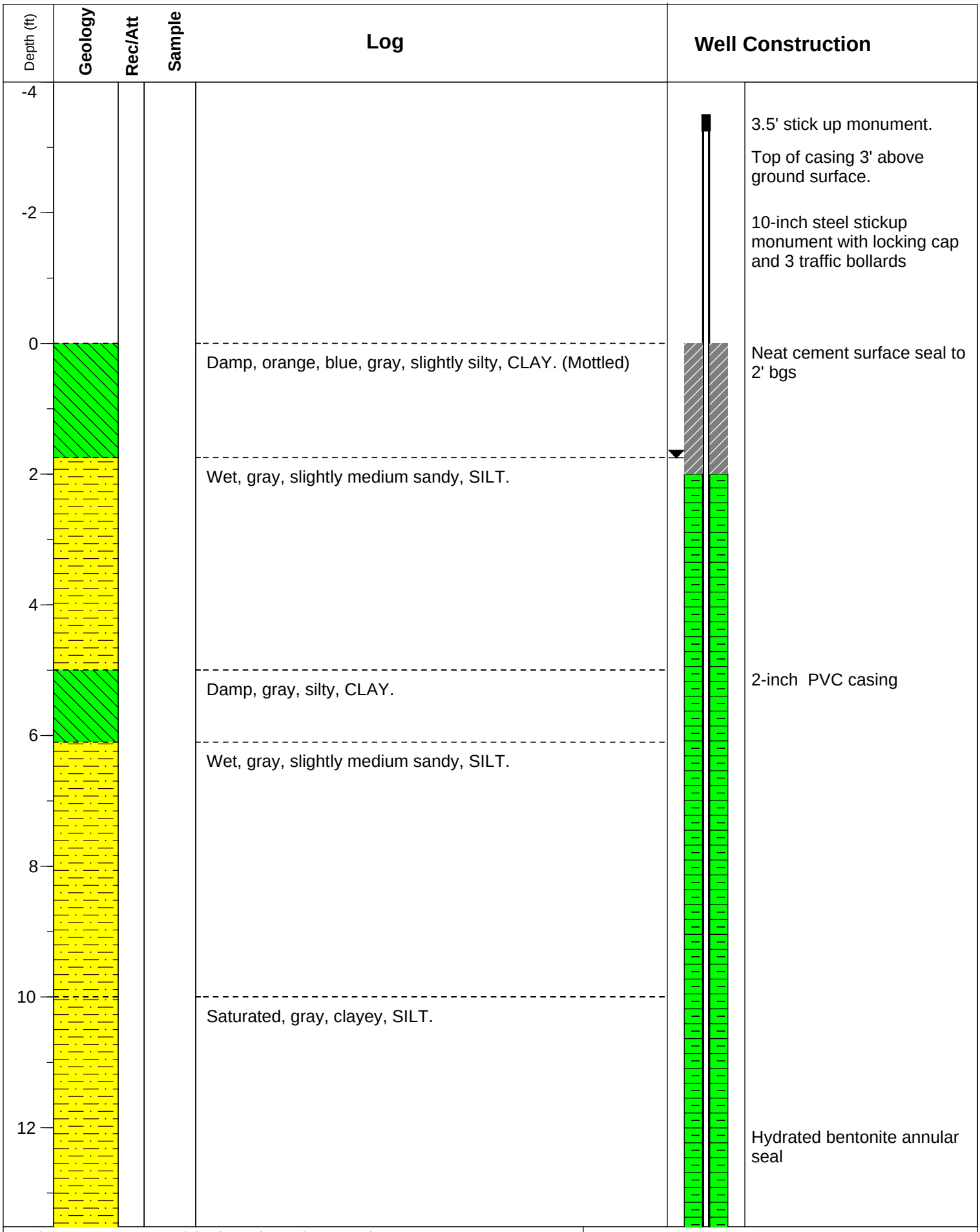


Project Name: Sammamish River Channel Restoration
Drilling Method: Hand Auger
Driller: Judy Oleson/Inger Jackson
Firm: Pacific Groundwater Group
Consulting Firm: Pacific Groundwater Group
Logged by: Judy Oleson/Inger Jackson

Borehole Name: S-16
Ecology ID: NA
MP Elevation: 95.44 (local datum)
Drilled: 7/26/2012
DTW: 4.9

FIGURE A-6
GEOLOGIC LOG AND AS-BUILT FOR BOREHOLE S-16
City of Bothell
Bothell, Washington
JS1204 7/26/2012

PgG



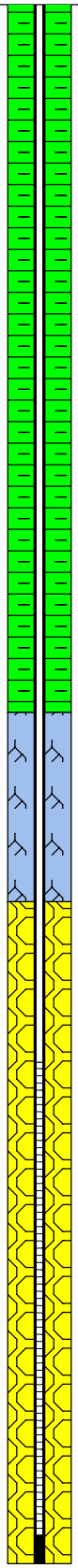
Project Name: Sammamish River Channel Restoration
Drilling Method: GeoProbe
Driller: Elijah Floyd
Firm: Cascade Drilling
Consulting Firm: Pacific Groundwater Group
Logged by: J. Oleson

Borehole Name: D-1
Ecology ID: BHS 198
MP Elevation: 97.69 (local datum)
Drilled: 8/24/2012
DTW: 1.75

FIGURE A-7
GEOLOGIC LOG AND AS-BUILT FOR BOREHOLE D-1
City of Bothell
Bothell, Washington
JS1204 8/24/2012

PgG

Depth (ft)	Geology	Rec/Att	Sample	Log	Well Construction
14				Saturated, gray, silty, fine SAND.	
				Saturated, gray, clayey, SILT.	
16					
18					
					Hydrated bentonite annular seal
20					
22					Native fill material
24					PVC pre pack; 2/12 sand
26					
					2-inch PVC 10-slot screen
28					
					4" tail pipe
30					Bottom of the hole 30'



Project Name: Sammamish River Channel Restoration
Drilling Method: GeoProbe
Driller: Elijah Floyd
Firm: Cascade Drilling
Consulting Firm: Pacific Groundwater Group
Logged by: J. Oleson

Borehole Name: D-1
Ecology ID: BHS 198
MP Elevation: 97.69 (local datum)
Drilled: 8/24/2012
DTW: 1.75

FIGURE A-7
GEOLOGIC LOG AND AS-BUILT FOR BOREHOLE D-1
City of Bothell
Bothell, Washington
JS1204 8/24/2012

PgG

Depth (ft)	Geology	Rec/Att	Sample	Log	Well Construction
-2					Top of casing 1.82' above ground surface.
					1.25" to 1.5" galvanized stick up with well cap.
0				Damp, orange, blue, gray, slightly silty, CLAY. (Mottled)*	Hydrated bentonite annular seal
2				Wet, gray, slightly medium sandy, SILT.*	Natural pack
					1.25" to 1.5" galvanized steel riser pipe.
4					
				Damp, gray, silty, CLAY.*	3' screen (5' to 8') constructed with a perforated jacket over gauze.
6				Wet, gray, slightly medium sandy, SILT.*	2" well point
8					Bottom of the hole at 8'.

* all geology is based upon nearby boring D-1, no samples collected, well point driven.

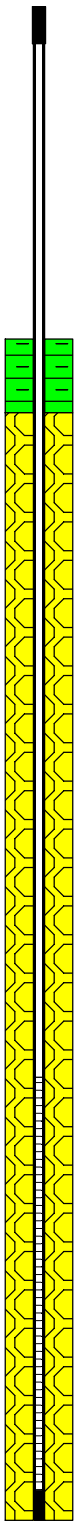
Project Name: Sammamish River Channel Restoration
Drilling Method: Push probe 7730 geoprobe
Driller: Elijah Floyd
Firm: Cascade Drilling
Consulting Firm: Pacific Groundwater Group
Logged by: Judy Oleson

Borehole Name: S-13
Ecology ID: NA
MP Elevation: 96.43 (local datum)
Drilled: 8/24/2012
DTW: 7.2

FIGURE A-8
GEOLOGIC LOG AND AS-BUILT FOR BOREHOLE S-13
City of Bothell
Bothell, Washington
JS1204 8/24/2012

PgG

Depth (ft)	Geology	Rec/Att	Sample	Log	Well Construction
-2					Top of casing 1.86' above ground surface.
					1.25" to 1.5" galvanized stick up with well cap.
0				No soil samples taken, well point driven.	Hydrated bentonite annular seal
2					Natural pack
					1.25" to 1.5" galvanized steel riser pipe.
4					
					3' screen (5' to 8') constructed with a perforated jacket over gauze.
6					
					2" well point
					Bottom of hole at 8'
8					

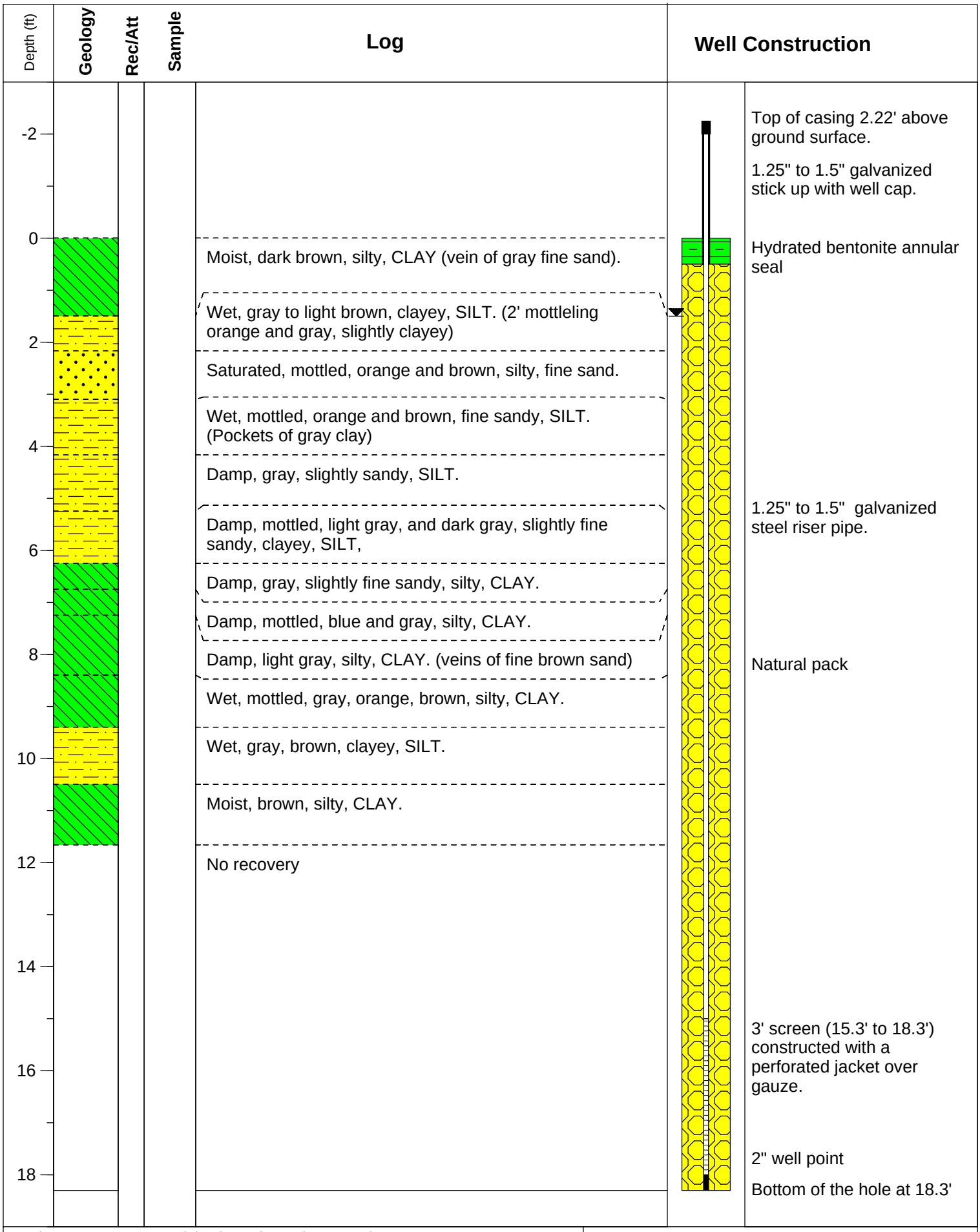


Project Name: Sammamish River Channel Restoration
Drilling Method: Push probe 7730 geoprobe
Driller: Elijah Floyd
Firm: Cascade Drilling
Consulting Firm: Pacific Groundwater Group
Logged by: Judy Oleson

Borehole Name: S-14
Ecology ID: NA
MP Elevation: 95.6 (local datum)
Drilled: 8/24/2012
DTW: Dry

FIGURE A-9
GEOLOGIC LOG AND AS-BUILT FOR BOREHOLE S-14
City of Bothell
Bothell, Washington
JS1204 8/24/2012

PgG



Project Name: Sammamish River Channel Restoration
Drilling Method: Hand Auger
Driller: J. Oleson/Inger Jackson
Firm: Pacific Groundwater Group
Consulting Firm: Pacific Groundwater Group
Logged by: J. Oleson

Borehole Name: D-2
Ecology ID:
MP Elevation: 94.46 (local datum)
Drilled: 7/26/2012
DTW: 1.5

FIGURE A-10
GEOLOGIC LOG AND AS-BUILT FOR BOREHOLE D-2
City of Bothell
Bothell, Washington
JS1204 7/26/2012

PgG

Depth (ft)	Geology	Rec/Att	Sample	Log	Well Construction
-2					Top of casing 2.21' above ground surface.
					1.25" to 1.5" galvanized stick up with well cap.
0				Moist, dark brown, silty, CLAY. (vein of gray fine sand)	Hydrated bentonite annular seal
					1.25" to 1.5" galvanized steel riser pipe.
2				Wet, gray to light brown, clayey, SILT. (2' mottleling orange and gray, slightly clayey)	Natural pack
				Saturated, mottled, orange and brown, silty, fine sand.	
4				Wet, mottled, orange and brown, fine sandy, SILT. (Pockets of gray clay)	3' screen (3.1' to 6.1') constructed with a perforated jacket over gauze.
				Damp, gray, slightly sandy, SILT.	
6				Damp, mottled, light gray, and dark gray, slightly fine sandy, clayey, SILT.	2" well point
					Bottom of the hole at 6.1'

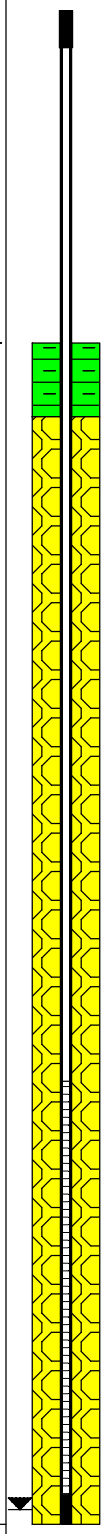
Project Name: Sammamish River Channel Restoration
Drilling Method: Hand Auger
Driller: Judy Oleson
Firm: Pacific Groundwater Group
Consulting Firm: Pacific Groundwater Group
Logged by: Judy Oleson

Borehole Name: S-12
Ecology ID: NA
MP Elevation: 94.14 (local datum)
Drilled: 8/24/2012
DTW: 2.79

FIGURE A-11
GEOLOGIC LOG AND AS-BUILT FOR BOREHOLE S-12
City of Bothell
Bothell, Washington
JS1204 8/24/2012

PgG

Depth (ft)	Geology	Rec/Att	Sample	Log	Well Construction
-2					Top of casing 1.74' above ground surface.
					1.25" to 1.5" galvanized stick up with well cap.
0				No recovery, well point driven.	Hydrated bentonite annular seal
2					Natural pack
					1.25" to 1.5" galvanized steel riser pipe.
4					
					3' screen (5' to 8') constructed with a perforated jacket over gauze.
6					2" well point
8					Bottom of the hole at 8'



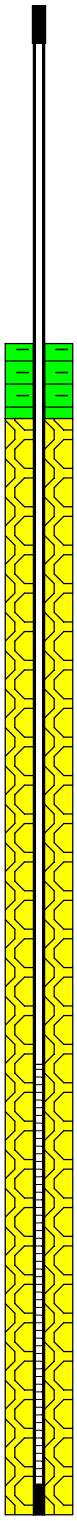
Project Name: Sammamish River Channel Restoration
Drilling Method: Push probe 7730 Geoprobe
Driller: Elijah Floyd
Firm: Cascade Drilling
Consulting Firm: Pacific Groundwater Group
Logged by: Judy Oleson

Borehole Name: S-8
Ecology ID: NA
MP Elevation: 93.62 (local datum)
Drilled: 8/24/2012
DTW: 7.9

FIGURE A-12
GEOLOGIC LOG AND AS-BUILT FOR BOREHOLE S-8
City of Bothell
Bothell, Washington
JS1204 8/24/2012

PgG

Depth (ft)	Geology	Rec/Att	Sample	Log	Well Construction
-2					Top of casing 2.03' above ground surface.
					1.25" to 1.5" galvanized stick up with well cap.
0				No samples taken, well point driven.	Hydrated bentonite annular seal
2					Natural pack
					1.25" to 1.5" galvanized steel riser pipe.
4					
					3' screen (4.8' to 7.8') constructed with a perforated jacket over gauze.
6					
					2" well point
					Bottom of the hole at 7.8'
8					



Project Name: Sammamish River Channel Restoration
Drilling Method: Push probe 7730 Geoprobe
Driller: Elijah Floyd
Firm: Cascade Drilling
Consulting Firm: Pacific Groundwater Group
Logged by: Judy Oleson

Borehole Name: S-10
Ecology ID: NA
MP Elevation: 101.6 (local datum)
Drilled: 8/24/2012
DTW: Dry

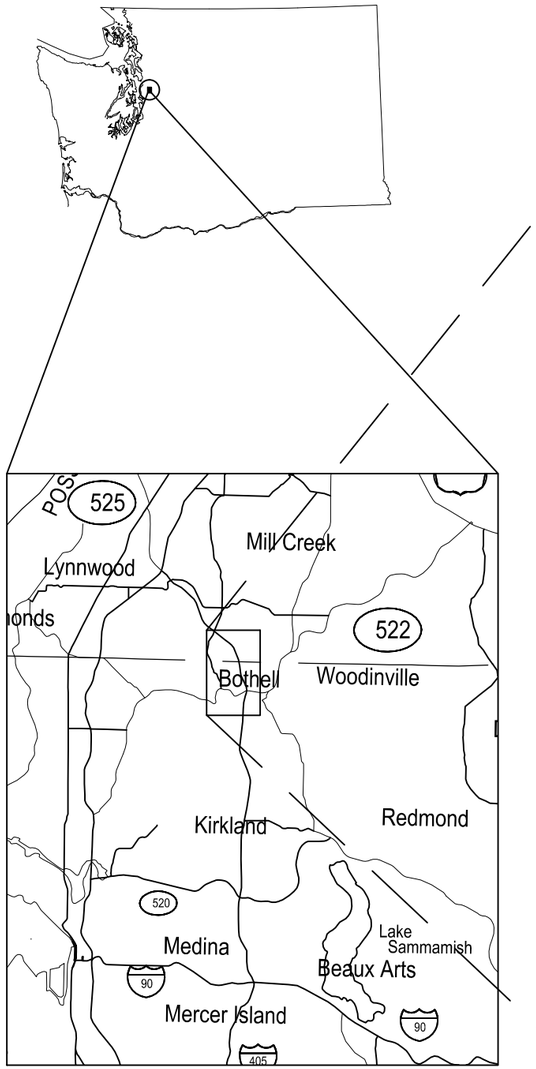
FIGURE A-13
GEOLOGIC LOG AND AS-BUILT FOR BOREHOLE S-10
City of Bothell
Bothell, Washington
JS1204 8/24/2012

PgG

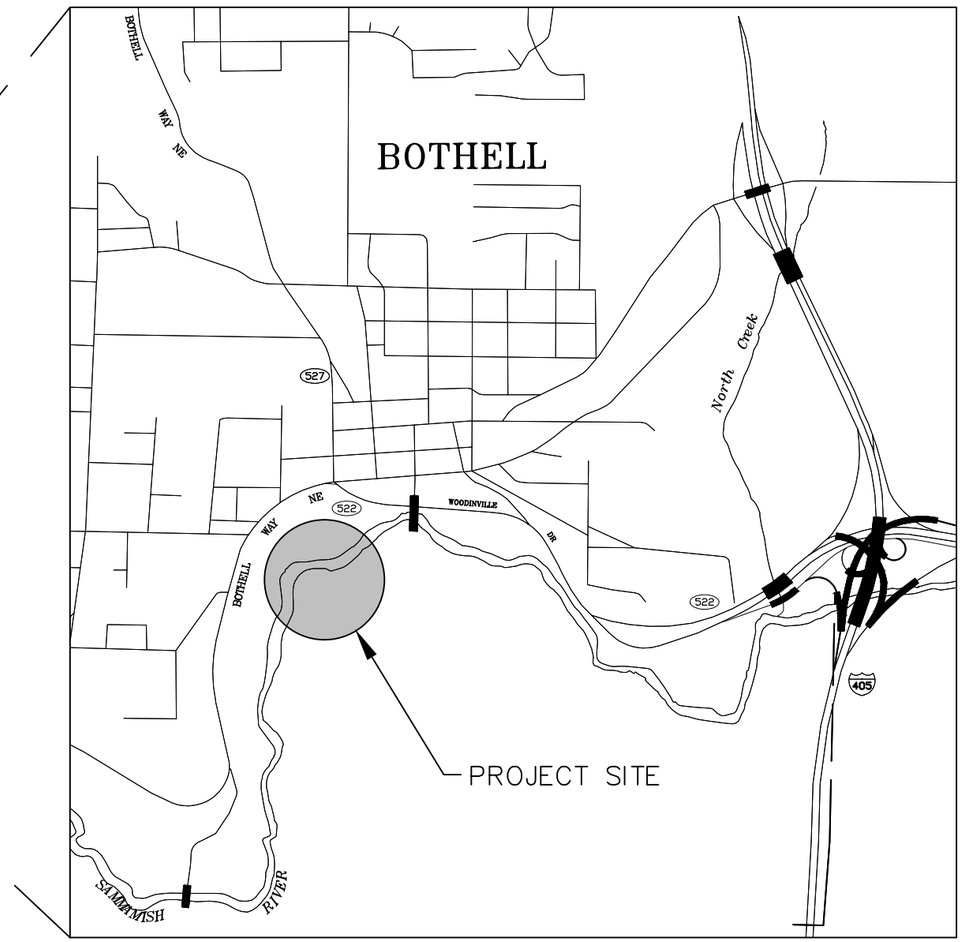
APPENDIX C

Preliminary Design Drawings

CITY OF BOTHELL
SAMMAMISH RIVER OFF-CHANNEL HABITAT RESTORATION PROJECT
PRELIMINARY DESIGN



VICINITY MAP



SITE MAP

PROJECT MANAGER

ANDY LOCH
CITY OF BOTHELL
DEPARTMENT OF PUBLIC WORKS
9654 NE 182nd ST
BOTHELL WA 98011

SHEET INDEX

SHEET NAME	SHEET #
COVER SHEET	1
LEGEND, ABBREVIATIONS, SURVEY & SURVEY QTY'S	2
SITE & ACCESS/STAGING PLAN	3
CHANNEL EXCAVATION PLAN	4
NEW CHANNEL PROFILE	5
NEW CHANNEL SECTIONS	6
CULVERT PLANS	7
CULVERT SECTIONS	8
CULVERT DETAILS	9
FILL PLAN	10
PLANTING PLAN – PLAN VIEW	11
PLANTING PLAN – SECTIONS, DETAILS	12

NO.	DATE	REVISION DESCRIPTION	BY	CHK

0 1"
BAR MEASURES ONE INCH ON ORIGINAL DRAWINGS

CITY OF BOTHELL

DESIGNED BY: PDV, JE, RN
DRAWN BY: PDV,BG
CHECKED BY: JE
PROJECT MGR: PDV

Resource Consultants, Inc.
REDMOND, WA 98052
PHONE: (425) 556-1288

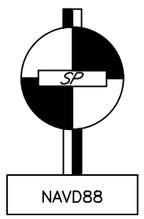
SAMMAMISH RIVER
OFF-CHANNEL HABITAT RESTORATION

COVER SHEET
–
PRELIMINARY DESIGN

DATE: SEP 11 2014
SHEET: 1
REV: –

SURVEY NOTES

SURVEY HORIZONTAL DATUM FOR THIS PROJECT IS WASHINGTON STATE PLANE NORTH ZONE COORDINATES, NORTH AMERICAN DATUM NAD83/07; VERTICAL DATUM IS NAVD88.



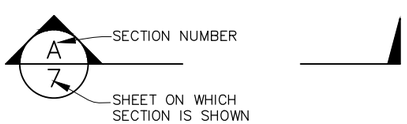
WSDOT SURVEY CONTROL POINT DATA

PROJECT CONTROL POINTS:	#1	#2
POINT ID#	R2 MON-1	R2 MON-2
NORTHING (FT)	279357.62	278761.23
EASTING (FT)	1302567.19	1302035.94
ELEVATION (FT; NAVD88)	25.56	23.86

DRAWING REFERENCES

THE DRAWINGS ARE REFERENCED IN THE FOLLOWING MANNER

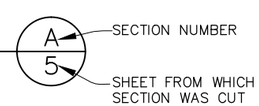
SECTION CUT ON SHEET 5, SHOWN ON SHEET 7:



ON SHEET 7 THIS SECTION IS DEFINED AS:

SECTION

NO SCALE



LEGEND

- APPROXIMATE PARCEL LINES
- FEMA MAP 100 YR FLOOD EXTENT
- PRESENT SAMMAMISH RIVER ALIGNMENT
- EXISTING CONTOURS
- VEGETATION ZONE BOUNDARY
- ACCESS ROAD
- SIGNIFICANT TREE
- SURVEY CONTROL POINT
- TRAIL
- POOL
- WOOD
- UNDISTURBED EARTH
- DISTURBANCE AREA
- STAGING AREA
- CUT
- FILL
- BLACKBERRY RESTORATION AREA
- REVEGETATION AREA (GENERAL)
- REED CANARY GRASS RESTORATION AREA

ABBREVIATIONS

BM	BENCH MARK
CG	CENTER OF GRAVITY
CL, ℄	CENTERLINE
CP	CONTROL POINT
CS	CROSS SECTION
CY	CUBIC YARD
DBH	DIA AT BREAST HEIGHT
DIA	DIAMETER
DS, D/S	DOWNSTREAM
DSEL	DOWNSTREAM ELEVATION
DWG	DRAWING
E	EAST
EA	EACH
ELEV, EL	ELEVATION
ELJ	ENGINEERED LOG JAM
EXIST	EXISTING
FT	FOOT, FEET
HORZ	HORIZONTAL
HPA	HYDRAULIC PROJECT APPROVAL
ID	IDENTIFICATION, INNER DIA
IN	INCH, INCHES
LB	POUNDS
LT	LEFT
LF	LINEAR FOOT
LWD	LARGE WOODY DEBRIS
MAX	MAXIMUM
MIN	MINIMUM
MISC	MISCELLANEOUS
MON	MONUMENT
N	NORTH
NO	NUMBER
NTS	NOT TO SCALE
OC	ON CENTER
OHWL	ORDINARY HIGH WATER LEVEL
OHWM	ORDINARY HIGH WATER MARK
RT	RIGHT
S	SLOPE, SOUTH
SHT	SHEET
SP	STATE PLANE COORDINATES
SPEC	SPECIFICATION
STA	STATION
STD	STANDARD
SF	SQUARE FOOT
SY	SQUARE YARD
TESC	TEMPORARY EROSION AND SEDIMENT CONTROL
TYP	TYPICAL
USEL	UPSTREAM ELEVATION
VAR	VARIES
VERT	VERTICAL
W	WEST, WIDE
W/	WITH
WM	WATER MARK
W/O	WITHOUT
WSDOT	WA DEPT OF TRANSPORTATION
WSEL	WATER SURFACE ELEVATION
WT	WEIGHT
YR	YEAR

NO.	DATE	REVISION DESCRIPTION	BY	CHK

0 1"

BAR MEASURES ONE INCH ON ORIGINAL DRAWINGS

CITY OF BOTHELL

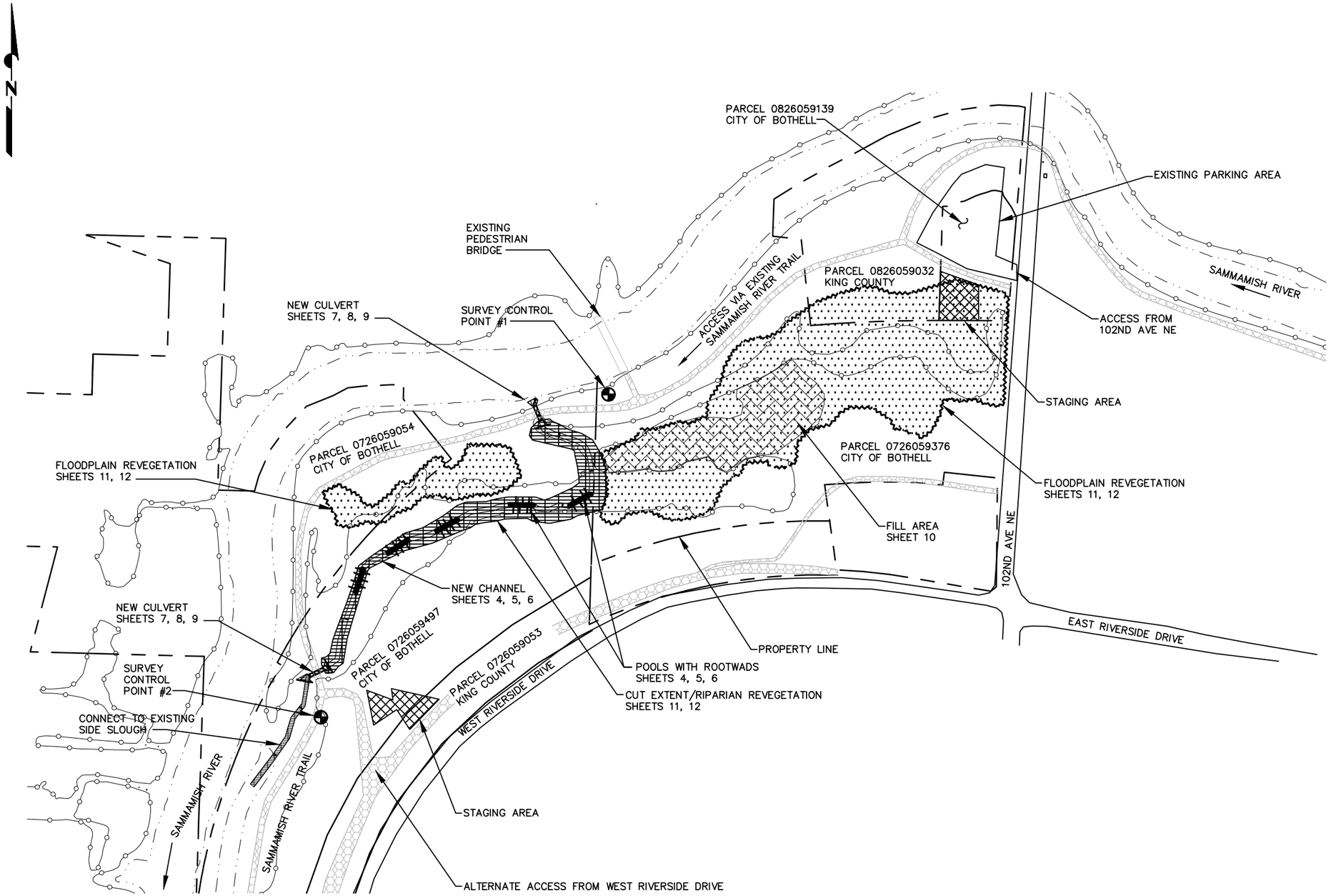
DESIGNED BY: PDV, JE, RN
DRAWN BY: PDV,BG
CHECKED BY: JE
PROJECT MGR: PDV

Resource Consultants, Inc.
REDMOND, WA 98052
PHONE: (425) 556-1288

SAMMAMISH RIVER
OFF-CHANNEL HABITAT RESTORATION

LEGEND, ABBREVIATIONS, SURVEY & SUMMARY QTY'S
PRELIMINARY DESIGN

DATE: SEP 11 2014
SHEET: 2
REV: —



PLAN VIEW

NO.	DATE	REVISION DESCRIPTION	BY	CHK

100' 50' 0 100' 200'
1"=200'

0 1"
BAR MEASURES ONE INCH
ON ORIGINAL DRAWINGS

CITY OF BOTHELL

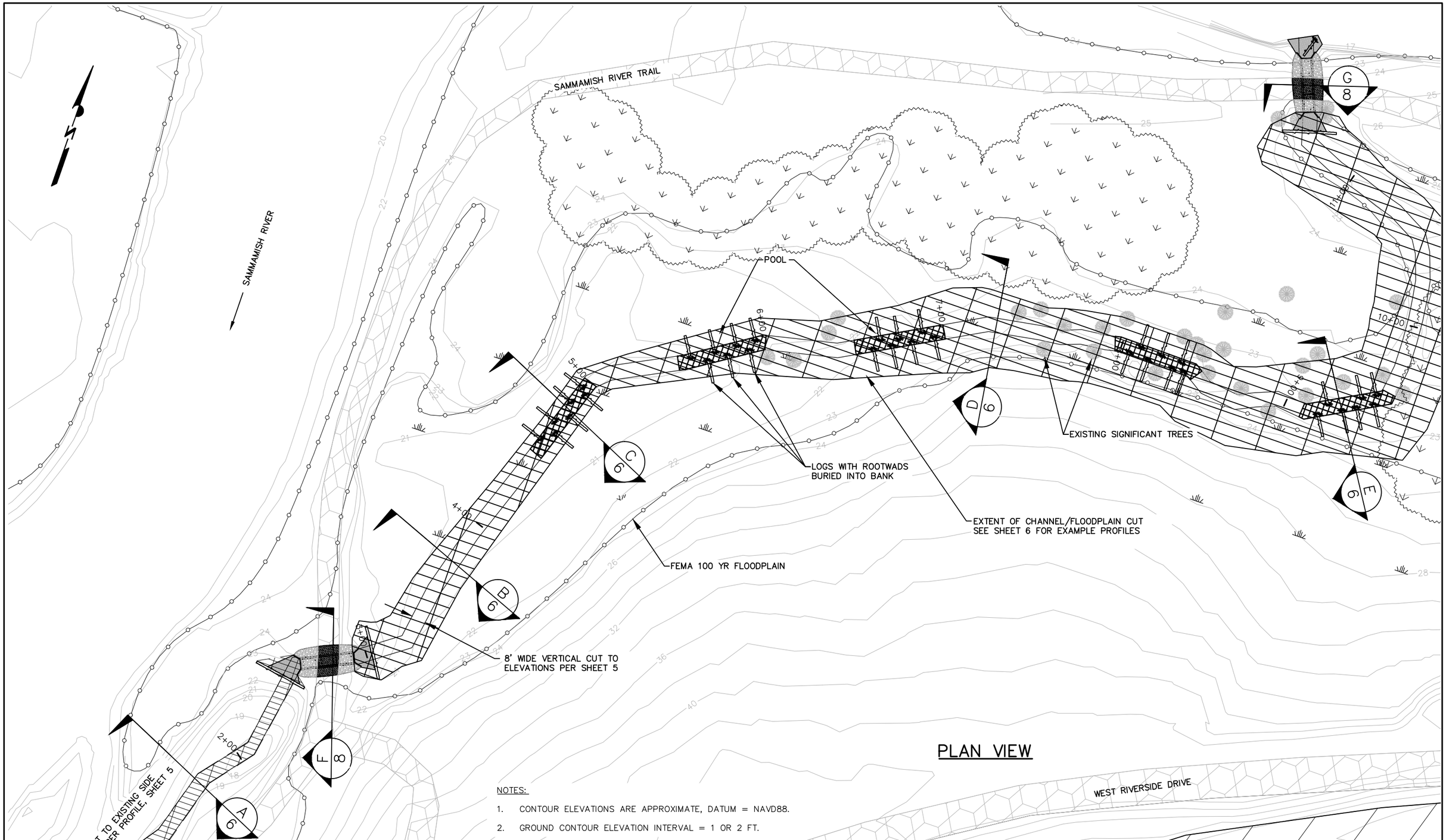
DESIGNED BY: PDV, JE, RN
DRAWN BY: PDV,BG
CHECKED BY: JE
PROJECT MGR: PDV

Resource Consultants, Inc.
REDMOND, WA 98052
PHONE: (425) 556-1288

SAMMAMISH RIVER
OFF-CHANNEL HABITAT RESTORATION

SITE PLAN; ACCESS/STAGING;
PROPERTY BOUNDARIES
PRELIMINARY DESIGN

DATE: SEP 11 2014
SHEET: 3
REV: —



PLAN VIEW

NOTES:

1. CONTOUR ELEVATIONS ARE APPROXIMATE, DATUM = NAVD88.
2. GROUND CONTOUR ELEVATION INTERVAL = 1 OR 2 FT.

NO.	DATE	REVISION DESCRIPTION	BY	CHK

25' 12.5' 0 25' 50'
1"=50'

0 1"
BAR MEASURES ONE INCH ON ORIGINAL DRAWINGS

CITY OF BOTHELL

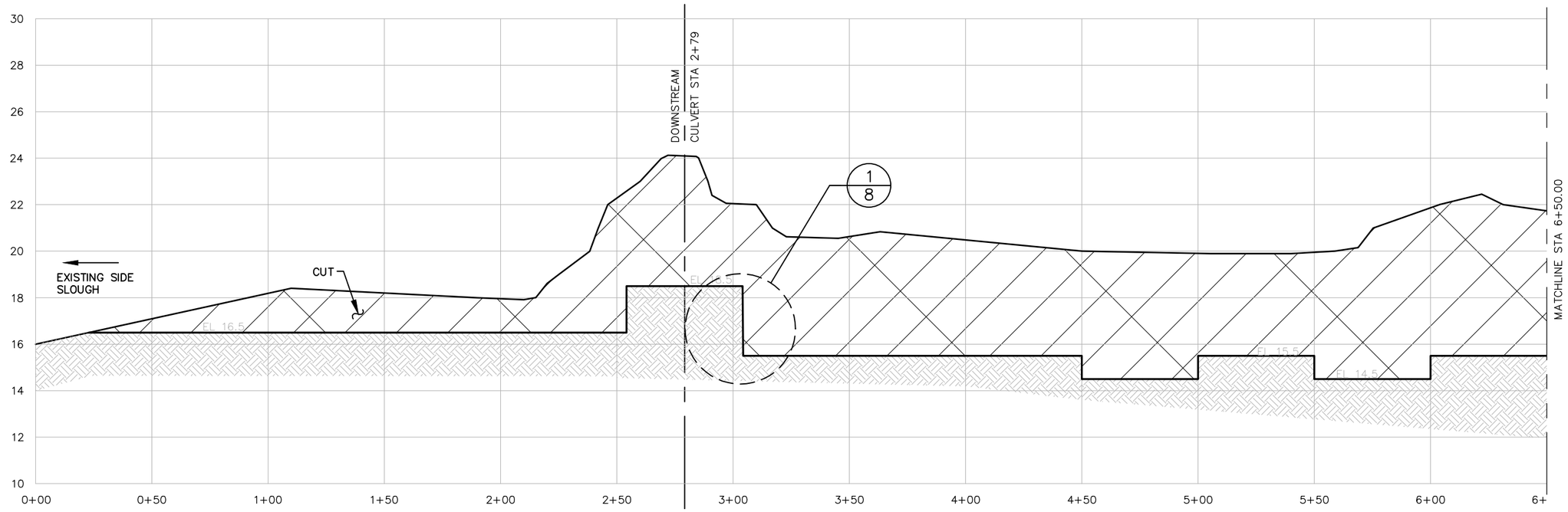
DESIGNED BY: PDV, JE, RN
DRAWN BY: PDV,BG
CHECKED BY: JE
PROJECT MGR: PDV

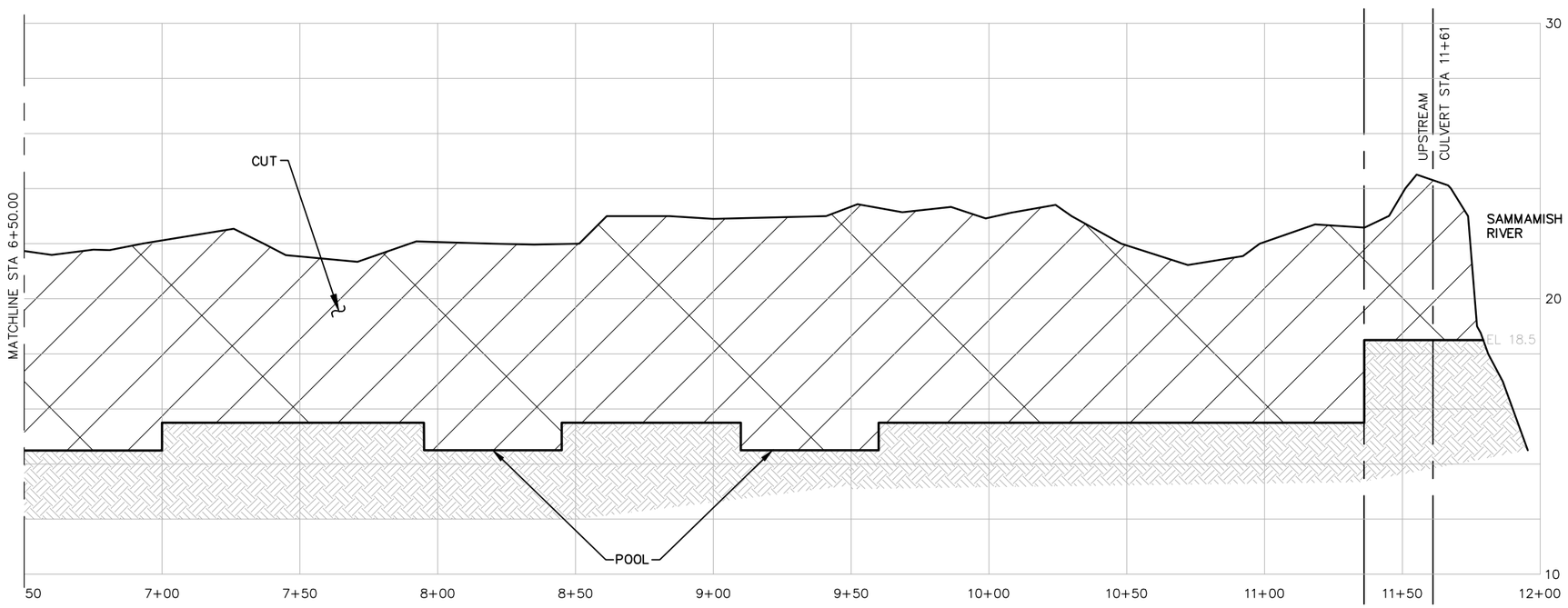
Resource Consultants, Inc.
REDMOND, WA 98052
PHONE: (425) 556-1288

SAMMAMISH RIVER
OFF-CHANNEL HABITAT RESTORATION

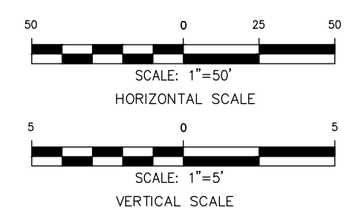
CHANNEL EXCAVATION PLAN
—
PRELIMINARY DESIGN

DATE: SEP 11 2014
SHEET: 4
REV: —





NEW CHANNEL PROFILE



NO.	DATE	REVISION DESCRIPTION	BY	CHK

0 1"
BAR MEASURES ONE INCH
ON ORIGINAL DRAWINGS

CITY OF BOTHELL

DESIGNED BY: PDV, JE, RN
DRAWN BY: PDV,BG
CHECKED BY: JE
PROJECT MGR: PDV

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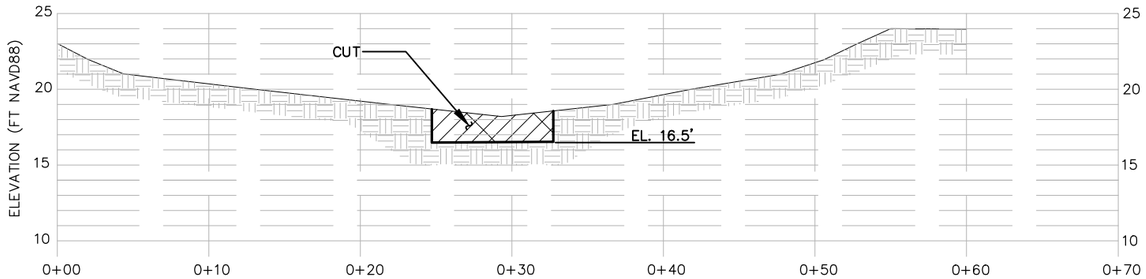
SAMMAMISH RIVER
OFF-CHANNEL HABITAT RESTORATION

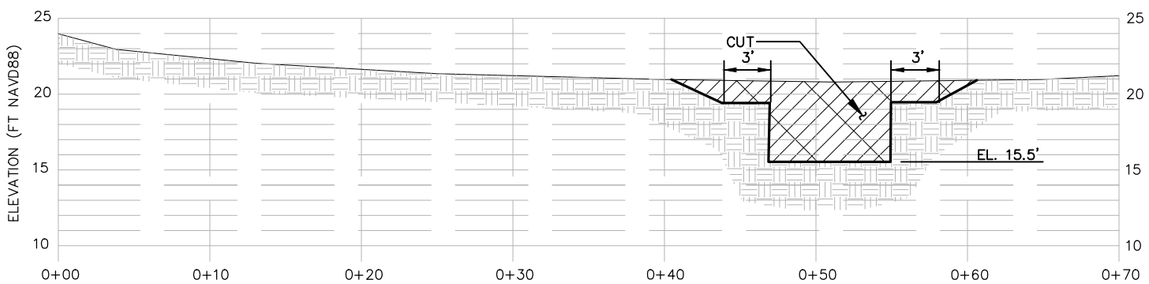
NEW CHANNEL PROFILE
—
PRELIMINARY DESIGN

DATE: SEP 11 2014
SHEET: 5
REV: —



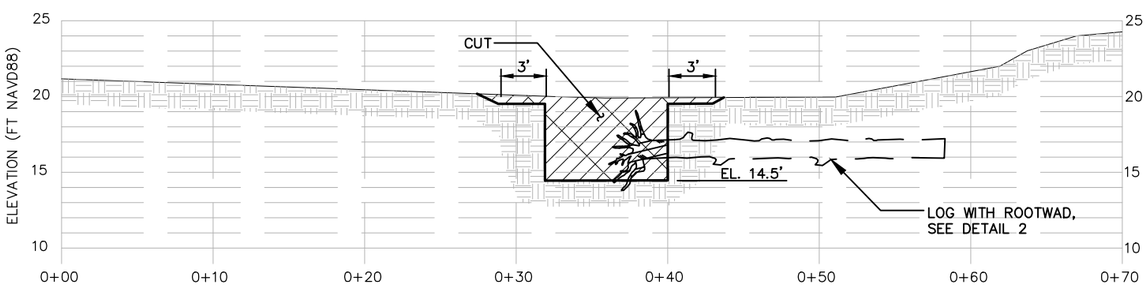
SECTION A/4
NEW CHANNEL CUT

SCALE: 1"=10'



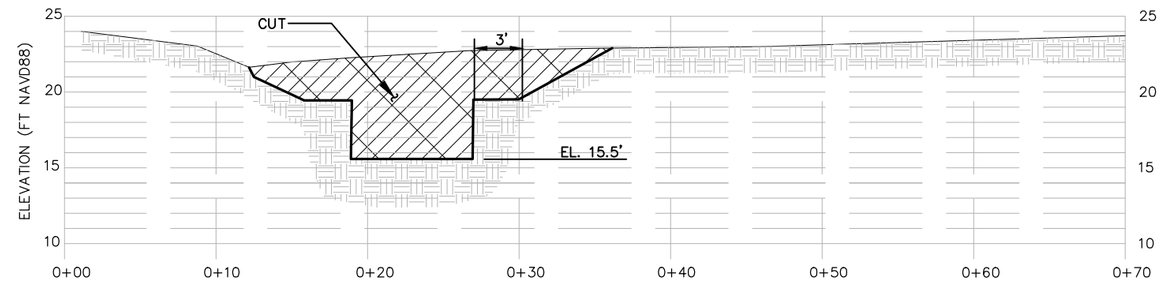
SECTION B/4
NEW CHANNEL CUT

SCALE: 1"=10'



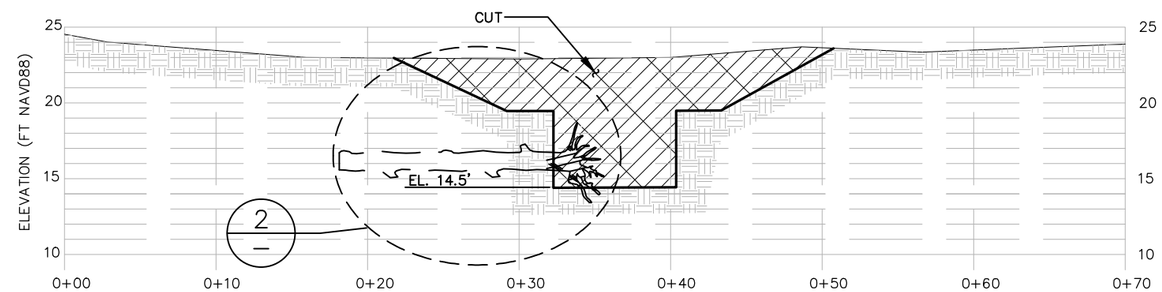
SECTION C/4
NEW CHANNEL CUT

SCALE: 1"=10'



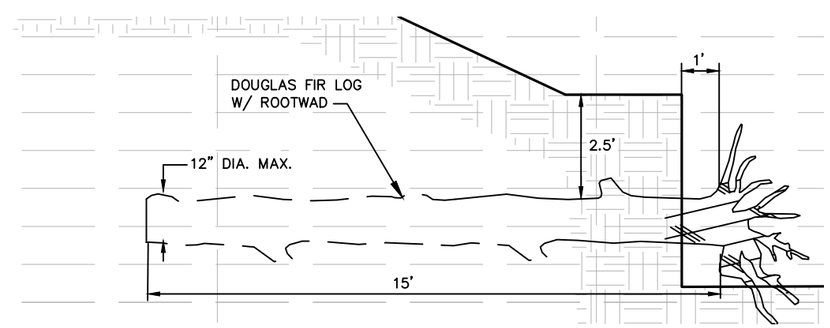
SECTION D/4
NEW CHANNEL CUT

SCALE: 1"=10'



SECTION E/4
NEW CHANNEL CUT

SCALE: 1"=10'



DETAIL 2/—
LOG INSTALLATION

SCALE: 1"=4'

NO.	DATE	REVISION DESCRIPTION	BY	CHK

0 1"
BAR MEASURES ONE INCH
ON ORIGINAL DRAWINGS

CITY OF BOTHELL

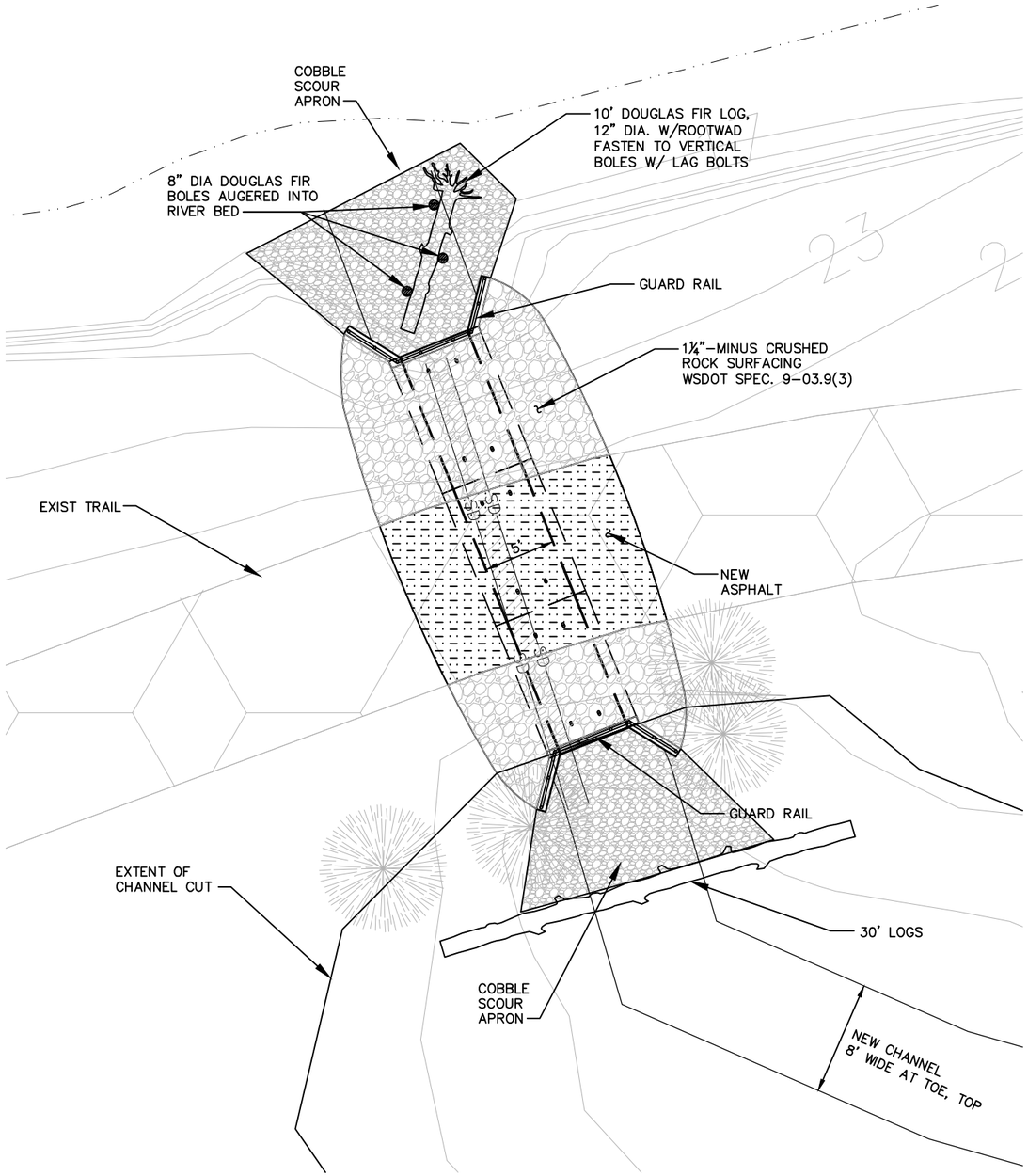
DESIGNED BY: PDV, JE, RN
DRAWN BY: PDV,BG
CHECKED BY: JE
PROJECT MGR: PDV

Resource Consultants, Inc.
REDMOND, WA 98052
PHONE: (425) 556-1288

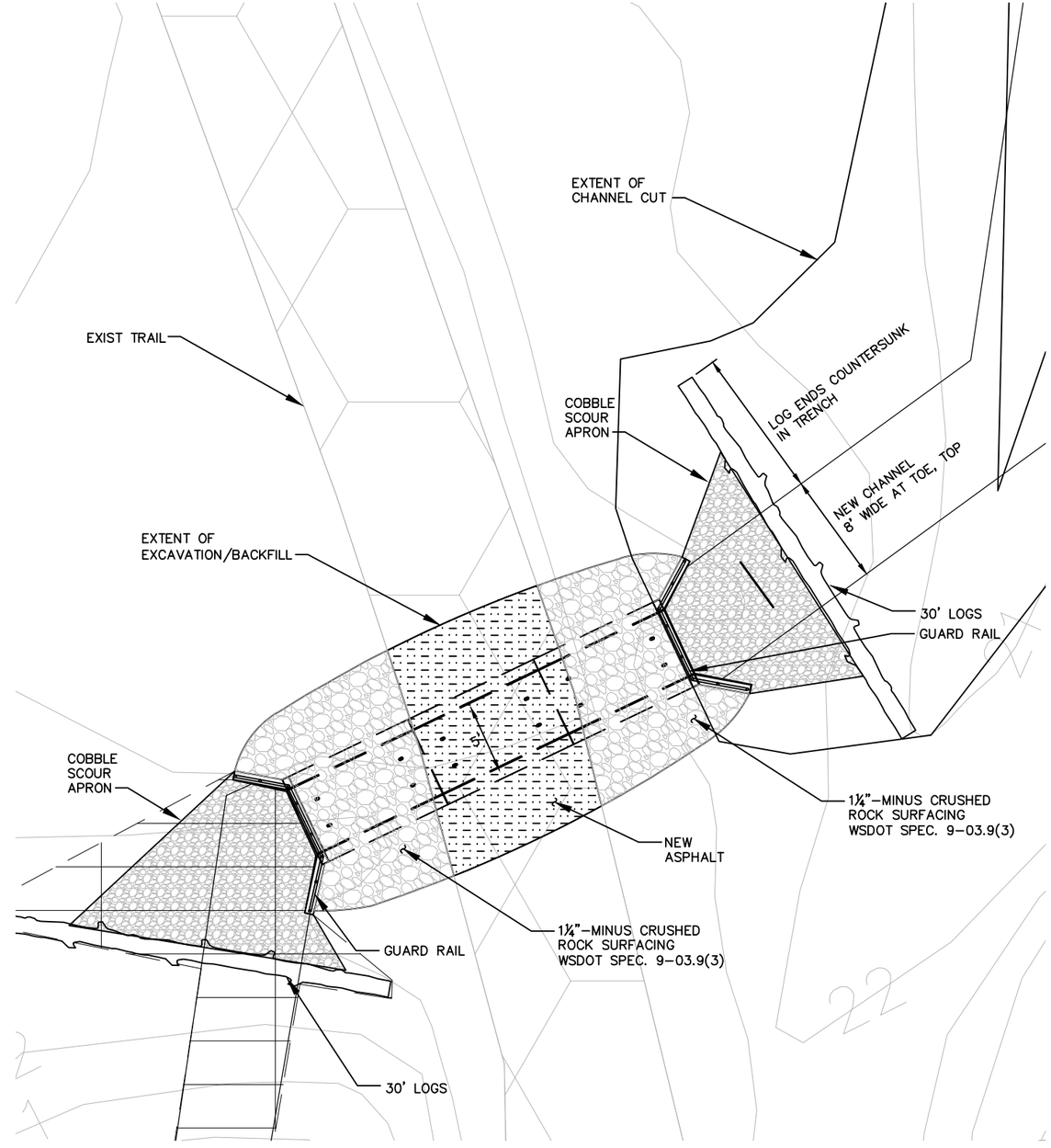
SAMMAMISH RIVER
OFF-CHANNEL HABITAT RESTORATION

NEW CHANNEL SECTIONS,
LOG INSTALLATION DETAIL
PRELIMINARY DESIGN

DATE: SEP 11 2014
SHEET: 6
REV: —



PLAN
UPSTREAM CULVERT



PLAN
DOWNSTREAM CULVERT

NO.	DATE	REVISION DESCRIPTION	BY	CHK

5' 2.5' 0 5' 10'
1"=10'

0 1"
BAR MEASURES ONE INCH ON ORIGINAL DRAWINGS

CITY OF BOTHELL

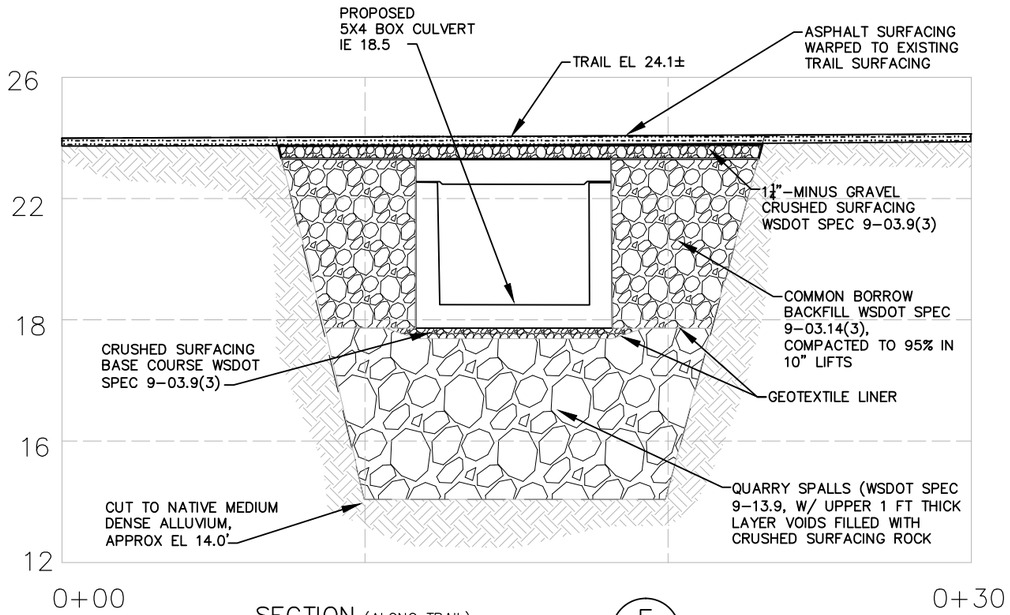
DESIGNED BY: PDV, JE, RN
DRAWN BY: PDV,BG
CHECKED BY: JE
PROJECT MGR: PDV

Resource Consultants, Inc.
REDMOND, WA 98052
PHONE: (425) 556-1288

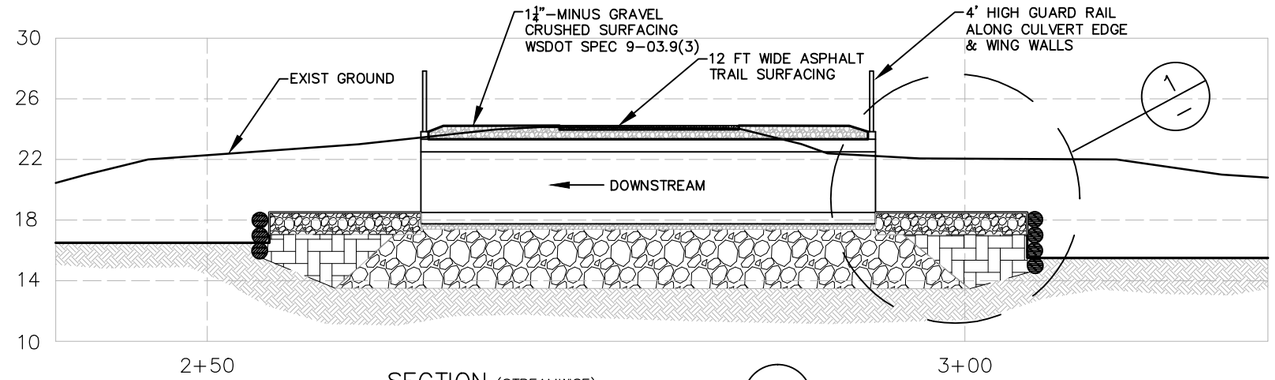
SAMMAMISH RIVER
OFF-CHANNEL HABITAT RESTORATION

CULVERT PLANS
—
PRELIMINARY DESIGN

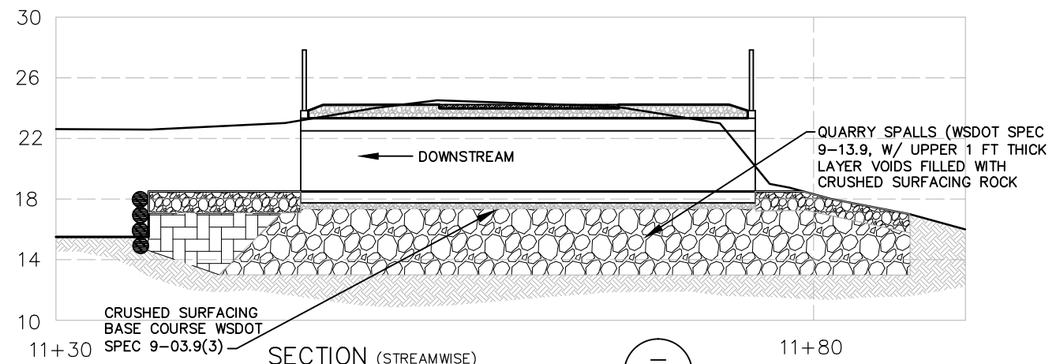
DATE: SEP 11 2014
SHEET: 7
REV: —



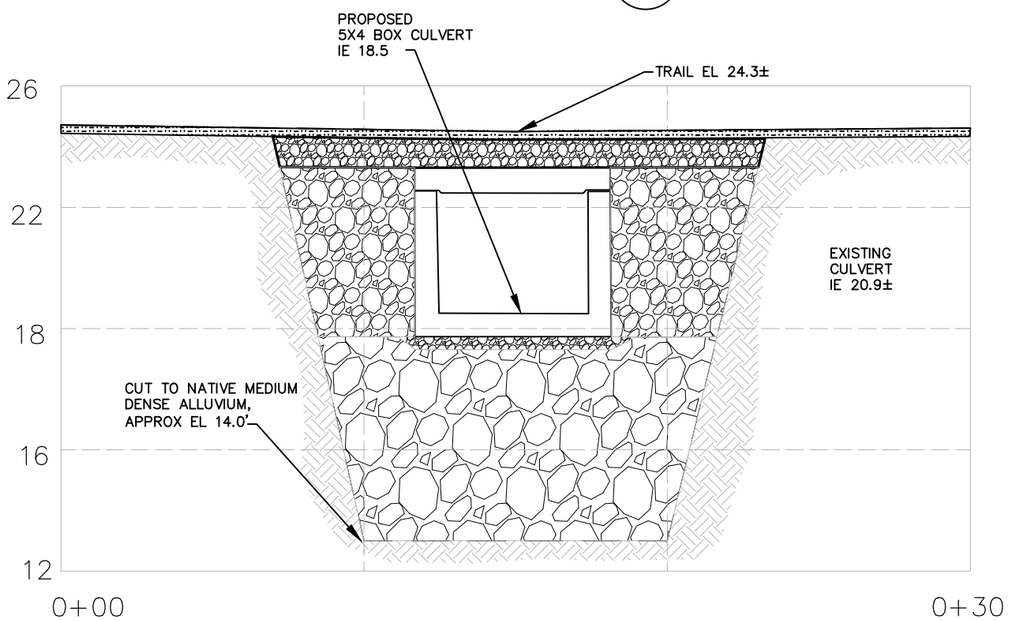
SECTION (ALONG TRAIL) F/4
DOWNSTREAM CULVERT



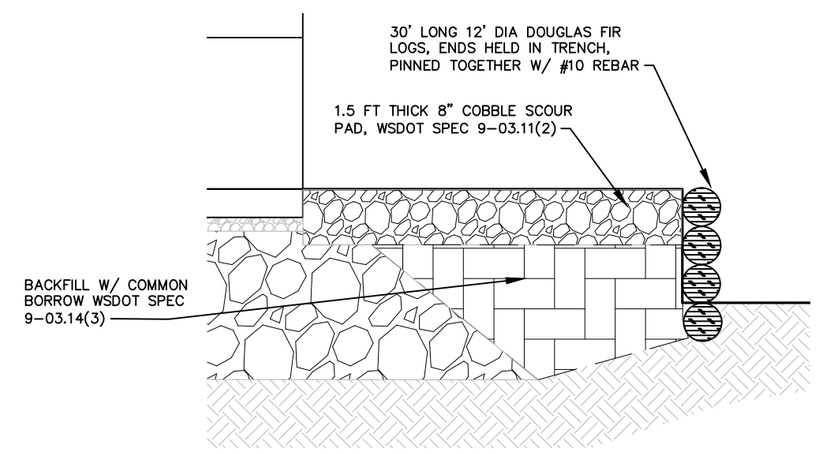
SECTION (STREAMWISE) –/4
DOWNSTREAM CULVERT



SECTION (STREAMWISE) –/4
UPSTREAM CULVERT



SECTION (ALONG TRAIL) G/4
UPSTREAM CULVERT



DETAIL 1/5,8
CULVERT SCOUR APRON & LOGS

NO.	DATE	REVISION DESCRIPTION	BY	CHK

0 1"
BAR MEASURES ONE INCH
ON ORIGINAL DRAWINGS

CITY OF BOTHELL

DESIGNED BY: PDV, JE, RN
DRAWN BY: PDV,BG
CHECKED BY: JE
PROJECT MGR: PDV

Resource Consultants, Inc.
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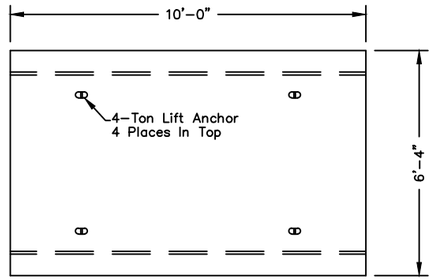
SAMMAMISH RIVER
OFF–CHANNEL HABITAT RESTORATION

CULVERT SECTIONS
–
PRELIMINARY DESIGN

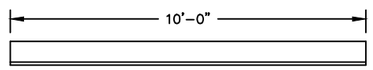
DATE: SEP 11 2014
SHEET: 8
REV: –

5076 TRENCH

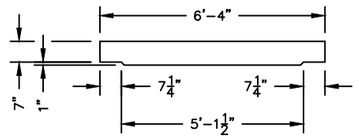


PLAN-COVER

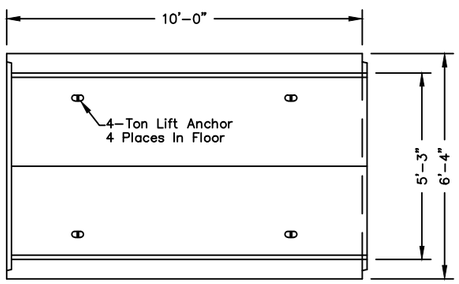
NOTE: SCHEMATIC IS REPRESENTATIVE,
FINAL DESIGN = 4 FT HIGH INSIDE



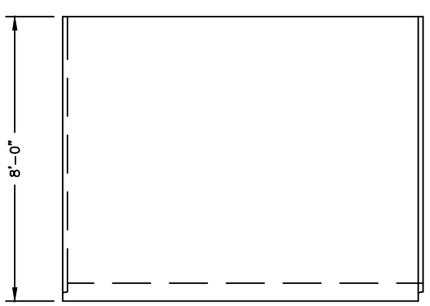
SIDE-COVER



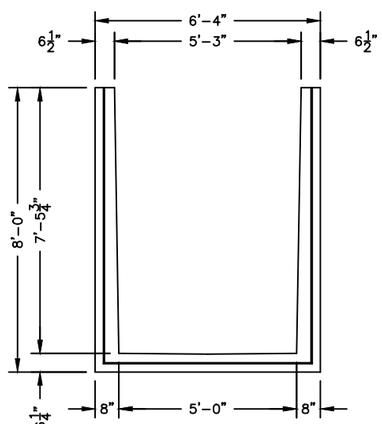
END-COVER



PLAN-TRENCH



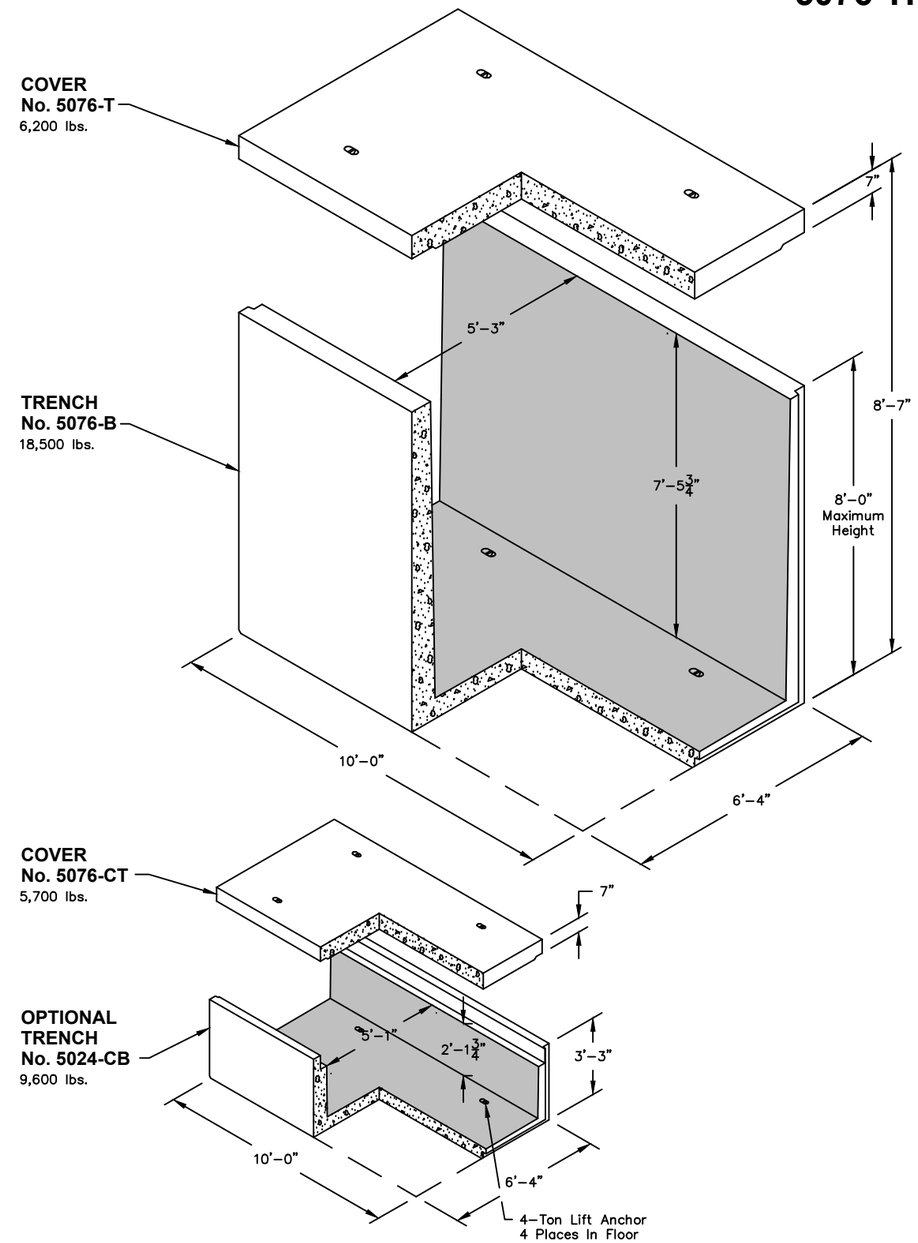
SIDE-TRENCH



END-TRENCH

SCALE: 1/4"=1'-0"

5076 TRENCH



NO.	DATE	REVISION DESCRIPTION	BY	CHK

0 1"
BAR MEASURES ONE INCH
ON ORIGINAL DRAWINGS

CITY OF BOTHELL

DESIGNED BY: PDV, JE, RN
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SAMMAMISH RIVER
OFF–CHANNEL HABITAT RESTORATION

CULVERT DETAILS
EXAMPLE CULVERT DIMENSIONS
PRELIMINARY DESIGN

DATE: SEP 11 2014
SHEET: 9
REV: —

SAMMAMISH RIVER

11+00

10+00

00+6

CHANNEL CUT AREA; SPOILS FROM HERE ARE DISTRIBUTED IN FILL AREAS TO EAST DEPICTED ON THIS SHEET

MOW REED CANARY GRASS & BLACKBERRY CLOSE TO GROUND; PLACE EXCAVATION SPOILS, 1.5 FT THICK LATER; RE-VEGETATE PER SHEET 11.

MOW REED CANARY GRASS & BLACKBERRY CLOSE TO GROUND; PLACE EXCAVATION SPOILS, 3 FT THICK LATER; RE-VEGETATE PER SHEET 11.

FEMA 100-YR FLOODPLAIN MAP BOUNDARY

NO.	DATE	REVISION DESCRIPTION	BY	CHK

25' 12.5' 0 25' 50'

1"=50'

0 1"

BAR MEASURES ONE INCH ON ORIGINAL DRAWINGS

CITY OF BOTHELL

DESIGNED BY: PDV, JE, RN
DRAWN BY: PDV,BG
CHECKED BY: JE
PROJECT MGR: PDV

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REDMOND, WA 98052
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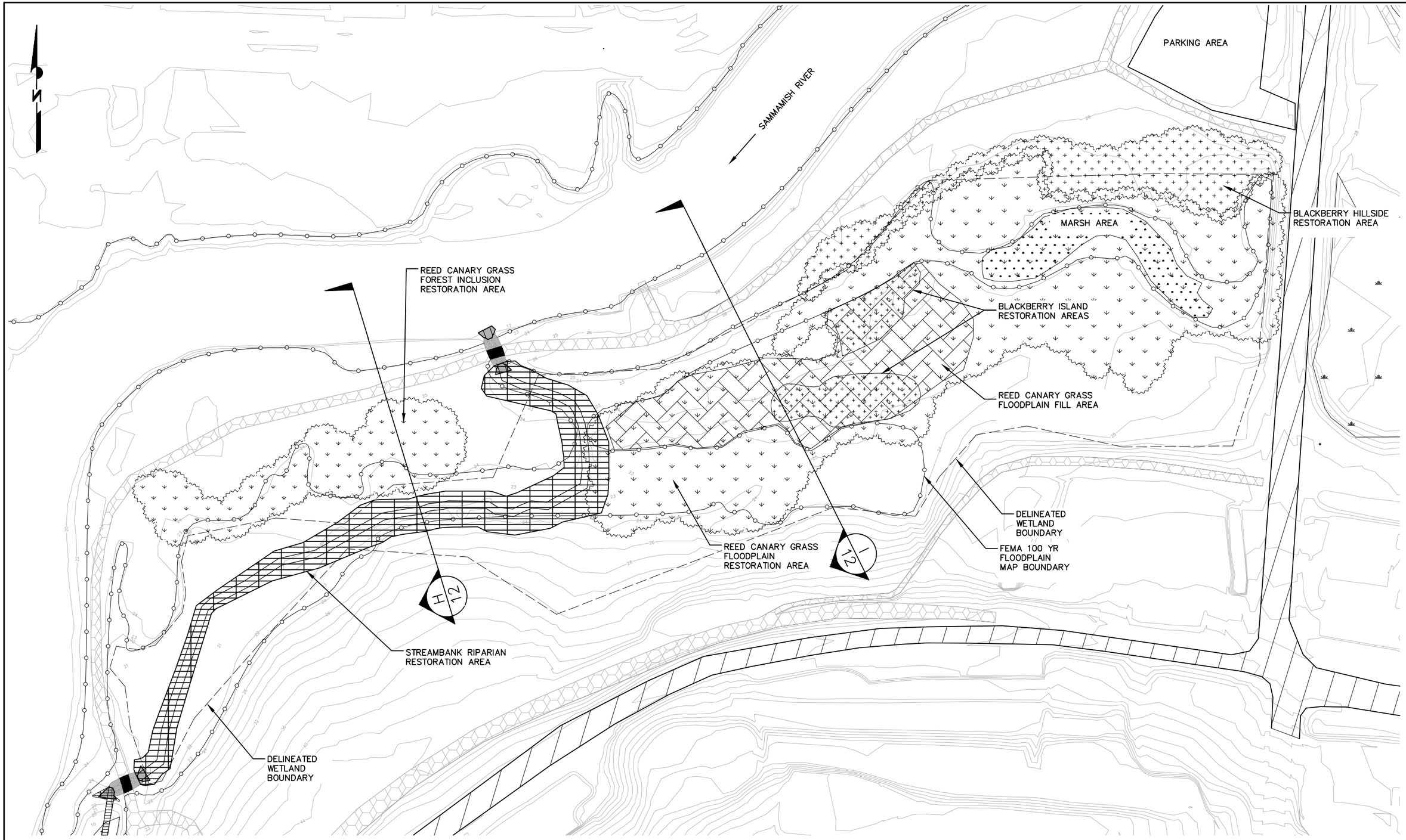
SAMMAMISH RIVER
OFF-CHANNEL HABITAT RESTORATION

FILL PLAN
–
PRELIMINARY DESIGN

DATE: SEP 11 2014
SHEET: 10
REV: –



NO.	DATE	REVISION DESCRIPTION	BY	CHK

50' 25' 0 50' 100'
1"=100'

0 1"
BAR MEASURES ONE INCH ON ORIGINAL DRAWINGS

CITY OF BOTHELL

DESIGNED BY: PDV, JE, RN
DRAWN BY: PDV,BG
CHECKED BY: JE
PROJECT MGR: PDV

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REDMOND, WA 98052
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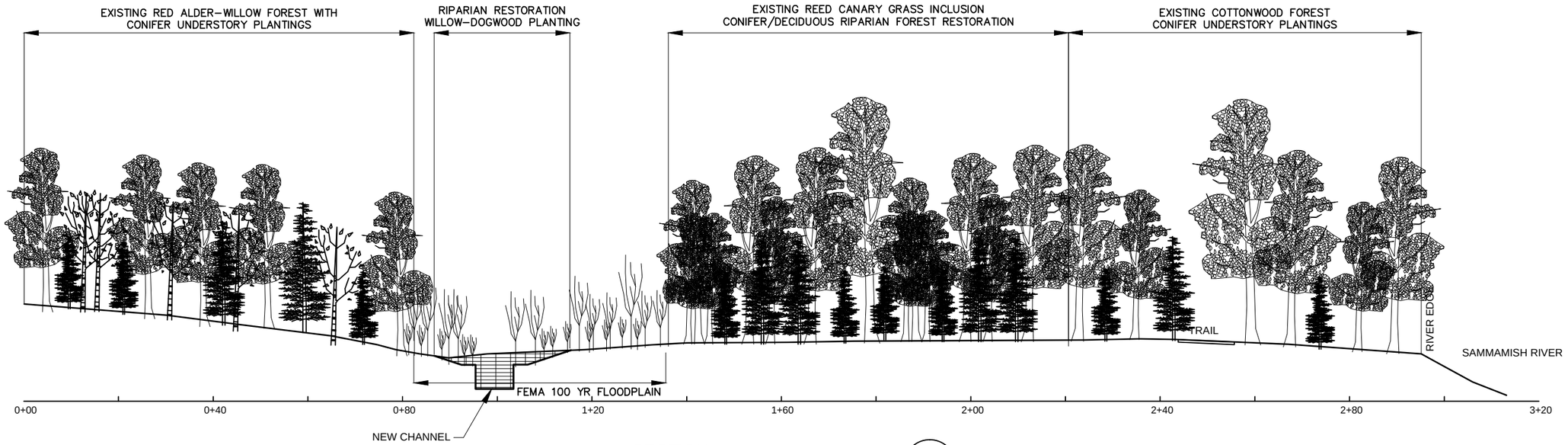
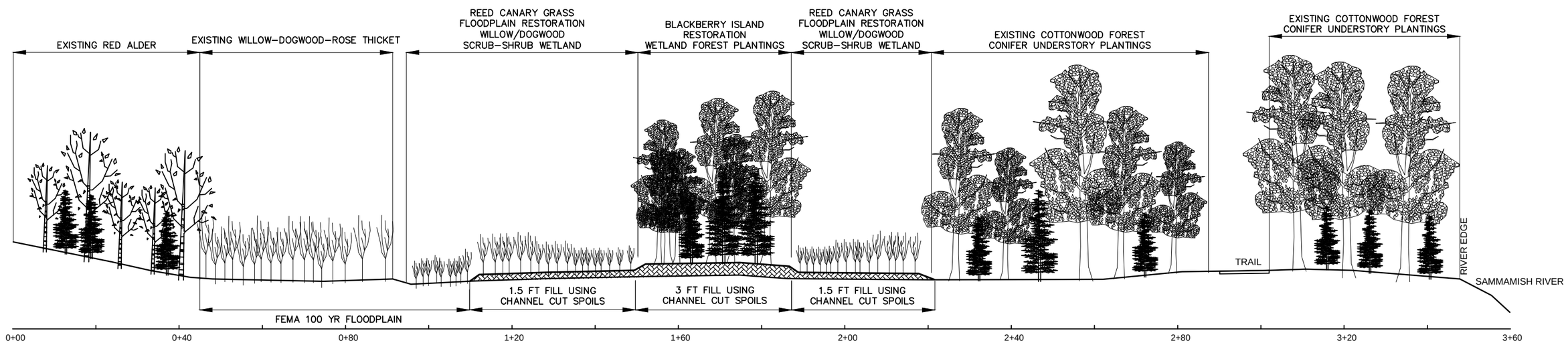
SAMMAMISH RIVER
OFF-CHANNEL HABITAT RESTORATION

PLANTING PLAN
PLAN VIEW
PRELIMINARY DESIGN

DATE: SEP 11 2014
SHEET: 11
REV: —



SECTION H/4
FOREST + RIPARIAN RESTORATION



SECTION I/4
FLOODPLAIN RESTORATION

NO.	DATE	REVISION DESCRIPTION	BY	CHK

0 1"
BAR MEASURES ONE INCH
ON ORIGINAL DRAWINGS

CITY OF BOTHELL

DESIGNED BY: PDV, JE, RN
DRAWN BY: PDV,BG
CHECKED BY: JE
PROJECT MGR: PDV

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PHONE: (425) 556–1288

SAMMAMISH RIVER
OFF–CHANNEL HABITAT RESTORATION

PLANTING PLAN,
SECTIONS, DETAILS
PRELIMINARY DESIGN

DATE: SEP 11 2014
SHEET: 12
REV: –