Appendices

1. Bioretention Hydrologic Performance (BHP) Study Site Selection Process and List of Selected Sites Technical Memo - Deliverables 2.2 and 2.3 Combined. Taylor Aquatic Science. 10/23/15
2. Bioretention Hydrologic Performance Study - Hydrologic Monitoring Results. Aspect Consulting. 6/26/18
3. Deliverable 4.5, Site B145, Geotechnical/Soils Assessment Design Data and Current Conditions, 145th Place SE and SE 22nd Street Roadway Improvement Project, Bellevue, Washington. Associated Earth Sciences, Inc. 10/25/16
4. Deliverable 4.5, Site BDP, Geotechnical/Soils Assessment Design Data and Current Conditions, Bloedel Donavan Park, Bellingham, Washington. Associated Earth Sciences, Inc. 10/25/16
5. Deliverable 4.5, Site IHS, Geotechnical/Soils Assessment Design Data and Current Conditions, Issaquah High School, Issaquah, Washington. Associated Earth Sciences, Inc. 10/25/16
6. Deliverable 4.5, Site MCCA, Geotechnical/Soils Assessment Design Data and Current Condition, Mill Creek Community Association, Mill Creek, Washington. Associated Earth Sciences, Inc. 10/25/16
7. Deliverable 4.5, Site NOLL, Geotechnical/Soils Assessment Design Data and Current Conditions, Noll Roundabout, Poulsbo, Washington. Associated Earth Sciences, Inc. 10/25/16
8. Deliverable 4.5, Site ORLA, Geotechnical/Soils Assessment Design Data and Current Conditions, Olympia Regional Learning Academy, Thurston County, Washington. Associated Earth Sciences, Inc. 10/25/16
9. Deliverable 4.5, Site SLP, Geotechnical/Soils Assessment Design Data and Current Conditions, Spanaway Lake Park, Pierce County, Washington. Associated Earth Sciences, Inc. 10/25/16
10. Bellingham Bioretention Study - Vegetation Monitoring Methods and Results. Raedeke Associates, Inc. 10/19/16
11. Bioretention Hydrologic Performance Phase II Deliverable 5.2 Hydrologic Modeling Results. Clear Creek Solutions, Inc. 6/26/18

APPENDIX 1

Bioretention Hydrologic Performance (BHP) Study Site Selection Process and List of Selected Sites Technical Memo - Deliverables 2.2 and 2.3 Combined. Taylor Aquatic Science. 10/23/15

Taylor Aquatic Science and Policy

Technical Memo

To: Bill Reilly, City of Bellingham
Brandy Lubliner, WDOE

From: William J. Taylor, Taylor Aquatic Science and Policy
Douglas Beyerlein, Clear Creek Solutions, Inc.

Date: October 23, 2015

Re: Bioretention Hydrologic Performance (BHP) Study
Site Selection Process and List of Selected Sites
Technical Memo – Deliverables 2.2 and 2.3 Combined

This memo provides a summary of the site selection process and results of the site evaluations combined into one memo. As the selection process and recommended sites for selection are closely intertwined, it make sense to combine these into one product.

Background

Phase I of the BHP study involved contacting Puget Sound Basin jurisdictions to identify "candidate" bioretention facilities to be recommended for an overall list of facilities for evaluation and possible selection of a set of ten facilities for performance monitoring. The selected sites would then be monitored for inflow and outlflowing stormwater flows during Phase II. Additional site data would also be collected for groundwater and ponding levels, bioretention soil mix composition and infiltration rate, subsurface soil conditions, and vegetation composition and density as supporting information to evaluate the site performances.

Outreach to Jurisdictions, and Candidate Sites Identified and Evaluated in the Field

Jurisdictions selected for contact for nomination of potential sites came from three different sources:

1. Jurisdictions indicating interest in the BHP study during the proposal phase of the Regional Stormwater Monitoring Program (RSMP)

2. Jurisdictions identified through the Ecology Water Quality Grant program as having funded construction of a bioretention facility as part of their grant funded project, and

3. Jurisdictions that contacted the consultant team as a result of group emails from the Stormwater Work Group, the APWA Stormwater Managers Committee, and from the NPDES Stormwater Permit Coordinators forum.

Approximately twenty jurisdictions were contacted through direct telephone contact with stormwater managers or related engineers and water quality specialists to discuss the BHP study, and their thoughts on possible candidate sites within their jurisdiction.

From these twenty jurisdictions, twenty-eight facilities were recommended for possible site evaluation. Site design plans (including planting plans), technical information reports (TIRs) and modeling information was gathered for most of these facilities. Twenty-four facilities were then visited in the field for final evaluation.

Because most of the sites contained multiple cells, each with their own conditions, the site visits for these twenty-three facilities resulted in evaluation of approximately seventy individual cells.

Attachment 1 provides a list of the final bioretention facilities assessed in the field, their location, and the jurisdiction contact for the project. Figure 1 provides a map of the distribution of these sites throughout the Puget Sound Basin.

Site Field Evaluation

After receipt of design drawings, TIRs, and hydrologic modeling results, each consultant discipline leader evaluated their background material before assessing each site in the field. Information then assessed in the field related to each of the main disciplines for selection of the sites:

- Accessibility of inflow and outflow locations for flow monitoring feasibility
- Contributing drainage area
- Qualitative soil media composition and soil probe depths
- Plant community composition, relative density, and apparent maintenance activity

Site Selection Criteria

A long list of site selection criteria was prepared to help evaluate candidate sites. These criteria identified factors that could affect the feasibility of monitoring, site logistics, or later assessment of the results of Phase II. This site selection criteria checklist was previously prepared and delivered to the City and Ecology.

While the criteria checklist provides an almost exhaustive list of items that could be considered in the site selection, the final realistic considerations were limited to those items identified as "fatal flaws" for selection. Once these factors were addressed, understandably, the accessibility of flow monitoring to attain accurate hydrologic results was almost exclusively the deciding factor. The remaining criteria checklist items were nonetheless useful as a checklist reminder of factors affecting site performance and additional data collection needs.

Separate from the criteria checklist, there was a need in both the selection of candidate sites, and sites finally recommended for monitoring, to be geographically well distributed in the Puget Sound Basin to provide a wide surficial geological, meteorological, and jurisdictional representation.

Compilation of Site Information and Recommended Sites for Monitoring

Attachment 2 provides spreadsheets of information on each site used to evaluate the site conditions and existing information for selection. The spreadsheet provides additional information to that listed in the Criteria Checklist compiled by each of the consultant team discipline leads. The spreadsheets cover the disciplines of monitoring access, geotechnical conditions, hydrologic modeling background and vegetation conditions.

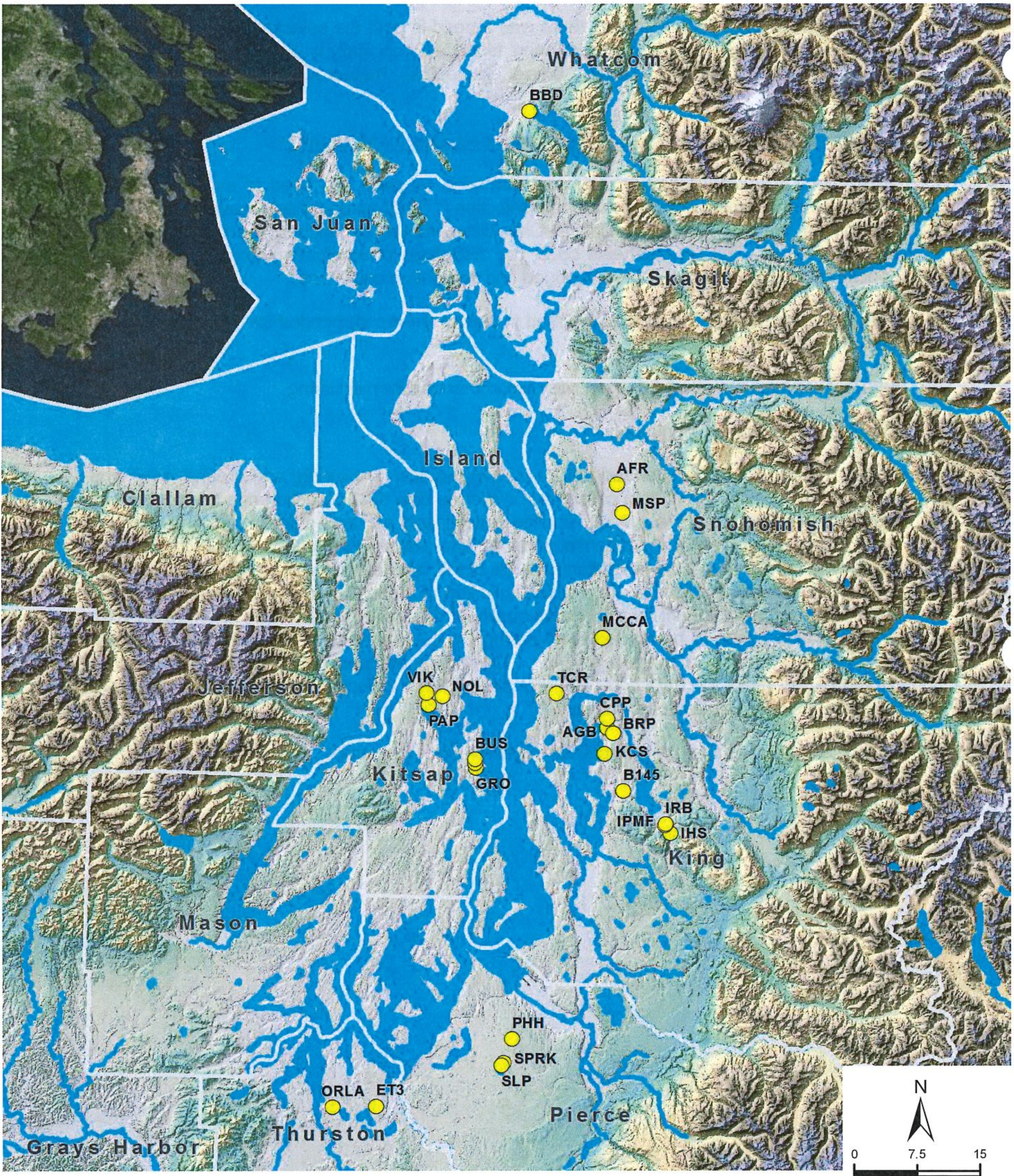
With this spreadsheet, the sites highlighted in yellow are recommended for monitoring, with a total of 10 sites highlighted.

Figure 2 provides a map of these ten sites recommended for monitoring.

Seasonal Schedule for Monitoring

Phase II of the project is intended for conducting the flow monitoring, and ground water and surface water pooling level data collection. While the flow data collection can be storm event targeted data, the ground water and pooling water levels are best collected on a continuous basis during the course of a substantial portion of the wet season to help use the continuity of these data to help reveal the infiltration patterns of the facilities, and to reflect those patterns in the model calibration process. As a result, initiation of these data collection early enough in the wet season is important for the overall quality of the model results. The storm event data collection also needs to be started early enough in the wet season to attain collection of at least storm events of a range of sizes. Of course the uncertainty of the wet weather conditions will affect the data collection, but starting data collection by some time in January would be the latest effective time to start.

If you have any questions, please call Bill Taylor or Doug Beyerlein.



REFERENCE:

NOTE: BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION.

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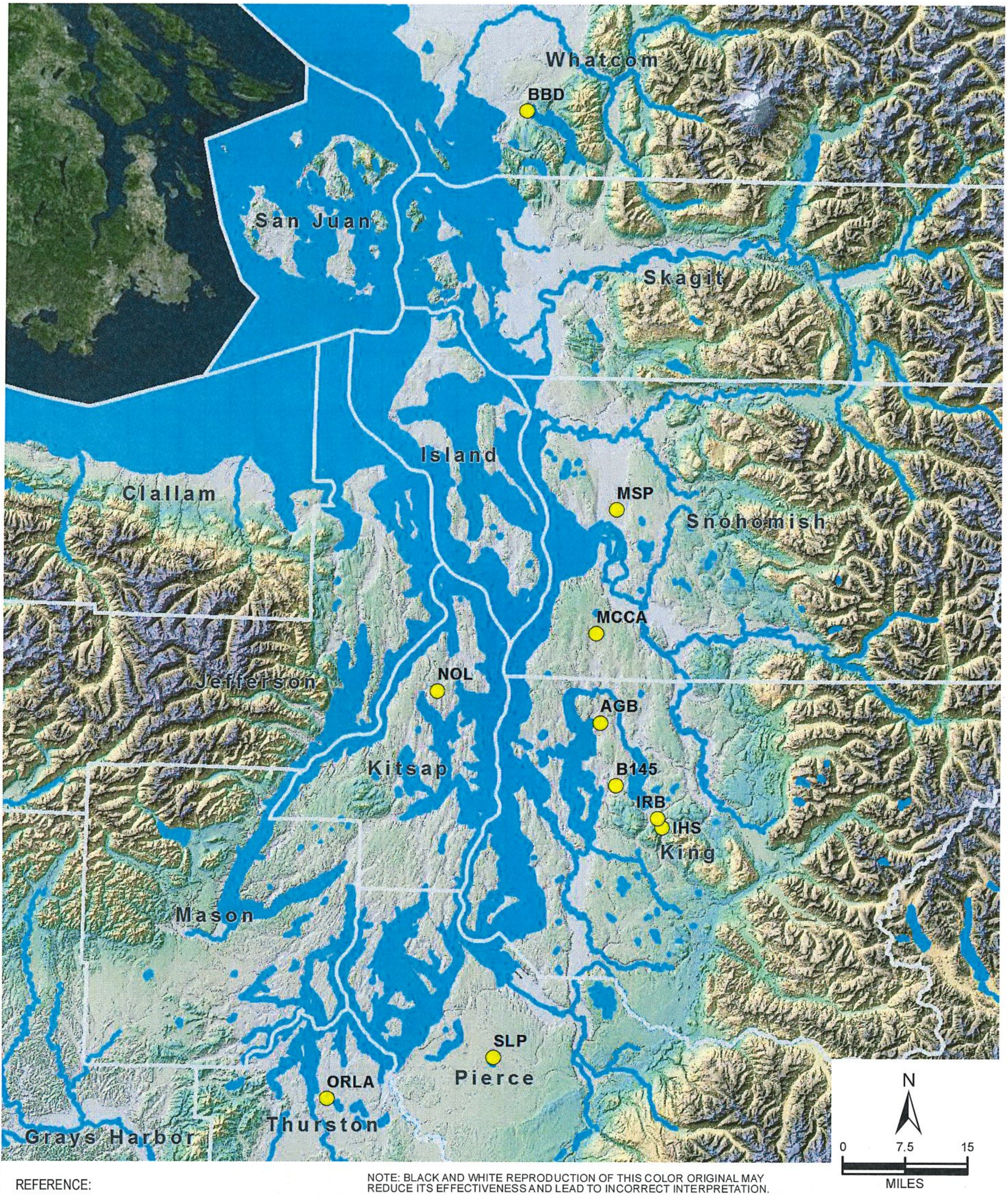
BIORETENTION SITES ASSESSED

BIORETENTION HYDROLOGIC PERFORMANCE MONITORING STUDY
PUGET LOWLAND, WASHINGTON

FIGURE 1

DATE 10/15

PROJ. NO. KH150387A



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BIORETENTION SITES SELECTED

BIORETENTION HYDROLOGIC PERFORMANCE MONITORING STUDY
PUGET LOWLAND, WASHINGTON

FIGURE 2
DATE 10/15
PROJ. NO. KH150387A

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Attachment 1. List of candidate bioretention monitoring sites visited and assessed for selection as a site to be monitored during Phase II of the BHP study. Sites highlighted in yellow are selected for monitoring in Phase II.

Jurisdiction	Project Name	Location	Contact Name	Contact Phone
Bainbridge Island	Bainbridge Isl. High School	Bus Barn NE1/4 SE1/4 S22, T25N R2E	Melva Hill	206-780-3724
Bainbridge Island	Bainbridge Isl. High School	200 Building 9330 NE High School Rd.	Melva Hill	206-780-3724
Bainbridge Island	Grow Community	280 Madison Avenue N.	Melva Hill	206-780-3724
Bellevue	145th Place SE	145th Place SE & SE 22nd Street	Rick Watson	425-452-4896
Bellingham	Bloedell Donovan Park	2214 Electric Avenue	Bill Reilly	360-778-7955
Kirkland	AG Bell	11212 NE 112th St	Kelli Jones	425-587-3855
Kirkland	Benjamin Ryan Short Plat-Lot 1	10220 124th Avenue NE	Kelli Jones	425-587-3855
Kirkland	Cedar Park	112th Avenue NE	Kelli Jones	425-587-3855
Kirkland	Kirkland Children's School	5311 108th Avenue NE	Kelli Jones	425-587-3855
Issaquah	Rainier Blvd. LID Phase II	Rainier Boulevard and NW Holly Street	Kerry Ritland	425-837-3410
Issaquah	Park Maintenance Facility	525 1st Avenue NW	Kerry Ritland	425-837-3410
Issaquah	Issaquah High School	700 2nd Avenue SE	Kerry Ritland	425-837-3410
Marysville	Art Investments Res. Devel.	51st Ave NE & 83rd Street NE	Brooke Ensor	360-363-8288
Marysville	Armed Forces Reserve Center	13613 40th Avenue NE	Brooke Ensor	360-363-8288
Mill Creek	MC Community Association Bldg	15524 Country Club Dr.	Mary Ann Heine	425-316-3344
Olympia	ORLA School	12th Avenue SE & Boulevard Rd SE	Jake Lund	360-753-8152
Pierce County	Spanaway Lake Park	14905 Bresemann Blvd S.	Dawn Anderson	253-798-4671
Pierce County	Woods at Golden gibbon	104th and Golden Gibbon	Dawn Anderson	253-798-4671
Poulsbo	Anderson Parkway	Anderson Pkwy & NE Lincoln Rd	Anja Hart	360-394-9753
Poulsbo	Noll Roundabout	Lincoln Rd & Noll Rd	Anja Hart	360-394-9753
Poulsbo	Viking Ave	between SR 305 & New Finn Hill Rd	Anja Hart	360-394-9753
Shoreline	N Fork Thornton Creek	multiple sites	Uki Dele	206-801-2451
Thurston County	Evergreen Terrace III	9th Ave & Torrey	Steve Johnson	360-867-2332

Site Information for Monitoring Assessment

BHP Phase I
Site Selection

Monitoring

Yellow = 1st Choice

					Ability to monitor Inflow				Location of nearby rain gauge		Number of inlets and outlets (fewer better)			Type of inlets and outlets (piped or weir preferred)		Underdrain	Hydraulic head available	Near other sites		Availability of current or previous monitoring data at site? Y/N	Stability of inlet and outlet control	Site security for installation of monitoring equipment?		
	AESI KMZ Label	Jurisdiction	Site	Arbitrary Site numbering (in order visited)	Can inflow be easily monitored; 1 = Yes; 0 = No	Can inflow be monitored with simple modifications; 1 = Yes; 0 = No or Not applicable	Accessibility (especially for outflow to monitor (see above) Y/N	Owner staff available to initiate monitoring equipment? Y/N	Rain gauge location very representative of site rainfall? Y/N	Owner staff available to conduct good maintenance/data? Y/N	One primary inlet? Y/N	Multiple inlets? 1-10	Can temp. retrofit for calibration monitoring then remove? Y/N	Piped, weir, or sheet flow?	Can be temporarily retrofitted for calibration monitoring	is underdrain accessible for monitoring	Range is head space for access - can counter sink? 1-10	Inproved efficiency by nearness to other sites? 1-10	Owner staff available for multiple site support? Y/N	Quality of data? 1-10	Hard structures better than soft (grass channel). 1-10	Good/poor site security? 1-10	Monitoring Comments	Comments
1	BRP	Kirkland	Ben Ryan Short Plat (3 cells)	1	1	0	Y	?	?	?	Y	1	Y	Piped in and out	Y	NA	limited, inlet is right at cell bottom, likely submerges	?	?	NA	1	1	4" inlet would need 6" stub for thelmar. Inlet is right on cell floor so likely inundates, good in that one thelmar for inlet, 1 for outlet	underconstruction; upper RG in till, middle in wx till, lower filled with BSM
2	AGB	Kirkland	Alex.Graham Bell Elem. School (2 cells)	2	1	0	Y	?	N	NA	N	5 in #3, 4 in #4	Y	piped in and out	Y	Y	Y	2 cells on same property	?	NA	1	1	6" roof inlets, 6" underdrain, 8" outlets, no sheet flow, would need to use roof runoff for inflow or else monitor multiple inlets	good access, need geotech
3	CPP	Kirkland	Cedar Park Short Plat (several cells)	3	0	1	No outflow	N	?	?	Y	1	Y	curb cut	Y	NA	good head space, edge of curb cut is 3" above cell bottom and 3" below street level	?	N	NA	1	exposed but quiet cul de sac	Only curb cuts, small drainage areas, would need separate transducer to know if cell was full and bypassing	good access, heavily maintained; compacted by foot traffic
4	KCS	Kirkland	Kirkland Children's School (1 cell)	4	1	0	Y	?	?	?	N	2 inlets 4" roof and 8" pipe	Y	piped	Y	NA	OK, inlets are above cell floor	?	?	NA	1	good, behind fence and hidden in brush	4" roof drain need 6" stub, two 8 " thelmars, access only during school hours	poor access
5	B145	Bellevue	145th Bellevue (3 cells)	5	1	0	Y	N	?	?	Y-for RG1 and RG2	1	Y	piped	Y	NA	Y inlet pipes high enough above cell botttom	N	?	need to look	1	pretty exposed, could hide some but would need to harden installation	RG1 and RG2 good with single inlet and single outlet, RG3 has multiple inlets, exisitng float switch installed in RG2 and 3 to record overflows?	good access, check for mon data; need AMEC geotech report
6	GRO	Bainbridge	Grow Community (several cells)	6	0	0	Y	?	?	?	N	11 curb cuts	N	sheet	Y	Y	Y	?	?	NA	riprap cuts	exposed out of the way	too many curb cuts, erosion on inlets, missing outlet control structure at time of visit	Unk geotech
7	BHS	Bainbridge	High School (several cells)	7	?	1-need to clear brush	Y	?	?	?	Y	1-2 area, footing or roof drains	Y	piped	Y	Y	? Couldn't fin inlet pipes	N	N	?	1	exposed on school property	couldn't find inlets, need sheet C-302 to more thoroughly review upper cells.	Geotech report not provided
8	BUS	Bainbridge	Bus Barn (2 cells)	8	0	0	Y	?	?	?	N	yes very convoluted		both and	maybe	Y	Y	?	?	NA	mix of grass and pipe	1	very complicated, couldn't find some pipes. Not a good site unless last resort	Unk geotech
9	NOL	Poulsbo	Noll Roundabout (1 cell)	9	1	0	Y	?	?	?	Y	1	Y	Piped	Y	Y	Y	N	?	?	1	5-exposed but could hide somewhat	inlet and outlet both 12" and close enough to share single datalogger.	Unk geotech
10	VIK	Poulsbo	Viking Ave (several linked cells)	10	0	0	Y	?	?	?	N	1 pipe, long sheet flow stretch	N	pipe and sheet	sheet=no	Y	Y	?	?	?	1	poor but could maybe hide stuff in brush	long sheet flow stretch, single outlet pipe. 1 inlet pipe too. Too much sheet flow and multiple cells chained together by single underdrain pipe	Non-standard BSM; geotech rpt did not address infiltration;
11	PAP	Poulsbo	Anderson Pkwy (Lined)	11	NOT APPLICABLE																			Shallow gw at 6-8' bgs, tidally influenced; geotech rpt did not address infiltration;
12	TCR	Shoreline	Thornton Creek Retrofit (several cells)	12	0	0-would require interception pipe and spreader	Y	N	?	?	N	sheet	N	sheet through gravel	N	Y	Y	Y	?	?	N	poor	only sheet flow through gravel shoulders, would require installation of interception and spreader pipes=look elsewhere	17 bioretention cells; used Ecology '05 manual grain size to est infiltration rate
13	SLP	Pierce County	Spanaway Lake Park (9 cells)	13	0	1	Y for Cell J, NA for cell I	Y	Y	?	2 for J, 1 for I	2 for J, 1 for I	Y	curb cuts	Y	NA	Y	Y if doing both sites	?	NA	3-some spall could rerode	poor	puplic park-could only temporarily install equipment for targeted events. Use tarp to funnel water to 6 or 8 inche thelmar	Spanaway Lake level expression of water table
14	PHH	Pierce County	Habitat for Humanity (several cells)	14	0	1	Y	N	?	?	Y	1	Y	piped roof drain	Y	NA	Y	?	?	NA	1	poor	no outlet, small roof drains only, would need to retrofit drain from4" to 6" for thelmar. No cover but in neighborhood	Standing water present in nearby excvation; looks like glacial till exposed
15	ORLA	Olympia	ORLA (several cells)	15	1	0	Y-could hide it well	?	?	?	N	4 roof drains	Y	Piped	Y	Y	Y	N	?	?	1	outlet very secure, inlet less so	could monitor each inlet a few times to dial in roof drainage/rainfall, outlet is easy, underdrain is lower to promote infiltration	bioretention -> gravel trenches-> infiltration trenches -> pond
16	ET3	Olympia	Evergreen Terrace Phase 3 (several cells)	16	0	0	no outflow just lots of curb cuts and not a good site																	no drainage or geotech report
17	IRB	Issaquah	Ranier Blvd LID Phase II (4 cells)	17	0	1	Y	?	?	?	N	2 curb cuts	Y	curb cut in piped out	Y	NA	Y	?	?	NA	1	poor	would need to tarp and pipe both curb cuts, could secure monitoring box ot sidewall and put themlar in outlet, NE facitlity only	based on MW's; proximity to Issaquah Ck; field rates lower than average for some
18	IPMF	Issaquah	Parks Maintenance FacilityRetrofit (1 cell)	18	0	0	Y	?	?	?	N	4 pipes and many curb cuts	N	pipe and sheet	N	NA	Y	?	?	?	loose sheet flow areas with erosion	good	too many inlets	expect shallow gw; likely lateral flow issues
19	IHS	Issaquah	Issaquah High School Cell #24 (24 cells)	19	1	0	Y	N	?	N	N	2	Y	piped	Y	Y	Y	?	N	NA	Y	good	easy to hide in dense brush	AESI currently monitors surface water level and shallow ground water level
20	AFR	Marysville	AFRC	20	1	0	Y	?	?	?	N	3	Y	piped in, ditch out	Maybe	NA	Y	?	?	?	inlet yes, outlet no	poor	would need to install weir or flume in outlet ditch or tarp and pipe	
21	MSP	Marysville	Residential	21	1	0	Y	?	?	?	Y	1	Y	pipe	Y	No overflow	Y	?	?	?	1	ok, could hide behind fence	1 inlet pipe, overflow sturcture goes into 3 underdrain pipes.	
22	MCCA	Mill Creek	Mill Creek Community Association (MCCA)	22	0	1	NA	?	?	?	N	2-maybe 1 inlet and one out	Y	piped	Y	NA	Y	N	?	NA	1	marginal, quiet area	1 4 in roof drain, another pipe tied to parking lot, not sure if it is inlet or outlet	
23	BBD	Bellingham	Bloedel Donovan Park	23	0	1	Y	Y	Y	Y	N	2	Y	curb cut, pipe out	Y	NA	Y	N	Y	some data exists, not sure how much	Y	OK, could hide most in brush or in CB	2 curb cuts in, overflows to 8" pipe out, outlet may have slight backwater issues, City notes that isde overflow also occurs, may need to sandbag	
24	SPRK	Pierce Cty (Park/ Span)	Sprinker Parking Lot LID Retrofit	Did not visit per Dawn at Pierce County																				no drainage or geotech report; MGS mdl 30 iph, dtw of 15 ft

Site Information for Geotechnical Assessment

IP Phase I
Site Selection
Yellow = 1st Choice

Geotech

	AESI KMZ Label	Jurisdiction	Site	Geotech	CF	Geology	Explorations	Inf Test Type	Hydrogeo	BSM rate < Native iph	Estimated Construction	Site Visit Date	Comments
1	BRP	Kirkland	Ben Ryan Short Plat (3 cells)	Geo-resources	4.76 or 0.21	Till	TP/HA	EPA FH	B1	NO	Aug-15	8/27/15	underconstruction; upper RG in till, middle in wx till, lower filled with BSM
2	AGB	Kirkland	Alex.Graham Bell Elem. School (2 cells)	Unk	NA	Till	Unk	None	B2	NO	2013	8/27/15	good access, need geotech
3	CPP	Kirkland	Cedar Park Short Plat (several cells)	Earth Consultg	Yes	Rec. OW	TP/HA	Unk	AX	YES	2010	8/27/15	good access, heavily maintained; compacted by foot traffic
4	KCS	Kirkland	Kirkland Children's School (1 cell)	Terra		Adv. OW	TP/HA	EPA FH	CX	YES	Sep-13	8/27/15	poor access
5	B145	Bellevue	145th Bellevue (3 cells)	Herrera and AMEC	None	unk (likely thin Till over Qva)	TP	PIT (3'x3')	CX	NO	2012?	8/27/15	good access, check for mon data; need AMEC geotech report
6	GRO	Bainbridge	Grow Community (several cells)	Unk		Likely Till	Unk	Unk	B2 like	Unk		9/1/15	Unk geotech
7	BHS	Bainbridge	High School (several cells)	Krazan (rpt missing)	NA	Till	Unk	None	B2	NO		9/1/15	Geotech report not provided
8	BUS	Bainbridge	Bus Barn (2 cells)	Unk		unk - Till likely	Unk	Unk	B2 like	Unk		9/1/15	Unk geotech
9	NOL	Poulsbo	Noll Roundabout (1 cell)	Unk	None	unk - Till likely	Unk	None (D10 est)	B2	NO		9/1/15	Unk geotech
10	VIK	Poulsbo	Viking Ave (several linked cells)	Krazan (foundations only)	None	unk - Till likely	B	None (D10 est)	B2	NO		9/1/15	Non-standard BSM; geotech rpt did not address infiltration;
11	PAP	Poulsbo	Anderson Pkwy (Lined)	Landau (for seawall)	Unk	Unk - Fill likely	B	None (D10 est)	E	NO		9/1/15	Shallow gw at 6-8' bgs, tidally influenced; geotech rpt did not address infiltration;
12	TCR	Shoreline	Thornton Creek Retrofit (several cells)	HWA	yes, varies	Sandy Till to Qva	B	None (D10 est)	BX/CX	NO		(BT and BB only)	17 bioretention cells; used Ecology '05 manual grain size to est infiltration rate
13	SLP	Pierce County	Spanaway Lake Park (9 cells)	None	2 to 4	Rec. OW Steilacoom	Unk	None	AX	NO		9/9/2015	Spanaway Lake level expression of water table
14	PHH	Pierce County	Habitat for Humanity (several cells)	Unk	Unk	unk - Till likely	Unk	Unk	B2 like	Unk		9/9/2015	Standing water present in nearby excvation; looks like glacial till exposed
15	ORLA	Olympia	ORLA (several cells)	ICI	Yes	Rec. OW Sand	TP/B	None (D10 est)	A2	YES	2014?	9/9/2015	bioretention -> gravel trenches-> infiltration trenches -> pond
16	ET3	Olympia	Evergreen Terrace Phase 3 (several cells)	Unk		Rec. OW Sand	Unk	Unk	AX	Unk	Approved June 2010	9/9/2015	no drainage or geotech report
17	IRB	Issaquah	Ranier Blvd LID Phase II (4 cells)	GeoDesign	0.18	Recent Alluvium	B/HA	EPA FH	D1	NO	Est. Sum 2014	9/16/2015	based on MW's; proximity to Issaquah Ck; field rates lower than average for some
18	IPMF	Issaquah	Parks Maintenance FacilityRetrofit (1 cell)	South Fork Geosciences	0.25	Recent Alluvium	TP	Small Scale PIT	D1	NO	Est. Sum 2014	9/16/2015	expect shallow gw; likely lateral flow issues
19	IHS	Issaquah	Issaquah High School Cell #24 (24 cells)	AESI		Outwash	TP	PIT	A1	NO	Summer 2010	9/16/2015	AESI currently monitors surface water level and shallow ground water level
20	AFR	Marysville	AFRC	AESI		Rec. OW Sand	TP/B	PIT	A1			BT, BK, CW 9/18/2015	
21	MSP	Marysville	Residential									BT, BK, CW 9/18/2015	
22	MCCA	Mill Creek	Mill Creek Community Association (MCCA)										
23	BBD	Bellingham	Bloedel Donovan Park										
24	SPRK	Pierce Cty (Park/ Span)	Sprinker Parking Lot LID Retrofit	Unk		Rec. OW Steilacoom	Unk	Unk	A2	YES	Stamped Oct'10	Did not visit	no drainage or geotech report; MGS mdl 30 iph, dtw of 15 ft

Site Information for Modeling Assessment

BHP Phase I
Site Selection
Yellow = 1st Choice

Modeling

	AESI KMZ Label	Jurisdiction	Site	Design Manual	Model	Underdrains	Liner	Overflow	BSM Rate	BSM b	BSM n	Subgrade Design Rate	TIR Civil	Comments
1	BRP	Kirkland	Ben Ryan Short Plat (3 cells)	KC'09	MGS Fld v.4.12	No	No	Yes	2	1	40	RG#1, 0.21 and RG#2-#3, 0.42	Larson and Assoc.	underconstruction; upper RG in till, middle in wx till, lower filled with BSM
2	AGB	Kirkland	Alex.Graham Bell Elem. School (2 cells)	KC'09	MGS Fld v.4.12	Yes	No	Yes	1	1.5	30	0	CPL	good access, need geotech
3	CPP	Kirkland	Cedar Park Short Plat (several cells)	KC'98	KCRTS	No	No	No	1	1	?	1 iph	Blueline Group	good access, heavily maintained; compacted by foot traffic
4	KCS	Kirkland	Kirkland Children's School (1 cell)	KC'09	MGS Fld	No	No	Yes	1	1.5	40	2	CPH	poor access
5	B145	Bellevue	145th Bellevue (3 cells)	COB'10 (Ecology'05)	WWHM3 Pro	No	No	Yes	2.5	2	40	RG#3 1.3 iph; rate used for RGs, no CF	Herrera (RK)	good access, check for mon data; need AMEC geotech report
6	GRO	Bainbridge	Grow Community (several cells)			Yes	No	Yes	1	1.5 to 2		unk?	Browne Wheeler	Unk geotech
7	BHS	Bainbridge	High School (several cells)	Ecology '05	MGS Fld 3.1	Yes	No	Yes	1	1.5		Nil	CPL	Geotech report not provided
8	BUS	Bainbridge	Bus Barn (2 cells)			Yes	No	Yes						Unk geotech
9	NOL	Poulsbo	Noll Roundabout (1 cell)	WSDOT '08; Ecology '05	WWHM3 Pro	Yes	No	Yes	2	1.5	40	0.5	Parametrix	Unk geotech
10	VIK	Poulsbo	Viking Ave (several linked cells)	WSDOT '08; Ecology '05	WWHM3 Pro	Yes	No	Yes	2	2	40	0.5	Parametrix	Non-standard BSM; geotech rpt did not address infiltration;
11	PAP	Poulsbo	Anderson Pkwy (Lined)	Ecology '05, '12	WWHM	Yes	YES	Yes				initial 2 iph in '09; 2012 plan set shows pvc liner	Parametrix	Shallow gw at 6-8' bgs, tidally influenced; geotech rpt did not address infiltration;
12	TCR	Shoreline	Thornton Creek Retrofit (several cells)	Ecology '05	MGS Fld v.4.29								Perteet	17 bioretention cells; used Ecology '05 manual grain size to est infiltration rate
13	SLP	Pierce County	Spanaway Lake Park (9 cells)		WWHM	No	No		1.5 to 3	2		set equal to BSM;	Pierce County	Spanaway Lake level expression of water table
14	PHH	Pierce County	Habitat for Humanity (several cells)	Unk	Unk	Not seen in field	Unk	Unk	Unk	Unk	Unk	Unk	Unk	Standing water present in nearby excvation; looks like glacial till exposed
15	ORLA	Olympia	ORLA (several cells)	City of Olympia '09	WWHM v4	No	No	Yes	1.5	1.5		varies	LPD	bioretention -> gravel trenches-> infiltration trenches -> pond
16	ET3	Olympia	Evergreen Terrace Phase 3 (several cells)		Unk	No	No	No	Unk	1.5	Unk	Unk	Unk	no drainage or geotech report
17	IRB	Issaquah	Ranier Blvd LID Phase II (4 cells)	City of Issaquah '11 (KC'09)	WWHM v4 and KCRTS Flow Control	No but geotech rec'd	No	Unk - check	Unk	1.5	Unk	field rate of 2.8 iph x 0.18 = 0.5 iph	KPG	based on MW's; proximity to Issaquah Ck; field rates lower than average for some
18	IPMF	Issaquah	Parks Maintenance FacilityRetrofit (1 cell)	City of Issaquah '11 (KC'09)	WWHM v3	No	No	Yes	Unk	1.5	Unk	average rate of 5.7 iph x 0.25 = 1.425 iph	City of Issaquah	expect shallow gw; likely lateral flow issues
19	IHS	Issaquah	Issaquah High School Cell #24 (24 cells)	City of Issaquah '11 (KC'09)		No	No	No	1.5	1.5	40	greater than BSM	CPL	AESI currently monitors surface water level and shallow ground water level
20	AFR	Marysville	AFRC	Ecology '05		No	No							
21	MSP	Marysville	Residential											
22	MCCA	Mill Creek	Mill Creek Community Association (MCCA)		WWHM3	No	No	???		1	40		Harmsen & Associates	
23	BBD	Bellingham	Bloedel Donovan Park											
24	SPRK	Pierce Cty (Park/ Span)	Sprinker Parking Lot LID Retrofit		MGS Fld	No	No	No	Unk	2.5	Unk	30	Unk	no drainage or geotech report; MGS mdl 30 iph, dtw of 15 ft

Site Information for Vegetation Assessment

BHP Phase I
Site Selection
Yellow = 1st Choice

Vegetation

	AESI KMZ Label	Jurisdiction	Site	Planting Plan	Herbaceous (H) or Woody (W) Vegetation or Both	Percent Cover	Comments
1	BRP	Kirkland	Ben Ryan Short Plat (3 cells)	No	Zone 1- H		underconstruction; upper RG in till, middle in wx till, lower filled with BSM
2	AGB	Kirkland	Alex.Graham Bell Elem. School (2 cells)	Yes	Back Cell -W Front cell W, H	Back Cell -90-95% Front cell 75%	good access, need geotech
3	CPP	Kirkland	Cedar Park Short Plat (several cells)	Yes	1st Cell in Series-W	50%	good access, heavily maintained; compacted by foot traffic
4	KCS	Kirkland	Kirkland Children's School (1 cell)	No	Zone 1- H Zone 2- W	90%	poor access
5	B145	Bellevue	145th Bellevue (3 cells)	Yes	Cell #1 -H (Zone 1) Cell #2- H (Zone 1) Cell #3- H (Zone 1)	Cell #1 -70% Cell #2-65% Cell #3- 90%	good access, check for mon data; need AMEC geotech report
6	GRO	Bainbridge	Grow Community (several cells)	Yes	W	50%	Unk geotech
7	BHS	Bainbridge	High School (several cells)	No	Circular Cell-W, H Entry Cell- W Lower & Upper Cells Courtyard-Zone 1-H Front Cell- W, H	Circular Cell-70 % Entry Cell- 80 % Lower & Lower Cells Courtyard-80% Front Cell-90%	Geotech report not provided
8	BUS	Bainbridge	Bus Barn (2 cells)	No	Cell Adj to Road-H Cell # 2- W, H	Cell Adj to Road- 80% Cell #2- 60%	Unk geotech
9	NOL	Poulsbo	Noll Roundabout (1 cell)	No	W, H	70%	Unk geotech
10	VIK	Poulsbo	Viking Ave (several linked cells)	Yes	W	80%	Non-standard BSM; geotech rpt did not address infiltration;
11	PAP	Poulsbo	Anderson Pkwy (Lined)		NA (lined)		Shallow gw at 6-8' bgs, tidally influenced; geotech rpt did not address infiltration;
12	TCR	Shoreline	Thornton Creek Retrofit (several cells)		Did not Visit		17 bioretention cells; used Ecology '05 manual grain size to est infiltration rate
13	SLP	Pierce County	Spanaway Lake Park (9 cells)	Yes	Cell J- W Cell I- W, H	Cell J- 60% Cell I- 90 %	Spanaway Lake level expression of water table
14	PHH	Pierce County	Habitat for Humanity (several cells)	No	H	50-70%	Standing water present in nearby excvation; looks like glacial till exposed
15	ORLA	Olympia	ORLA (several cells)	No	Basin 1B- H Basin 2B- H Side yard Cells- H	Basin 1B- 60 % Basin 2B- 70 % Side yard Cells-100%	bioretention -> gravel trenches-> infiltration trenches -> pond
16	ET3	Olympia	Evergreen Terrace Phase 3 (several cells)	No	H	(mowed lawn	no drainage or geotech report
17	IRB	Issaquah	Ranier Blvd LID Phase II (4 cells)	Yes	SW Corner Cell- H SE Corner Cell-H	SW Corner Cell- 50% SE Corner Cell-70%	based on MW's; proximity to Issaquah Ck; field rates lower than average for some
18	IPMF	Issaquah	Parks Maintenance FacilityRetrofit (1 cell)	Yes	H	50%	expect shallow gw; likely lateral flow issues
19	IHS	Issaquah	Issaquah High School Cell #24 (24 cells)	No	Maint. Area Cell-	int. Area Cell-	AESI currently monitors surface water level and shallow ground water level
20	AFR	Marysville	AFRC	No	H	80%	
21	MSP	Marysville	Residential	No	H	90%	
22	MCCA	Mill Creek	Mill Creek Community Association (MCCA)	No	East Cell- H West Cell- H	East Cell- 70% West Cell-80%	
23	BBD	Bellingham	Bloedel Donovan Park	No	Boat Launch Cell-W Entry Cell-W	Boat Launch Cell- 75% Entry Cell-85%	
24	SPRK	Pierce Cty (Park/ Span)	Sprinker Parking Lot LID Retrofit				no drainage or geotech report; MGS mdl 30 iph, dtw of 15 ft

Acronyms Used in Attachment Spreadsheets

KC: King County
TIR: Techical Information Report
COB: City of Bellevue
b: soil thickness in feet
n: soil porosity in percent
CF: correction factor, when applied to field infiltration rate
Rec. OW: recessional outwash
Adv. OW: advance outwash
EPA FH: Environmental Protection Agency Falling Head
TP/HA: test pits/hand augers
B: exploration boring

Hydrogeo Category

AX: recessional outwash, no underdrain, ground water depth unknown
A1: recessional outwash, no underdrain, ground water within 10 feet
A2: recessional outwash, no underdrain, ground water greater than10 feet
BX: glacial till, unknown underdrain configuration
B1: glacial till, no underdrain
B2: glacial till, underdrained
CX: advance outwash, no underdrain, ground water depth unknown
C1: advance outwash, no underdrain, ground water within 10 feet
C2: advance outwash, no underdrain, ground water greater than10 feet
DX: recent alluvium, no underdrain, ground water depth unknown
D1: recent alluvium, no underdrain, ground water within 10 feet
D2: recent alluvium, no underdrain, ground water greater than10 feet
E: other

APPENDIX 2

Bioretention Hydrologic Performance Study - Hydrologic Monitoring Results. Aspect Consulting. 6/26/18

CLEAR CREEK SOLUTIONS

CLEAR CREEK SOLUTIONS, INC.

15800 Village Green Drive #3
Mill Creek, WA 98012
425-225-5997
www.clearcreeksolutions.com

MEMORANDUM

DATE: 26 June 2018

TO: Eli Mackiewicz, Engineering Technician, City of Bellingham

CC: Bill Taylor, Principal Investigator

FROM: Doug Beyerlein, P.E., Hydrology Lead and Project Manager

SUBJECT: Bioretention Hydrologic Performance Phase II Deliverable 5.2 Hydrologic Modeling Results

For Task 5 of the Bioretention Hydrologic Performance Phase II we have completed Deliverable 5.2 – Hydrologic Modeling Results.

Modeling Procedures

The field monitoring provided information that was used as part of the WWHM2012 model input for each of the ten bioretention sites.

The hydrologic monitoring data collection (previously discussed) provided time series data for rainfall, inflow, overflow, groundwater, and ponding at 5-minute intervals for use in the individual site models. Each data time series was copied into (imported into) the individual site model's data base for later use in either the model's calculations (rainfall data) or comparison with the model's results (inflow, overflow, groundwater, and ponding data).

The geotechnical data collection provided information about the bioretention soil mix found at each of the ten bioretention sites and the native soil infiltration rate, as measured on-site. Because these bioretention sites were designed and constructed before a standard bioretention soil mix was specified by Ecology it was not expected that any of the soil mixes would meet a specific standard. However, their general soil characteristics, as they related to water movement, provided guidance in the selection of appropriate engineered soil mixes for each of the ten bioretention sites. The native soil infiltration rate was also used in the same way to determine the appropriate infiltration value to include in each model. As will later be discussed, there were sites were groundwater mounding influenced the native soil infiltration rate during the winter months and the input infiltration value was adjusted accordingly to represent these high groundwater periods.

The vegetation data collection was not used directly in the input to the individual site models. However, its potential impact on the hydrologic performance of each site was considered in terms of leaf litter impact on ponding and water infiltrating into the top bioretention soil layer. Also, vegetation influences evapotranspiration from the soil layer. WWHM2012 assumes a standard evapotranspiration rate from the soil that may be dependent based on the type and amount of vegetation.

The other field monitoring data collected for use in the individual bioretention site models were the dimensions of the bioretention facility (length, width, maximum depth of ponding) and the outlet control structure(s), if any. The size of each facility was field measured and compared with design drawings, if available. The elevation of the inlets, outlet riser or weir, and the top of the facility were surveyed. The underdrain elevation and outlet diameter was also measured for the one site (Noll Road) that had an active underdrain.

All of the above field data were used in one way or another in either the WWHM2012 model input for each of the ten bioretention sites or evaluating the model output.

Data Analysis and Results

Modeling Comparison of Observed versus Design Results

Summary

The hydrologic performance of the ten early-design (pre-2012 Ecology manual) bioretention facilities was well represented by WWHM2012. The range in performance in terms of ponding depths and well point elevations met or exceeded the expected WWHM2012 model graphical results comparison with the monitored data more often than not.

In general, the WWHM2012 models of the ten bioretention sites reproduced the monitored bioretention hydrologic performance data with good results when viewing the long-term graphical trends. Good results are defined as periods where the simulated results match closely with the recorded (monitored) data and other periods where the simulated results are sometimes high and sometimes low. There is no obvious bias high or low.

Based on all of the above modeling results it appears that there are two major model inputs that may be influencing the results. The vegetative litter cover noted in the two Spanaway sites may be reducing the infiltration of the ponded water into the bioretention soil mix. Except for SLPI and SLPJ this vegetative litter cover was not explicitly modeled.

The other major model input that may be influencing the results is the evapotranspiration (ET) from the bioretention soil mix. It is set in WWHM2012 to equal 0.5*PET (Potential ET). There is evidence from the well point data that the 0.5 multiplier factor should be higher. That will help to remove water faster from the bioretention soil mix layer.

At this time, based on the bioretention modeling completed for this study, we do not recommended any changes in the Ecology bioretention sizing criteria.

Site Characteristics

The field collected data, described in the previous section, was used to provide input data in the construction of the individual WWHM2012 models of each bioretention site. These data are summarized in Table 1 below.

Table 1. Site General Information

Site	Drainage Area (ac)	Top Area (ft2)	Bottom Area (ft2)	Bottom to Drainage Percentage	Overflow Height (ft)	Modeled Depth (ft)	Native Soil Infiltration (in/hr)	Underdrain
B145	0.494	1600	470	2%	0.4	4.5	9	Yes(1)
BDP	0.8	550	550	2%	0.9	3.6	0.2	No
IHS	2.01	3207	1080	1%	2.5	10.7	60	Yes(2)
MCCA1	0.01	804	299	69%	0.3	1.5	0.04	No
MCCA2	0.142(3)	747	286	5%	0.4	3.4	2	No
ORLA1	0.4	3180	2100	12%	0.67	3.4	23	Yes(3)
ORLA2	0.338	3664	1924	13%	0.52	1.3	4	Yes(3)
NOLL	0.679	4567	520	2%	1.13	2.6	0.01	Yes
SLPI	0.429	1810	792	4%	1.0	2.4(4)	40	No
SLPJ	0.618	2066	1008	4%	0.6	2.6(4)	60	No

Notes:

(1) The underdrain is capped and currently not used.
(2) The underdrain leads to an infiltration gallery and does not discharge to a surface outlet.
(3) The drainage area includes 5400 square feet of drainage from the adjacent permeable pavement parking lot that was not monitored.
(4) The underdrain leads to a gravel trench and does not discharge to a surface outlet.
(5) The modeled depth includes 0.3 feet of surface leaf litter.

The drainage area is the area that contributes runoff to the bioretention site. For each bioretention facility this information was taken from design reports and drawings, if available. Where there was a question about the drainage area it was field checked. For three of the sites (BDP, IHS, and MCCA2) the drainage area in the model was modified to more accurately reflect either measured inflows or ponding depths.

The bottom area is the bottom footprint of each of the bioretention cells. The bottom area is calculated from the field survey information. Most of the bioretention sites had a flat bottom area and sloping sides. The side slopes were calculated based on the difference in bottom and top lengths and widths and bioretention cell heights.

The bottom to drainage percentage is the relative size of the bioretention bottom area to the contributing drainage area. The larger the percentage the larger the bioretention area is to the surrounding area that drains to it. MCCA1, which drains just a portion of the adjacent MCCA Building roof, has the largest percentage at 69%. The proportionally large size of the MCCA1 bottom area relative to the roof area compensates for the very slow native soil infiltration rate. Most of the sites have percentages in the 1-5% rate. This is more typical for a bioretention site and reflects the designer's desire to minimize the size of the bioretention cell.

The overflow height is the height (depth) from the bioretention soil surface to an overflow. The overflow may be a riser inlet, weir, or lowest spot on the side of the bioretention facility. When the ponding depth reaches this height then water can flow out of the bioretention cell via surface discharge (the other ways that water can flow out are by infiltrating into the native soil or discharging through an underground underdrain).

The modeled depth is the total soil depth modeled in the individual WWHM2012 models. This modeled depth typically includes two modeled soil layers. The top modeled soil layer (Layer 1) is the bioretention soil mix (BSM). The second modeled soil layer (Layer 2) is the soil layer below the BSM soil mix (Layer 1) and above the bottom of the monitored well point. Layer 2 was included in each model to provide a subsurface water depth/height that can be compared with the monitored well point data. For the two Spanaway sites (SLPI and SLPJ) a third modeled soil layer was added. For these two sites only a top layer (Layer 1) was added above the BSM layer to represent the effect of leaf litter in reducing the water movement into the BSM layer (which in these models is Layer 2). Details of the composition of the modeled depth in each bioretention site are presented in Table 2 below.

Native soil infiltration (inches per hour) for each site was initially based on the infiltration tests conducted as part of the geotechnical field measurements. Through the modeling process some of the native soil infiltration rates were adjusted to compensate for the effects of seasonal high groundwater or groundwater mounding that reduced the ability of water to move vertically through the modeled soil layers and into the underlying native soils.

An underdrain is a set of pipes in the bottom of the bioretention facility that collect water and discharge it through an outlet control structure. Typically underdrains are connected to a storm sewer system. Underdrains are used where it appears that the native soil infiltration rate is insufficient to remove all of the water from the bioretention cell and there is a potential for surface ponding to overtop the facility and flood surrounding properties. Underdrains can prevent this from happening. Most of the ten sites do not have underdrains and most or all of the water infiltrates into the native soil. Three sites (B145, IHS, and NOLL) have underdrains, but only NOLL has an underdrain that provides surface discharge. This surface discharge (outflow) was both monitored and modeled.

Table 2 provides information on the modeled soil layers in each bioretention model.

Table 2. Modeled Soil Layer Information

Site	Layer 1 Soil	Layer 1 Depth (ft)	Layer 2 Soil	Layer 2 Depth (ft)	Layer 3 Soil	Layer 3 Depth (ft)	Native Soil Infiltration (in/hr)
B145	ASTM15	1.6	ASTM4	2.9	None	0	9
BDP	ASTM15	1.7	Gravel	1.9	None	0	0.2
IHS	ASTM9	1.6	ASTM35	9.1	None	0	60
MCCA1	ASTM4	0.8	ASTM4	0.7	None	0	0.04
MCCA2	ASTM1	1.0	ASTM12	2.4	None	0	2
ORLA1	ASTM2	1.3	ASTM24	2.1	None	0	23
ORLA2	ASTM2	1.3	ASTM24	5.0	None	0	4
NOLL	ASTM60	1.5	Gravel	1.1	None	0	0.01
SLPI	ASTM2	0.3	ASTM50	1.7	Gravel	0.4	40
SLPJ	ASTM2	0.3	ASTM60	1.9	Gravel	0.4	60

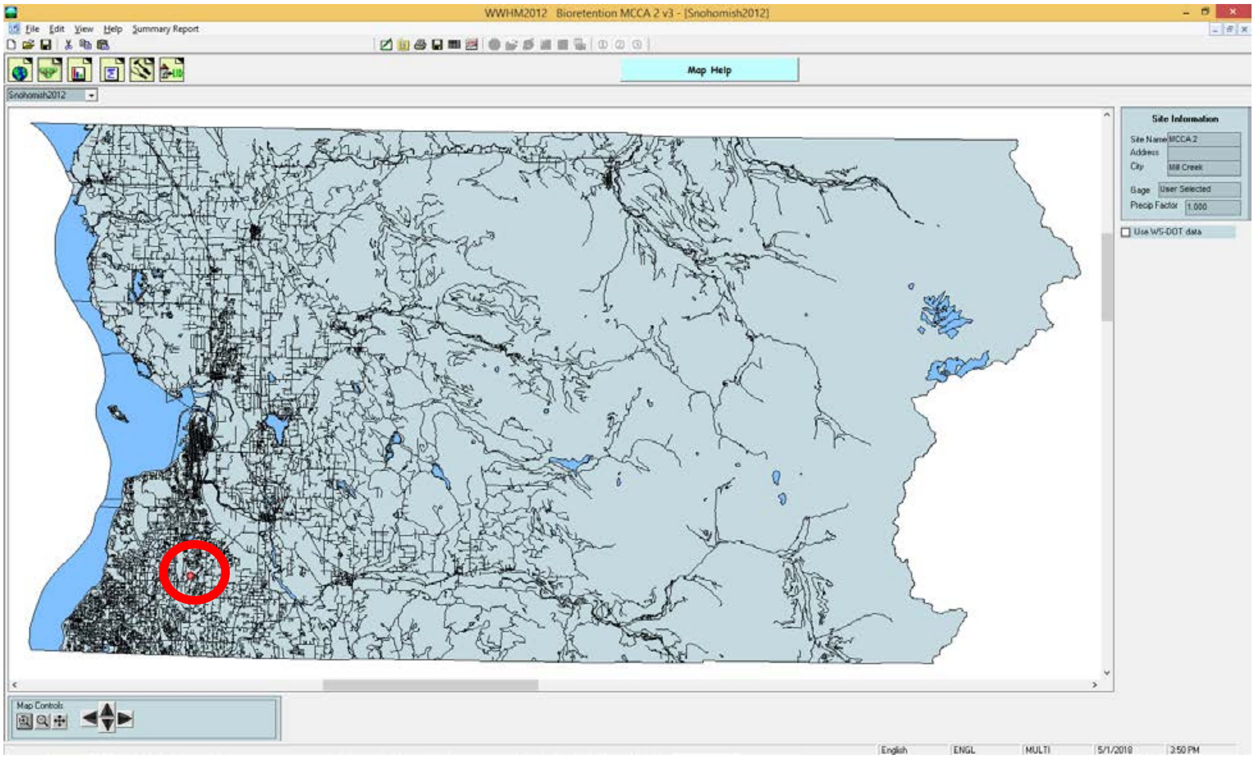
As described above, the modeled depth is the total soil depth modeled in the individual WWHM2012 models. The modeled soil depth is composed two or more individual soil layers.

For each model (except the two Spanaway models) Layer 1 represents the bioretention soil mix (BSM) type and depth. The Layer 1 depth is the depth or thickness of the BSM, as measured in the geotechnical field work. The actual Layer 1 soil mix was initially unknown, but could be determined by comparing the monitored and modeled surface pond depths and soil water depths. WWHM2012 provides the soil input parameter values for the Ecology-standard bioretention soil mix, but all of these sites were designed and constructed before that standard mix was required. WWHM2012 also provides soil input parameter values for a range of ASTM (American Society for Testing and Materials) soils. For the purposes of hydrologic modeling the ASTM number specification (for example, ASTM15) refers to the saturated conductivity value (15 inches per hour for ASTM15).

Layer 2 is not necessarily an engineered bioretention soil mix soil. Layer 2 is the soil layer below the BSM soil mix (Layer 1) and above the bottom of the monitored well point. Layer 2 was included in each model to provide a subsurface water depth/height that can be compared with the monitored well point data. For the two Spanaway sites (SLPI and SLPJ) a third modeled soil layer was added. For these two sites only a top layer (Layer 1) was added above the BSM layer to represent the effect of leaf litter in reducing the water movement into the BSM layer (which in these models is Layer 2). Layer 2 soils were typically found to have different saturated conductivity values than the Layer 1 BSM soils.

WWHM2012 Model Construction

A separate WWHM2012 model was constructed for each of the ten bioretention sites. The bioretention site was located on the appropriate WWHM2012 project site map (see Figure 1 for an example).

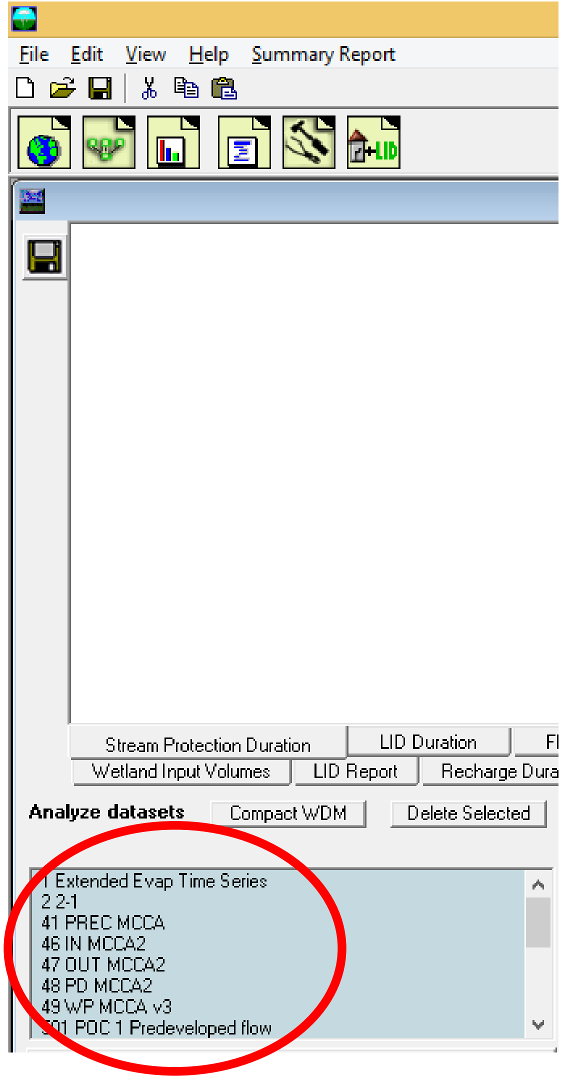


Site Name MCCA 2
Address
City Mill Creek
Gage User Selected
Precip Factor 1.000
☐ Use WS-DOT data

Figure 1. WWHM2012 Project Site (MCCA2) in Snohomish County

The MCCA2 bioretention site is located at the red dot in the center of the red circle in Snohomish County.

For each model the corresponding monitored 5-minute data were imported into the specific model's data base file (HSPF WDM file), as shown in Figure 2.



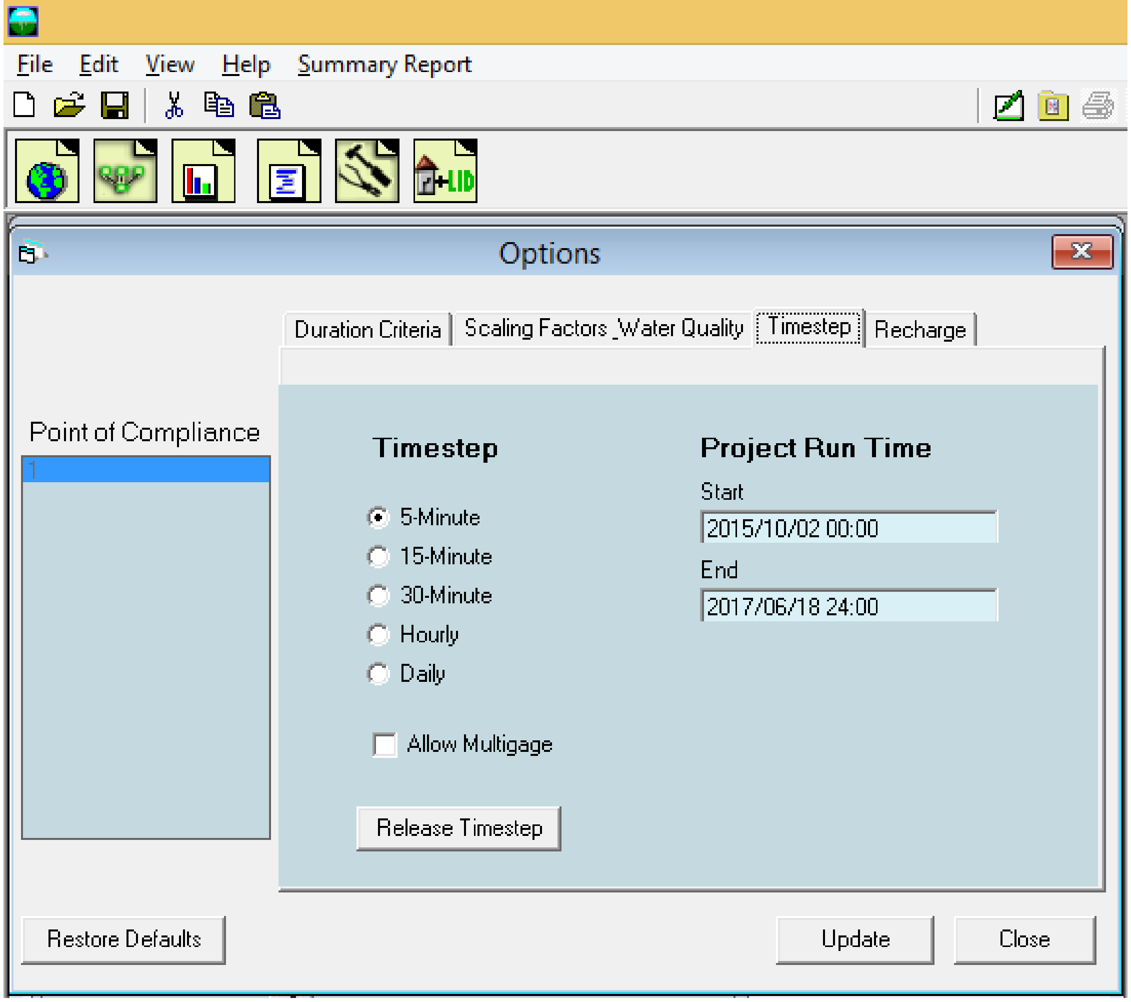
1 Extended Evap Time Series
2 2-1
41 PREC MCCA
46 IN MCCA2
47 OUT MCCA2
48 PD MCCA2
49 WP MCCA v3
501 POC 1 Predeveloped flow

Figure 2. WWHM2012 Time Series Data

Each monitored data set is given a unique data set number (DSN), as shown in Figure 2.

For MCCA2 the monitored 5-minute precipitation time series is data set number 41; the monitored inflow is DSN 46; the monitored outflow is DSN 47; the pond depth is DSN 48; and the well point depth is DSN 49. These monitored time series will be used to compare and evaluate the model results.

The model simulation period time step and start and end dates were changed from the default WWHM2012 simulation values. These changes were made by going to View, Options, Timestep (see Figure 3). The WWHM2012 default time step was changed from 15 minutes to 5 minutes because all of the monitored data were collected in 5-minute intervals. The WWHM2012 simulation start and end dates were changed to run from 1 October 2015 through the end of the data collection period (typically June or July 2017). The monitored data did not actually start until October 2016, but the model simulation period was started a year earlier to provide a start-up period for the simulation. The model results were compared with the monitored data only for the period of October 2016 through June/July 2017.



Timestep

● 5-Minute
○ 15-Minute
○ 30-Minute
○ Hourly
○ Daily

☐ Allow Multigage

Project Run Time

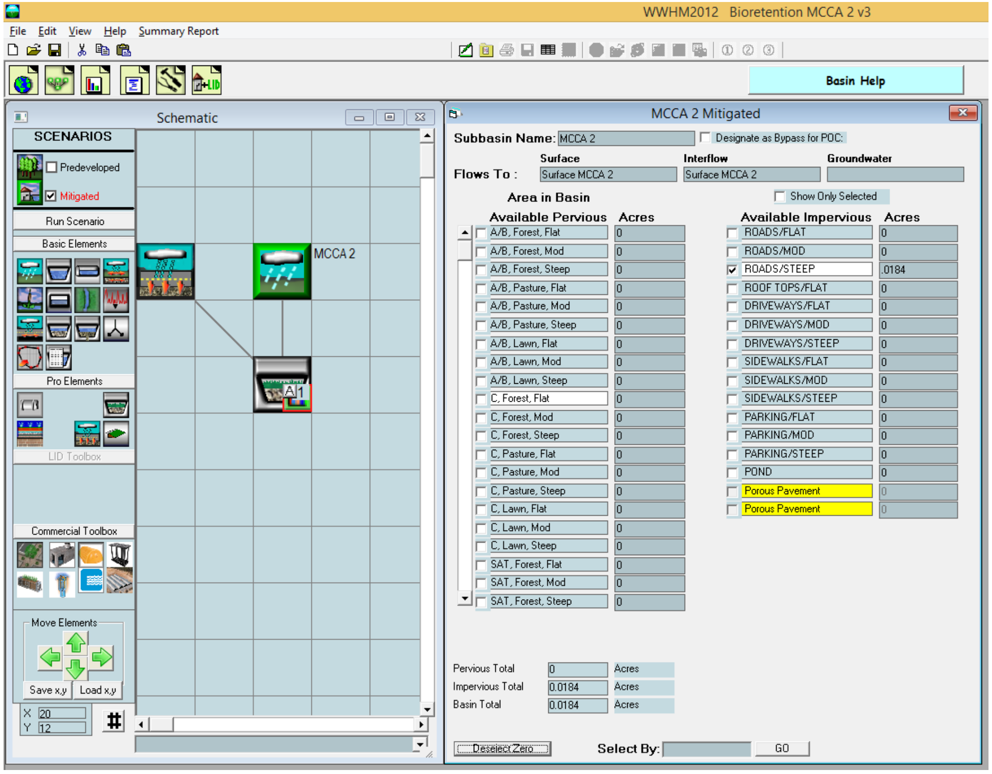
Start
2015/10/02 00:00

End
2017/06/18 24:00

Figure 3. WWHM2012 Simulation Time Step and Start and End Dates (for MCCA2)

The contributing drainage area for each bioretention facility was determined from design reports and drawings, if available. Where there was a question about the drainage area it was field checked, as described above. The specific acreages were input to each WWHM2012 model using the WWHM2012 Land-use element (see Figure 4). For the MCCA sites (both MCCA1 and MCCA2) the MCCA Building roof area was designated as “Roads/Steep” instead of “Roof Tops/Flat” because this roof has a slope greater than 15 percent and the only roof option is for a flat (<5%) roof. The “Roads/Steep” designation better represents the roof’s actual hydrologic behavior than “Roof Tops/Flat”.

For the MCCA2 site the WWHM2012 Permeable Pavement element was also added to the model to represent runoff from the adjacent permeable pavement parking lot (Figure 5).



☐ Predeveloped
☑ Mitigated

X 20
Y 12

Subbasin Name: MCCA 2 ☐ Designate as Bypass for POC:

	Surface	Interflow	Groundwater
Flows To :	Surface MCCA 2	Surface MCCA 2	

Area in Basin ☐ Show Only Selected

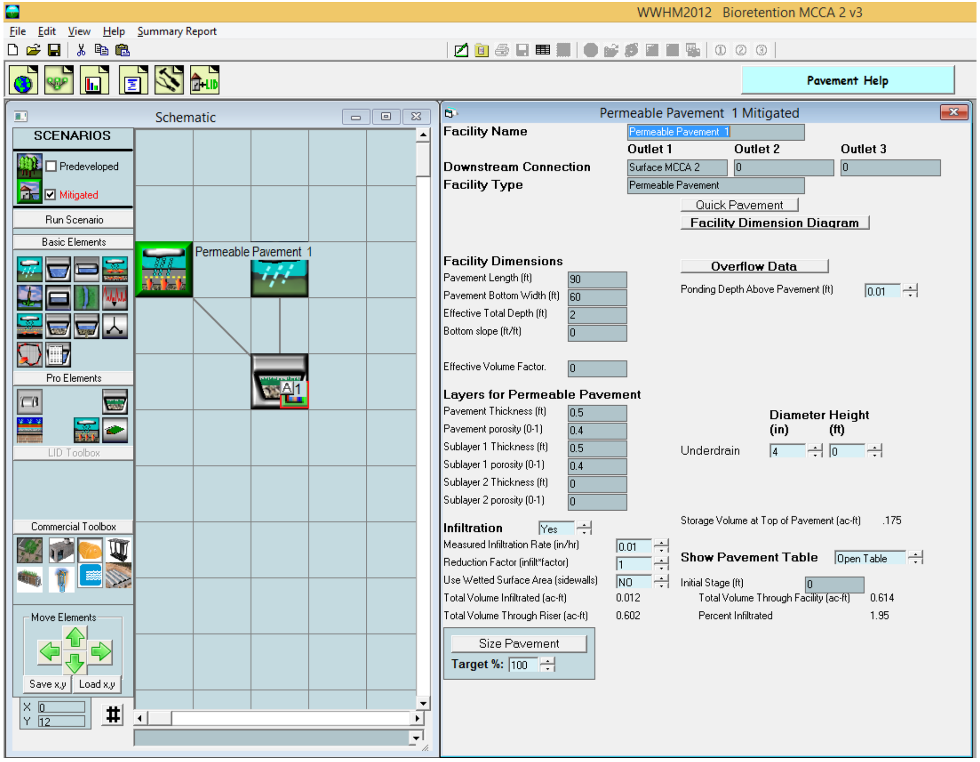
Available Pervious	Acres
☐ A/B, Forest, Flat	0
☐ A/B, Forest, Mod	0
☐ A/B, Forest, Steep	0
☐ A/B, Pasture, Flat	0
☐ A/B, Pasture, Mod	0
☐ A/B, Pasture, Steep	0
☐ A/B, Lawn, Flat	0
☐ A/B, Lawn, Mod	0
☐ A/B, Lawn, Steep	0
☐ C, Forest, Flat	0
☐ C, Forest, Mod	0
☐ C, Forest, Steep	0
☐ C, Pasture, Flat	0
☐ C, Pasture, Mod	0
☐ C, Pasture, Steep	0
☐ C, Lawn, Flat	0
☐ C, Lawn, Mod	0
☐ C, Lawn, Steep	0
☐ SAT, Forest, Flat	0
☐ SAT, Forest, Mod	0
☐ SAT, Forest, Steep	0

Available Impervious	Acres
☐ ROADS/FLAT	0
☐ ROADS/MOD	0
☑ ROADS/STEEP	.0184
☐ ROOF TOPS/FLAT	0
☐ DRIVEWAYS/FLAT	0
☐ DRIVEWAYS/MOD	0
☐ DRIVEWAYS/STEEP	0
☐ SIDEWALKS/FLAT	0
☐ SIDEWALKS/MOD	0
☐ SIDEWALKS/STEEP	0
☐ PARKING/FLAT	0
☐ PARKING/MOD	0
☐ PARKING/STEEP	0
☐ POND	0
☐ Porous Pavement	0
☐ Porous Pavement	0

Pervious Total	0	Acres
Impervious Total	0.0184	Acres
Basin Total	0.0184	Acres

Select By:

Figure 4. WWHm2012 Land-use Element



☐ Predeveloped
☑ Mitigated

X 0
Y 12

Facility Name: Permeable Pavement 1

	Outlet 1	Outlet 2	Outlet 3
Downstream Connection	Surface MCCA 2	0	0
Facility Type	Permeable Pavement		

Facility Dimensions
Pavement Length (ft) 90
Pavement Bottom Width (ft) 60
Effective Total Depth (ft) 2
Bottom slope (ft/ft) 0

Effective Volume Factor. 0

Ponding Depth Above Pavement (ft) 0.01

Layers for Permeable Pavement
Pavement Thickness (ft) 0.5
Pavement porosity (0-1) 0.4
Sublayer 1 Thickness (ft) 0.5
Sublayer 1 porosity (0-1) 0.4
Sublayer 2 Thickness (ft) 0
Sublayer 2 porosity (0-1) 0

	Diameter (in)	Height (ft)
Underdrain	4	0

Storage Volume at Top of Pavement (ac-ft) .175

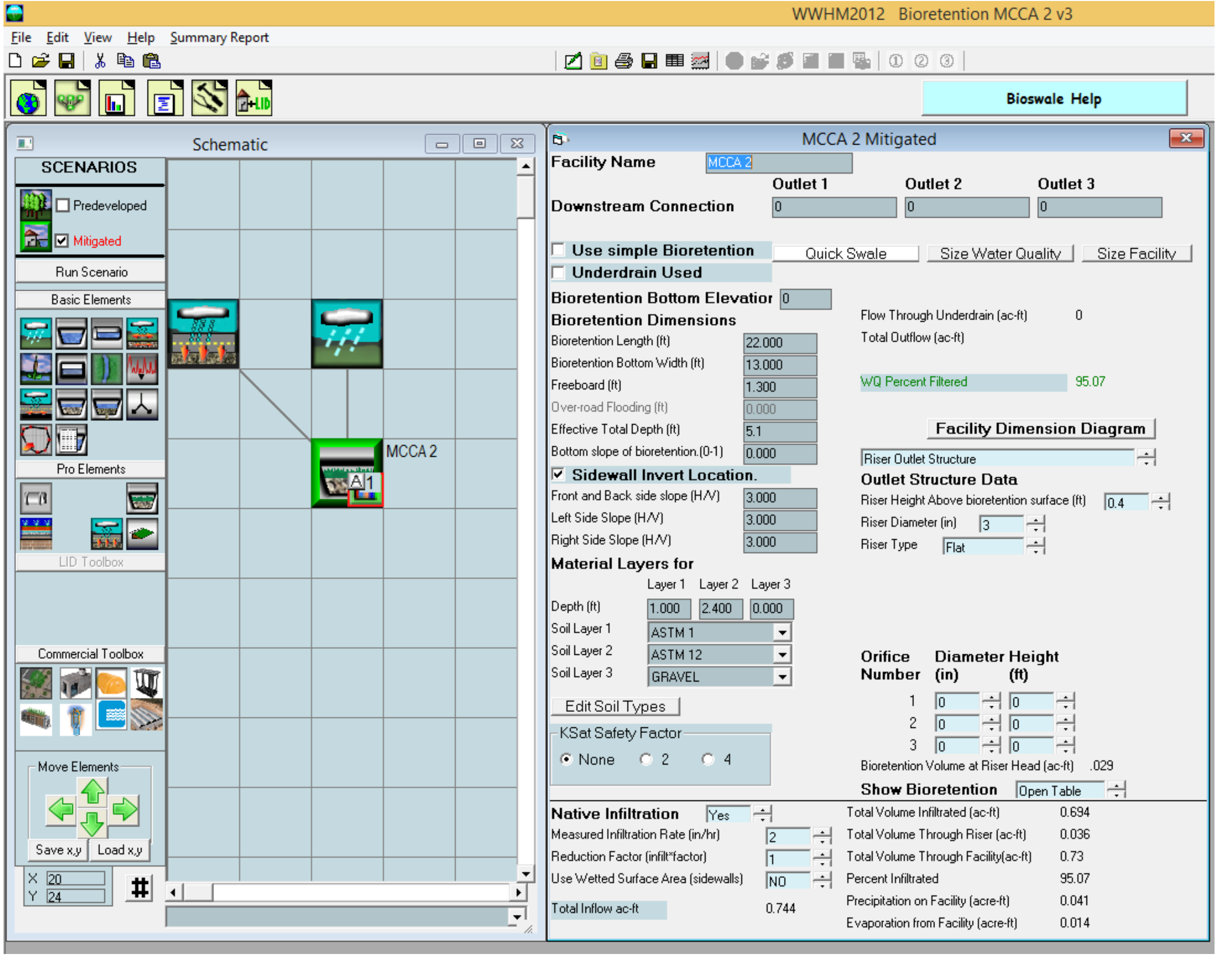
Infiltration Yes
Measured Infiltration Rate (in/hr) 0.01
Reduction Factor (infilt*factor) 1
Use Wetted Surface Area (sidewalls) NO
Total Volume Infiltrated (ac-ft) 0.012
Total Volume Through Riser (ac-ft) 0.602

Show Pavement Table: Open Table
Initial Stage (ft) 0
Total Volume Through Facility (ac-ft) 0.614
Percent Infiltrated 1.95

Target %: 100

Figure 5. WWHM2012 Permeable Pavement Element

The specific bioretention facility is represented in WWHM2012 by the Bioretention element and contains all of the user input for defining the dimensions and characteristics of the bioretention site. The reader is referred to the *WWHM2012 User Manual* for more details about the Bioretention element input and model calculations. The MCCA2 Bioretention element is shown in Figure 6.



X 20
Y 24

Facility Name: MCCA 2

	Outlet 1	Outlet 2	Outlet 3
Downstream Connection	0	0	0

☐ Use simple Bioretention
☐ Underdrain Used

Bioretention Bottom Elevatior 0

Bioretention Dimensions

Bioretention Length (ft) 22.000
Bioretention Bottom Width (ft) 13.000
Freeboard (ft) 1.300
Over-road Flooding (ft) 0.000
Effective Total Depth (ft) 5.1
Bottom slope of bioretention.(0-1) 0.000

☑ Sidewall Invert Location.

Front and Back side slope (H/V) 3.000
Left Side Slope (H/V) 3.000
Right Side Slope (H/V) 3.000

Material Layers for

	Layer 1	Layer 2	Layer 3
Depth (ft)	1.000	2.400	0.000

Soil Layer 1 ASTM 1
Soil Layer 2 ASTM 12
Soil Layer 3 GRAVEL

KSat Safety Factor: ● None ○ 2 ○ 4

Flow Through Underdrain (ac-ft) 0
Total Outflow (ac-ft)
WQ Percent Filtered 95.07

Riser Outlet Structure

Outlet Structure Data

Riser Height Above bioretention surface (ft) 0.4
Riser Diameter (in) 3
Riser Type Flat

Orifice Number	Diameter (in)	Height (ft)
1	0	0
2	0	0
3	0	0

Bioretention Volume at Riser Head (ac-ft) .029

Show Bioretention Open Table

Native Infiltration Yes
Measured Infiltration Rate (in/hr) 2
Reduction Factor (infilt*factor) 1
Use Wetted Surface Area (sidewalls) NO
Total Inflow ac-ft 0.744

Total Volume Infiltrated (ac-ft) 0.694
Total Volume Through Riser (ac-ft) 0.036
Total Volume Through Facility(ac-ft) 0.73
Percent Infiltrated 95.07
Precipitation on Facility (acre-ft) 0.041
Evaporation from Facility (acre-ft) 0.014

Figure 6. WWHM2012 Bioretention Element (for MCCA2)

WWHM2012 Model Results

Two sets of WWHM2012 model results were generated and evaluated. For each site WWHM2012 was first set up to compare the model results with the monitored data. For the comparison of the model simulation results with the monitored/recorded data the primary focus was trying to match the simulated and recorded ponding depths and the simulated and recorded well point data. The ponding depths showed how the water ponded on the surface of the bioretention facility. The well point data showed how the water filled up the bioretention soil column. The ponding and well point data are linked. If the well point data shows that the bioretention soil column is completely saturated then water cannot drain from the surface into the bioretention soil and this causes water to pond on the surface. Water can also pond on the surface even if the soil column is not completely saturated if the inflow of water into the bioretention facility is greater than the infiltration into the top layer (Layer 1) of the bioretention soil mix.

At each site the specific bioretention soil mix was not known (this problem is discussed above). The infiltration rate into the native soil was known from the geotechnical field work, but could be different based on seasonal factors.

Each model was set up with a specific bioretention soil mix for each soil layer and an infiltration rate. These model inputs were then adjusted to produce the best match of the simulated ponding and well point results with the recorded data. Those final model inputs are shown in Table 3. The ponding depth plots and the well point plots are shown for each site in the Individual Bioretention Site Results discussion below.

The model inflow and outflow simulation results were also compared with the monitored inflow and outflow data, where available. A number of issues were found with the monitored inflow data. Specifically, there were numerous periods in December 2016 and January and February 2017 where because of freezing conditions and/or snow the monitored inflow data matched poorly with the monitored rainfall data. For this reason the inflow to the bioretention site was simulated from monitored rainfall data rather than using the monitored inflow data. This decision eliminated the possibility of any error in the monitored/recorded inflow data affecting the bioretention results. The simulated inflow volumes were plotted together with the recorded inflow data to identify inconsistencies. The comparison plot for each site is shown in in the Individual Bioretention Site Results discussion below.

For the majority of the bioretention sites there was no outflow. This was because all of the inflow to the bioretention site infiltrated into the native soil. Also, outflow, when it did occur, could be difficult to measure due to the outlet configuration.

Model results are presented in both statistical and graphical formats. The statistical format compares the model simulated versus recorded/monitored inflow data, pond depths, soil layer water content depths, and underdrain discharge volumes for the ten sites in terms of maximum values, minimum, mean, and standard deviation of the 5-minute data for the data collection period. For the statistical comparison periods where there were identified data collection problems (primarily due to freezing conditions and/or snow in December 2016, January 2017, and February 2017) were deleted from the statistical calculations.

The statistical results are shown in tables 3, 4, 5, and 6, below. Table 3 shows the maximum, minimum, mean, and standard deviation of the 5-minute data for monitored/recorded (R) and model simulated (S) bioretention site inflow results.

Table 3. Bioretention Site Inflow (cfs)

Site	MAX-R	MAX-S	MIN-R	MIN-S	MEAN-R	MEAN-S	STD DEV-R	STD DEV-S
B145	0.522	0.211	0.000	0.000	0.003	0.003	0.016	0.008
BDP	0.372	0.627	0.000	0.000	0.006	0.005	0.020	0.018
IHS	0.688	0.986	0.000	0.000	0.023	0.018	0.055	0.042
MCCA1	0.071	0.009	0.000	0.000	0.0003	0.0001	0.0014	0.0003
MCCA2	0.069	0.061	0.000	0.000	0.001	0.001	0.002	0.003
ORLA1	0.072	0.817	0.000	0.000	0.003	0.004	0.006	0.012
ORLA2	0.067	0.690	0.000	0.000	0.001	0.004	0.004	0.010
NOLL	0.139	0.287	0.000	0.000	0.001	0.004	0.005	0.011
SLPI	0.191	0.232	0.000	0.000	0.003	0.002	0.011	0.008
SLPJ	0.298	0.322	0.000	0.000	0.006	0.003	0.018	0.011

Table 4. Bioretention Site Pond Depth (feet)

Site	MAX-R	MAX-S	MIN-R	MIN-S	MEAN-R	MEAN-S	STD DEV-R	STD DEV-S
B145	0.52	0.45	-0.13	0.00	0.02	0.01	0.07	0.03
BDP	1.15	2.04	0.24	0.00	0.38	0.34	0.16	0.42
IHS	1.38	1.57	-0.15	0.00	0.04	0.01	0.12	0.06
MCCA1	0.08	0.08	-0.08	0.00	-0.010	0.0004	0.015	0.003
MCCA2	0.58	0.48	-0.15	0.00	0.15	0.02	0.14	0.07
ORLA1	0.08	0.38	-0.05	0.00	0.01	0.003	0.01	0.01
ORLA2	0.57	0.37	-0.17	0.00	0.01	0.004	0.02	0.01
NOLL	0.48	0.63	-0.07	0.00	0.04	0.01	0.08	0.03
SLPI	0.54	0.44	-0.08	0.00	0.02	0.003	0.04	0.02
SLPJ	0.63	0.52	-0.38	0.00	0.01	0.004	0.05	0.02

Table 5. Bioretention Site Well Point Depth (feet)

Site	MAX-R	MAX-S	MIN-R	MIN-S	MEAN-R	MEAN-S	STD DEV-R	STD DEV-S
B145	3.94	3.77	0.09	0.07	0.59	1.14	0.27	0.68
BDP	3.57	3.49	0.89	0.00	2.20	2.10	0.74	1.44
IHS	10.17	10.01	0.58	0.21	3.77	2.07	1.48	1.28
MCCA1	1.46	1.41	-0.22	0.00	0.48	0.34	0.14	0.29
MCCA2	2.78	2.97	-0.30	0.00	0.99	0.71	0.71	0.54
ORLA1	1.07	2.03	0.00	0.00	0.72	0.53	0.18	0.34
ORLA2	0.67	0.60	0.18	0.11	0.55	0.52	0.09	0.08
NOLL	1.98	1.55	1.29	0.00	1.45	0.21	0.08	0.19
SLPI	0.10	2.17	0.00	0.00	0.05	0.25	0.01	0.20
SLPJ	1.19	2.40	-0.07	0.00	-0.02	0.26	0.05	0.22

Table 6. Bioretention Underdrain Discharge (cfs) – NOLL Only

Site	MAX-R	MAX-S	MIN-R	MIN-S	MEAN-R	MEAN-S	STD DEV-R	STD DEV-S
NOLL	0.024	0.237	0.000	0.000	0.0001	0.004	0.001	0.011

The statistical comparisons do not necessarily match well. This can be for a number of reasons, as discussed in the individual site results below. As such, the statistical comparison of results can be misleading. What is more important is the ability to match trends rather than statistics. By looking at graphical trends we can visually see if the model provides the same trends in terms of inflow, ponding, and well point data as the monitored info. The statistics cannot show trends and therefore are less useful in evaluating the modeling results than the graphical comparisons.

A summary of the model graphical comparisons is presented in Table 7. The table presents a comparison of the model simulated versus recorded/monitored inflow data, pond depths, soil layer water content depths, and underdrain discharge volumes for the ten sites.

Table 7. Comparison of Model (S) versus Monitored (R) Results

Site	S vs R Inflow	S vs R Pond	S vs R Soil Layer	S vs R Underdrain
B145	Good*	Mixed	Good	N/A
BDP	Mixed	Good	Good	N/A
IHS	Mixed	Mixed	Good	N/A
MCCA1	Mixed	Good	Mixed	N/A
MCCA2	High**	Good	Mixed	N/A
ORLA1	High	Mixed	High	N/A
ORLA2	High	Low	Good	N/A
NOLL	High	Mixed	High	High
SLPI	Mixed	Mixed	High	N/A
SLPJ	Low	Mixed	High	N/A

* Good, expect for frozen conditions; ** High due to parking lot runoff

S vs R Inflow is the comparison of the simulated (S) inflow volume to the bioretention site compared to the monitored or recorded (R) inflow volume. The simulated inflow volume is calculated from the rainfall on the contributing drainage area to the bioretention site. The monitored inflow volume is calculated from the inflow measurements collected at specific input locations entering the bioretention site.

S vs R Pond is the comparison of the simulated (S) bioretention site surface ponding depths compared to the monitored or recorded (R) ponding depths.

S vs R Soil Layer is the comparison of the simulated (S) bioretention site subsurface soil layer water elevations compared to the monitored or recorded (R) well point data.

S vs R Underdrain is the comparison of the simulated (S) bioretention site underdrain outflow compared to the monitored or recorded (R) underdrain outflow.

The comparison categories of “Good”, “Mixed”, “High”, and “Low” are somewhat subjective, but are based on a total view of the comparison plot for each type of data. There is no statistical measure or test that can adequately represent the ability of the model results to reproduce the monitored data, due to missing data periods, weather problems related to freezing conditions, and timing issues. An evaluation of the results by a modeling professional takes these issues into account and allows for an unbiased opinion.

For this purposes of this comparison, “Good” is defined as a good overall match of the simulated and recorded data. Even if there is not an exact match, both sets of data follow the same trends and magnitudes.

“Mixed” is similar to “Good” but shows more variability. With “Mixed” some periods match well while other periods match poorly, but the simulated results are neither consistently high or low.

“High” means that the simulated results are consistently high. There may be a valid reason for this different between the simulated and recorded results, but regardless the difference is noticeable. “Low” is similar, but in the opposite direction (the simulated results are consistently low).

Further discussion of these graphical results and the comparison plots from which they were determined is presented below in the individual site modeling section of this report.

The second set of model results was based on the long-term county precipitation data. For each site the long-term (50 years or longer) precipitation record was used to generate long-term simulated ponding and outflow data. These simulated data were not compared against the monitored data, but were used to evaluate the individual bioretention’s site to meet Ecology minimum requirements #5 and #6.

Minimum Requirement #5 (MR#5) is the LID flow duration performance standard. MR#5 requires that flow durations between 8 percent of the 2-year flow (0.08Q2) and 50 percent of the 2-year flow (0.50Q2) do not increase above the predevelopment land use conditions. For each of these models the predevelopment land use was defined as forested. WWHM2012 provides the appropriate calculations to demonstrate compliance with MR#5.

Minimum Requirement #6 (MR#6) is the water quality performance standard. MR#6 requires that at least 91 percent of the total runoff volume be treated. Treatment in a bioretention facility consists of water movement through the bioretention soil mix. This treated water can then either infiltrated into the native soil or exit via an underdrain or both. Water that discharges through the surface outlet (riser or weir) is not treated. WWHM2012 provides the appropriate calculations to demonstrate compliance with MR#6.

Compliance with MR#5 and MR#6 is shown in Table 8.

Table 8. Minimum Requirement Compliance

Site	MR#5	MR#6
B145	Yes	Yes
BDP	No	No
IHS	Yes	Yes
MCCA1	Yes	Yes
MCCA2	Yes	Yes
ORLA1	Yes	Yes
ORLA2	Yes	Yes
NOLL	No	Yes
SLPI	Yes	Yes
SLPJ	Yes	Yes

All of the sites, except BDP and NOLL, pass the MR#5 LID flow duration criterion. BDP does not pass because of too many outlet overflows (see Individual Bioretention Site Results for details). NOLL does not pass because there is no flow constrictor (orifice) on the NOLL bioretention site underdrain and the underdrain flows exceed MR#5.

All of the sites pass the MR#6 water quality standard, except BDP. As with MR#5, BDP does not pass because too much of the bioretention discharge is surface discharge over the outlet weir. BDP does not have the needed 91% of the flow being treated by filtering through the bioretention soil mix.

Bioretention facilities can also be designed and constructed to meet Minimum Requirement #7 (MR#7). MR#7 is the stream protection flow control standard. MR#7 requires that flow durations between 50 percent of the 2-year flow (0.50Q2) and the 50-year flow (Q50) do not increase above the predevelopment land use conditions. While WWHM2012 provides the appropriate calculations to demonstrate compliance with MR#7, we did not evaluate the bioretention facilities for this compliance. This is because they did not have to be designed to meet this standard and to test them for compliance would be potentially misleading as to the effectiveness of their hydrologic performance. Specific compliance with MR#7 usually requires an orifice on the underdrain outlet and a riser designed specifically to control the release of high flows to meet MR#7. None of the ten bioretention facilities were observed to have these flow control features.

Individual Bioretention Site Results

Individual bioretention model results are discussed below. Each bioretention site has a unique set of characteristics that influenced the model set up and the comparison of model (simulation) results with the monitored (recorded) field data.

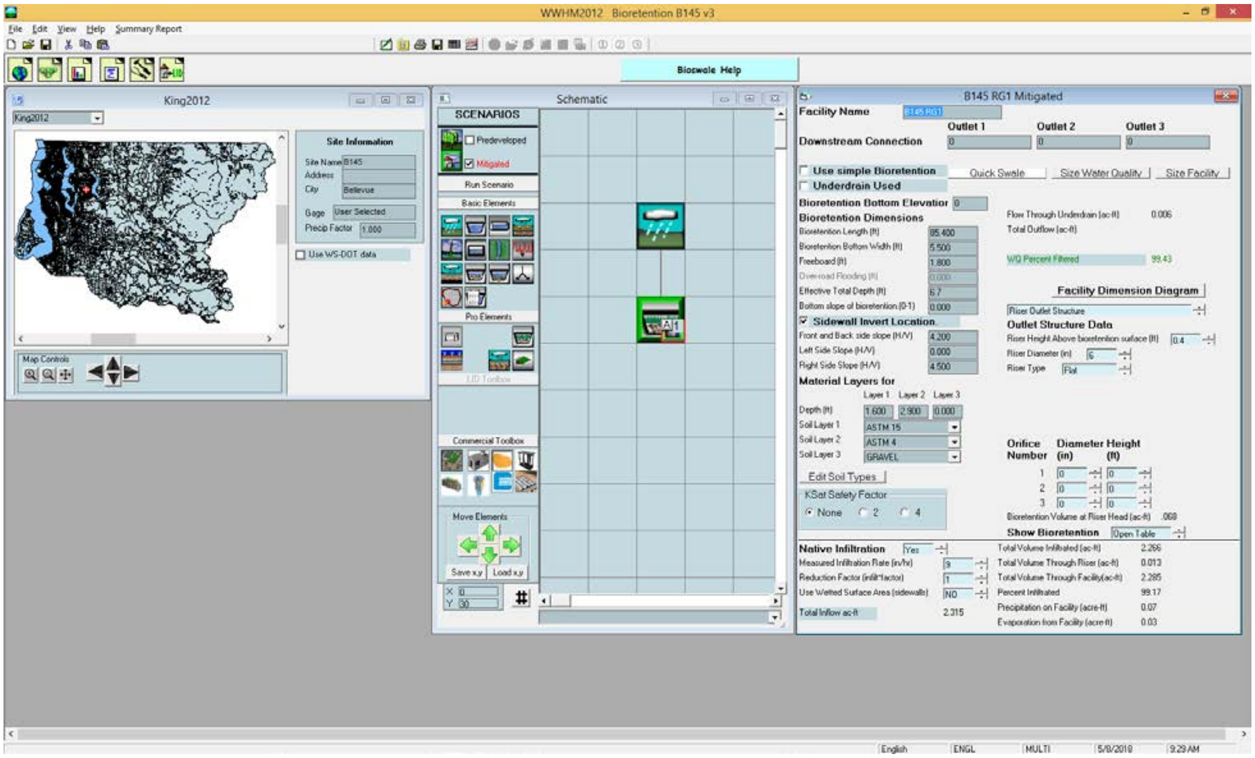
At each site the simulated and recorded daily inflow volumes are plotted and compared. The purpose of this comparison is to identify any potential errors in either the simulated or recorded inflow volumes. The simulated inflow volumes are calculated by WWHM2012 using the monitored rainfall data and the contributing drainage area to the bioretention site. It is possible that either one of those model inputs contains errors. The recorded/monitored inflow volumes are field measured values. These recorded values also may contain errors due to weather conditions (snow and/or freezing temperatures) and/or not recording all of the inflow sources to the bioretention site. By comparing the two sets of daily inflow volumes it is possible to identify problems that can and will affect the ability of WWHM2012 to correctly reproduce the surface ponding and soil layer elevations measured in the field.

At each site the simulated and recorded bioretention surface ponding depths are plotted and compared. The purpose of this comparison is to see how well WWHM2012 can reproduce the recorded/monitored ponding data. Surface ponding is a critical measure of the bioretention site's hydrologic performance. Excessive surface ponding can result in surface discharge via riser or weir that does not provide any water quality treatment or LID flow control.

At each site the simulated and recorded bioretention well point data are also plotted and compared. The well point data shows how the water fills up the bioretention soil column. The ponding and well point data are linked. If the well point data shows that the bioretention soil column is completely saturated then water cannot drain from the surface into the bioretention soil layer and this causes water to pond on the surface. Water can also pond on the surface even if the soil column is not completely saturated if the inflow of water into the bioretention facility is greater than the infiltration into the top layer (Layer 1) of the bioretention soil mix.

It should be noted that the monitored well point data is not a perfect match for the WWHM2012 soil layer moisture calculations. The monitored well point data is a measure of the "free" water in the soil column. This is water that freely drains to the well and fluctuates up and down depending on inflow to the soil from above and infiltration to the native soil below. The WWHM2012 simulated soil layer data is calculated based on the soil's hydraulic conductivity and wilting point (and other factors). Included in these simulated soil moisture calculates is both the "free" water measured in the monitored wells (well point data) and water that cannot freely flow, but remains trapped in the void spaces between soil particles. In WWHM2012 this "trapped" water is removed by evapotranspiration. The "trapped" water is not included in the well point monitored data. This is the reason for the discrepancy between the simulated and recorded soil layer plotted results.

B145: Bellevue, King County



King2012

Site Information

Site Name: B145
Address:
City: Bellevue
Gage: User Selected
Precip Factor: 1.000
☐ Use WS-DOT data

☐ Predeveloped
☑ Mitigated

X: 0
Y: 30

B145 RG1 Mitigated

Facility Name: B145 RG1

	Outlet 1	Outlet 2	Outlet 3
Downstream Connection	0	0	0

☐ **Use simple Bioretention**
☐ **Underdrain Used**

Bioretention Bottom Elevation: 0

Bioretention Dimensions

Bioretention Length (ft): 85.400
Bioretention Bottom Width (ft): 5.500
Freeboard (ft): 1.800
Over-road Flooding (ft): 0.000
Effective Total Depth (ft): 6.7
Bottom slope of bioretention.(0-1): 0.000

☑ **Sidewall Invert Location**

Front and Back side slope (H/V): 4.200
Left Side Slope (H/V): 0.000
Right Side Slope (H/V): 4.500

Material Layers for

	Layer 1	Layer 2	Layer 3
Depth (ft)	1.600	2.900	0.000

Soil Layer 1: ASTM 15
Soil Layer 2: ASTM 4
Soil Layer 3: GRAVEL

KSat Safety Factor: ● None ○ 2 ○ 4

Flow Through Underdrain (ac-ft): 0.006
Total Outflow (ac-ft):
WQ Percent Filtered: 99.43

Riser Outlet Structure

Outlet Structure Data

Riser Height Above bioretention surface (ft): 0.4
Riser Diameter (in): 6
Riser Type: Flat

Orifice Number	Diameter (in)	Height (ft)
1	0	0
2	0	0
3	0	0

Bioretention Volume at Riser Head (ac-ft): .068

Show Bioretention: Open Table

Native Infiltration: Yes
Measured Infiltration Rate (in/hr): 9
Reduction Factor (infilt*factor): 1
Use Wetted Surface Area (sidewalls): NO
Total Inflow ac-ft: 2.315

Total Volume Infiltrated (ac-ft): 2.266
Total Volume Through Riser (ac-ft): 0.013
Total Volume Through Facility(ac-ft): 2.285
Percent Infiltrated: 99.17
Precipitation on Facility (acre-ft): 0.07
Evaporation from Facility (acre-ft): 0.03

The B145 bioretention site is located in Bellevue, King County, Washington. The drainage area to B145 consists of 0.19 acres of NRCS Type C soil, lawn vegetation, on a moderate slope (5-15%) and 0.304 acres of roads on a flat slope (0-5%).

The B145 surface bottom footprint is 470 square feet. This equals 2% of the tributary drainage area to B145.

B145 has a surface discharge via riser outlet set at 0.4 feet above the surface bottom. Most of the inflow to B145 is infiltrated into the native soil beneath the bioretention soil layers. An underdrain was included in the construction of the bioretention facility, but is capped and provides no discharge from the site.

A native soil infiltration rate of 9 inches per hour together with a bioretention top soil layer of ASTM15 soil and a second soil layer of ASTM4 soil best reproduced the monitored soil moisture and surface ponding conditions.

Figure B145-1 shows the simulated (red) and recorded (blue) daily inflow volumes and, along the top of the figure, the B145 site monitored daily rainfall data. The simulated and recorded daily inflow volumes match well, except for winter periods (January and February 2017) where snow and freezing conditions affected the recorded values.

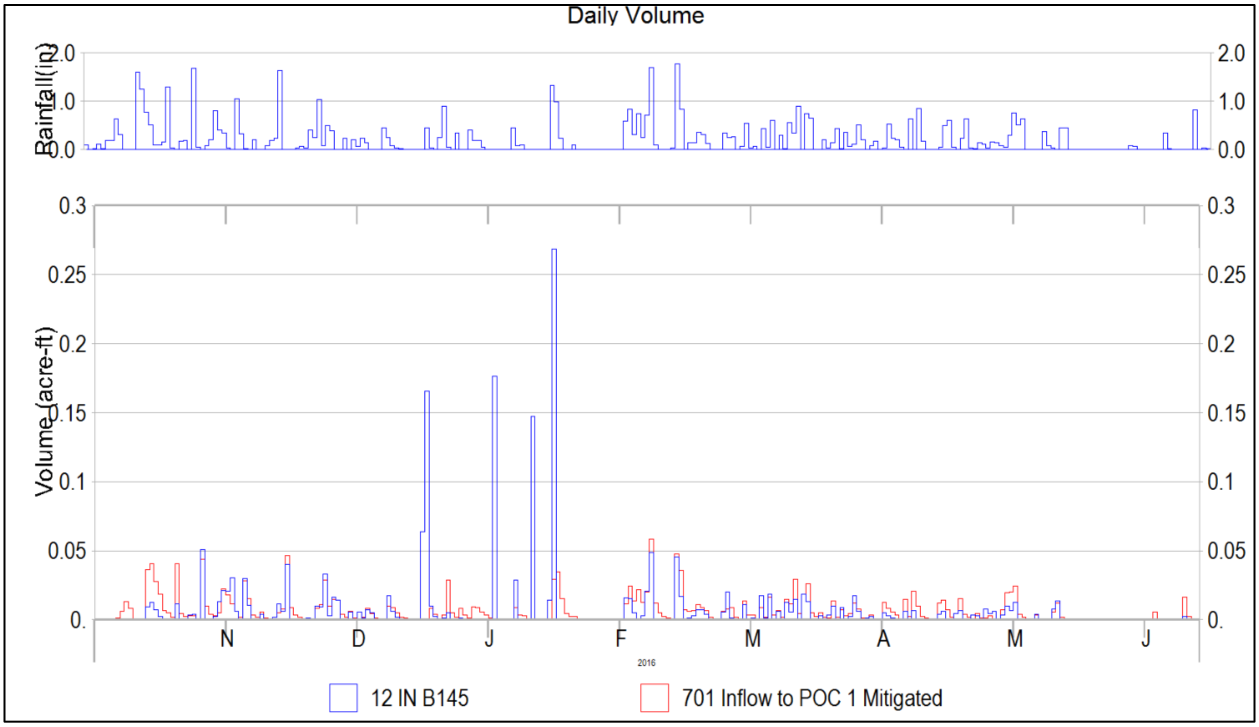


Figure B145-1. B145 Daily Inflow Volumes

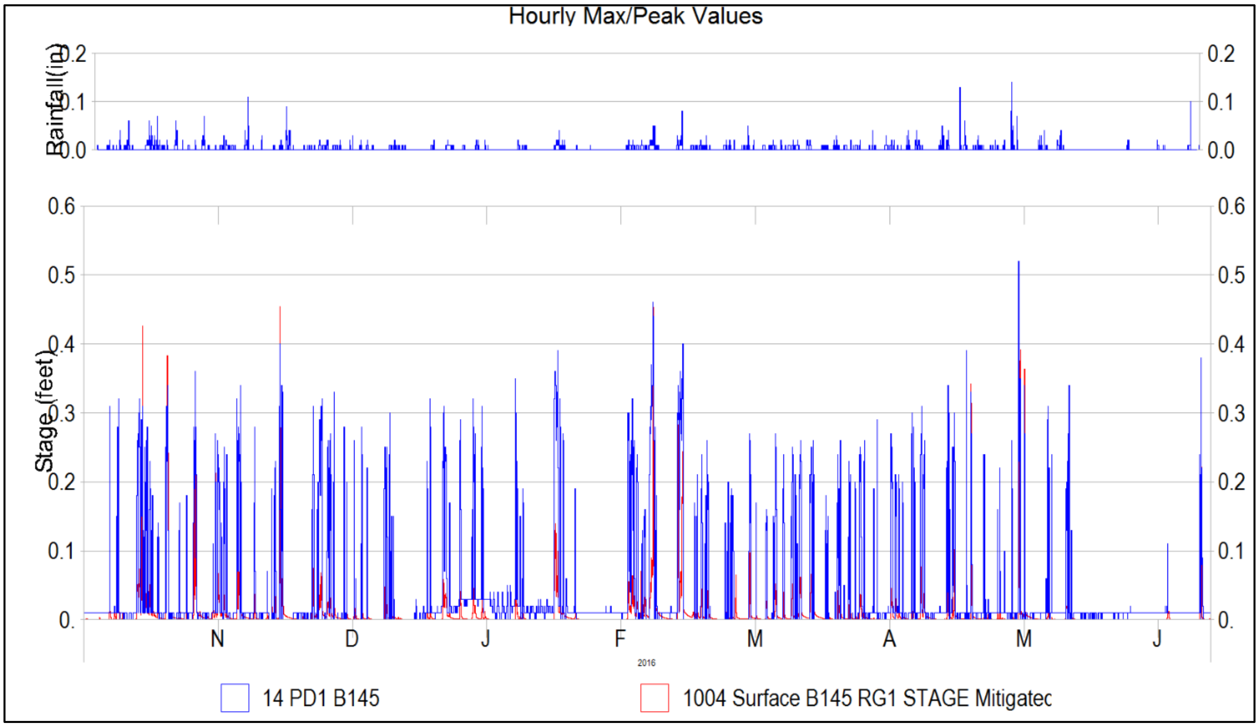


Figure B145-2. B145 Hourly Surface Ponding Depths

Figure B145-2 shows the simulated (red) and recorded (blue) hourly maximum 5-minute surface ponding (stage) values and, along the top of the figure, the B145 site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values are mixed. The higher/larger ponding depths match well, but the simulated depths for the smaller events do not show as much of a response as the monitored data.

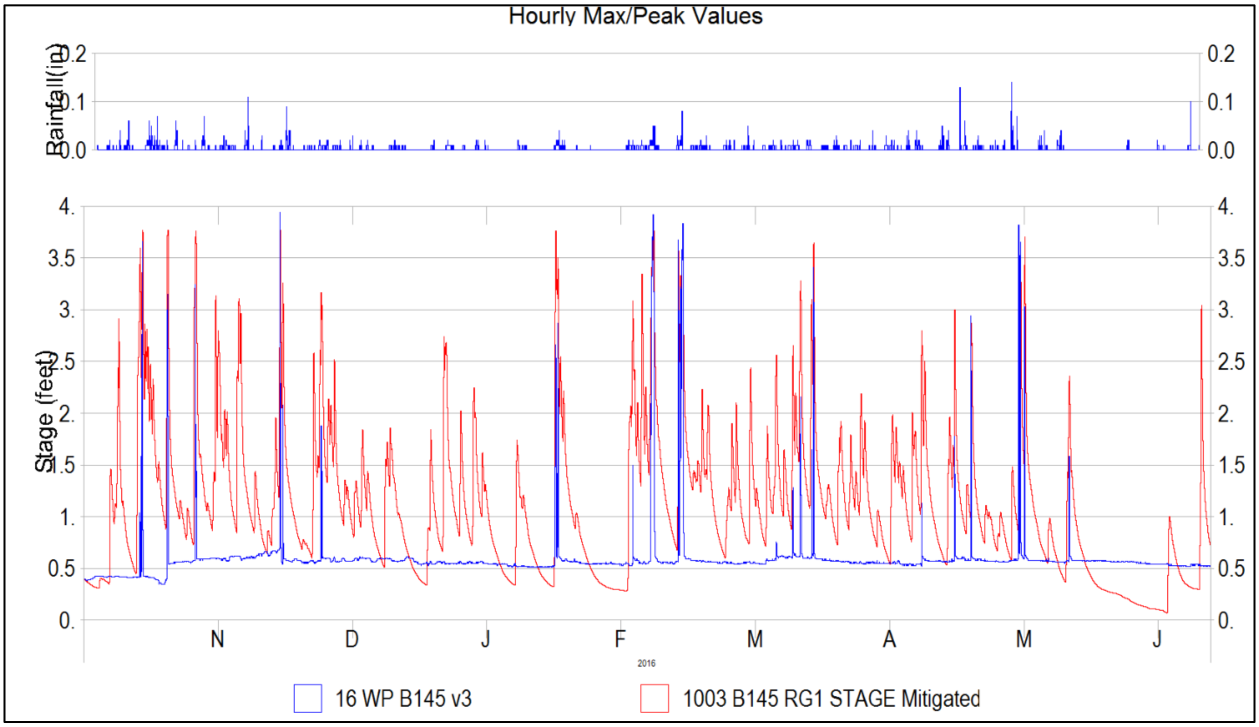
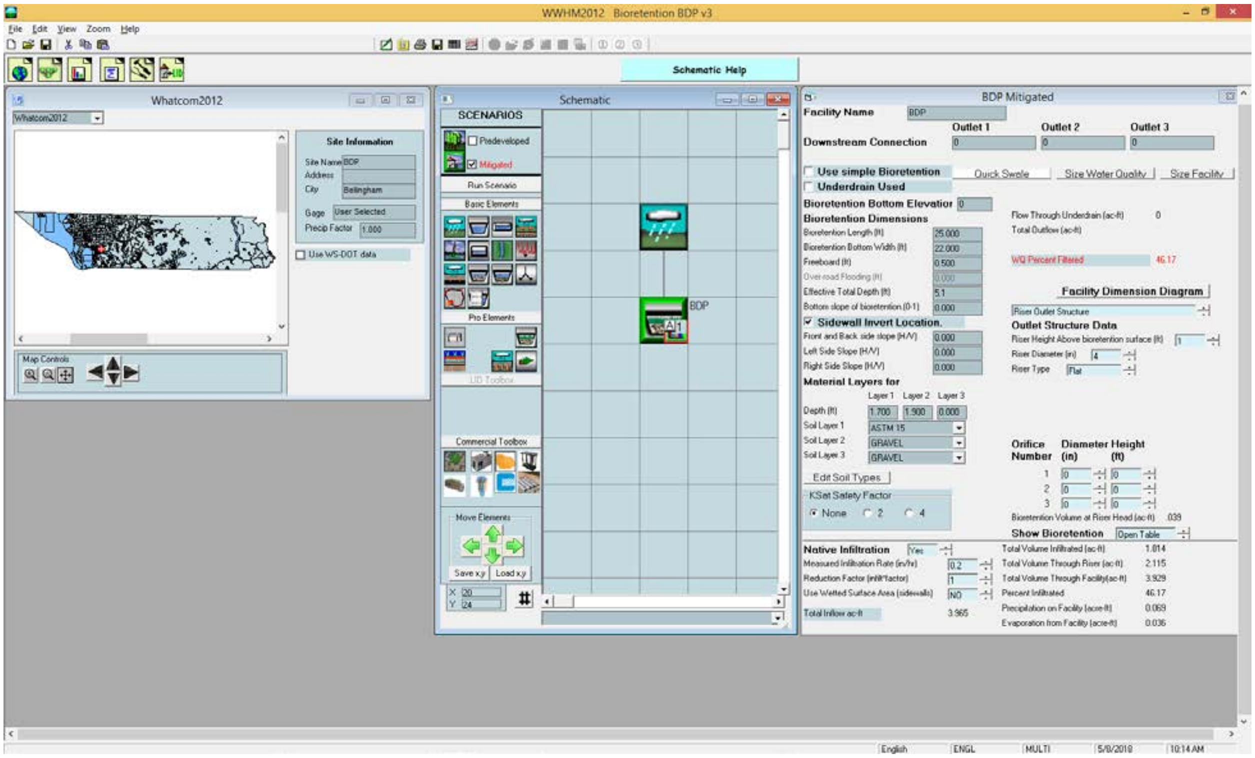


Figure B145-3. B145 Hourly Soil Layer Well Point Elevations

Figure B145-3 shows the simulated (red) and recorded (blue) hourly maximum 5-minute soil layer well point elevations (stage) values and, along the top of the figure, the B145 site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values match well for the major events. The simulated values for the smaller events show more fluctuation than the recorded well point data and longer recession periods. This is probably due to difference in the water that is included in the two sets of data, as described in the introductory remarks to this section.

BDP: Bellingham, Whatcom County



Site Information
Site Name BDP
City Bellingham
Gage User Selected
Precip Factor 1.000
☐ Use WS-DOT data

BDP Mitigated
Facility Name BDP

	Outlet 1	Outlet 2	Outlet 3
Downstream Connection	0	0	0

☐ Use simple Bioretention
☐ Underdrain Used
Bioretention Bottom Elevation 0
Bioretention Dimensions
Bioretention Length (ft) 25.000
Bioretention Bottom Width (ft) 22.000
Freeboard (ft) 0.500
Over-road Flooding (ft) 0.000
Effective Total Depth (ft) 5.1
Bottom slope of bioretention (0-1) 0.000
☑ Sidewall Invert Location.
Front and Back side slope (H/V) 0.000
Left Side Slope (H/V) 0.000
Right Side Slope (H/V) 0.000
Material Layers for

	Layer 1	Layer 2	Layer 3
Depth (ft)	1.700	1.900	0.000

Soil Layer 1 ASTM 15
Soil Layer 2 GRAVEL
Soil Layer 3 GRAVEL
KSat Safety Factor ● None ○ 2 ○ 4

Flow Through Underdrain (ac-ft) 0
Total Outflow (ac-ft)
WQ Percent Filtered 46.17
Riser Outlet Structure
Outlet Structure Data
Riser Height Above bioretention surface (ft) 1
Riser Diameter (in) 4
Riser Type Flat

Orifice Number	Diameter (in)	Height (ft)
1	0	0
2	0	0
3	0	0

Bioretention Volume at Riser Head (ac-ft) .039
Show Bioretention Open Table

Native Infiltration Yes
Measured Infiltration Rate (in/hr) 0.2
Reduction Factor (infilt*factor) 1
Use Wetted Surface Area (sidewalls) NO
Total Inflow ac-ft 3.965

Total Volume Infiltrated (ac-ft) 1.014
Total Volume Through Riser (ac-ft) 2.115
Total Volume Through Facility(ac-ft) 3.929
Percent Infiltrated 46.17
Precipitation on Facility (acre-ft) 0.069
Evaporation from Facility (acre-ft) 0.036

The BDP bioretention site is located in Bellingham, Whatcom County, Washington. The drainage area to BDP consists of 0.80 acres of pavement on a flat slope (0-5%). Initially, it was believed that 1.60 acres of pavement drains to BDP, but modeling inflow results when compared to the monitored data showed this to be unlikely and that half that amount (0.80 acres) is a more probable contributing drainage area.

The BDP surface bottom footprint is 550 square feet. This equals 2% of the 0.8-acre tributary drainage area to BDP.

BDP has a surface discharge via weir outlet set at 0.9 feet above the surface bottom. Approximately one-half of the inflow to BDP is infiltrated into the native soil beneath the bioretention soil layers. BDP contains no underdrain.

A native soil infiltration rate of 0.2 inches per hour together with a bioretention top soil layer of ASTM15 soil and a second soil layer of gravel best reproduced the monitored soil moisture and surface ponding conditions. A high groundwater table from Lake Whatcom appears to greatly reduce the native soil infiltration rate.

Figure BDP-1 shows the simulated (red) and recorded (blue) daily inflow volumes and, along the top of the figure, the BDP site monitored daily rainfall data. The simulated and recorded daily inflow volumes are mixed. Winter periods (November 2016 through February 2017) show major differences where snow and freezing conditions affected the recorded values.

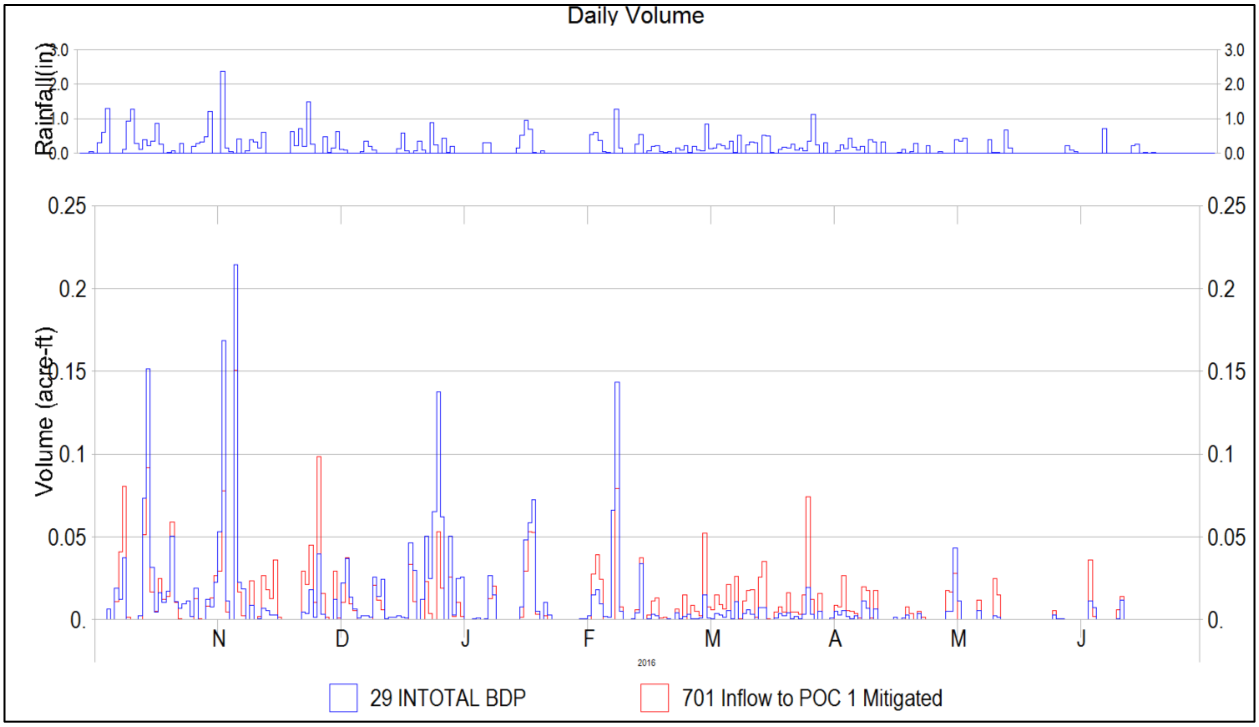


Figure BDP-1. BDP Daily Inflow Volumes

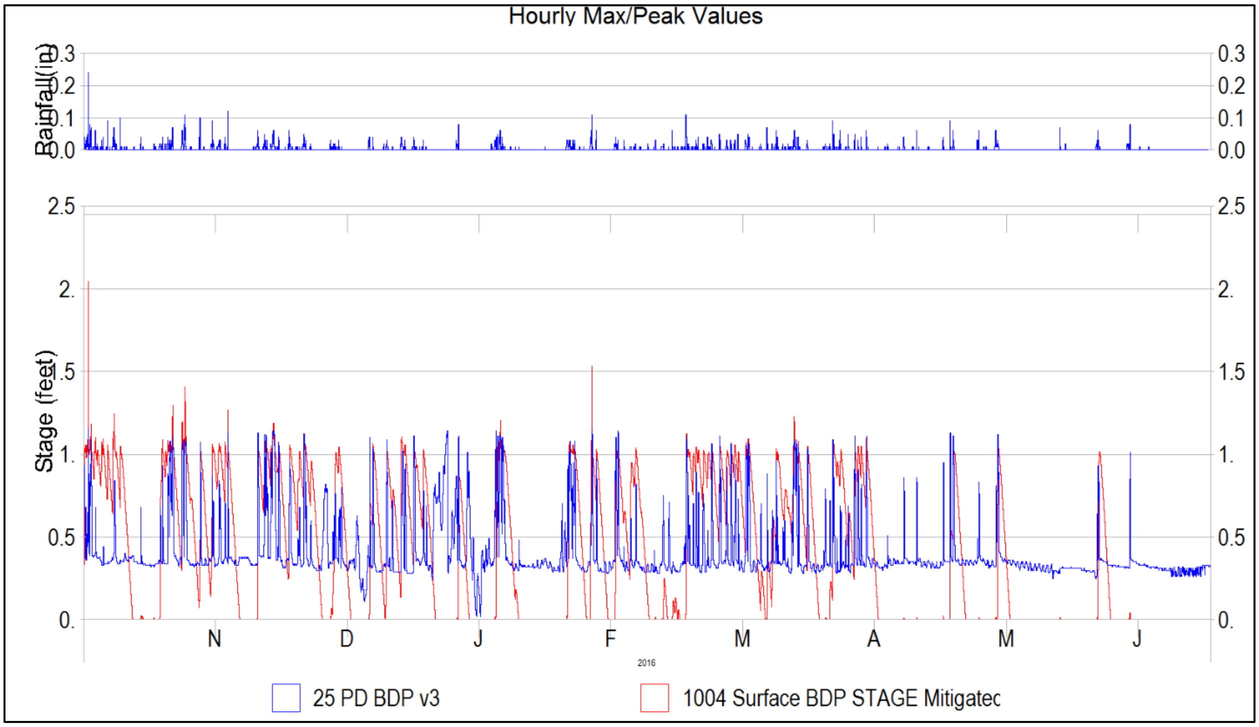


Figure BDP-2. BDP Hourly Surface Ponding Depths

Figure BDP-2 shows the simulated (red) and recorded (blue) hourly maximum 5-minute surface ponding (stage) values and, along the top of the figure, the BDP site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values in general show a good match, except for dry periods where the simulated depths drop down to zero and the recorded depths stay elevated. These consistently elevated recorded ponding depths are due to the effect of Lake Whatcom's groundwater influence.

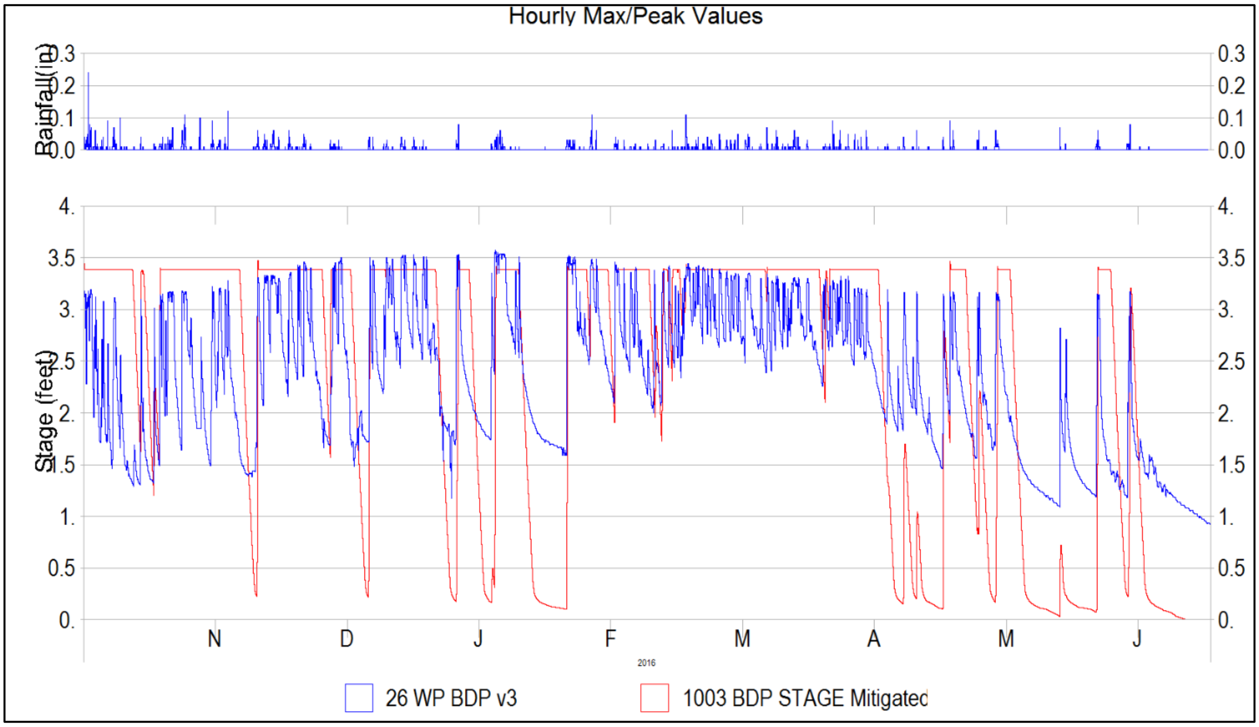
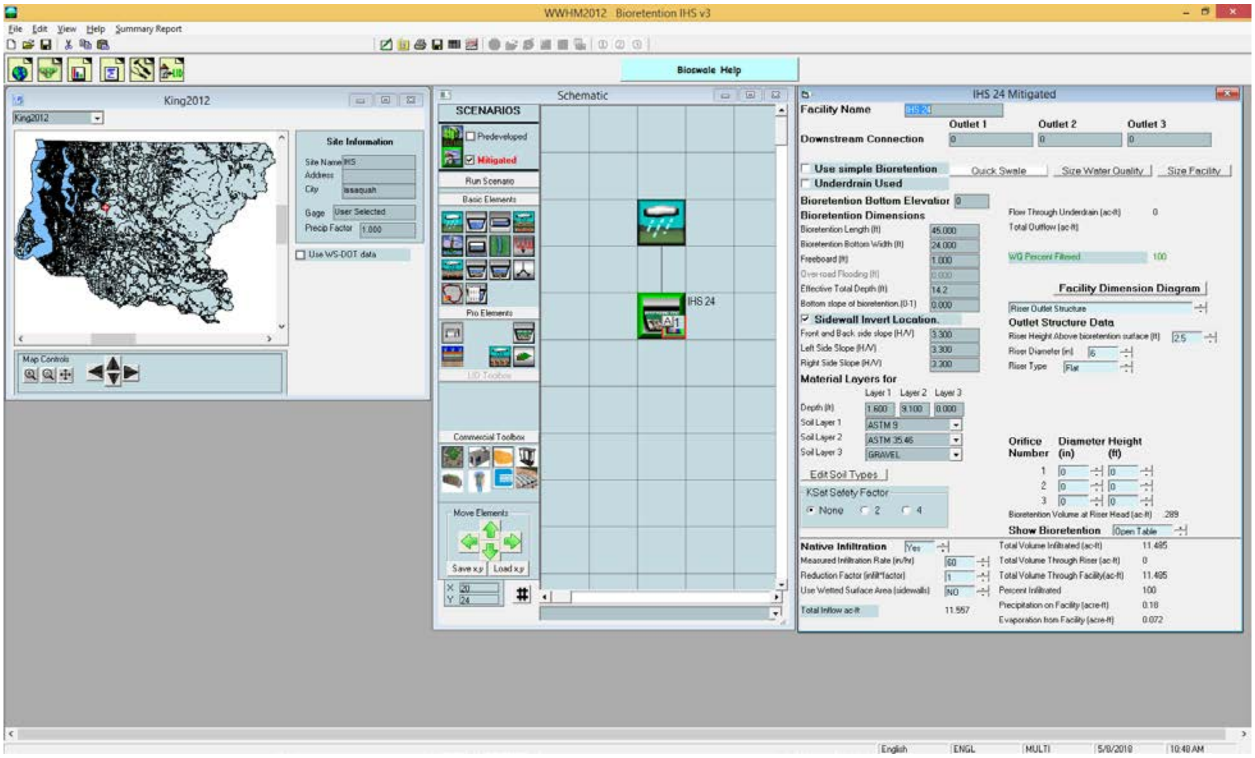


Figure BDP-3. BDP Hourly Soil Layer Well Point Elevations

Figure BDP-3 shows the simulated (red) and recorded (blue) hourly maximum 5-minute soil layer well point elevations (stage) values and, along the top of the figure, the BDP site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values match well. As with the ponding results above, the simulated values show more fluctuation than the recorded well point data. These consistently elevated recorded well point depths are due to the effect of Lake Whatcom's groundwater influence.

IHS: Issaquah, King County



King2012

Site Information
Site Name: IHS
Address:
City: Issaquah
Gage: User Selected
Precip Factor: 1.000
☐ Use WS-DOT data

☐ Predeveloped
☑ Mitigated

X: 20
Y: 24

IHS 24 Mitigated

Facility Name: IHS 24

	Outlet 1	Outlet 2	Outlet 3
Downstream Connection	0	0	0

☐ Use simple Bioretention
☐ Underdrain Used
Bioretention Bottom Elevation: 0

Bioretention Dimensions
Bioretention Length (ft): 45.000
Bioretention Bottom Width (ft): 24.000
Freeboard (ft): 1.000
Over-road Flooding (ft): 0.000
Effective Total Depth (ft): 14.2
Bottom slope of bioretention (0-1): 0.000
☑ Sidewall Invert Location.
Front and Back side slope (H/V): 3.300
Left Side Slope (H/V): 3.300
Right Side Slope (H/V): 3.300

Material Layers for

	Layer 1	Layer 2	Layer 3
Depth (ft)	1.600	9.100	0.000

Soil Layer 1: ASTM 9
Soil Layer 2: ASTM 35.46
Soil Layer 3: GRAVEL

KSat Safety Factor: ● None ○ 2 ○ 4

Flow Through Underdrain (ac-ft): 0
Total Outflow (ac-ft):
WQ Percent Filtered: 100

Riser Outlet Structure
Outlet Structure Data
Riser Height Above bioretention surface (ft): 2.5
Riser Diameter (in): 6
Riser Type: Flat

Orifice Number	Diameter (in)	Height (ft)
1	0	0
2	0	0
3	0	0

Bioretention Volume at Riser Head (ac-ft): .289
Show Bioretention: Open Table

Native Infiltration: Yes
Measured Infiltration Rate (in/hr): 60
Reduction Factor (infilt*factor): 1
Use Wetted Surface Area (sidewalls): NO
Total Inflow ac-ft: 11.557

Total Volume Infiltrated (ac-ft): 11.495
Total Volume Through Riser (ac-ft): 0
Total Volume Through Facility(ac-ft): 11.495
Percent Infiltrated: 100
Precipitation on Facility (acre-ft): 0.18
Evaporation from Facility (acre-ft): 0.072

The IHS bioretention site is located in Issaquah, King County, Washington. The drainage area to IHS consists of 0.41 acres of NRCS Type C soil, lawn vegetation, on a moderate slope (5-15%) and 1.60 acres of pavement on a flat slope (0-5%). Initially, it was believed that 0.80 acres of pavement drains to IHS, but modeling inflow results when compared to the monitored data showed this to be too small and that twice that amount (1.60 acres) is a more probable contributing drainage area.

The IHS surface bottom footprint is 1080 square feet. This equals 2% of the 2.01-acre tributary drainage area to IHS.

IHS has a surface discharge via riser outlet set at 2.5 feet above the surface bottom. Most of the inflow to IHS is infiltrated into the native soil beneath the bioretention soil layers. The riser outlet is connected to an infiltration gallery so all of the inflow infiltrates into the native soil either through the bottom of the bioretention facility or through the overflow infiltration gallery.

A native soil infiltration rate of 60 inches per hour together with a bioretention top soil layer of ASTM9 soil and a second soil layer of ASTM35 soil best reproduced the monitored soil moisture and surface ponding conditions.

Figure IHS-1 shows the simulated (red) and recorded (blue) daily inflow volumes and, along the top of the figure, the IHS site monitored daily rainfall data. The simulated and recorded daily inflow volumes match well, except for winter periods (January and February 2017) where snow and freezing conditions affected the recorded values.

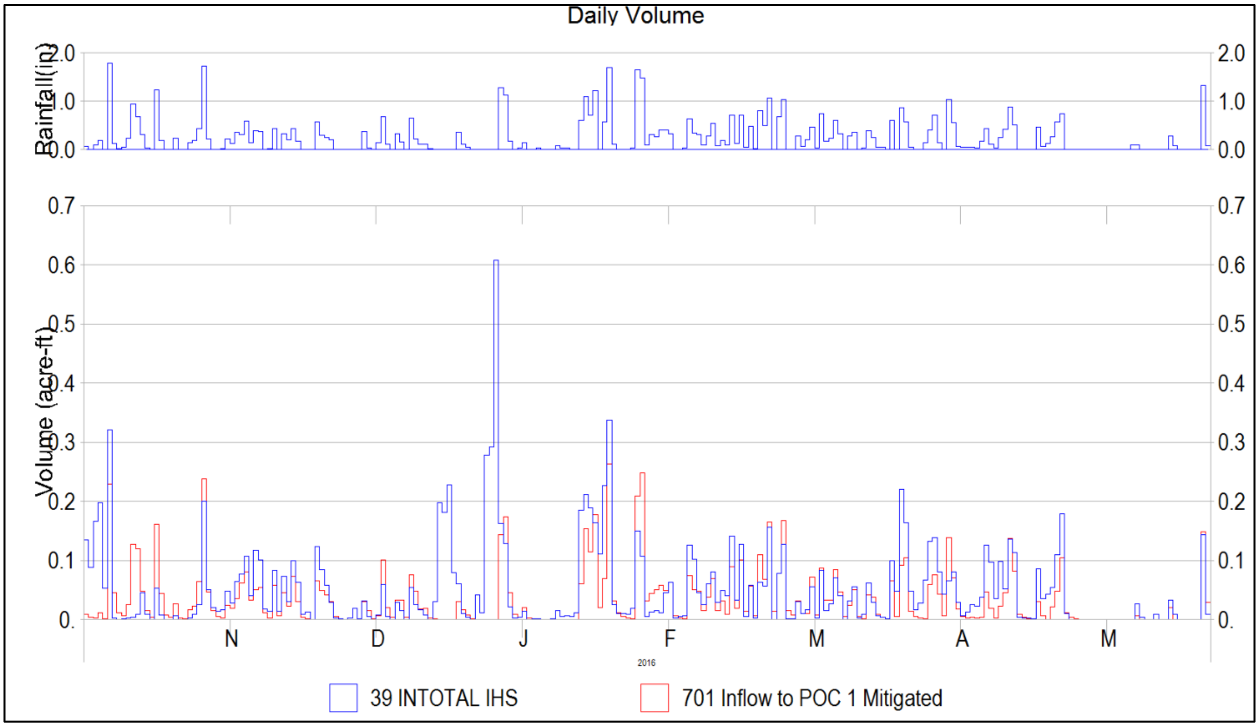


Figure IHS-1. IHS Daily Inflow Volumes

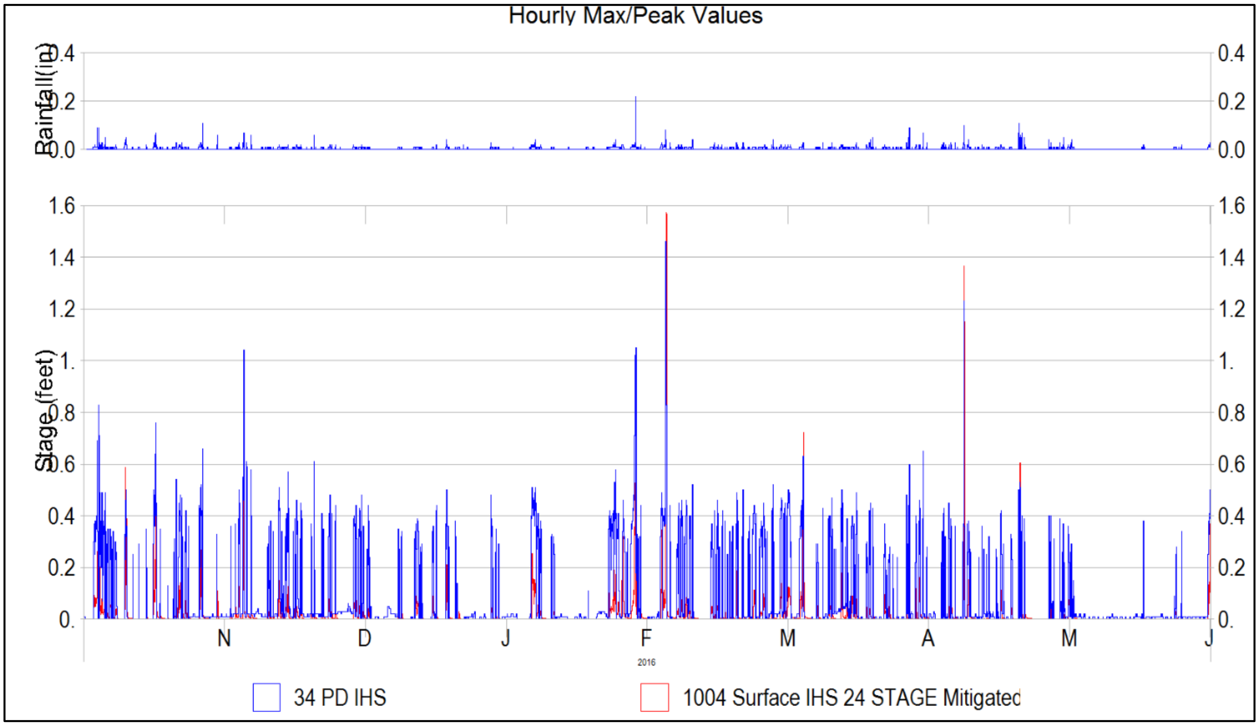


Figure IHS-2. IHS Hourly Surface Ponding Depths

Figure IHS-2 shows the simulated (red) and recorded (blue) hourly maximum 5-minute surface ponding (stage) values and, along the top of the figure, the IHS site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values are mixed. The higher/larger ponding depths match well, but the simulated depths for the smaller events do not show as much of a response as the monitored data.

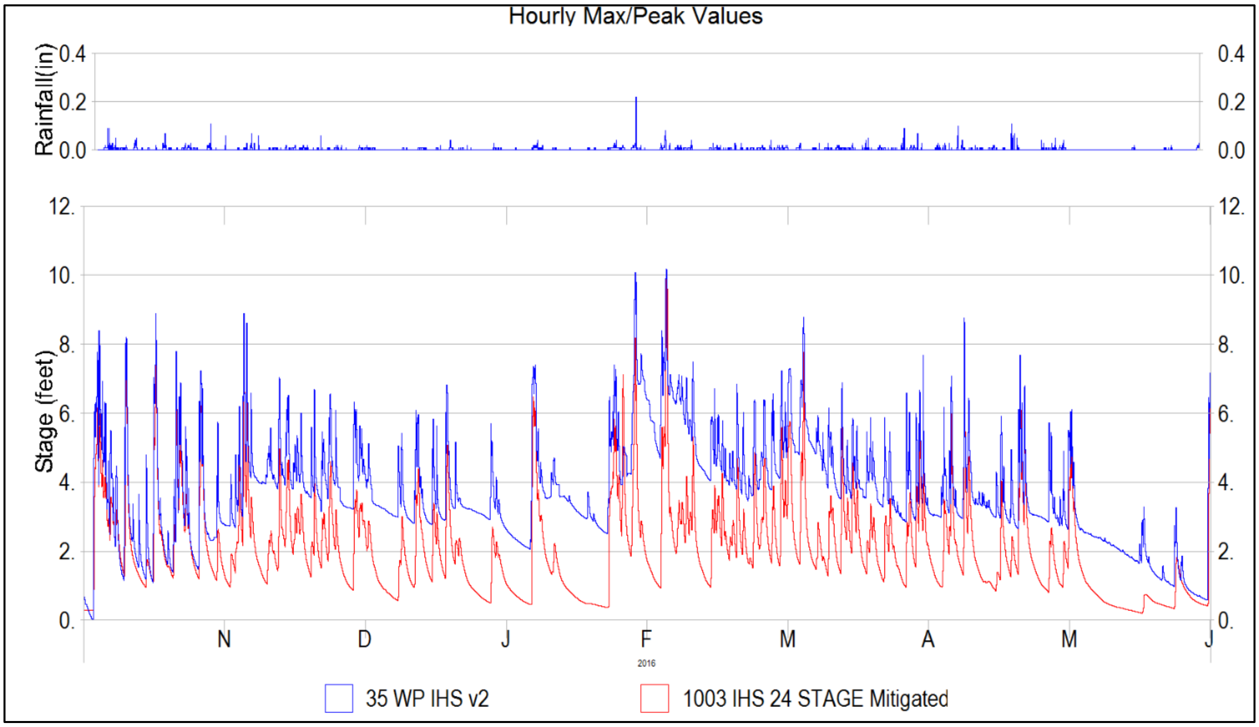
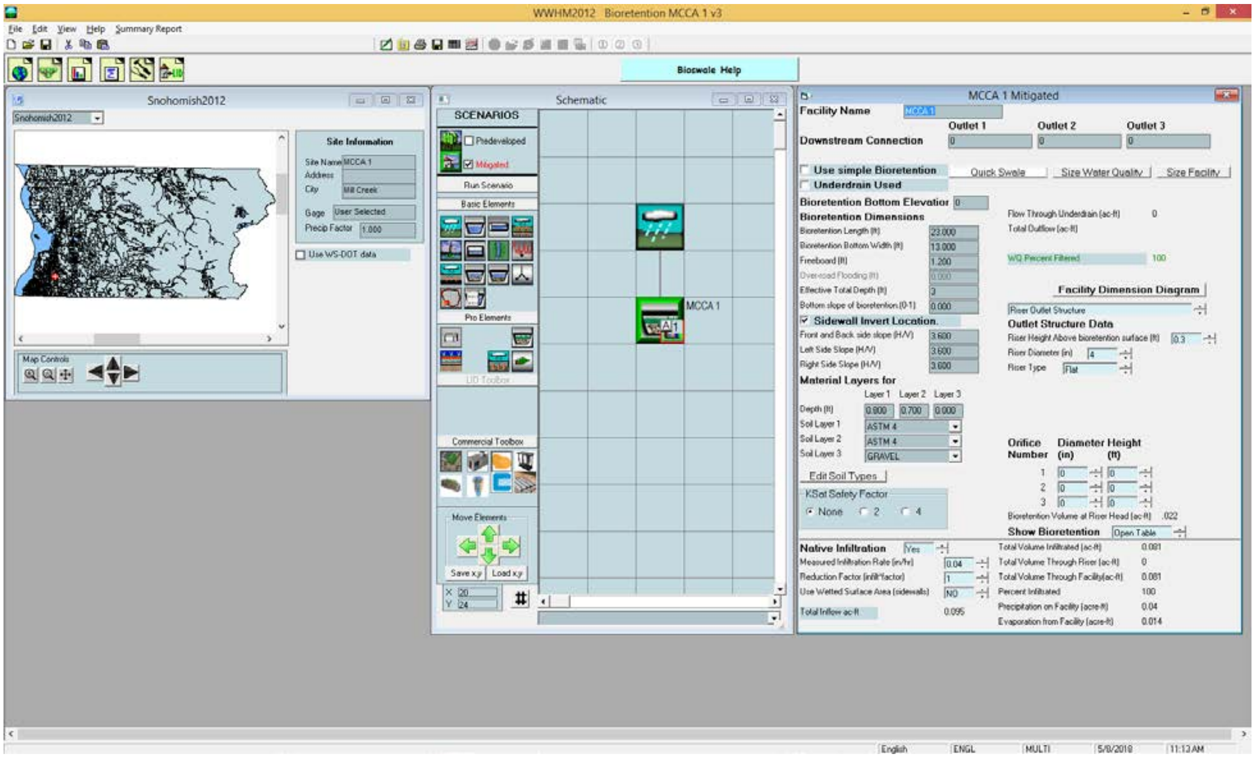


Figure IHS 3. IHS Hourly Soil Layer Well Point Elevations

Figure IHS 3 shows the simulated (red) and recorded (blue) hourly maximum 5-minute soil layer well point elevations (stage) values and, along the top of the figure, the IHS site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values match well for the major events. The simulated values for the smaller events show more fluctuation than the recorded well point data and longer recession periods. This may be due to raised groundwater levels in winter and spring months (groundwater mounding) affecting the recorded data.

MCCA1: Mill Creek, Snohomish County



Site Information
Site Name: MCCA 1
Address:
City: Mill Creek
Gage: User Selected
Precip Factor: 1.000
☐ Use WS-DOT data

☐ Predeveloped
☑ Mitigated

X: 20
Y: 24

Facility Name MCCA 1

	Outlet 1	Outlet 2	Outlet 3
Downstream Connection	0	0	0

☐ **Use simple Bioretention**
☐ **Underdrain Used**

Bioretention Bottom Elevation 0
Bioretention Dimensions
Bioretention Length (ft): 23.000
Bioretention Bottom Width (ft): 13.000
Freeboard (ft): 1.200
Over-road Flooding (ft): 0.000
Effective Total Depth (ft): 3
Bottom slope of bioretention (0-1): 0.000
☑ **Sidewall Invert Location.**
Front and Back side slope (H/V): 3.600
Left Side Slope (H/V): 3.600
Right Side Slope (H/V): 3.600

Material Layers for

	Layer 1	Layer 2	Layer 3
Depth (ft)	0.800	0.700	0.000

Soil Layer 1: ASTM 4
Soil Layer 2: ASTM 4
Soil Layer 3: GRAVEL

KSat Safety Factor: ● None ○ 2 ○ 4

Flow Through Underdrain (ac-ft): 0
Total Outflow (ac-ft):
WQ Percent Filtered: 100

Riser Outlet Structure
Outlet Structure Data
Riser Height Above bioretention surface (ft): 0.3
Riser Diameter (in): 4
Riser Type: Flat

Orifice Number	**Diameter (in)**	**Height (ft)**
1	0	0
2	0	0
3	0	0

Bioretention Volume at Riser Head (ac-ft): .022
Show Bioretention: Open Table

Native Infiltration: Yes
Measured Infiltration Rate (in/hr): 0.04
Reduction Factor (infilt*factor): 1
Use Wetted Surface Area (sidewalls): NO
Total Inflow ac-ft: 0.095

Total Volume Infiltrated (ac-ft): 0.081
Total Volume Through Riser (ac-ft): 0
Total Volume Through Facility(ac-ft): 0.081
Percent Infiltrated: 100
Precipitation on Facility (acre-ft): 0.04
Evaporation from Facility (acre-ft): 0.014

The MCCA1 bioretention site is located in Mill Creek, Snohomish County, Washington. The drainage area to MCCA1 consists of 0.01 acres of roof on a steep slope (>15%).

The MCCA1 surface bottom footprint is 299 square feet. This equals 69% of the tributary drainage area to MCCA1.

MCCA1 has no surface outlet but overtops the site at 0.3 feet above the surface bottom. All of the inflow to MCCA1 is infiltrated into the native soil beneath the bioretention soil layers.

A native soil infiltration rate of 0.04 inches per hour together with a bioretention top soil layer of ASTM4 soil and a second soil layer of ASTM4 soil best reproduced the monitored soil moisture and surface ponding conditions.

Figure MCCA1-1 shows the simulated (red) and recorded (blue) daily inflow volumes and, along the top of the figure, the MCCA1 site monitored daily rainfall data. The simulated and recorded daily inflow volumes match well, except for winter periods (January and February 2017) where snow and freezing conditions affected the recorded values.

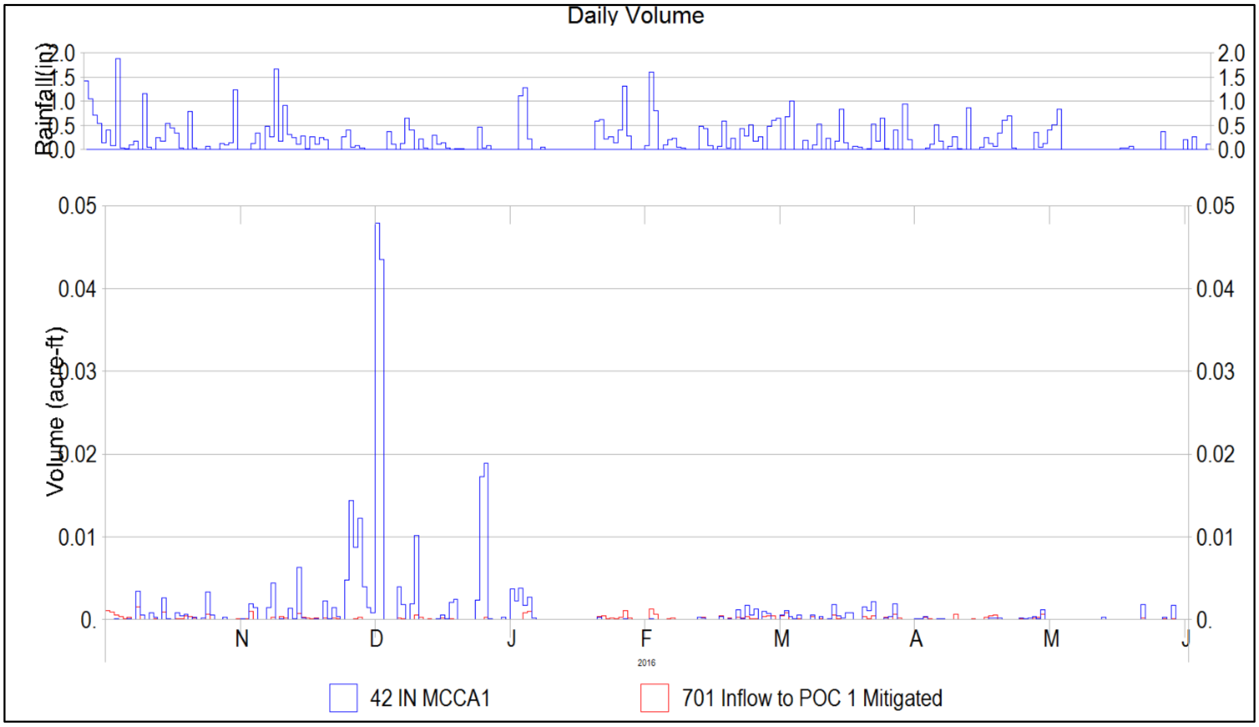


Figure MCCA1-1. MCCA1 Daily Inflow Volumes

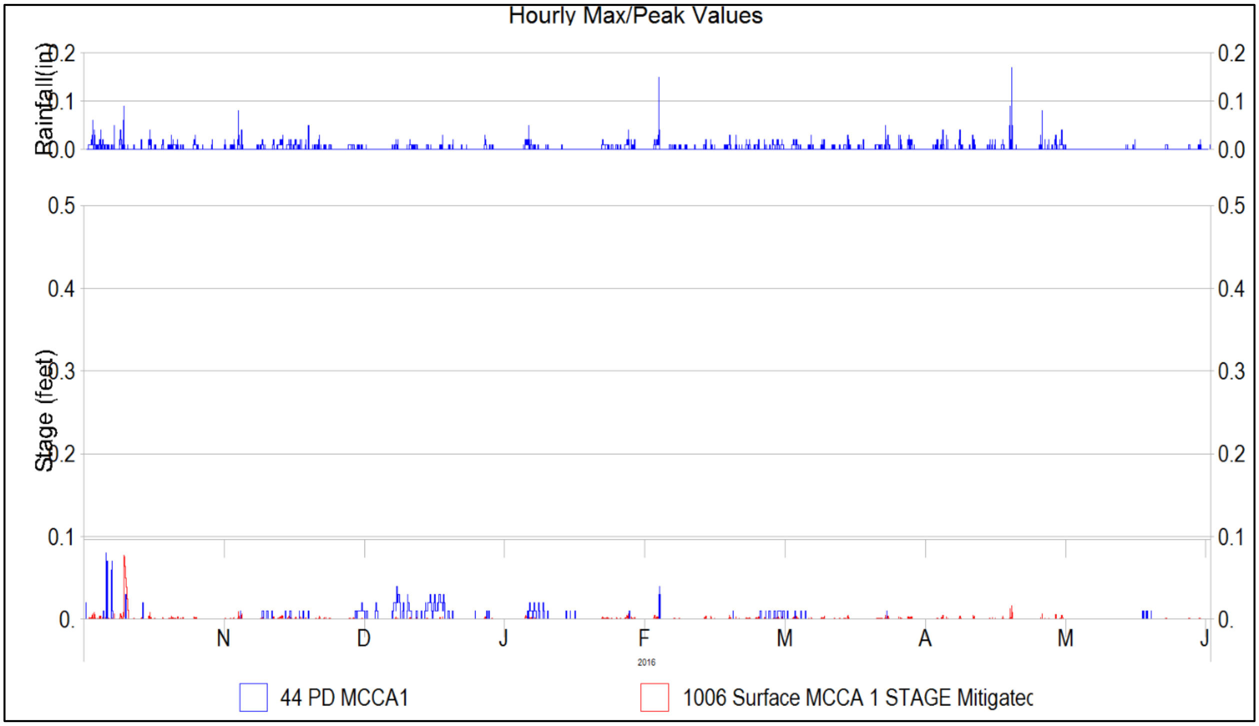


Figure MCCA1-2. MCCA1 Hourly Surface Ponding Depths

Figure MCCA1-2 shows the simulated (red) and recorded (blue) hourly maximum 5-minute surface ponding (stage) values and, along the top of the figure, the MCCA1 site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values match well. Due to the relatively large bioretention surface bottom area compared to the contributing roof drainage area there is very little surface ponding, even during major storm events.

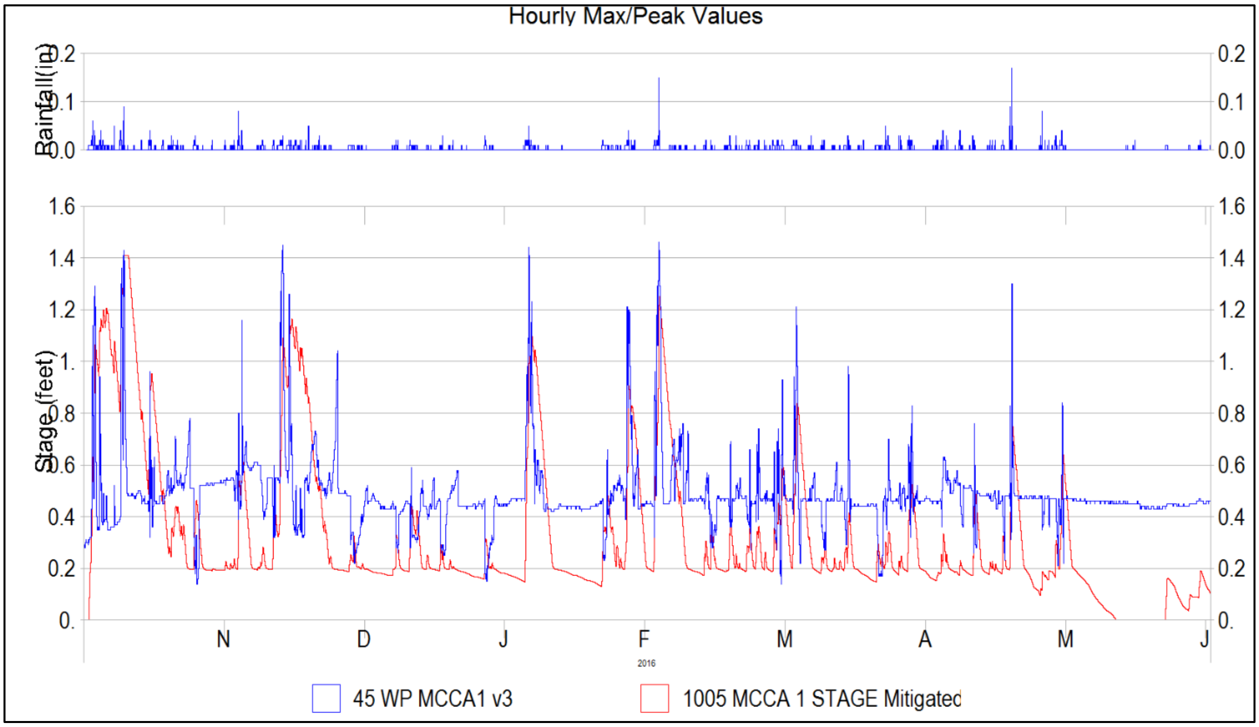
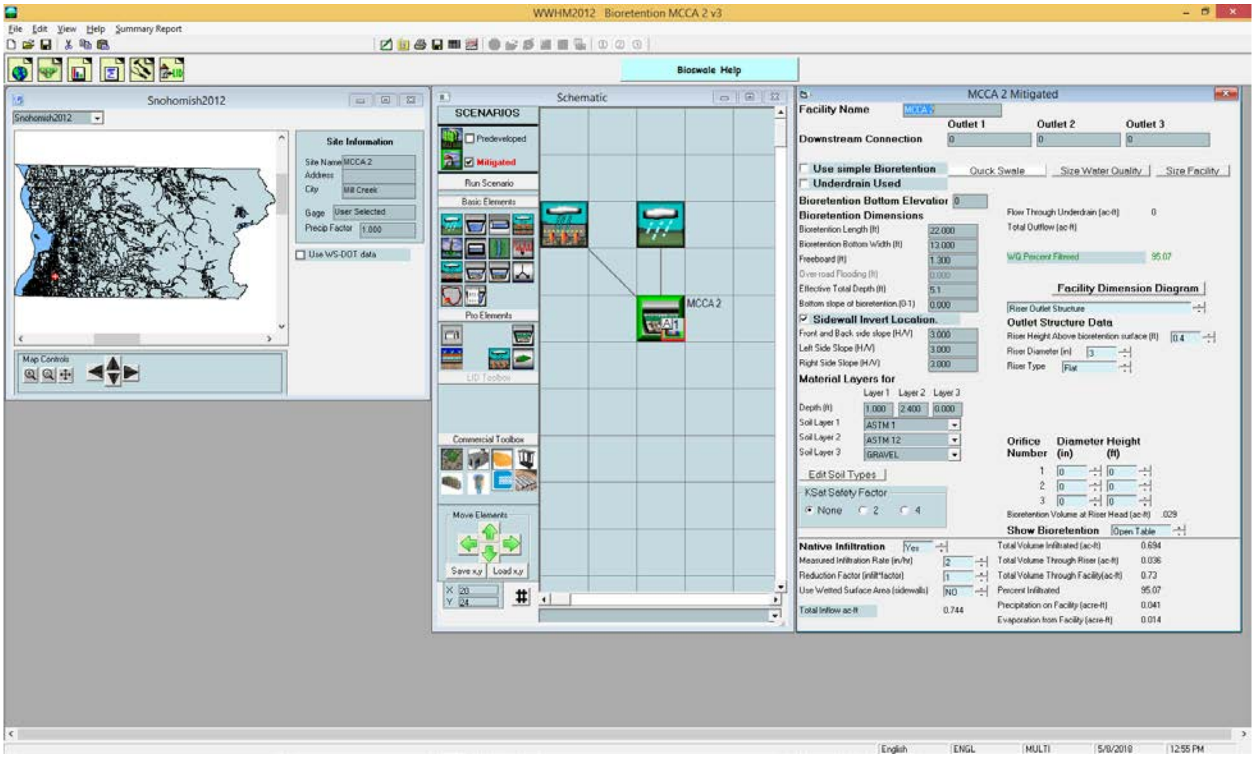


Figure MCCA1-3. MCCA1 Hourly Soil Layer Well Point Elevations

Figure MCCA1-3 shows the simulated (red) and recorded (blue) hourly maximum 5-minute soil layer well point elevations (stage) values and, along the top of the figure, the MCCA1 site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values match well for the major events. The simulated values for the smaller events show more fluctuation than the recorded well point data and longer recession periods. This may be due to raised groundwater levels in winter and spring months (groundwater mounding) affecting the recorded data.

MCCA2: Mill Creek, Snohomish County



Site Information
Site Name MCCA 2
Address
City Mill Creek
Gage User Selected
Precip Factor 1.000
☐ Use WS-DOT data

☐ Predeveloped
☑ Mitigated

X 20
Y 24

MCCA 2 Mitigated
Facility Name MCCA 2

	Outlet 1	Outlet 2	Outlet 3
Downstream Connection	0	0	0

☐ Use simple Bioretention
☐ Underdrain Used
Bioretention Bottom Elevation 0

Bioretention Dimensions
Bioretention Length (ft) 22.000
Bioretention Bottom Width (ft) 13.000
Freeboard (ft) 1.300
Over-road Flooding (ft) 0.000
Effective Total Depth (ft) 5.1
Bottom slope of bioretention (0-1) 0.000
☑ Sidewall Invert Location.
Front and Back side slope (H/V) 3.000
Left Side Slope (H/V) 3.000
Right Side Slope (H/V) 3.000

Material Layers for

	Layer 1	Layer 2	Layer 3
Depth (ft)	1.000	2.400	0.000

Soil Layer 1 ASTM 1
Soil Layer 2 ASTM 12
Soil Layer 3 GRAVEL

KSat Safety Factor
● None ○ 2 ○ 4

Flow Through Underdrain (ac-ft) 0
Total Outflow (ac-ft)
WQ Percent Filtered 95.07

Riser Outlet Structure
Outlet Structure Data
Riser Height Above bioretention surface (ft) 0.4
Riser Diameter (in) 3
Riser Type Flat

Orifice Number	Diameter (in)	Height (ft)
1	0	0
2	0	0
3	0	0

Bioretention Volume at Riser Head (ac-ft) .029
Show Bioretention Open Table

Native Infiltration Yes
Measured Infiltration Rate (in/hr) 2
Reduction Factor (infilt*factor) 1
Use Wetted Surface Area (sidewalls) NO
Total Inflow ac-ft 0.744

Total Volume Infiltrated (ac-ft) 0.694
Total Volume Through Riser (ac-ft) 0.036
Total Volume Through Facility(ac-ft) 0.73
Percent Infiltrated 95.07
Precipitation on Facility (acre-ft) 0.041
Evaporation from Facility (acre-ft) 0.014

The MCCA2 bioretention site is located in Mill Creek, Snohomish County, Washington. The drainage area to MCCA2 consists of 0.0184 acres of roof on a steep slope (>15%) plus 5400 square feet (0.124 acres) of adjacent permeable pavement (see below for explanation).

The MCCA2 surface bottom footprint is 286 square feet. This equals 5% of the tributary drainage area to MCCA2.

MCCA2 was designed to have a surface outlet at 0.4 feet above the surface bottom. This designed (and constructed) outlet was via a pipe to the gravel under layer of the adjacent permeable pavement parking lot. However, monitored ponding data indicates that this outlet to the parking lot actually acts as an inlet from the gravel layer of the permeable pavement to MCCA2.

A native soil infiltration rate of 2 inches per hour together with a bioretention top soil layer of ASTM1 soil and a second soil layer of ASTM12 soil best reproduced the monitored soil moisture and surface ponding conditions.

Figure MCCA2-1 shows the simulated (red) and recorded (blue) daily inflow volumes and, along the top of the figure, the MCCA2 site monitored daily rainfall data. The simulated and recorded daily inflow volumes do not match because the recorded inflow volumes do not include the inflow from the permeable pavement.

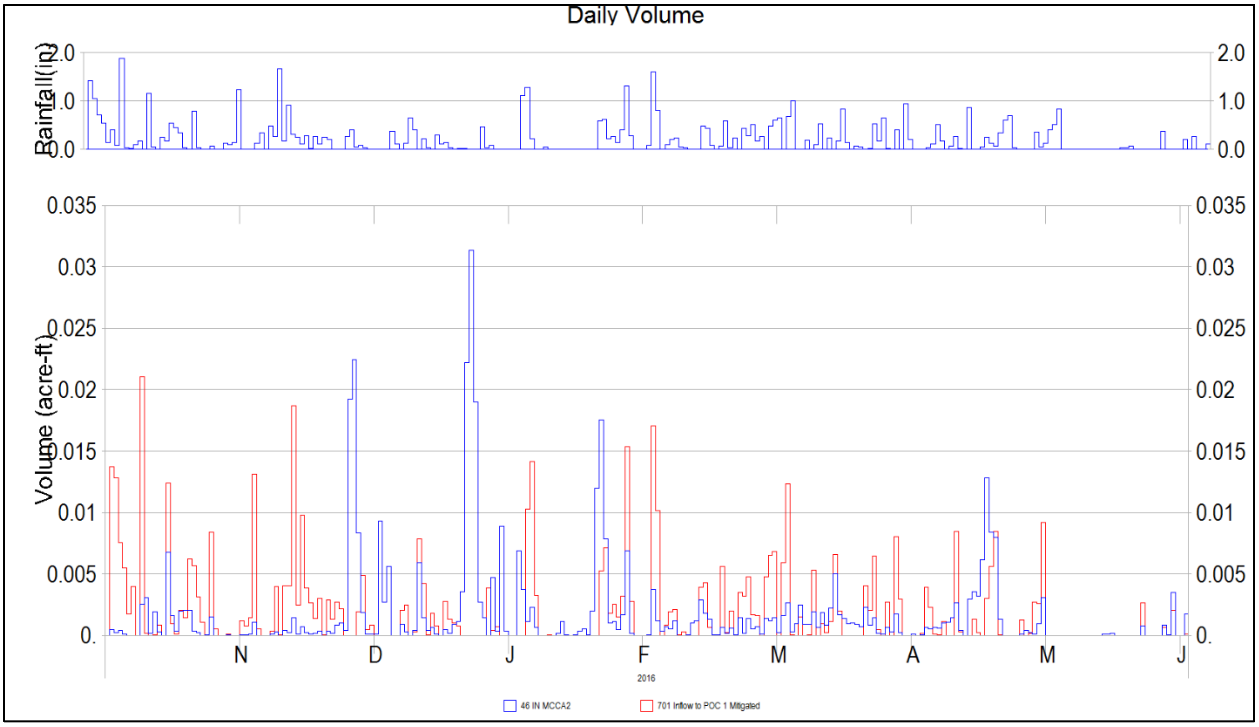


Figure MCCA2-1. MCCA2 Daily Inflow Volumes

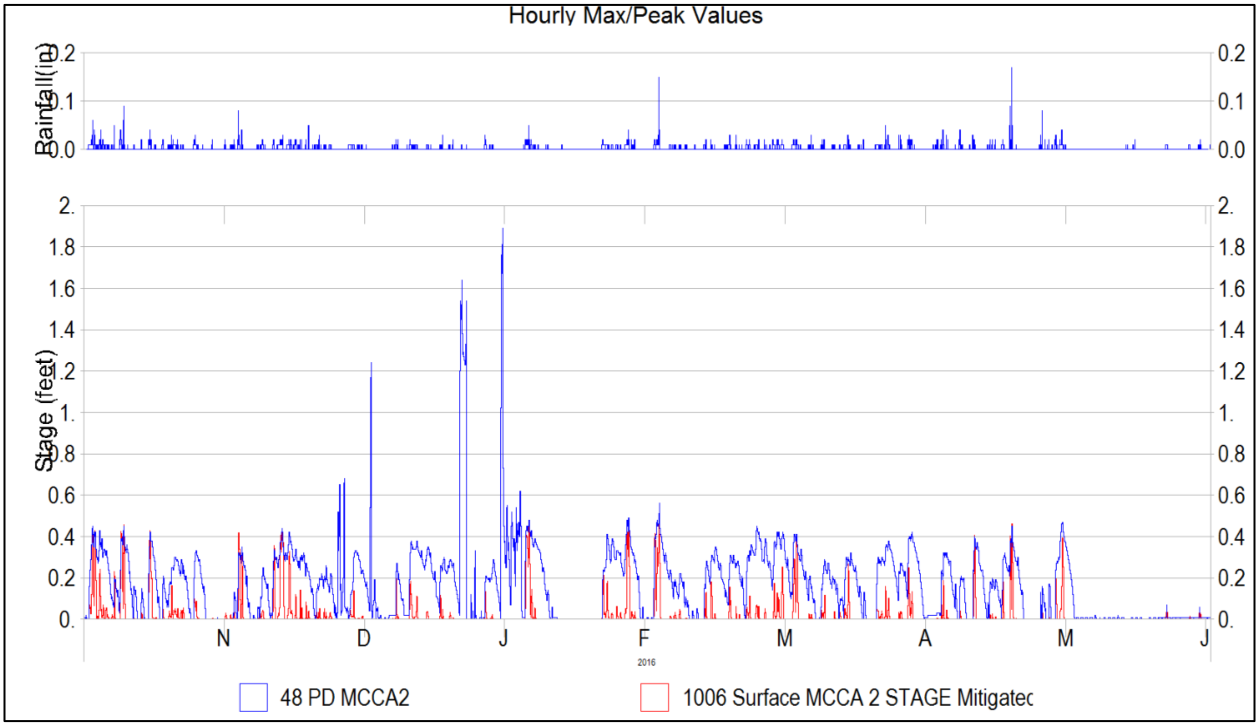


Figure MCCA2-2. MCCA2 Hourly Surface Ponding Depths

Figure MCCA2-2 shows the simulated (red) and recorded (blue) hourly maximum 5-minute surface ponding (stage) values and, along the top of the figure, the MCCA2 site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values match well with the inclusion of the inflow from the permeable pavement. Without the permeable pavement inflow MCCA2 would have similar minimal ponding depths to what was monitored in MCCA1.

To confirm that the monitored roof runoff inflow to MCCA2 is insufficient to provide enough water to produce ponding a hand calculation outside of WWHM2012 was made to compare the inflow volume with the ponding volume for the first major storm event in October 2016. The total rainfall volume on the portion of the roof that drains to MCCA2 plus the rainfall volume falling directly on the bioretention surface area was calculated and found to be smaller than the monitored pond volume in MCCA2. The extra water must come from somewhere and a thorough site investigation concluded that the only realistic source of this additional water must be from the gravel layer under the permeable pavement in the parking lot. When the permeable pavement was added to the WWHM MCCA2 bioretention model the simulated and recorded pond depths matched well, except for winter periods (January and February 2017) where snow and freezing conditions affected the recorded values.

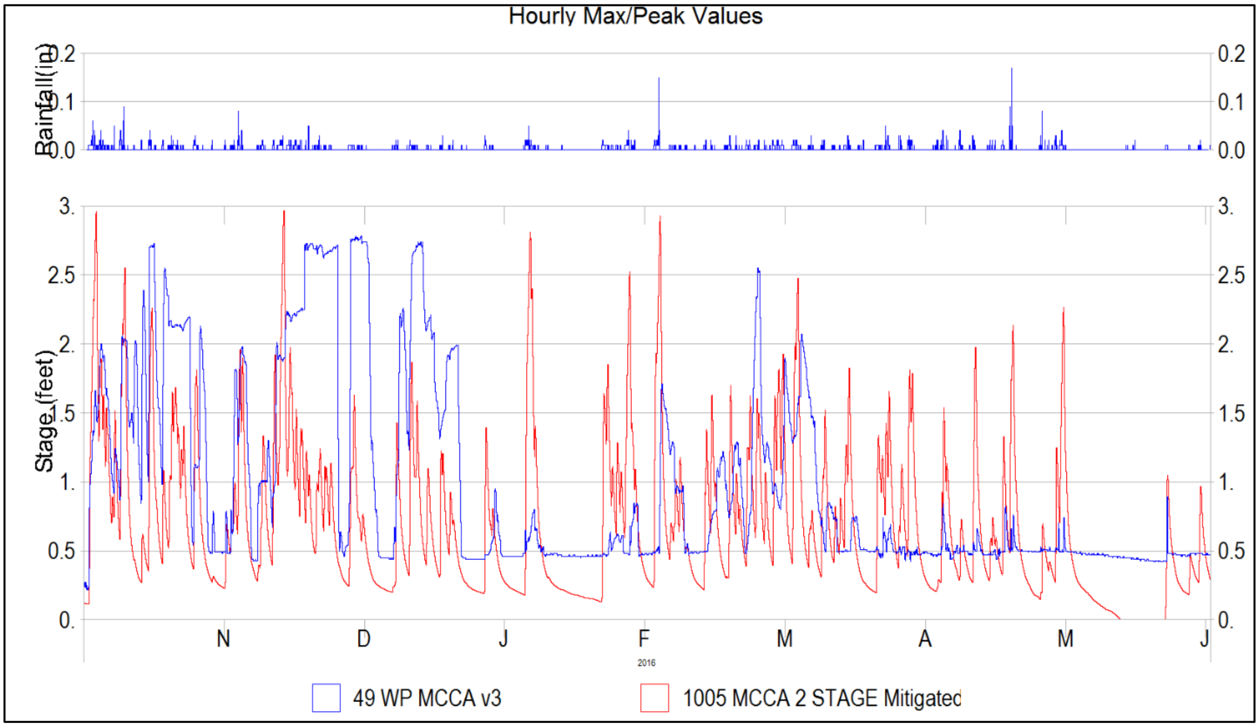
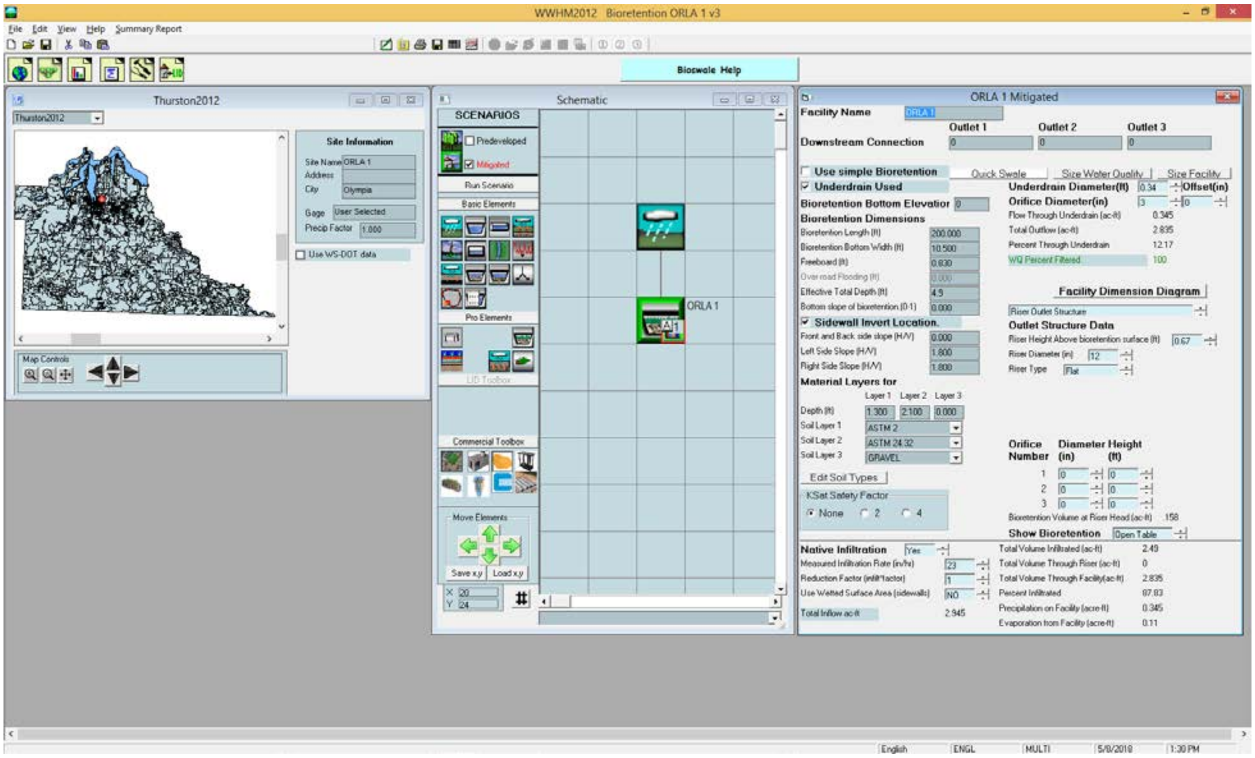


Figure MCCA2-3. MCCA2 Hourly Soil Layer Well Point Elevations

Figure MCCA2-3 shows the simulated (red) and recorded (blue) hourly maximum 5-minute soil layer well point elevations (stage) values and, along the top of the figure, the MCCA2 site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values match well for the major events. The simulated values for the smaller events show more fluctuation than the recorded well point data. This may be due to raised groundwater levels in winter and spring months (groundwater mounding) affecting the recorded data.

ORLA1: Olympia, Thurston County



Site Information
Site Name ORLA 1
Address
City Olympia
Gage User Selected
Precip Factor 1.000
☐ Use WS-DOT data
X 20
Y 24

ORLA 1 Mitigated
Facility Name ORLA 1

	Outlet 1	Outlet 2	Outlet 3
Downstream Connection	0	0	0

☐ Use simple Bioretention
☑ Underdrain Used
Bioretention Bottom Elevation 0
Bioretention Dimensions
Bioretention Length (ft) 200.000
Bioretention Bottom Width (ft) 10.500
Freeboard (ft) 0.830
Over road Flooding (ft) 0.000
Effective Total Depth (ft) 4.9
Bottom slope of bioretention (0-1) 0.000
☑ Sidewall Invert Location.
Front and Back side slope (H/V) 0.000
Left Side Slope (H/V) 1.800
Right Side Slope (H/V) 1.800
Material Layers for

	Layer 1	Layer 2	Layer 3
Depth (ft)	1.300	2.100	0.000

Soil Layer 1 ASTM 2
Soil Layer 2 ASTM 24.32
Soil Layer 3 GRAVEL
KSat Safety Factor ● None ○ 2 ○ 4

Underdrain Diameter(ft) 0.34 Offset(in)
Orifice Diameter(in) 3 0
Flow Through Underdrain (ac-ft) 0.345
Total Outflow (ac-ft) 2.835
Percent Through Underdrain 12.17
WQ Percent Filtered 100

Riser Outlet Structure
Outlet Structure Data
Riser Height Above bioretention surface (ft) 0.67
Riser Diameter (in) 12
Riser Type Flat

Orifice Number	Diameter (in)	Height (ft)
1	0	0
2	0	0
3	0	0

Bioretention Volume at Riser Head (ac-ft) .158
Show Bioretention Open Table

Native Infiltration Yes
Measured Infiltration Rate (in/hr) 23
Reduction Factor (infilt*factor) 1
Use Wetted Surface Area (sidewalls) NO
Total Inflow ac-ft 2.945

Total Volume Infiltrated (ac-ft) 2.49
Total Volume Through Riser (ac-ft) 0
Total Volume Through Facility(ac-ft) 2.835
Percent Infiltrated 87.83
Precipitation on Facility (acre-ft) 0.345
Evaporation from Facility (acre-ft) 0.11

The ORLA1 bioretention site is located in Olympia, Thurston County, Washington. The drainage area to ORLA1 consists of 0.40 acres of roof on a flat slope (0-5%).

The ORLA1 surface bottom footprint is 2100 square feet. This equals 12% of the tributary drainage area to ORLA1.

ORLA1 has a surface outlet at 0.67 feet above the surface bottom. ORLA1 also has an underdrain. The underdrain is set at the bottom of the bioretention soil layer. Most of the inflow to ORLA1 is infiltrated into the native soil beneath the bioretention soil layers. The underdrain is connected to a gravel trench so all of the inflow infiltrates into the native soil either through the bottom of the bioretention facility or through the underdrain gravel trench.

A native soil infiltration rate of 23 inches per hour together with a bioretention top soil layer of ASTM2 soil and a second soil layer of ASTM24 soil best reproduced the monitored soil moisture and surface ponding conditions.

Figure ORLA1-1 shows the simulated (red) and recorded (blue) daily inflow volumes and, along the top of the figure, the ORLA1 site monitored daily rainfall data. The simulated daily inflow volumes are consistently higher than the recorded data in the early months of October and November 2017, but then tend to match well for the later months starting in January. There is no obvious reason for the seasonal difference in inflow volumes.

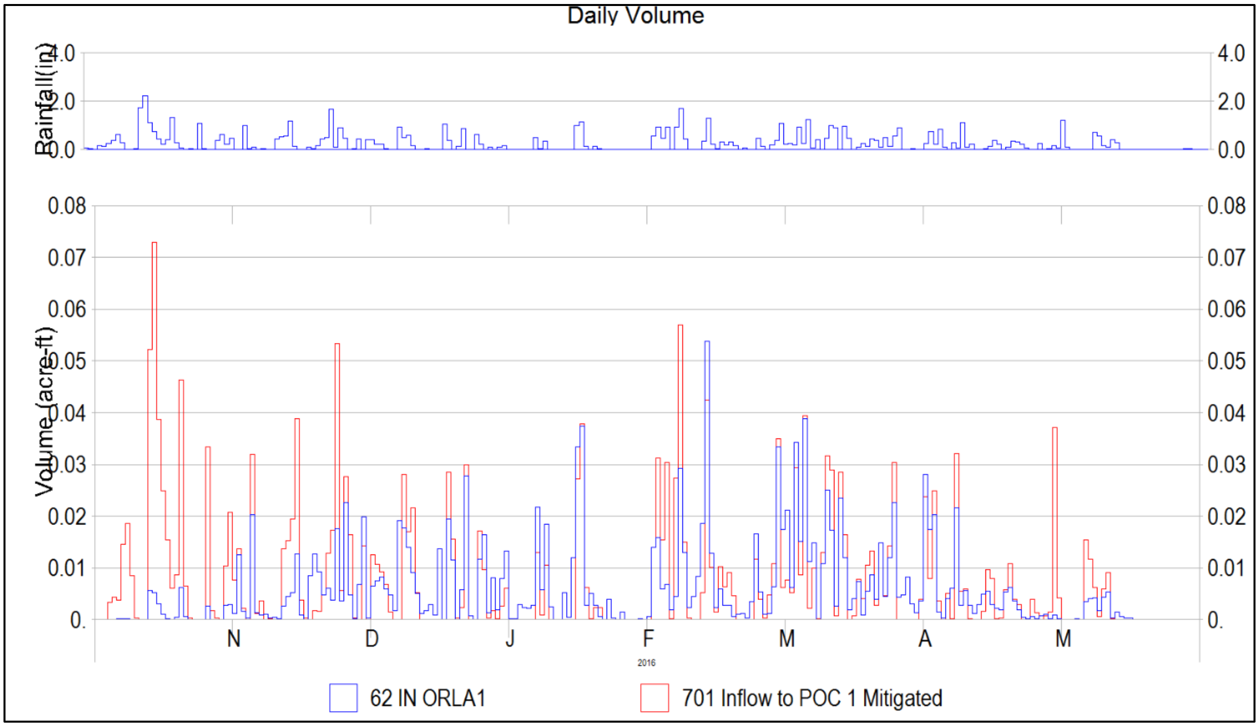


Figure ORLA1-1. ORLA1 Daily Inflow Volumes

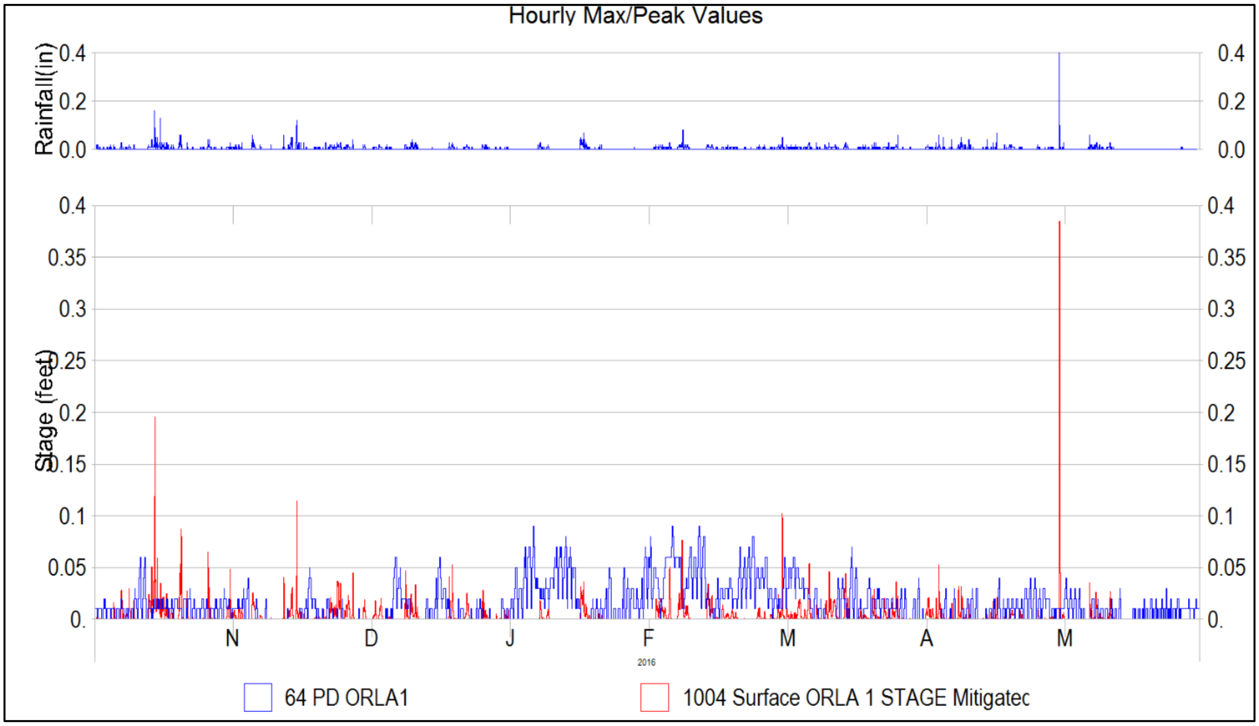


Figure ORLA1-2. ORLA1 Hourly Surface Ponding Depths

Figure ORLA1-2 shows the simulated (red) and recorded (blue) hourly maximum 5-minute surface ponding (stage) values and, along the top of the figure, the ORLA1 site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values show mixed results. Most of the time there is very little surface ponding. This is due to the relatively large bioretention surface bottom area compared to the contributing roof drainage area. However, there are some large storm events in October 2016 and May 2017 that produce high simulated runoff and corresponding high ponding depths, but neither are seen in the recorded data. The monitored rainfall data were compared with surrounding county rain gages and appear to be correct, but there is no obvious reason for the discrepancy between the monitored rainfall data and the inflow (and ponding) data.

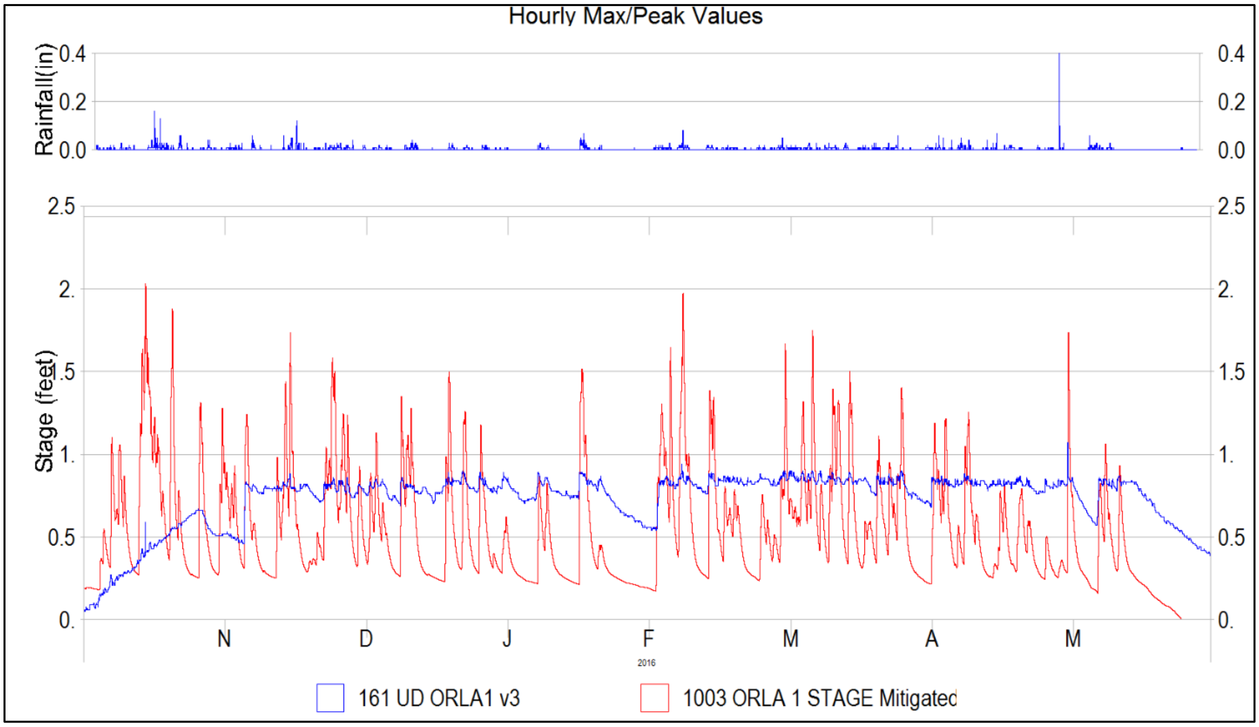
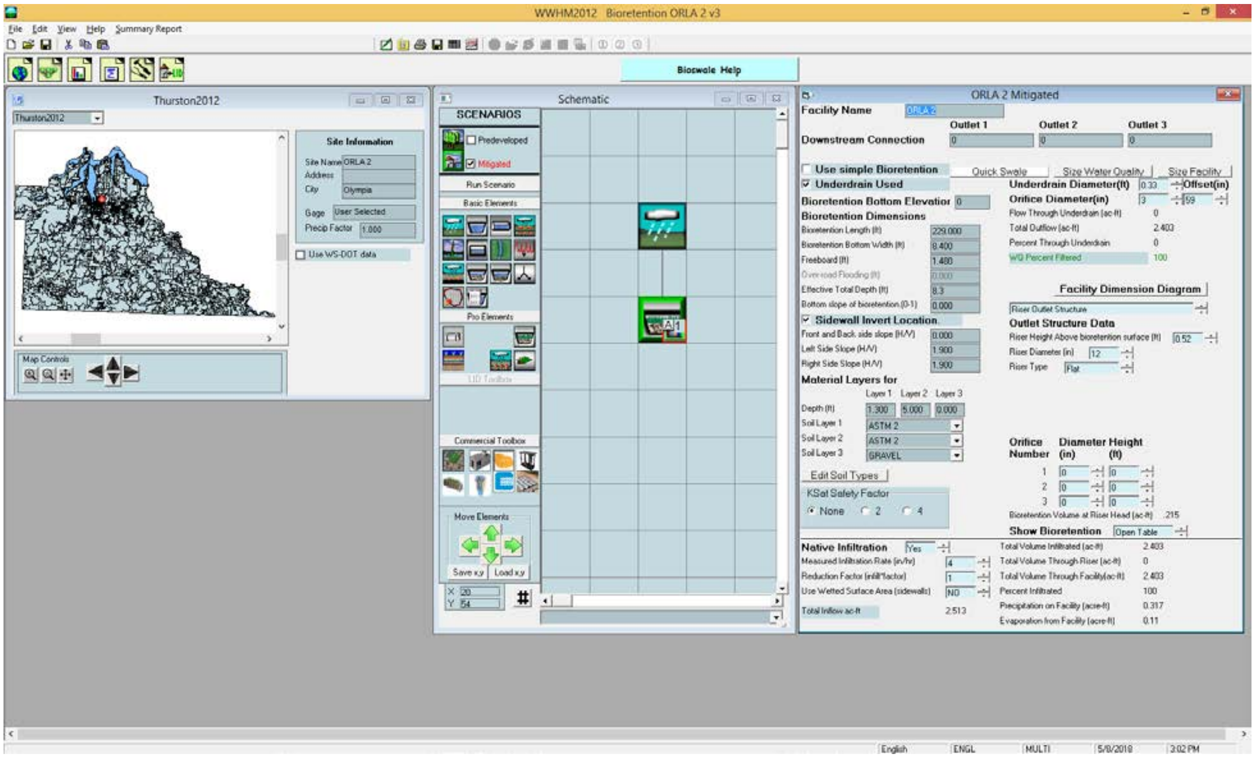


Figure ORLA1-3. ORLA1 Hourly Soil Layer Well Point Elevations

Figure ORLA1-3 shows the simulated (red) and recorded (blue) hourly maximum 5-minute soil layer well point elevations (stage) values and, along the top of the figure, the ORLA1 site monitored hourly maximum 5-minute rainfall data. The simulated values show more fluctuation than the recorded well point data. This may be due to raised groundwater levels in winter and spring months (groundwater mounding) affecting the recorded data.

ORLA2: Olympia, Thurston County



Site Name ORLA 2
City Olympia
Gage User Selected
Precip Factor 1.000
X 20
Y 54

Facility Name ORLA 2

	Outlet 1	Outlet 2	Outlet 3
Downstream Connection	0	0	0

☐ Use simple Bioretention
☑ Underdrain Used
Bioretention Bottom Elevation 0
Bioretention Dimensions
Bioretention Length (ft) 229.000
Bioretention Bottom Width (ft) 8.400
Freeboard (ft) 1.480
Overroad Flooding (ft) 0.000
Effective Total Depth (ft) 8.3
Bottom slope of bioretention (0-1) 0.000
☑ Sidewall Invert Location
Front and Back side slope (H/V) 0.000
Left Side Slope (H/V) 1.900
Right Side Slope (H/V) 1.900

Material Layers for

	Layer 1	Layer 2	Layer 3
Depth (ft)	1.300	5.000	0.000

Soil Layer 1 ASTM 2
Soil Layer 2 ASTM 2
Soil Layer 3 GRAVEL
KSat Safety Factor ● None ○ 2 ○ 4

Underdrain Diameter(ft) 0.33 Offset(in)
Orifice Diameter(in) 3 59
Flow Through Underdrain (ac-ft) 0
Total Outflow (ac-ft) 2.403
Percent Through Underdrain 0
WQ Percent Filtered 100

Riser Outlet Structure
Outlet Structure Data
Riser Height Above bioretention surface (ft) 0.52
Riser Diameter (in) 12
Riser Type Flat

Orifice Number	Diameter (in)	Height (ft)
1	0	0
2	0	0
3	0	0

Bioretention Volume at Riser Head (ac-ft) .215
Show Bioretention Open Table

Native Infiltration Yes
Measured Infiltration Rate (in/hr) 4
Reduction Factor (infilt*factor) 1
Use Wetted Surface Area (sidewalls) NO
Total Inflow ac-ft 2.513

Total Volume Infiltrated (ac-ft) 2.403
Total Volume Through Riser (ac-ft) 0
Total Volume Through Facility(ac-ft) 2.403
Percent Infiltrated 100
Precipitation on Facility (acre-ft) 0.317
Evaporation from Facility (acre-ft) 0.11

The ORLA2 bioretention site is located in Olympia, Thurston County, Washington. The drainage area to ORLA2 consists of 0.338 acres of roof on a flat slope (0-5%).

The ORLA2 surface bottom footprint is 1924 square feet. This equals 13% of the tributary drainage area to ORLA2.

ORLA2 has a surface outlet at 0.52 feet above the surface bottom. ORLA2 also has an underdrain. The underdrain is set at 59 inches above the bottom of the bioretention soil layer. Most of the inflow to ORLA2 is infiltrated into the native soil beneath the bioretention soil layers. The underdrain is connected to a gravel trench so all of the inflow infiltrates into the native soil either through the bottom of the bioretention facility or through the underdrain gravel trench.

A native soil infiltration rate of 4 inches per hour together with a bioretention top soil layer of ASTM2 soil and a second soil layer of ASTM24 soil best reproduced the monitored soil moisture and surface ponding conditions.

Figure ORLA2-1 shows the simulated (red) and recorded (blue) daily inflow volumes and, along the top of the figure, the ORLA2 site monitored daily rainfall data. The simulated daily inflow volumes are consistently higher than the recorded data for most of the monitored period. The recorded data is from monitored roof runoff via downspouts to ORLA2. There is no obvious reason for the difference in inflow volumes.

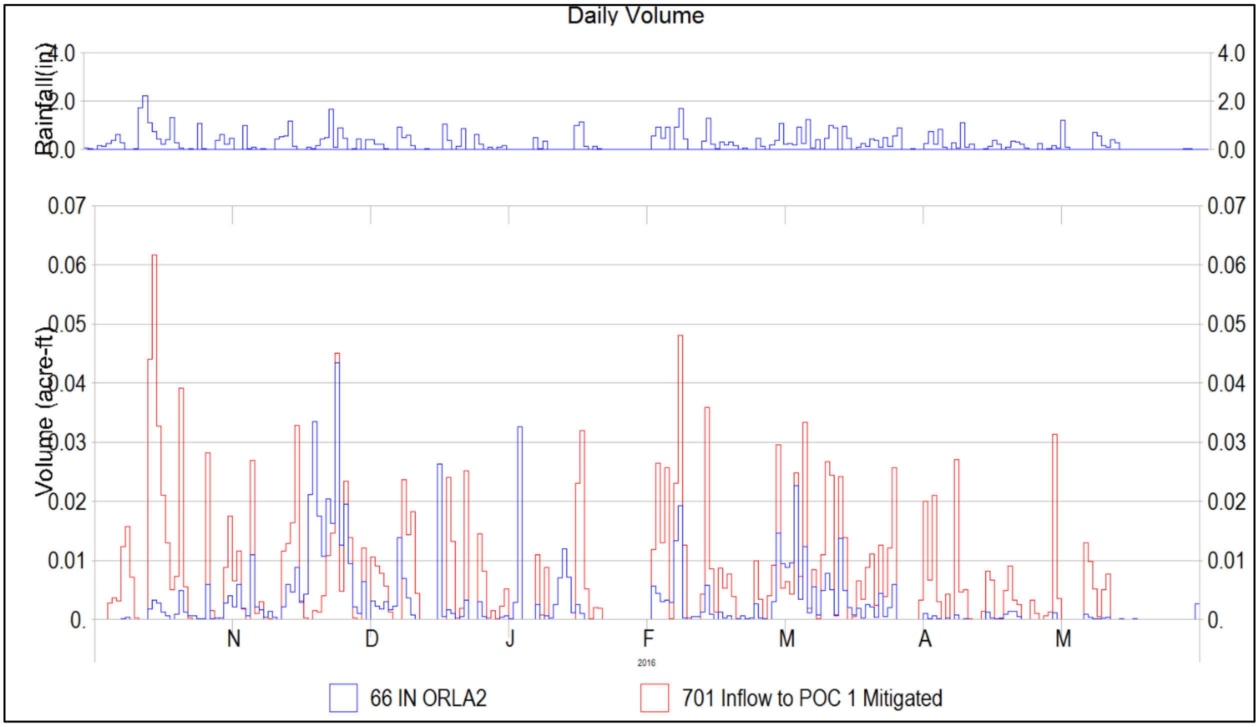


Figure ORLA2-1. ORLA2 Daily Inflow Volumes

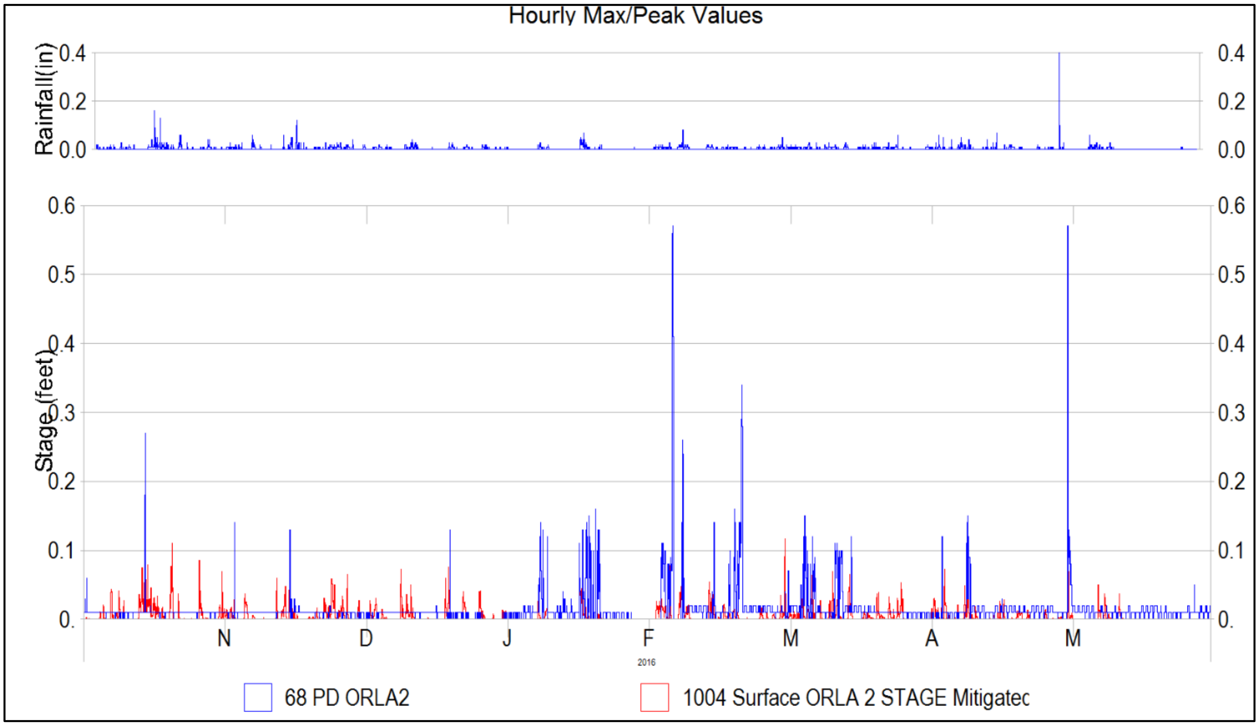


Figure ORLA2-2. ORLA1 Hourly Surface Ponding Depths

Figure ORLA2-2 shows the simulated (red) and recorded (blue) hourly maximum 5-minute surface ponding (stage) values and, along the top of the figure, the ORLA2 site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values show low simulated ponding depths compared to the recorded depths. That said, most of the time there is very little surface ponding. This is due to the relatively large bioretention surface bottom area compared to the contributing roof drainage area. However, there are some large storm events in October 2016 and May 2017 that produce high recorded ponding depths not reproduced by the simulated results (this is the opposite of what was seen in ORLA1).

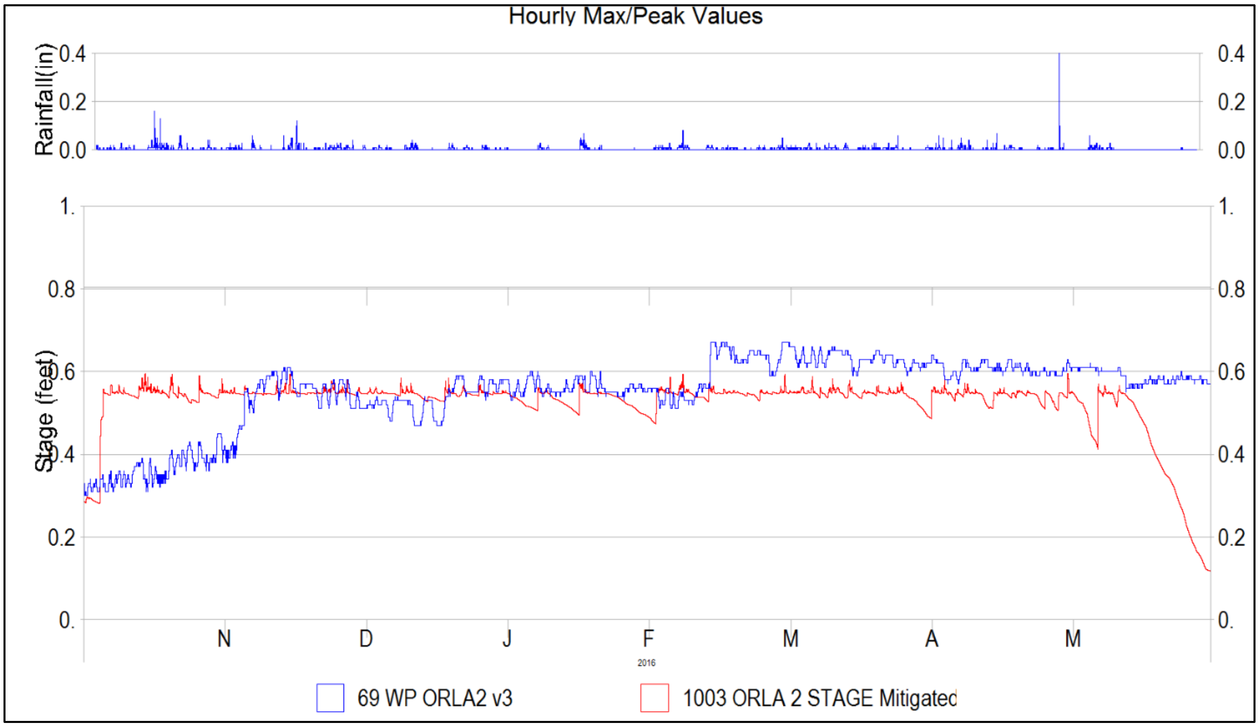
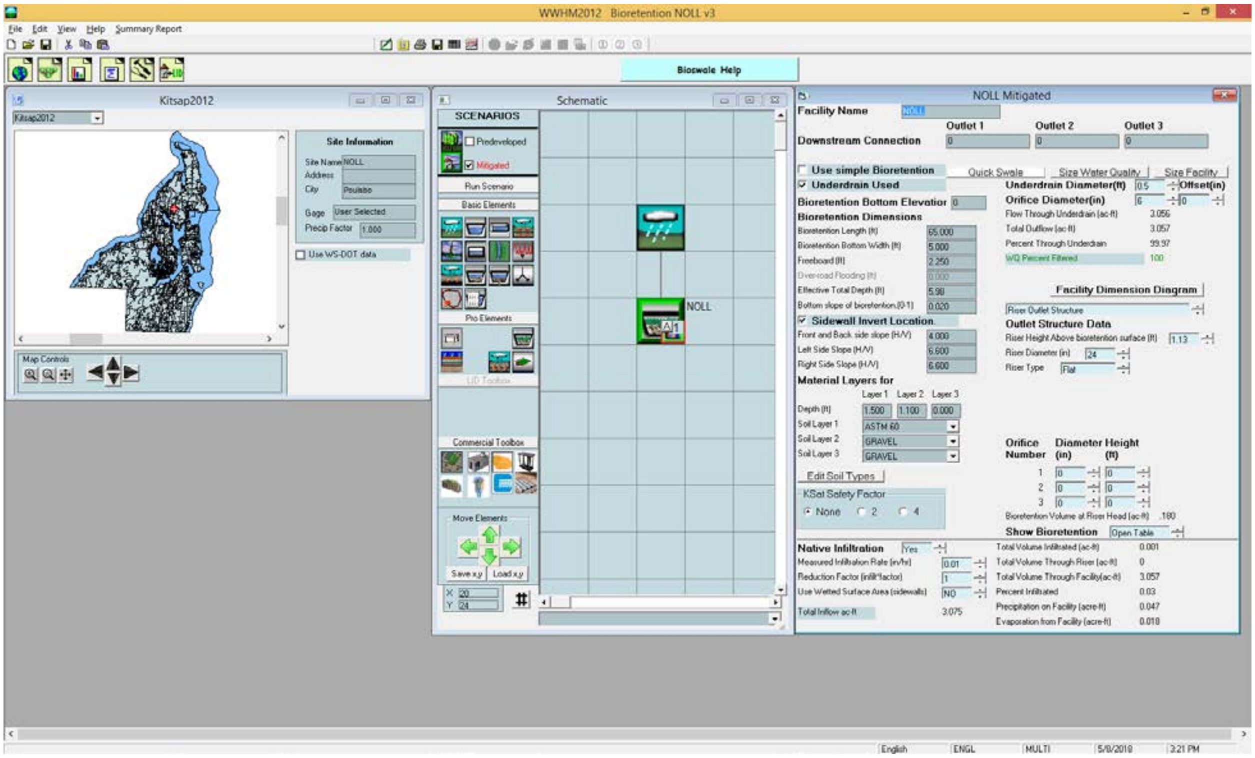


Figure ORLA2-3. ORLA2 Hourly Soil Layer Well Point Elevations

Figure ORLA2-3 shows the simulated (red) and recorded (blue) hourly maximum 5-minute soil layer well point elevations (stage) values and, along the top of the figure, the ORLA2 site monitored hourly maximum 5-minute rainfall data. The simulated values match well with the recorded well point data, even though the ponding depths do not show a good match.

NOLL: Poulsbo, Kitsap County



Kitsap2012

Site Information
Site Name: NOLL
Address:
City: Poulsbo
Gage: User Selected
Precip Factor: 1.000
☐ Use WS-DOT data

☐ Predeveloped
☑ Mitigated

X: 20
Y: 24

NOLL Mitigated

Facility Name: NOLL

	Outlet 1	Outlet 2	Outlet 3
Downstream Connection	0	0	0

☐ Use simple Bioretention
☑ Underdrain Used
Bioretention Bottom Elevation: 0

Bioretention Dimensions
Bioretention Length (ft): 65.000
Bioretention Bottom Width (ft): 5.000
Freeboard (ft): 2.250
Over-road Flooding (ft): 0.000
Effective Total Depth (ft): 5.90
Bottom slope of bioretention.(0-1): 0.020
☑ Sidewall Invert Location.
Front and Back side slope (H/V): 4.000
Left Side Slope (H/V): 6.600
Right Side Slope (H/V): 6.600

Material Layers for

	Layer 1	Layer 2	Layer 3
Depth (ft)	1.500	1.100	0.000

Soil Layer 1: ASTM 60
Soil Layer 2: GRAVEL
Soil Layer 3: GRAVEL

KSat Safety Factor: ● None ○ 2 ○ 4

Underdrain Diameter(ft): 0.5 Offset(in)
Orifice Diameter(in): 6 0
Flow Through Underdrain (ac-ft): 3.056
Total Outflow (ac-ft): 3.057
Percent Through Underdrain: 99.97
WQ Percent Filtered: 100

Riser Outlet Structure
Outlet Structure Data
Riser Height Above bioretention surface (ft): 1.13
Riser Diameter (in): 24
Riser Type: Flat

Orifice Number	Diameter (in)	Height (ft)
1	0	0
2	0	0
3	0	0

Bioretention Volume at Riser Head (ac-ft): .180
Show Bioretention: Open Table

Native Infiltration: Yes
Measured Infiltration Rate (in/hr): 0.01
Reduction Factor (infilt*factor): 1
Use Wetted Surface Area (sidewalls): NO
Total Inflow ac-ft: 3.075

Total Volume Infiltrated (ac-ft): 0.001
Total Volume Through Riser (ac-ft): 0
Total Volume Through Facility(ac-ft): 3.057
Percent Infiltrated: 0.03
Precipitation on Facility (acre-ft): 0.047
Evaporation from Facility (acre-ft): 0.018

The NOLL bioretention site is located in Poulsbo, Kitsap County, Washington. The drainage area to NOLL consists of 0.288 acres of NRCS Type C soil, lawn vegetation, on a flat slope (0-5%), 0.36 acres of roads on a flat slope (0-5%), and 0.041 acres of sidewalk on a flat slope (0-5%).

The NOLL surface bottom footprint is 520 square feet. This equals 2% of the tributary drainage area to NOLL.

NOLL has a surface outlet at 1.13 feet above the surface bottom. NOLL also has an underdrain. The underdrain is set at the bottom of the bioretention soil layer. Most of the inflow to NOLL is discharged through the underdrain. The underdrain is connected to a stormwater surface conveyance system.

A native soil infiltration rate of 0.01 inches per hour together with a bioretention top soil layer of ASTM60 soil and a second soil layer of gravel best reproduced the monitored soil moisture and surface ponding conditions.

Figure NOLL-1 shows the simulated (red) and recorded (blue) daily inflow volumes and, along the top of the figure, the NOLL site monitored daily rainfall data. The simulated and recorded daily inflow volumes match well, except for December 2016 where snow and freezing conditions affected the recorded values.

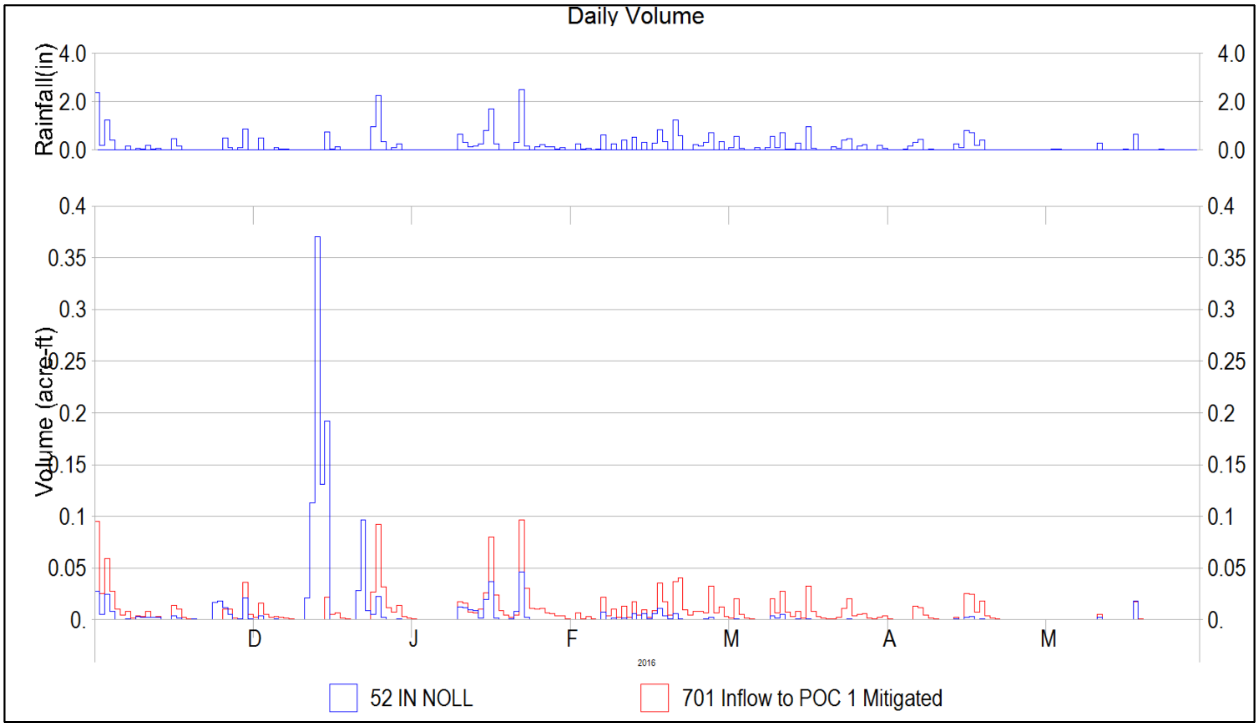


Figure NOLL-1. NOLL Daily Inflow Volumes

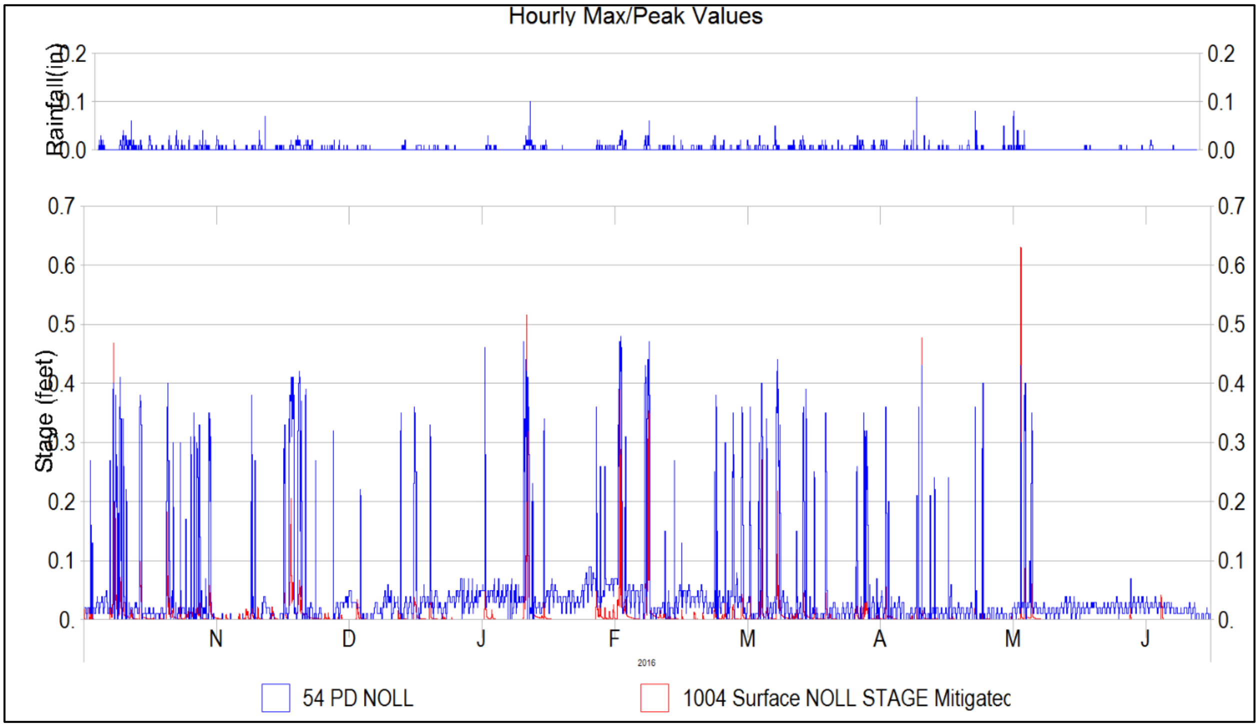


Figure NOLL-2. NOLL Hourly Surface Ponding Depths

Figure NOLL-2 shows the simulated (red) and recorded (blue) hourly maximum 5-minute surface ponding (stage) values and, along the top of the figure, the NOLL site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values are mixed. The higher/larger ponding depths match well, but the simulated depths for the smaller events do not show as much of a response as the monitored data.

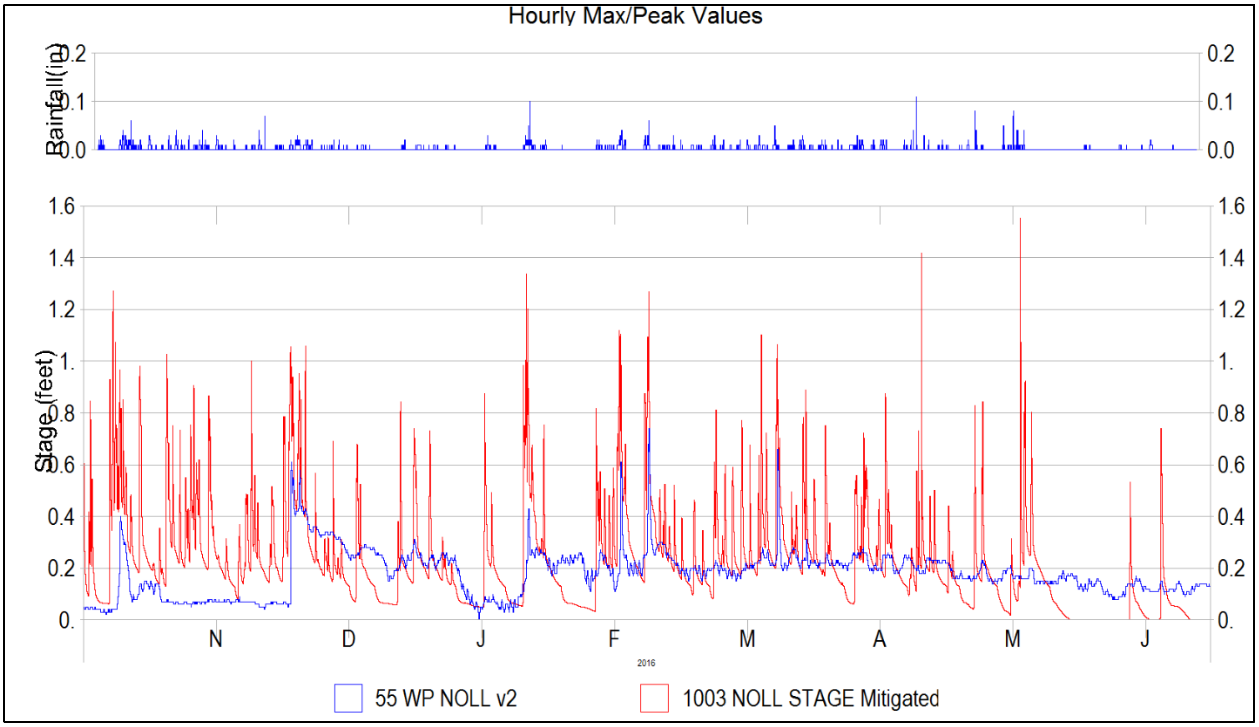


Figure NOLL-3. NOLL Hourly Soil Layer Well Point Elevations

Figure NOLL-3 shows the simulated (red) and recorded (blue) hourly maximum 5-minute soil layer well point elevations (stage) values and, along the top of the figure, the NOLL site monitored hourly maximum 5-minute rainfall data. The simulated values show more fluctuation than the recorded well point data. This may be due to the underdrain's drainage of water from the soil layers.

Figure NOLL-4 shows the simulated (red) and recorded (blue) daily underdrain discharge volumes and, along the top of the figure, the NOLL site monitored daily rainfall data. The simulated daily underdrain discharges volumes are consistently higher than the recorded volumes.

Figure NOLL-5 shows that the simulated (blue) daily inflow volumes and the simulated (red) daily underdrain discharge (outflow) volumes are nearly identical (note that the inflow volume does not include rain on NOLL bioretention site). This shows that all or nearly all of the inflow is discharged via the underdrain. These results are consistent and expected.

The recorded (monitored) underdrain outlet flows do not show this consistency with the inflow volumes.

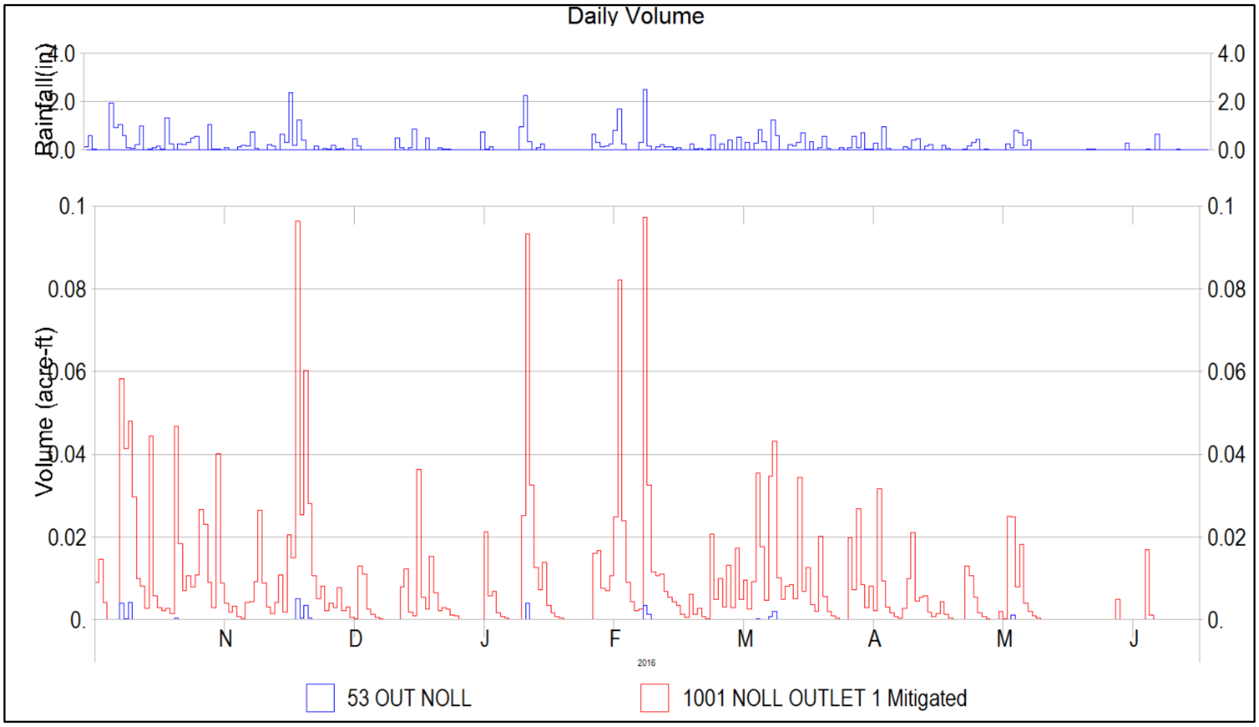


Figure NOLL-4. NOLL Daily Underdrain Discharge Volumes

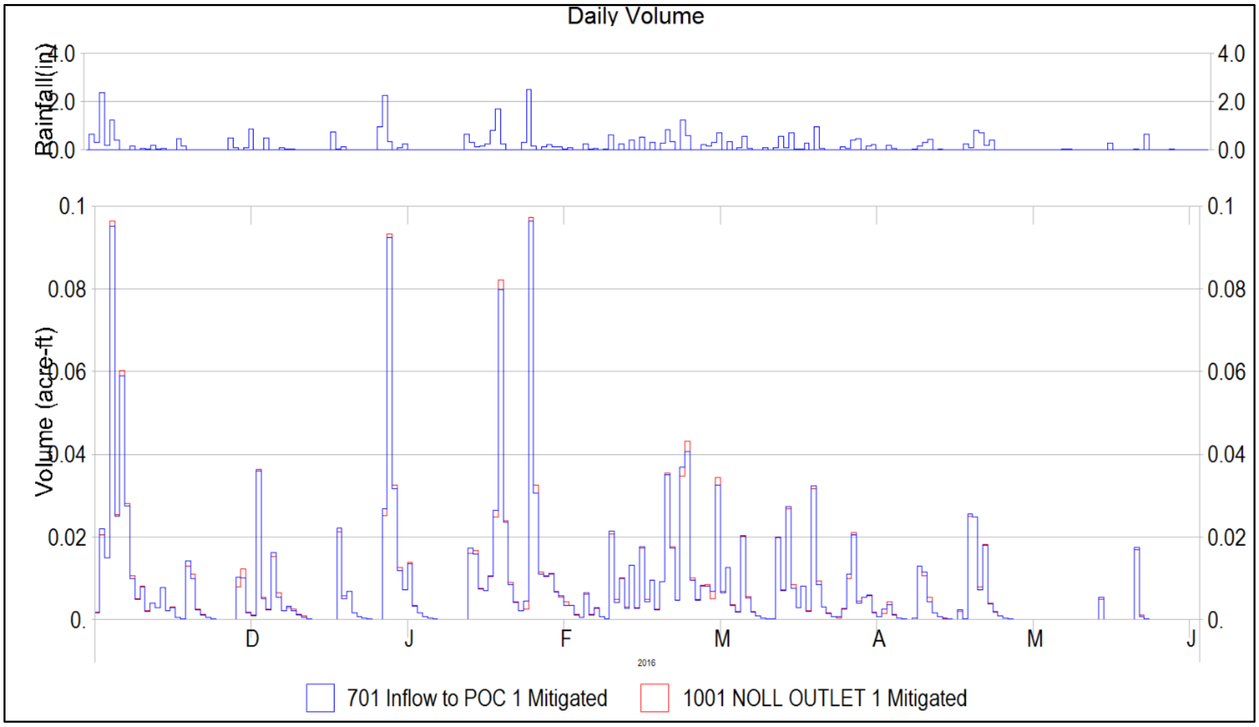
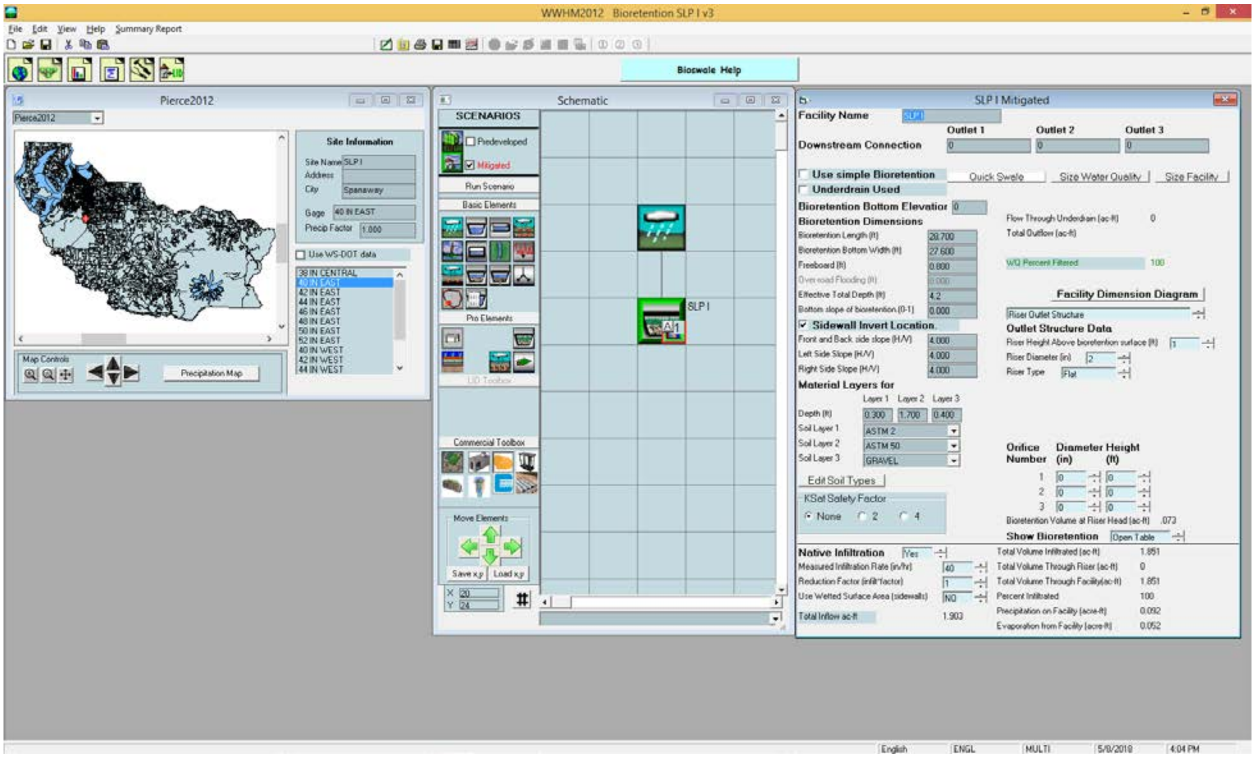


Figure NOLL-5. NOLL Daily Simulated Inflow and Underdrain Discharge Volumes

SLPI: Spanaway, Pierce County



Site Information
Site Name SLP I
Address
City Spanaway
Gage 40 IN EAST
Precip Factor 1.000
☐ Use WS-DOT data
38 IN CENTRAL
40 IN EAST
42 IN EAST
44 IN EAST
46 IN EAST
48 IN EAST
50 IN EAST
52 IN EAST
40 IN WEST
42 IN WEST
44 IN WEST

☐ Predeveloped
☑ Mitigated

X 20
Y 24

Facility Name SLP I

	Outlet 1	Outlet 2	Outlet 3
Downstream Connection	0	0	0

☐ Use simple Bioretention
☐ Underdrain Used
Bioretention Bottom Elevation 0

Bioretention Dimensions
Bioretention Length (ft) 28.700
Bioretention Bottom Width (ft) 27.600
Freeboard (ft) 0.800
Over-road Flooding (ft) 0.000
Effective Total Depth (ft) 4.2
Bottom slope of bioretention (0-1) 0.000
☑ Sidewall Invert Location
Front and Back side slope (H/V) 4.000
Left Side Slope (H/V) 4.000
Right Side Slope (H/V) 4.000

Material Layers for

	Layer 1	Layer 2	Layer 3
Depth (ft)	0.300	1.700	0.400

Soil Layer 1 ASTM 2
Soil Layer 2 ASTM 50
Soil Layer 3 GRAVEL

KSat Safety Factor
● None ○ 2 ○ 4

Flow Through Underdrain (ac-ft) 0
Total Outflow (ac-ft)
WQ Percent Filtered 100

Riser Outlet Structure
Outlet Structure Data
Riser Height Above bioretention surface (ft) 1
Riser Diameter (in) 2
Riser Type Flat

Orifice Number	Diameter (in)	Height (ft)
1	0	0
2	0	0
3	0	0

Bioretention Volume at Riser Head (ac-ft) .073
Show Bioretention Open Table

Native Infiltration Yes
Measured Infiltration Rate (in/hr) 40
Reduction Factor (infilt*factor) 1
Use Wetted Surface Area (sidewalls) NO
Total Inflow ac-ft 1.903

Total Volume Infiltrated (ac-ft) 1.851
Total Volume Through Riser (ac-ft) 0
Total Volume Through Facility(ac-ft) 1.851
Percent Infiltrated 100
Precipitation on Facility (acre-ft) 0.092
Evaporation from Facility (acre-ft) 0.052

The SLPI bioretention site is located in Spanaway, Pierce County, Washington. The drainage area to SLPI consists of 0.429 acres of road on a flat slope (0-5%).

The SLPI surface bottom footprint is 792 square feet. This equals 4% of the tributary drainage area to SLPI.

SLPI has no surface outlet control structure but overtops the site at 1.0 feet above the surface bottom. All of the inflow to SLPI is infiltrated into the native soil beneath the bioretention soil layers.

A native soil infiltration rate of 40 inches per hour together with a bioretention top soil layer of ASTM2 soil, a second soil layer of ASTM50 soil, and a third soil layer of gravel best reproduced the monitored soil moisture and surface ponding conditions. The top ASTM layer of 0.3 feet represents leaf litter. This was added to reproduce monitored surface ponding depths.

Figure SLPI-1 shows the simulated (red) and recorded (blue) daily inflow volumes and, along the top of the figure, the SLPI site monitored daily rainfall data. The simulated and recorded daily inflow volumes are mixed. Winter periods (November 2016 through February 2017) show major differences where snow and freezing conditions affected the recorded values. The simulated daily inflow volumes are also low in the spring, during the drier months.

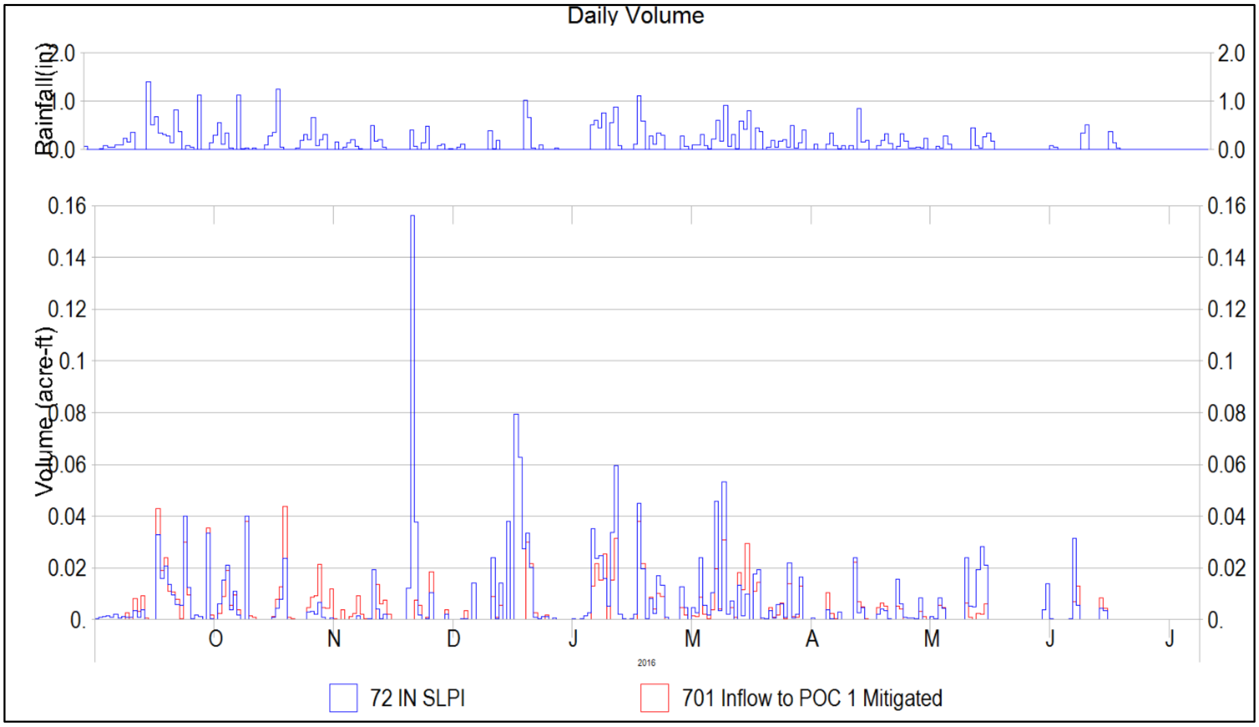


Figure SLPI-1. SLPI Daily Inflow Volumes

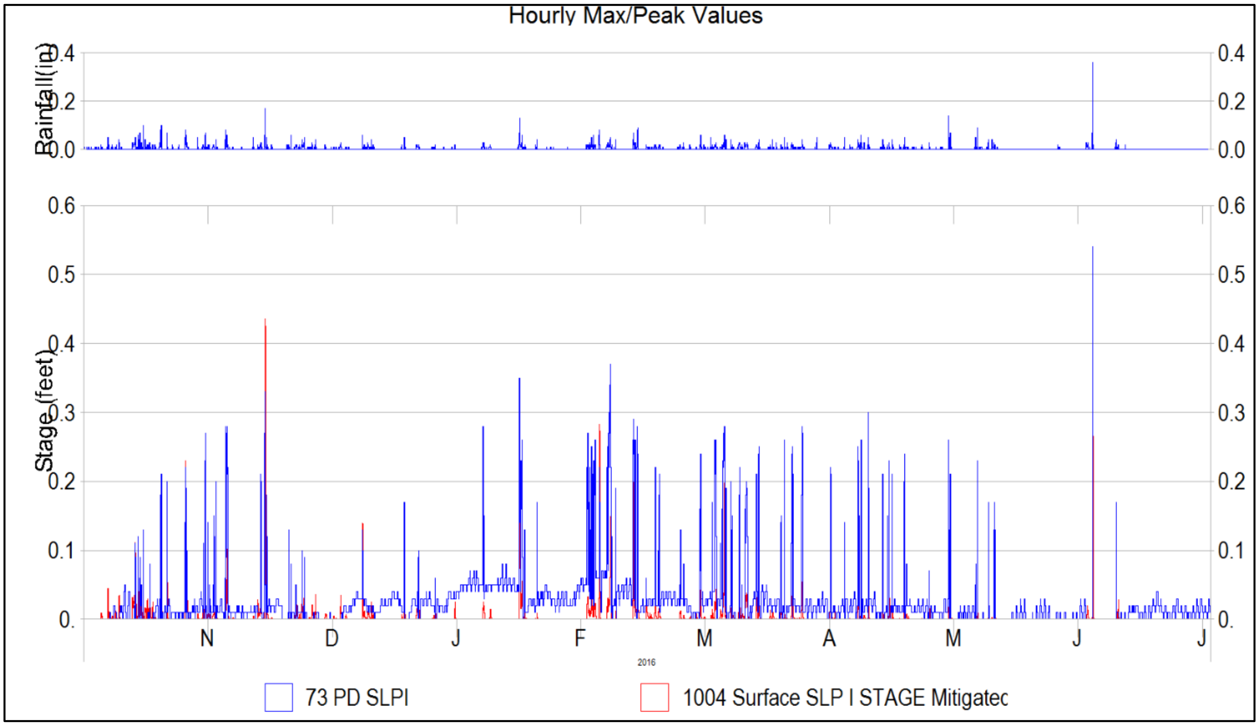


Figure SLPI-2. SLPI Hourly Surface Ponding Depths

Figure SLPI-2 shows the simulated (red) and recorded (blue) hourly maximum 5-minute surface ponding (stage) values and, along the top of the figure, the SLPI site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values are mixed. The higher/larger ponding depths match well, but the simulated depths for the smaller events do not show as much of a response as the monitored data.

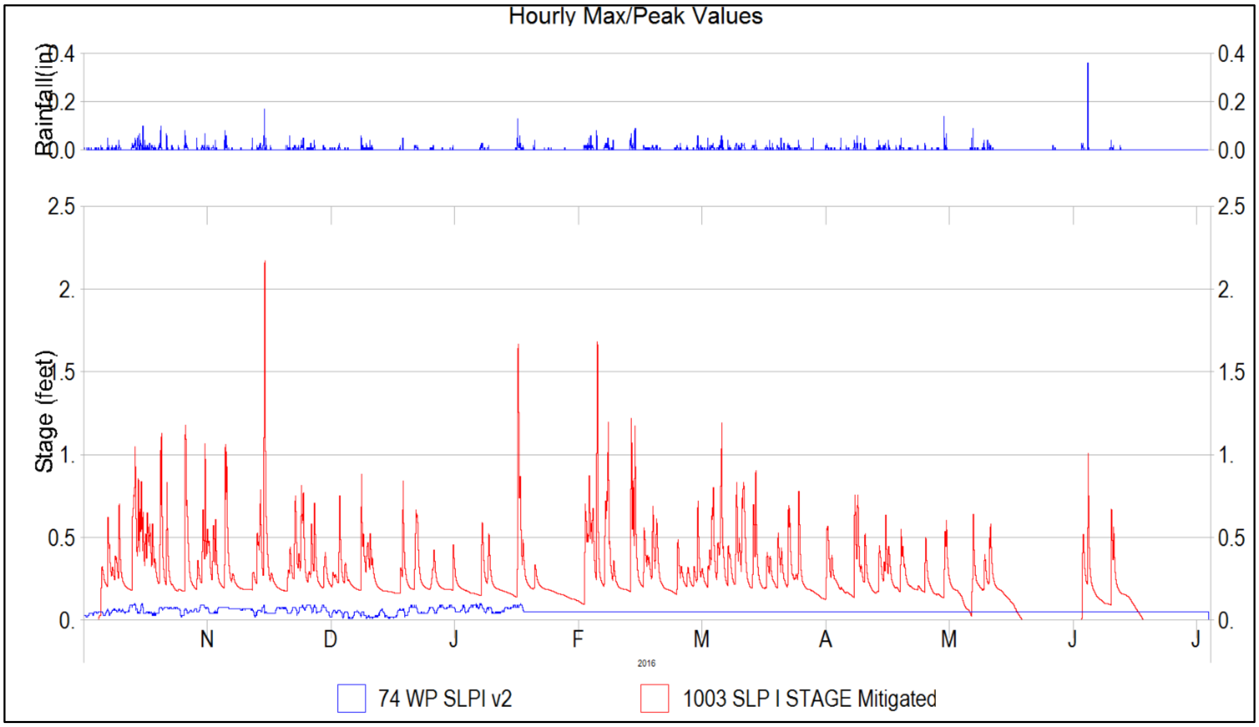
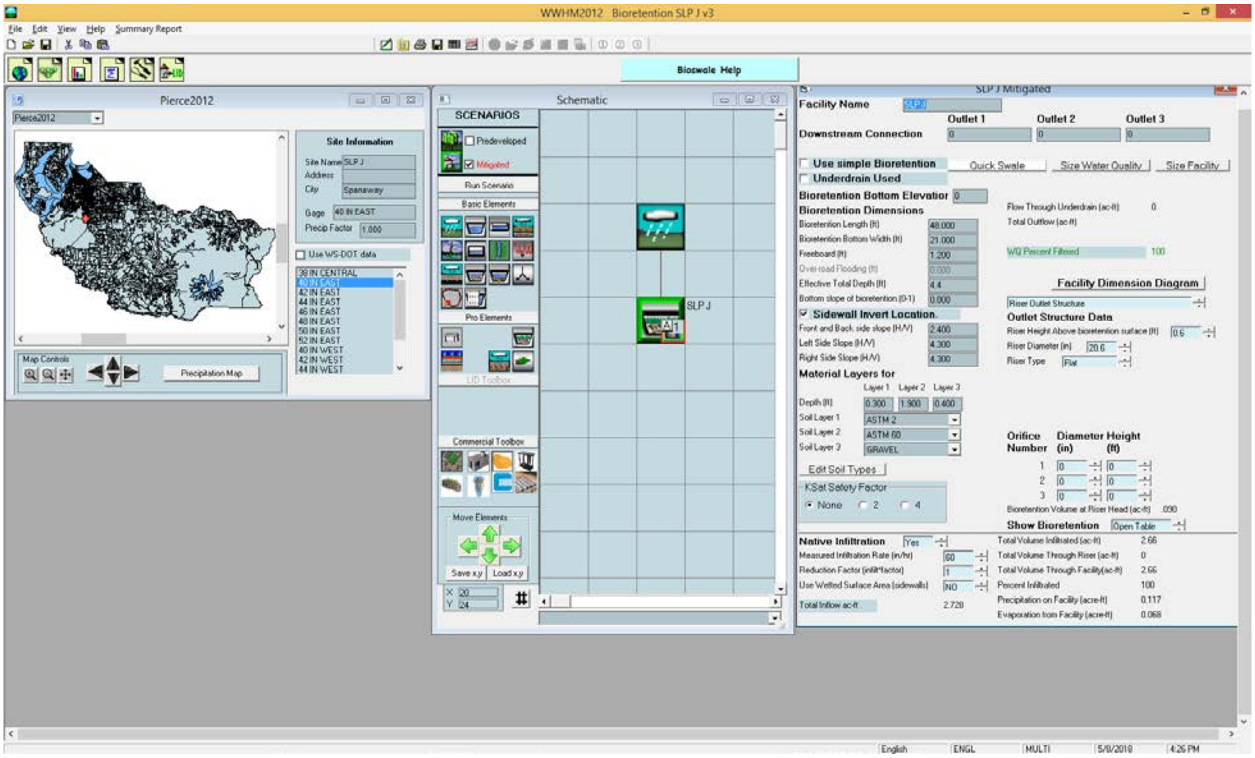


Figure SLPI-3. SLPI Hourly Soil Layer Well Point Elevations

Figure SLPI-3 shows the simulated (red) and recorded (blue) hourly maximum 5-minute soil layer well point elevations (stage) values and, along the top of the figure, the SLPI site monitored hourly maximum 5-minute rainfall data. The simulated values show more fluctuation than the recorded well point data. This may be due to the high native soil infiltration rate and drainage of water from the soil layers.

SLPJ: Spanaway, Pierce County



Site Information
Site Name SLP J
Address
City Spanaway
Gage 40 IN EAST
Precip Factor 1.000
☐ Use WS-DOT data

Facility Name SLPJ

	Outlet 1	Outlet 2	Outlet 3
Downstream Connection	0	0	0

☐ Use simple Bioretention
☐ Underdrain Used
Bioretention Bottom Elevation 0
Bioretention Dimensions
Bioretention Length (ft) 48.000
Bioretention Bottom Width (ft) 21.000
Freeboard (ft) 1.200
Over-road Flooding (ft) 0.000
Effective Total Depth (ft) 4.4
Bottom slope of bioretention.(0-1) 0.000
☑ Sidewall Invert Location.
Front and Back side slope (H/V) 2.400
Left Side Slope (H/V) 4.300
Right Side Slope (H/V) 4.300
Material Layers for

	Layer 1	Layer 2	Layer 3
Depth (ft)	0.300	1.900	0.400

Soil Layer 1 ASTM 2
Soil Layer 2 ASTM 60
Soil Layer 3 GRAVEL
KSat Safety Factor ● None ○ 2 ○ 4

Flow Through Underdrain (ac-ft) 0
Total Outflow (ac-ft)
WQ Percent Filtered 100
Riser Outlet Structure
Outlet Structure Data
Riser Height Above bioretention surface (ft) 0.6
Riser Diameter (in) 20.6
Riser Type Flat

Orifice Number	Diameter (in)	Height (ft)
1	0	0
2	0	0
3	0	0

Bioretention Volume at Riser Head (ac-ft) .090
Show Bioretention Open Table

Native Infiltration Yes
Measured Infiltration Rate (in/hr) 60
Reduction Factor (infilt*factor) 1
Use Wetted Surface Area (sidewalls) NO
Total Inflow ac-ft 2.720

Total Volume Infiltrated (ac-ft) 2.66
Total Volume Through Riser (ac-ft) 0
Total Volume Through Facility(ac-ft) 2.66
Percent Infiltrated 100
Precipitation on Facility (acre-ft) 0.117
Evaporation from Facility (acre-ft) 0.068

The SLPJ bioretention site is located in Spanaway, Pierce County, Washington. The drainage area to SLPI consists of 0.618 acres of road on a flat slope (0-5%).

The SLPJ surface bottom footprint is 1008 square feet. This equals 4% of the tributary drainage area to SLPJ.

SLPJ has a surface outlet control structure that overtops at 0.6 feet above the surface bottom. All of the inflow to SLPJ is infiltrated into the native soil beneath the bioretention soil layers.

A native soil infiltration rate of 60 inches per hour together with a bioretention top soil layer of ASTM2 soil, a second soil layer of ASTM60 soil, and a third soil layer of gravel best reproduced the monitored soil moisture and surface ponding conditions. The top ASTM layer of 0.3 feet represents leaf litter. This was added to reproduce monitored surface ponding depths.

Figure SLPJ-1 shows the simulated (red) and recorded (blue) daily inflow volumes and, along the top of the figure, the SLPJ site monitored daily rainfall data. The simulated daily inflow volumes are consistently lower than the recorded volumes although there are good matches in both the early fall (October 2017) and late spring (May-June 2017).

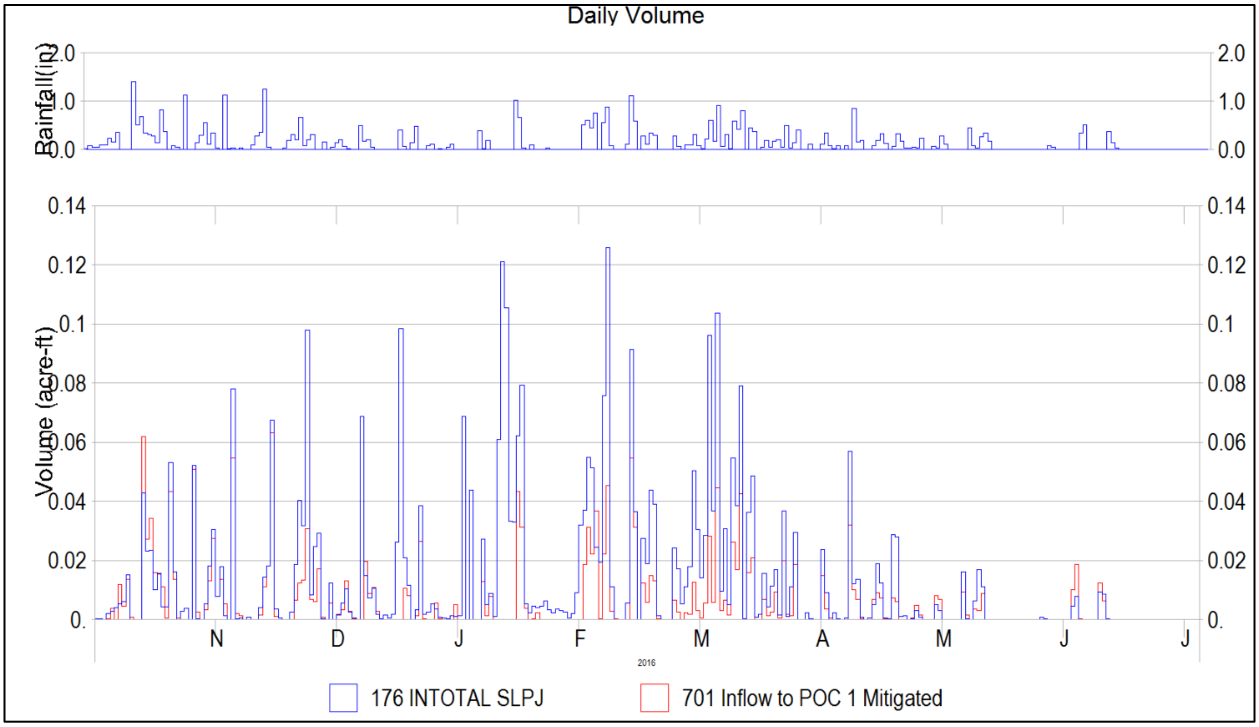


Figure SLPJ-1. SLPI Daily Inflow Volumes

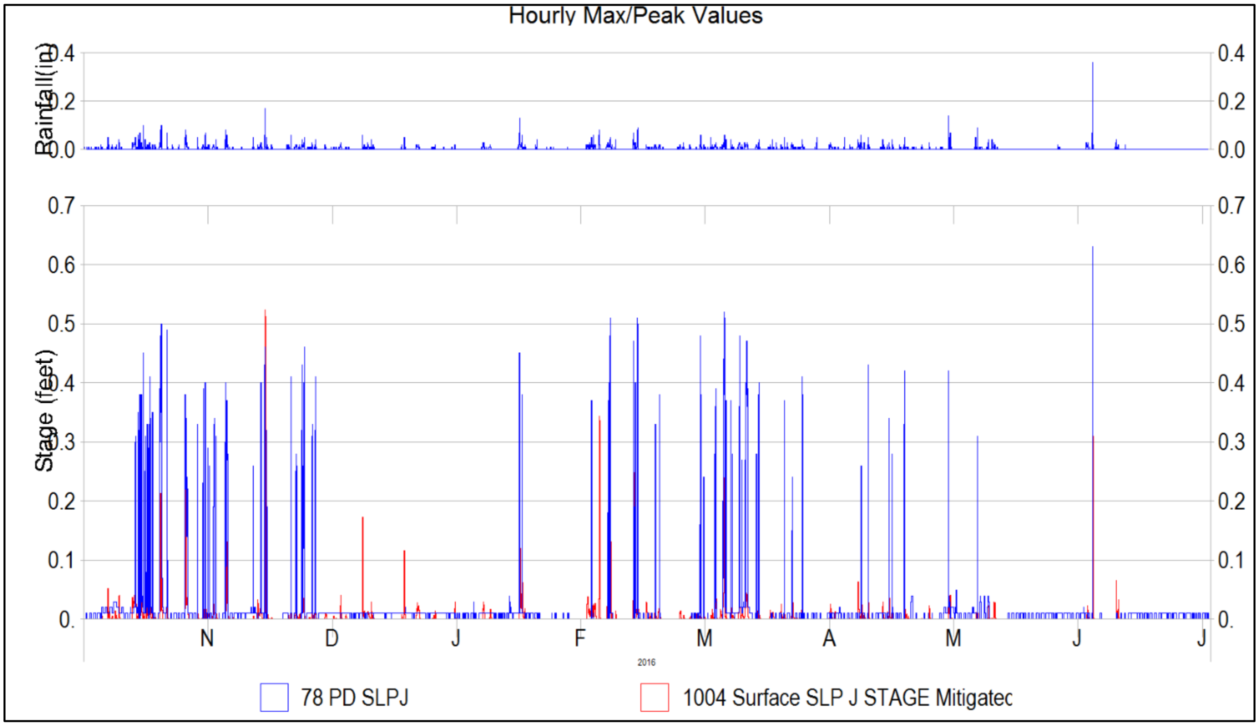


Figure SLPJ-2. SLPJ Hourly Surface Ponding Depths

Figure SLPJ-2 shows the simulated (red) and recorded (blue) hourly maximum 5-minute surface ponding (stage) values and, along the top of the figure, the SLPJ site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values are mixed. The higher/larger ponding depths match well, but the simulated depths for the smaller events do not show as much of a response as the monitored data.

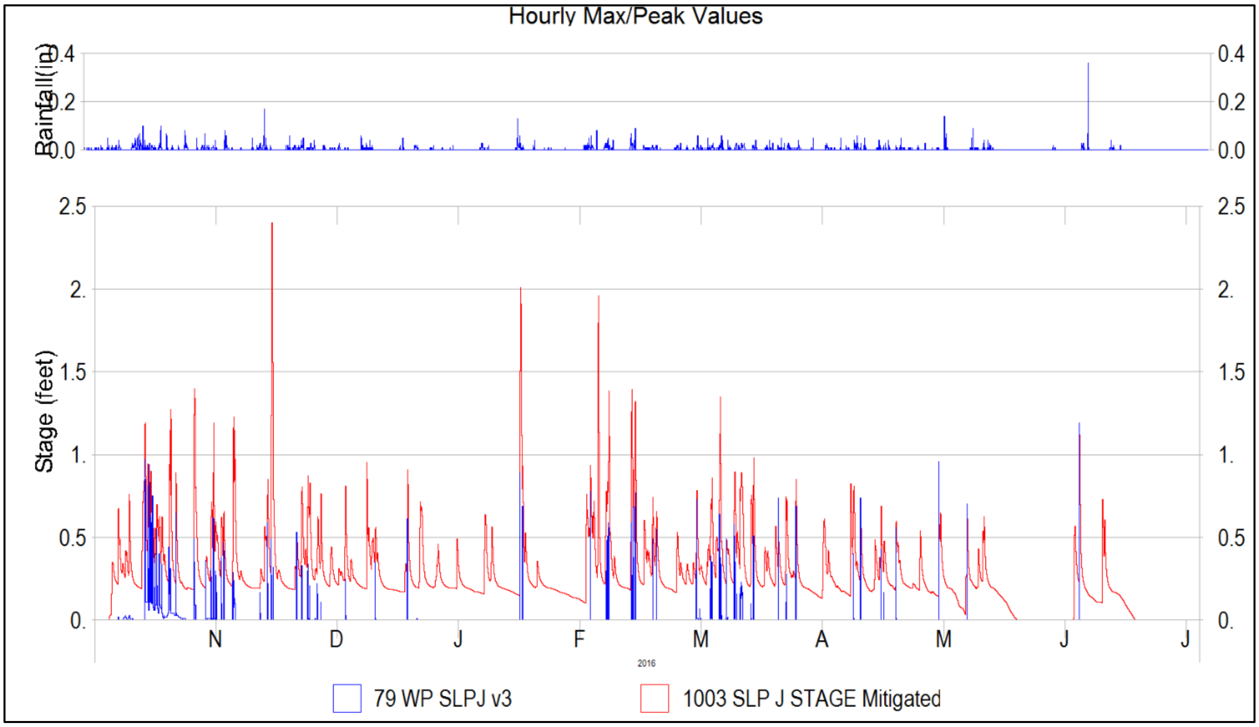


Figure SLPJ-3. SLPJ Hourly Soil Layer Well Point Elevations

Figure SLPJ-3 shows the simulated (red) and recorded (blue) hourly maximum 5-minute soil layer well point elevations (stage) values and, along the top of the figure, the SLPJ site monitored hourly maximum 5-minute rainfall data. The simulated values show more fluctuation than the recorded well point data. This may be due to the high native soil infiltration rate and drainage of water from the soil layers.

Summary

In general, the WWHM2012 models of the ten bioretention sites reproduced the monitored bioretention hydrologic performance data with good results when viewing the graphical trends. Good results are defined as periods where the simulated results match closely with the recorded (monitored) data and other periods where the simulated results are sometimes high and sometimes low. There is no obvious bias high or low.

Based on all of the above modeling results it appears that there are two major model inputs that may be influencing the results. The vegetative litter cover noted in the two Spanaway sites may be reducing the infiltration of the ponded water into the bioretention soil mix. Except for SLPI and SLPJ this vegetative litter cover was not explicitly modeled.

The other major model input that may be influencing the results is the evapotranspiration (ET) from the bioretention soil mix. It is set in WWHM2012 to equal 0.5*PET (Potential ET). There is evidence from the well point data that the 0.5 multiplier factor should be higher. That will help to remove water faster from the bioretention soil mix layer.

The complete set of WWHM2012 models for the ten sites has been provided to the Department of Ecology.

APPENDIX 3

Deliverable 4.5, Site B145, Geotechnical/Soils Assessment Design Data and Current Conditions, 145th Place SE and SE 22nd Street Roadway Improvement Project, Bellevue, Washington. Associated Earth Sciences, Inc. 10/25/16

associated
earth sciences
incorporated

Technical Memorandum

Date:	October 25, 2016	**From:**	Jennifer H. Saltonstall, L.G., L.Hg.
To:	Clear Creek Solutions, Inc.	**Project Manager:**	Jennifer H. Saltonstall, L.G., L.Hg.
	15800 Village Green Drive #3 Mill Creek, Washington 98012	**Principal in Charge:**	Curtis J. Koger, L.G., L.E.G., L.Hg.
		Project Name:	Bioretention Hydrologic Performance Study
Attn:	Doug Beyerlein, P.E.	**Project No:**	KH150387A
Subject:	Deliverable 4.5, Site B145, Geotechnical/Soils Assessment Design Data and Current Conditions, 145th Place SE and SE 22nd Street Roadway Improvement Project, Bellevue, Washington		

1.0 INTRODUCTION

This technical memorandum documents existing shallow soil and ground water conditions in Rain Garden #1 of the 145th Place SE and SE 22nd Street Roadway Improvement Project, located in the City of Bellevue, Washington (Figure B145 F1). This memorandum was prepared in accordance with Task 4 of the contract scope of work. Associated Earth Sciences, Inc. (AESI) collected shallow soil and ground water conditions data related to bioretention cell function, and documented the current condition of the facility relative to the as-built drawings and available background geotechnical information. The information will be used in the WWHM2012 modeling that will be conducted as part of Task 5 (Data Analysis). In Task 5, the team will compare the previously documented hydrologic design information with our field-collected information and will note where there are significant differences. The purpose of this technical memorandum is to document the collection of current and accurate geotechnical, geologic and hydrogeologic site information for this later work.

The following summary of shallow soil and ground water conditions integrates the observations made during the geotechnical assessment which included site visits on July 6 and July 22, 2016, infiltration testing on August 30 and September 1, 2016, and background geotechnical information.

This technical memorandum has been prepared for the exclusive use of Clear Creek Solutions and the City of Bellingham and their agents for specific application to this project. Within the limitations of scope, schedule, and budget, our services have been performed in accordance with generally accepted hydrogeologic and geotechnical engineering practices in effect in this area at the time our document was prepared. No other warranty, express or implied, is made.

2.0 PURPOSE AND SCOPE

The purpose of our work was to perform a shallow soil and ground water conditions assessment and provide baseline documentation data to assess effectiveness of bioretention hydrologic performance.

Specifically, our scope included the following activities:

- Review of project documents.
- Site reconnaissance.
- Visual condition assessment of erosion and deposition features near inlet and outlet.
- Review project plans relative to constructed facility, in particular, the number and location of inlets, energy dissipation devices, outlets, and other flow-related details.
- Survey elevations of inlet, outlet, well point rim, and other observation points relative to a project datum.
- Excavate shallow hand augers through the bioretention soil and into the underlying material, extending one hand auger deeper into the subgrade for installation of a well point.
- Classify sediment according to the Unified Soil Classification System (USCS) and *American Society for Testing and Materials* (ASTM) D2488, "Standard Recommended Practice for Description of Soils."
- Collect samples for laboratory testing of (1) particle size distribution in accordance with ASTM D422-63, "Standard Test Method for Particle-Size Analysis of Soils"; (2) organic matter content per ASTM D2974.
- Conduct qualitative assessment of bioretention soil compaction via T-probe.
- Conduct infiltration testing.
- Preparation of descriptive exploration logs for each exploration.
- Preparation of this summary document.

Topography of the site and surrounding area is shown on Figure B145 F2, "LiDAR-Based Topography." Existing facility features and the locations of hand-auger boreholes completed for this study are shown on Figure B145 F3, "Facility and Exploration Plan." Project civil plans are attached as Appendix A. Exploration logs and laboratory testing data conducted as part of this study are attached as Appendix B. Background soil, geology, and ground water information are attached as Appendix C. Soil probe, level survey, and field infiltration testing data are attached as Appendix D. Site photos are attached as Appendix E.

3.0 SITE DESCRIPTION AND DESIGN BACKGROUND

The project site is the City of Bellevue 145th Place SE and SE 22nd Street Roadway Improvement Project as shown on the attached "Vicinity Map" (Figure B145 F1). The project is the City's first major demonstration of the use of Natural Drainage Practices (NDPs) in the public right-of-way. No natural surface water features are present in the immediate vicinity. Per the Washington State Source Water Assessment Program Mapping Application, no water supply wells are located within 0.5 miles of the site. LiDAR topography and other near-site vicinity features are illustrated on Figure B145 F2, "LiDAR-Based Topography."

Our specific area of study for this project includes the bioretention facility located on the west side of 145th Place SE, between the intersections with SE 22nd Street and SE 24th Street. This cell is referred to as Rain Garden #1 on the plan sheets and is referred to as cell B145 for this study. The shape of cell B145 is a long narrow rectangle with the long sides bordered by a sidewalk and 145th Place SE on the east and the base of a rock wall on the west. The north and south ends are bordered by landscape beds. The attached "Facility and Exploration Plan" (Figure B145 F3) illustrates the cell area and some of the surrounding site features and utilities.

Details of the bioretention facility design and basis for design were presented in the following documents:

- Geotechnical Engineering Report, Bellevue 145th Place SE, SE 22nd Street, and SE 22nd Place, Bellevue, Washington, AMEC Earth and Environmental, Inc., November 24 2008, prepared for Skillings Connolly.
- Hydraulic Report Supplement, 145th Place SE and SE 22nd Street Roadway Improvement Project, Herrera Environmental Consultants, August 26, 2010, prepared for City of Bellevue Transportation Department.
- Site Plans titled 145 PL SE – SE 16 ST TO SE 24 ST, SE 22 ST – 145 PL SE to 156 AVE SE Roadway Improvements, March 7, 2011, prepared by City of Bellevue Transportation Department.

3.1 Summary of Facility Design

From our review of these documents, the bioretention facility design for Rain Garden #1 (cell B145) consists of approximately a long rectangular bioretention cell with approximately 350 square feet of base area, as shown on Figure B145 F3, "Facility and Exploration Plan." We understand that the cell was sized per Chapter 24.06 of the *Bellevue Storm and Surface Water Utility Code* (amended December 2003) and the 2008 *City of Bellevue Surface Water Engineering Standards*, and modeled using WWHM3 Pro based on a developed condition basin of 0.52 acres. Land use within the drainage basin is primarily roadway and grass lawn. Per Plan Sheet 12 (City of Bellevue Transportation Department, March 2011), the facility design includes 3 inches of compost overlying 24 inches of bioretention soil mix overlying native soil. The portion of the cell near base of the rock wall is underlain by compacted crushed rock. The facility is designed to infiltrate 99 percent of inflow into the subgrade. Stormwater enters the facility through a 12-inch ductile iron pipe on the south end. Overflow from the cell would discharge into a Type I Catch Basin with a beehive grate located at the north end of the cell, and into the City storm drainage pipe system. The rim of the Type I Catch Basin was designed to be 6 inches higher than the cell base to create 6 inches of ponding depth. An observation port is indicated along the east side of the cell, near the northern end. Per Plan Sheet 11, this observation port consists of a PVC pipe which penetrates vertically to the base of the raingarden, and then extends horizontally across the base of the raingarden subsurface, with a screen present across the base of the raingarden. The facility was constructed in December 2011 and began receiving runoff that month (Email communication, Tom Kuykendall, City of Bellevue, August 23, 2016).

4.0 SITE OBSERVATIONS

During AESI's site visits, we made notes regarding the physical construction of the bioretention cell including documenting site inlet/outlet layout relative to site plans and qualitative bioretention soil thickness and compaction. These notes were used to indicate key features of the facilities on Figure B125 F3, "Facility and Exploration Plan."

- Level Survey: AESI conducted an elevation survey of the cell using a Leitz C40 automatic level and a stadia rod. An arbitrary project datum was established for this survey, with the south rim of a nearby manhole (identified as point S-1 on the "B145 Level Survey Data" map in Appendix D) defined as project datum elevation 100 feet. All other elevations measured by the survey are relative to this project datum. Key level data is summarized in Table 1. Additional data points are included in Appendix D to this document. This survey was not conducted by a licensed surveyor. Surveyed elevations are expected to be sufficiently accurate for this general assessment of facility construction, but may be inaccurate for purposes requiring greater precision.

- Inflow: The inflow pipe to the facility is 12-inch pipe consistent with project plans, which discharges onto an approximately 0.5-foot splash pad consisting of rounded rock. No evidence of erosion was noted. AESI observed deposition of up to approximately 0.1 feet of leaf litter and organic debris, and no obvious erosion.

- Overflow: The overflow consists of a Type I Catch Basin, which was a square structure with a beehive grate. The rim of this grate was approximately 0.3 to 0.4 feet above the base of the facility. Water was observed in the sump approximately 0.15 feet below the lip of the outlet pipe at the time of our site visit.

- Observation port: The observation port was in place as indicated on Plan Sheet 11. It consists of a 6-inch PVC pipe, set within a metal manhole structure. The total depth is approximately 4.6 feet, and the base consists of a 90-degree elbow, which we understand as connecting to a horizontal screen as indicated on the plan.

- Piezometer: An existing piezometer was in place near the overflow structure. This consisted of a 2-inch-diameter PVC pipe, with a total length of approximately 5.3 feet and a stick up above ground surface of 3.9 feet, such that the base of the piezometer is approximately 1.4 feet below ground surface.

- AESI investigated the loose bioretention soil thickness present in cell B145 using a geotechnical soil T-probe. This qualitative data was used in conjunction with the hand-auger observations to understand loose soil thickness and relative potential compactness of the bioretention soils at depth. AESI measured the depth of penetration of the soils probe at locations generally arranged in a 5- to 10-foot grid on the facility base. Penetration of the T-probe generally ranged from approximately 0.7 feet to 2.2 feet, and averaged 1.1 feet. Probe depths were consistently deeper on the rockery side of the cell, on the order of 0.5 feet, indicating that the soil adjacent to the rockery was significantly looser than soil on the sidewalk side of the cell. Probe penetration data is included in Appendix D to this document.

Table 1
Cell B145
Summary of Level Survey Data

Location	**Elevation (feet, project datum)**
(S-1) Manhole, south rim	100
Overflow rim, NE corner	98.90
Existing 2-inch PVC piezometer, top of casing	102.51
Existing observation port, top of casing	100.15
Well point, top of casing	100.31
Survey points in base of cell	Onsite plan in Appendix D to this document

5.0 SITE SETTING

The text sections below describe our research findings in regards to the topographic, geologic, and hydrogeologic setting of the project site both from regional studies and background site-specific geotechnical and ground water studies. Our sources of information included the following.

- Site-specific documents cited previously under “Project and Site Description.”
- Associated Earth Sciences, Inc., Bellevue 4-lot Short Plat, Subsurface Exploration and Geotechnical Engineering Report, 2205 145th Place Southeast, Bellevue, Washington, 1989.
- Troost, K.G., Geologic Map of Bellevue, Washington, Pacific Center for Geologic Mapping Studies, 1/1/2012.
- Natural Resources Conservation Service, 2016, Web Soil Survey, United States Department of Agriculture, http://websoilsurvey.nrcs.usda.gov/, accessed September 2016.
- *Soil Survey of King County area, Washington*, United States Department of Agriculture, Natural Resource Conservation Service (NRCS), in cooperation with Washington Agricultural Experiment Station, 1973.
- Liesch, Bruce A., Price, Charles E., and Walters, Kenneth L., 1963, *Geology and Ground-water Resources of Northwestern King County, Washington*, Washington State Division of Water Resources, Water Supply Bulletin 20.

5.1 Regional Topography and Project Grading

The project site is situated on a localized upland elongated in the north-south direction, as shown on Figure B145 F2, "LiDAR-Based Topography." The upland slopes down gradually to the north, extends south to about Interstate 90, and is bordered to the west by the Richards Creek valley, and to the east by the Larsen and Phantom Lakes valley. No surface water features are mapped relatively close to the project.

On a closer scale, the site occupies the northeastern flank of a low ridge, and drains northward, eventually draining to Richards Creek. The ground surface descends gradually to the north in the vicinity of the site. Prior to bioretention cell construction, the site existing condition consisted partially of paved 145th Place SE right-of-way and partially of sloped vegetated area. Rockery construction and minor cuts of varying depth, typically on the order of 3 to 7 feet, were necessary to achieve bioretention cell dimensions and subgrade, based on a review of existing topography compared with built topography.

5.2 Regional Geology and Background Geotechnical Information

According to the 2012 *Geologic Map of Bellevue* (Troost), the site vicinity is underlain by Vashon lodgement till. Vashon advance outwash is mapped at the ground surface west of the site. Vashon lodgement till typically has a highly variable thickness, and is underlain by Vashon advance outwash.

- *Vashon Lodgement Till (Qvt):* The Vashon lodgement till is typically composed of a hard gray mixture of clay, silt, sand and gravel, of variable thickness. This unit was deposited at the base of the advancing Vashon-age glacier, during the Vashon Stade of the Fraser Glaciation. Subsequently, this material was overrun by thousands of feet of ice, which has resulted in a material with high-strength, low-compressibility, and low-permeability characteristics.

- *Advance Outwash (Qva):* This unit was deposited by streams flowing from the glacier as it advanced. This unit typically consists of stratified sands and gravels. Advance outwash was subsequently overridden by the Vashon ice sheet, resulting in a high degree of compaction. However, due to deposition by flowing water, the material typically contains few fines, resulting in moderate permeability characteristics.

No explorations were conducted in the proposed cell B145 footprint. Two sets of background geotechnical data exist near cell B145; one set (AMEC Earth and Environmental, Inc. [AMEC], 2008) was conducted as part of the City of Bellevue 145th Place SE and SE 22nd Street Roadway Improvement Project and the other set (AESI, 1989) was conducted as part of site geotechnical work for the adjacent residential development.

Three explorations (B-01, B-02, and HB-02) were conducted south of the proposed footprint of cell B145 and were contained in Appendix A of the AMEC geotechnical report. The explorations reached depths of 10.8, 11, and 2 feet, respectively, and describe gray to brown, dense to very dense silty fine to medium sand with trace to some gravel, interpreted by AMEC as glacial till.

Four explorations (EP-4 to EP-7) were conducted north of the proposed footprint of cell B145 as part of the adjacent residential development (AESI, 1989). The explorations reached depths of 10 to 12 feet, and describe brown becoming gray with depth, poorly bedded in some areas, gravelly fine to coarse sand with occasional cobbles, and became less coarse with depth, interpreted by AESI as Vashon advance outwash.

5.3 Regional Soils and Soil Data Used in Site Stormwater Model

AESI reviewed the *Soil Survey of King County Area, Washington* (NRCS, 1973) and soils mapping from the NRCS web portal (NRCS, 2016). The soil survey identifies different soil map units based on parent material, climate, topography, (slope), organisms (biota), and time. The soils in the study area formed mostly from young glacial deposits and have not had time to develop the deep weathering profiles present in soils in unglaciated terrains. Instead, they exhibit a direct relationship to the underlying parent material, local climate, topography, and vegetation.

Mapped soils in the project area consist of Alderwood type soils. Alderwood soils are formed from the weathering of glacial till. NRCS describes the permeability in the undisturbed upper 27 inches of the Alderwood soil as ranging from 2.0 to 6.3 inches per hour (in/hr). However, in developing areas, this upper soil is typically removed or compacted. The lower portion of the soil profile has a low permeability, less than 0.06 in/hr at depth (NRCS, 1973). This is a key limitation for shallow infiltration and can be easily misinterpreted. The very low infiltration rate reflects the permeability of the glacial till "parent" material. These soils commonly become saturated during the winter and typically contain shallow ground water referred to as interflow.

As described in the "Hydraulic Report Supplement" (Herrera Environmental Consultants, 2010), the existing condition was modeled as Type C soils, consistent with mapped soil and background geotechnical data.

5.4 Regional Hydrogeology and Background Ground Water Data

Descriptions of regional hydrogeology are contained in reports prepared by the Washington State Division of Water Resources titled *Geology and Ground-Water Resources of Northwestern King County, Washington*, Water Supply Bulletin 20, by Bruce A. Liesch, Charles E. Price, and Kenneth L. Walters (Liesch et al., 1963).

Vashon-age lodgement till is exposed at ground surface across much of the city. Where the lodgement till underlies the Vashon-age recessional outwash deposits, it forms an aquitard to ground water flow. The lodgement till is comprised of very dense, glacially compacted silty sand with varying amounts of gravel. The high silt content and high density impedes the movement of ground water in the lodgement till. The lodgement till has been eroded by streams and rivers in some areas exposing the underlying Vashon-age advance outwash, creating potential "windows" of recharge to deeper aquifers. The Vashon-age advance outwash is interpreted to contain an aquifer at depth beneath the site.

Previous explorations in the vicinity of the facility by AMEC (2008) and AESI (1989) did not encounter ground water.

6.0 SUBSURFACE EXPLORATION

Limited information on subsurface conditions was obtained for this study from hand-auger samples and soil probe penetration measurements at about 2-foot increments in each hand-augered borehole. One hand-auger boring was performed in the facility bottom and advanced through the bioretention soil and into the underlying subgrade. Additional hand-auger borings were completed to the base of the bioretention soil. Representative samples were collected, visually classified in the field, stored in water-tight containers and transported to AESI's offices for additional classification, geotechnical testing, and study. At the conclusion of the excavation, each borehole was immediately backfilled with the excavated material.

The various types of sediments, as well as the depths where characteristics of the sediments changed, are indicated on the exploration logs presented in Appendix B. A detailed record of the observed bioretention soil, subsurface soil, geology, and ground water conditions was made. The sediments were described by visual and textural examination using the soil classification in general accordance with ASTM D2488, "Standard Recommended Practice for Description of Soils." The depths indicated on the logs where conditions changed may represent gradational variations between sediment types in the field. The exploration logs in Appendix B are based on the field observations, inspection of the samples, and where applicable, laboratory grain-size analysis. Our explorations were approximately located in the field relative to known site features, and are shown on Figure B145 F3, "Facility and Exploration Plan." GPS coordinates for the explorations were taken using a handheld GPS, and are summarized in Appendix B.

The results presented in this document are based on the explorations completed for this study and review of background data. The number, locations, and depths of the explorations were completed within site and budgetary constraints. Because of the nature of exploratory work below ground, interpolation of subsurface conditions between field explorations is necessary. It should be noted that differing subsurface conditions may sometimes be present due to the random nature of deposition and the alteration of topography by past grading and/or filling.

6.1 Hand-Auger Borings

Hand-auger borings in the raingarden were completed on July 6 and July 22, 2016. No rain was observed during this time, and no flow was observed from the inlet pipe.

Hand-auger boring number 1 and 2 (B145-HA-1 and B145-HA-2) encountered approximately 2.5 feet and 2.3 feet, respectively, of bioretention soil, overlying material interpreted as Vashon advance outwash to a total depth of 3.2 feet and 3 feet, respectively. No seepage or caving were observed.

Hand-auger boring number 3 (B145-HA-3) was completed near the center of the cell. B145-HA-3 encountered approximately 2.3 feet of bioretention soil, overlying material interpreted as Vashon advance outwash, to a total depth of 4.3 feet. No seepage or caving were observed. AESI installed a well point in this location.

In each hand auger, the loose thickness of bioretention soil was less than the observed thickness of bioretention soil, indicating that the lower portion of the bioretention soil was compacted, likely during construction.

6.2 Well Points

A well point was installed in HA-3. Key dimensions of this well point, as well as dimensions of existing structures are provided in Table 2, below.

Table 2
Summary of Cell B145
Well Point and Other Existing Monitoring Point Dimensions

Well Point	Exploration in which WP was installed	Total Length of Casing (feet)	Interior Diameter	Stickup Height (feet)	Total Depth Inside Casing Below Ground Surface
B145-WP	B145-HA-3	6.3	1.25-inch nominal	1.8	4.5
B145 Existing observation port	Existing	4.6	6-inch	~0*	4.6
B145 Existing piezometer	Existing	5.3	2-inch	3.9	1.4

*The observation port is a pipe with a 90-degree elbow. The access port top of casing is situated outside of cell base but the slotted pipe extends beneath the bioretention soil.

7.0 LABORATORY ANALYSIS

Laboratory testing included mechanical grain-size distribution and percent organic matter by weight in accordance with the ASTM D422 and D2974, respectively. Two samples of bioretention soil were first tested for organic matter content and then the burned material was tested for grain-size distribution for comparison with the aggregate fraction of the bioretention soil mix guidance in the Washington State Department of Ecology (Ecology) 2014 *Stormwater Management Manual for Western Washington* (2014 Ecology Manual). One sample of material interpreted as representative of the subgrade was tested for grain size distribution. The data is summarized in Table 3.

Table 3
Summary of Cell B145
Organic Content and Grain-Size Data

Exploration Number	Depth (feet)	Soil Type	Organic Content (% by weight)	USCS Soil Description	Fines Content (% passing #200)	Cu	Cc	USDA Soil Texture*
B145-HA-2	0.2-0.5	Bioretention Soil	3.5	SAND, trace silt, trace gravel (SP)	0.4%	3.7	1.1	Sand
B145-HA-3	0.6-0.9	Bioretention Soil	4.2	SAND, trace silt, trace gravel (SP)	0.4%	4.4	1.0	Sand
B145-HA-3	2.4-2.9	Vashon advance outwash	Not tested	Gravelly SAND, some silt (SW-SM)	5%	6.0	1.2	Sand

USCS: Unified Soil Classification System; Cu: coefficient of uniformity; Cc: coefficient of curvature; USDA: U.S. Dept. of Agriculture;*No hydrometers were performed. USDA soil texture range assumes fines consist entirely of silt to entirely of clay.

7.1 Bioretention Soil Mix

We compared the organic content and burned fraction gradation against the general guidelines for the bioretention soil mix (Table 4).

The organic content of the tested bioretention soils ranged between 3.5 and 4.2 percent by weight. This is below the recommended organic content by weight of 5 to 8 percent in the 2014 Ecology Manual.

The grain-size analysis test results on the burned soil fraction indicate that the bioretention soils tested correlate to a “SAND” with trace silt and trace gravel based on ASTM D2487 USCS. The respective fines content as measured on the No. 200 sieve was approximately 0.4 percent for both samples sieved, less than the recommend range of 2 to 5 percent. The coefficient of uniformity ranged from 3.6 to 4.4, less than or in the low range of the recommended value of equal to or greater than 4. The coefficient of curvature ranged from 1.0 to 1.1, on the low end of the recommended range of greater than or equal to 1 and less than or equal to 3. The soil mix generally did not meet (contained less than) the recommended range of fine sand and silt fractions. The tested bioretention soil was predominantly medium-grained sand.

7.2 Subgrade

In cell B145, a sample of native glacial advance outwash was sieved. The tested material correlates to a gravelly SAND with 5 percent by weight of the material passing the No. 200 sieve

The grain-size distribution data were also transformed to describe the U.S. Department of Agriculture soil texture. The grain-size distributions were normalized to the No. 10 sieve—i.e., the coarse sand and gravel fraction of the sample is discounted and the remainder is taken as

100 percent of the sample. The fines were assessed relative to the No. 270 sieve. The respective U.S. Department of Agriculture fines content as measured on the No. 270 sieve after adjusting to remove the weight retained on the No. 10 sieve was 6 percent for the native glacial advance outwash material.

Table 4
General Guidelines for
Bioretention Soil Mix (2014 Ecology Manual)
Compared to Averaged Cell B145 Site Data

Parameter	Recommended Range	Cell B145
Organic Content (by weight)	5 to 8 percent	3.9 percent by weight
Cu coefficient of uniformity	4 or greater	3.9
Cc coefficient of curvature	1 to 3	1.1
Sieve Size	**Percent Passing**	
3/8” (9.51 mm)	100	100
#4 (4.76 mm)	95 to 100	98
#10 (2.0 mm)	75 to 90	78
#40 (0.42 mm)	25 to 40	15
#100 (0.15 mm)	4 to 10	1.7
#200 (0.074 mm)	2 to 5	0.4

Note: The general guidelines for mineral aggregate gradation are from Table 7.4.1 of the 2014 Ecology Manual.
mm: millimeters

8.0 INFILTRATION TESTING

8.1 General Infiltration Test Method

Because of the limited flow rate possible with the on-site water source, we performed two infiltration tests in the B145 raingarden facility: Infiltration Test 1 (IT-1) near the overflow, and Infiltration Test 2 (IT-2) near the inflow.

The infiltration tests were conducted in general accordance with the 2014 Ecology Manual. Each test was conducted by discharging water into the facility for a “soaking period,” to allow the receptor soils to become saturated. After completion of the soaking period, water was discharged into the cell at a rate sufficient to maintain a relatively constant head. This constitutes the “constant head” phase of infiltration testing. For the infiltration tests in the B145 raingarden, the soaking period and the constant head phase were both conducted at the maximum possible flow rate using the available on-site water source. Immediately following the constant head phase of infiltration testing, flow into the facilities was discontinued, and the water level was monitored as it dropped. This constitutes the “falling head” portion of the infiltration testing.

The water for testing was obtained from an on-site irrigation system with a 1.25-inch quick-connect valve, and conveyed to the test area with 2-inch lay-flat and non-collapse hose. During infiltration testing, the water was conveyed into the bioretention cell via a digital flow meter with gallons per minute (gpm) and total gallon readouts, and discharged through a flow diffuser onto the base of the facility. Water levels were monitored using a temporary metal staff gauge marked in 0.02-foot increments which was installed for the duration of the test adjacent to the well point (SG-1), a second temporary metal staff gauge marked in 0.01-foot increments installed near the test IT-2 discharge (SG-2), within the well point B145 WP and within the existing observation port and piezometer with a digital water level tape, and with digital pressure transducers. The overflow structure was observed periodically during testing. Data from the digital pressure transducers was compensated for barometric response using a separate digital barometer. The area of the pool was measured periodically during testing.

Infiltration tests are discussed below, and results are presented in Table 5. Infiltration test data is included in Appendix D to this document.

8.2 Infiltration Test IT-1 in Cell B145

AESI performed IT-1 near the northern end of cell B145, in the vicinity of the overflow structure, on August 30, 2016. During IT-1, light rain was noted near the conclusion of testing, and flow from the inflow at the southern end of the facility was noted for a period of approximately 30 minutes, which wet an approximately 2-square-foot area near the inflow, on the opposite end of the facility from the infiltration test. This inflow is interpreted as having no impact on infiltration test IT-1.

Flow was maintained at approximately 20 gpm (the maximum flow off of the water source) for approximately 7.5 hours, during which the water level in the facility rose slowly to 0.14 feet as measured on the temporary staff gauge (SG-1), and wetted an area of approximately 44 square feet. AESI observed that this wetted area generally consisted of a pool on the northern end of the facility, around the overflow structure. Approximately 9,000 gallons of water were used. No water flowed into the overflow structure.

After about 7.5 hours, AESI shut off the flow and monitored the water level as it fell. AESI observed that the pooled water in the base of the facility infiltrated over the course of approximately 1.5 minutes.

No water was observed in well point B145 WP, the existing observation port, or existing piezometer during IT-1.

8.3 Infiltration Test IT-2 in Cell B145

AESI performed IT-2 near the southern end of cell B145, in the vicinity of the inflow pipe, on September 1, 2016. During IT-2 heavy rain was noted at the conclusion of testing, and flow from the inflow discharged into the wetted area from the infiltration test. Due to this inflow, no falling head test could be conducted as part of IT-2.

Flow was maintained at approximately 24 gpm (the maximum flow off of the water source) for approximately 7.5 hours, during which the water level in the facility rose slowly to 0.08 feet as measured on the temporary staff gauge (SG-2), and wetted an area of approximately 124 square feet. AESI observed that this wetted area consisted of a strip generally covering the width of the base of the facility, starting near the facility inflow at the southern end and continuing north by for approximately 22 feet. Approximately 11,000 gallons of water were used.

During IT-2, water was observed in well point B145 WP and the observation port. The water level response in well point B145 WP lagged by about 2.7 hours, appearing after 160 minutes after inflow began based on data logger readings. The water level rose to about approximately 2.5 feet below ground surface. The water level response in the observation port lagged by about 2.7 to 3 hours, measured at 180 minutes after inflow began based on hand readings. The water level rose to about approximately 2.6 feet below ground surface within the cell (4.4 feet below the top of casing observation port, which is an elbowed slotted 6-inch PVC casing installed below the base of the bioretention soil). Based on a comparison of level survey elevations for the top of the well point and the top of the observation port, the observed water level in the observation port was approximately 0.3 feet lower than the observed water level in the well point. This may represent a drop in the subsurface pool surface away from the inflow and surface wetted area. The observation port's screened interval is located approximately 10 feet farther to the north from well point B145 WP, away from the surface wetted area.

After about 7.5 hours, rainfall occurred and flow through the inlet pipe began. AESI shut off the test flow. Due to relatively intense rainfall and resulting inflow, the level of water in the cell did not fall. Water level within well point B145 WP was monitored as it dropped by approximately 1.4 feet over the course of approximately 1 hour.

Table 5
Cell B145
Infiltration Test Results

Test No. and Depth	Surface Area (square feet)	Discharge Time (minutes)	Total Volume Discharged (gallons)	Approximate Constant Head Level (feet)	Field Infiltration Rates	
					Constant Head Test (in/hr)	Falling Head Test (in/hr)
B145 IT-1 (bioretention soil)	44	455	8,929	0.14	43	50
B145 IT-1 (subgrade)	Interpreted to be similar to wetted area				Assumed similar to bioretention soil rate; no water was observed in B145 WP or observation port	
B145 IT-2 (bioretention soil)	124	450	10,703	0.07	18	Not measured
B145 IT-2 (subgrade)	At least twice wetted area				~9 Actual pooled area unknown	

in/hr: inches per hour

9.0 CONCLUSIONS AND RECOMMENDATIONS

Cell B145 site varied somewhat from the design shown on the civil plan sheets. Variations included the following:

- Bioretention soil
    - Thickness: The apparent thickness of loose bioretention soil based on soil probe data varied, and was generally less than the 2 feet indicated on the plan. However, all three hand-auger explorations encountered greater than 2 feet of bioretention soil. AESI interprets that this discrepancy is due to the base layer of the bioretention soil mix being compacted; therefore, the soil probe data does not represent the full thickness of the bioretention soil. Probe depths were consistently deeper on the rockery side of the cell, on the order of 0.5 feet, indicating that the soil adjacent to the rockery was significantly looser than soil on the sidewalk side of the cell.
    - Composition: The soil tested in B145 did not meet the recommended guidelines for organic content and sand gradation, and did not meet the recommended fraction of silt.

- The overflow is slightly different than plans in that the ponded water surface can only build up to about 0.3 to 0.4 feet before the cell begins to overflow. Site design documents indicate that the ponding level was designed as 0.5 feet.

- Subgrade conditions: The subgrade is interpreted to consist of Vashon advance outwash. The subgrade conditions encountered contained less fines than what was described as glacial till in the geotechnical report for the project (AMEC, 2008) and the gradation was consistent with deeper strata encountered west of the cell in explorations for the adjacent residential development, described as Vashon advance outwash.

- Review of existing and developed topography indicates that cuts on the order of 3 to 7 feet were necessary to achieve bioretention cell dimensions and subgrade. This is consistent with the presence of Vashon advance outwash in the cell base instead of weathered Vashon lodgement till as described in the project documents. It is likely that the weathered till, if present, was removed during grading of cell B145.

- Field infiltration rates were measured at about 43 to 50 in/hr (IT-1) on the northern end of cell B145 near the overflow, and 18 in/hr (IT-2) on the southern end of cell B145 near the inflow.

- AESI interprets that lower infiltration rate in IT-2 near the inflow may be due to a combination of factors, such as localized compaction of the bioretention soil, variations in the native subsurface, differences in the amount of grading (cuts) removing surficial weathered till soils, and the deposition of fines from the facility inflow to the surface of the bioretention soil mix. In particular, the higher infiltration rate in IT-1 near the southern portion of the cell could be influenced (increased) by excavation for the overflow structure. The overflow structure was installed deeper than the bioretention cell base, and would have included additional excavation into potentially cleaner Vashon advance outwash interpreted to be present at depth. Water that soaks through the bioretention soil could encounter the backfill around the structure, allowing for preferential pathways vertically into the subsurface.

- In both infiltration tests, water readily soaked through the bioretention soil mix. During IT-1, on the northern end of the facility, no water was observed within the well point or the observation port, indicating that water was continuing to soak vertically downward into the native subgrade at a rate similar to the bioretention soil. During IT-2, after approximately 160 and 180 minutes, water was observed within the well point and observation port, respectively, both of which were located downgradient from the wetted pool area. This response demonstrates that water was accumulating on the underlying subgrade and spreading laterally in the bioretention soil column during testing, indicating that the subgrade in the vicinity of IT-2 has a lower permeability than the overlying bioretention soil. The area of the subsurface pool is unknown but is at least twice that of the surface wetted area.

- Shallow ground water was not encountered at the time of exploration or testing. Ground water may mound up during the winter months. The ongoing monitoring data will be reviewed during the coming months for ground water influence.

10.0 CLOSURE

We appreciate the opportunity to be of continued service to you on this project. Should you have any questions regarding this letter-report or other geotechnical/hydrogeologic aspects of the project, please call us at your earliest convenience.

State of Washington
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2335
Jennifer H. Saltonstall

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Attachments:
Figure B145 F1: Vicinity Map
Figure B145 F2: LiDAR-Based Topography
Figure B145 F3: Facility and Exploration Plan

Appendix A: Project Civil Plans
Appendix B: Current Study Exploration Logs and Laboratory Testing Data
Appendix C: Background Soil, Geology, and Ground Water Data (Regional Maps, Previous Studies Exploration Logs and Laboratory Testing Data)
Appendix D: Soil Probe, Level Survey, and Field Infiltration Testing Data
Appendix E: Site Photos

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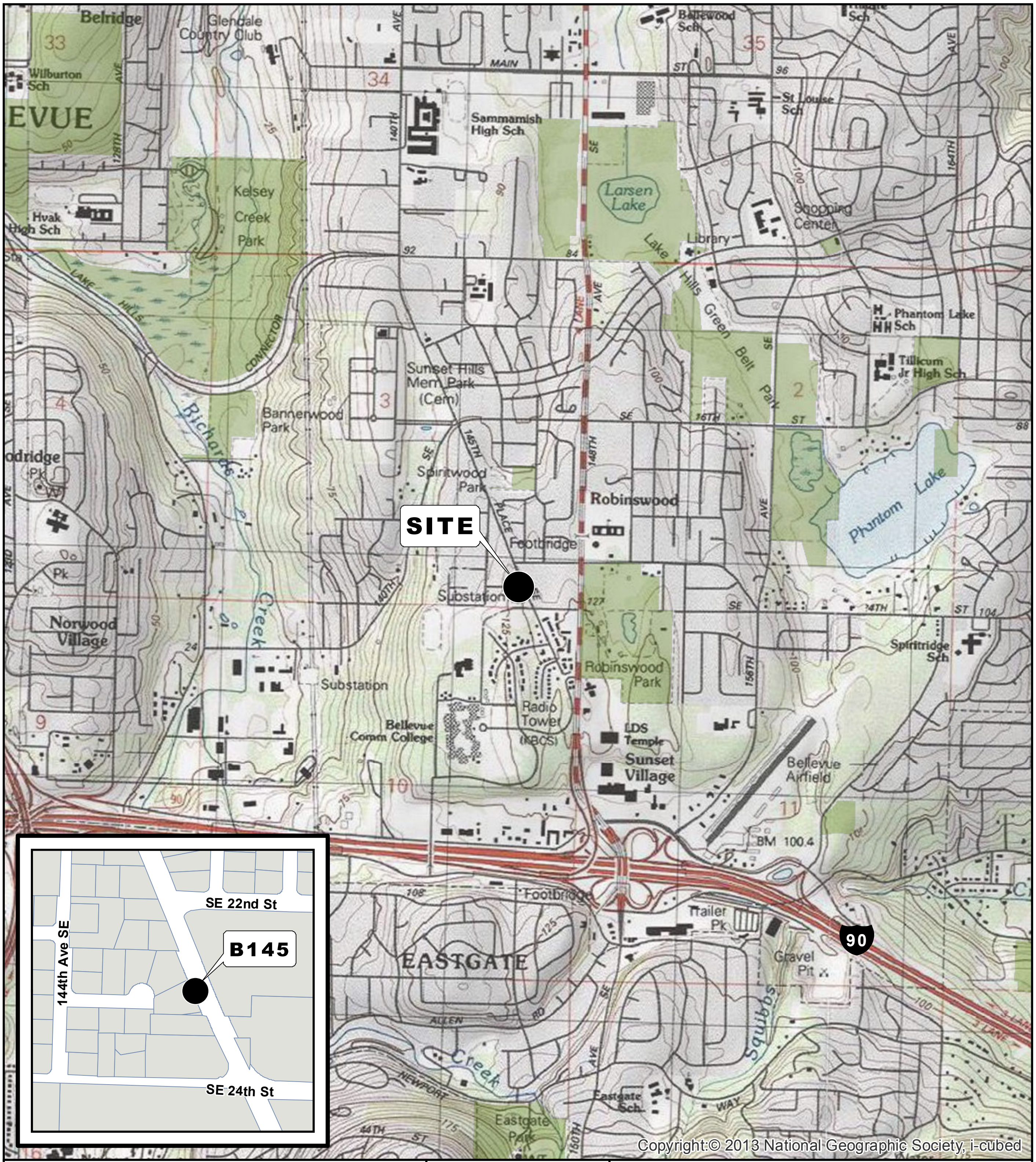

DATA SOURCES / REFERENCES:
USGS: 24K SERIES TOPOGRAPHIC MAPS
KING CO: STREETS, PARCELS 2015

LOCATIONS AND DISTANCES SHOWN ARE APPROXIMATE

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0 1000 2000
FEET

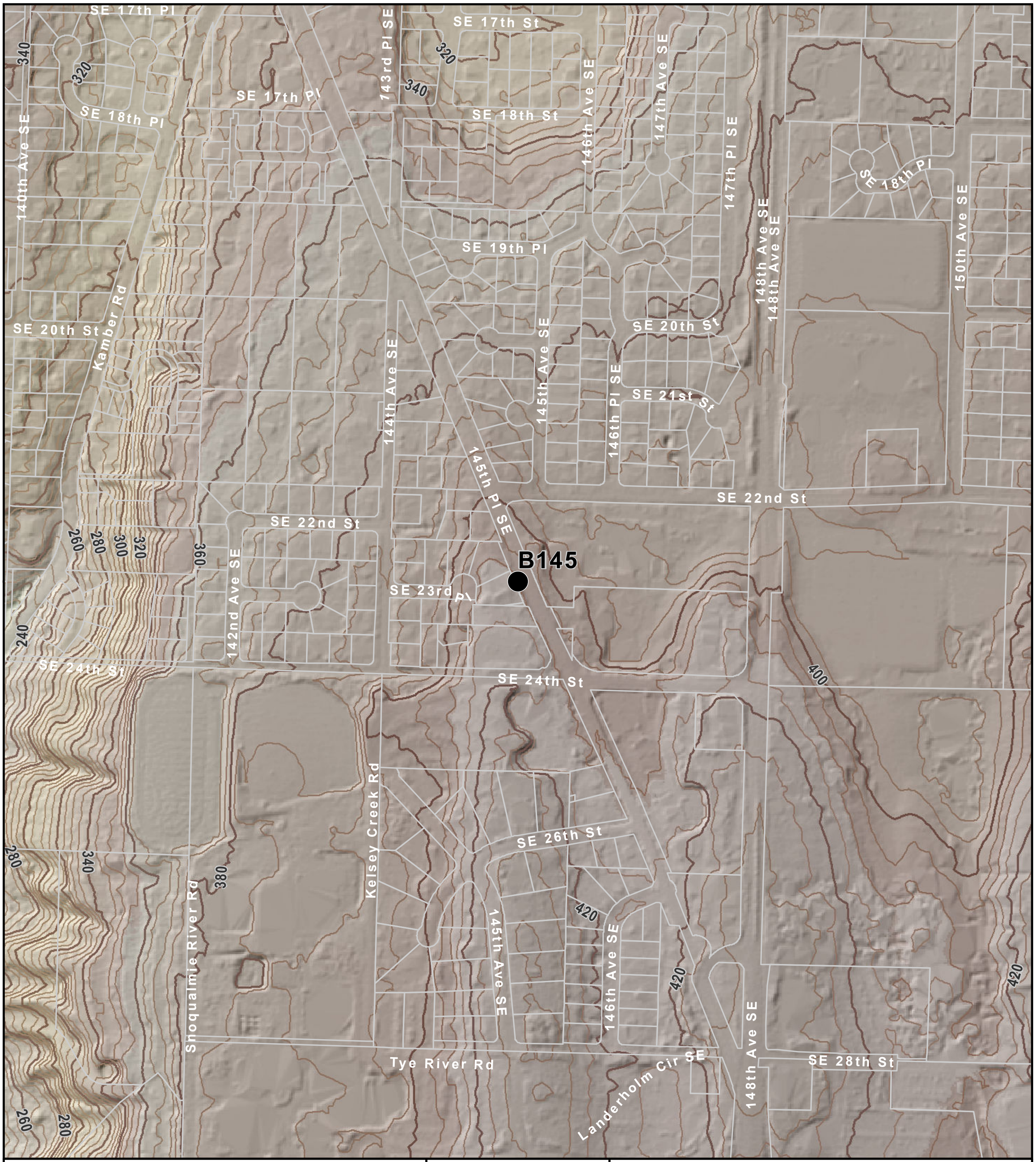
NOTE: BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION

associated
earth sciences
incorporated

VICINITY MAP

BIORETENTION HYDROLOGIC PERFORMANCE STUDY, B145 SITE
BELLEVUE, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	B145 F1



N

0 250 500

FEET

DATA SOURCES / REFERENCES:
PSLC: LIDAR 2000-2005 SUPERMOSAIC, 6' CELL
KING CO: STREETS, PARCELS 2016

LOCATIONS AND DISTANCES SHOWN ARE APPROXIMATE

NOTE: BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION

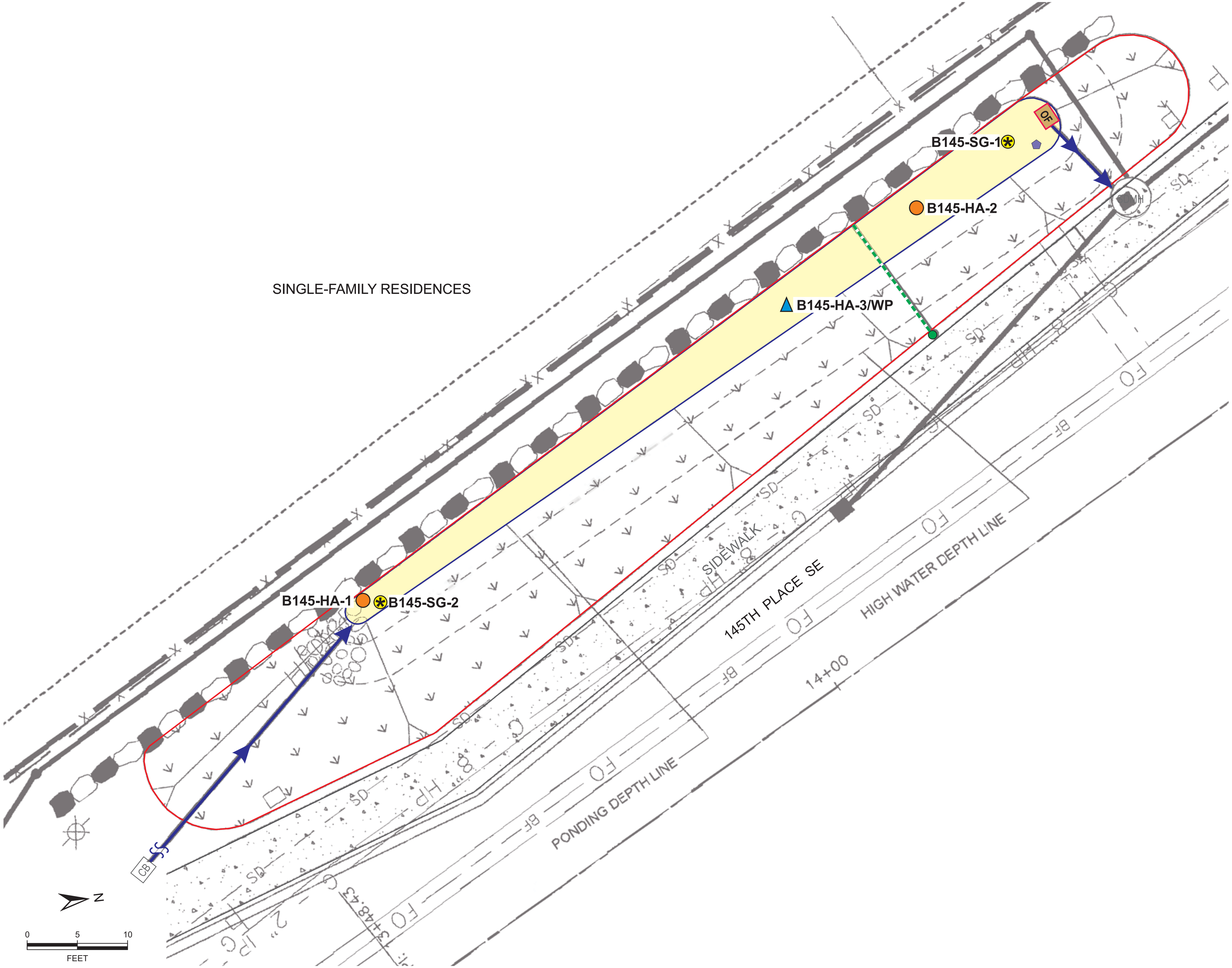
associated earth sciences incorporated

LIDAR BASED TOPOGRAPHY

BIORETENTION HYDROLOGIC
PERFORMANCE STUDY, B145 SITE
BELLEVUE, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	B145 F2

Document Path: G:\GIS_Projects\aYear2015postJuly2016\150387 Bioretention Hydro Performance Monitoring\mxd\Fig2s\150387 B145 Fig2B LIDAR.mxd



LEGEND:

● **HA**	HAND AUGER
▲ **WP**	WELL POINT
⊛	TEMPORARY STAFF GAUGE
▭	BASE OF FACILITY
▭	TOP OF FACILITY SLOPE
→	INFLOW / OVERFLOW DIRECTION
OF	OVERFLOW GRATE
- - -	PERFORATED PIPE
●	OBSERVATION PORT
⬟	PRE-EXISTING 2 INCH PIEZOMETER
SD	STORM DRAIN

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:
1. BASE MAP REFERENCE: CITY OF BELLEVUE TRANSPORTATION DEPARTMENT, 145 PL SE / SE 22 ST ROADWAY IMPROVEMENTS, RAIN GARDEN DRAINAGE PLAN AND DETAILS, SHEET 13 OF 64, 03/11

BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION.

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earth sciences
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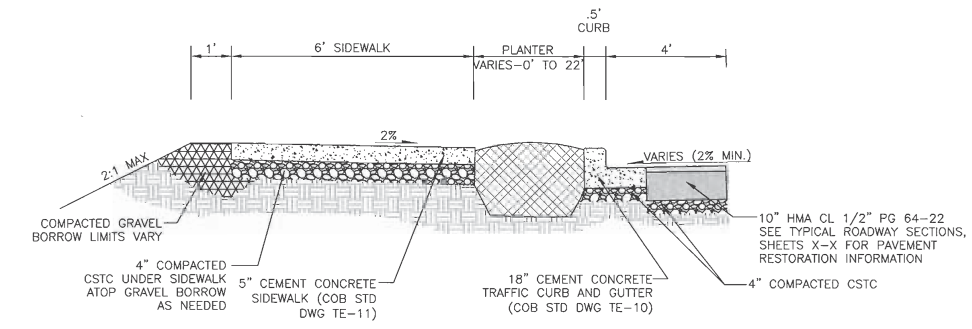
FACILITY AND EXPLORATION PLAN
B145 SITE
BIORETENTION HYDROLOGIC PERFORMANCE
BELLEVUE, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	B145 F3

150387 BHPS MCCA \ 150387 Site-Expl.cdr PAGE 1: B145

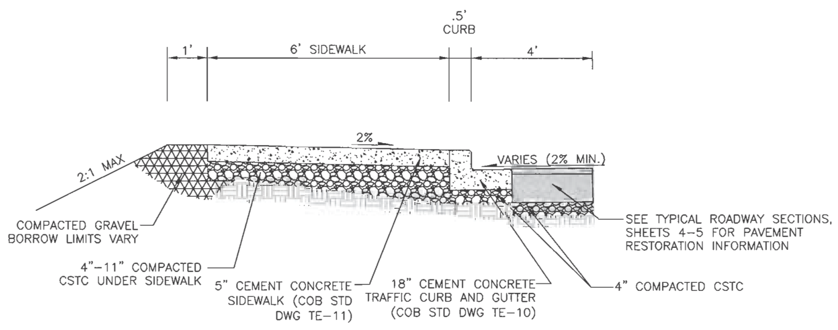
APPENDIX A

Project Civil Plans



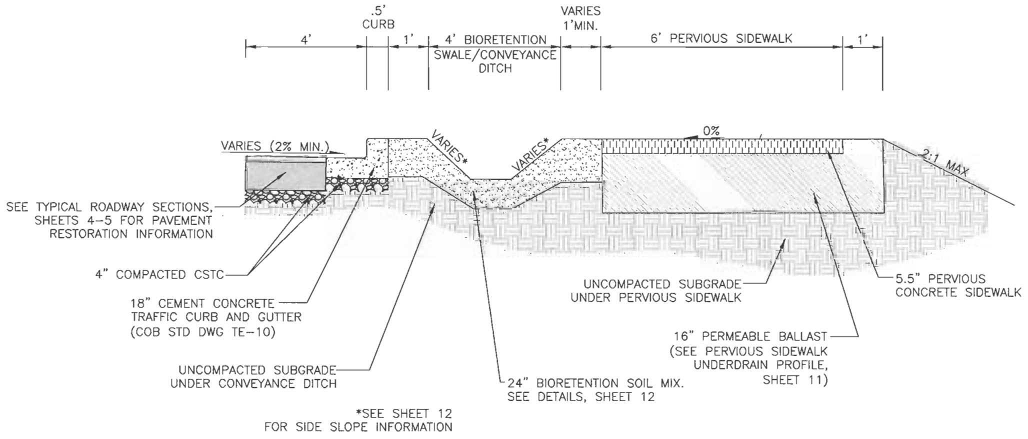
SIDEWALK SECTION WITH PLANTER

NOT TO SCALE



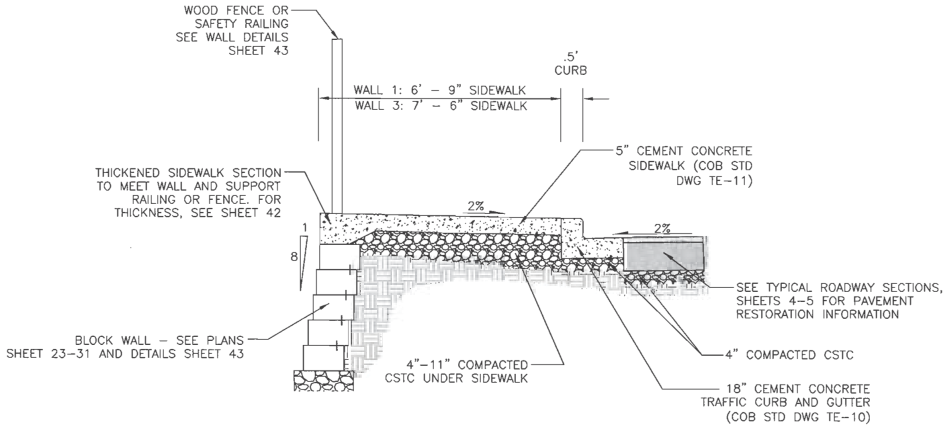
SIDEWALK SECTION WITHOUT PLANTER

NOT TO SCALE



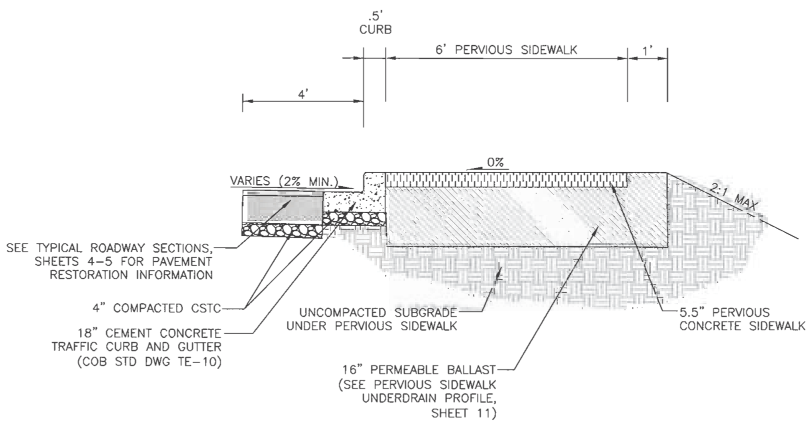
PERVIOUS SIDEWALK SECTION WITH BIORETENTION SWALE / CONVEYANCE DITCH

NOT TO SCALE
STA 17+75 TO STA 24+80



WALL AND SIDEWALK TYPICAL SECTION

NOT TO SCALE
STA 12+66 TO STA 13+95 RT
STA 20+78 TO STA 24+52 LT



PERVIOUS SIDEWALK SECTION WITHOUT PLANTER

NOT TO SCALE

3/7/11

NO.	DATE	BY	APPR.	REVISIONS

Approved By

TRANSPORTATION DESIGN MANAGER DATE
PROJECT MANAGER DATE
DATE

C. Masek 03/11
DESIGNED BY DATE
C. Masek 03/11
DRAWN BY DATE
C. Masek 03/11
CHECKED BY DATE

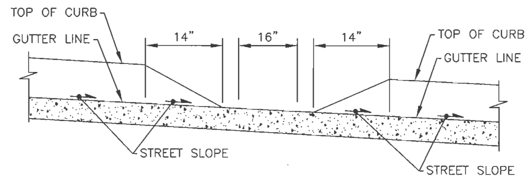
City of Bellevue
Transportation Department

CHRISTOPHER D. MASEK
45856

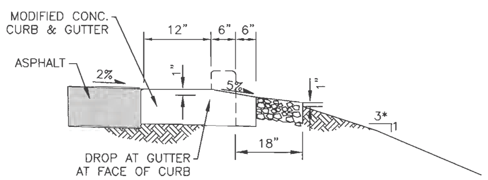
145 PL SE / SE 22 ST ROADWAY IMPROVEMENTS

TYPICAL ROADWAY SECTIONS

SHT 6 OF 64

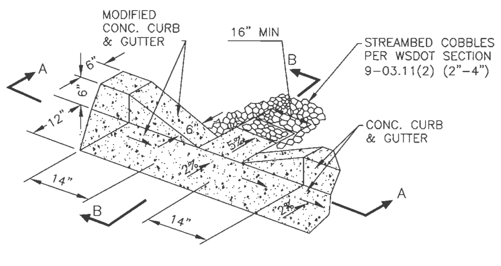


SECTION A-A

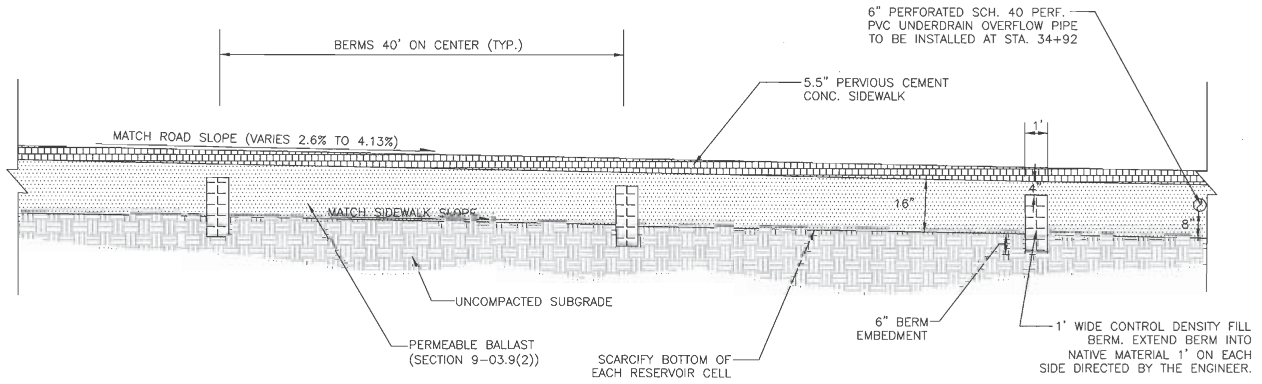


* IS 2.5:1 WHEN USED WITH BS #2

SECTION B-B



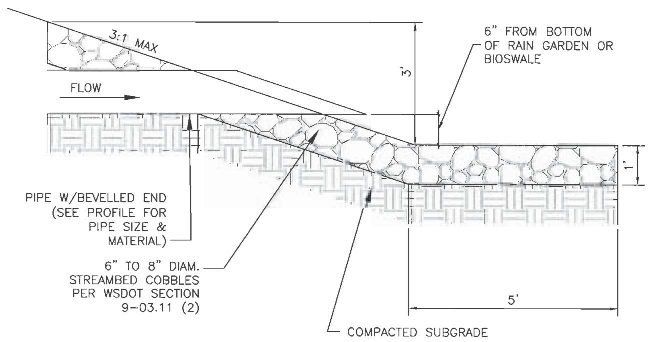
CURB CUT OPENING
NOT TO SCALE



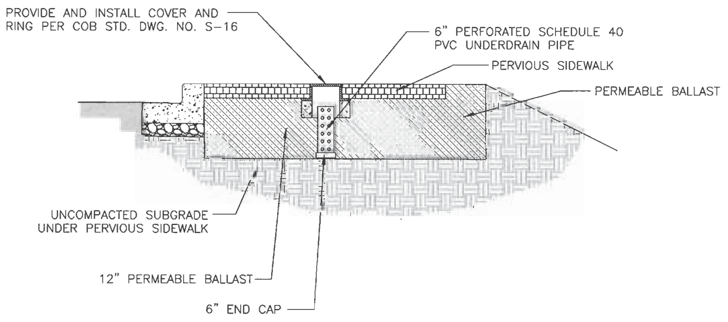
NOTES

1. SCARCIFY BOTTOM OF EACH RESERVOIR CELL. CONTRACTOR SHALL NOT COMPACT THE SOILS AROUND THE STORAGE CELLS.
2. CONTRACTOR MAY EXCAVATE SLOPE OF BOTTOM OF STORAGE AREA LEVEL. ADDTIONAL EXCAVATION SHALL BE AT NO ADDTIONAL COST TO THE CITY.

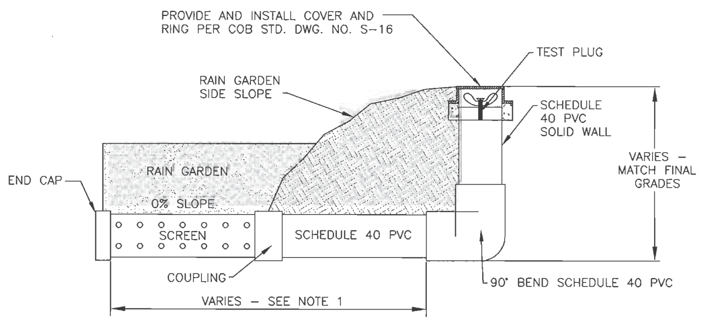
PERVIOUS SIDEWALK DRAINAGE SYSTEM TYPICAL PROFILE
NOT TO SCALE



ROCK PROTECTION DETAIL
NOT TO SCALE



PERVIOUS SIDEWALK OBSERVATION PORT DETAIL
NOT TO SCALE



NOTES:
1. EXTEND OBSERVATION PORT ACROSS ENTIRE LENGTH OF RAIN GARDEN, SEE RAIN GARDEN PLANS, SHEET 13.

RAIN GARDEN OBSERVATION PORT DETAIL
NOT TO SCALE

3/7/11

NO.	DATE	BY	APPR.	REVISIONS

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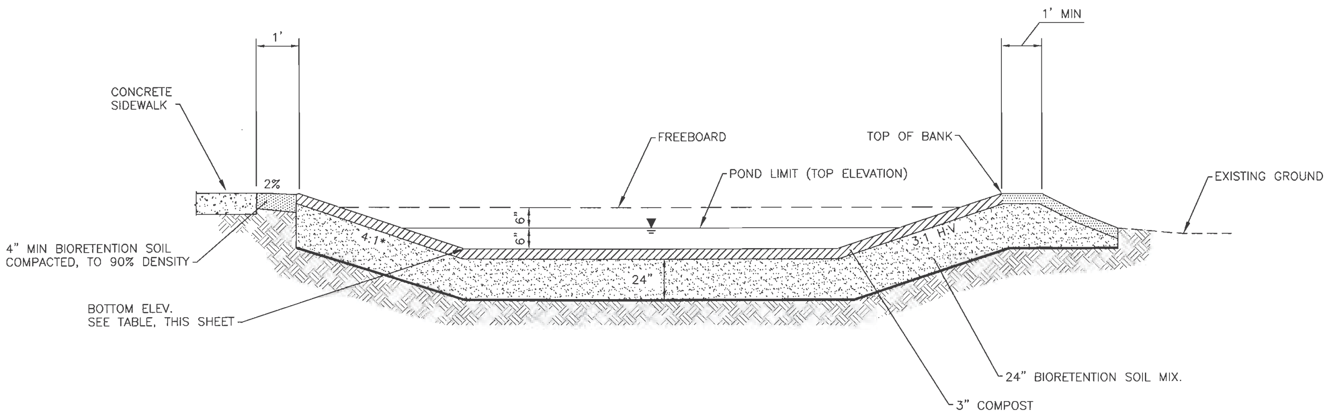
City of Bellevue
Transportation Department

CHRISTOPHER D. MASEK 45856

145 PL SE / SE 22 ST
ROADWAY IMPROVEMENTS

DRAINAGE DETAILS

SHT 11 OF 64



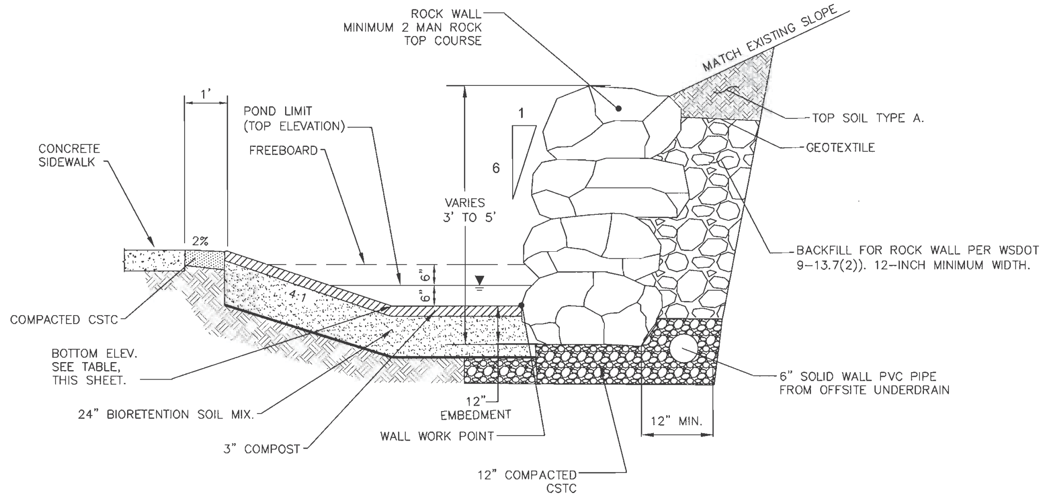
NOTES:

1. SEE LANDSCAPE PLANS FOR PLANTING DETAILS
2. INSTALL OFFSET OBSERVATION PORT PER DETAIL THIS SHEET IN EACH RAIN GARDEN.

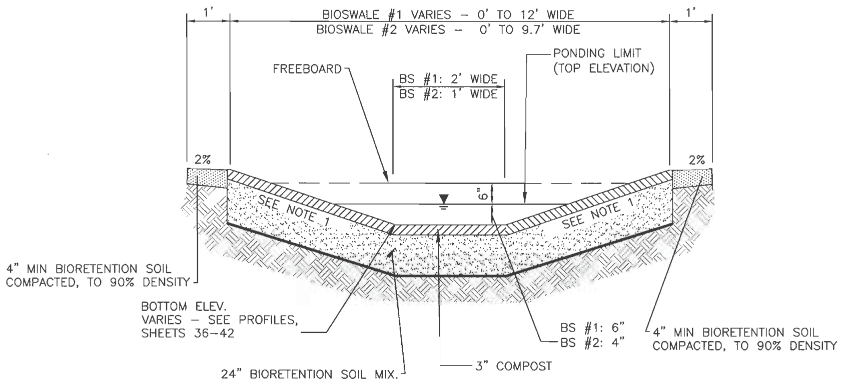
* WHEN SLOPE IS ADJACENT TO SIDEWALK. OTHERWISE, 3:1.

RAIN GARDEN (#)	BOTTOM ELEVATION (FT)	BOTTOM AREA (SF)	HIGH WATER ELEVATION (FT)	HIGH WATER AREA (SF)
1	404.54	356	405.04	540
2	364.58	408	365.08	580
3	359.00	604	359.50	875

RAIN GARDEN 2 & 3 TYPICAL SECTION A-A
NOT TO SCALE



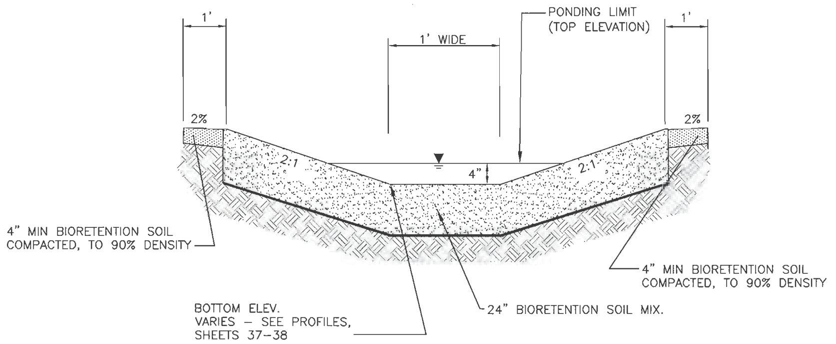
RAIN GARDEN #1 TYPICAL SECTION B-B
NOT TO SCALE



NOTES:

1. SIDE SLOPES FOR BS# 1 SHALL BE 3:1. SIDE SLOPES FOR BS# 2 SHALL BE 2.5:1
2. SEE PLANS (SHEETS 24, 25, & 28) AND PROFILES (SHEETS 34, 35 & 38) FOR ADDITIONAL GRADING INFORMATION
3. INSTALL CDF CHECK DAMS EVERY 22 FT FOR BS #1 ONLY.

BIORETENTION SWALE TYPICAL SECTION DETAIL
NOT TO SCALE



NOTES:

1. SEE PLANS (SHEETS 23 & 26 AND PROFILES (SHEETS 33 & 36) FOR ADDITIONAL GRADING INFORMATION

CONVEYANCE DITCH DETAIL
NOT TO SCALE

3/7/11

NO.	DATE	BY	APPR.	REVISIONS

Approved By

TRANSPORTATION DESIGN MANAGER DATE
PROJECT MANAGER DATE
DATE

C. Masek 03/11
DESIGNED BY DATE
C. Masek 03/11
DRAWN BY DATE
C. Masek 03/11
CHECKED BY DATE

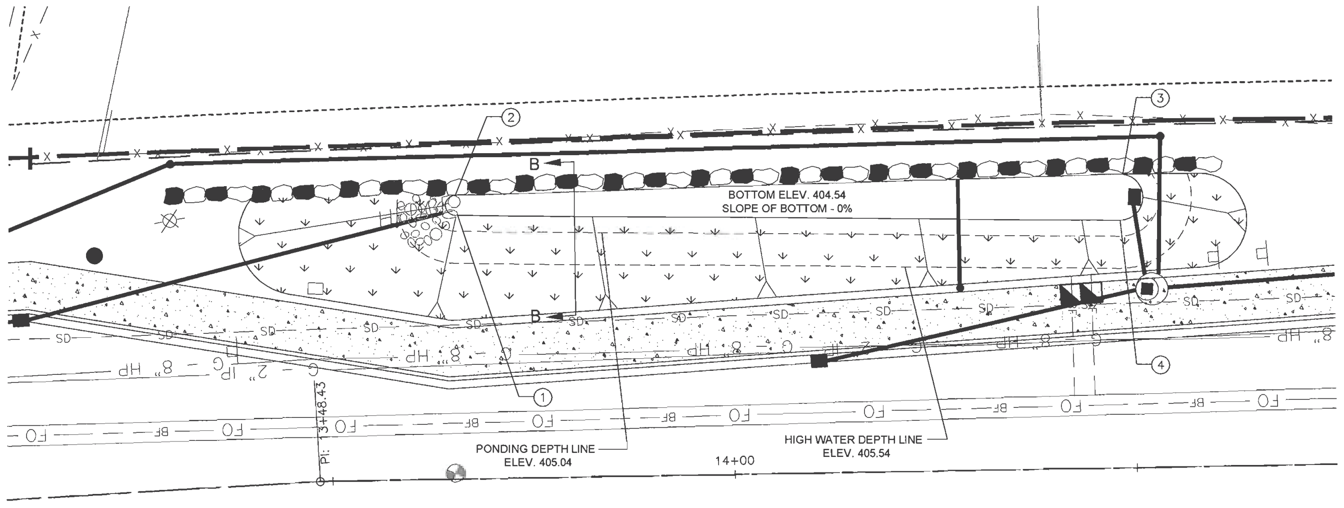
City of Bellevue
Transportation Department

CHRISTOPHER D. MASEK
45856

145 PL SE / SE 22 ST
ROADWAY IMPROVEMENTS

DRAINAGE DETAILS

SHT 12 OF 64



RAIN GARDEN #1 PLAN

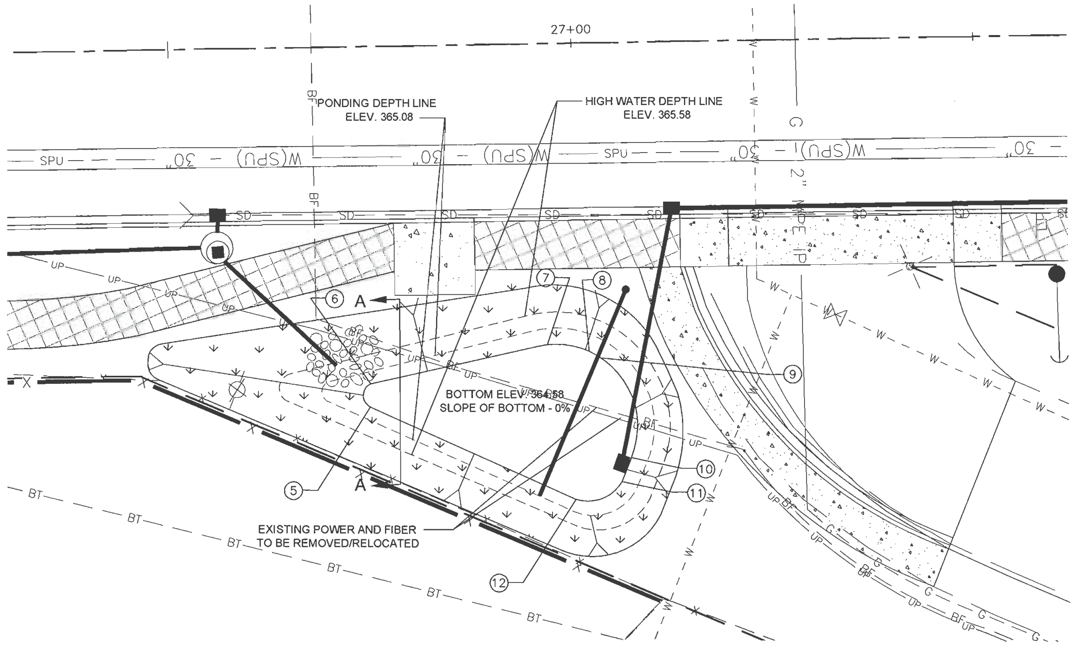
SCALE 1"=10'

RAIN GARDEN POINTS LAYOUT TABLE

POINT	DESCRIPTION	RADIUS	LENGTH	STATION	OFFSET
1	PC	1.25'	—	13+65.88	32.83' LT
2	PT	—	82.45	13+65.84	35.32' LT
3	PC	2.87'	–	14+48.28	36.52' LT
4	PT	–	82.51'	14+48.37	30.78' LT
5	PC	1.60'	–	26+74.30	44.79' RT
6	PT	–	21.00'	26+74.38	41.91' RT
7	PC	10.00'	–	26+94.95	37.62' RT
8	PT	–	1.62'	27+06.33	42.97' RT
9	PC	11.00'	–	27+07.05	44.43' RT
10	PT	–	3.20'	27+06.58	51.63' RT
11	PC	5.00'	–	27+05.38	54.58' RT
12	PT	–	27.94'	26+99.58	56.69' RT
13	PC	2.50'	–	28+78.37	31.59' LT
14	PT	–	45.69'	28+78.40	36.57' LT
15	PC	20.00'	–	29+23.99	39.66' LT
16	PT	–	12.13'	29+34.40	37.47' LT
17	PC	3.00'	–	29+45.21	32.04' LT
18	PT	–	65.45'	29+43.62	26.37' LT

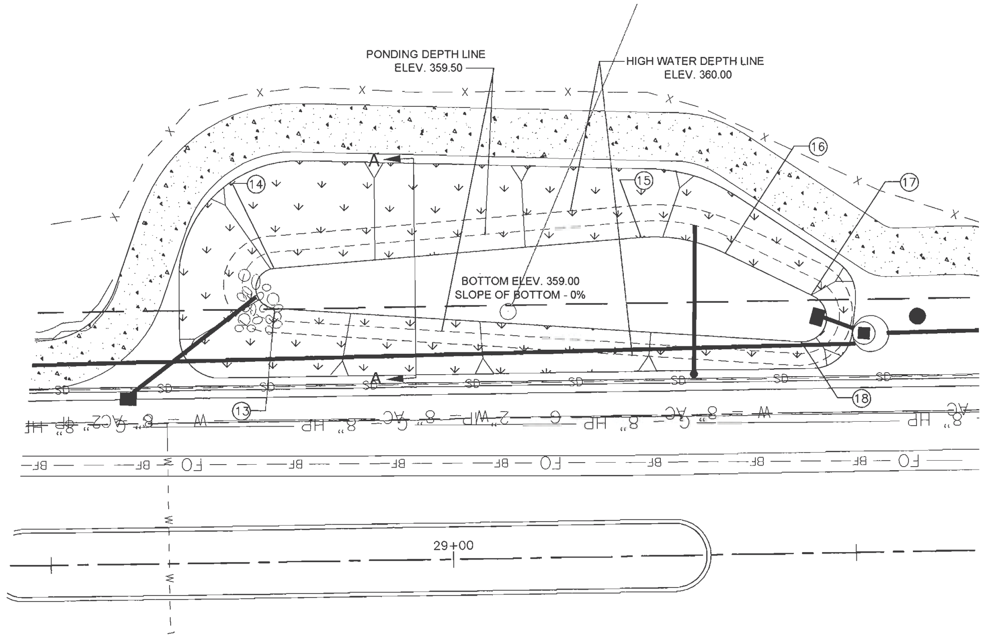
RAIN GARDEN NOTES

1. SECTIONS A–A AND B–B SHOWN ON SHEET 12



RAIN GARDEN #2 PLAN

SCALE 1"=10'



RAIN GARDEN #3 PLAN

SCALE 1"=10'

3/7/11

NO.	DATE	BY	APPR.	REVISIONS

Approved By

TRANSPORTATION DESIGN MANAGER DATE

PROJECT MANAGER DATE

DATE

C. Masek 03/11
DESIGNED BY DATE
C. Masek 03/11
DRAWN BY DATE
C. Masek 03/11
CHECKED BY DATE

City of
Bellevue
Transportation Department

CHRISTOPHER D. MASEK
45856

145 PL SE / SE 22 ST
ROADWAY IMPROVEMENTS

RAIN GARDEN GRADING PLAN AND
DETAILS

SHT 13 OF 64

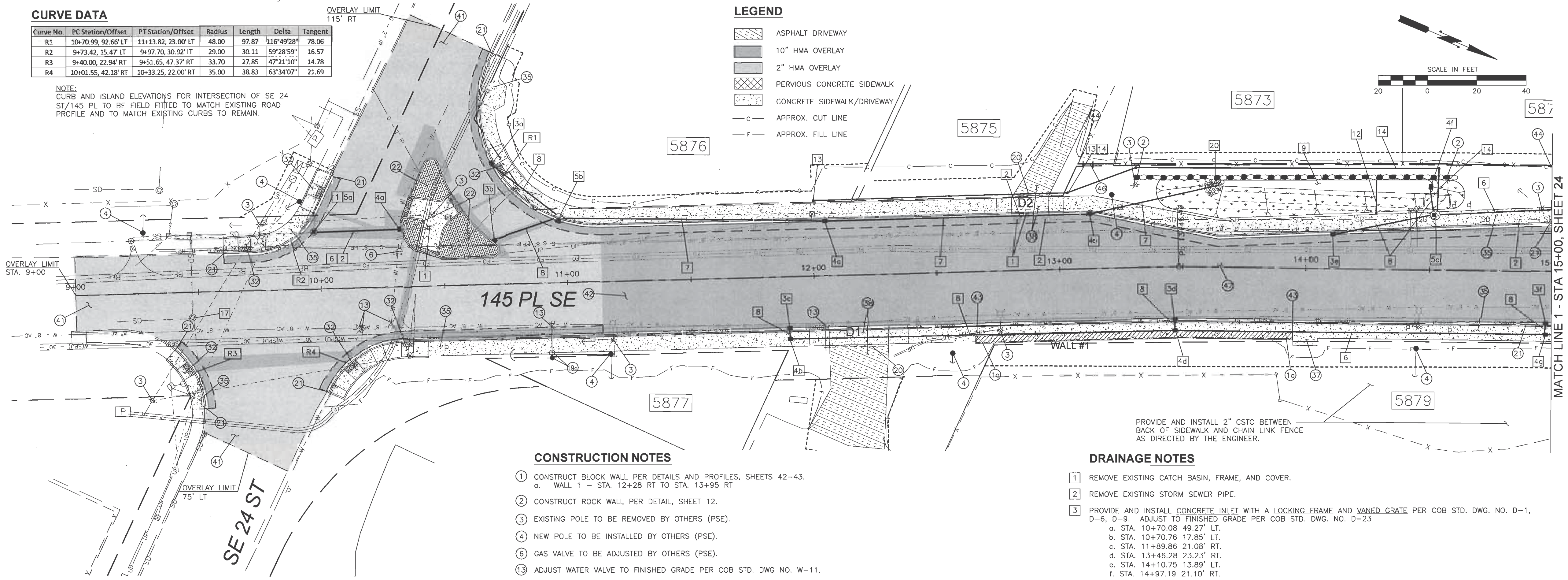
CURVE DATA

Curve No.	PC Station/Offset	PT Station/Offset	Radius	Length	Delta	Tangent
R1	10+70.99, 92.66' LT	11+13.82, 23.00' LT	48.00	97.87	116°49'28"	78.06
R2	9+73.42, 15.47' LT	9+97.70, 30.92' IT	29.00	30.11	59°28'59"	16.57
R3	9+40.00, 22.94' RT	9+51.65, 47.37' RT	33.70	27.85	47°21'10"	14.78
R4	10+01.55, 42.18' RT	10+33.25, 22.00' RT	35.00	38.83	63°34'07"	21.69

NOTE:
CURB AND ISLAND ELEVATIONS FOR INTERSECTION OF SE 24 ST/145 PL TO BE FIELD FITTED TO MATCH EXISTING ROAD PROFILE AND TO MATCH EXISTING CURBS TO REMAIN.

LEGEND

▨	ASPHALT DRIVEWAY
■	10" HMA OVERLAY
▒	2" HMA OVERLAY
▩	PERVIOUS CONCRETE SIDEWALK
░	CONCRETE SIDEWALK/DRIVEWAY
—C—	APPROX. CUT LINE
—F—	APPROX. FILL LINE



CONSTRUCTION NOTES

① CONSTRUCT BLOCK WALL PER DETAILS AND PROFILES, SHEETS 42-43.
  a. WALL 1 - STA. 12+28 RT TO STA. 13+95 RT

② CONSTRUCT ROCK WALL PER DETAIL, SHEET 12.

③ EXISTING POLE TO BE REMOVED BY OTHERS (PSE).

④ NEW POLE TO BE INSTALLED BY OTHERS (PSE).

⑥ GAS VALVE TO BE ADJUSTED BY OTHERS (PSE).

⑬ ADJUST WATER VALVE TO FINISHED GRADE PER COB STD. DWG NO. W-11.

⑲ REMOVE EXISTING FIRE HYDRANT AND INSTALL NEW HYDRANT SAME LOCATION ON THE WATER MAIN PER COB. STD. DWG NO. W-13. ADJUST HYDRANT TO FINISHED GRADE.
  a. STA. 10+92, 30.5' RT

⑳ PROVIDE AND INSTALL IRRIGATION LINE SLEEVE CROSSING. SEE IRRIGATION SHEETS L1-L10 FOR ADDITIONAL INFORMATION.

㉑ CONSTRUCT CEMENT CONCRETE CURB AND GUTTER PER COB STD DWG NO. TE-10. PATCH BACK TO EXISTING PAVEMENT WITH 10" ASPHALT CONCRETE PAVEMENT PER TYPICAL ROADWAY SECTION DETAILS, SHEETS 4-5.

㉒ CONSTRUCT TRAFFIC ISLAND 1 WITH CEMENT CONCRETE TRAFFIC CURB PER DETAIL, SHEET 9 AND SECTIONS A-A AND B-B, SHEET 8.

㉜ CONSTRUCT CEMENT CONCRETE SIDEWALK RAMP TYPE 2 PER COB STD. DWG. NO. TE-13.

㉟ CONSTRUCT CONCRETE SIDEWALK, 5" DEPTH, ON TOP OF 4"-11" COMPACTED CSTC PER TYPICAL SECTION DETAILS, SHEET 6.

㊲ CONSTRUCT CEMENT CONCRETE BUS STOP PAD PER DETAIL, SHEET 7.

㊳ CONSTRUCT CONCRETE DRIVEWAY APPROACH TYPE 1 AND DRIVEWAY DETAILS & SCHEDULE SHEET 44 AND DRIVEWAY PROFILES, SHEETS 45-48.

㊶ GRIND AND OVERLAY ENTIRE ROADWAY WITH HMA Cl. 1/2" PG 64-22. GRIND BUTT JOINT PER DETAIL, SHEET 8. SEE SHEETS 4-5 FOR GRIND AND OVERLAY DEPTHS

㊷ GRIND EXISTING ROADWAY TO A DEPTH OF 5" AND OVERLAY WITH 10" OF NEW HMA TOTAL - 4" HMA Cl. 1/2" PG 64-22 ATOP 6" HMA Cl. 1" PG 64-22. SEE ROADWAY PROFILES FOR FINAL CENTERLINE ELEVATION INFORMATION. MATCH INTO EXISTING PAVEMENT PER OVERLAY TRANSITION DETAIL, SHEET 8.

㊸ PROVIDE AND INSTALL SAFETY RAILING PER COB STD. DWG. NO. TE-34 AND WALL DETAILS, SHEET 43 .

㊹ CONSTRUCT 6' WOOD FENCE PER DETAIL, SHEET 7.

㊻ CONSTRUCT GATE FOR WOOD FENCE PER DETAIL, SHEET 7.

㊼ ADJUST MONUMENT CASE AND COVER TO FINISHED GRADE PER COB STD. DWG. NO. DEV-12.

DRAINAGE NOTES

1 REMOVE EXISTING CATCH BASIN, FRAME, AND COVER.

2 REMOVE EXISTING STORM SEWER PIPE.

3 PROVIDE AND INSTALL CONCRETE INLET WITH A LOCKING FRAME AND VANED GRATE PER COB STD. DWG. NO. D-1, D-6, D-9. ADJUST TO FINISHED GRADE PER COB STD. DWG. NO. D-23
  a. STA. 10+70.08 49.27' LT.
  b. STA. 10+70.76 17.85' LT.
  c. STA. 11+89.86 21.08' RT.
  d. STA. 13+46.28 23.23' RT.
  e. STA. 14+10.75 13.89' LT.
  f. STA. 14+97.19 21.10' RT.

4 PROVIDE AND INSTALL CATCH BASIN TYPE I WITH A LOCKING FRAME PER COB STD. DWG. NO. D-2 & D-9. PROVIDE AND INSTALL STRUCTURE LID AS NOTED BELOW. ADJUST TO FINISHED GRADE PER COB STD. DWG. NO. D-23.
  a. STA. 10+32.00, 23.47' LT. - VANED GRATE PER COB STD DWG NO. D-6
  b. STA. 11+89.79, 25.52' RT. - SOLID COVER PER COB STD DWG NO. D-8
  c. STA. 12+04.91, 22.31' LT. - VANED GRATE PER COB STD DWG NO. D-6
  d. STA. 13+46.11, 26.13' RT. - SOLID COVER PER COB STD DWG NO. D-8
  e. STA. 13+12.40, 22.14' LT. - VANED GRATE PER COB STD DWG NO. D-6
  f. STA. 14+50.22, 33.56' LT. - BEEHIVE GRATE NEENAH FOUNDRY R-4346
  g. STA. 14+97.40, 25.84' RT. - SOLID COVER PER COB STD DWG NO. D-8

5 PROVIDE AND INSTALL CATCH BASIN TYPE II, 48" DIAMETER WITH A LOCKING RING AND SOLID ROUND COVER PER BELLEVUE STD. DWG. NO. D-4, D-5, & D-22 UNLESS OTHERWISE NOTED BELOW.. ADJUST TO FINISHED GRADE PER BELLEVUE STD. DWG. NO. D-23
  a. STA. 9+97.40, 23.28' LT.
  b. STA. 10+97.03, 26.03' LT - STANDARD FRAME AND VANED GRATE PER COB STD DWG NO. D-6 & D-9.
  c. STA. 14+52.26, 22.20' LT.

6 PROVIDE AND INSTALL 12" PVC STORM SEWER PIPE PER COB STD DWG. NO. D-25 & D-46. SEE PROFILE, SHEETS 33-40 FOR PIPE SLOPES.

7 PROVIDE AND INSTALL 12" DUCTILE IRON STORM SEWER PIPE PER COB STD DWG. NO. D-25 & D-46. SEE PROFILE, SHEETS 33-40 FOR PIPE SLOPES.

8 PROVIDE AND INSTALL 8" DUCTILE IRON STORM SEWER PIPE PER COB STD DWG. NO. D-25 & D-46. PIPE SLOPE IS 2% UNLESS OTHERWISE NOTED ON THE PROFILE, SEE SHEETS 33-40.

9 EXCAVATE AND CONSTRUCT RAIN GARDEN PER GRADING PLANS SHEET 13 AND DETAILS, SHEETS 11-12. BOTTOM OF RAIN GARDEN ELEVATION TO MATCH RAIN GARDEN DETAILS.

12 CONSTRUCT RAIN GARDEN OBSERVATION PORT PER DETAIL, SHEET 11.

13 PROVIDE AND INSTALL 6" PVC PERFORATED UNDERDRAIN PIPE AND CLEANOUTS PER COB STD. DWG NO. 52 WITH A MINIMUM BURY DEPTH OF 1 FT. BACKFILL UNDERDRAIN PIPE WAS DRAIN ROCK.

14 PROVIDE AND INSTALL 6" PVC SOLID WILL STORM SEWER PIPE PER COB STD DWG. NO. D-25 & D-46 AND CLEANOUTS PER COB STD. DWG NO. 52.

17 ADJUST MANHOLE TO FINISHED GRADE PER COB STD. DWG. NO. D-23.

20 PROVIDE PIPE OUTLET ROCK PROTECTION PER DETAIL, SHEET 11.

GENERAL NOTES

1. CALL UTILITIES UNDERGROUND LOCATION CENTER AT 1-800-424-5555 48 HOURS PRIOR TO CONSTRUCTION.

2. THE CONTRACTOR SHALL POTHOLE ALL POTENTIAL CONFLICTS WITH UTILITIES TO VERIFY THE HORIZONTAL AND VERTICAL LOCATION OF THE EXISTING UTILITIES. WHERE THE VERTICAL DISTANCE BETWEEN UTILITIES IS LESS THAN 6 INCHES, THE CONTRACTOR SHALL PROVIDE AN O.D. X O.D. X 2.5 INCH ETHAFOAM PAD PER THE SPECIAL PROVISIONS 7-08.3(2)j.

3. THE CONTRACTOR SHALL MAINTAIN 11' FOOT MINIMUM TRAVEL LANES DURING CONSTRUCTION EXCEPT DURING FINAL PAVEMENT RESTORATION.

5. DETECTABLE WARNINGS SHALL CONSIST OF RAISED TRUNCATED DOMES MEETING APPLICABLE CHARACTERISTICS SPECIFIED BY THE ADA AND COB STANDARD DRAWINGS TE-12 AND TE-13. MATERIAL SHALL BE "CAST IN PLACE" BY ARMOR-TILE, APPLIED INTEGRAL TO THE CONCRETE POURING OF THE RAMP FOR ALL NEW CONCRETE INSTALLATIONS. MATERIAL SHALL BE PRE-FORMED MAT-TYPE "SURFACE APPLIED SYSTEMS" BY ARMOR TILE, "TOPMARK" BY FLINT TRADING OR APPROVED EQUAL FOR ALL RETROFIT AND ASPHALT INSTALLATIONS. NO SUBSTITUTIONS WILL BE PERMITTED WITHOUT PRIOR WRITTEN APPROVAL BY THE CITY. DETECTABLE WARNINGS SHALL BE YELLOW AS SPECIFIED BY THE MANUFACTURER AND SHALL INSTALLED PER THE MANUFACTURER'S SPECIFICATIONS.

5. FOR JUNCTION BOX AND ELECTRICAL CONDUIT INSTALLATION, SEE SHEETS 60-62.

6. FOR CENTERLINE AND CURB ELEVATION INFORMATION, SEE ROADWAY PROFILES, SHEETS 33-40.

TRAFFIC CONTROL NOTES

1. TWO-WAY TRAFFIC SHALL BE MAINTAINED AT ALL TIMES UNLESS OTHERWISE APPROVED BY THE CITY.

2. WORK HOURS FOR CONSTRUCTION INCLUDING LANE CLOSURES WILL BE 7 AM TO 6 PM MONDAY THROUGH FRIDAY, 9 AM TO 6 PM ON SATURDAY.

3. CONTRACTOR SHALL PROVIDE PROJECT SPECIFIC TRAFFIC CONTROL PLAN AT LEAST 10 DAYS PRIOR TO CONSTRUCTION.

4. TWO - 14 CONSECUTIVE DAY CLOSURES OF 145 PL SE BETWEEN SE 16 ST AND SE 24 ST WILL BE PERMITTED FOR ROADWAY RECONSTRUCTION, PAVING AND CHANNELIZATION WORK. WORK HOURS DURING THE CLOSURE SHALL BE 7 AM TO 6 PM MONDAY THROUGH FRIDAY AND 9 AM TO 6 PM ON SATURDAYS. LOCAL ACCESS SHALL BE MAINTAINED FOR RESIDENTS.

3/7/11

NO.	DATE	BY	APPR.	REVISIONS

Approved By

TRANSPORTATION DESIGN MANAGER DATE

PROJECT MANAGER DATE

DATE

C. Masek 03/11
DESIGNED BY DATE
C. Masek 03/11
DRAWN BY DATE
C. Masek 03/11
CHECKED BY DATE

City of
Bellevue
Transportation Department

CHRISTOPHER D. MASEK
45856

145 PL SE / SE 22 ST
ROADWAY IMPROVEMENTS

ROADWAY & DRAINAGE PLAN
145 PL SE - STA. 9+00 TO STA. 15+00

SHT 23 OF 64

APPENDIX B

Current Study Exploration Logs and Laboratory Testing Data

Cell B145
Exploration Latitude and Longitude

Exploration	Latitude	Longitude
B145-HA-1	47.58988	-122.14611
B145-HA-2	47.59010	-122.14630
B145-HA-3	47.59004	-122.14622

associated earth sciences incorporated

Exploration Log

Project Number	Exploration Number	Sheet
KH150387A	B145-HA-1	1 of 1

Project Name: Bioretention Hydrologic Performance Study
Location: Bellevue, WA
Driller/Equipment: Hand Auger
Hammer Weight/Drop: N/A

Ground Surface Elevation (ft):
Datum: Not Surveyed
Date Start/Finish: 7/6/16,7/6/16
Hole Diameter (in): 4 inches

Depth (ft)	S T	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot 10 20 30 40	Other Tests
				Vegetation Debris / Pine Needles / Leaves Surface: vegetation, leaf litter					
				Bioretention Soil Mix Loose, slightly moist, dark brown, SAND, trace silt; organics present; mostly medium sand (~60 percent) (SP).					
				Vashon Advance Outwash Dense, moist, brown, SAND, trace gravel, trace silt; silt interbed at 3 feet; mostly fine to medium sand (SP-SM).					
				Bottom of exploration boring at 3.2 feet No seepage. No caving.					

Sampler Type (ST):

- ▯ 2" OD Split Spoon Sampler (SPT)
- ▯ 3" OD Split Spoon Sampler (D & M)
- ☐ Grab Sample
- ☐ No Recovery
- ◧ Ring Sample
- ▨ Shelby Tube Sample

M - Moisture
▽ Water Level ()
▼ Water Level at time of drilling (ATD)

Logged by: JHS
Approved by: JHS

associated earth sciences incorporated

Exploration Log

Project Number	Exploration Number	Sheet
KH150387A	B145-HA-2	1 of 1

Project Name: Bioretention Hydrologic Performance Study
Location: Bellevue, WA
Driller/Equipment: Hand Auger
Hammer Weight/Drop: N/A

Ground Surface Elevation (ft):
Datum: Not Surveyed
Date Start/Finish: 7/22/16,7/22/16
Hole Diameter (in): 4 inches

Depth (ft)	S T	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot 10 20 30 40	Other Tests
				Bioretention Soil Mix Surface: vegetation, leaf litter Loose, slightly moist, dark brown, SAND, trace silt; organics present; mostly medium sand (~66 percent) (SP).					
				Vashon Advance Outwash Dense, moist, brown, gravelly SAND, some silt; mostly fine to medium sand (SW-SM).					
				Bottom of exploration boring at 3 feet Refusal on cobbles. No seepage. No caving.					

Sampler Type (ST):

▯ 2" OD Split Spoon Sampler (SPT)
▯ 3" OD Split Spoon Sampler (D & M)
✋ Grab Sample
☐ No Recovery
◧ Ring Sample
▱ Shelby Tube Sample
M - Moisture
▽ Water Level ()
▼ Water Level at time of drilling (ATD)

Logged by: ADY
Approved by: JHS

AESIBOR 150387B145.GPJ October 24, 2016

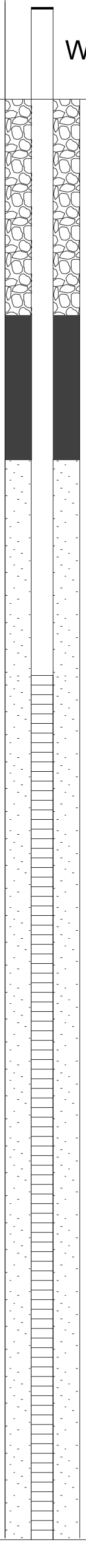
associated earth sciences incorporated

Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KH150387A	-B145-HA-3/WP	1 of 2

Project Name: Bioretention Hydrologic Performance Study
Elevation (Top of Well Casing): ~1.8 feet (stick up)
Water Level Elevation:
Drilling/Equipment: Hand Auger
Hammer Weight/Drop: N/A
Location: Bellevue, WA
Surface Elevation (ft):
Date Start/Finish: 7/22/16,7/22/16
Hole Diameter (in): 4 inches

Depth (ft) | Water Level | WELL CONSTRUCTION | ST | Blows/ 6" | Graphic Symbol | DESCRIPTION

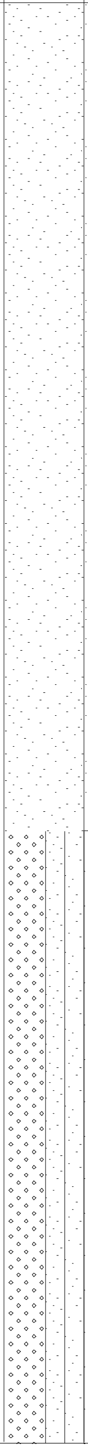


WELL CONSTRUCTION

Above ground stick up -1.8 feet
Threaded PVC cap
Bioretention soil mix 0 to 0.6 foot

Bentonite chips 0.6 to 1.0 foot
Threaded steel pipe -1.8 to 1.6 feet

Stainless steel jacket over stainless steel #60 gauze welded to perforated steel pipe 1.6 to 4.1 feet
Medium sand 1.0 to 4.3 feet



DESCRIPTION

Bioretention Soil Mix

Surface: vegetation, leaf litter

Loose, slightly moist, dark brown, SAND, trace silt; organics present; mostly medium sand (~61 percent) (SP).

Vashon Advance Outwash

Dense, moist, brown, gravelly SAND, some silt; mostly fine to medium sand (SW-SM).

Sampler Type (ST):

- ▯ 2" OD Split Spoon Sampler (SPT)
- ▯ 3" OD Split Spoon Sampler (D & M)
- ▯ Grab Sample
- ☐ No Recovery
- ▮ Ring Sample
- ▱ Shelby Tube Sample

M - Moisture
▽ Water Level ()
▼ Water Level at time of drilling (ATD)

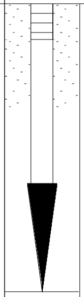
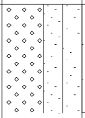
Logged by: ADY
Approved by: JHS

associated earth sciences incorporated

Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KH150387A	-B145-HA-3/WP	2 of 2

Project Name Bioretention Hydrologic Performance Study
Elevation (Top of Well Casing) ~1.8 feet (stick up)
Water Level Elevation
Drilling/Equipment Hand Auger
Hammer Weight/Drop N/A
Location Bellevue, WA
Surface Elevation (ft)
Date Start/Finish 7/22/16,7/22/16
Hole Diameter (in) 4 inches

Depth (ft)	Water Level	WELL CONSTRUCTION	S T	Blows/ 6"	Graphic Symbol	DESCRIPTION
		 Threaded steel pipe, 1 1/4 inch ID and end cap 4.1 to 4.5 feet Native soil 4.3 to 4.8 feet Solid drive point 4.5 to 4.8 feet				Boring terminated at 4.3 feet. Well completed at 4.8 feet on 7/22/16. Refusal on cobbles. No seepage. No caving.
5						

Sampler Type (ST):

▯	2" OD Split Spoon Sampler (SPT)	▯	No Recovery	M -	Moisture
▯	3" OD Split Spoon Sampler (D & M)	▮	Ring Sample	▽	Water Level ()
▯	Grab Sample	▯	Shelby Tube Sample	▼	Water Level at time of drilling (ATD)

Logged by: ADY
Approved by: JHS

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Moisture, Ash, and Organic Matter of Peat and Other Organic Soils - ASTM 2974

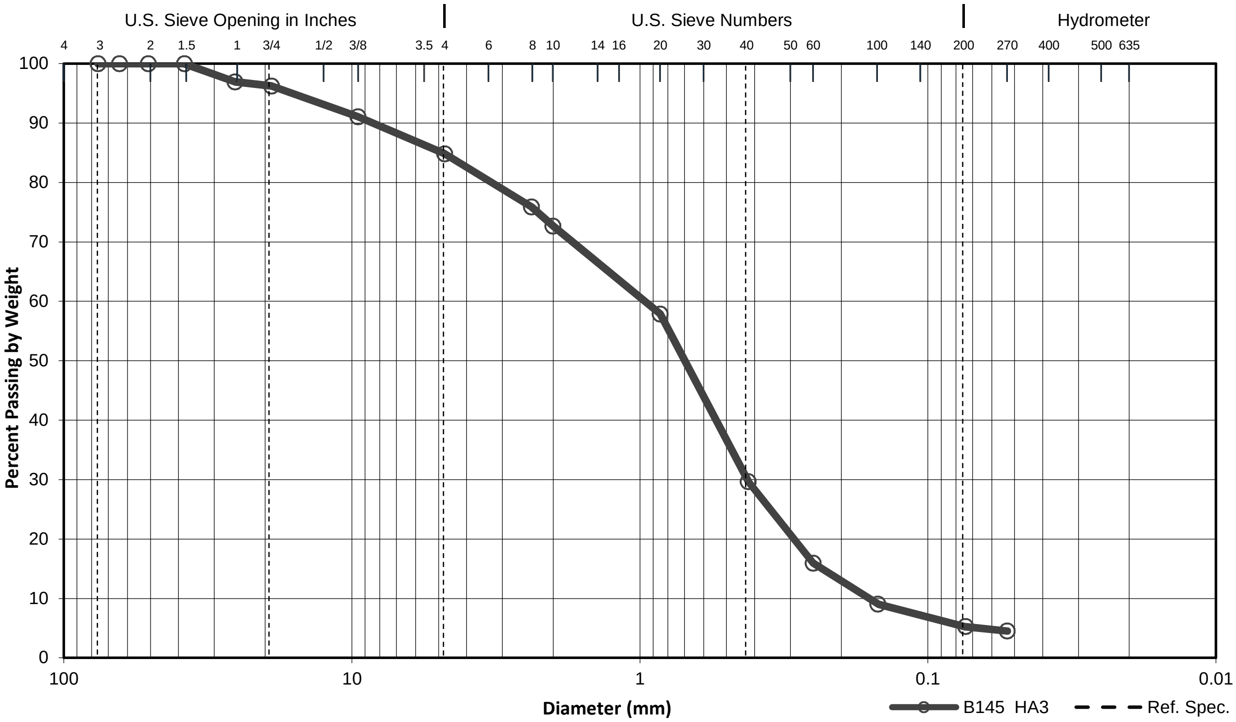
Date Sampled 7/22/2016	**Project** BHPS	**Project No.** KH150387A		**Soil Description** Bioretention soil mix
Tested By MS	**Location** B145	**EB/EP No.** B145	**Depth**	

Moisture Content	**B145**	**Moisture Content**	**B145**
Sample ID	**HA2 0.2-0.5**	Sample ID	**HA3 0.6-0.9**
Wet Weight + Pan	**962.09**	Wet Weight + Pan	**880.40**
Dry Weight + Pan	**897.14**	Dry Weight + Pan	**805.00**
Weight of Pan	**273.40**	Weight of Pan	**296.32**
Weight of Moisture	**64.95**	Weight of Moisture	**75.40**
Dry Weight of Soil	**623.74**	Dry Weight of Soil	**508.68**
% Moisture	**10.4**	% Moisture	**14.8**

Organic Matter and Ash Content		**Organic Matter and Ash Content**	
Dry Soil Befor Burn + Pan	**1015.77**	Dry Soil Befor Burn + Pan	**857.48**
Dry Soil After Burn + Pan	**993.70**	Dry Soil After Burn + Pan	**836.05**
Weight of Pan	**393.13**	Weight of Pan	**348.69**
Wt. Loss Due to Ignition	**22.07**	Wt. Loss Due to Ignition	**21.43**
Actual Wt. Of Soil After Burr	**600.57**	Actual Wt. Of Soil After Burr	**487.36**
% Organics	**3.5**	% Organics	**4.2**

GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

Project Name	Project Number	Date Sampled	Date Tested	Tested By
BHPS	**KH150387A**	**7/22/2016**	**9/1/2016**	**MS**
Sample Source	Sample No.	Depth (ft)	Soil Description	
Onsite	**B145 HA3**	**2.4-2.9**	**gravelly SAND, some silt (SW-SM)**	
Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification	
1562.2	**4**	**0.159**	**Not applicable: native material**	



Cobb.	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4	48.2	3.1	96.9		
3/4	19	59.0	3.8	96.2		
3/8	9.51	139.3	8.9	91.1		
#4	4.76	237.4	15.2	84.8		
#8	2.38	376.7	24.1	75.9		
#10	2	426.8	27.3	72.7		
#20	0.85	658.0	42.1	57.9		
#40	0.42	1099.1	70.4	29.6		
#60	0.25	1313.1	84.1	15.9		
#100	0.149	1420.7	90.9	9.1		
#200	0.074	1480.1	94.7	5.3		
#270	0.053	1491.6	95.5	4.5		

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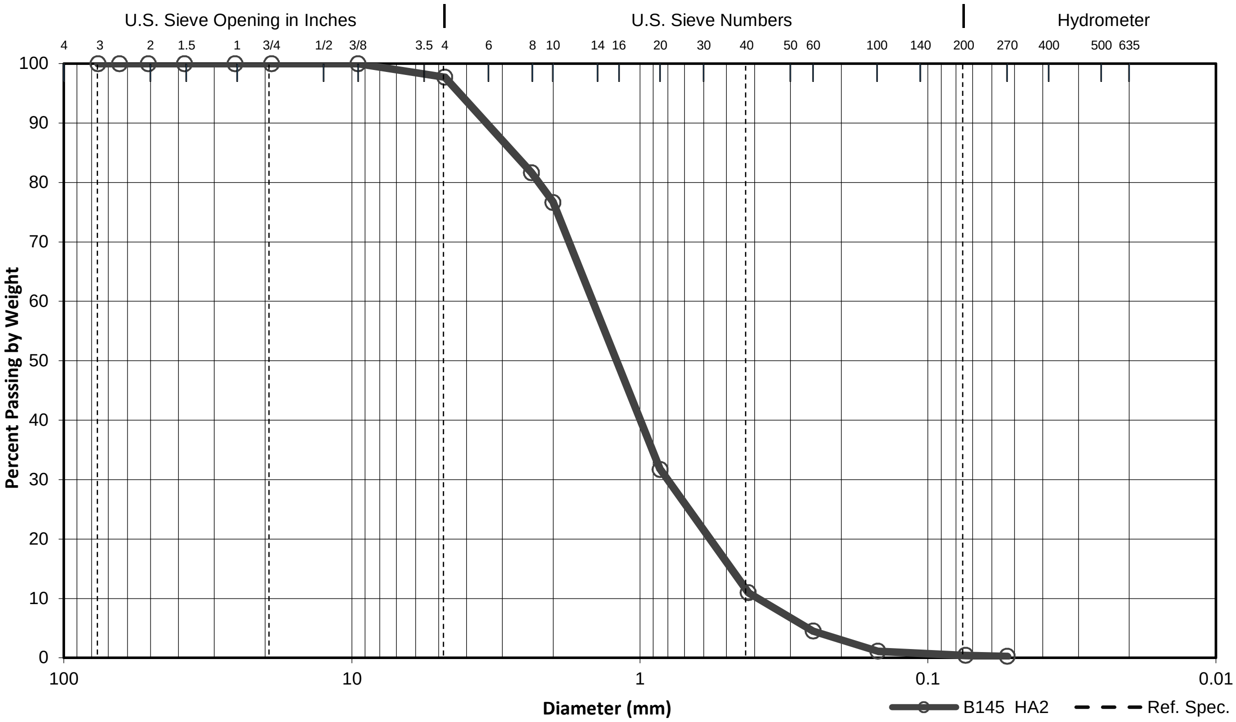
GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

Project Name	Project Number	Date Sampled	Date Tested	Tested By
BHPS	**KH150387A**	**7/22/2016**	**9/1/2016**	**MS**
Sample Source	Sample No.	Depth (ft)	Soil Description	
Onsite	**B145 HA2**	**0.2-0.5**	**SAND, trace silt, trace gravel (SP)**	
Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification	
601.6	**0**	**0.388**	**Bioretention soil mix: burned sample**	



Cobb.	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4		0.0	100.0		
3/4	19		0.0	100.0		
3/8	9.51		0.0	100.0		
#4	4.76	13.5	2.2	97.8		
#8	2.38	110.4	18.3	81.7		
#10	2	140.6	23.4	76.6		
#20	0.85	410.8	68.3	31.7		
#40	0.42	535.6	89.0	11.0		
#60	0.25	574.5	95.5	4.5		
#100	0.149	594.9	98.9	1.1		
#200	0.074	599.0	99.6	0.4		
#270	0.053	600.1	99.8	0.2		

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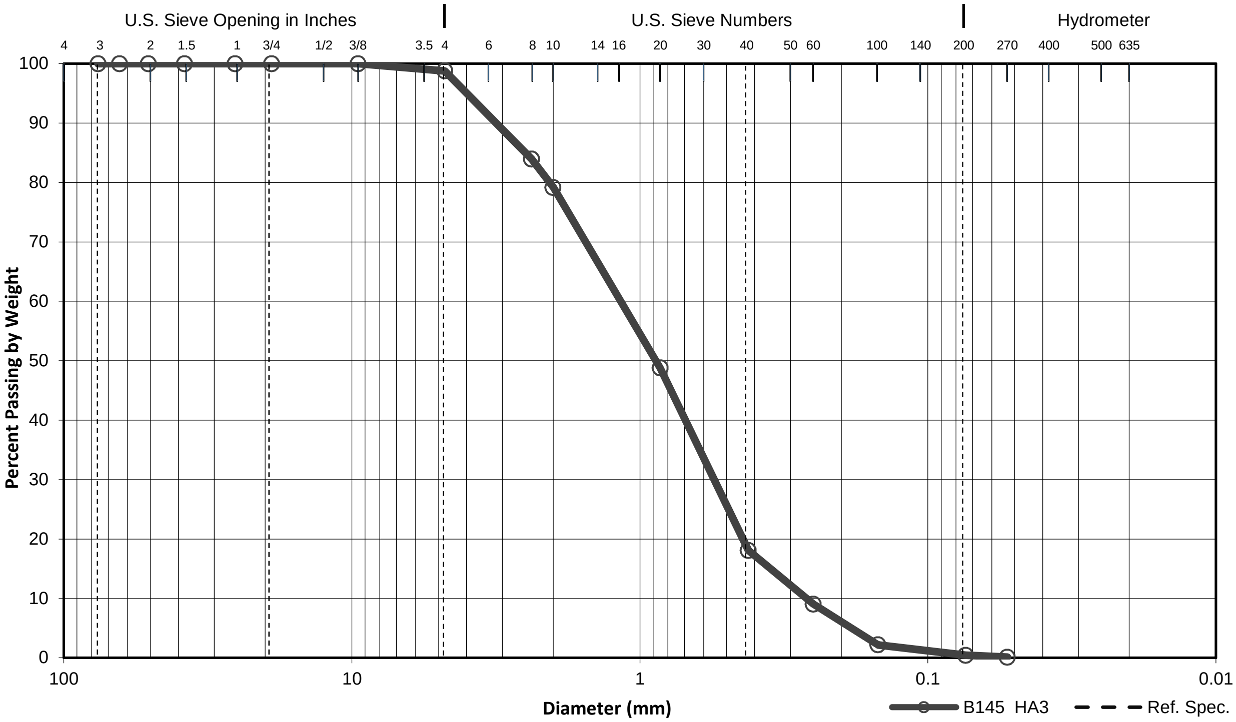
GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

Project Name	Project Number	Date Sampled	Date Tested	Tested By
BHPS	**KH150387A**	**7/22/2016**	**9/1/2016**	**MS**
Sample Source	Sample No.	Depth (ft)	Soil Description	
Onsite	**B145 HA3**	**0.6-0.9**	**SAND, trace silt, trace gravel (SP)**	
Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification	
486.7	**0**	**0.263**	**Bioretention soil mix: burned sample**	

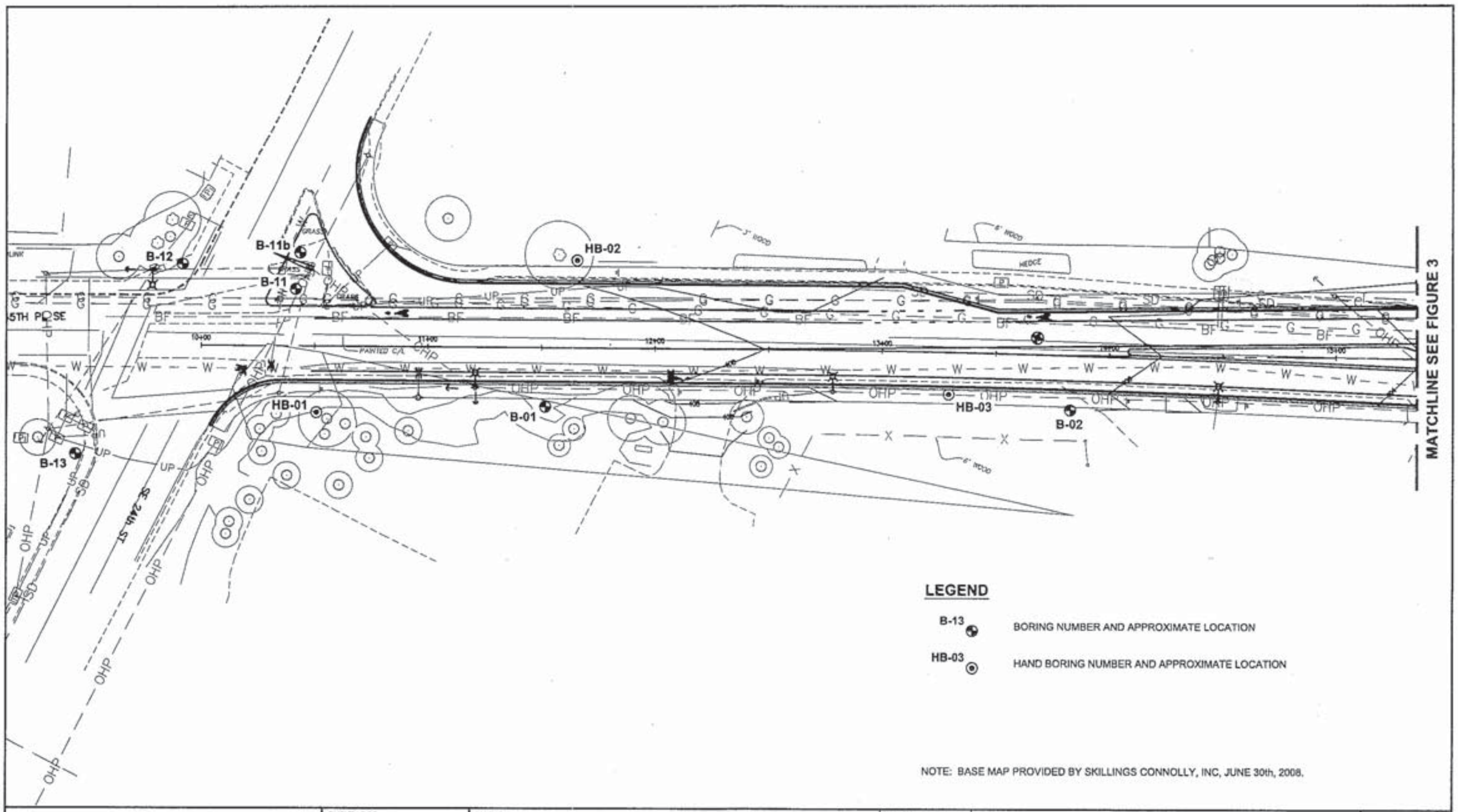


Cobb.	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4		0.0	100.0		
3/4	19		0.0	100.0		
3/8	9.51		0.0	100.0		
#4	4.76	5.9	1.2	98.8		
#8	2.38	78.1	16.0	84.0		
#10	2	101.3	20.8	79.2		
#20	0.85	249.2	51.2	48.8		
#40	0.42	398.8	81.9	18.1		
#60	0.25	442.7	90.9	9.1		
#100	0.149	476.1	97.8	2.2		
#200	0.074	484.6	99.6	0.4		
#270	0.053	486.1	99.9	0.1		

APPENDIX C

Background Soil, Geology, and Ground Water Data (Regional Maps, Previous Studies Exploration Logs and Laboratory Testing Data)



LEGEND

B-13 ●	BORING NUMBER AND APPROXIMATE LOCATION
HB-03 ⊙	HAND BORING NUMBER AND APPROXIMATE LOCATION

NOTE: BASE MAP PROVIDED BY SKILLINGS CONNOLLY, INC, JUNE 30th, 2008.

0 40 80
SCALE IN FEET

CLIENT LOGO	CLIENT: SKILLINGS CONNELLY	DWN BY: JRS CHK'D BY: LE	PROJECT BELLEVUE 145TH PLACE SE AND SE 22ND PLACE	DATE: JULY 2008 PROJECT NO: 8-917-16425-0
	AMEC Earth & Environmental 11335 N.E. 122nd Way, Suite 100 Kirkland, WA, U.S.A. 98034-6918	DATUM: NAD83 PROJECTION: WA STATE PLANE SCALE: AS SHOWN	TITLE SITE AND EXPLORATION PLAN 145th Place SE, Stations 10+00 to 15+35.2	REV. NO.: FIGURE No. 2

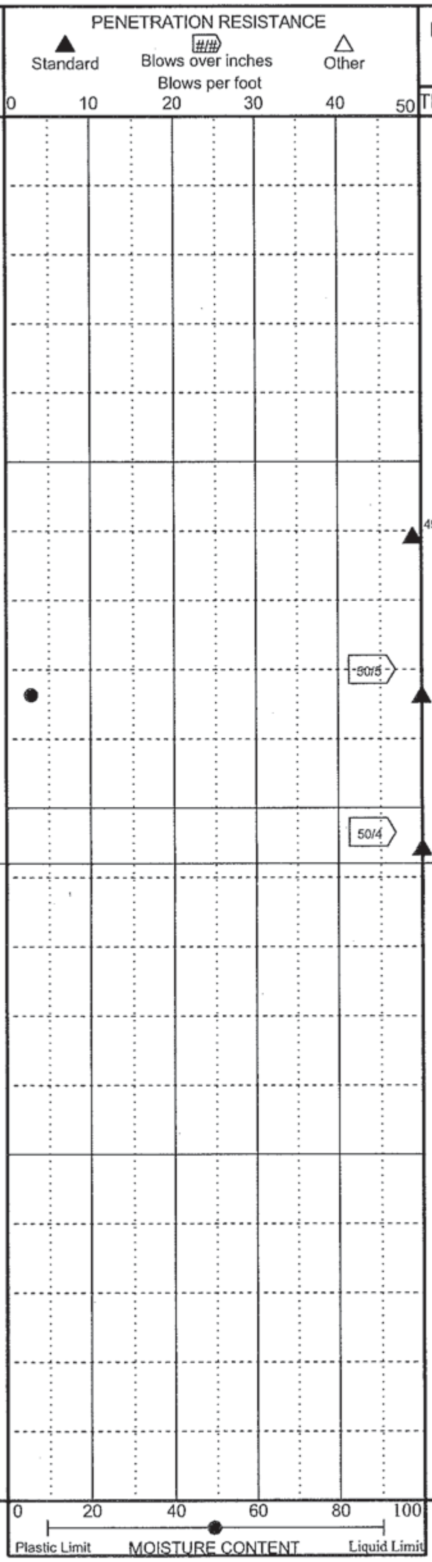
G:\91\16000\16425 – 145th Place SE\16425–02.dwg – Exploration I – Jul. 09, 2008 11:53am – dench.pollk

PROJECT: *Bellevue 145th Pl SE & SE 22nd Pl* JOB No. *8-917-16425-0* BORING No. *B-01*

Location: Station 11+52, 30' R
Approximate ground surface elevation: 409 feet

Page 1 of 1

DEPTH (feet)	Soil Description	USCS/USGS GRAPHICS	SAMPLE TYPE	SAMPLE NUMBER	GROUND WATER	TESTING
0	Less than 0.1 foot of moss and weeds over Loose, moist, dark brown, silty, fine to medium SAND with some gravel and scattered roots; (Fill) SM		🖐	G-1	N/E	
	Medium dense, moist, brown, fine to medium SAND with some silt and gravel; (Fill) SP-SM		🖐	G-2		
	Dense, damp to moist, grey and brown mottles with oxidation staining, silty, fine to medium SAND with gravel; (Weathered Glacial Till) SM					
5			▯	S-1		
	Very dense, damp, gray, fine to medium SAND with some silt and trace gravel; (Glacial Till) SP-SM					
			▯	S-2		
10	Becomes damp to moist, brown-grey, and silty		▯	S-3		
	Boring terminated at approximately 10.8 feet					
15						
20						



LEGEND

🖐 Grab Sample

▯ 2.00-inch OD split-spoon sampler

N/E No groundwater encountered

amec

11335 N.E. 122nd Way Suite 100
Kirkland, Washington 98034-6913

Drilling Method: HSA Hammer Type: Cathead Date drilled: *June 16, 2008* Logged By: *LME*

Drilled by: *Boretech*

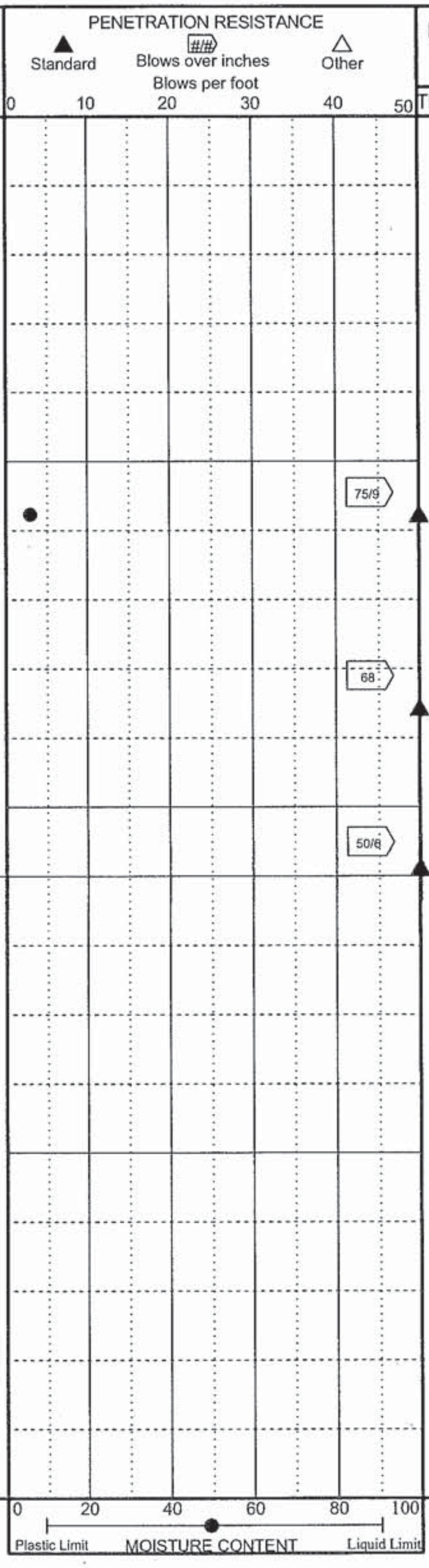
PROJECT: *Bellevue 145th Pl SE & SE 22nd Pl* JOB No. *8-917-16425-0* BORING No. *B-02*

Page 1 of 1

Location: Station 13+83, 30' R

Approximate ground surface elevation: 406 feet

DEPTH (feet)	Soil Description	USCS/USGS GRAPHICS	SAMPLE TYPE	SAMPLE NUMBER	GROUND WATER
0	0.42 feet of asphalt				N/E
	Dense, moist, gray-brown with oxidation staining, silty, fine to medium SAND with trace gravel; (Weathered Glacial Till) SM				
	Very dense, damp, brown, silty, fine to medium SAND with trace to some gravel; (Glacial Till) SM				
5				S-1	
	Becomes brown-gray, with some silt and gravel			S-2	
10	Becomes moist			S-3	
	Boring terminated at approximately 11 feet				
15					
20					



TESTING

LEGEND

2.00-inch OD split-spoon sampler

N/E No groundwater encountered

amec

11335 N.E. 122nd Way Suite 100
Kirkland, Washington 98034-6913

Drilling Method: HSA Hammer Type: Cathead Date drilled: *June 16, 2008* Logged By: *LME*

Drilled by: *Boretech*

PROJECT: *Bellevue 145th Pl SE & SE 22nd Pl* JOB No. *8-917-16425-0* BORING No. *HB-02*

DEPTH (feet)	Soil Description Location: Station 11+66, 32' L Approximate ground surface elevation: 409 feet	USCS/USGS GRAPHICS	SAMPLE TYPE	SAMPLE NUMBER	GROUND WATER	PENETRATION RESISTANCE ▲ Standard ##/## Blows over inches △ Other Blows per foot 0 10 20 30 40 50	Page 1 of 1 TESTING
0	Forest duff	▨					
	Loose to medium dense, moist, dark-brown, sandy SILT / silty SAND, with trace gravel and abundant roots; (Topsoil) ML-SM		✋	G-1	N/E		
	Medium dense, moist, oxidized brown, silty, fine to medium SAND with trace gravel; (Weathered Glacial Till) SM	▒	✋	G-2			
	Refusal on rock Boring terminated at approximately 2 feet						
5							

0 20 40 60 80 100

Plastic Limit MOISTURE CONTENT Liquid Limit

LEGEND

✋ Grab Sample

N/E No groundwater encountered

amec

11335 N.E. 122nd Way Suite 100
Kirkland, Washington 98034-6913

Drilling Method: Hand Auger Hammer Type: Not Applicable Date drilled: *June 17, 2008* Logged By: *LME*

Drilled by:

PROJECT: *Bellevue 145th Pl SE & SE 22nd Pl* JOB No. *8-917-16425-0* BORING No. *HB-03*

DEPTH (feet)	Soil Description Location: Station 13+30, 27' R Approximate ground surface elevation: 407 feet	USCS/USGS GRAPHICS	SAMPLE TYPE	SAMPLE NUMBER	GROUND WATER	PENETRATION RESISTANCE ▲ Standard ▨ Blows over inches △ Other Blows per foot 0 10 20 30 40 50	Page 1 of 1 TESTING
0	Forest duff	▨					
	Loose to medium dense, moist, dark-brown, silty, fine to coarse SAND, with trace to some gravel and abundant roots; (Topsoil) SM		🖐	G-1	N/E		
	Medium dense, moist, oxidized brown, silty, fine to medium SAND with some gravel and trace cobbles; (Weathered Glacial Till) SM		🖐	G-2			
	Refusal on rock Boring terminated at approximately 2 feet						
5							

0 20 40 60 80 100

Plastic Limit MOISTURE CONTENT Liquid Limit

LEGEND

🖐 Grab Sample

N/E No groundwater encountered

SOIL_ROCK_COMBO 4-1-05 EXPLORATIONLOGS145THBELLEVUE.GPJ GEOTECH3_05.GDT 7/29/08

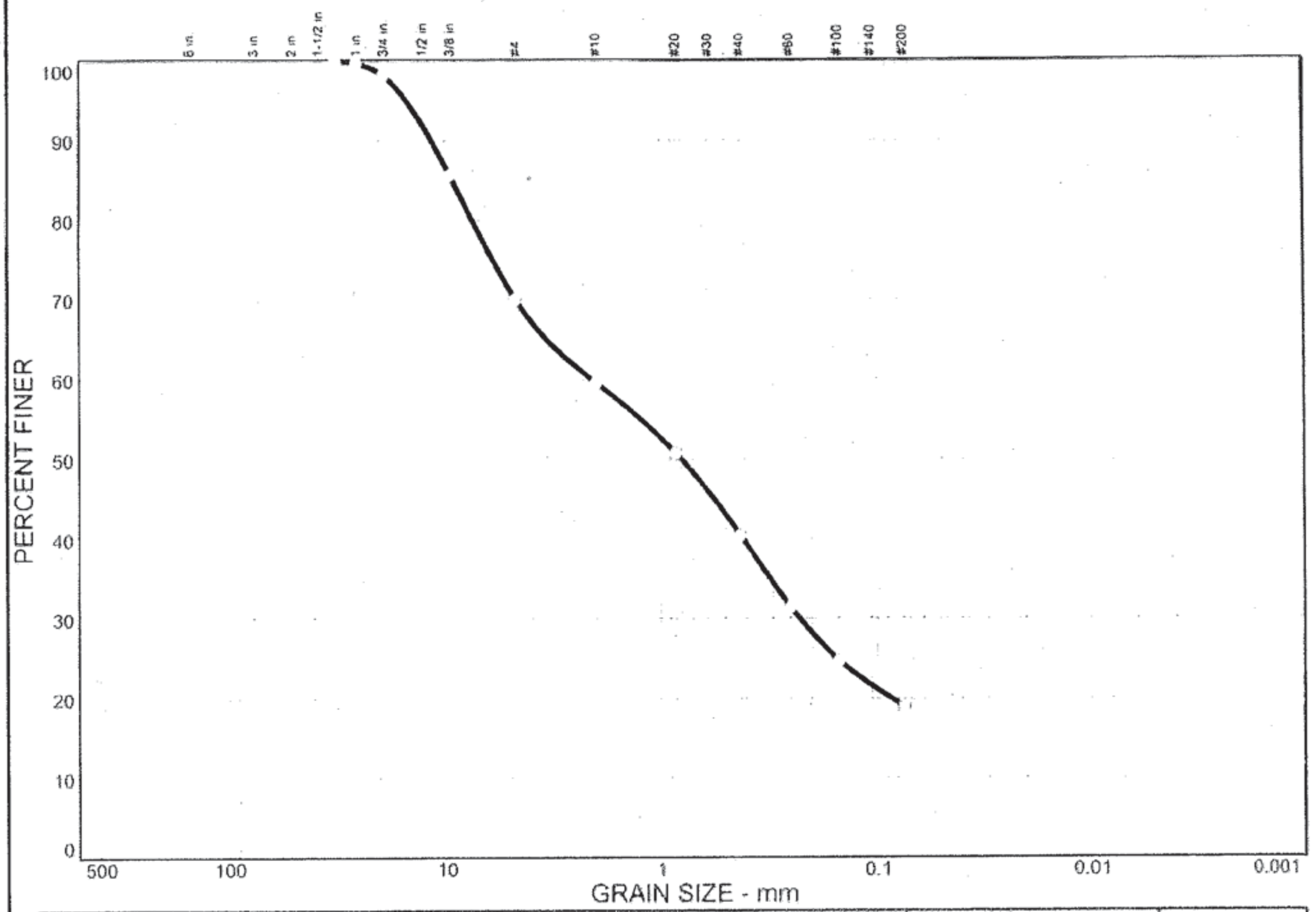
amec

11335 N.E. 122nd Way Suite 100
Kirkland, Washington 98034-6913

Drilling Method: Hand Auger Hammer Type: Not Applicable Date drilled: *June 17, 2008* Logged By: *LME*

Drilled by:

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	30.0	51.1	18.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.25 in.	100.0		
1 in.	99.6		
3/4 in.	98.1		
3/8 in.	85.6		
#4	70.0		
#10	59.5		
#20	50.7		
#40	40.4		
#60	31.4		
#100	24.7		
#200	18.9		

* (no specification provided)

Soil Description

Brown silty sand with gravel
Moisture: 6.4%

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 9.29 D_{60}= 2.11 D_{50}= 0.804
D_{30}= 0.228 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO= A-1-b

Remarks

Tested by: JW Reviewed by: SMS
ASTM: C136-01, D1140-00, D2216-05
Sampled: 6/18/08 lme

Sample No.: 8910.77 **Source of Sample:** **Date:** 6/23/08
Location: B-2, B-9 **Elev./Depth:**

Client: Skillings Connolly
Project: Bellevue 145th Pl SE & SE 122nd Pl

Project No: 8917164250 **Plate**

Herrera Environmental Consultants, Inc.

Memorandum

To	Marina Arakelyan and Chris Masek, City of Bellevue
cc	Mark Dewey and Arthur Chi, City of Bellevue
From	Robin Kirschbaum and Meghan Feller, Herrera Environmental Consultants
Date	June 18, 2010
Subject	145th Place SE and 22nd Street SE Roadway Improvement Project – Pilot Infiltration Test Results

This memorandum documents the methods and results of a pilot infiltration test (PIT) performed by the City of Bellevue (City) Transportation Department and Herrera Environmental Consultants (Herrera) on June 9, 2010 for the 145th Place SE and 22nd Street SE roadway improvement project in Bellevue, Washington.

The results of the test indicate that a long-term design infiltration rate of 1.3 inches per hour is appropriate for final design of rain gardens and bioretention swales for the project. A lower long-term design infiltration rate of 0.3 inches per hour will be used for pervious pavement. This lower rate includes a factor of safety of 4 to account for the lack of pre-treatment of stormwater runoff prior to contacting the native soil layer. For the rain gardens and bioretention swales, an 18-inch to 24-inch thick layer of imported bioretention soil mix will be placed on top of the native soil, providing a high level of on-going protection for the infiltration capacity of the underlying native soils.

The remainder of this memorandum provides project background information, detailed discussion of the methods used to perform the PIT test, results, and a summary of lessons learned and recommendations for future PIT tests to be conducted by the City.

Background

The City of Bellevue Transportation Department is developing designs for improving 145th Place SE between SE 24th Street and SE 16th Street. Improvements will include widening and overlaying the roadway, constructing sidewalk, and improving landscaping within the right of way. The project is among the City's first demonstration projects utilizing Natural Drainage Practice (NDP) facilities including rain gardens, bioretention swales, pervious pavement, and extensive compost amendment to meet or help to satisfy flow control and water quality treatment requirements.

Long-term design infiltration rates for the NDP facilities were previously determined by AMEC (2008) on behalf of Skillings Connolly, Inc. during earlier phases of design based on textural classification and D_{10} grain size distributions, as summarized in Table 1.

Table 1. Summary of grain size distributions and infiltration rates for the 145th Place SE and 22nd Street SE roadway improvement project.

Test Pit	Location	Soil Type	D_{10} (mm)	Infiltration Rate (in/hr)
B-03, S-1	Station 18+65, 20’ R	Sand	0.22	4
B-04, S-4	Station 23+15, 24’ L	Loamy Sand	0.01	0.4
B-06, S-3	Station 25+07, 24’ R	Sand	0.11	2
B-08, S-2	Station 29+30, 20’ R	Loamy Sand	--	0.5
B-10, S-2	Station 33+30, 31’ L	Sandy Loam	--	0.25
B-09, S-4	Station 33+32, 19’ R	Sandy Loam	0.003	0.3
B-16, S-2	Station 6+21, 23’ L	Loamy Sand	0.01	0.4
B-15, S-1	Station 34+65, 8’ L	Loamy Sand	0.02	0.7
B-14, S-1	Station 35+53, 28’ L	Loamy Sand	--	0.5

Source: AMEC (2008)

D_{10}: soil particle diameter at which 10 percent of the mass of a soil sample is finer

mm: millimeters

in/hr: inches per hour

AMEC described in their report that the infiltration rates presented in Table 1 incorporated a correction factor of 4 to represent an average degree of long-term maintenance and the glacially over-consolidated subsurface soil conditions. Skillings Connolly, Inc. conservatively used 0.3 inches per hour, the lowest value for which D_{10} was analyzed, as the basis for designing the NDPs for the entire project site through the 95 percent complete design stage (Skillings Connolly 2010).

While the textural classification and grain size distribution methods are approved by the City, the Washington State Department of Ecology (Ecology) strongly recommends in-situ infiltration testing whenever possible using the PIT method, as described in detail in Appendix III-D of the Stormwater Management Manual for Western Washington (SWMM) (Ecology 2005). The PIT method provides the best information for design of infiltration facilities because it relies on physical measurement of the infiltration rate in the location of the proposed facility. Because of the relatively large scale of the test, errors typically associated with smaller-scale methods, such as the falling head and double ring infiltrometer tests, are substantially reduced.

Methods

The methods used for conducting the PIT were slightly modified from Appendix III-D of the SWMM (Ecology 2005). The modification included digging a smaller test pit than specified by

Ecology (bottom dimensions of 3 feet by 3 feet were used, rather than 10 feet by 10 feet) due to space constraints on the site. The methods used were as follows:

1. The City of Bellevue Transportation Department excavated a test pit in the location of proposed Rain Garden 1 in the 95 percent plan submittal (station 29+25, offset 35’L (±3’)) with approximate dimensions of 3 feet wide x 3 feet long x 2.6 feet deep. Figure 1 shows the approximate location of the test pit. Note that Rain Garden 1 in the 95 percent plan submittal is now being referred to as Rain Garden 3 by the Transportation Department for the final design phase.

2. A vertical measuring rod was installed near the center of the pit bottom (see Photo Log).

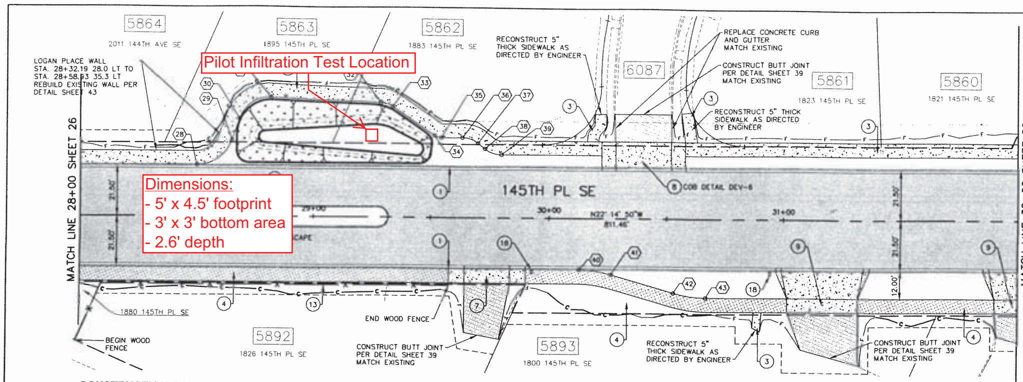
3. The City of Bellevue Water Department began filling the test pit with water from a 1,000-gallon water truck and 4-inch fire hose at approximately 9:00 am. At approximately 10:35 am, the Water Department switched to a fire hydrant with a fire hose connected to a 3/4-inch garden hose to maintain more consistent pressure and flow at Herrera’s request.

4. A 5-gallon bucket was place at the bottom of the pit to dissipate energy from the hose and reduce disturbance of the pit sidewalls and bottom.

5. Flow rate into the test pit was initially measured by recording the amount of time to fill a 5-gallon bucket every 15 to 30 minutes. This method proved to be too time consuming and allowed the water surface elevation in the test pit to begin drawing down during the measurements. When the water source was switched from the water truck to the fire hydrant, a 3/4-inch domestic water meter was attached in-line with the 3/4-inch garden hose to provide more accurate flow measurements. Readings of water level and flow rate were manually recorded approximately every 15 minutes.

6. Water was added to the pit at a rate that maintained an approximate water depth of 10 to 11 inches. This depth was considered to be a good depth for testing because it represents the maximum rain garden and bioretention swale ponding depth of 6 inches with additional depth for freeboard (or height over the overflow structure). Appendix III-D of the SWMM (Ecology 2005) recommends a depth of 3 to 4 feet; however, that greater depth is not representative of the intended function of the NDP facilities for this project and might result in artificially high infiltration rates. This phase of the test, referred to as “pre-steady state”, lasted approximately 3-1/2 hours (until approximately 12:38 pm) and was sufficient to saturate the soils surrounding the test pit.

95% SUBMITTAL 2-25-2010



	QUANTITY TABULATION CODE U.O.M.=UNIT OF MEASURE	CEMENT CONC. TRAFFIC CURB AND GUTTER	CEMENT CONC. TRAFFIC CURB	CEMENT CONC. SIDEWALK	PERVIOUS CEMENT CONC. SIDEWALK	CEMENT CONC. DRIVEWAY ENTRANCE DEV-5	CEMENT CONC. DRIVEWAY ENTRANCE DEV-6	CEMENT CONC. DRIVEWAY ENTRANCE DEV-7E	6 FT. SOLID BOARD WOOD FENCE	MAILBOX SUPPORT TYPE 1	SEE REMARKS
CODE	LOCATION ▼ / U.O.M. ▶	L.F.	L.F.	S.Y.	S.Y.	S.Y.	S.Y.	S.Y.	L.F.	EACH	
1	28+00 TO 32+00, LT	400									1
1	28+00 TO 32+00, RT	400									1
2	28+42 TO 29+32		187								2
3	28+00 TO 30+28, LT			170							4
3	30+52 TO 32+00, LT			102							4
3	30+87 TO 30+91, RT			3							3
4	28+00 TO 29+58, RT				105						15
4	29+90 TO 31+02, RT				75						15
4	31+32 TO 31+90, RT				39						15
7	29+58 TO 29+90, 21.5' RT					22					8
8	30+23 TO 30+57, 21.5' LT						44				
9	30+97 TO 31+37, 21.5' RT							65			10
9	31+85 TO 32+00, 21.5' RT							22			10
13	27+98, 53.6' RT TO 29+58, 29' RT								176		11
18	29+92.77, 22.2' RT									1	17
18	30+94.34, 22.2' RT									1	17
	SHEET TOTAL	800	187	275	219	22	44	87	176	2	

REMARKS

COB: CITY OF BELLEVUE
WSDOT: WASHINGTON STATE
DEPARTMENT OF TRANSPORTATION

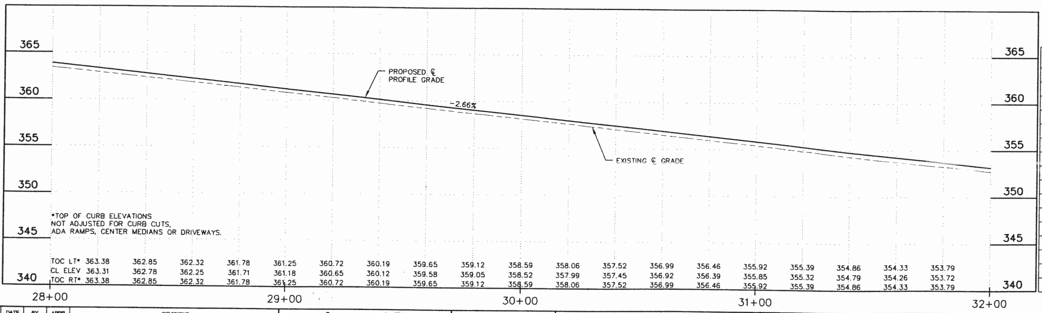
1. COB DETAIL TE-10, CEMENT CONC. TRAFFIC CURB AND GUTTER
2. COB DETAIL TE-10, CEMENT CONC. TRAFFIC CURB
3. COB DETAIL TE-11, CURBSIDE SIDEWALK
4. COB DETAIL TE-11, SIDEWALK WITH PLANTER STRIP
5. COB DETAIL TE-12, SIDEWALK RAMP TYPE 1
6. COB DETAIL TE-13, SIDEWALK RAMP TYPE 2
7. COB DETAIL TE-32, PATTERNED CONC. ENTRY TREATMENT
8. COB DETAIL DEV-5, COMMERCIAL DRIVEWAY APPROACH WITHOUT PLANTER STRIP
9. COB DETAIL DEV-6, COMMERCIAL DRIVEWAY APPROACH WITH PLANTER STIRP
10. COB DETAIL DEV-7E, DRIVEWAY APPROACH ADA OPTION 2
11. SEE DETAILS - SHEET 39, WOOD FENCE DETAIL
12. COB DETAIL TE-34, METAL SAFETY RAILING
13. COB DETAIL TE-12 AND TE-13, SIDEWALK RAMP
14. SEE ISLAND DETAILS - SHEET 37, 38 FOR CONCRETE COLOR & PATTERNS
15. SEE DETAILS - SHEET 40, PERVIOUS SIDEWALK DETAIL
16. COB DETAIL DEV-12, PIPE MONUMENT, CASE AND COVER. PIPE MONUMENT TO BE FURNISHED AND SET BY THE CITY OF BELLEVUE
17. REMOVE EXISTING MAILBOX, INSTALL NEW PER COB DETAIL DEV-11, MAILBOX STAND

CONSTRUCTION GENERAL NOTES

1. EXISTING ROADWAY BASE TO BE PROTECTED AND MAINTAINED WITH THE EXCEPTION OF MINOR PRELEVEL GRADING.
2. SEE SHEET 34 FOR TRAFFIC CONTROL GENERAL NOTES.

LEGEND

░	ASPHALT PAVEMENT – 2" HMA OVERLAY
▒	ASPHALT PAVEMENT – 10" HMA OVERLAY
▧	ASPHALT CONCRETE DRIVEWAY
⁘	CEMENT CONCRETE SIDEWALK / DRIVEWAY
░	CEMENT CONCRETE PERVIOUS SIDEWALK, SEE SHEET 40
▩	STAMPED COLORED CONCRETE
∙	RAIN GARDEN, SEE SHEETS 72

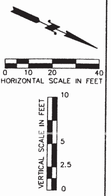


*TOP OF CURB ELEVATIONS NOT ADJUSTED FOR CURB CUTS, ADA RAMPS, CENTER MEDIANS OR DRIVEWAYS.

TOC LT*	363.38	362.85	362.32	361.78	361.25	360.72	360.19	359.65	359.12	358.59	358.06	357.52	356.99	356.46	355.92	355.39	354.86	354.33	353.79
CL ELEV	363.31	362.78	362.25	361.71	361.18	360.65	360.12	359.58	359.05	358.52	357.99	357.45	356.92	356.39	355.85	355.32	354.79	354.26	353.72
TOC RT*	363.38	362.85	362.32	361.78	361.25	360.72	360.19	359.65	359.12	358.59	358.06	357.52	356.99	356.46	355.92	355.39	354.86	354.33	353.79

145 th PL SE SIDEWALK POINTS

⬡	DESCRIPTION	RADIUS	LENGTH	STATION	OFFSET	DELTA
28	PC	16.00'	19.61'	28+49.29	22.00' LT	Δ=70.23°
29	PT	16.00'	19.61'	28+64.35	32.59' LT	
30	PC	14.00'	17.73'	28+67.64	41.74' LT	Δ=72.58°
31	PT	14.00'	17.73'	28+81.38	50.99' LT	
32	PC	10.00'	5.57'	29+28.47	49.06' LT	Δ=31.92°
33	PT	10.00'	5.57'	29+33.70	47.34' LT	
34	PC	5.00'	3.06	29+51.60	35.14' LT	Δ=35.08°
35	PT	5.00'	3.06	29+54.48	34.27' LT	
36	PC	10.00'	7.06'	29+63.47	34.40' LT	Δ=40.47°
37	PT	10.00'	7.06'	29+70.00	32.10' LT	
38	PC	11.00'	7.61'	29+72.92	29.68' LT	Δ=39.65°
39	PT	11.00'	7.61'	29+79.93	27.15' LT	
40	PC	50.00'	14.00'	30+12.96	22.00' RT	Δ=16.04°
41	PT	50.00'	14.00'	30+26.77	23.95' RT	
42	PC	50.00'	14.00'	30+53.23	31.55' RT	Δ=16.04°
43	PT	50.00'	14.00'	30+67.04	33.50' RT	



THOMAS E. SKILLINGS

NO.	DATE	BY	APPR.	REVISIONS

Approved By

ENGINEERING MANAGER DATE
PROJECT MANAGER DATE
PROJECT ENGINEER DATE

D07151_PP_6.dwg
FILENAME
L.LEE 05/09
DESIGNED BY DATE
S. KIRK 11/08
DRAWN BY DATE
G. RICHARDSON 02/10
CHECKED BY DATE

City of Bellevue
Transportation Department

SKILLINGS CONNOLLY
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(206) 838-5988 (800) 454-7545 Fax (206) 838-4361

145th PLACE SE
IMPROVEMENTS PROJECT
24th STREET TO 16th STREET

CONSTRUCTION
PLAN AND PROFILE
STA 28+00 TO 32+00

SHT 27 OF 92

File: G:\Project\2007\07151 Bellevue 145th Pl SE\CAD\Drawings\Construction\D07151_PP_6.dwg ID: bruce2 Date: 25-Feb-10 2:21:34pm

Figure 1. Pilot Infiltration Test Location

7. The “steady state” phase of the test is defined as a 1-hour period during which the water surface elevation does not change by more than 1/2-inch with a constant flow rate over the course of that hour. Steady state was achieved for this test with a flow rate of approximately 0.5 gallons per minute and water surface elevations ranging from 10.25 to 10.75 inches.

8. After steady state conditions were maintained for a 1-hour period, the water was turned off and the rate of infiltration (inches per hour) was recorded from the measuring rod until the pit was nearly empty. Heavy rainfall started at approximately 5:00 pm (8 hours after the test was begun) and directly entered the pit, thereby making it impossible to draw down the pit entirely within one working day (See Photo Log). At 7:00 pm, approximately 10 hours after the test was begun, the test was stopped with approximately 4.5 inches of water remaining in the pit. An estimated cumulative volume of 22.7 cubic feet (or roughly 170 gallons) of water was delivered to the test pit over the duration of the test.

9. Water depths observed after 5:00 pm were adjusted to account for the direct input of rainfall over the 2-hour period between 5:00 pm (when the heavy rain began) and 7:00 pm (when the test was stopped). The rainfall at the test site was recorded every 15 minutes using a 5-gallon bucket placed near the test pit. The cumulative rainfall observed was approximately 1.02 inches over 2 hours, which equates to an average intensity of approximately 0.5 inches per hour. The maximum rainfall intensity observed during this period was 0.3 inches in 15 minutes, or approximately 1.2 inches per hour (Figure 2).

10. The infiltration rate was then computed based on the following formula:

$$IR = \frac{\Delta L}{\Delta T}$$

where:

IR = Infiltration rate (inches/hour)

ΔL = Change in water level (inches) from point when water inputs are turned off to end of test

ΔT = Change in time (hours) from point when water inputs are turned off to end of test

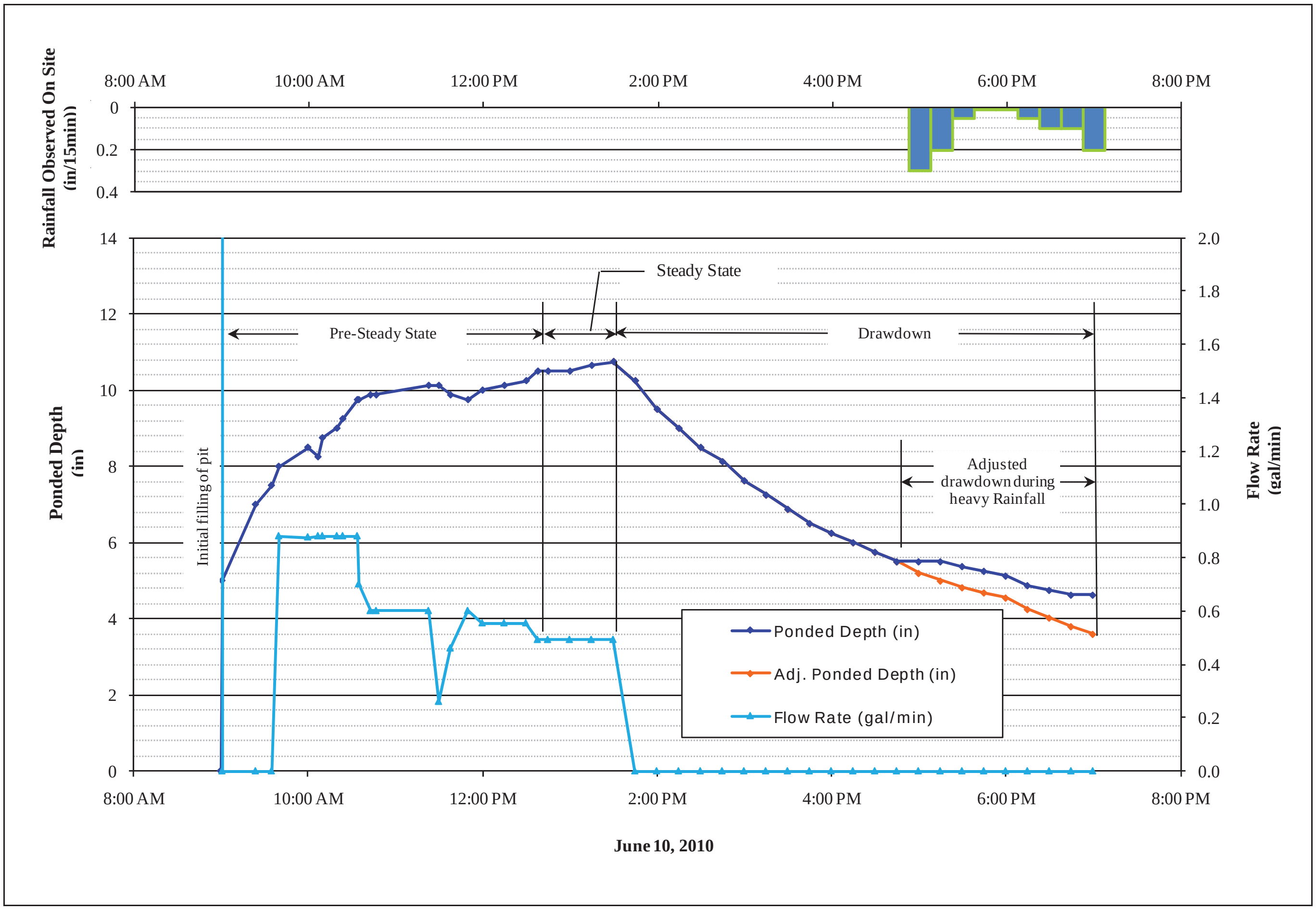


Figure 2. Pilot infiltration test results for the 145th Place SE and 22nd Street SE roadway improvement project.

Results

The results of the infiltration test are shown graphically in Figure 2 and in tabular format in Table 2. During the drawdown period, the ponded depth (adjusted for rainfall) fell from 10.8 inches to 3.6 inches over a 5-1/2 hour period, resulting in a design infiltration rate of 1.3 inches per hour.

Table 2. Pilot infiltration test drawdown data.

Time	Staff Gage Reading [a] (in)	Depth [a] (in)	Notes	Field Estimated Rainfall [b] (in)	Cumulative Rainfall (in)	Adjusted Depth [c] (in)	Infiltration Rate (in/hr) [d]
1:30 PM	12.75	10.75		0	0	10.75	
1:45 PM	12.25	10.25		0	0	10.25	
2:00 PM	11.50	9.50		0	0	9.5	
2:15 PM	11.00	9.00		0	0	9	
2:30 PM	10.50	8.50		0	0	8.5	
2:45 PM	10.13	8.13		0	0	8.13	
3:00 PM	9.63	7.63		0	0	7.63	
3:15 PM	9.25	7.25		0	0	7.25	
3:30 PM	8.88	6.88		0	0	6.88	
3:45 PM	8.50	6.50		0	0	6.50	
4:00 PM	8.25	6.25		0	0	6.25	
4:15 PM	8.00	6.00		0	0	6.00	
4:30 PM	7.75	5.75		0	0	5.75	
4:45 PM	7.50	5.50		0	0	5.50	
5:00 PM	7.50	5.50	Heavy rain	0.3	0.30	5.20	
5:15 PM	7.50	5.50	Rain	0.2	0.50	5.00	
5:30 PM	7.38	5.38	Rain	0.05	0.55	4.83	
5:45 PM	7.25	5.25	Light rain	0.01	0.56	4.69	
6:00 PM	7.13	5.13	Light rain	0.01	0.57	4.56	
6:15 PM	6.88	4.88	Rain	0.05	0.62	4.26	
6:30 PM	6.75	4.75	Rain	0.1	0.72	4.03	
6:45 PM	6.63	4.63	Rain	0.1	0.82	3.81	
7:00 PM	6.63	4.63	Rain	0.2	1.02	3.61	1.30

in: inches

in/hr: inches per hour

Notes:

[a] The staff gage was buried 2 inches deep in the bottom of the pit. The “Depth” column is the “Staff Gage Reading” minus 2 inches.

[b] Rainfall was estimated at the test pit location by observing the depth of rainfall in a 5-gallon bucket in 15-minute intervals from the beginning of the rainfall until the test was stopped.

[c] “Adjusted Depth (in)” = “Depth (in)” – “Cumulative Rainfall (in)”.

[d] “Infiltration Rate (in/hr)” = $\Delta L/\Delta T$ = (10.75 in – 3.61 in) / 5.5 hours = 1.3 in/hr.

For most design applications, the infiltration rate obtained from the PIT test must be reduced by a correction factor to account for factors such as degree of long-term maintenance, level of pretreatment/control of influent, and potential for long-term clogging due to siltation and bio-buildup. However, when imported bioretention soil is used, which will be the case for the rain gardens and bioretention swales for this project, no correction factor is required for the infiltration rate of the underlying native soil. Therefore, the long-term design infiltration rate to be used for final design of the rain gardens and bioretention swales for the 145th Pl SE roadway improvement project is 1.3 inches per hour. For pervious pavement, a correction factor of 4 is applied to the measured short-term infiltration rate, resulting in a long-term design infiltration rate of 0.3 inches per hour.

Lessons Learned and Recommendations for Future PIT Tests

Based on lessons learned during this PIT test, we recommend that the City consider the following measures for all future PIT tests:

- Use a fire hydrant instead of a water truck if possible. The fire hydrant provides more steady pressure throughout the duration of the test and has no risk of running out of water before the test is completed.

- Use a garden hose rather than fire hose to convey flows into the test pit. A fire hose was initially used in the test, but was found to be too large and was unable to maintain the pressure needed to deliver constant flow rates at low flows (i.e., <1 gallon per minute).

- Use a highly accurate in-line flow monitoring device. A 5-gallon bucket and stopwatch were initially used to estimate flow rates for this test. During the time it takes to fill the 5-gallon bucket at low flow rates (i.e., <1 gallon per minute), we observed the test pit beginning to draw down before steady state had been achieved. The City’s Water Department supplied a ¾-inch domestic meter to monitor flow volumes part-way through the test, which greatly simplified the test and improved the accuracy of the results.

- Lay back the sides of the test pit. For this test, the walls were dug vertically and the spoils were piled on the edges of the test pit (see Photo Log). This configuration greatly increases the possibility that fines will enter the pit and clog the bottom, resulting in artificially low infiltration rates. This is especially true if the pit is exposed to rainfall, which was the case during this test. Alternatively, if space constraints or time do not allow for laying back the sides of the test pit, shore the vertical sides of the pit with a constructed plywood box, concrete pipe section, or other sufficiently strong shoring method and move the spoils away from the edge.

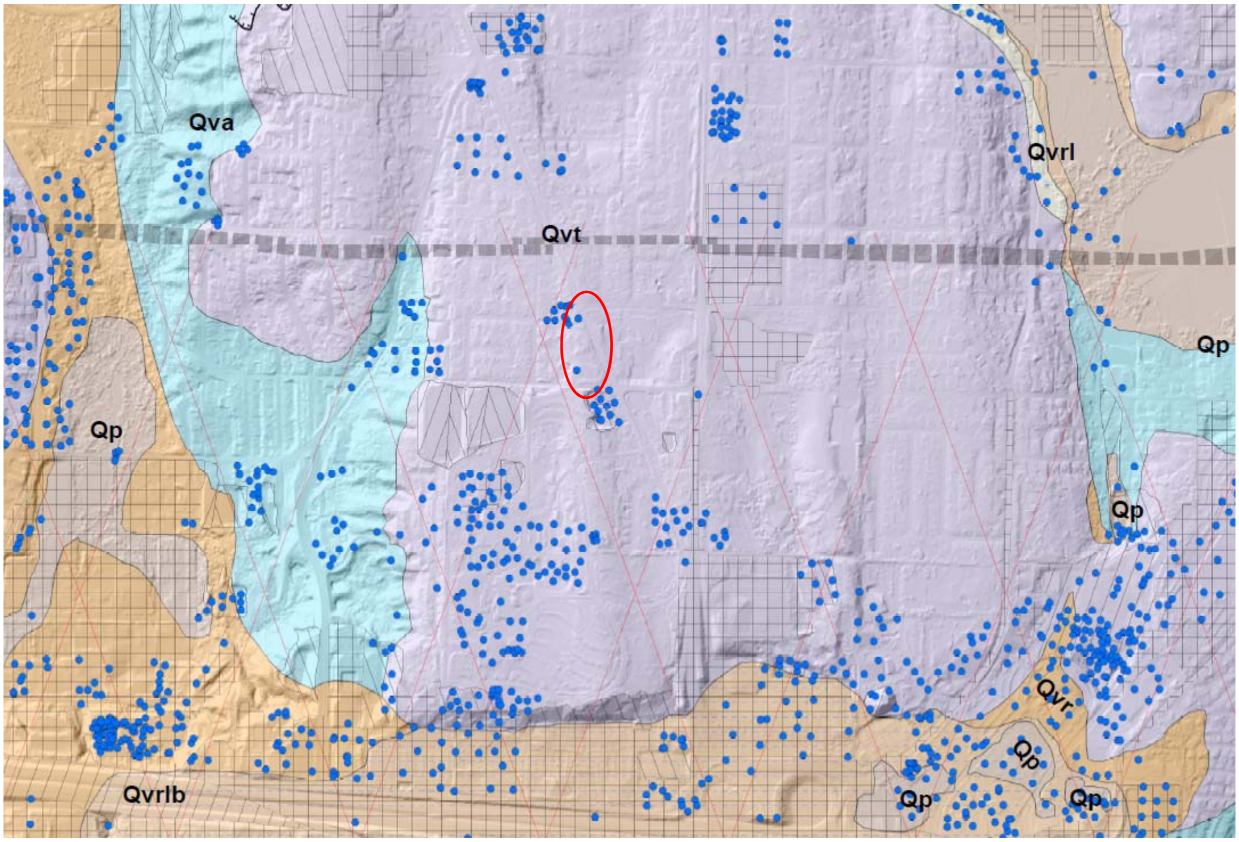
- Cover the test pit if rain is expected. Heavy rainfall directly entering the test pit can skew the measurements and result in artificially low infiltration rates. A tarp that is at least twice as large as the pit and erected at least 6 feet above the top of the pit to allow work to be performed beneath it is one possible method for covering the test pit to prevent direct rainfall input.
- Be prepared to accurately measure rainfall at the test site if rain is expected.

References

AMEC. 2008. Geotechnical Engineering Report; Bellevue 145th Place SE, SE 22nd Street, and SE 22nd Place. Prepared by AMEC Earch and Environmental, Inc. for Skillings Connolly, November 24, 2008.

Ecology. 2005. Stormwater Management in Western Washington – Volume III: Hydrologic Analysis and Flow Control Design/BMPs. Publication No. 05-10-31 (a revision of Publication No. 99-13). Washington State Department of Ecology, Water Quality Program, Olympia, Washington. February 2005.

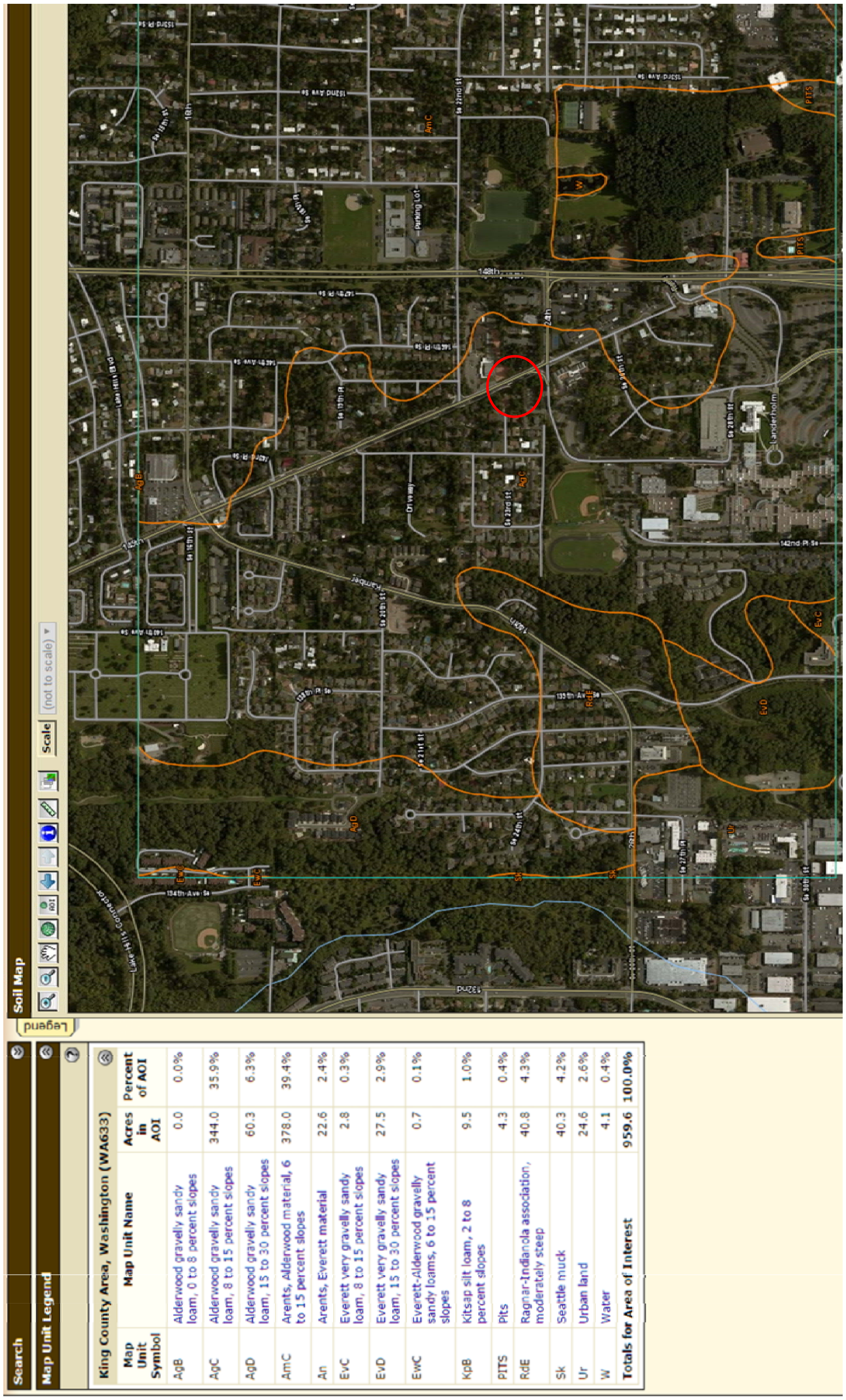
Skillings Connolly. 2010. City of Bellevue 145th Pl SE Improvements Project; 24th Street to 16th Street, Hydraulic Report, 95 Percent Submittal, Prepared by Skillings Connolly, Inc. for City of Bellevue. February 23, 2010.



Approximate location of site indicated by red outline

Qvt	Vashon till	Compact deposit with a silt-sand matrix supporting subrounded to rounded gravel, glacially transported and deposited under ice. Contains large, often tabular, sand and gravel bodies, cobbles and boulders common. Coarse-grained layers may exceed 50% of the volume of the deposit. May appear to be cemented due to great degree of compaction. Commonly fractured and has intercalated sand lenses. Generally forms undulating, elongated surfaces. Upper +/- 3 feet is commonly weathered: oxidized, medium dense to dense, clean to silty, gravelly sand capping unweathered till. Often present, but not always differentiated on boring logs. May include areas of Qvr too small to separate or be observed during mapping. Likely not as continuous as mapped. Locally gradational with units Qva and Qvi
Qva	Advance Outwash Deposits	Well-sorted sand and gravel deposited by streams issuing from advancing ice sheet. May grade upward into till. Silt lenses locally present in upper part and are common in lower part. Generally unoxidized to only slightly oxidized. May be overlain by Vashon till in areas too small to show at map scale. Includes Esperance Sand Member of the Vashon Drift of Mullineaux and others (1965). Grades downward into unit Qvlc with increasing silt content or unconformably overlies older glacial or interglacial deposits. Locally contains groundwater that emanates as springs and seeps park

Excerpt from Troost, K. G., 2012, Geologic Map of Bellevue, Washington, Pacific Center for Geologic Mapping Studies, 1/1/2012.



King County Area, Washington (WA633)

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
AgB	Alderwood gravelly sandy loam, 0 to 8 percent slopes	0.0	0.0%
AgC	Alderwood gravelly sandy loam, 8 to 15 percent slopes	344.0	35.9%
AgD	Alderwood gravelly sandy loam, 15 to 30 percent slopes	60.3	6.3%
AmC	Arents, Alderwood material, 6 to 15 percent slopes	378.0	39.4%
An	Arents, Everett material	22.6	2.4%
EvC	Everett very gravelly sandy loam, 8 to 15 percent slopes	2.8	0.3%
EvD	Everett very gravelly sandy loam, 15 to 30 percent slopes	27.5	2.9%
EwC	Everett-Alderwood gravelly sandy loams, 6 to 15 percent slopes	0.7	0.1%
KpB	Kitsap silt loam, 2 to 8 percent slopes	9.5	1.0%
PITS	Pits	4.3	0.4%
RdE	Ragnar-Indianola association, moderately steep	40.8	4.3%
Sk	Seattle muck	40.3	4.2%
Ur	Urban land	24.6	2.6%
W	Water	4.1	0.4%
Totals for Area of Interest		959.6	100.0%

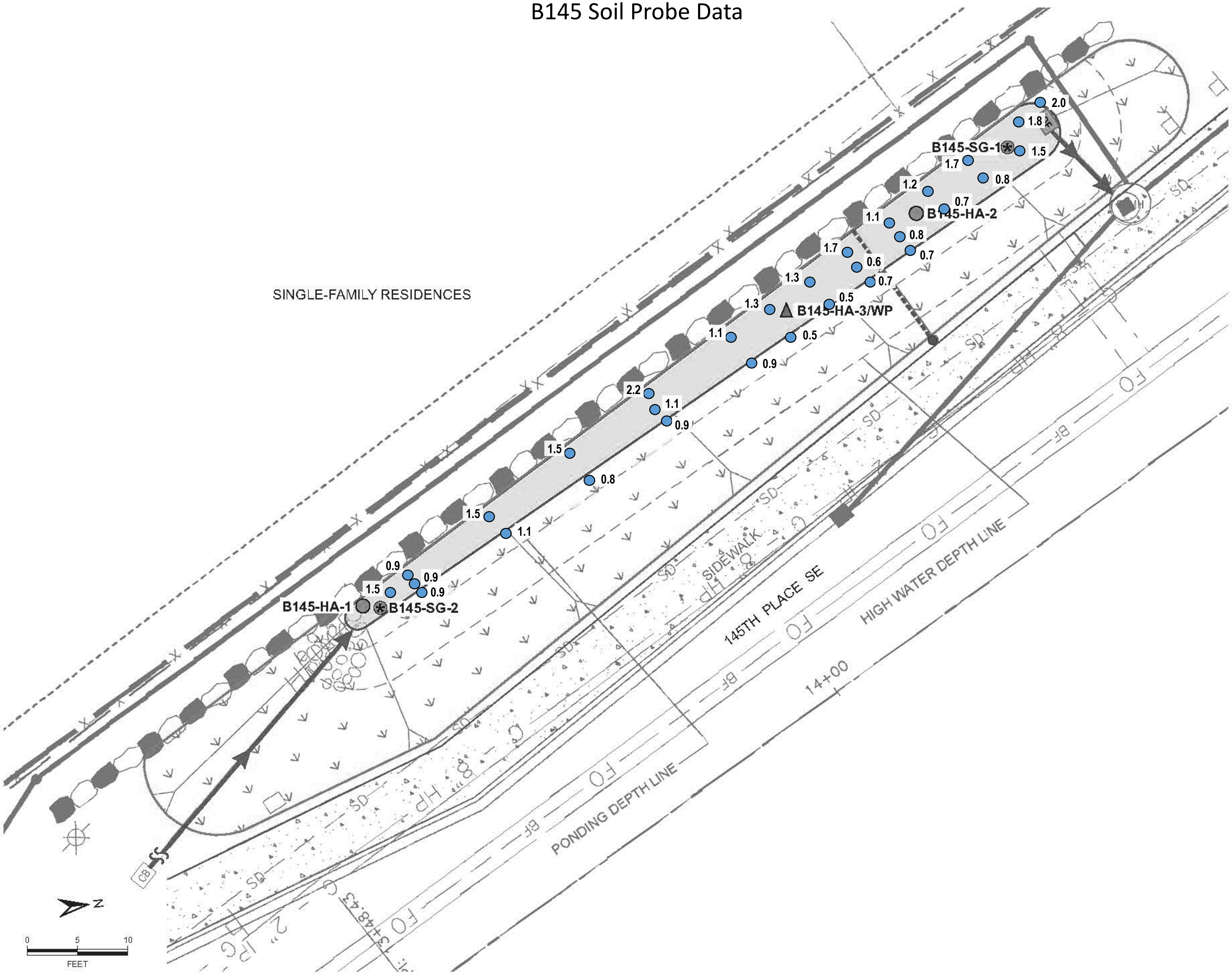
Approximate location of site indicated by red outline

Excerpt from Natural Resources Conservation Service, 2016, Web soil survey

APPENDIX D

Soil Probe, Level Survey, and Field Infiltration Testing Data

B145 Soil Probe Data



LEGEND:

● HA	HAND AUGER
▲ WP	WELL POINT
⊛	TEMPORARY STAFF GAUGE
▭	BASE OF FACILITY
▭	TOP OF FACILITY SLOPE
→	INFLOW / OVERFLOW DIRECTION
OF	OVERFLOW GRATE
-----	PERFORATED PIPE
●	OBSERVATION PORT
⬠	PRE-EXISTING 2 INCH PIEZOMETER
SD	STORM DRAIN
● 0.8	Soil Probe and Depth of Loose Soil

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:

1. BASE MAP REFERENCE: CITY OF BELLEVUE TRANSPORTATION DEPARTMENT, 145 PL SE / SE 22 ST ROADWAY IMPROVEMENTS, RAIN GARDEN DRAINAGE PLAN AND DETAILS, SHEET 13 OF 64, 03/11

BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION.

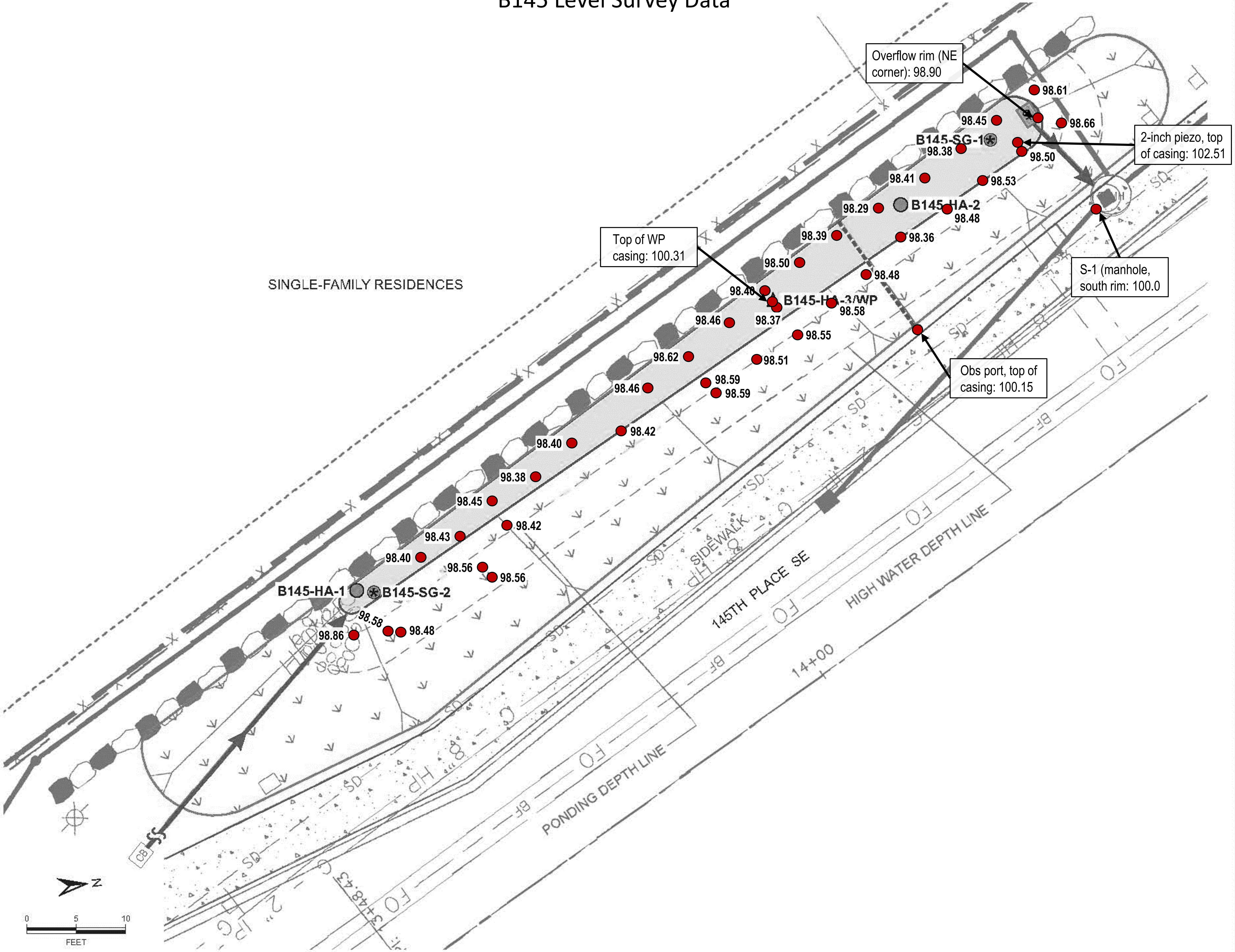
associated earth sciences incorporated

SOIL PROBE DATA
B145 SITE
BIORETENTION HYDROLOGIC PERFORMANCE
BELLEVUE, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	D1

150387 BHPS MCCA \ 150387 Site-Expl.cdr PAGE 1: B145

B145 Level Survey Data



Overflow rim (NE corner): 98.90

2-inch piezo, top of casing: 102.51

Top of WP casing: 100.31

S-1 (manhole, south rim: 100.0

Obs port, top of casing: 100.15

LEGEND:

● HA	HAND AUGER
▲ WP	WELL POINT
⊛	TEMPORARY STAFF GAUGE
▭	BASE OF FACILITY
▭	TOP OF FACILITY SLOPE
→	INFLOW / OVERFLOW DIRECTION
OF	OVERFLOW GRATE
-----	PERFORATED PIPE
●	OBSERVATION PORT
⬟	PRE-EXISTING 2 INCH PIEZOMETER
SD	STORM DRAIN
● 98.66	Elevation, Project Datum (see text)

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:
1. BASE MAP REFERENCE: CITY OF BELLEVUE TRANSPORTATION DEPARTMENT, 145 PL SE / SE 22 ST ROADWAY IMPROVEMENTS, RAIN GARDEN DRAINAGE PLAN AND DETAILS, SHEET 13 OF 64, 03/11

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LEVEL SURVEY DATA
B145 SITE
BIORETENTION HYDROLOGIC PERFORMANCE
BELLEVUE, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	D2

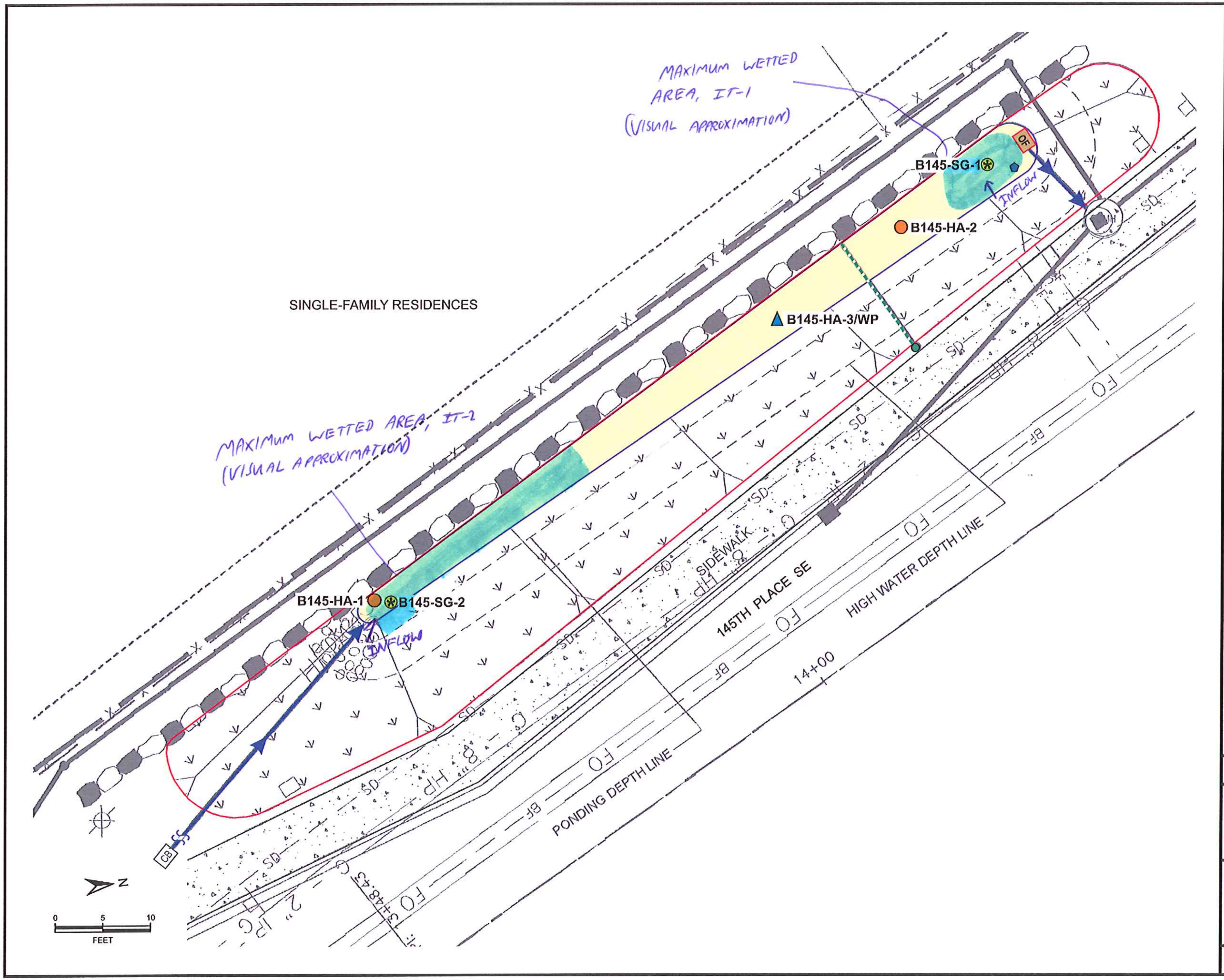
150387 BHPS MCCA \ 150387 Site-Expl.cdr PAGE 1: B145

Cell B145
Level Survey Data

Location	Elevation (feet, project datum)
(S-1) Manhole, south rim	100
Overflow rim, NE corner	98.90
Pre-existing 2 inch PVC piezometer, top of casing	102.51
Pre-existing observation port, top of casing	100.15
Well point, top of casing	100.31
Survey points in base of cell	On site plan

Cell B145
Probe Survey Data List (Excludes Outliers)

Probe Penetration (feet):
1.5
0.9
0.9
0.9
1.1
1.5
0.8
1.5
0.9
1.1
2.2
0.9
1.1
0.5
1.3
0.5
1.3
0.7
0.6
1.7
0.7
0.8
1.1
0.7
1.2
0.8
1.7
1.5
1.8
2
AVERAGE: 1.1



LEGEND:

● HA	HAND AUGER
▲ WP	WELL POINT
⊛	TEMPORARY STAFF GAUGE
▭	BASE OF FACILITY
▭	TOP OF FACILITY SLOPE
→	INFLOW / OVERFLOW DIRECTION
OF	OVERFLOW GRATE
┅	PERFORATED PIPE
●	OBSERVATION PORT
⬟	PRE-EXISTING 2 INCH PIEZOMETER
SD	STORM DRAIN

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:
1. BASE MAP REFERENCE: CITY OF BELLEVUE TRANSPORTATION DEPARTMENT, 145 PL SE / SE 22 ST ROADWAY IMPROVEMENTS, RAIN GARDEN DRAINAGE PLAN AND DETAILS, SHEET 13 OF 64, 03/11

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WETTED AREA

B145 SITE
BIORETENTION HYDROLOGIC PERFORMANCE
BELLEVUE, WASHINGTON

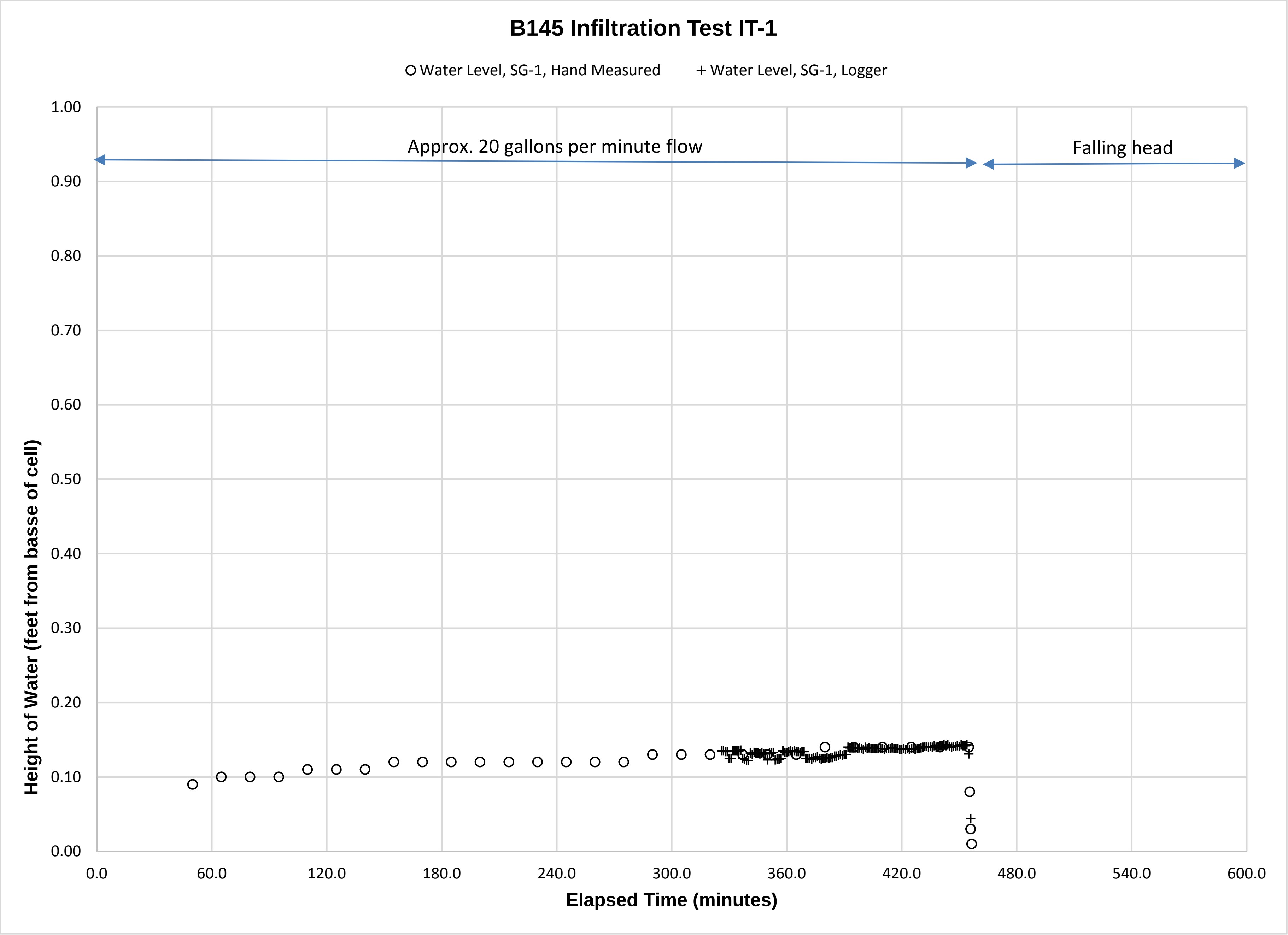
PROJ NO.	DATE:	FIGURE:
KH150387A	10/16	Appendix D

150387 BHPS MCCA \ 150387 Site-Explr.cdr PAGE 1: B145

Project Name	Bioretention Hydrologic Performance Assessment		**Receptor Soils**	Bioretention Soil over Qva
Project Number	KH150387A		**Testing Performed By**	HFW
Date	8/31/16			
Weather	Cloudy, Intermittent Rain			
Test No.	B145 IT-1, near overflow			
Meter	FM3			
Water Source	Irrigation System			

Time (24-hr)	Total (min)	Flow Rate (gpm)	Totalizer (gal)	Head (temporary staff gauge SG-1, feet)	Wetted area (ft^2)	Depth to water, well point (feet)	Depth to water, observation port (feet)	Depth to water, from rim of overflow grate (feet)	Depth to water, pre-existing piezometer (feet)	Notes
7:40:00	0.0	24.11	0	0.00		Dry at 7:08	Dry at 7:22			Flow on
7:45:00	5.0	19.39	101	0.10						
8:00:00	20.0	19.56	390	0.09						
8:15:00	35.0	19.50	683	0.09				2.05 at 8:10	Dry at 8:10	
8:30:00	50.0	19.50	975	0.09						
8:45:00	65.0	19.56	1268	0.10						
9:00:00	80.0	19.50	1561	0.10	28	Dry	Dry		Dry	
9:15:00	95.0	19.56	1853	0.10						
9:30:00	110.0	19.56	2147	0.11						
9:45:00	125.0	19.61	2441	0.11						
10:00:00	140.0	19.61	2735	0.11	28	Dry	Dry	2.05	Dry	
10:15:00	155.0	19.56	3029	0.12						
10:30:00	170.0	19.67	3323	0.12						
10:45:00	185.0	19.67	3617	0.12						
11:00:00	200.0	19.61	3911	0.12	28	Dry	Dry	2.04	Dry	
11:15:00	215.0	19.61	4206	0.12						
11:30:00	230.0	19.67	4501	0.12						
11:45:00	245.0	19.72	4796	0.12						
12:00:00	260.0	19.67	5090	0.12	32	Dry	Dry	2.04	Dry	Light rain begins
12:15:00	275.0	19.56	5385	0.12						
12:30:00	290.0	19.72	5680	0.13						
12:45:00	305.0	19.72	5975	0.13						Light rain continues

Time (24-hr)	Total (min)	Flow Rate (gpm)	Totalizer (gal)	Head (temporary staff gauge SG-1, feet)	Wetted area (ft^2)	Depth to water, well point (feet)	Depth to water, observation port (feet)	Depth to water, from rim of overflow grate (feet)	Depth to water, pre-existing piezometer (feet)	Notes
13:00:00	320.0	19.72	6272	0.13	44	Dry	Dry	2.04	Dry	Light rain continues
13:17:00	337.0	19.78	6607	0.13						Datalogger placed in standing water at SG-1
13:30:00	350.0	19.56	6863	0.13						
13:45:00	365.0	19.56	7157	0.13						
14:00:00	380.0	19.72	7451	0.14	44	Dry	Dry	2.04	Dry	Flow from inlet observed, Rain has stopped
14:15:00	395.0	19.61	7746	0.14						
14:30:00	410.0	19.56	8041	0.14						Flow from inlet pipe has stopped
14:45:00	425.0	19.61	8336	0.14						
15:00:00	440.0	19.67	8631	0.14	44	Dry	Dry	2.04	Dry	
15:15:00	455.0	19.67	8927	0.14						flow off, begin falling head
15:15:30	455.5			0.08						
15:16:00	456.0			0.03						
15:16:30	456.5			0.01						End of test, Datalogger retrieved

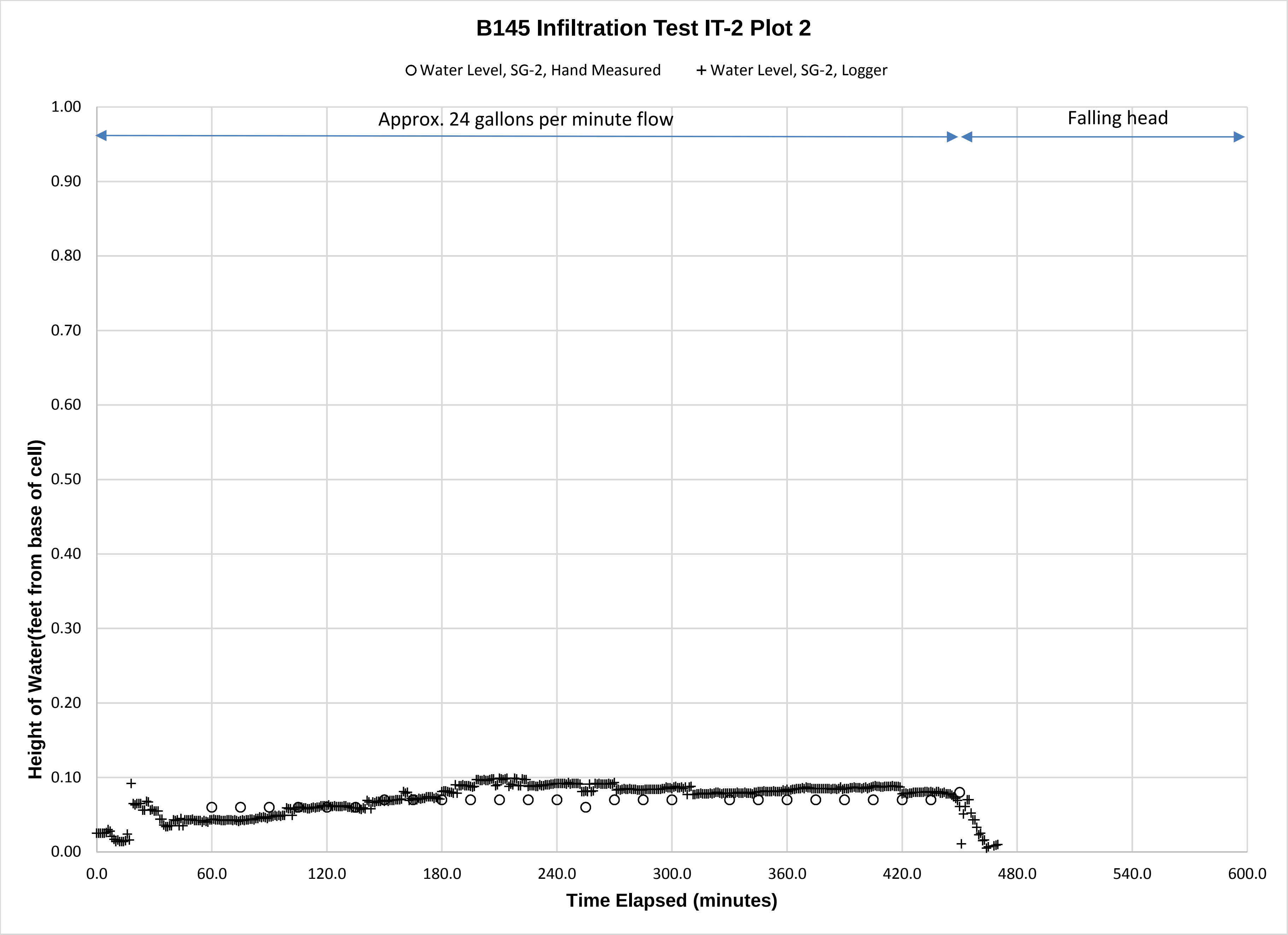

B145 Infiltration Test IT-1
○ Water Level, SG-1, Hand Measured
+ Water Level, SG-1, Logger
Approx. 20 gallons per minute flow
Falling head
Height of Water (feet from basse of cell)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.0
60.0
120.0
180.0
240.0
300.0
360.0
420.0
480.0
540.0
600.0
Elapsed Time (minutes)

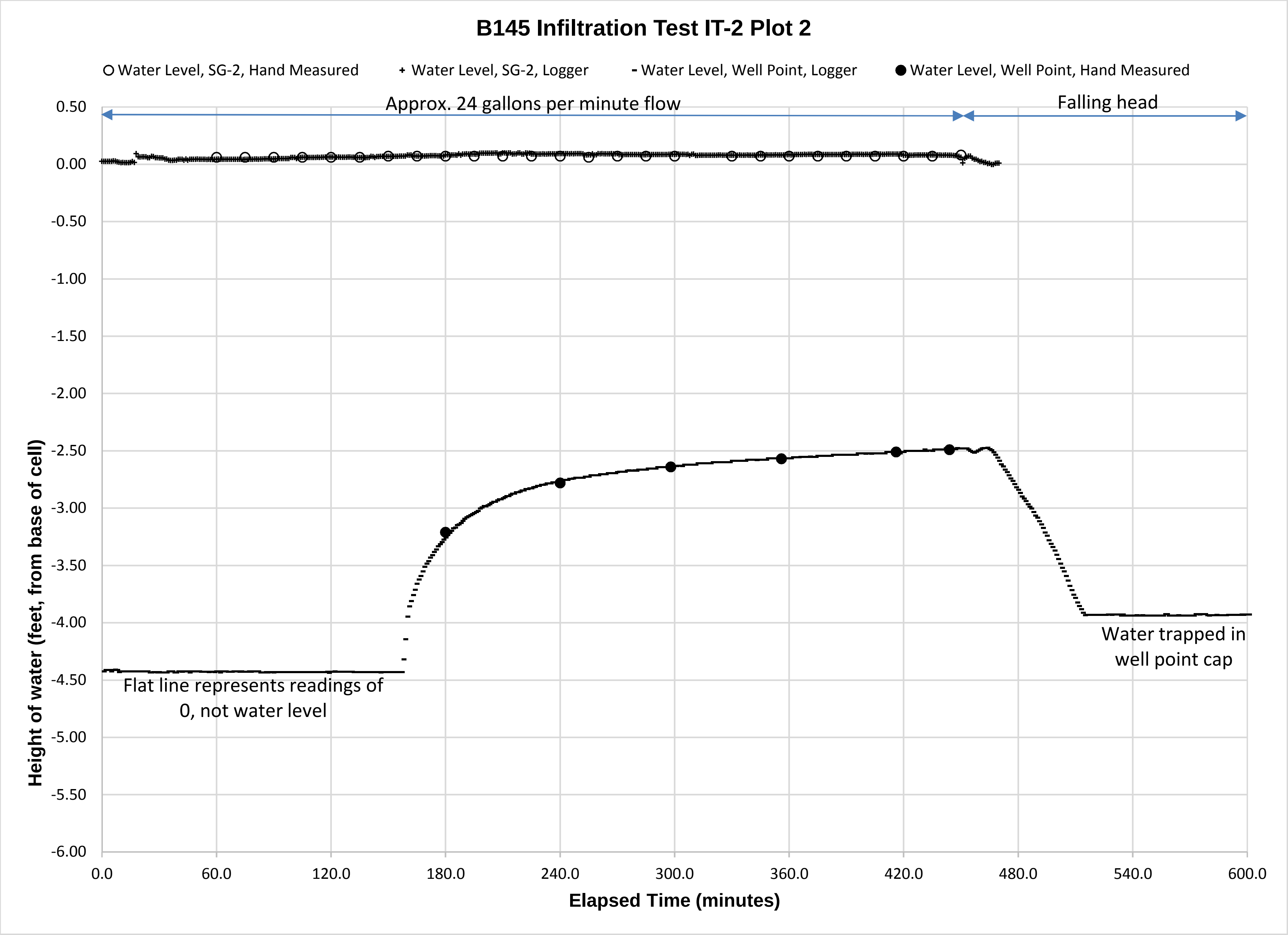
Project Name Bioretention Hydrologic Performance Assessment
Project Number KH150387A
Date 9/1/16
Weather Cloudy, rain
Test No. B145 IT-2, near inlet
Meter FM3
Water Source Irrigation System

Receptor Soils Bioretention Soil over Qva
Testing Performed By HFW

Time (24-hr)	Total (min)	Flow Rate (gpm)	Totalizer (gal)	Head (temporary staff gauge SG-2, feet)	Wetted area (ft^2)	Depth to water, well point (feet)	Depth to water, observation port (feet)	Depth to water, from rim of overflow grate (feet)	Notes
7:15:00	0.0	23.84	0	0.00		Dry	Dry	2.05	Flow on
7:30:00	15.0	23.50	344	0.10	33				
7:45:00	30.0	23.78	699	0.07					
8:00:00	45.0	23.56	1054	0.06	54				
8:15:00	60.0	23.72	1409	0.06	108	Dry	Dry	2.05	
8:30:00	75.0	23.83	1765	0.06					
8:45:00	90.0	23.78	2121	0.06					
9:00:00	105.0	23.72	2477	0.06					
9:15:00	120.0	23.78	2835	0.06	108	Dry	Dry		
9:30:00	135.0	23.83	3192	0.06	124				
9:45:00	150.0	23.72	3548	0.07					
10:00:00	165.0	23.72	3905	0.07					
10:15:00	180.0	23.94	4261	0.07		5.01	trace water		
10:30:00	195.0	23.83	4618	0.07					
10:45:00	210.0	23.89	4977	0.07					
11:00:00	225.0	23.94	5336	0.07					
11:15:00	240.0	23.94	5695	0.07	124	4.58 at 11:12	4.41		
11:30:00	255.0	23.94	6053	0.06					
11:45:00	270.0	23.94	6412	0.07					
12:00:00	285.0	23.94	6771	0.07					
12:15:00	300.0	23.94	7130	0.07	124	4.44 at 12:13	4.42 at 12:12		
12:45:00	330.0	23.83	7847	0.07					

Time (24-hr)	Total (min)	Flow Rate (gpm)	Totalizer (gal)	Head (temporary staff gauge SG-2, feet)	Wetted area (ft^2)	Depth to water, well point (feet)	Depth to water, observation port (feet)	Depth to water, from rim of overflow grate (feet)	Notes
13:00:00	345.0	23.78	8205	0.07					
13:15:00	360.0	23.89	8561	0.07	124	4.37 at 1:11	4.41 at 1:11		
13:30:00	375.0	23.83	8918	0.07					
13:45:00	390.0	23.72	9275	0.07					
14:00:00	405.0	23.82	9632	0.07					
14:15:00	420.0	23.78	9989	0.07		4.31 at 14:11	4.41 at 14:11		
14:30:00	435.0	23.78	10346	0.07					
14:45:00	450.0	23.72	10703	0.08		4.29 at 14:39	4.41 at 14:30		Moderate rainfall begins, water off, no falling head due to stormwater flow into wetted area from testing
						6/2/2016, 5.75 at 07:29			Datalogger retrieved


B145 Infiltration Test IT-2 Plot 2
○ Water Level, SG-2, Hand Measured
+ Water Level, SG-2, Logger
Approx. 24 gallons per minute flow
Falling head
Height of Water(feet from base of cell)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.0
60.0
120.0
180.0
240.0
300.0
360.0
420.0
480.0
540.0
600.0
Time Elapsed (minutes)


B145 Infiltration Test IT-2 Plot 2
○ Water Level, SG-2, Hand Measured
+ Water Level, SG-2, Logger
- Water Level, Well Point, Logger
● Water Level, Well Point, Hand Measured
Approx. 24 gallons per minute flow
Falling head
Water trapped in well point cap
Flat line represents readings of 0, not water level
Height of water (feet, from base of cell)
0.50
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
-3.00
-3.50
-4.00
-4.50
-5.00
-5.50
-6.00
0.0
60.0
120.0
180.0
240.0
300.0
360.0
420.0
480.0
540.0
600.0
Elapsed Time (minutes)

APPENDIX E

Site Photos

Cell B145 view from north end

Cell B145 overflow structure and pre-existing piezometer

Cell B145 inlet

Cell B145 pre-existing observation port

APPENDIX 4

Deliverable 4.5, Site BDP, Geotechnical/Soils Assessment Design Data and Current Conditions, Bloedel Donavan Park, Bellingham, Washington. Associated Earth Sciences, Inc. 10/25/16

associated earth sciences incorporated

Technical Memorandum

Date:	October 25, 2016	**From:**	Jennifer H. Saltonstall, L.G., L.Hg.
To:	Clear Creek Solutions, Inc.	**Project Manager:**	Jennifer H. Saltonstall, L.G., L.Hg.
	15800 Village Green Drive #3 Mill Creek, Washington 98012	**Principal in Charge:**	Curtis J. Koger, L.G., L.E.G., L.Hg.
		Project Name:	Bioretention Hydrologic Performance Study
Attn:	Doug Beyerlein, P.E.	**Project No:**	KH150387A
Subject:	Deliverable 4.5, Site BDP, Geotechnical/Soils Assessment Design Data and Current Conditions, Bloedel Donavan Park, Bellingham, Washington		

1.0 INTRODUCTION

This technical memorandum documents existing shallow soil and ground water conditions in the raingarden at the northeastern corner of the Bloedel Donovan Park parking lot, on the east side of Electric Avenue, located in Bellingham, Washington (Figure BDP F1). This memorandum was prepared in accordance with Task 4 of the contract scope of work. Associated Earth Sciences, Inc. (AESI) collected shallow soil and ground water conditions data related to bioretention cell function, and documented the current condition of the facility relative to the as-built drawings and background geotechnical information. The information will be used in the WWHM2012 modeling that will be conducted as part of Task 5 (Data Analysis). In Task 5, the team will compare the previously documented hydrologic design information with our field-collected information and will note where there are significant differences. The purpose of this technical memorandum is to document the collection of current and accurate geotechnical, geologic and hydrogeologic site information for this later work.

The following summary of shallow soil and ground water conditions integrates the observations made during the geotechnical assessment which included site visits on July 29, 2016, infiltration testing on September 2, 2016, and background geotechnical information.

This technical memorandum has been prepared for the exclusive use of Clear Creek Solutions and the City of Bellingham and their agents for specific application to this project. Within the limitations of scope, schedule, and budget, our services have been performed in accordance with generally accepted hydrogeologic and geotechnical engineering practices in effect in this area at the time our document was prepared. No other warranty, express or implied, is made.

2.0 PURPOSE AND SCOPE

The purpose of our work was to perform a shallow soil and ground water conditions assessment and provide baseline documentation data to assess effectiveness of bioretention hydrologic performance.

Specifically, our scope included the following activities:

- Review of project documents.
- Site reconnaissance.
- Visual condition assessment of erosion and deposition features near inlet and outlet.
- Review project plans relative to constructed facility, in particular, the number and location of inlets, energy dissipation devices, outlets, and other flow-related details.
- Survey elevations of inlet, outlet, well point rim, and other observation points relative to a project datum.
- Excavate shallow hand augers through the bioretention soil.
- Classify sediment according to the Unified Soil Conservation System (USCS) and *American Society for Testing and Materials* (ASTM) D2488, “Standard Recommended Practice for Description of Soils.”
- Collect samples for laboratory testing of (1) particle size distribution in accordance with ASTM D422-63, “Standard Test Method for Particle-Size Analysis of Soils”; (2) organic matter content per ASTM D2974.
- Conduct qualitative assessment of soil compaction via T-probe.
- Conduct infiltration testing.
- Preparation of descriptive exploration logs for each exploration.
- Preparation of this summary document.

Topography of the site and surrounding area is shown on Figure BDP F2, “LiDAR-Based Topography.” Existing facility features and the locations of hand-auger boreholes completed for this study are shown on Figure BDP F3, “Facility and Exploration Plan.” Project civil plans are attached as Appendix A. Exploration logs and laboratory testing data conducted as part of this study are attached as Appendix B. Background soil, geology, and ground water information are attached as Appendix C. Soil probe, level survey, and field infiltration testing data are attached as Appendix D. Site photos are attached as Appendix E.

3.0 SITE DESCRIPTION AND DESIGN BACKGROUND

The project site is the Bloedel Donovan Park - City of Bellingham North Shore Water Quality Project, located in Bellingham, Washington, as shown on the attached “Vicinity Map” (Figure BDP F1). Bloedel Donovan Park is about 19 acres in size, and is roughly delineated by Electric Avenue to the west, by a grassy field to the south, and by Lake Whatcom to the north and east. Lake Whatcom is the largest surface water feature onsite. The lake discharges to the southwest of the park via Whatcom Creek. Per the Washington State Source Water Assessment Program Mapping Application, no water supply wells are located within approximately 1 mile of the site. Lake Whatcom is used as a water supply for the City of Bellingham. LiDAR topography and other near-site vicinity features are illustrated on Figure BDP F2, "LiDAR-Based Topography."

Our specific area of study for this project includes the bioretention facility (referred to as cell BDP for this study) located adjacent to Electric Avenue, just north of a parking lot exit road. The attached "Facility and Exploration Plan" (Figure BDP F3) illustrates our study area.

Details of the bioretention facility design and basis were presented in the following documents:

- City of Bellingham, Washington, Public Works Department, North Shore Water Quality Project, July 7, 2003.
- GeoEngineers, Inc., Memorandum, Bloedel-Donovan, May 19, 2003.
- "Storm Calcs BBD Site 23.pdf," undated. Document transmitted to AESI by Clear Creek Solutions June 29, 2016.

3.1 Summary of Facility Design

From our review of these documents, the bioretention facility design for cell BDP consists of one approximately 550-square-foot basin (area estimated from plan sheet 4, City of Bellingham, 2003) with three internal "weirs" within the facility, generally running northeast to southwest across the facility, dividing the cell into chambers, as shown on Figure BDP F3, "Facility and Exploration Plan." We understand that the cell was sized using the Santa Barbara Unit Hydrograph (SBUH) model based on a developed condition drainage basin of 1.6 acres. Land use within the drainage basin consists of parking lot area. Per plan sheet 2 (City of Bellingham, 2003), a nearby facility designed as part of the same project is constructed with 18 to 24 inches of bioretention soil, overlaying three 6-inch layers of 6-inch drain rock, each separated by geomembrane fabric. Similar details were not available for cell BDP, and we assume that cell BDP is constructed similarly. The facility was constructed in August 2003, and began receiving runoff in September or October 2003 (Email communication, Eli Mackiewicz, City of Bellingham Public Works Department, August 23, 2016).

Inflow to cell BDP is from two curb cuts on the northeast and southeast side of the cell. A water bar consisting of an asphalt berm about 2 feet wide and 3 inches high is shown as located across the parking lot to control and direct drainage into cell BDP through the curb cut on the southeast side of the cell. Water can pond up to approximately 0.9 feet in the final chamber before flowing over the overflow weir. Water that flows over the overflow weir is collected in an area drain and discharged to a separate storm filter, indicated on the plans as "Stormfilter 'B'."

4.0 SITE OBSERVATIONS

During AESI's site visits, we made notes regarding the physical construction of the bioretention facilities including documenting site inlet/outlet layout relative to site plans and qualitative bioretention soil thickness and compaction. These notes were used to indicate key features of the facility in Figure BDP F3, "Facility and Exploration Plan".

- Level Survey: AESI conducted an elevation survey of the facility using a Leitz C40 automatic level and a stadia rod. An arbitrary project datum was established for this survey, with the center of the nearby sewer manhole (indicated on the site plan in Appendix D) defined as project datum elevation 100 feet. All other elevations measured are relative to this project datum. Due to the density of vegetation within the facility, AESI's ability to survey elevations within the base of the BDP facility was limited. To obtain additional elevation data, AESI used a 1-meter rod, a hand level, and a ruler to measure elevation change along two profiles across the base of the facility. These profiles and additional data points are included in Appendix D. Key level data is summarized in Table 1. These profile surveys were not conducted by a licensed surveyor. Surveyed elevations are expected to be sufficiently accurate for this general assessment of facility construction, but may be inaccurate for purposes requiring greater precision.

- Inflows: Two inflows to cell BDP are present, which consist of 12-inch-wide curb cuts. Near the northern curb cut, rilling to a depth of 0.05 feet was observed. Near the southern curb cut, AESI noted an eroded channel 0.8 feet wide, and up to 0.2 feet deep.

- The plans indicate that a water bar consisting of an asphalt berm about 2 feet wide and 3 inches high would be located across the parking lot to control and direct drainage into the cell. The water bar was not constructed. Instead, a shallow depression (generally less than ½ inch) in the asphalt surface directed water north across the parking lot exit. This parking lot exit generally slopes downwards to the west, so water which overtops the shallow depression flows west to Electric Avenue rather than following the path of the depression to the southern inflow to the BDP facility. Water was observed to overtop the depression in the presence of collected leaf litter partially damming the curb cut, as discussed under "Infiltration Testing" later in this document. Water could also overtop the shallow depression in the case of high flows during large storm events.

- Internal cell weirs: The plans indicate three internal "weirs" within the facility, generally running northeast to southwest across the facility, dividing the cell into chambers. AESI noted that the "weirs" are constructed of materials similar to composite/plastic decking boards. There are gaps between the base of the boards and the top of the bioretention soil for significant portions of their length, so that ponded water can flow under the boards.

- Monitoring well: The existing monitoring well, indicated on plan sheet 3 as "Type 1 C.B. solid, licking lid (monitoring well)," consists of a 6-inch-diameter white PVC pipe which sticks up approximately 0.3 feet from ground surface and has a total depth of 3.8 feet from the top of the casing. This monitoring well is set within a square, metal structure with a solid metal lid. Due to the stickup of the monitoring well, the metal lid does not close or lock, and instead can only be propped against the PVC casing of the monitoring well, partially covering the top of the monitoring well. No other cap on the PVC pipe is present. Per our level survey, the top of the monitoring well is 0.03 feet higher in elevation than the overflow weir. It is possible that when the facility is full of water to the level at which it flows over the overflow weir, water or debris could enter the open top of the monitoring well.

- Overflow: One overflow is present. This overflow consists of an approximately curved 12-foot-long curb which acts as a weir on the western side of the facility. Water which flows over this weir would pool in a low area surrounded by curbs, and flow into the storm drain in this location, and be directed to a separate storm filter, indicated on the plans as "Stormfilter 'B'."
- AESI investigated the loose bioretention soil thickness present in cell BDP using a geotechnical soil T-probe. This qualitative data was used in conjunction with the hand-auger observations to understand loose soil thickness and relative potential compactness of the bioretention soils at depth. In the three western chambers, the apparent thickness of bioretention soil generally ranged from approximately 1.6 feet to 1.9 feet, and averaged 1.7 feet. In the easternmost chamber, probe penetration was typically 0 to 0.5 feet, and cement blocks were present beneath the bioretention soil. Probe penetration data is included in Appendix D to this document.

Table 1
Summary of Cell BDP
Level Survey Data

Location	Elevation (feet, project datum)
(S-1) Center sewer manhole	100
(S-2) Overflow weir, S. edge	98.94
Overflow weir, middle	98.94
(S-3) Overflow weir, N edge	98.94
(S-4) Curb corner	100.75
(S-5) Corner of grate	98.12
Pre-existing survey nail (near S-1)	99.62
North curb cut, middle, bottom edge	99.82
South curb cut, middle, bottom edge	On site plan in Appendix D to this document

5.0 SITE SETTING

The text sections below describe our research findings in regards to the topographic, geologic, and hydrogeologic setting of the project site both from regional studies and background site-specific geotechnical and ground water studies. Our sources of information included the following.

- Site-specific documents cited previously under "Project and Site Description."
- Easterbrook, D.J., *Geologic Map of Western Whatcom County, Washington*, United States Geological Survey, Miscellaneous Investigations Map I-854-B, scale 1:62,500, 1976.

- *Soil Survey of Whatcom County area, Washington*, United States Department of Agriculture, Natural Resource Conservation Service (NRCS), 1992.
- Natural Resources Conservation Service, Web Soil Survey, United States Department of Agriculture, http://websoilsurvey.nrcs.usda.gov/, accessed September 2016.
- Lake Whatcom Reservoir, City of Bellingham, Washington, https://www.cob.org/services/environment/lake-whatcom/pages/about-lw.aspx, accessed September 21, 2016.
- Mitchell, R. et al., *Lake Whatcom Bathymetry and Morphology*, Institute for Watershed Studies, Geology Department, Western Washington University, Bellingham, Washington, October 28, 2010.

5.1 Regional Topography and Project Grading

The project site is situated near the outlet of the Lake Whatcom basin, a glacially scoured bedrock basin. The lake level is partially controlled by a dam at the head waters of Whatcom Creek and the maximum regulated lake elevation is about elevation 307 to 312.5 feet NAVD88 (Mitchell, et al., 2010) or about 7.5 feet below current site grades. Whatcom Creek flows south-southwest from the lake, and eventually discharges into Bellingham Bay.

On a closer scale, the site is located on a generally level, approximately 1,200-foot-wide peninsula, and is surrounded by Lake Whatcom to the west, north, and east. Ground surface in the vicinity of cell BDP ranges from about elevation 320 to 322 feet. The parking lot is sloped to the west toward cell BDP. The ground surface rises gradually to the south.

Prior to bioretention cell construction, the site existing condition was likely paved drive lane and parking area. Prior to creation of the park, the site was part of saw mill operations. Cuts on the order of about 3 feet were needed to achieve the assumed design bioretention cell grade based on a review of existing topography compared with built conditions.

5.2 Regional Geology and Background Geotechnical Information

According to the geologic map (Easterbrook, 1976), the site vicinity is underlain at shallow depths by bedrock described as the Chuckanut Formation, which consists of sandstone, conglomerate, shale, and coal. Limited background geotechnical data was available. Soil logs by GeoEngineers, Inc. dated May 19, 2003, which reached a maximum depth of 3.2 feet, encountered silty sand with occasional gravel, and brown silty sand, in two locations on the project site.

The material encountered in the GeoEngineers, Inc. soil logs is considered undifferentiated sediments for this study. The sediment could consist of undocumented fill used to level the site or re-worked native colluvium sediments, consistent with soils mapping, described below.

5.3 Regional Soils and Soil Data Used in Site Stormwater Model

AESI reviewed the *Soil Survey of Whatcom County Area* (Natural Resources Conservation Service [NRCS], 1980), and soils mapping from the NRCS web portal (NRCS, 2016). The soil survey identifies different soil map units based on parent material, climate, topography (slope), organisms (biota), and time. The soils in the study area formed mostly from young glacial deposits and have not had time to develop the deep weathering profiles present in soils in unglaciated terrains. Instead, they exhibit a direct relationship to the underlying parent material, local climate, topography, and vegetation.

Mapped soils in the area consist of the Squalicum Urban Land Complex, which is defined as consisting of approximately 50 percent Squalicum and similar soils, approximately 30 percent urban land, and approximately 20 percent other minor components. The Squalicum gravelly loam is described as forming in a mixture of volcanic ash, loess, and slope alluvium over glacial till. The depth to dense glacial till typically ranges from 40 to 60 inches, but can be greater. Permeability is moderate (0.6 to 2 inches per hour [in/hr]) in the upper part of the soil, and very slow (less than 0.06 in/hr) in the glacial till.

Squalicum Urban Land Complex and glacial till typically would be modeled as Type C soils.

5.4 Regional Hydrogeology and Background Ground Water Data

Due to the location of the study site on a relatively level peninsula in Lake Whatcom at near lake level, the level of ground water at the site is likely closely associated with the level of water in the lake. Average lake elevation is approximately 311.5 feet NAVD88 (Lake Whatcom Reservoir, City of Bellingham). The lake level is partially controlled by a dam at the head waters of Whatcom Creek and the maximum regulated lake elevation is about elevation 307 to 312.5 feet NAVD88 (Mitchell, et al., 2010) or about 8 feet below current site grades.

No background data on ground water was provided although we understand that the existing monitoring well was monitored by the City of Bellingham. No seepage was encountered in the background geotechnical explorations. Shallow ground water was measured in the existing monitoring well (see Section 6.2) at the time of our fieldwork.

6.0 BIORETENTION CELL SUBSURFACE EXPLORATION

Limited information on subsurface conditions was obtained for this study from hand-auger samples and soil probe penetration measurements at about 2-foot increments in each hand-augered borehole. Two hand-auger borings were performed in the facility bottom and advanced through the bioretention soil and to the underlying subgrade. An additional hand-auger boring was advanced through landscaping bark and topsoil in a landscape planter adjacent to the cell, and into the native material. Representative samples were collected, visually classified in the field, stored in water-tight containers and transported to AESI's offices for additional classification, geotechnical testing and study. At the conclusion of the excavation, each borehole was immediately backfilled with the excavated material.

The various types of sediments, as well as the depths where characteristics of the sediments changed, are indicated on the exploration logs presented in Appendix B. A detailed record of the observed bioretention soil, subsurface soil, geology, and ground water conditions was made. The sediments were described by visual and textural examination using the soil classification in general accordance with ASTM D2488, “Standard Recommended Practice for Description of Soils.” The depths indicated on the logs where conditions changed may represent gradational variations between sediment types in the field. The exploration logs in Appendix B are based on the field observations, inspection of the samples, and where applicable, laboratory grain-size analysis. Our explorations were approximately located in the field relative to known site features, and are shown on Figure BDP F3, "Facility and Exploration Plan." GPS coordinates for the explorations were taken using a hand-held GPS, and are summarized in Appendix B.

The results presented in this document are based on the explorations completed for this study and review of background data. The number, locations, and depths of the explorations were completed within site and budgetary constraints. Because of the nature of exploratory work below ground, interpolation of subsurface conditions between field explorations is necessary. It should be noted that differing subsurface conditions may sometimes be present due to the random nature of deposition and the alteration of topography by past grading and/or filling.

6.1 Hand-Auger Borings

Hand-auger borings in and near cell BDP were completed on July 29, 2016. No rain was observed during this time, and no flow was observed from the inlet pipes.

Hand-auger boring number 1 (BDP-HA-1) was completed in the western portion of the cell near the overflow, and encountered approximately 1.7 feet of bioretention soil, overlaying geomembrane fabric. A flap was cut in this geomembrane fabric, and beneath it, AESI observed gravel drain rock. The flap of geomembrane fabric was folded back into place during backfill activities. No seepage or caving were observed.

Hand-auger boring number 2 (BDP-HA-2) was completed in the landscape beds to the north of the cell to obtain information to correlate with soils underlying the drain rock beneath cell BDP. This exploration encountered landscaping bark and topsoil to 0.7 feet below ground surface, and gravelly, very silty sand with cobbles to a total depth of 2.3 feet below ground surface. The borehole encountered refusal on a cobble at 2.3 feet.

Hand-auger boring number 3 (BDP-HA-3) was completed near the existing monitoring well. This exploration encountered bioretention soil to 1.5 feet below ground surface, and geomembrane fabric at 1.5 feet, covering gravel drain rock.

6.2 Well Points

Because the existing monitoring well penetrated deeper beneath ground surface than the hand-auger explorations, no well point was installed. Dimensions of the existing monitoring well are provided in Table 2, below.

Table 2
Summary of Cell BDP
Existing Monitoring Well Dimensions

Existing Monitoring Well	Total Length of Casing (feet)	Interior Diameter	Stickup Height (feet)	Total Depth Inside Casing Below Ground Surface	Static Water Level, Date and Depth (feet bgs)
BDP-MW	3.9	6-inch	0.3	3.6	7/29/16: 2.6 feet 9/2/16: 2.0 feet 9/6/16: 2.2 feet

bgs: below ground surface

7.0 LABORATORY ANALYSIS

Laboratory testing included mechanical grain-size distribution and percent organic matter by weight in accordance with the ASTM D422 and D2974, respectively. Two samples of bioretention soil were first tested for organic matter content and then the burned material was tested for grain-size distribution for comparison with the aggregate fraction of the bioretention soil mix guidance in the Washington State Department of Ecology (Ecology) 2014 *Stormwater Management Manual for Western Washington* (2014 Ecology Manual). One sample of material interpreted as representative of the subgrade was tested for grain size distribution. The data is summarized in Table 3.

Table 3
Summary of Cell BDP
Organic Content and Grain Size Data

Exploration Number	Depth (feet)	Soil Type	Organic Content (% by weight)	USCS Soil Description	Fines Content (% passing #200)	Cu	Cc	USDA Soil Texture*
BDP-HA-1	0.1-0.6	Bioretention Soil	5.8	SAND (SP)	1.0%	3.7	1.0	Sand
BDP-HA-3	0.7-1	Bioretention Soil	4.8	SAND (SP)	0.4%	3.4	1.3	Sand
BDP-HA-2	0.8-1.3	Undifferentiated Sediments	Not tested	Gravelly, very silty SAND (SM)	30%	100	>20	Sandy clay to sandy loam

USCS: Unified Soil Classification System; Cu: coefficient of uniformity; Cc: coefficient of curvature; USDA: US Dept. of Agriculture; *No hydrometers were performed. USDA soil texture range assumes fines consist entirely of silt to entirely of clay.

7.1 Bioretention Soil Mix

We compared the organic content and burned fraction gradation against the general guidelines for the bioretention soil mix (Table 4).

The organic content of the tested bioretention soils ranged between 4.8 to 5.8 percent by weight. This is below or in the low range of the recommended organic content by weight of 5 to 8 percent in the 2014 Ecology Manual.

The grain-size analysis test results on the burned soil fraction indicate that the bioretention soils tested correlate to a "SAND" based on ASTM D2487 USCS. The respective fines content as measured on the No. 200 sieve ranged from approximately 0.4 to 1 percent, consistently less than the recommend range of 2 to 5 percent. The coefficient of uniformity ranged from 3.4 to 3.7, consistently less than the recommended value of equal to or greater than 4. The coefficient of curvature ranged from 1.0 to 1.1, consistent with the recommended range of greater than or equal to 1 and less than or equal to 3. The soil mix generally did not meet (contained less than) the recommended range of fine sand and silt fractions. The tested bioretention soil was predominantly medium-grained sand.

Table 4
General Guidelines for Bioretention Soil Mix (2014 Ecology Manual)
Compared to Averaged Cell BDP Site Data

Parameter	Recommended Range	BDP
Organic Content (by weight)	5 to 8 percent	5.3 percent by weight
Cu coefficient of uniformity	4 or greater	3.5
Cc coefficient of curvature	1 to 3	1.1
Sieve Size	**Percent Passing**	
3/8" (9.51 mm)	100	100
#4 (4.76 mm)	95 to 100	98
#10 (2.0 mm)	75 to 90	81
#40 (0.42 mm)	25 to 40	14
#100 (0.15 mm)	4 to 10	2.2
#200 (0.074 mm)	2 to 5	0.7

Note: The general guidelines for mineral aggregate gradation are from Table 7.4.1 of the 2014 Ecology Manual.
mm: millimeters

7.2 Subgrade

One sample of material collected from BDP-HA-2 interpreted as representative of the subgrade was sieved. The tested material correlates to a gravelly, very silty SAND with 30 percent by weight of the material passing the No. 200 sieve.

The grain size distribution data were also transformed to describe the United States Department of Agriculture soil texture. The grain-size distributions were normalized to the No. 10 sieve—i.e., the coarse sand and gravel fraction of the sample is discounted and the remainder is taken as 100 percent of the sample. The fines were assessed relative to the No. 270 sieve. The respective United States Department of Agriculture fines content as measured on the No. 270 sieve after adjusting to remove the weight retained on the #10 sieve was 41 percent.

8.0 INFILTRATION TESTING

8.1 General Infiltration Test Method

The infiltration test was conducted in general accordance with the 2014 Ecology Manual. The test was conducted by discharging water into the facility for a “soaking period,” to allow the receptor soils to become saturated. After completion of the soaking period, water was discharged into the cell at a rate sufficient to maintain a relatively constant head. This constitutes the “constant head” phase of infiltration testing. Immediately following the constant head phase of infiltration testing, flow into the facilities was discontinued, and the water level was monitored as it dropped. This constitutes the “falling head” portion of the infiltration testing.

The water for testing was obtained from an on-site hose bib, and conveyed to the test area with garden hoses. During infiltration testing, the water was conveyed into the bioretention cell via a digital flow meter with gallons per minute (gpm) and total gallon readouts, and discharged through a flow diffuser into the southern inflow for the facility. Water levels were monitored using a temporary metal staff gauge marked in 0.02-foot increments which was installed next to the monitoring well for the duration of the test, within the monitoring well with a digital water level tape, and with digital pressure transducers. Data from the digital pressure transducers was compensated for barometric response using a separate digital barometer. The area of the pool was measured periodically during testing.

The infiltration test in cell BDP is discussed below, and results are presented in Table 5. Infiltration test data is included in Appendix D to this document.

8.2 Infiltration Test in Cell BDP

AESI performed infiltration testing of cell BDP on September 2, 2016. Rainfall was noted during the beginning of the infiltration test, and flow from both inflows was observed. AESI visually estimated flow from the inflows as approximately 5 gpm from the southern inflow, and approximately 2 gpm from the northeastern inflow. These flow rates were observed to decrease with time, and no flow from rainfall in either inflow was observed during the final 3.5 hours of testing. Upon arrival to the site, prior to the start of testing, AESI noted that leaf litter was collected in the southern inflow, and approximately half of the stormwater channeled to the southern inflow was instead flowing to the roadway (Photo 1). When AESI removed the collected leaf litter from the inflow, the bypass flow to the roadway ceased, allowing additional inflow.

Photo 1. *Cell BDP, southeastern inlet clogged with leaves. Some water bypass toward Electric Avenue. 9/2/16.*

During this test, flow was maintained for approximately 7 hours. For the initial 3.5 hours, as described above, additional inflow from stormwater runoff flowed into the facility. Controlled inflow was added to the facility at the maximum rate possible with the on-site water source, approximately 4.2 gpm. During the latter half of the test, the wetted pool was approximately 17 square feet near the inflow, in the eastern chamber of the cell. Head within this wetted area was typically less than 0.5 inches. No pooling of water on the surface of the base of the raingarden was observed other than this wetted area near the inflow, and the staff gauge in place for the infiltration test adjacent to the monitoring well was never wetted.

During the test the ground water level (as measured in BDP-MW) beneath the facility rose slowly from 2.0 feet below ground surface (before inflow for the test began) to 1.1 feet below ground surface as the constant head phase of testing was completed. AESI interprets this response to indicate that water from the infiltration test infiltrated rapidly through the bioretention soil and then mounded on the shallow ground water present beneath the site.

After about 7 hours, AESI shut off the flow and monitored water level within the monitoring well as it fell. AESI observed that the water in the monitoring well dropped about 0.3 feet in 30 minutes. A digital pressure transducer was left in the monitoring well to record the falling water level, and was retrieved 4 days later. The pressure transducer recorded the water falling at a slowly decreasing rate by a total of approximately 1.2 feet over the course of approximately 85 hours after testing, before rapidly increasing again due to a storm event.

The constant head test infiltration rate in Table 5 is calculated based on flow rate from the hose for infiltration testing, and the wetted area of bioretention soil through which the water infiltrated, and represents the infiltration rate of the bioretention soil.

Table 5
Cell BDP
Infiltration Test Results

Test No.	Surface Area (square feet)	Discharge Time (minutes)	Total Volume Discharged (gallons)	Approximate Constant Head Level (feet)	Field Infiltration Rates	
					Constant Head Test (in/hr)	Falling Head Test (in/hr)
BDP (bioretention soil)	17	420	1,655	< ½ inch	~25	Not measured
BDP (subgrade)	Shallow ground water mounding response in well point				Unknown	

in/hr: inches per hour

9.0 CONCLUSIONS AND RECOMMENDATIONS

The bioretention cell at the BDP site varied somewhat from the design shown on the civil plan sheets. Variations included the following:

- Bioretention soil
    - Thickness: Cell BDP within the three western chambers generally contained 18 inches of bioretention soil, consistent with the planned 18 to 24 inches. However, the eastern chamber contained angular concrete blocks near the inflows, buried in the bioretention soil. This may have been intended for energy dissipation purposes, but is not displayed on plan sheets.

    - Composition: The soil tested in cell BDP did not meet the recommended guidelines for silt and sand gradation. The soil tested was at the low end of the recommended range for organic content.

- Internal cell weirs: The internal cell weirs were not in contact with the ground for significant portions of their length so that ponded water can flow under the boards. This limits the effectiveness in erosion and flow control.

- Subgrade conditions: The subgrade conditions are unknown due to refusal of hand augers within the cells. The hand auger completed outside of the cell and historic site data were used to interpret the subgrade; however, the information was not enough to adequately determine whether the subgrade was undocumented fill or native sediments. Additional excavation equipment would be necessary to adequately characterize the subgrade.

- The field infiltration rate was measured at about 25 in/hr, and is interpreted as the bioretention soil infiltration rate.

- Shallow ground water is present in the location of the BDP facility as measured in the monitoring well. AESI interprets that the infiltration test water soaked rapidly through the bioretention soil and mounded on the underlying shallow water table, then dissipated both laterally and vertically as shallow ground water flow. The relationship between inflow and shallow ground water mounding will be better approximated after reviewing the planned flow monitoring data and winter water level data.

- During infiltration testing, the water level within the existing monitoring well responded rapidly to inflow. This is consistent with the well screen intersecting bioretention soil and drain rock layers. The lag time in response to start of inflow and stop of inflow was less than 1 minute.

10.0 CLOSURE

We appreciate the opportunity to be of continued service to you on this project. Should you have any questions regarding this document or other geotechnical/hydrogeologic aspects of the project, please call us at your earliest convenience.

State of Washington
Licensed Geologist
Hydrogeologist
2335
Jennifer H. Saltonstall

Jennifer Saltonstall 10/25/16

Anton Ypma
Staff Geologist

Curtis J. Koger, L.G., L.E.G., L.Hg.
Senior Principal Geologist/Hydrogeologist

Jennifer H. Saltonstall, L.G., L.Hg.
Senior Associate Geologist/Hydrogeologist

Attachments:	Figure BDP F1:	Vicinity Map
	Figure BDP F2:	LiDAR-Based Topography
	Figure BDP F3:	Facility and Exploration Plan
	Appendix A:	Project Civil Plans
	Appendix B:	Current Study Exploration Logs and Laboratory Testing Data
	Appendix C:	Background Soil, Geology, and Ground Water Data (Regional Maps, Previous Studies Exploration Logs and Laboratory Testing Data)
	Appendix D:	Soil Probe, Level Survey, and Field Infiltration Testing Data
	Appendix E:	Site Photos

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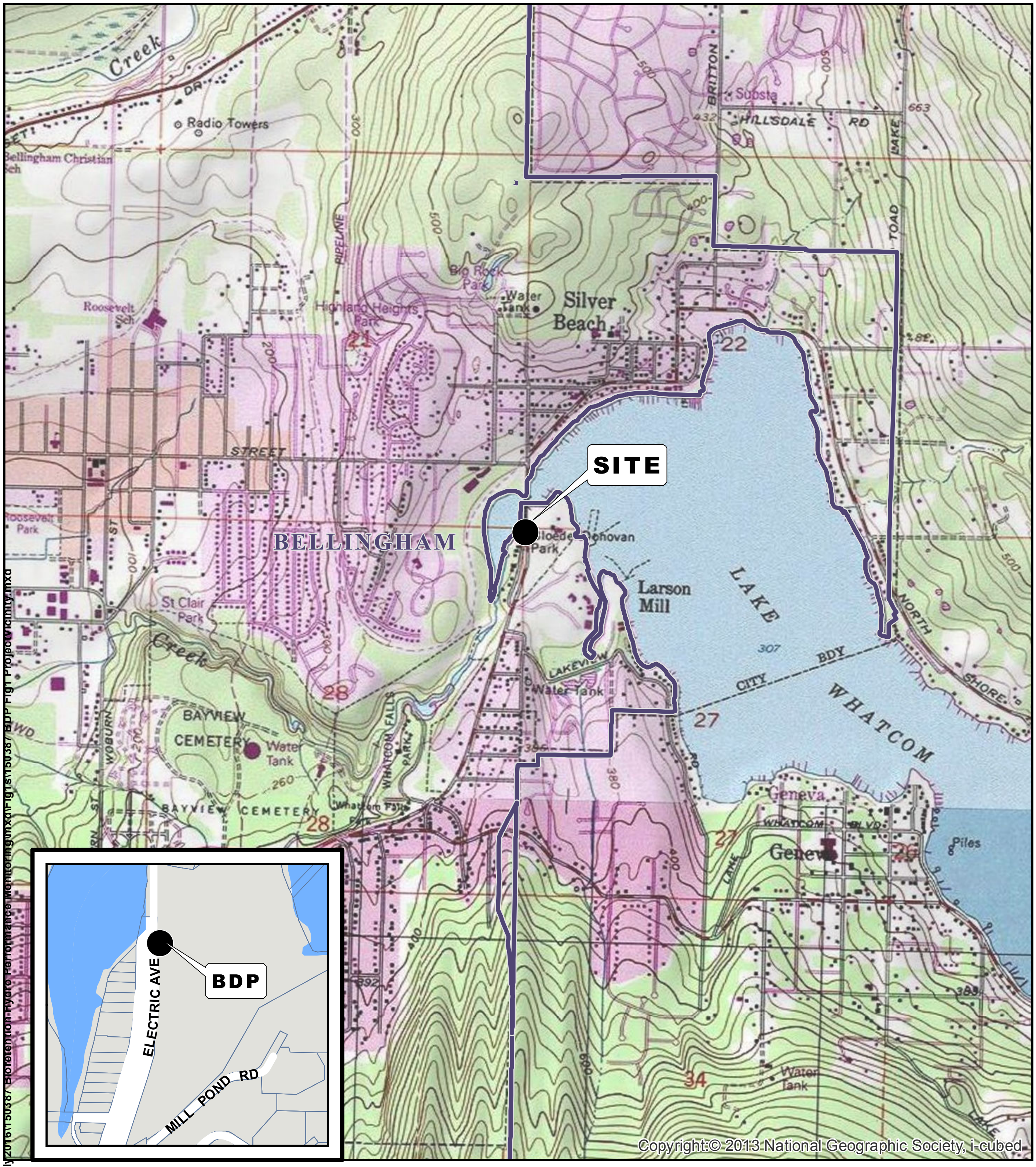

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DATA SOURCES / REFERENCES:
USGS: 24K SERIES TOPOGRAPHIC MAPS
WHATCOM CO: PARCELS, WATER 2015
CITY OF BELLINGHAM: STREETS 2016

LOCATIONS AND DISTANCES SHOWN ARE APPROXIMATE

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FEET

NOTE: BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION

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VICINITY MAP

BIORETENTION HYDROLOGIC PERFORMANCE STUDY, BDP SITE
BELLINGHAM, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	BDP F1

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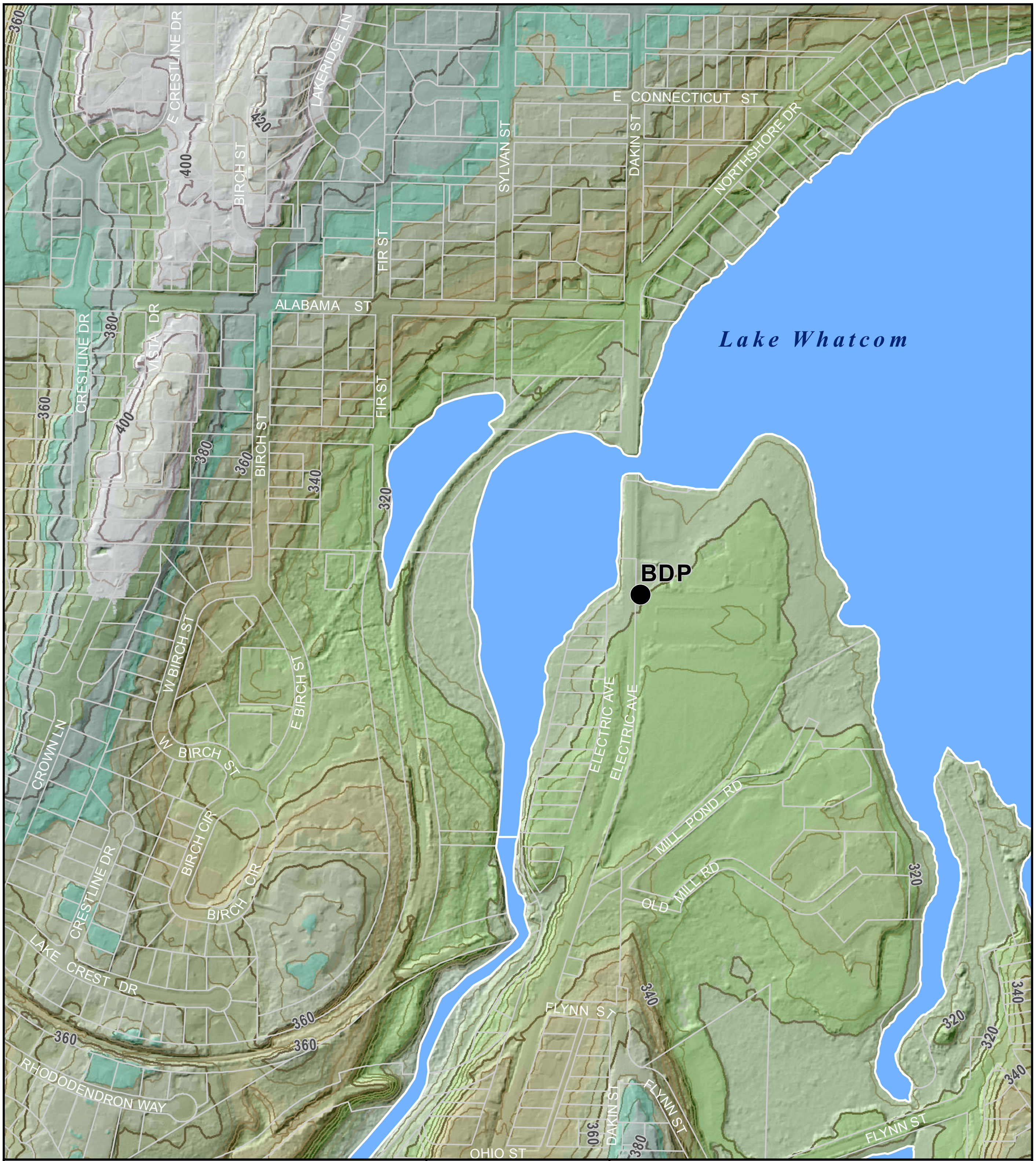
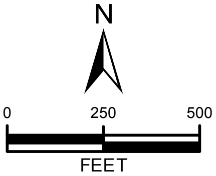


DATA SOURCES / REFERENCES:
PSLC: LIDAR CITY OF BELLINGHAM 2013, 3' CELL
WHATCOM CO: PARCELS 2015
CITY OF BELLINGHAM STREETS, WATER 2016

LOCATIONS AND DISTANCES SHOWN ARE APPROXIMATE



NOTE: BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION

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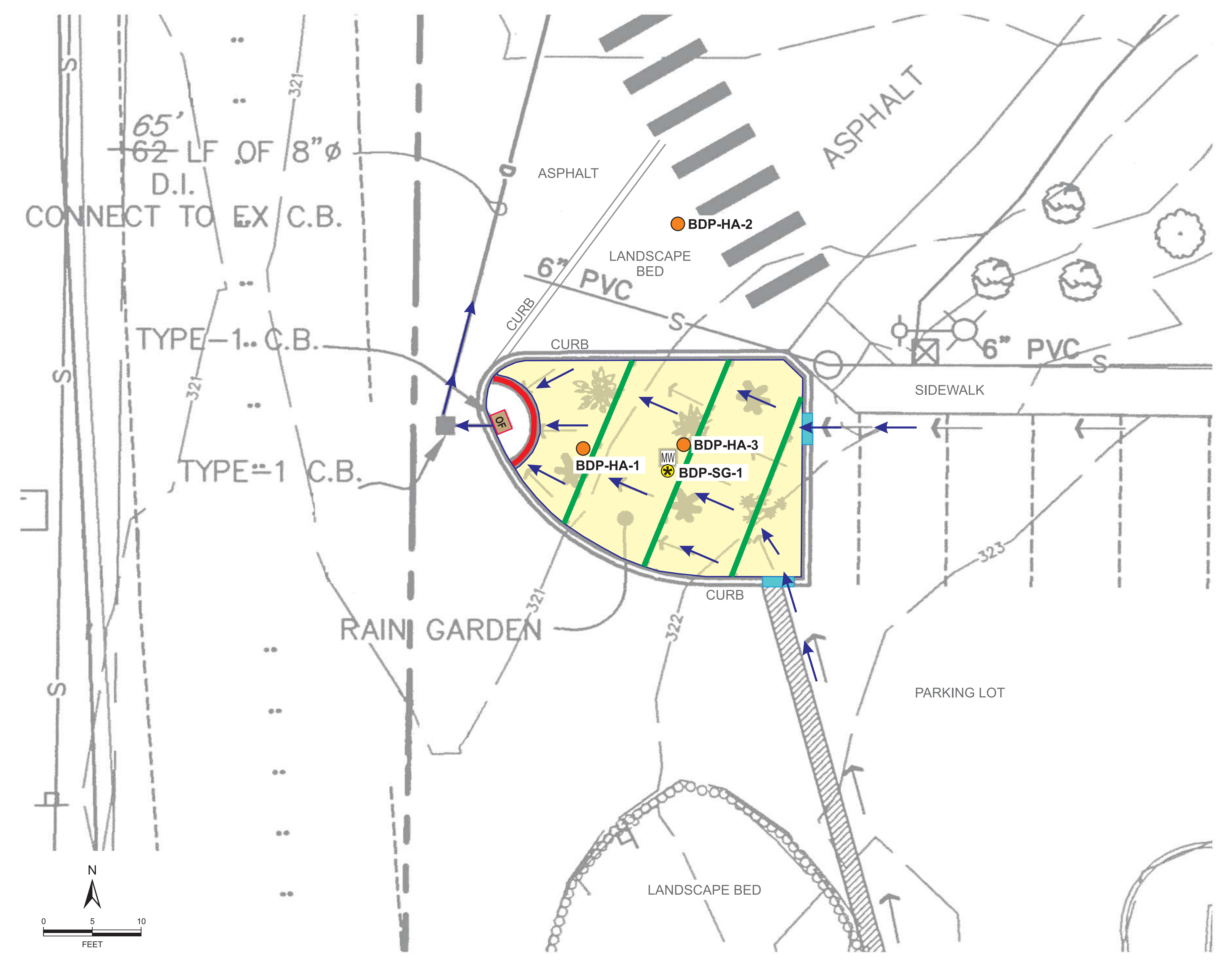
LIDAR BASED TOPOGRAPHY

BIORETENTION HYDROLOGIC
PERFORMANCE STUDY, BDP SITE
WHATCOM CO, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	BDP F2

Document Path: G:\GIS_Projects\aYear2015postJuly2016\150387 Bioretention Hydro Performance Monitoring\mxd\Fig2s\150387 BDP Fig2B LIDAR.mxd



LEGEND:

● HA	HAND AUGER
⊛	TEMPORARY STAFF GAUGE
⬭	BASE OF FACILITY
→	INFLOW / OVERFLOW DIRECTION
OF	OVERFLOW STORM DRAIN
🟩	WEIR
🟥	OVERFLOW WEIR
🟦	CURB CUT
MW	MONITORING WELL WITH METAL COVER

CONTOUR INTERVAL = 1'

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:
1. BASE MAP REFERENCE: CITY OF BELLINGHAM PUBLIC WORKS DEPT, NORTHSHORE WATER QUALITY PROJECT, PARKING LOT-ELECTRIC AVE, SHEET 3 OF 4, 7/7/03

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FACILITY AND EXPLORATION PLAN
BDP SITE
BIORETENTION HYDROLOGIC PERFORMANCE
BELLINGHAM, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	BDP F3

150387 BHPS MCCA \ 150387 Site-Expl.cdr PAGE 2: BDP

APPENDIX A

Project Civil Plans

NORTH SHORE WATER QUALITY PROJECT

CITY OF BELLINGHAM, WASHINGTON
EV-20

RAIN GARDEN SPECIFICATIONS

Amended Soil Specification:

Composted Organics	12 - 18%
Total Organic Matter	20 - 25%
Sand	75 - 80%

Sand Specification:

The sand in a filter must consist of a medium sand meeting the size gradation (by weight).

U.S. Sieve Number	Percent Passing
4	95-100
8	70-100
16	40-90
30	25-75
50	2-25
100	<4
200	<2

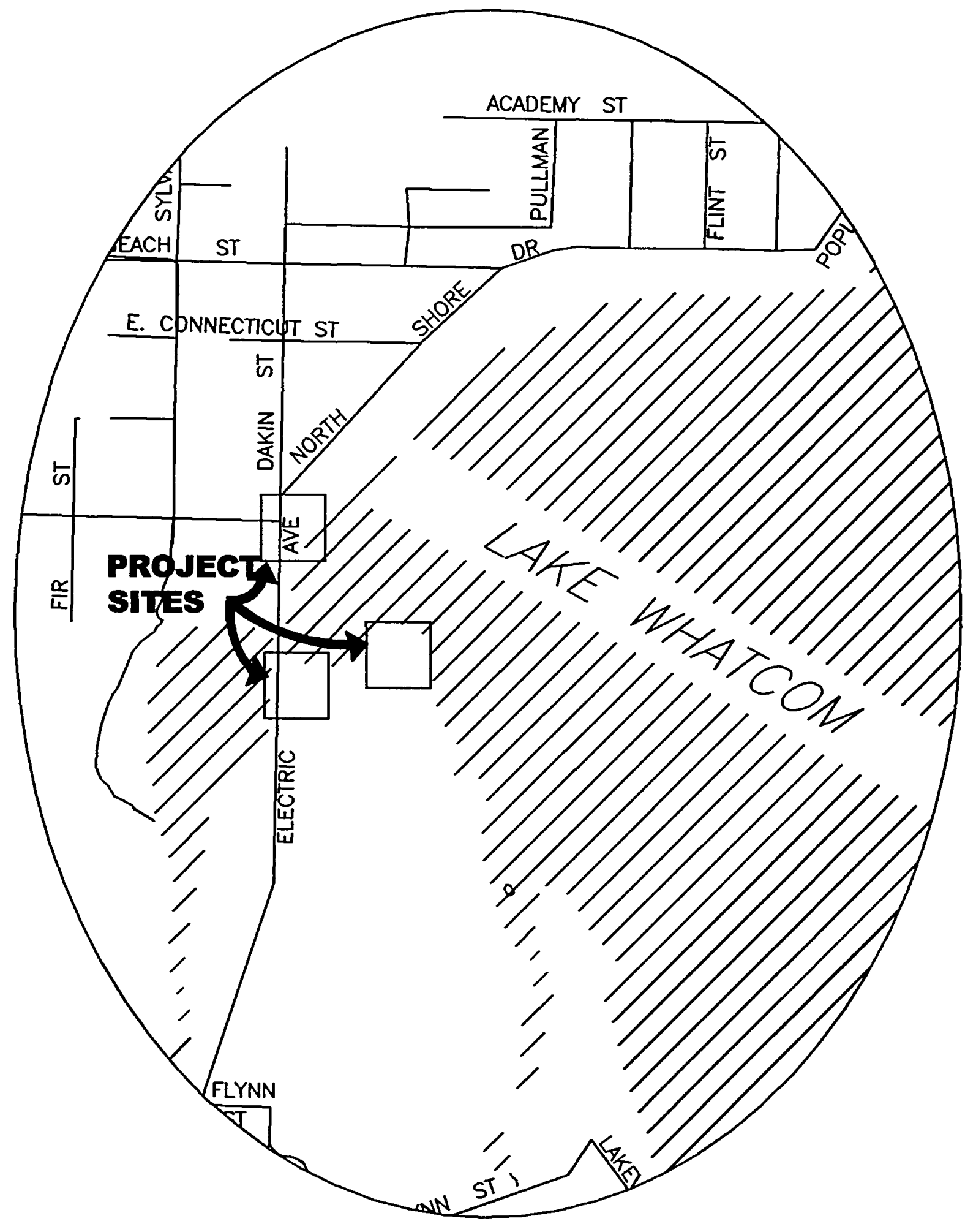
Drain Rock Specification:

Sieve Number	Percent Passing
1" Square	100
3/4" Square	80-100
3/8" Square	10-40
U.S. No.4	<4
U.S. No.200	<2

Geomembrane Specification:

Non-woven Geotextile for underground drainage filtration.

Grab Tensile (lbs)	200
Elongation (%)	50
Tear (lbs)	85
Puncture (lbs)	110
AOS (sieve)	80
Permittivity (sec-1)	1.4
Permeability (cm/sec)	0.38
Water Flow (gpm/ft2)	90
Thickness (mil)	85



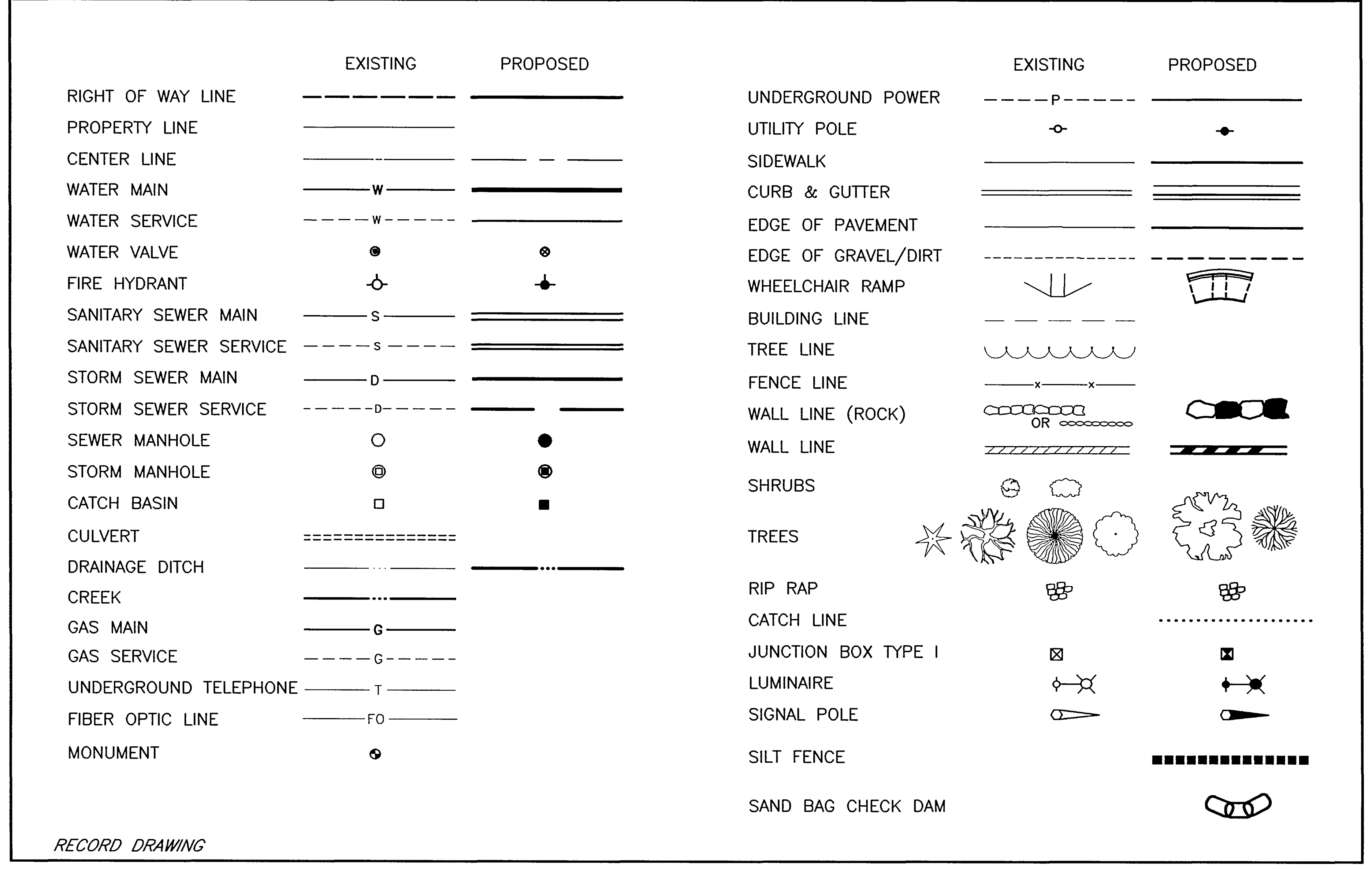
VICINITY MAP

PLANTS

	PLANTS	QUANTITY • 1 GALLON/EACH
✱	HARDHACK (SPIREA DOUGLASII)	20
⁂	NOOTKA ROSE (ROSA NUTKANA)	20
✺	KINNIKINNICK (ARCTOSTAPHYLOS UVA-URSI)	3
✹	BLACK TWINBERRY (LONI UVA INVOLUCRATA)	20
✳	HUCKLEBERRY (VACCINIUM OVATUM)	20
○	SNOWBERRY (SYMPHORICARPOS ALBUS)	15

PLANT LOCATIONS TO BE DETERMINED ON SITE BY PLANNING OR PARKS STAFF.

LEGEND



RECORD DRAWING

FOR MORE INFORMATOIN CONTACT: KIRK CHRISTENSEN, PROJECT ENGINEER, AT 676-6961

GENERAL NOTES

ALL WORK SHALL CONFORM TO THE 2002 STANDARD PLANS AND SPECIFICATIONS OF THE WASHINGTON STATE DEPARTMENT OF TRANSPORTATION (WSDOT), AND CITY OF BELLINGHAM STANDARDS UNLESS INDICATED OTHERWISE BY THE CONTRACT DOCUMENTS. IN CASE OF A CONFLICT BETWEEN THE REGULATORY STANDARDS OR SPECIFICATIONS, THE MORE STRINGENT REQUIREMENT WILL PREVAIL.

ALL TRENCH EXCAVATIONS CROSSING EXISTING PAVEMENT SHALL BE CONDUCTED IN ACCORDANCE WITH BELLINGHAM STANDARD PLAN ST–3.

ALL TRENCH EXCAVATION SHALL BE ACCORDING TO SECTION 7–08 OF THE STANDARD SPECIFICATIONS.

THE BEDDING SHALL BE ACCORDING TO SECTION 7–08 OF THE STANDARD SPECIFICATIONS. THE BEDDING FOR PVC PIPE SHALL BE PEA GRAVEL, ACCORDING TO CITY OF BELLINGHAM STANDARD PLAN NO.SE–4.

ALL TRENCH BACKFILL UNDER EXISTING OR FUTURE PAVING SHALL BE BANK RUN GRAVEL FOR TRENCH BACKFILL AND SHALL BE COMPACTED TO 95% OF MAXIMUM DENSITY.

TRENCH EXCAVATIONS SHALL NOT BE LEFT OPEN OVERNIGHT.

CONNECT NEW CONSTRUCTION TO EXISTING AS SHOWN ON THE PLANS OR AS DIRECTED BY THE ENGINEER.

PLUG ALL CULVERTS, SEWERS, AND CONDUITS PRIOR TO ABANDONMENT.

ALL LAWN AND VEGETATED AREAS WILL BE RESTORED TO ORIGINAL CONDITION.

THIS PROJECT REQUIRES VARIOUS PERMITS AS OUTLINED IN THE SPECIFICATION GENERAL PROVISIONS. ALL WORK SHALL BE PERFORMED IN A MANNER TO ASSURE CONFORMANCE WITH THE PERMIT REQUIREMENTS.

THE CONTRACTOR SHALL ATTEND PRE–CONSTRUCTION CONFERENCE WITH THE CITY OF BELLINGHAM ENGINEERING DIVISION PRIOR TO BEGINNING CONSTRUCTION.

THE LOCATION OF EXISTING UTILITIES SHOWN IS APPROXIMATE. IT IS THE RESPONSIBILITY OF THE CONTRACTOR TO FIELD VERIFY THESE LOCATIONS PRIOR TO CONSTRUCTION.

UNDERGROUND UTILITIES ARE KNOWN TO EXIST IN THE AREA OF CONSTRUCTION. IT IS THE RESPONSIBILITY OF THE CONTRACTOR TO CONTACT THE UTILITY OWNERS FOR LOCATIONS AND TO NOTIFY THE ENGINEER PROMPTLY OF ANY CONFLICT. THE ONE–CALL NUMBER FOR UNDERGROUND UTILITIES IS: 1–800–424–5555.

THE CONTRACTOR SHALL BE RESPONSIBLE FOR MAINTAINING THE INTEGRITY OF ADJACENT UTILITIES WHICH MAY INCLUDE, BUT ARE NOT LIMITED TO, WATER, SEWER, STORM SEWER, POWER, TELEPHONE, CABLE TV, GAS, IRRIGATION, AND STREET LIGHTING.

THE CONTRACTOR SHALL NOTIFY RESIDENTS AND BUSINESSES 48 HOURS IN ADVANCE OF ANY WORK AFFECTING ACCESS OR SERVICE AND SHALL MINIMIZE INTERRUPTIONS TO DRIVEWAYS FOR RESIDENTS AND BUSINESSES ADJACENT TO THE PROJECT.

PUBLIC RIGHTS–OF–WAY SHALL BE KEPT IN A CLEAN AND SERVICEABLE CONDITION AT ALL TIMES. IN THE EVENT MATERIALS ARE INADVERTENTLY DEPOSITED ON ROADWAYS, THE MATERIAL SHALL BE PROMPTLY REMOVED. MATERIALS ARE TO BE SWEPT AND REMOVED WITH A VACUUM SWEEPER. PUBLIC AND PRIVATE DRAINAGE WAYS SHALL BE PROTECTED FROM POLLUTION. NO MATERIAL IS TO BE DISCHARGED TO OR DEPOSITED IN STORMWATER SYSTEMS THAT MAY RESULT IN VIOLATION OF STATE OR FEDERAL WATER QUALITY STANDARDS.

THE CONTRACTOR SHALL BE RESPONSIBLE FOR CONSTRUCTING, MAINTAINING, & REMOVING EROSION CONTROL MEASURES (SILT FENCE, STRAW BALE DAMS, SILT PONDS, CATCH BASIN FILTERS, ETC.) THROUGHOUT THE DURATION OF THE PROJECT. ALL EROSION CONTROL WORK IS CONSIDERED INCIDENTAL TO THE ITEMS OF WORK IN THE CONTRACT FOR THIS PROJECT.

THE CITY OF BELLINGHAM WILL PROVIDE ALL CONSTRUCTION STAKING FOR THIS PROJECT.

STORM NOTES

BEDDING AND BACKFILL FOR PVC STORM MAIN PIPE SHALL CONFORM TO STANDARD PLAN SE–4.

THE CONTRACTOR SHALL BE RESPONSIBLE FOR MAINTAINING EROSION CONTROL MEASURES (SILT FENCE, STRAW BALE DAMS, SILT PONDS, ETC., AS DIRECTED BY THE ENGINEER) THROUGHOUT THE DURATION OF THE PROJECT.

DURING CONSTRUCTION PLACE CB INSERTS UNDER ALL EXISTING AND PROPOSED CATCH BASIN GRATES WITHIN THE PROJECT SITE.

IN THE EVENT MATERIALS ARE INADVERTENTLY DEPOSITED ON ROADWAYS, THE MATERIAL SHALL BE PROMPTLY REMOVED. MATERIALS ARE TO BE SWEPT AND REMOVED PRIOR TO ANY STREET FLUSHING. PUBLIC AND PRIVATE DRAINAGE WAYS SHALL BE PROTECTED FROM POLLUTION. NO MATERIAL IS TO BE DISCHARGED OR DEPOSITED IN STORMWATER SYSTEMS THAT MAY RESULT IN VIOLATION OF STATE OR FEDERAL WATER QUALITY STANDARDS.

ALL CATCH BASINS WITHIN THE PROJECT LIMITS SHALL BE CLEANED OUT AT THE COMPLETION OF THE PROJECT AND ANY MATERIAL REMOVED SHALL BE PROPERLY DISPOSED OF. IN ADDITION, INLET PROTECTION MUST BE PROVIDED FOR ALL EXISTING CATCH BASINS. CB INSERTS OR ACCEPTABLE ALTERNATIVE CAN BE USED.

DURING ANY DITCH, CREEK & DRAINAGE WORK WATER SHALL BE DIVERTED AROUND THE PROJECT WITH A PUMP OR OTHER ADEQUATE METHOD APPROVED BY THE ENGINEER.

ANY MISCELLANEOUS DRAINAGE FOUND WILL BE REQUIRED TO BE REMOVED OR CONNECTED TO THE NEW DRAINAGE SYSTEM WITH THE DIRECTION OF THE ENGINEER.

STORMWATER PERMIT & EROSION CONTROL PLAN TO BE SUBMITTED BY THE CONTRACTOR. CONTRACTOR SHALL SUPPLY DETAILS ON CONSTRUCTION TIMING, HAUL ROUTES AND CONSTRUCTION ENTRANCES, AND GROUND STABILIZATION.

BEDDING AND BACKFILL FOR PVC STORM MAIN PIPE SHALL CONFORM TO STANDARD PLAN SE–4.

EROSION CONTROL NOTES

THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE INSTALLATION, MAINTENANCE AND REMOVAL OF ALL EROSION CONTROL MEASURES (SILT FENCE, STRAW BALE DAMS, SILT PONDS, ETC., AS DIRECTED BY THE ENGINEER) THROUGHOUT THE DURATION OF THE PROJECT.

IN THE EVENT MATERIALS ARE INADVERTENTLY DEPOSITED ON ROADWAYS, THE MATERIAL SHALL BE PROMPTLY REMOVED. MATERIALS ARE TO BE SWEPT AND REMOVED PRIOR TO ANY STREET FLUSHING. PUBLIC AND PRIVATE DRAINAGE WAYS SHALL BE PROTECTED FROM POLLUTION. NO MATERIAL IS TO BE DISCHARGED OR DEPOSITED IN STORMWATER SYSTEMS THAT MAY RESULT IN VIOLATION OF STATE OR FEDERAL WATER QUALITY STANDARDS.

ALL CATCH BASINS WITHIN THE PROJECT LIMITS SHALL BE CLEANED OUT AT THE COMPLETION OF THE PROJECT AND ANY MATERIAL REMOVED SHALL BE PROPERLY DISPOSED OF. IN ADDITION, INLET PROTECTION MUST BE PROVIDED FOR ALL EXISTING CATCH BASINS DURING CONSTRUCTION.

DURING ANY DITCH, CREEK & DRAINAGE WORK WATER SHALL BE DIVERTED AROUND THE PROJECT WITH A PUMP OR OTHER ADEQUATE METHOD APPROVED BY THE ENGINEER.

ANY MISCELLANEOUS DRAINAGE FOUND WILL BE REQUIRED TO BE REMOVED OR CONNECTED TO THE NEW DRAINAGE SYSTEM WITH THE DIRECTION OF THE ENGINEER.

NO EARTHWORK, INCLUDING CLEANING OF VEGETATION, GRADING FILLING, EXCAVATION OR TRENCHING OF SOIL OR EARTH MATERIALS THAT WILL RESULT IN AN EXPOSED EARTH AREA THAT EXCEEDS 500 SQ.FT. SHALL BE PERMITTED FROM OCTOBER 1ST THROUGH APRIL 30TH.

STABILIZE SOILS– ALL EXPOSED AND UNWORKED SOILS SHALL BE STABILIZED BY APPLICATION OF EFFECTIVE BEST MANAGEMENT PRACTICES, THAT PROTECT THE SOIL FROM THE EROSIVE FORCES OF WATER & WIND EROSION. NO UNWORKED SOILS SHALL REMAIN EXPOSED FOR MORE THAN SEVEN (7) DAYS.

SAWCUTTING– SLURRY AND CUTTINGS SHALL BE VACUUMED DURING CUTTING AND SURFACING OPERATIONS. SLURRY AND CUTTINGS SHALL NOT REMAIN ON PAVEMENT OVERNIGHT.

NO EARTHWORK, INCLUDING CLEARING OF VEGETATION, GRADING, FILLING, EXCAVATING OR TRENCHING OF SOIL OR EARTH MATERIALS, THAT WILL RESULT IN AN EXPOSED SOIL OR EARTH AREA THAT EXCEEDS 500 SQUARE FEET SHALL BE PERMITTED FROM OCTOBER 1st THROUGH APRIL 30th WITHIN THE SILVER BEACH NEIGHBORHOOD, EXCEPT AREAS 11 AND 15.

RORY A. ROUTHE
31979
3/2/07
EXPIRES: 3/4/08

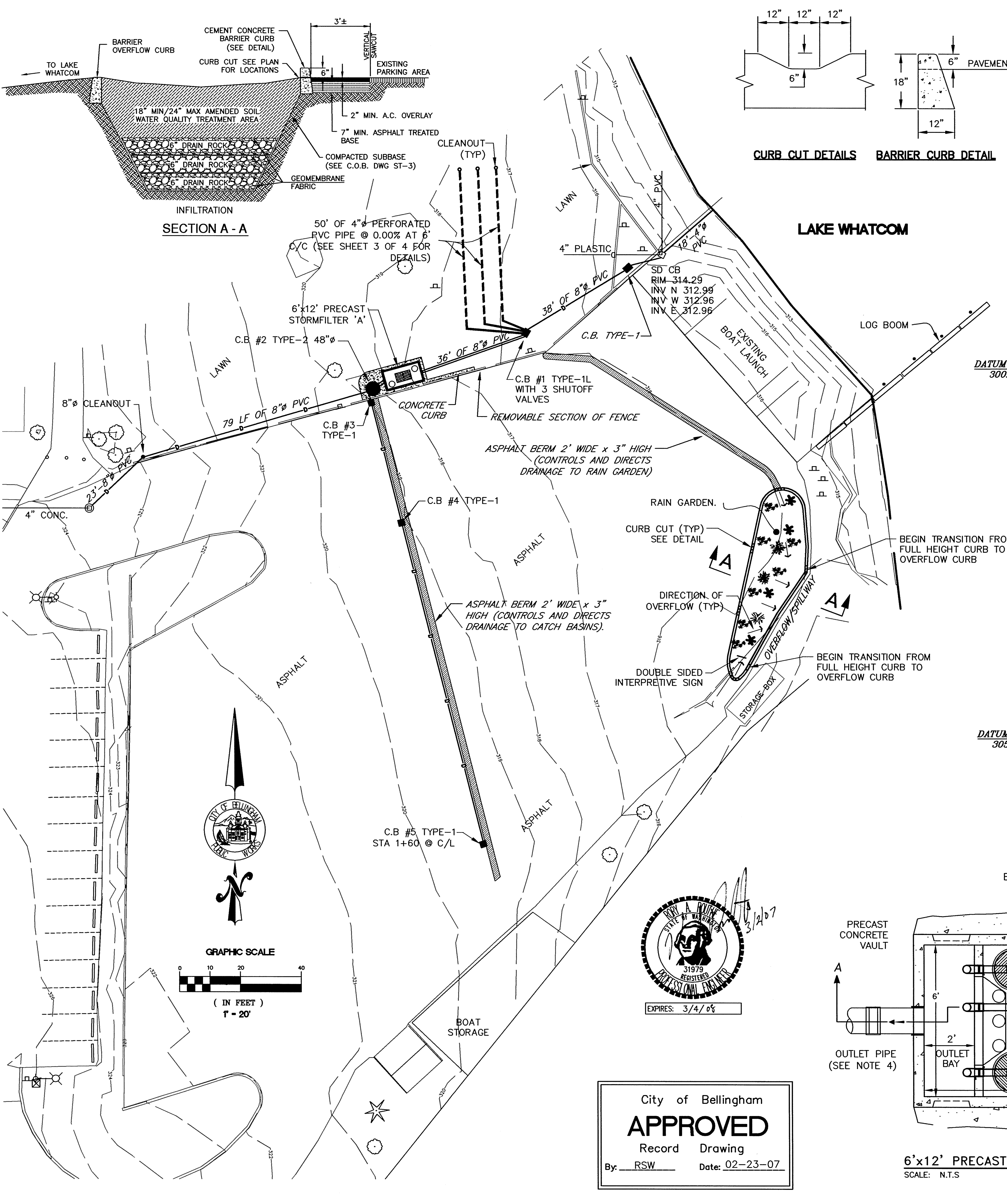
SHEET INDEX

1-COVER SHEET
2-PLAN/PROFILE PARKING LOT/ LAKE FRONT
3-PLAN/PROFILE PARKING LOT / ELECTRIC AVE.
4-PLAN/PROFILE INTERSEC. ALABAMA ST. / ELECTRIC AVE.

City of Bellingham
APPROVED
Record Drawing
By: RSW Date: 02-23-07

SHEET 1 OF 4

CITY OF BELLINGHAM – ENGINEERING DEPARTMENT – 210 LOTTIE STREET – BELLINGHAM WASHINGTON 98225   PARENT DRIVE & DIRECTORY: EV-20 RECORD DWG   DRAWING NAME: EV20.DWG   LAST UPDATED: 02-23-07



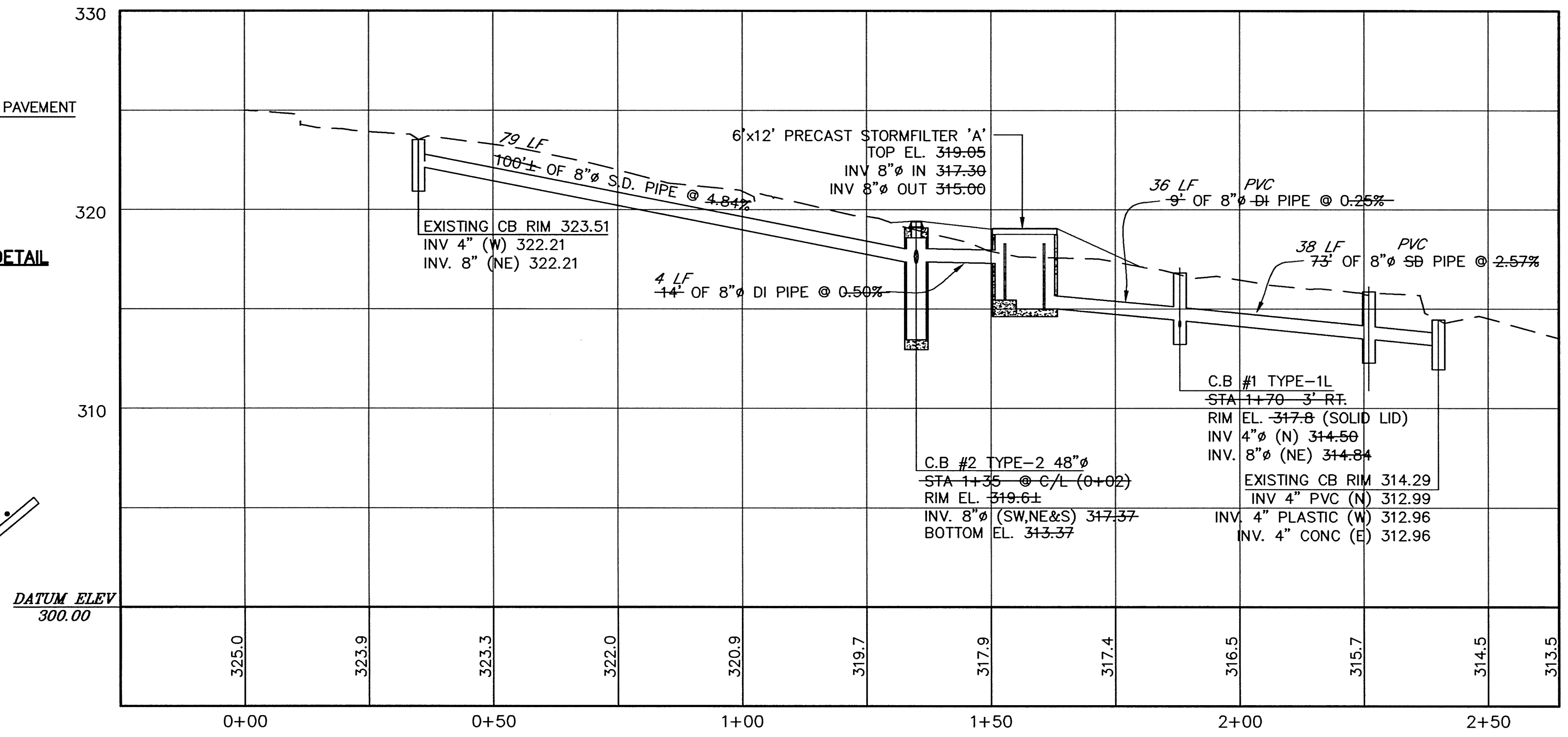
SECTION A - A

CURB CUT DETAILS

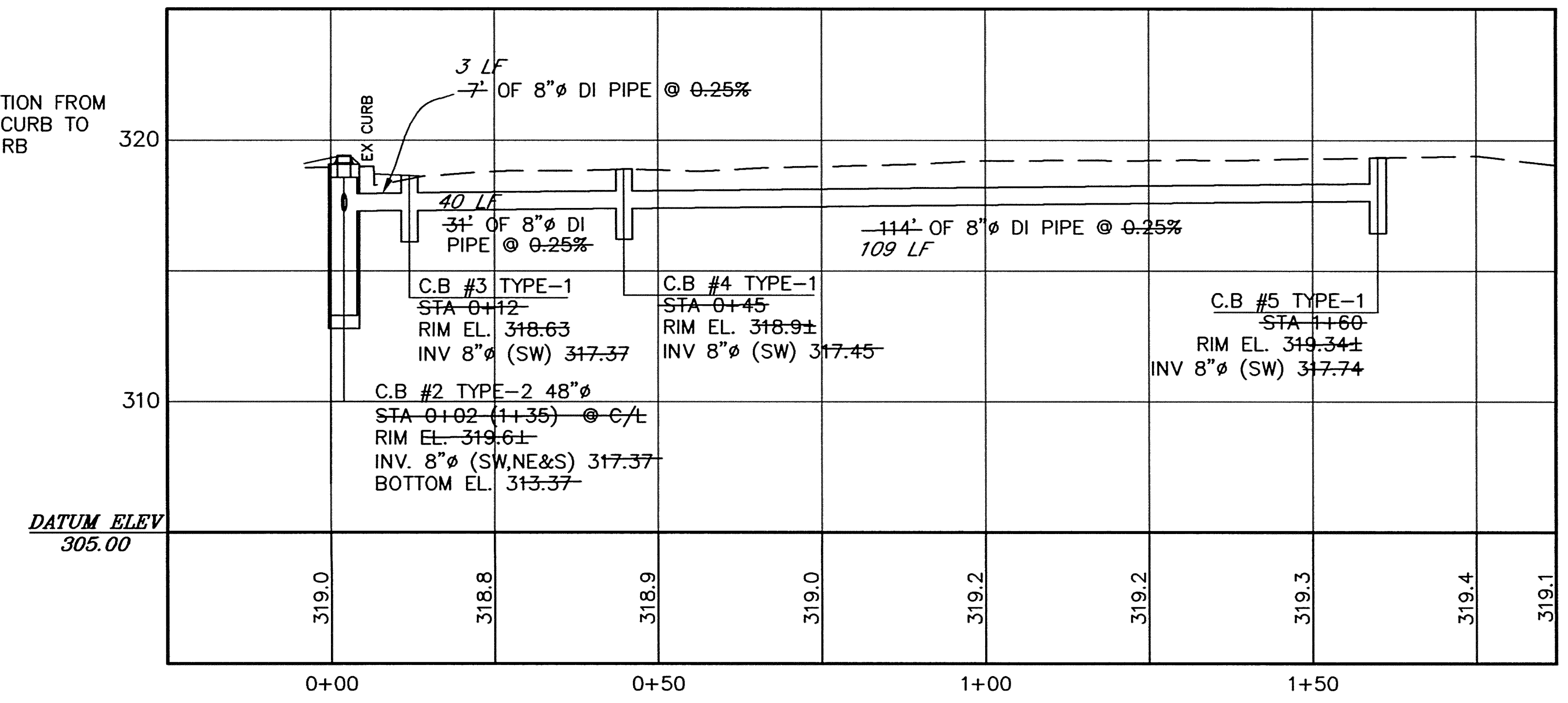
BARRIER CURB DETAIL

City of Bellingham
APPROVED
Record Drawing
By: RSW   Date: 02-23-07

31979
EXPIRES: 3/4/08



NORTH EDGE DRAINAGE



PARKING LOT DRAINAGE

GENERAL NOTES

1.) STORMFILTER BY STORMWATER MANAGEMENT, PORTLAND, OREGON (503-240-3393).

2.) ALL STORMFILTERS REQUIRE REGULAR MAINTENANCE. REFER TO OPERATION AND MAINTENANCE GUIDELINES FOR DETAILS.

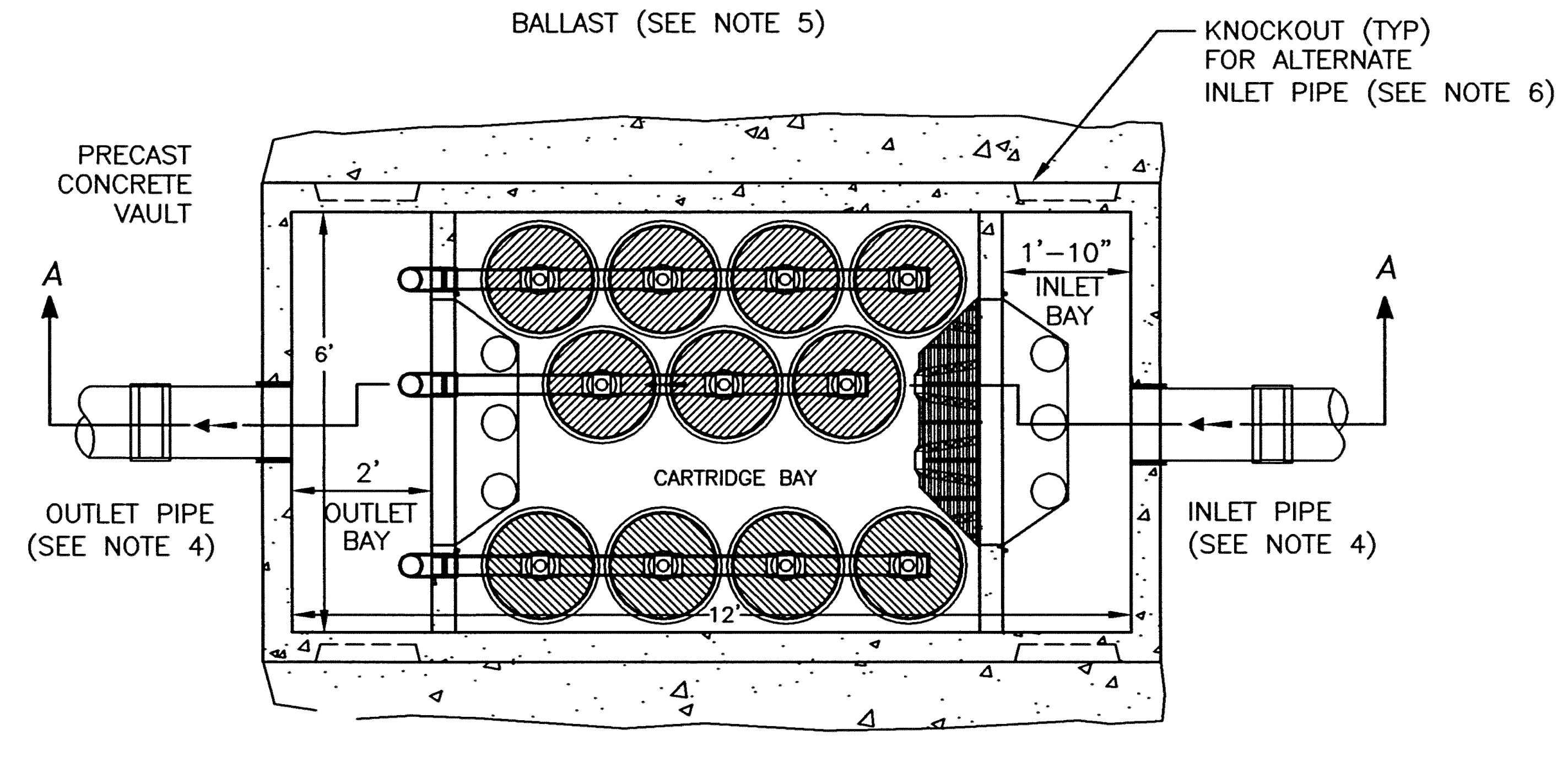
3.) PRECAST CONCRETE VAULT TO BE CONSTRUCTED IN ACCORDANCE WITH ASTM C858.

4.) INLET AND OUTLET PIPING TO BE SPECIFIED BY ENGINEER AND PROVIDED BY CONTRACTOR.

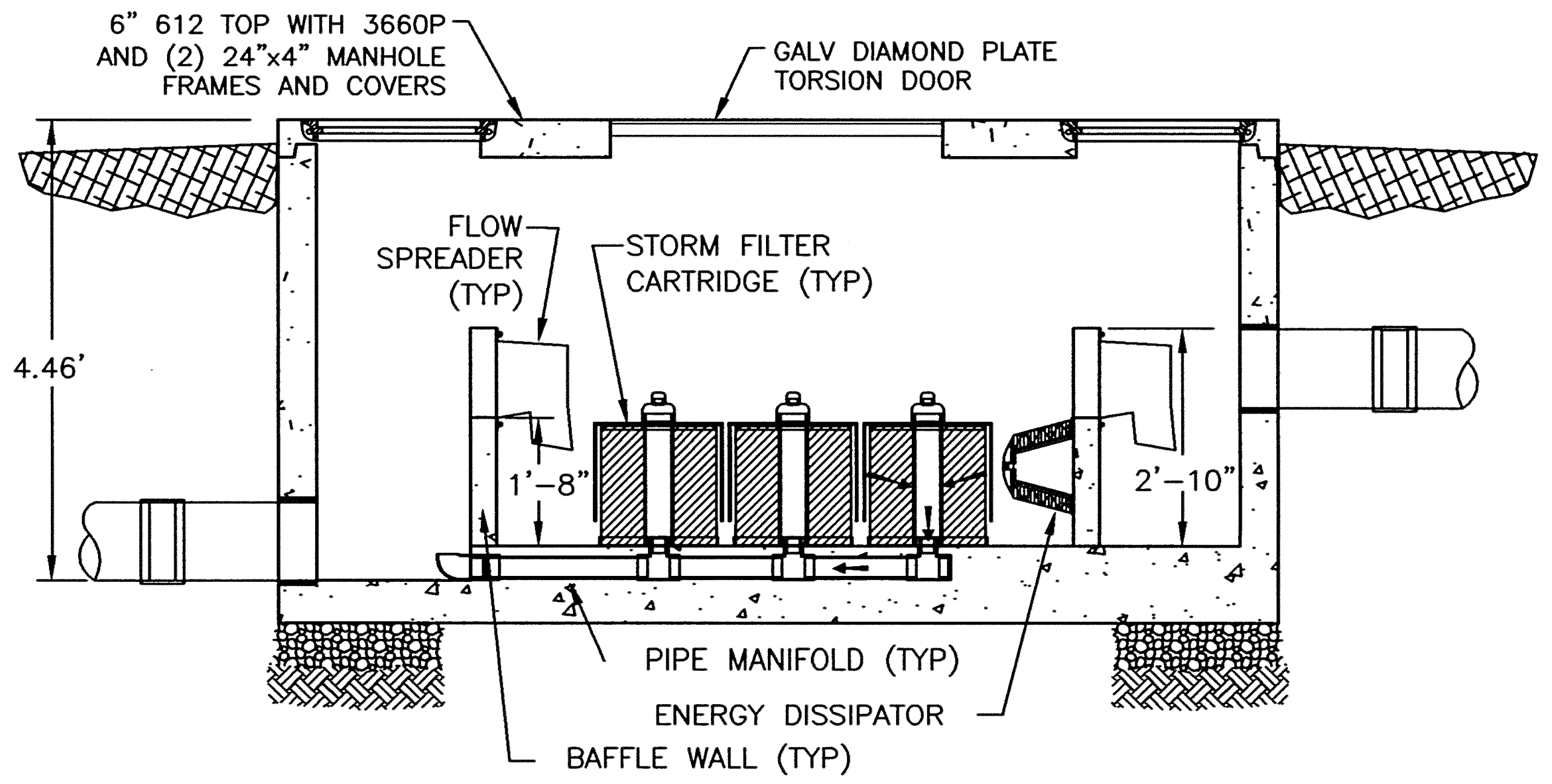
5.) ANTI-FLOATATION BALLAST TO BE SPECIFIED BY ENGINEER. BALLAST TO BE SET ALONG ENTIRE LENGTH OF BOTH SIDES OF VAULT. BALLAST MATERIALS TO BE PROVIDED BY CONTRACTOR.

6.) PRECAST STORMFILTER EQUIPPED WITH KNOCKOUTS AT ALT. INLET/OUTLET LOCATIONS. CORINGS AVAILABLE WHEN SPECIFIED.

7.) DETAIL REFLECTS DESIGN INTENT ONLY. ACTUAL VAULT DIMENSIONS AND CONFIGURATION WILL BE SHOWN ON THE PRODUCTION SHOP DRAWING.



6'x12' PRECAST STORMFILTER™– PLAN VIEW (1/1)
SCALE: N.T.S



6'x12' PRECAST STORMFILTER™– SECTION A-A (A-A/1)
SCALE: N.T.S

Date	No	Revision	By
	4		
	3		
	2		
03.16.04	1	RECORD DRAWING	DFO

PROJECT ENGINEER K.N.C.
DESIGNED/DRAWN D.F.O.
INSPECTOR

DIR. PUBLIC WORKS R.E.M.
CITY ENGINEER R.A.R.
OPER. ENGINEER T.L.R.

CITY OF BELLINGHAM, WASHINGTON
PUBLIC WORKS DEPARTMENT
ENGINEERING DIVISION

SCALE
Horiz. 1"=20'
Vert. 1"= 5'

DATUM
CITY

Job. No. EV-0020
Date 07/07/03
Field Bk.

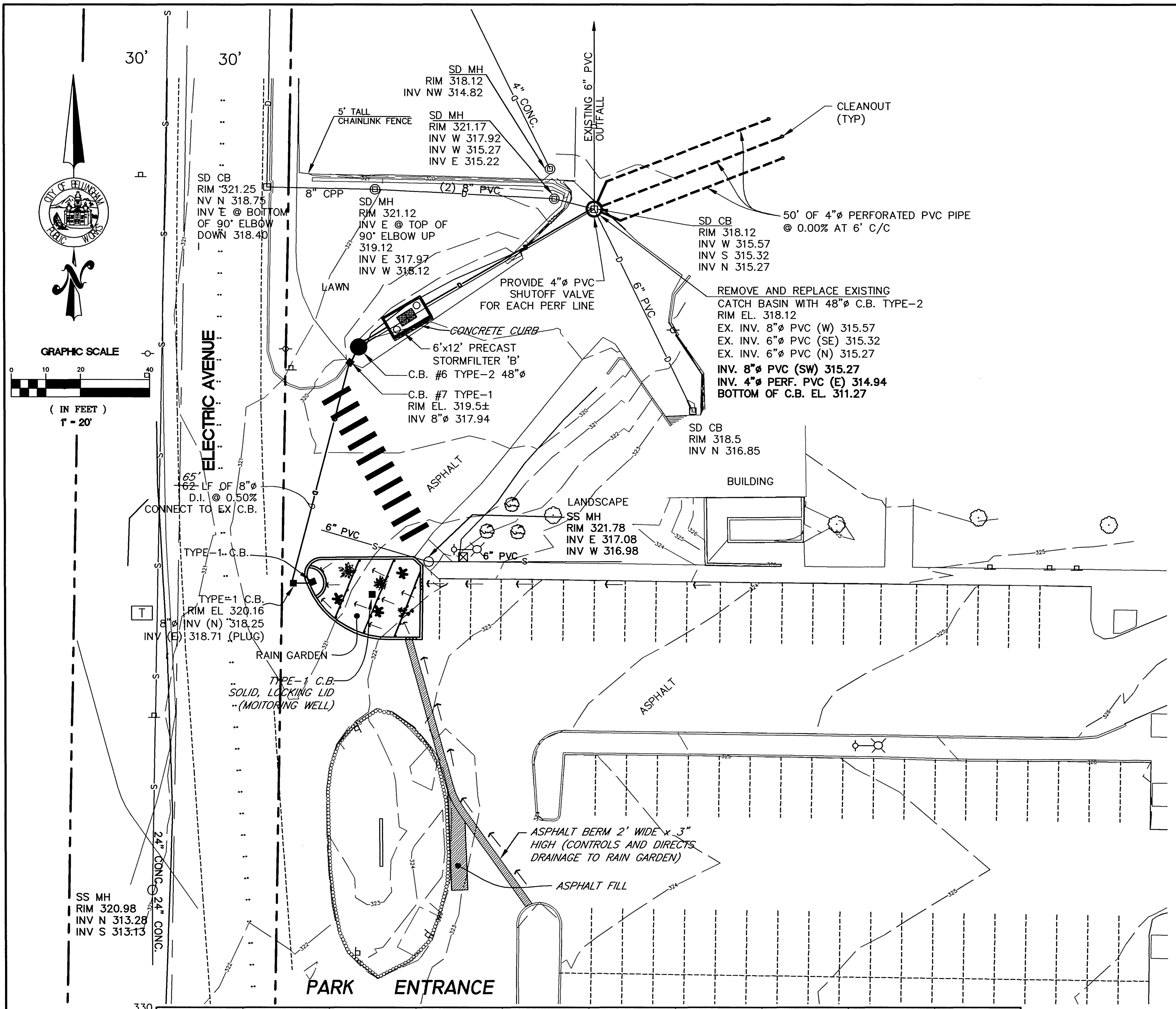
NORTH SHORE WATER QUALITY PROJECT
PARKING LOT - LAKE FRONT

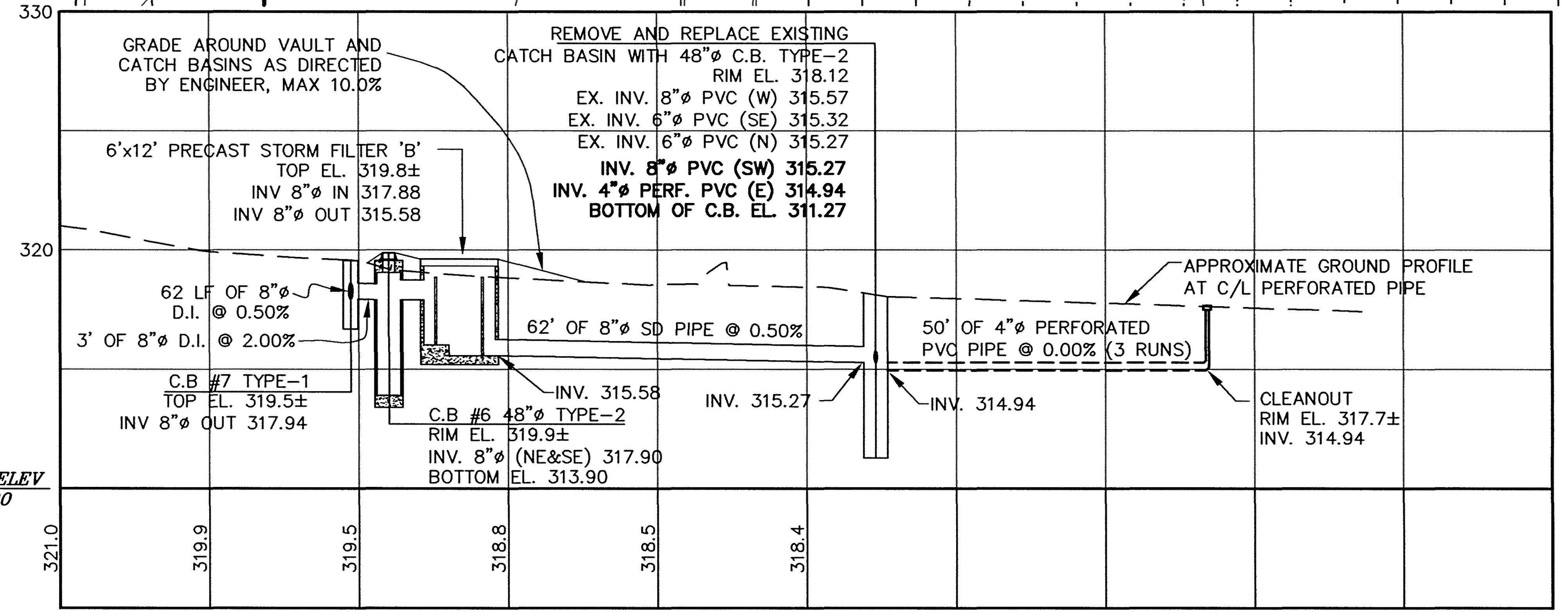
SHEET 2 **OF** 4

CONTACT PERSON: KIRK CHRISTENSEN , PROJECT ENGINEER AT 676-6961

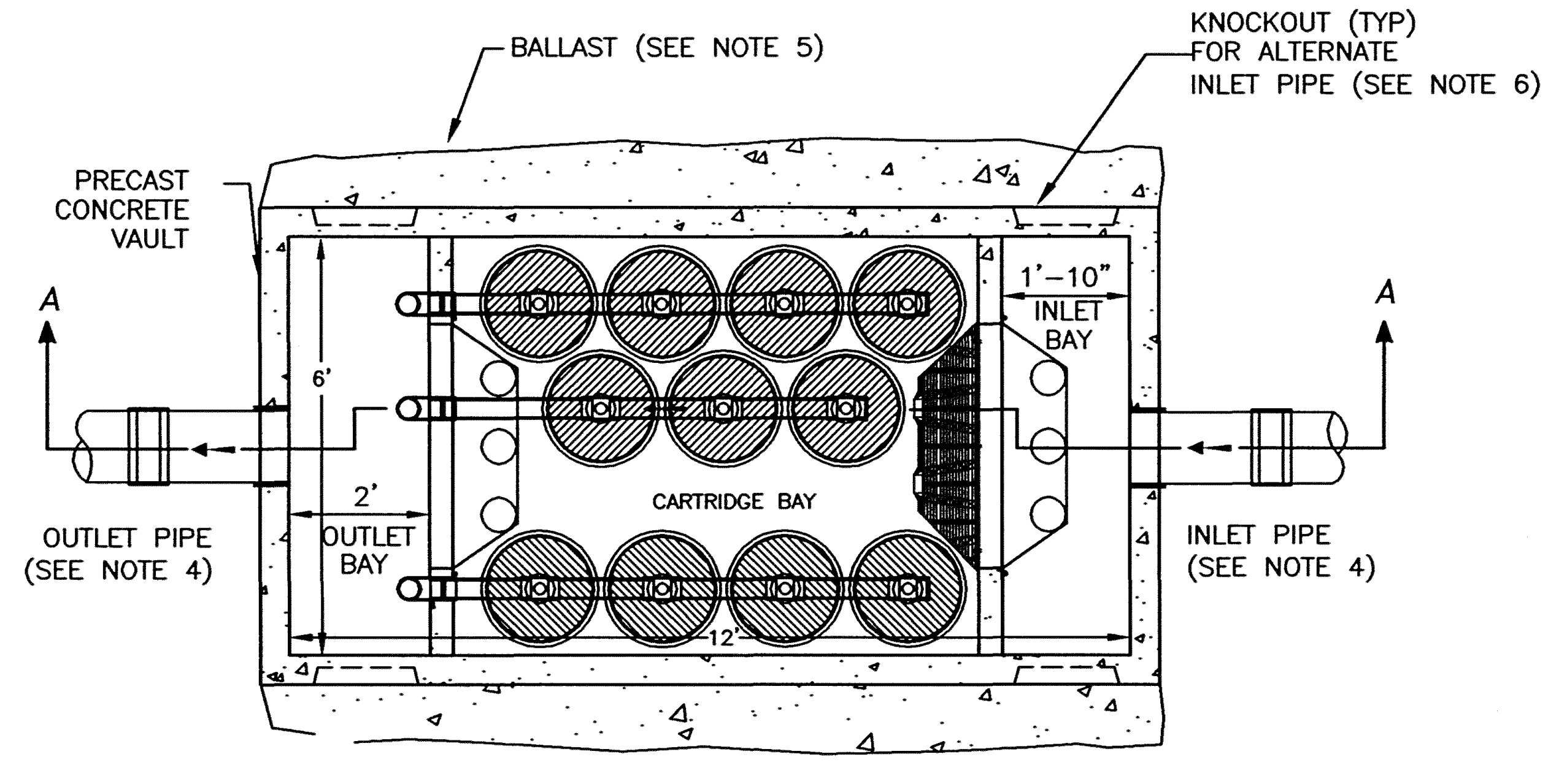
V0020-02

CITY OF BELLINGHAM – ENGINEERING DEPARTMENT – 210 LOTTIE STREET – BELLINGHAM WASHINGTON 98225   PARENT DRIVE & DIRECTORY: EV-20 RECORD DWG   DRAWING NAME: EV20.DWG   LAST UPDATED: 02-23-07

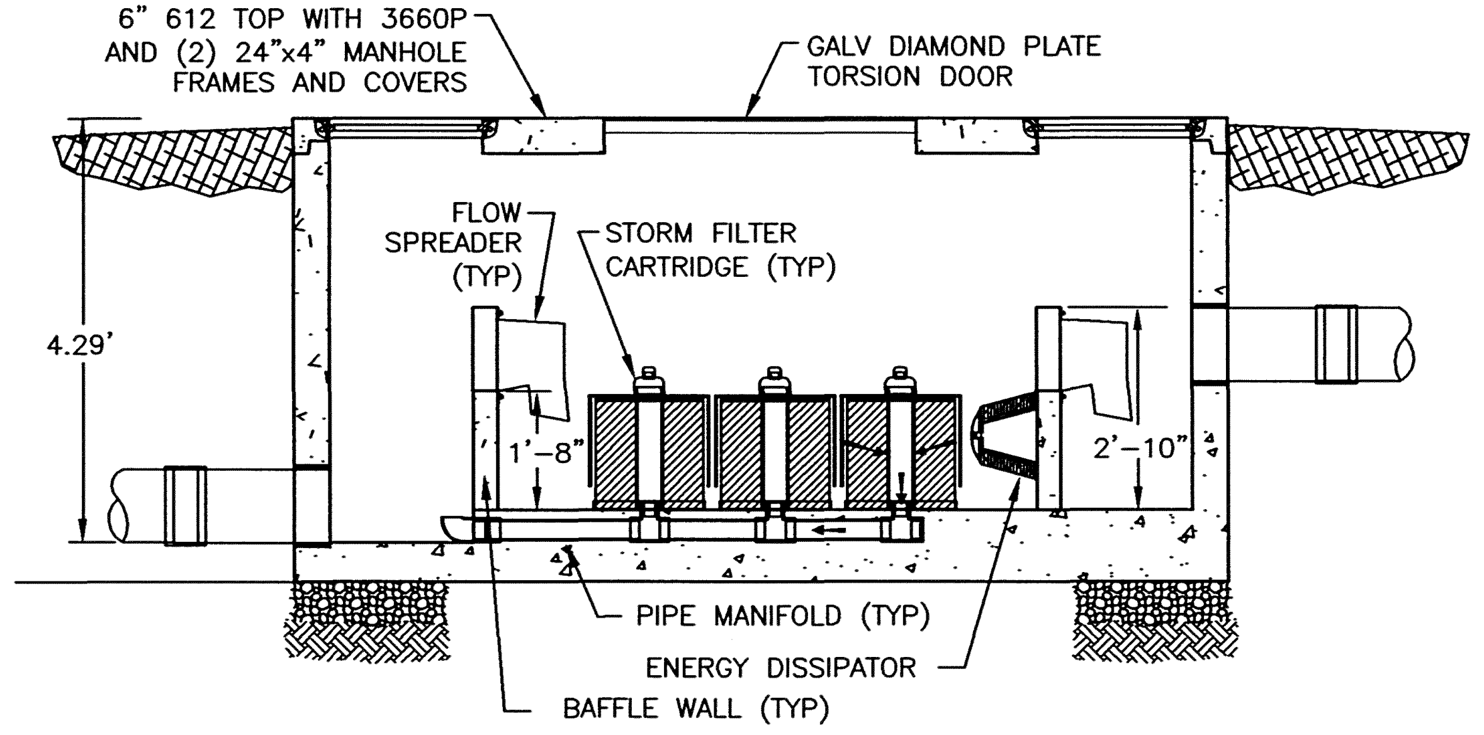




DRAINAGE PROFILE



6'x12' PRECAST STORMFILTER™– PLAN VIEW (1/1)
SCALE: N.T.S



6'x12' PRECAST STORMFILTER™– SECTION A–A (A–A/1)
SCALE: N.T.S

GENERAL NOTES

1.) STORMFILTER BY STORMWATER MANAGEMENT, PORTLAND, OREGON (503-240-3393).

2.) ALL STORMFILTERS REQUIRE REGULAR MAINTENANCE. REFER TO OPERATION AND MAINTENANCE GUIDELINES FOR DETAILS.

3.) PRECAST CONCRETE VAULT TO BE CONSTRUCTED IN ACCORDANCE WITH ASTM C858.

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5.) ANTI-FLOATATION BALLAST TO BE SPECIFIED BY ENGINEER. BALLAST TO BE SET ALONG ENTIRE LENGTH OF BOTH SIDES OF VAULT. BALLAST MATERIALS TO BE PROVIDED BY CONTRACTOR.

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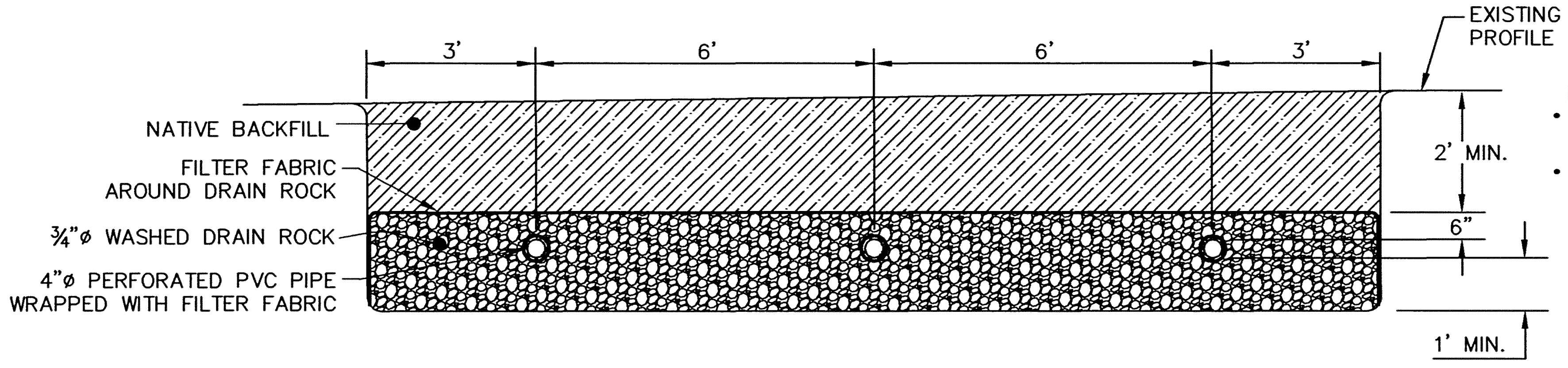
7.) DETAIL REFLECTS DESIGN INTENT ONLY. ACTUAL VAULT DIMENSIONS AND CONFIGURATION WILL BE SHOWN ON THE PRODUCTION SHOP DRAWING.



NOTE:
- DRAINFIELD MAY BE ENLARGED AS DIRECTED BY ENGINEER
- REMOVE SOD WITH SODCUTTER, SET ASIDE FOR REINSTALLATION, (KEEP WATERED). HYDROSEED OR REPLACE WITH NEW SOD AS NECESSARY.

INFILTRATION TRENCH DETAILS
NTS

3/2/07
31979
EXPIRES: 3/4/08

City of Bellingham
APPROVED
Record Drawing
By: RSW Date: 02-23-07

Date	No	Revision	By
	4		
	3		
	2		
03.16.04	1	RECORD DRAWING	DFO

PROJECT ENGINEER K.N.C.
DESIGNED/DRAWN D.F.O.
INSPECTOR

DIR. PUBLIC WORKS R.E.M.
CITY ENGINEER R.A.R.
OPER. ENGINEER T.L.R.

CITY OF BELLINGHAM, WASHINGTON
PUBLIC WORKS DEPARTMENT
ENGINEERING DIVISION

SCALE
Horiz. 1"=20'
Vert. 1"= 5'

DATUM
CITY

Job. No. EV-0020
Date 07/07/03
Field Bk.

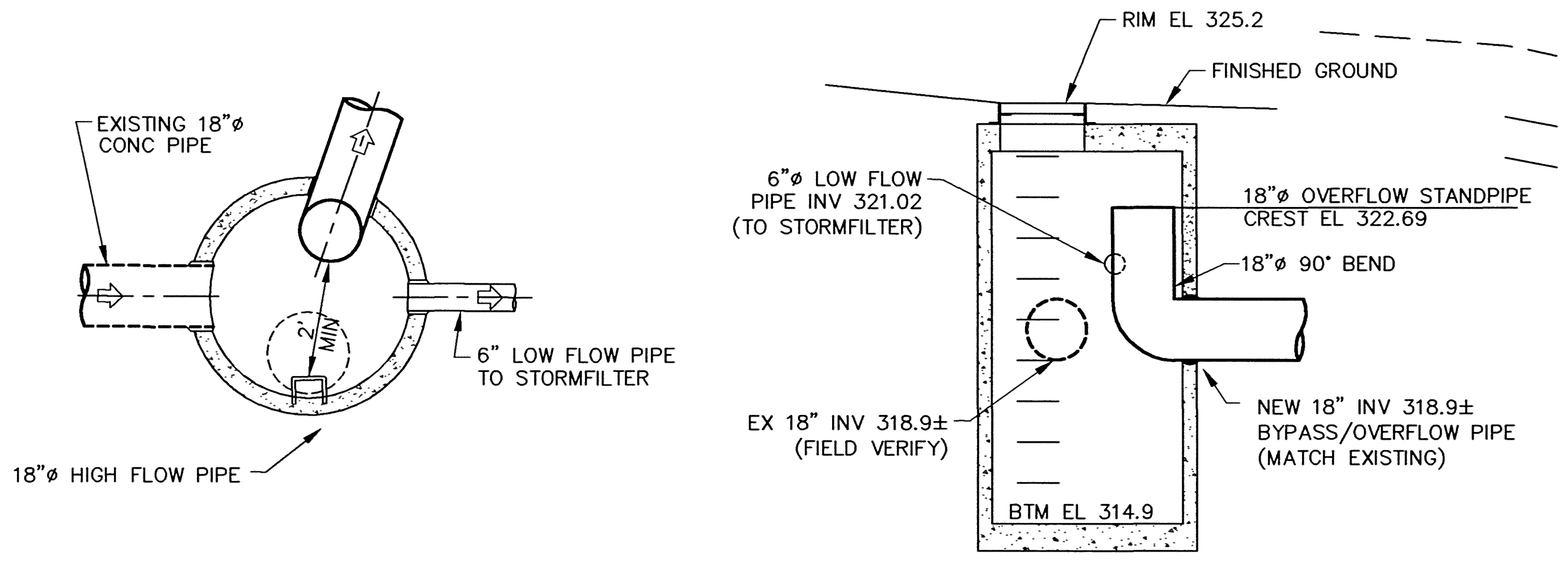
NORTH SHORE WATER QUALITY PROJECT
PARKING LOT - ELECTRIC AVENUE

SHEET 3 OF 4

CONTACT PERSON: KIRK CHRISTENSEN , PROJECT ENGINEER AT 676-6961

V0020-03

CITY OF BELLINGHAM - ENGINEERING DEPARTMENT - 210 LOTTIE STREET - BELLINGHAM WASHINGTON 98225 PARENT DRIVE & DIRECTORY: EV-20 RECORD DWG DRAWING NAME: EV20.DWG LAST UPDATED: 02-23-07

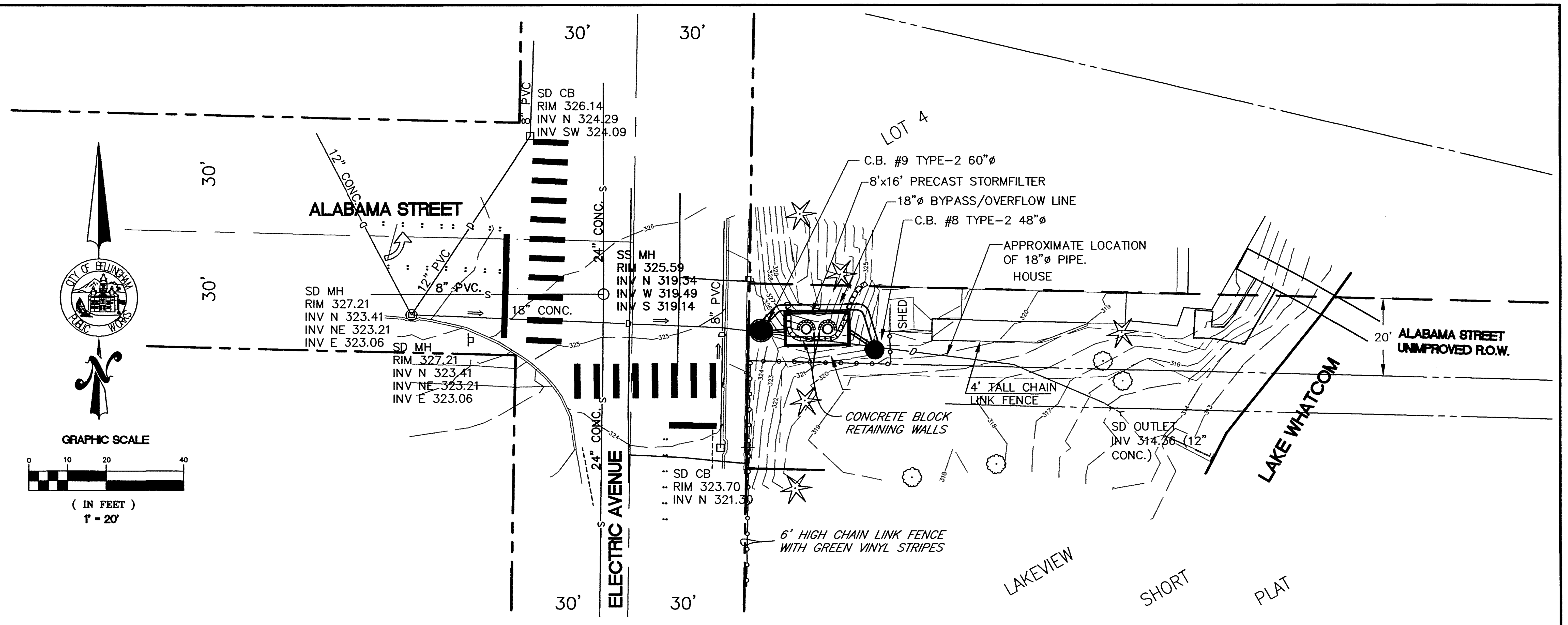


PLAN

SECTION

60"ø C.B. #9

NTS



GENERAL NOTES

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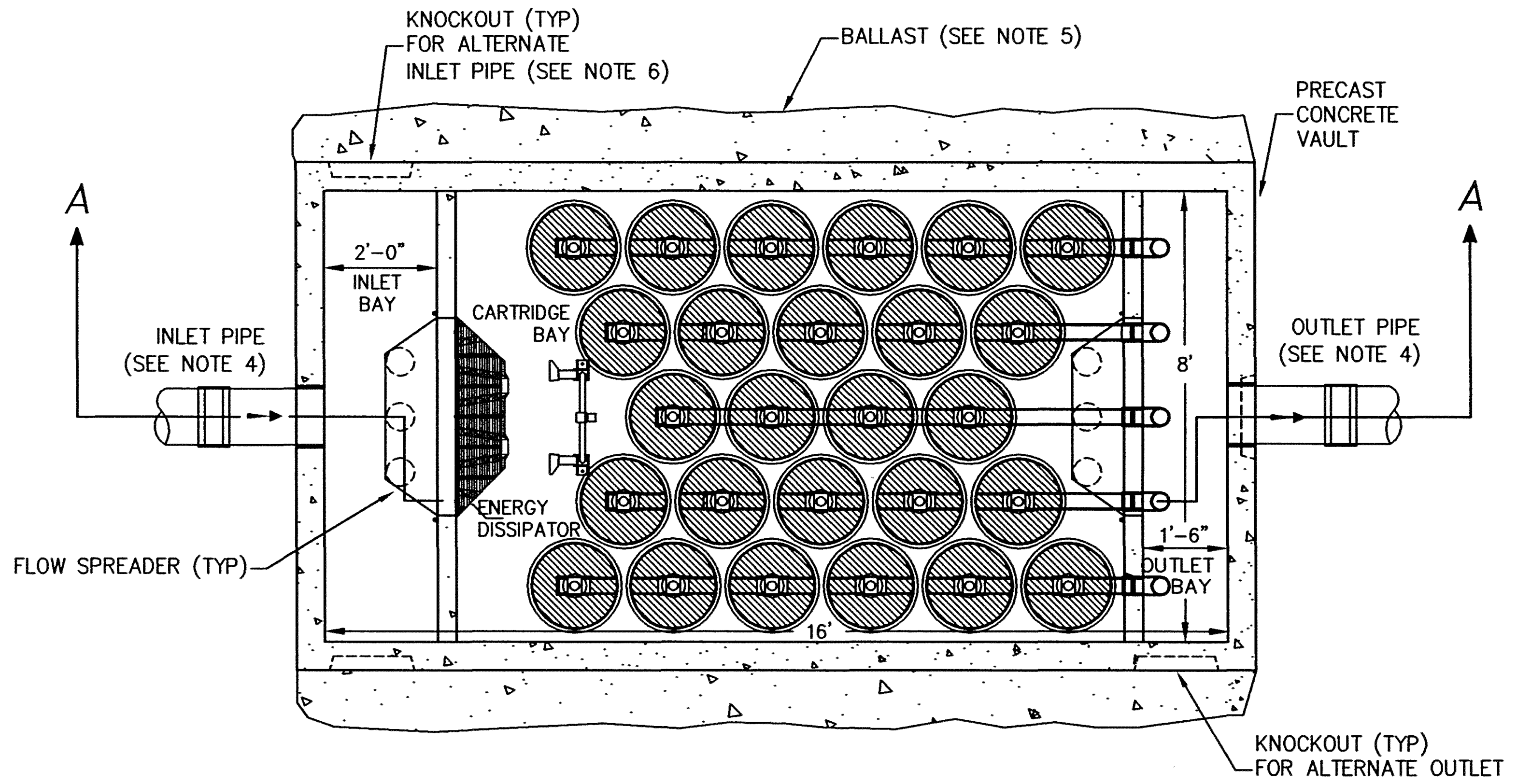
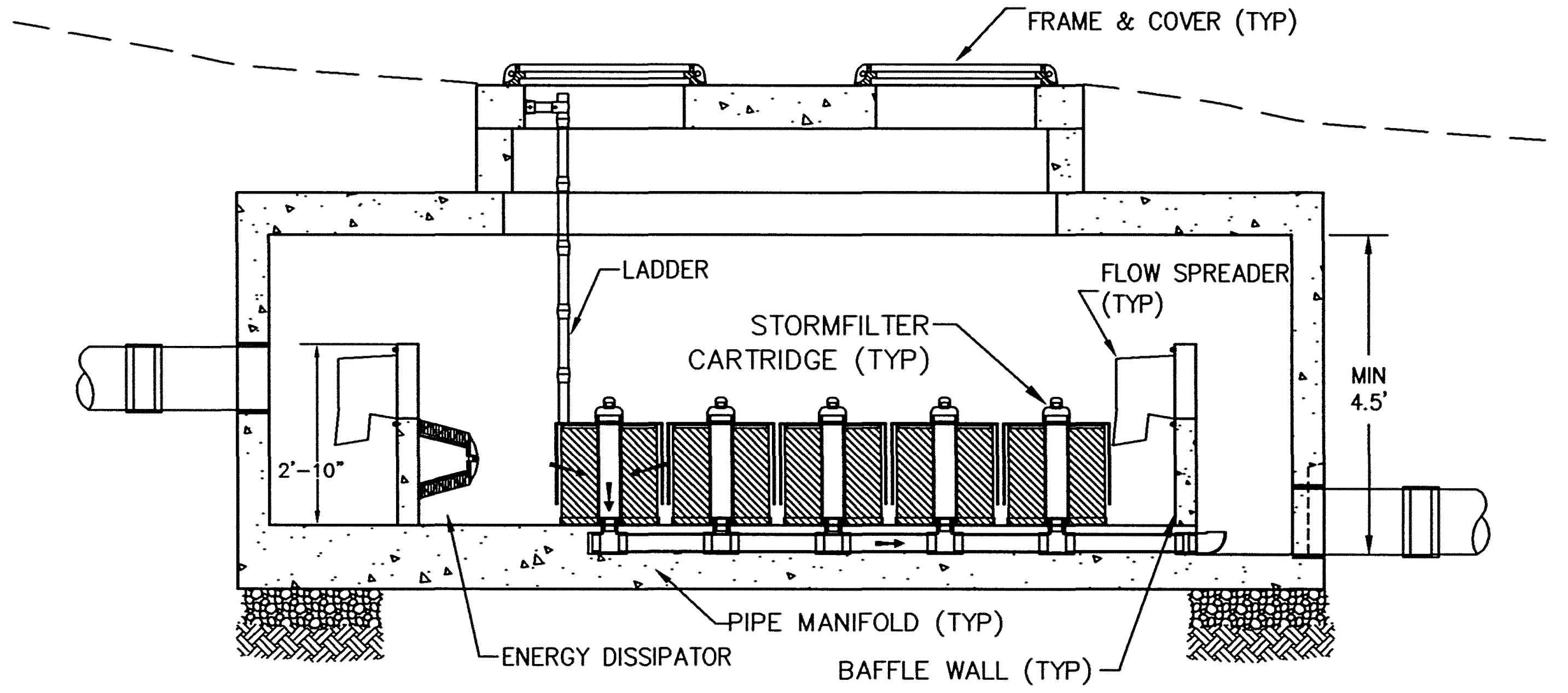


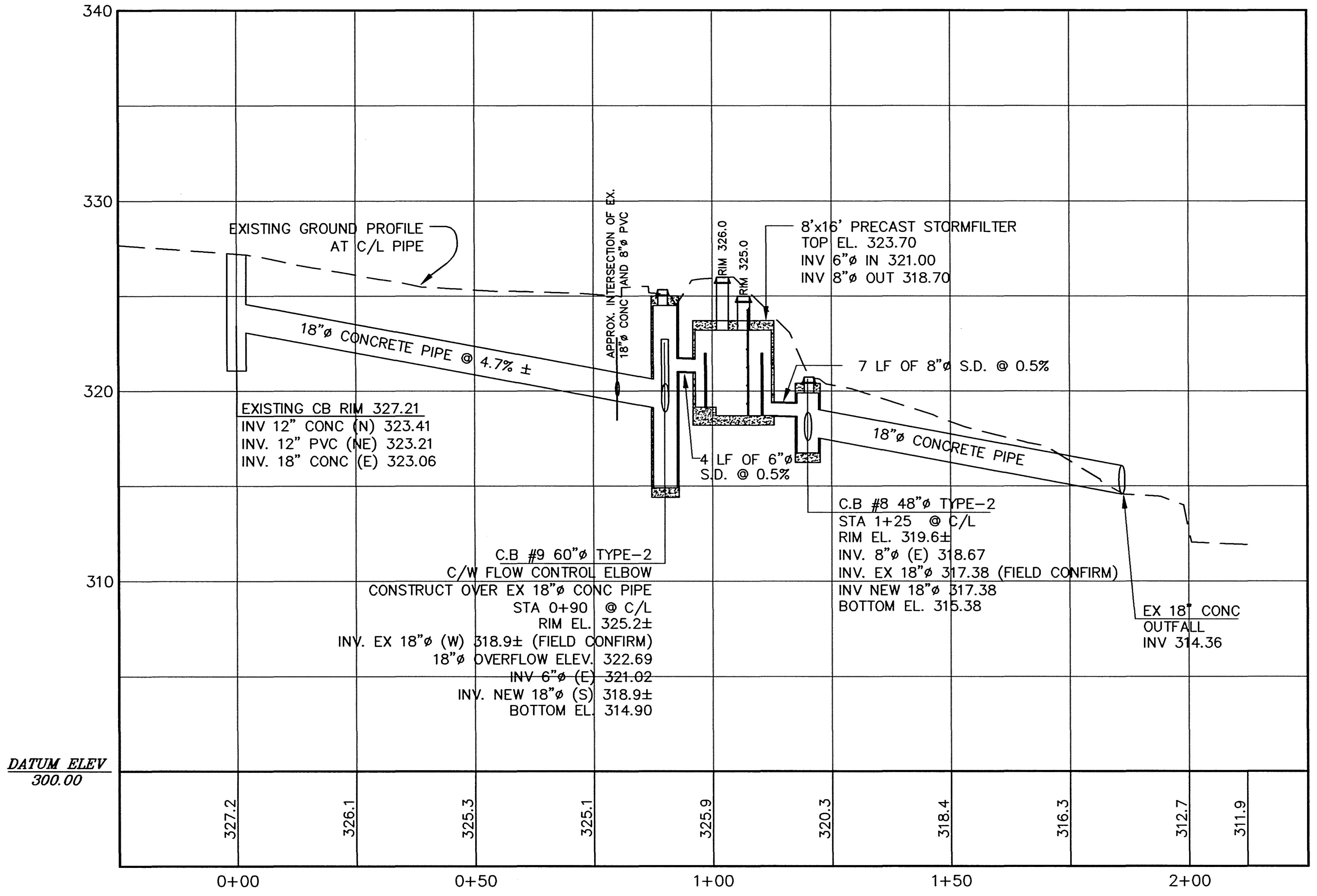
1/1 8'x16' PRECAST STORMFILTER – PLAN VIEW

SCALE: N.T.S.



A-A/1 8'x16' PRECAST STORMFILTER™ – SECTION VIEW

SCALE: N.T.S.



DRAINAGE PROFILE

31979 3/2/07

EXPIRES: 3/4/08

City of Bellingham
APPROVED
Record Drawing
By: RSW Date: 02-23-07

	4		
	3		
	2		
03.16.04	1	RECORD DRAWING	DFO
Date	No	Revision	By

PROJECT ENGINEER K.N.C.
DESIGNED/DRAWN D.F.O.
INSPECTOR

DIR. PUBLIC WORKS R.E.M.
CITY ENGINEER R.A.R.
OPER. ENGINEER T.L.R.

CITY OF BELLINGHAM, WASHINGTON
PUBLIC WORKS DEPARTMENT
ENGINEERING DIVISION

SCALE
Horiz. 1"=20'
Vert. 1"= 5'

DATUM
CITY

Job. No. EV-0020
Date 07/07/03
Field Bk.

NORTH SHORE WATER QUALITY PROJECT
ELECTRIC/ALABAMA

SHEET 4 OF 4

CONTACT PERSON: KIRK CHRISTENSEN, PROJECT ENGINEER AT 676-6961

V0020-04

APPENDIX B

Current Study Exploration Logs and Laboratory Testing Data

Cell BDP
Exploration Latitude and Longitude

Exploration	Latitude	Longitude
BDP-HA-1	48.76025	-122.42065
BDP-HA-2	48.76030	-122.42059
BDP-HA-3	47.76024	-122.42658

associated earth sciences incorporated

Exploration Log

Project Number	Exploration Number	Sheet
KH150387A	BDP-HA-1	1 of 1

Project Name: Bioretention Hydrologic Performance Study
Location: Bellingham, Wa
Driller/Equipment: Hand Auger
Hammer Weight/Drop: N/A

Ground Surface Elevation (ft):
Datum: N/A
Date Start/Finish: 7/29/16,7/29/16
Hole Diameter (in): 4 inches

Depth (ft)	S T	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot 10 20 30 40	Other Tests
				Bioretention Soil Mix					
				Surface: leaf litter					
				Loose, slightly moist, dark brown, SAND, trace silt; organics present; mostly medium sand (~62 percent) (SP).					
				Geomembrane fabric over drain rock.					
				Drain Rock					
				Loose rounded gravel (~1 to 1.5 inches) (GP).					
				Bottom of exploration boring at 1.8 feet Refusal due to caving gravel. No seepage.					
				Note: Encountered geomembrane fabric at 1.7 feet. Cut and folded back a flap of material. Replaced flap of material during backfill.					

Sampler Type (ST):

- ▯ 2" OD Split Spoon Sampler (SPT)
- ▯ 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- ☐ No Recovery
- ◧ Ring Sample
- ▨ Shelby Tube Sample
- M - Moisture
- ▽ Water Level ()
- ▼ Water Level at time of drilling (ATD)

Logged by: ADY
Approved by: JHS

associated earth sciences incorporated

Exploration Log

Project Number	Exploration Number	Sheet
KH150387A	BDP-HA-2	1 of 1

Project Name Bioretention Hydrologic Performance Study
Location Bellingham, Wa
Driller/Equipment Hand Auger
Hammer Weight/Drop N/A

Ground Surface Elevation (ft)
Datum N/A
Date Start/Finish 7/29/16,7/29/16
Hole Diameter (in) 4 inches

Depth (ft)	S T	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot 10 20 30 40	Other Tests
				Landscaping bark / Topsoil Surface: landscape bark Loose, slightly moist, brown, SAND, trace silt; organics present; mostly medium sand (~62 percent) (SP-SM).					
				Undifferentiated Alluvium Medium dense, slightly moist, grayish brown, gravelly, very silty SAND; cobbles (5 inches) present (SM).					
				Bottom of exploration boring at 2.3 feet Refusal on cobble. No seepage. No caving. Note: Completed adjacent to cell BDP.					

Sampler Type (ST):

▯ 2" OD Split Spoon Sampler (SPT)	☐ No Recovery	M - Moisture
▯ 3" OD Split Spoon Sampler (D & M)	◧ Ring Sample	▽ Water Level ()
✋ Grab Sample	▨ Shelby Tube Sample	▼ Water Level at time of drilling (ATD)

Logged by: ADY
Approved by: JHS

associated earth sciences incorporated

Exploration Log

Project Number	Exploration Number	Sheet
KH150387A	BDP-HA-3	1 of 1

Project Name: Bioretention Hydrologic Performance Study
Location: Bellingham, Wa
Driller/Equipment: Hand Auger
Hammer Weight/Drop: N/A
Ground Surface Elevation (ft):
Datum: N/A
Date Start/Finish: 7/29/16,7/29/16
Hole Diameter (in): 4 inches

Depth (ft)	S T	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot 10 20 30 40	Other Tests
				Bioretention Soil Mix Surface: sand, leaf litter Loose, slightly moist, dark brown, SAND, trace silt; organics present; mostly medium sand (~70 percent) (SP). Geomembrane fabric interpreted as covering drain rock.					
				Bottom of exploration boring at 1.5 feet No seepage. No caving.					

Sampler Type (ST):

▯ 2" OD Split Spoon Sampler (SPT)	☐ No Recovery	M - Moisture	**Logged by:** ADY
▯ 3" OD Split Spoon Sampler (D & M)	◧ Ring Sample	▽ Water Level ()	**Approved by:** JHS
☐ Grab Sample	▨ Shelby Tube Sample	▼ Water Level at time of drilling (ATD)	

associated earth sciences incorporated

Moisture, Ash, and Organic Matter of Peat and Other Organic Soils - ASTM 2974

Date Sampled 7/29/2016	**Project** BHPS	**Project No.** KH150387A		**Soil Description** Bioretention soil mix
Tested By MS	**Location** BDP	**EB/EP No.** BDP	**Depth**	

Moisture Content	**BDP**	**Moisture Content**	**BDP**
Sample ID	**HA1 0.1-0.6**	Sample ID	**HA3 0.7-1**
Wet Weight + Pan	**844.21**	Wet Weight + Pan	**970.27**
Dry Weight + Pan	**786.28**	Dry Weight + Pan	**920.55**
Weight of Pan	**302.57**	Weight of Pan	**307.75**
Weight of Moisture	**57.93**	Weight of Moisture	**49.72**
Dry Weight of Soil	**483.71**	Dry Weight of Soil	**612.80**
% Moisture	**12.0**	% Moisture	**8.1**

Organic Matter and Ash Content		**Organic Matter and Ash Content**	
Dry Soil Befor Burn + Pan	**837.83**	Dry Soil Befor Burn + Pan	**969.02**
Dry Soil After Burn + Pan	**809.38**	Dry Soil After Burn + Pan	**939.46**
Weight of Pan	**348.71**	Weight of Pan	**348.69**
Wt. Loss Due to Ignition	**28.45**	Wt. Loss Due to Ignition	**29.56**
Actual Wt. Of Soil After Burr	**460.67**	Actual Wt. Of Soil After Burr	**590.77**
% Organics	**5.8**	% Organics	**4.8**

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earth sciences
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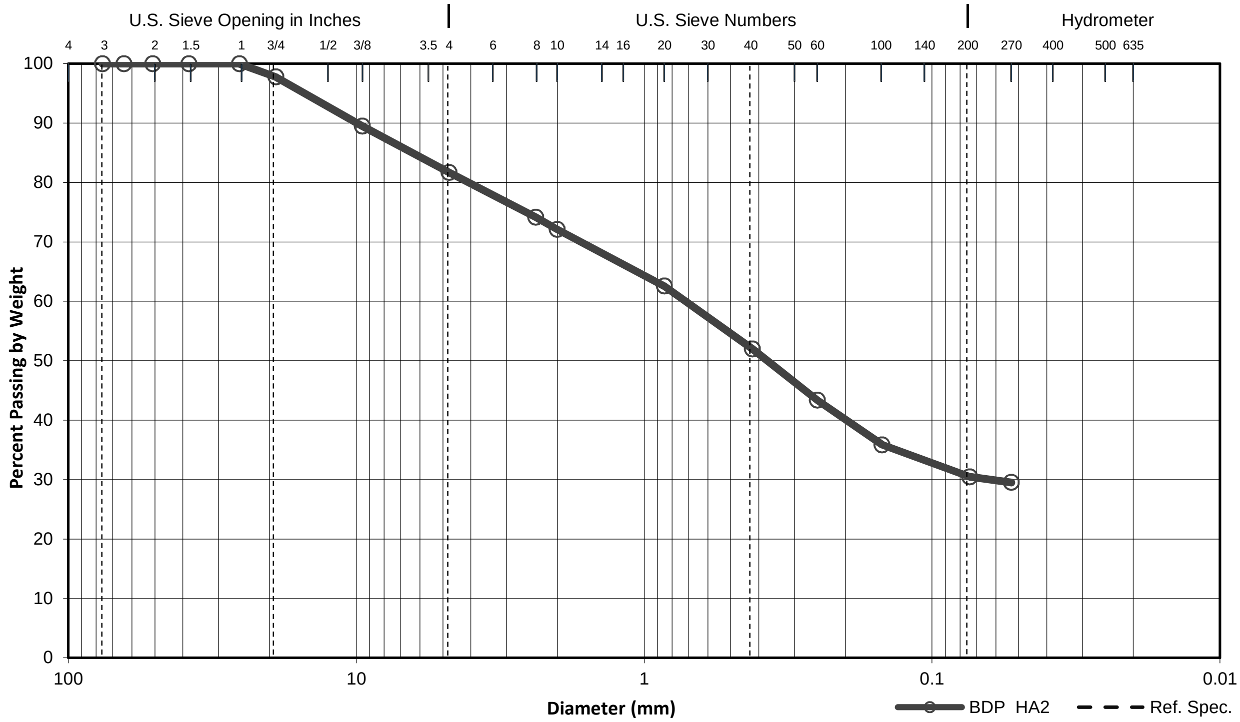
GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

Project Name	Project Number	Date Sampled	Date Tested	Tested By
BHPS	**KH150387A**	**7/29/2016**	**9/1/2016**	**MS**

Sample Source	Sample No.	Depth (ft)	Soil Description
Onsite	**BDP HA2**	**0.8-1.3**	**gravelly, very silty SAND (SM)**

Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification
698.5	**10**	**<0.01**	**Not applicable: native material**



Cobb.	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4		0.0	100.0		
3/4	19	15.6	2.2	97.8		
3/8	9.51	73.3	10.5	89.5		
#4	4.76	127.8	18.3	81.7		
#8	2.38	180.3	25.8	74.2		
#10	2	195.0	27.9	72.1		
#20	0.85	261.4	37.4	62.6		
#40	0.42	335.5	48.0	52.0		
#60	0.25	395.6	56.6	43.4		
#100	0.149	448.0	64.1	35.9		
#200	0.074	485.7	69.5	30.5		
#270	0.053	492.3	70.5	29.5		

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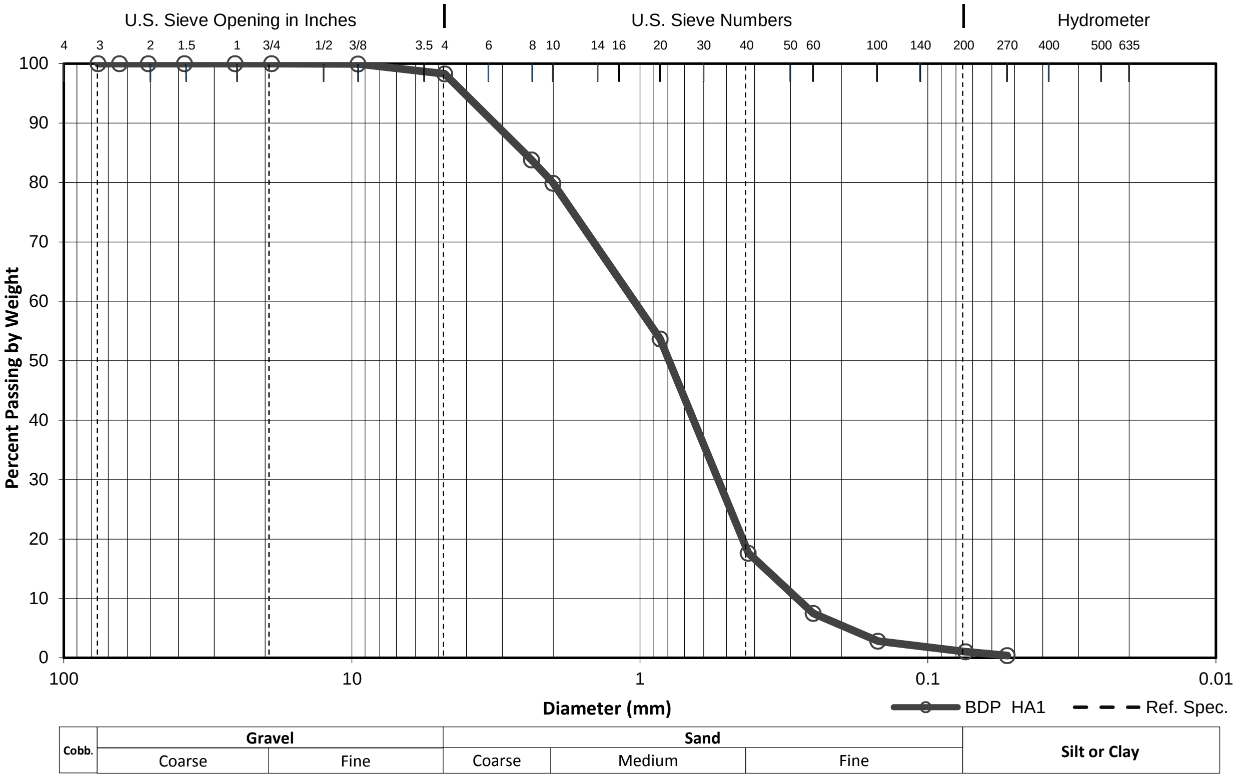
earth sciences
incorporated

GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

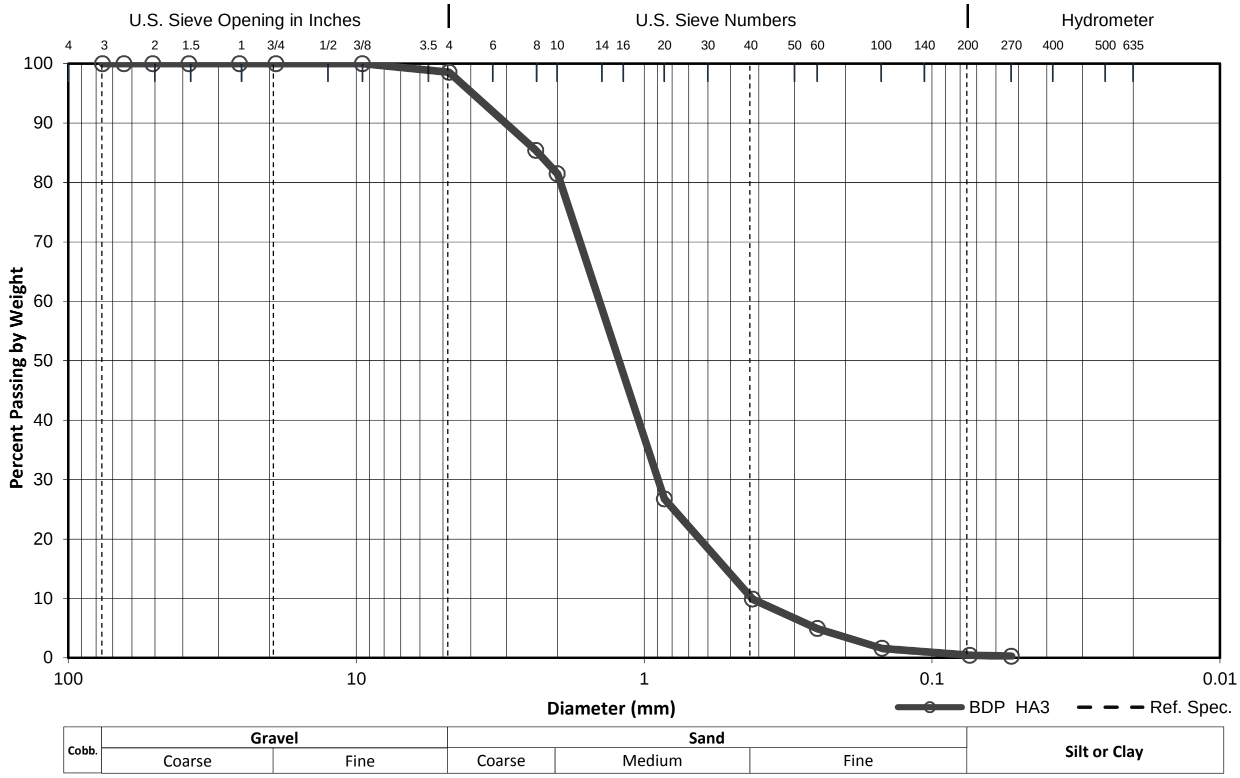
Project Name	Project Number	Date Sampled	Date Tested	Tested By
BHPS	**KH150387A**	**7/29/2016**	**9/1/2016**	**MS**
Sample Source	Sample No.	Depth (ft)	Soil Description	
Onsite	**BDP HA1**	**0.1-0.6**	**SAND, trace silt, trace gravel (SP)**	
Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification	
461.7	**0**	**0.284**	**Bioretention soil mix: burned sample**	



Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4		0.0	100.0		
3/4	19		0.0	100.0		
3/8	9.51	0.3	0.1	99.9		
#4	4.76	8.0	1.7	98.3		
#8	2.38	74.7	16.2	83.8		
#10	2	93.0	20.1	79.9		
#20	0.85	214.0	46.3	53.7		
#40	0.42	380.5	82.4	17.6		
#60	0.25	427.1	92.5	7.5		
#100	0.149	448.8	97.2	2.8		
#200	0.074	457.0	99.0	1.0		
#270	0.053	459.9	99.6	0.4		

GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

Project Name	Project Number	Date Sampled	Date Tested	Tested By
BHPS	**KH150387A**	**7/29/2016**	**9/1/2016**	**MS**
Sample Source	Sample No.	Depth (ft)	Soil Description	
Onsite	**BDP HA3**	**0.7-1**	**SAND, trace silt, trace gravel (SP)**	
Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification	
591.8	**0**	**0.421**	**Bioretention soil mix: burned sample**	



Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4		0.0	100.0		
3/4	19		0.0	100.0		
3/8	9.51		0.0	100.0		
#4	4.76	8.6	1.4	98.6		
#8	2.38	86.3	14.6	85.4		
#10	2	109.7	18.5	81.5		
#20	0.85	433.4	73.2	26.8		
#40	0.42	533.3	90.1	9.9		
#60	0.25	562.7	95.1	4.9		
#100	0.149	582.3	98.4	1.6		
#200	0.074	589.1	99.6	0.4		
#270	0.053	590.2	99.7	0.3		

APPENDIX C

Background Soil, Geology, and Ground Water Data (Regional Maps, Previous Studies Exploration Logs and Laboratory Testing Data)

Geo Engineers

600 Dupont
Bellingham, WA 98225
Telephone: (360) 647-1510
Fax: (360) 647-5044

MEMORANDUM

TO: Kirk Christensen at City of Bellingham
FROM: J. Gordon
DATE: May 19, 2003
SUBJECT: Bloedel-Donovan

We performed two hand auger holes at the proposed infiltration location.

The north hole was excavated to 3.3 feet to refusal.

- 0-2': Silty sand with occasional gravel
- 2-3': Silty sand/sandy silt with occasional gravel
- 3-3.2': Brown silty sand (refusal)
- No groundwater encountered

We filled the hole with water, and measured infiltration just as an indicator:

- Initially went down 3 inches in 5 minutes
- Then went down 1.5 inches in next 30 minutes

The south hole was excavated to 2.3 feet to refusal at three different locations.

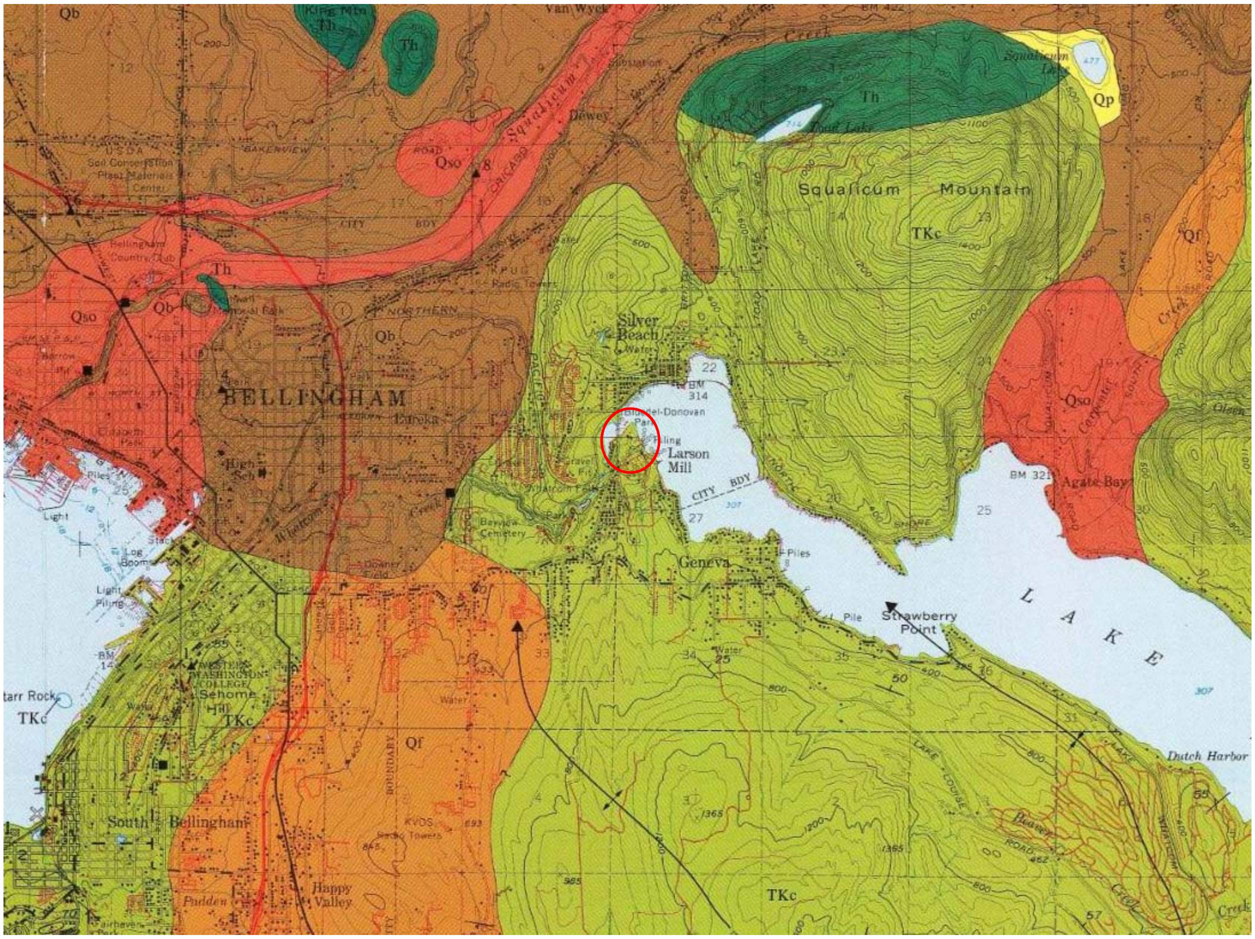
- 0-2': Silty sand with occasional gravel
- 2-3': Silty sand with gravel and roots; refusal on 2-inch gravel
- No groundwater encountered

We filled the hole with water, and measured infiltration just as an indicator:

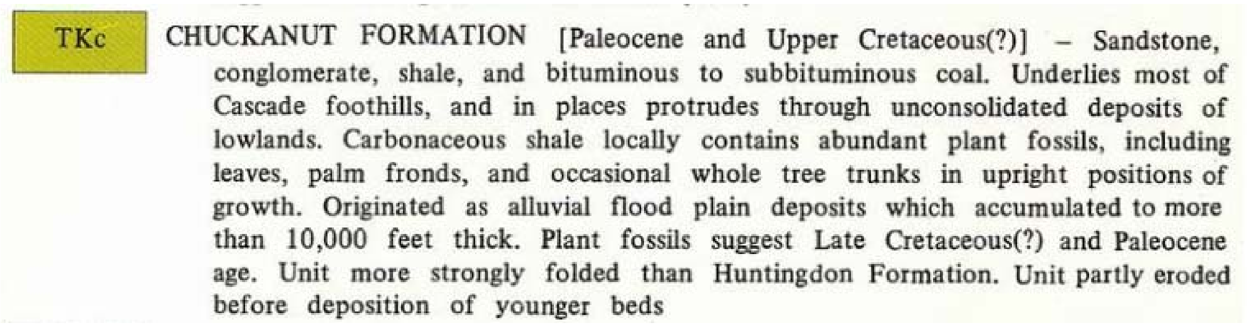
- Initially went down 2 inches in 5 minutes
- Then went down 2 inches in next 15 minutes

PRELIMINARY CONCLUSIONS

- Subsurface conditions consist of silty sand with occassional gravel.
- Assuming that groundwater will be encountered near about 3 feet (lake level), most infiltration would be lateral rather than vertical.
- The above study is not adequate for definitive conclusions. However, some limited infiltration will occur. An infiltration rate might be 0.5 with the new Ecology stormwater design procedures. Ecology suggests a safety factor of 4 for long term infiltration.
- There are some trees on the south side. It may be appropriate to evaluate potential impacts to the trees (with Parks Dept.).

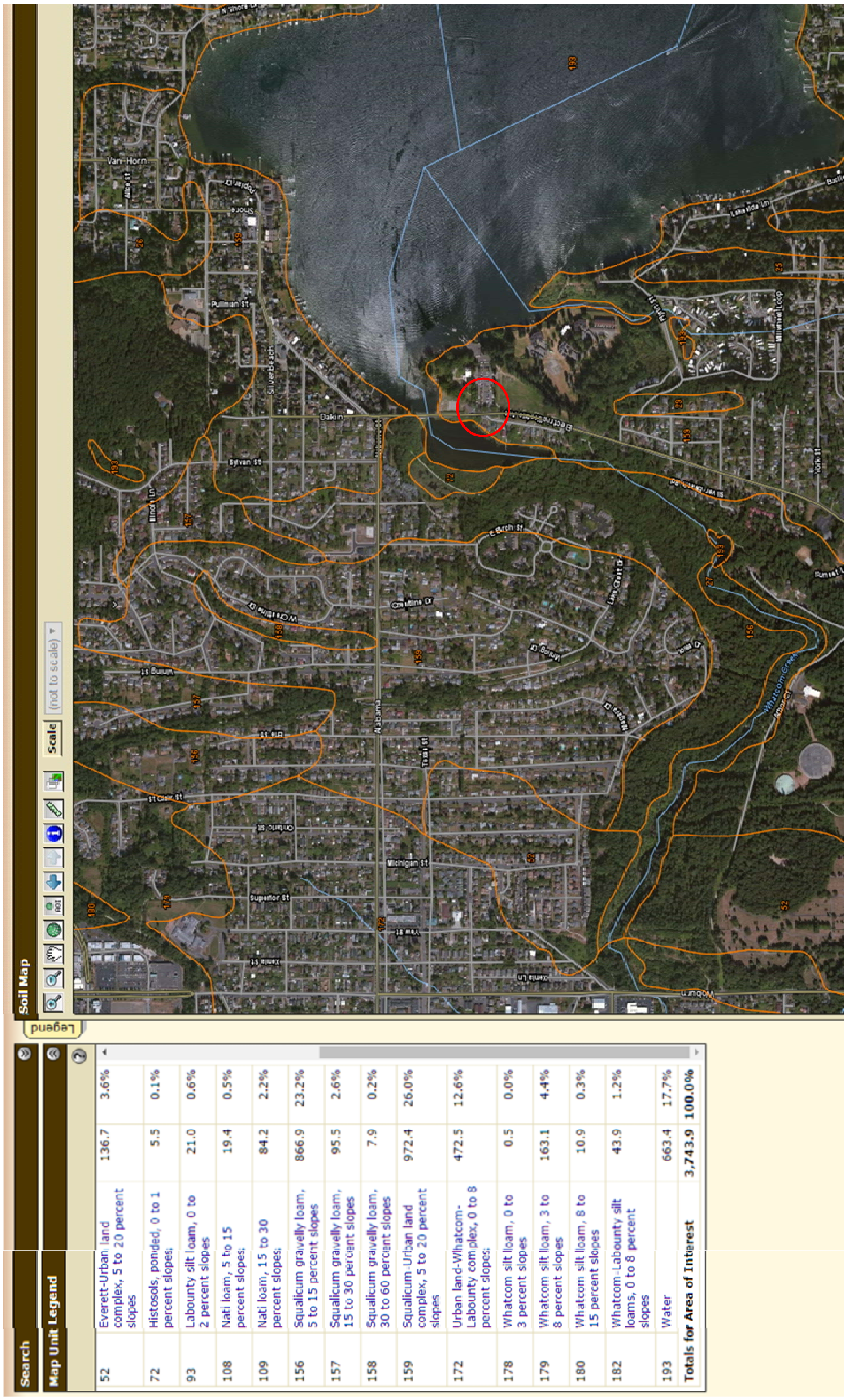


Approximate location of site indicated by red outline



TKc CHUCKANUT FORMATION [Paleocene and Upper Cretaceous(?)] – Sandstone, conglomerate, shale, and bituminous to subbituminous coal. Underlies most of Cascade foothills, and in places protrudes through unconsolidated deposits of lowlands. Carbonaceous shale locally contains abundant plant fossils, including leaves, palm fronds, and occasional whole tree trunks in upright positions of growth. Originated as alluvial flood plain deposits which accumulated to more than 10,000 feet thick. Plant fossils suggest Late Cretaceous(?) and Paleocene age. Unit more strongly folded than Huntingdon Formation. Unit partly eroded before deposition of younger beds

Excerpt from Easterbrook, D. J., 1976, Geologic Map of Western Whatcom County, Washington



52	Everett-Urban land complex, 5 to 20 percent slopes	136.7	3.6%
72	Histosols, ponded, 0 to 1 percent slopes	5.5	0.1%
93	Labounty silt loam, 0 to 2 percent slopes	21.0	0.6%
108	Nati loam, 5 to 15 percent slopes	19.4	0.5%
109	Nati loam, 15 to 30 percent slopes	84.2	2.2%
156	Squalicum gravelly loam, 5 to 15 percent slopes	866.9	23.2%
157	Squalicum gravelly loam, 15 to 30 percent slopes	95.5	2.6%
158	Squalicum gravelly loam, 30 to 60 percent slopes	7.9	0.2%
159	Squalicum-Urban land complex, 5 to 20 percent slopes	972.4	26.0%
172	Urban land-Whatcom-Labounty complex, 0 to 8 percent slopes	472.5	12.6%
178	Whatcom silt loam, 0 to 3 percent slopes	0.5	0.0%
179	Whatcom silt loam, 3 to 8 percent slopes	163.1	4.4%
180	Whatcom silt loam, 8 to 15 percent slopes	10.9	0.3%
182	Whatcom-Labounty silt loams, 0 to 8 percent slopes	43.9	1.2%
193	Water	663.4	17.7%
Totals for Area of Interest		**3,743.9**	**100.0%**

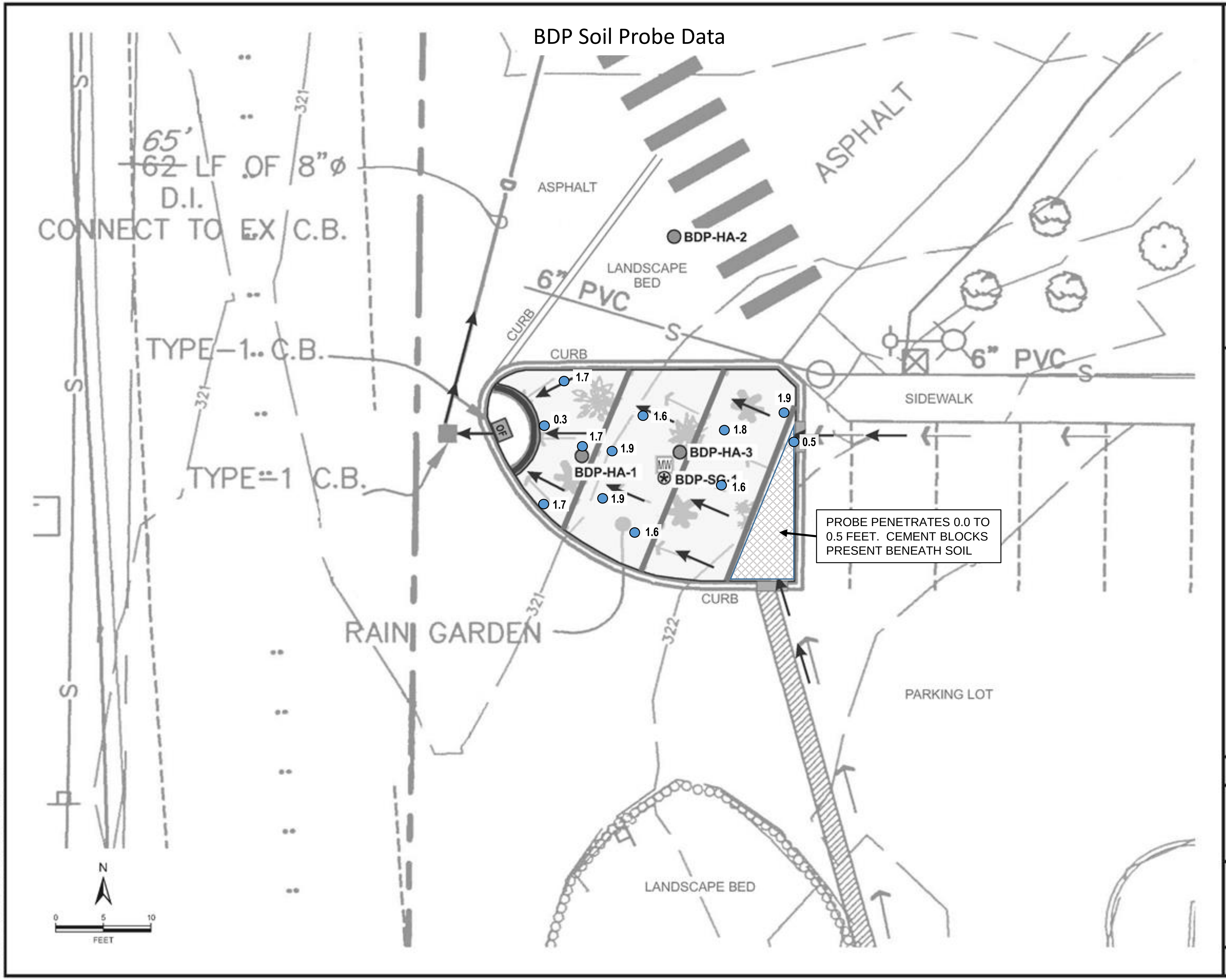
Approximate location of site indicated by red outline

Excerpt from Natural Resources Conservation Service, 2016, Web soil survey

APPENDIX D

Soil Probe, Level Survey, and Field Infiltration Testing Data

BDP Soil Probe Data



PROBE PENETRATES 0.0 TO 0.5 FEET. CEMENT BLOCKS PRESENT BENEATH SOIL

LEGEND:

● HA	HAND AUGER
⊛	TEMPORARY STAFF GAUGE
⬭	BASE OF FACILITY
→	INFLOW / OVERFLOW DIRECTION
OF	OVERFLOW STORM DRAIN
▬	WEIR
▬	OVERFLOW WEIR
▭	CURB CUT
MW	MONITORING WELL WITH METAL COVER

CONTOUR INTERVAL = 1'

● 0.8 Soil Probe and Depth of Loose Soil

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:

1. BASE MAP REFERENCE: CITY OF BELLINGHAM PUBLIC WORKS DEPT, NORTHSHORE WATER QUALITY PROJECT, PARKING LOT-ELECTRIC AVE, SHEET 3 OF 4, 7/7/03

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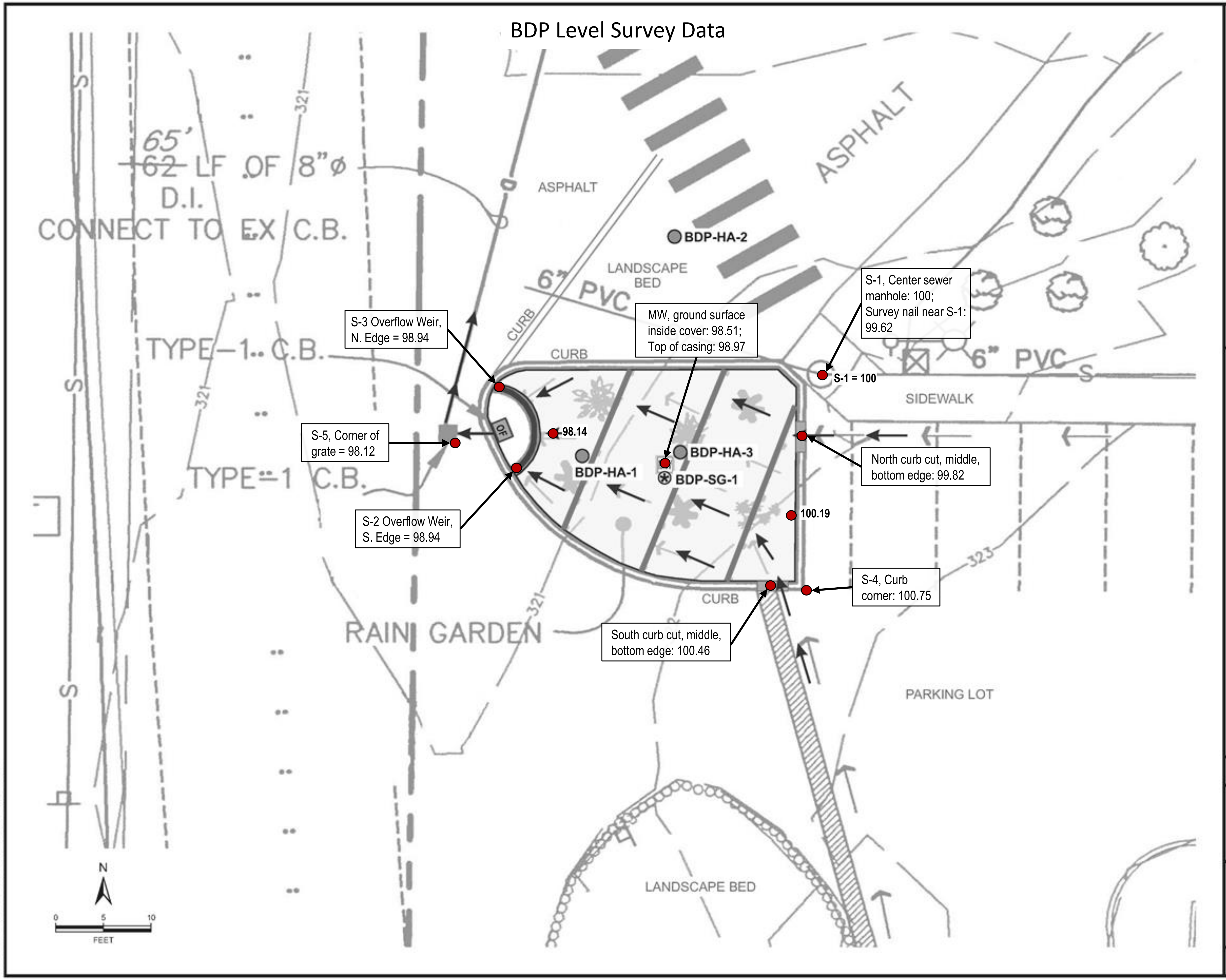
SOIL PROBE DATA
BDP SITE
BIORETENTION HYDROLOGIC PERFORMANCE
BELLINGHAM, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	D1

150387 BHPS MCCA \ 150387 Site-Expl.cdr PAGE 2: BDP

BDP Level Survey Data



S-3 Overflow Weir, N. Edge = 98.94

MW, ground surface inside cover: 98.51; Top of casing: 98.97

S-1, Center sewer manhole: 100; Survey nail near S-1: 99.62

S-5, Corner of grate = 98.12

North curb cut, middle, bottom edge: 99.82

S-2 Overflow Weir, S. Edge = 98.94

S-4, Curb corner: 100.75

South curb cut, middle, bottom edge: 100.46

LEGEND:

● HA	HAND AUGER
⊛	TEMPORARY STAFF GAUGE
▭	BASE OF FACILITY
→	INFLOW / OVERFLOW DIRECTION
OF	OVERFLOW STORM DRAIN
▬	WEIR
▬	OVERFLOW WEIR
▭	CURB CUT
MW	MONITORING WELL WITH METAL COVER

CONTOUR INTERVAL = 1'

● 98.66 Elevation, Project Datum (see text)

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:

1. BASE MAP REFERENCE: CITY OF BELLINGHAM PUBLIC WORKS DEPT, NORTHSHORE WATER QUALITY PROJECT, PARKING LOT-ELECTRIC AVE, SHEET 3 OF 4, 7/7/03

associated earth sciences incorporated

LEVEL SURVEY DATA
BDP SITE
BIORETENTION HYDROLOGIC PERFORMANCE
BELLINGHAM, WASHINGTON

PROJ NO. KH150387A
DATE: 9/16
FIGURE: D2

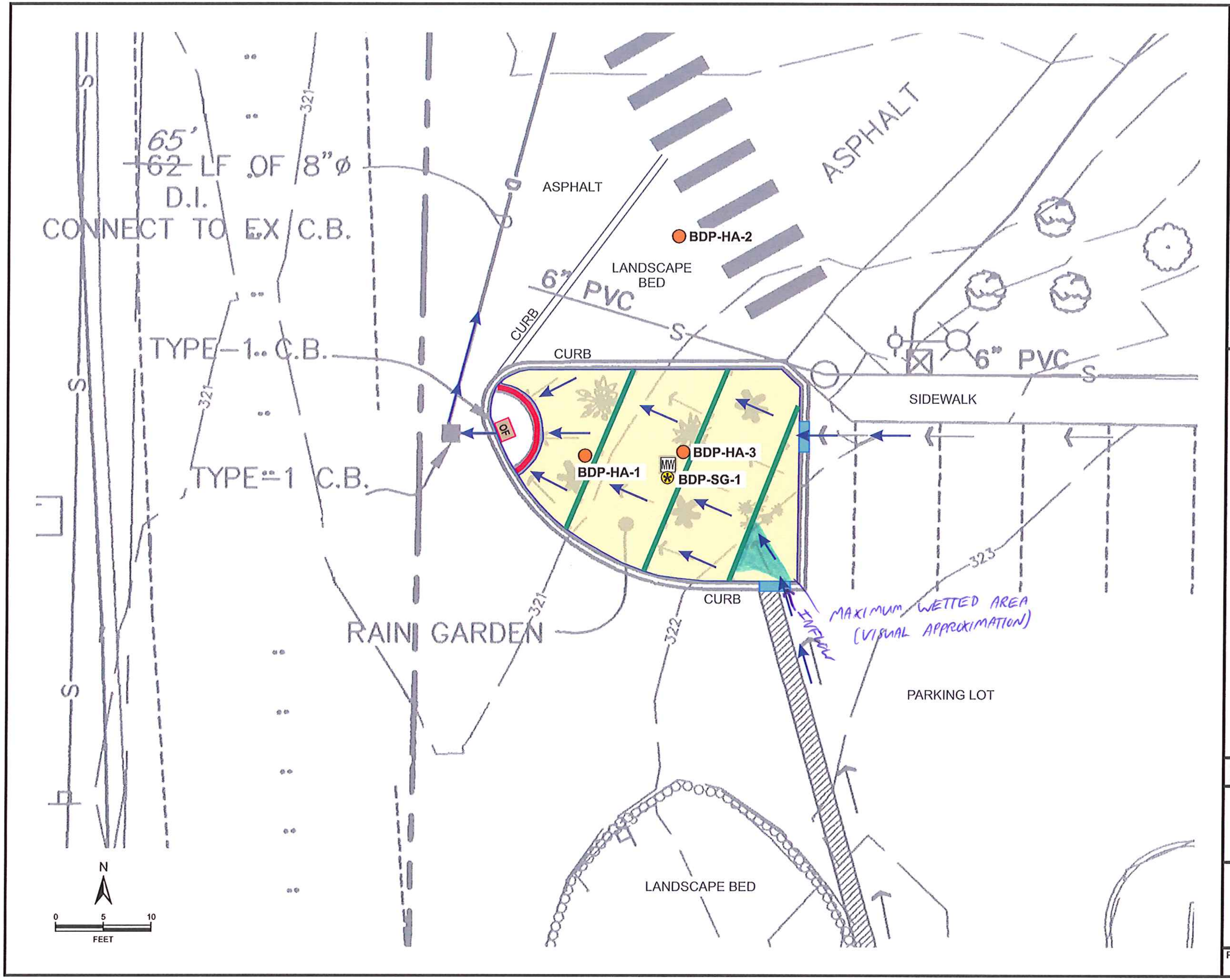
150387 BHPS MCCA \ 150387 Site-Explr.cdr PAGE 2: BDP

Cell BDP
Level Survey Data

Location	Elevation (feet, project datum)
(S-1) Center sewer manhole	100
(S-2) Overflow weir, S. edge	98.94
Overflow weir, middle	98.94
(S-3) Overflow weir, N edge	98.94
(S-4) Curb corner	100.75
(S-5) Corner of grate	98.12
Pre-existing survey nail (near S-1)	99.62
N curb cut, middle, bottom edge	99.82
S curb cut, middle, bottom edge	100.46
Top of existing monitoring well	98.97
Survey points in base of cell and profile	See Attached Map

Cell BDP
Probe Survey Data List (Excludes Outliers)

Probe Penetration (feet):
1.7
1.7
1.7
1.6
1.9
1.9
1.6
1.9
1.8
1.6
AVERAGE: 1.7



MAXIMUM WETTED AREA (VISUAL APPROXIMATION)

LEGEND:

● HA	HAND AUGER
⊛	TEMPORARY STAFF GAUGE
⬭	BASE OF FACILITY
→	INFLOW / OVERFLOW DIRECTION
OF	OVERFLOW STORM DRAIN
🟩	WEIR
🟥	OVERFLOW WEIR
🟦	CURB CUT
MW	MONITORING WELL WITH METAL COVER

CONTOUR INTERVAL = 1'

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:

1. BASE MAP REFERENCE: CITY OF BELLINGHAM PUBLIC WORKS DEPT, NORTHSHORE WATER QUALITY PROJECT, PARKING LOT-ELECTRIC AVE, SHEET 3 OF 4, 7/7/03

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WETTED AREA

BDP SITE
BIORETENTION HYDROLOGIC PERFORMANCE
BELLINGHAM, WASHINGTON

PROJ NO. KH150387A
DATE: 10/16
FIGURE: APPENDIX D

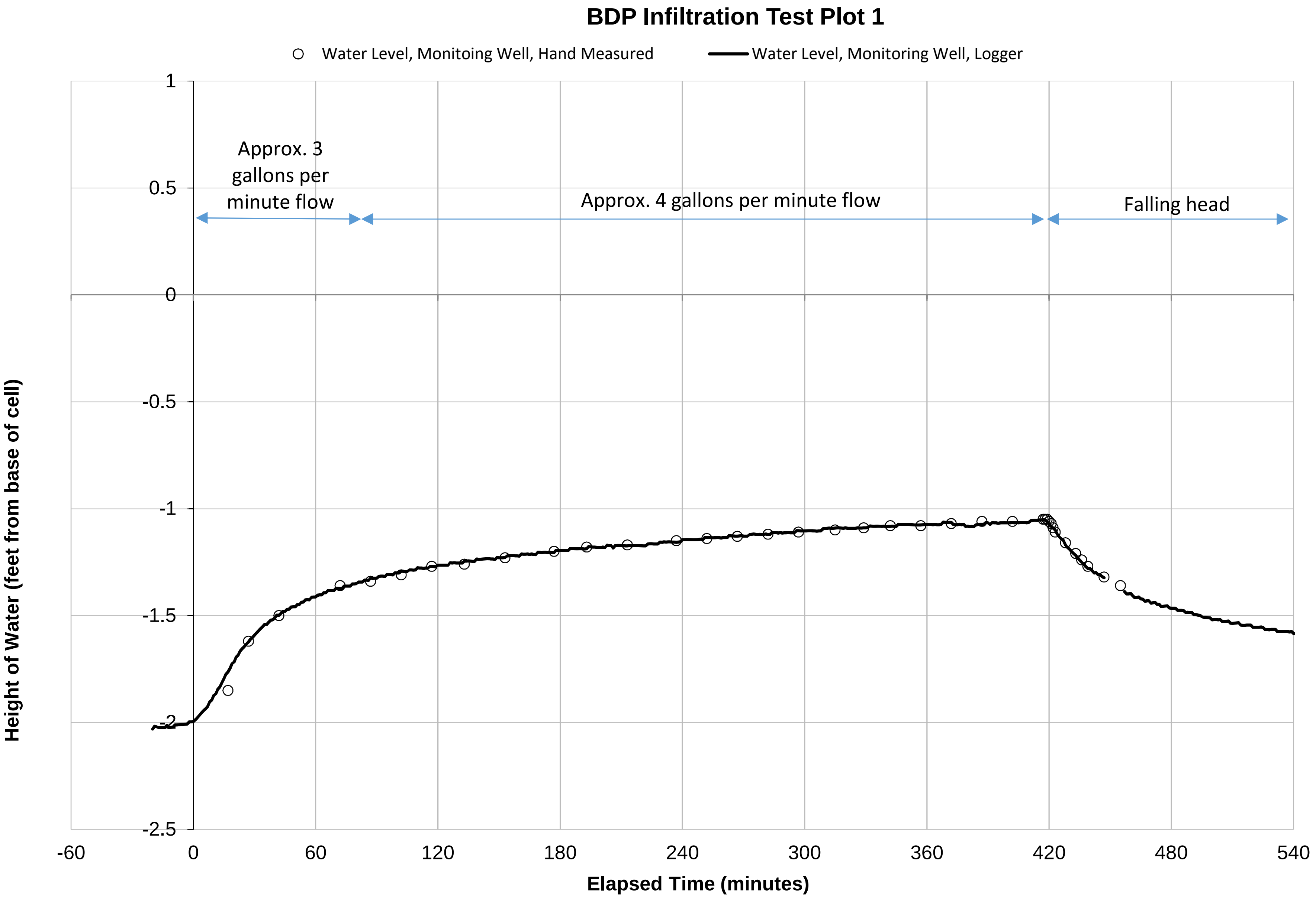
150387 BHPS MCCA \ 150387 Site-Explr.cdr PAGE 2: BDP

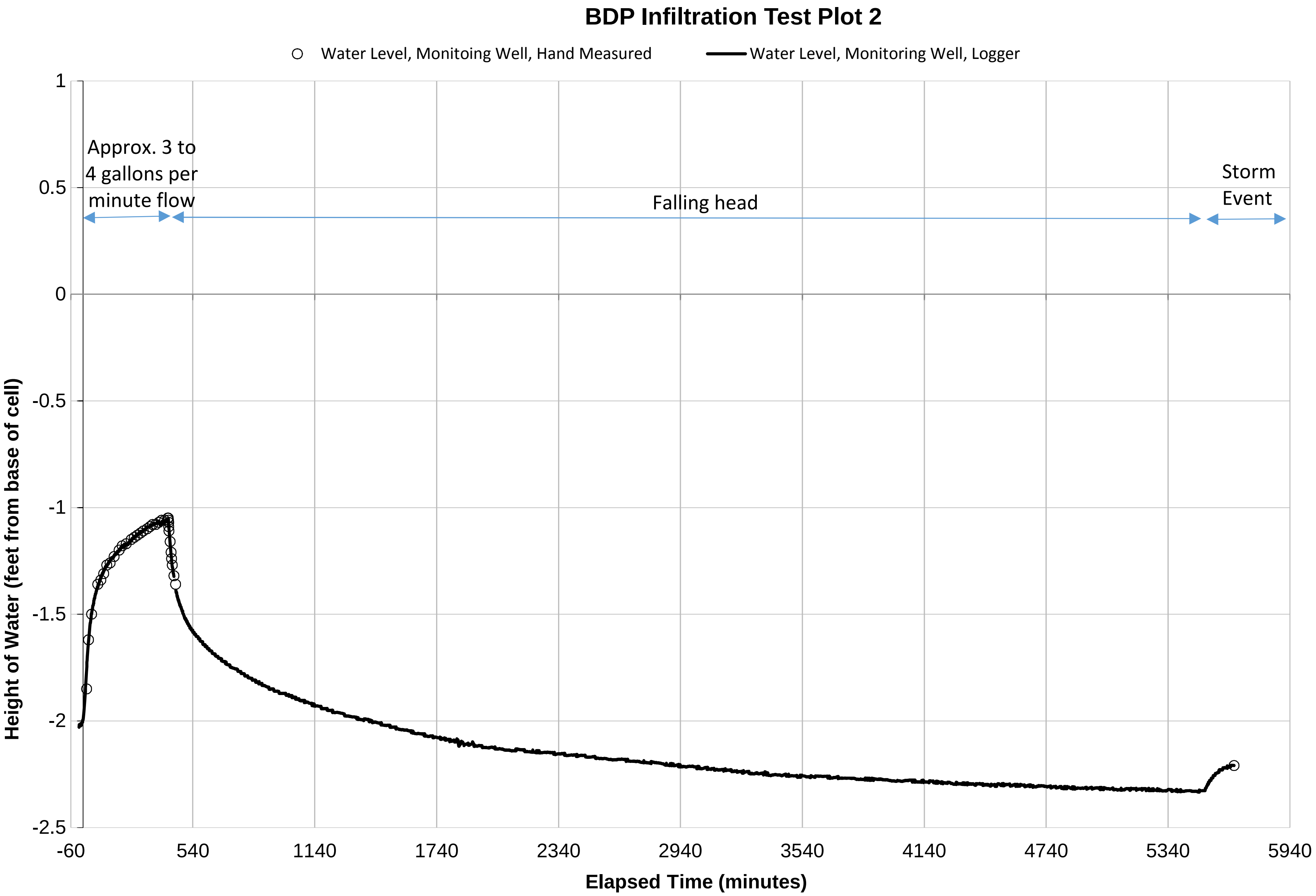
Project Name Bioretention Hydrologic Performance Study
Project Number KH150387A
Date 9/2/16
Weather Cloudy, some rain
Test No. BDP IT-1
Meter FM1/FM3
Water Source Hose bib

Receptor Soils Bioretention Soil over Undifferentiated Alluvium
Testing Performed By ADY

Time (24-hr)	Total (min)	Flow Rate (gpm)	Totalizer (gal)	Head (temporary staff gauge SG-1, feet)	Wetted area (ft^2)	Depth to Water, monitoring well, below top temporary casing (feet, stickup: ~1.5ft from ground surface))	Weather	Flow (southern curb cut, visual estimate, gallons per minute)	Flow (northern curb cut, visual estimate, gallons per minute)	Notes
8:30:00	0.0		0	Dry		3.43	Rain			Flow on, issue with flow meter rate reading.
8:32:00	0.0			Dry						Flow off, swap flow meter.
8:33:00	0.0	3	0	Dry						Flow on, restart test, time zero, totalizer zero.
8:50:00	17.0	3.01	57	Dry		3.28	Rain	~5	~2	
9:00:00	27.0	3.03	82	Dry		3.05	Rain	~4	~2	
9:15:00	42.0	2.97	131	Dry		2.93	Rain	~4	~1	
9:45:00	72.0	3.05	220	Dry		2.79				
10:00:00	87.0	4.17	282	Dry		2.77	Light rain	~1	~0.5	
10:15:00	102.0	4.24	348	Dry		2.74	No rain			
10:30:00	117.0	4.19	404	Dry		2.70				
10:46:00	133.0	4.18	473	Dry		2.69		~0.5 at 10:45	no flow	
11:06:00	153.0	4.22	556	Dry		2.66	No rain	very light flow		
11:30:00	177.0	4.18	660	Dry		2.63				
11:46:00	193.0	4.17	724	Dry		2.61				
12:06:00	213.0	4.18	808	Dry		2.60	No rain	no flow	no flow	
12:30:00	237.0	4.16	906	Dry		2.58				

Time (24-hr)	Total (min)	Flow Rate (gpm)	Totalizer (gal)	Head (temporary staff gauge SG-1, feet)	Wetted area (ft^2)	Depth to Water, monitoring well, below top temporary casing (feet, stickup: ~1.5ft from ground surface))	Weather	Flow (southern curb cut, visual estimate, gallons per minute)	Flow (northern curb cut, visual estimate, gallons per minute)	Notes
12:45:00	252.0	4.17	968	Dry		2.57				
13:00:00	267.0	4.19	1,032	Dry		2.56				
13:15:00	282.0	4.18	1,095	Dry	17	2.55	Light rain	no flow	no flow	
13:30:00	297.0	4.18	1,157	Dry	17	2.54				
13:48:00	315.0	4.07	1,232	Dry	17	2.53				
14:02:00	329.0	4.18	1,290	Dry	17	2.52	No rain	no flow	no flow	
14:15:00	342.0	4.16	1,344	Dry	17	2.51				
14:30:00	357.0	4.13	1,406	Dry	17	2.51				
14:45:00	372.0	4.15	1,469	Dry	17	2.50				
15:00:00	387.0	4.15	1,531	Dry	17	2.49	No rain	no flow	no flow	
15:15:00	402.0	4.15	1,594	Dry	17	2.49				
15:30:00	417.0	4.17	1,655	Dry	17	2.48				Flow off, begin falling head
15:31:00	418.0			Dry		2.48				
15:32:00	419.0			Dry		2.48				
15:33:00	420.0			Dry		2.49				
15:34:00	421.0			Dry		2.50				
15:35:00	422.0			Dry		2.52				
15:36:00	423.0			Dry		2.54				
15:41:00	428.0			Dry		2.59				
15:46:00	433.0			Dry		2.64				
15:49:00	436.0			Dry		2.67				
15:52:00	439.0			Dry		2.70				
16:00:00	447.0			Dry		2.75				
16:08:00	455.0			Dry		2.79				End of test
						On 9/6/16, 3.64 at 06:59				Retrieve datalogger


BDP Infiltration Test Plot 1
○ Water Level, Monitoing Well, Hand Measured
Water Level, Monitoring Well, Logger
Approx. 3 gallons per minute flow
Approx. 4 gallons per minute flow
Falling head
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-60
0
60
120
180
240
300
360
420
480
540
Height of Water (feet from base of cell)
Elapsed Time (minutes)


BDP Infiltration Test Plot 2
○ Water Level, Monitoing Well, Hand Measured
Water Level, Monitoring Well, Logger
Approx. 3 to 4 gallons per minute flow
Falling head
Storm Event
Height of Water (feet from base of cell)
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-60
540
1140
1740
2340
2940
3540
4140
4740
5340
5940
Elapsed Time (minutes)

APPENDIX E

Site Photos

Gap under weir board in Cell BDP

Pre-existing monitoring well and cover in Cell BDP

Cell BDP monitoring well cover, closed

Overflow structure in Cell BDP

Diversion of stormwater flow to street during storm event during infiltration testing, due to leaf litter collected in curb cut

APPENDIX 5

Deliverable 4.5, Site IHS, Geotechnical/Soils Assessment Design Data and Current Conditions, Issaquah High School, Issaquah, Washington. Associated Earth Sciences, Inc. 10/25/16

associated earth sciences incorporated

Technical Memorandum

Page 1 of 14

Date:	October 25, 2016	**From:**	Jennifer H. Saltonstall, L.G., L.Hg.
To:	Clear Creek Solutions, Inc.	**Project Manager:**	Jennifer H. Saltonstall, L.G., L.Hg.
	15800 Village Green Drive #3 Mill Creek, Washington 98012	**Principal in Charge:**	Curtis J. Koger, L.G., L.E.G., L.Hg.
		Project Name:	Bioretention Hydrologic Performance Study
Attn:	Doug Beyerlein, P.E.	**Project No:**	KH150387A
Subject:	Deliverable 4.5, Site IHS, Geotechnical/Soils Assessment Design Data and Current Conditions, Issaquah High School, Issaquah, Washington		

1.0 INTRODUCTION

This technical memorandum documents existing shallow soil and ground water conditions in Bio-Retention Cell #24 of the Issaquah High School Project, located in the city of Issaquah, Washington (Figure IHS F1). This memorandum was prepared in accordance with Task 4 of the contract scope of work. Associated Earth Sciences, Inc. (AESI) collected shallow soil and ground water conditions data related to bioretention cell function, and documented the current condition of the facility relative to the as-built drawings and available background geotechnical information. The information will be used in the WWHM2012 modeling that will be conducted as part of Task 5 (Data Analysis). In Task 5, the team will compare the previously documented hydrologic design information with our field-collected information and will note where there are significant differences. The purpose of this technical memorandum is to document the collection of current and accurate geotechnical, geologic and hydrogeologic site information for this later work.

The following summary of shallow soil and ground water conditions integrates the observations made during the geotechnical assessment which included site visits on July 6, 2016, infiltration testing on July 27, 2016, and background geotechnical information.

This technical memorandum has been prepared for the exclusive use of Clear Creek Solutions and the City of Bellingham and their agents for specific application to this project. Within the limitations of scope, schedule, and budget, our services have been performed in accordance with generally accepted hydrogeologic and geotechnical engineering practices in effect in this area at the time our document was prepared. No other warranty, express or implied, is made.

2.0 PURPOSE AND SCOPE

The purpose of our work was to perform a shallow soil and ground water conditions assessment and provide baseline documentation data to assess effectiveness of bioretention hydrologic performance.

Specifically, our scope included the following activities:

- Review of project documents.
- Site reconnaissance.
- Visual condition assessment of erosion and deposition features near inlet and outlet.
- Review project plans relative to constructed facility, in particular, the number and location of inlets, energy dissipation devices, outlets, and other flow-related details.
- Survey elevations of inlet, outlet, well point rim, and other observation points relative to a project datum
- Excavate shallow hand augers through the bioretention soil.
- Classify sediment according to the Unified Soil Classification System (USCS) and *American Society for Testing and Materials* (ASTM) D2488, "Standard Recommended Practice for Description of Soils."
- Collect samples for laboratory testing of (1) particle size distribution in accordance with ASTM D422-63, "Standard Test Method for Particle-Size Analysis of Soils"; (2) organic matter content per ASTM D2974.
- Conduct qualitative assessment of soil compaction via T-probe.
- Conduct infiltration testing.
- Preparation of descriptive exploration logs for each exploration.
- Preparation of this summary document.

Topography of the site and surrounding area is shown on Figure IHS F2, "LiDAR-Based Topography." Existing facility features and the locations of hand-auger boreholes completed for this study are shown on Figure IHS F3, "Facility and Exploration Plan." Project civil plans are attached as Appendix A. Exploration logs and laboratory testing data conducted as part of this study are attached as Appendix B. Background soil, geology, and ground water information are attached as Appendix C. Soil probe, level survey, and field infiltration testing data are attached as Appendix D. Site photos are attached as Appendix E.

3.0 SITE DESCRIPTION AND DESIGN BACKGROUND

The project site is the Issaquah High School Project, located in Issaquah, Washington as shown on the attached "Vicinity Map" (Figure IHS F1). The Issaquah High School Campus is located on a 46-acre parcel. The High School is bordered by 2nd Avenue on the west, a current new Middle School construction project on the north, the western slopes of Tiger Mountain on the east and residential development on the south. No surface water features are present onsite. Per the

Washington State Source Water Assessment Program Mapping Application, the site is located within the 10-year time of travel for the City of Issaquah municipal water supply wells and within an assigned time of travel zone for a Group B water supply well. LiDAR topography and other near-site vicinity features are illustrated on Figure IHS F2, "LiDAR-Based Topography."

Our specific area of study for this project includes bioretention facility #24 located on the southeast portion of campus referred to as cell IHS for this study. The attached "Facility and Exploration Plan" (Figure IHS F3) illustrates the cell area and some of the surrounding site features and utilities.

Details of the bioretention facility design and basis for design were presented in the following documents:

- Subsurface Exploration, Geologic Hazards and Geotechnical Engineering Report, New Issaquah High School, Issaquah, Washington, Associated Earth Sciences, Inc., July 26, 2007, prepared for Issaquah School District.
- Supplemental Geotechnical Exploration and Ground Water Mounding Analysis, Issaquah High School Replacement, Issaquah, Washington, Associated Earth Sciences, Inc., January 21, 2009, prepared for Issaquah School District.
- Rain Garden Sizing Calculations, Issaquah High School Project, Coughlin Porter Lundeen (CPL), January 29, 2009, prepared for Mahlum Architects.
- Sheet C-404 titled Record Drawing, Grading and Drainage Plan, Issaquah High School Project, May 16, 2014, prepared by Mahlum Architects and Coughlin Porter Lundeen (CPL).
- Field Report, Associated Earth Sciences, Inc., April 28, 2010, prepared for Issaquah School District.
- Construction and Post-Construction Photographs.
- Unpublished water level monitoring data, 2010 through 2015.

3.1 Summary of Facility Design

From our review of these documents, the bioretention facility design for cell IHS consists of an approximately L-shaped bioretention cell with approximately 1,050 square feet of base area, as shown on Figure IHS F3, "Facility and Exploration Plan." We understand that the site was developed under the 1998 *King County Surface Water Design Manual* (King County Manual) for design and construction of stormwater facilities and modeled using KCRTS with a design infiltration rate of 13 inches per hour (in/hr) in the native subgrade. Land use within the drainage basin is primarily access roadway and roof area. Per Record Drawing C-404 (CPL, May 16, 2014), the facility design includes 18 inches of bioretention soil mix overlying a minimum 6-foot-wide rock-filled trench. The rock-filled trench is separated from the overlying bioretention soil mix by an 18-inch-thick layer of medium sand and an 18-inch layer of coarse sand/fine pea gravel. The rock-filled trench contains a 6-inch-diameter perforated underdrain pipe bedded in approximately 1.5 feet of 9-03.12(4) "Gravel Backfill for Drains," which overlies native soil. In two areas along the perforated pipe, short infiltration trenches referred to as 'finger drains' extend to about 12 feet below bioretention cell base. A 4-inch-diameter piezometer was installed in each finger drain to allow for water level monitoring.

The facility is designed to infiltrate 100 percent of inflow into the subgrade. Stormwater enters the facility through two inlet pipes on the north end, one 12-inch and one 8-inch. If water ponds up on the bioretention soil, the ponded water would discharge into a Type I Catch Basin (SD #59) with a beehive grate located near the center of the cell, and then into the perforated pipe laterals in the rock-filled trench situated beneath the bioretention soil. The rim of the Type I Catch Basin was designed to be 2.5 feet higher than the cell base to create 2.5 feet of ponding depth. The facility was constructed during April through August 2010 and began receiving runoff in August 2010 (AESI field records).

4.0 SITE OBSERVATIONS

During AESI's site visits, we made notes regarding the physical construction of the bioretention facilities including documenting site inlet/outlet layout relative to site plans and qualitative bioretention soil thickness and compaction. These notes were used to indicate key features of the facility in Figure IHS F3, "Facility and Exploration Plan."

- Level Survey: AESI conducted an elevation survey of the cell using a Leitz C40 automatic level and a stadia rod. An arbitrary project datum was established for this survey, with the south rim of a storm drain #66 (identified on the "IHS Level Survey Data" map in Appendix D) defined as project datum elevation 100 feet. All other elevations measured by the survey are relative to this project datum. Due to the density of vegetation within the facility, AESI's ability to survey elevations within the base of the IHS facility was limited. Key level data is summarized in Table 1. Additional data points are included in Appendix D to this document. This survey was not conducted by a licensed surveyor. Surveyed elevations are expected to be sufficiently accurate for this general assessment of facility construction, but may be inaccurate for purposes requiring greater precision.

- Inflow: Two inflow pipes are present on the north side of cell IHS.
  - The primary inflow pipe (Inlet 1) to the facility is a 12-inch corrugated black pipe consistent with project plans, which discharges onto a rounded rock energy dissipation pad approximately 2 to 3 feet wide and 6 feet long. A small amount of water was discharging at the time of our July 6, 2016 site visit, and formed a pool of water (about 2 feet by 2 feet) at the inlet.

  - A second inflow pipe (Inlet 2) to the facility is a 6-inch pipe nearly buried in bioretention soil. The pipe was filled to about 0.3 feet from the crown. A few rounded rocks were visible. It was unclear whether the pipe was set too low or soil placed too deep.

  - AESI observed that a shallow channel (0.1 to 0.2 feet deep, a few feet wide) is present from Inlet 1 toward SD #59. The surface of the channel is exposed bioretention sand.

- Overflow: The overflow consists of Type I Catch Basin (SD #59) with a beehive grate. The rim of this grate was approximately 2.4 to 2.6 feet above the base of the facility. Two pipes exit SD #59 to convey water to the rock-filled trench and 'finger drains'.

- Piezometers: Two existing piezometers were in place as indicated on Plan Sheet C-404. Both consisted of a 4-inch (nominal diameter) SDR #35 pipe. We understand the lower 5 feet of the pipe is machine-slotted ($^3/_{16}$ inch wide by about 3½ inches long, spaced about 2 to 3 inches apart) and was attached to an upper solid (no perforations) pipe section by a glued, belled, slip coupling. A slip end cap was fastened to the bottom. The total length of 13 feet (south piezometer) and 13.5 feet (northwest piezometer), and a stick up above ground surface of 1.0 feet, such that the base of the piezometers are about 12 feet below ground surface.

- AESI investigated the loose bioretention soil thickness present in cell IHS using a geotechnical soil T-probe. This qualitative data was used in conjunction with the hand-auger observations to understand loose soil thickness and relative potential compactness of the bioretention soils at depth. AESI measured the depth of penetration of the soils probe at locations generally arranged in a 10-foot to 15-foot grid on the facility base. Penetration of the T-probe generally ranged from approximately 1.1 feet to 2.0 feet, and averaged 1.6 feet. Probe penetration data is included in Appendix D to this document.

Table 1
Summary of Cell IHS
Level Survey Data

Location	Elevation (feet, project datum)
SD #66	100
SD #61	100.59
SD #63	101.33
Bottom of pipe, inlet 1 (12-inch pipe)	97.5
Top of pipe, inlet 2 (8-inch pipe)	97.67
Piezometer 24-1 top of casing	98.17
Piezometer 24-2 top of casing	98.36
SD #59 rim	99.63
Survey points in base of cell	On site plan in Appendix D to this document

5.0 SITE SETTING

The text sections below describe our research findings in regards to the topographic, geologic, and hydrogeologic setting of the project site both from regional studies and background site-specific geotechnical and ground water studies. Our sources of information included the following:

- Site-specific documents cited previously under "Project and Site Description."

- Booth, Derek B., Walsh, Timothy J., Troost, Kathy Goetz, and Shimel, Scott A., *Geologic Map of the East Half of the Bellevue South 7.5' x 15' Quadrangle, Issaquah Area, King County, Washington*, United States Geological Survey Scientific Investigations Map (SIM) 3211, 2012.
- Natural Resources Conservation Service, Web Soil Survey, United States Department of Agriculture, http://websoilsurvey.nrcs.usda.gov/, accessed September 2016.
- *Soil Survey of King County area, Washington*, United States Department of Agriculture, Natural Resource Conservation Service (NRCS), in cooperation with Washington Agricultural Experiment Station, 1973.
- Liesch, Bruce A., Price, Charles E., and Walters, Kenneth L., *Geology and Ground-water Resources of Northwestern King County, Washington*, Washington State Division of Water Resources, Water Supply Bulletin 20, 1963.
- King County, *Issaquah Creek Basin, Current/Future Condition and Source Identification Report*, King County Surface Water Management, October 1991.

5.1 Regional Topography and Project Grading

The project site is situated at the base of Tiger Mountain on the eastern edge of a relatively narrow valley that contains Issaquah Creek. Elevations on the larger school site range from about 120 to 200 feet, as shown on Figure IHS F2, “LiDAR-Based Topography.” Glacial meltwater scoured through the Issaquah Creek valley and created level outwash terrain surfaces. Issaquah Creek, a modern stream, has incised the outwash terrain west of the site.

On a closer scale, the area near Cell IHS is relatively level, situated on an outwash terrace at about elevation 145 to 150 feet. The site is located about a half mile east of Issaquah Creek, and is about 40 to 60 feet higher in elevation than Issaquah Creek. East of the site, steep slopes rise several hundred feet, eventually rising to nearly elevation 3,000 feet near the West Tiger Mountain summit. Level parking and access road areas surround the cell on the north, west, and southwest. A curb separates the paved surfaces from the cell. A slope rises on the east.

The project site was previously developed as Issaquah High School which was demolished in stages during 2010, to allow for the construction of the new Issaquah High School. Minor cutting (about 5 feet) was needed to achieve design bioretention cell grades based on a review of existing topography compared with built topography.

5.2 Regional Geology and Background Geotechnical Information

According to the *Geologic Map of the East Half of the Bellevue South 7.5' x 15' Quadrangle, Issaquah Area, King County, Washington* by Derek B. Booth, Timothy J. Walsh, Kathy Goetz Troost, and Scott A. Shimel (U.S. Geological Survey Scientific Investigations Map 3211), the site vicinity is underlain by Vashon recessional outwash. Recessional outwash sediments in the project area are described on the referenced map to consist of deltaic deposits from meltwater streams entering glacial Lake Sammamish, which is consistent with our observations and interpretations of subsurface materials encountered in our explorations for this project.

- Vashon Recessional Outwash (Qvr): This unit is composed of stratified sand and gravel, moderately to well sorted; less common silty sand and silt. Recessional outwash in the project area was deposited along channels that carried glacial meltwater into glacial Lake Sammamish during ice retreat. Recessional outwash was deposited during the retreat of glacial ice, and has not been glacially overridden.

Exploration logs from the footprint of Bio-Retention Cell #24 dated April 28, 2010 reached depths of about 13 feet below current grades, and describe material generally consisting of gravel with variable sand content and a trace of silt to grading with depth to sand with variable gravel content and silt interbeds. This interpretation is consistent with the geologic mapping in the area.

5.3 Regional Soils and Soil Data Used in Site Stormwater Model

AESI reviewed the *Soil Survey of King County Area, Washington* (NRCS, 1973) and soils mapping from the NRCS web portal (NRCS, 2016). The soil survey identifies different soil map units based on parent material, climate, topography (slope), organisms (biota), and time. The soils in the study area formed mostly from young glacial deposits and have not had time to develop the deep weathering profiles present in soils in unglaciated terrains. Instead, they exhibit a direct relationship to the underlying parent material, local climate, topography, and vegetation.

Mapped soils in the project area consist of Everett very gravelly sandy loam soils. Everett soils are typically situated on terraces and formed from the weathering of glacial outwash. NRCS describes the permeability as rapid (6 to 20 in/hr) (NRCS, 1973).

As described in the “Rain Garden Sizing Calculations” (CPL, 2009), the pre-developed condition was modeled as Type A soils, consistent with mapped soil and background geotechnical data.

5.4 Regional Hydrogeology and Background Ground Water Data

Descriptions of regional hydrogeology are contained in reports prepared by the Washington State Division of Water Resources titled *Geology and Ground-Water Resources of Northwestern King County, Washington*, Water Supply Bulletin 20, by Bruce A. Liesch, Charles E. Price, and Kenneth L. Walters (Liesch et al., 1963) and the Issaquah Creek Basin, Current/Future Condition and Source Identification Report, King County Surface Water Management, October 1991 (King County, 1991).

Ground water was encountered in explorations from the footprint of Bio-Retention Cell #24 (cell IHS). Ground water seepage was encountered at a depth of about 8.5 to 9 feet below current cell base at the time of excavation (April 28, 2010). Ground water levels were monitored for several years after construction and ranged from about 12 feet below grade during late summer/early fall to at ground surface reflecting the ground water mounding resulting from stormwater infiltration (AESI, unpublished data). Hydrographs are included in Appendix C.

The ground water encountered onsite is an expression of the Lower Issaquah Valley regional aquifer, a relatively shallow, unconfined aquifer which is important for water supply in the south Lake Sammamish/Issaquah area (King County, 1991). At this site, the base of the Lower Issaquah Valley aquifer is formed by an underlying low-permeability recessional glacial lacustrine silt/clay deposit. The silt/clay acts as a leaky aquitard, preventing most of the aquifer water from recharging deeper aquifers. Ground water flow direction is westward toward Issaquah Creek, and northward toward Lake Sammamish.

6.0 BIORETENTION CELL SUBSURFACE EXPLORATION

Limited information on subsurface conditions was obtained for this study from hand-auger samples and soil probe penetration measurements at about 2-foot increments in each hand-augered borehole. Two hand-auger borings were performed in the facility bottom and advanced through the bioretention soil and to the underlying subgrade. Representative samples were collected, visually classified in the field, stored in water-tight containers, and transported to AESI’s offices for additional classification, geotechnical testing and study. At the conclusion of the excavation, each borehole was immediately backfilled with the excavated material.

The various types of sediments, as well as the depths where characteristics of the sediments changed, are indicated on the exploration logs presented in Appendix B. A detailed record of the observed bioretention soil, subsurface soil, geology, and ground water conditions was made. The sediments were described by visual and textural examination using the soil classification in general accordance with ASTM D2488, “Standard Recommended Practice for Description of Soils.” The depths indicated on the logs where conditions changed may represent gradational variations between sediment types in the field. The exploration logs in Appendix B are based on the field observations, inspection of the samples, and where applicable, laboratory grain-size analysis. Our explorations were approximately located in the field relative to known site features, and are shown on Figure IHS F3, "Facility and Exploration Plan." GPS coordinates for the explorations were taken using a handheld GPS, and are summarized in Appendix B.

The results presented in this document are based on the explorations completed for this study and review of background data. The number, locations, and depths of the explorations were completed within site and budgetary constraints. Because of the nature of exploratory work below ground, interpolation of subsurface conditions between field explorations is necessary. It should be noted that differing subsurface conditions may sometimes be present due to the random nature of deposition and the alteration of topography by past grading and/or filling.

6.1 Hand-Auger Borings

Hand-auger borings in cell IHS were completed on July 6, 2016. No rainfall was noted at the time of exploration.

Hand-auger boring number 1 (IHS-HA-1), which was completed in the northern portion of the cell, near the inflow, and hand-auger boring number 2 (IHS-HA-2), which was completed near the center of the cell, near the overflow, encountered approximately 1.5 feet of bioretention soil, overlying material interpreted as gravel backfill for drains to a total depth of 2 feet. No seepage or caving were observed.

6.2 Well Points

Because the existing piezometers penetrated deeper beneath ground surface than the hand-auger explorations, no well point was installed. Dimensions of the existing piezometers are provided in Table 2, below.

Table 2
Summary of Cell IHS
Existing Piezometer Dimensions

Existing Piezometer	Total Length of Casing (feet)	Interior Diameter	Stickup Height (feet)	Total Depth Inside Casing Below Ground Surface
IHS 24-1 (south)	13.4	4-inch nominal	0.8	12.6
IHS 24-2 (northwest)	13.0	4-inch nominal	1.0	12.0

7.0 LABORATORY ANALYSIS

Laboratory testing included mechanical grain-size distribution and percent organic matter by weight in accordance with the ASTM D422 and D2974, respectively. Two samples of bioretention soil were first tested for organic matter content and then the burned material was tested for grain-size distribution for comparison with the aggregate fraction of the bioretention soil mix guidance in the 2014 Washington State Department of Ecology (Ecology) *Stormwater Management Manual for Western Washington* (2014 Ecology Manual). One sample of material interpreted as representative of the subgrade was tested for grain-size distribution. The data is summarized in Table 3.

Table 3
Summary of Cell IHS
Organic Content and Grain Size Data

Exploration Number	Depth (feet)	Soil Type	Organic Content (% by weight)	USCS Soil Description	Fines Content (% passing #200)	Cu	Cc	USDA Soil Texture*
IHS-HA-1	0.3-0.6	Bioretention Soil	6.0	SAND, some silt, trace gravel (SW-SM)	5.2	6.8	1.1	Sand
IHS-HA-2	1.0-1.3	Bioretention Soil	5.6	SAND, trace silt, trace gravel (SW)	4.8	7.5	1.2	Sand

USCS: Unified Soil Classification System; Cu: coefficient of uniformity; Cc: coefficient of curvature; USDA: U.S. Dept. of Agriculture; *No hydrometers were performed. USDA soil texture range assumes fines consist entirely of silt to entirely of clay.

7.1 Bioretention Soil Mix

We compared the organic content and burned fraction gradation against the general guidelines for the bioretention soil mix (Table 4).

The organic content of the tested bioretention soils ranged between 5.6 and 6.0 percent by weight. This meets the recommended organic content by weight of 5 to 8 percent in the 2014 Ecology Manual.

The grain-size analysis test results on the burned soil fraction indicate that the bioretention soils tested correlate to a “SAND” with trace to some silt and trace gravel based on ASTM D2487 USCS. The respective fines content as measured on the No. 200 sieve was 4.8 to 5.2 percent, on the higher end of recommended range of 2 to 5 percent. The coefficient of uniformity ranged from 6.8 to 7.5, meeting the recommended value of equal to or greater than 4. The coefficient of curvature ranged from 1.1 to 1.2, within the recommended range of greater than or equal to 1 and less than or equal to 3. The soil mix contained slightly less than the recommended range of fine sand and slightly more than the recommended range of silt. The tested bioretention soil was a well-graded sand.

Table 4
General Guidelines for Bioretention Soil Mix (2014 Ecology Manual)
Compared to Averaged Cell IHS Site Data

Parameter	Recommended Range	Cell IHS
Organic Content (by weight)	5 to 8 percent	5.8 percent by weight
Cu coefficient of uniformity	4 or greater	7.1
Cc coefficient of curvature	1 to 3	1.2
Sieve Size	**Percent Passing**	
3/8” (9.51 mm)	100	98.6
#4 (4.76 mm)	95 to 100	96.9
#10 (2.0 mm)	75 to 90	74.5
#40 (0.42 mm)	25 to 40	22.8
#100 (0.15 mm)	4 to 10	7.6
#200 (0.074 mm)	2 to 5	5.0

Note: The general guidelines for mineral aggregate gradation are from Table 7.4.1 of the 2014 Ecology Manual.
mm: millimeters

7.2 Subgrade

In cell IHS, no samples of the subgrade were obtained for this study. However, AESI observed excavation of cell IHS during construction. Photos of finger drain excavation and bioretention cell grading are presented in Appendix E. The native material is recessional outwash, classified as a sandy GRAVEL with trace silt (GP).

8.0 INFILTRATION TESTING

8.1 General Infiltration Test Method

The infiltration test was conducted in general accordance with the 2014 Ecology Manual. The test was conducted by discharging water into the facility for a "soaking period," to allow the receptor soils to become saturated. After completion of the soaking period, water was discharged into the cell at a rate sufficient to maintain a relatively constant head. This constitutes the "constant head" phase of infiltration testing. Immediately following the constant head phase of infiltration testing, flow into the facilities was discontinued, and the water level was monitored as it dropped. This constitutes the "falling head" portion of the infiltration testing.

The water for testing was obtained from an on-site fire hydrant and conveyed to cell IHS with fire hoses. During infiltration testing, the water was conveyed into the bioretention cell via a digital flow meter with gallons per minute (gpm) and total gallon readouts, and discharged through a flow diffuser. Water levels were monitored using an existing staff gauge (SG-1) marked in 0.01-foot increments installed adjacent to SD #59, a second temporary metal staff gauge (SG-2) marked in 0.02-foot increments installed near the test discharge for the duration of the test, and within northern piezometers with a digital water level tape, and with digital pressure transducers. Data from the digital pressure transducers was compensated for barometric response using a separate digital barometer. The area of the pool was measured periodically during testing.

The infiltration test in cell IHS is discussed below, and results are presented in Table 5. Infiltration test data is included in Appendix D to this document.

8.2 Infiltration Test in Cell IHS

AESI performed infiltration testing on July 27, 2016. No rainfall was noted during testing, and no flow from the inflow pipes was present.

During this test, flow was initially maintained at about 102 gpm, then increased to 145 gpm (the maximum flow rate off the hydrant) for the duration of test. Inflow to the facility for the infiltration test was directed, through a diffuser, onto the cell. Initially, the water pooled near the inflow, then the pool broke through a low vegetation dam after about 80 minutes, and spread out again before the wetted area stabilized. After approximately 6 hours, the water level in the wetted area was about 0.25 feet as measured on SG-1. The wetted pool area had been generally stable for about 4 hours, and had filled in the low areas near Inlet 1 and Inlet 2 covering an area of about 230 square feet. Approximately 52,000 gallons of water were used.

Water in the northern piezometer was monitored with a data logger during the infiltration test and responded to inflow. Ground water was present at about 11.5 feet beneath the bioretention cell prior to the start of inflow, and represents the static shallow ground water level. The water level in the northern piezometer responded to inflow after about 10 minutes, and rose approximately 8.2 feet (from 11.55 feet below ground surface to 3.33 feet below ground surface) during the course of testing. AESI interprets this response to indicate that water from the infiltration test infiltrated rapidly through the bioretention soil and then mounded on the shallow ground water present beneath the facility.

After about 6.2 hours, AESI shut off the flow and monitored water level as it fell. AESI observed that the pooled water in the base of the facility infiltrated over the course of approximately 4.5 minutes.

The constant head test infiltration rate in Table 5 is calculated based on flow rate from the hose for infiltration testing, and the wetted area of bioretention soil through which the water infiltrated, and represents the infiltration rate of the bioretention soil.

Table 5
Cell IHS
Infiltration Test Results

Test No.	Surface Area (square feet)	Discharge Time (minutes)	Total Volume Discharged (gallons)	Approximate Constant Head Level (feet)	Field Infiltration Rates	
					Constant Head Test (in/hr)	Falling Head Test (in/hr)
IHS (bioretention soil)	230	368	52,277	0.25	61	37
IHS (subgrade)	Shallow ground water mounding response in well point					

in/hr: inches per hour

9.0 CONCLUSIONS AND RECOMMENDATIONS

Cell IHS was generally consistent with the design shown on the civil plan sheets. Observations on site design, shallow soil and ground water conditions are discussed below.

- Bioretention soil
    - Thickness: The apparent thickness of loose bioretention soil based on soil probe data was generally about 1.5 feet as indicated on the plan.
    - Composition: The soil tested in generally the recommended guidelines for organic content and sand gradation, although the soil mix contained slightly less than the recommended range of fine sand and slightly more than the recommended range of silt.

- The overflow is consistent with the plans. Site design documents indicate that the ponding level was designed as 2.5 feet.

- Subgrade conditions: The subgrade is interpreted to consist of Vashon recessional outwash, as documented during construction.

- The field infiltration rate was measured at about 61 in/hr. Water readily soaked through the bioretention soil mix, the field rate is interpreted to represent the bioretention soil infiltration rate.

- Shallow ground water is present in the location of the IHS facility as measured in the piezometers and documented during several years of water level monitoring. AESI interprets that the infiltration test water soaked rapidly through the bioretention soil and mounded on the underlying shallow water table, then dissipated both laterally and vertically as shallow ground water flow. During testing, the lag time in response to start of inflow and stop of inflow was approximately 10 minutes.

- The effects of shallow ground water mounding will increase during the wetter winter months, and will reduce the effective infiltration rate by reducing the vertical gradient. The ongoing monitoring data will be reviewed during the coming months for ground water influence.

10.0 CLOSURE

We appreciate the opportunity to be of continued service to you on this project. Should you have any questions regarding this document or other geotechnical/hydrogeologic aspects of the project, please call us at your earliest convenience.

State of Washington Licensed Geologist
Hydrogeologist
2335
Jennifer H. Saltonstall

Jennifer Saltonstall 10/25/16

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Senior Associate Geologist/Hydrogeologist

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Attachments:	Figure IHS F1:	Vicinity Map
	Figure IHS F2:	LiDAR-Based Topography
	Figure IHS F3:	Facility and Exploration Plan
	Appendix A:	Project Civil Plans
	Appendix B:	Current Study Exploration Logs and Laboratory Testing Data
	Appendix C:	Background Soil, Geology, and Ground Water Data (Regional Maps, Previous Studies Exploration Logs and Laboratory Testing Data)
	Appendix D:	Soil Probe, Level Survey, and Field Infiltration Testing Data
	Appendix E:	Site Photos

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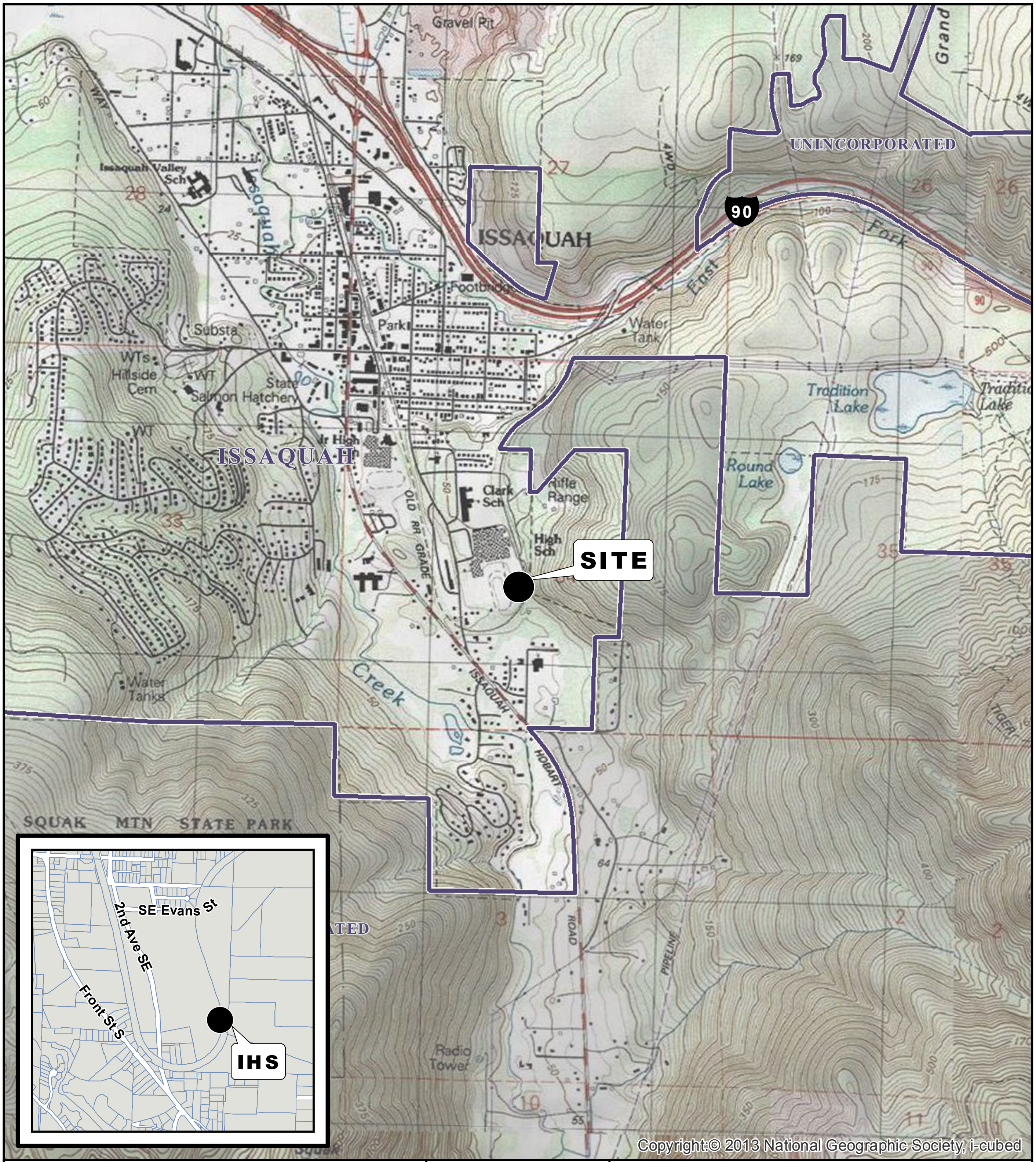

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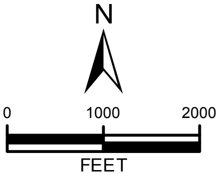
DATA SOURCES / REFERENCES:
USGS: 24K SERIES TOPOGRAPHIC MAPS
KING CO: STREETS, PARCELS 2016

LOCATIONS AND DISTANCES SHOWN ARE APPROXIMATE



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VICINITY MAP

BIORETENTION HYDROLOGIC PERFORMANCE STUDY, IHS SITE ISSAQUAH, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	IHS F1

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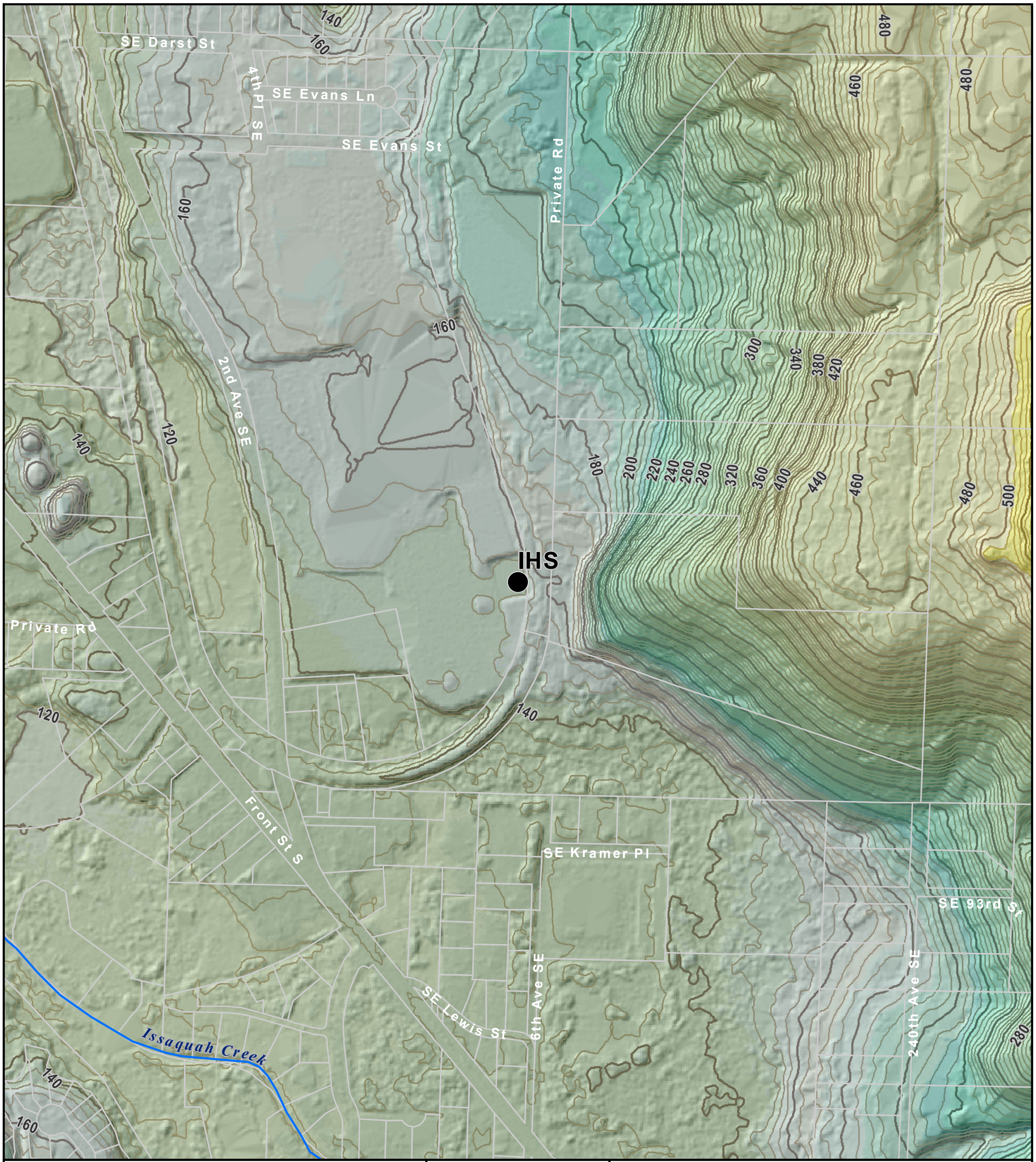
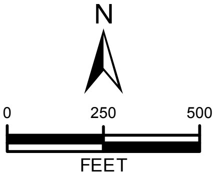


DATA SOURCES / REFERENCES:
PSLC: LIDAR 2000-2005 SUPERMOSAIC, 6' CELL
KING CO: STREETS, PARCELS 2016

LOCATIONS AND DISTANCES SHOWN ARE APPROXIMATE



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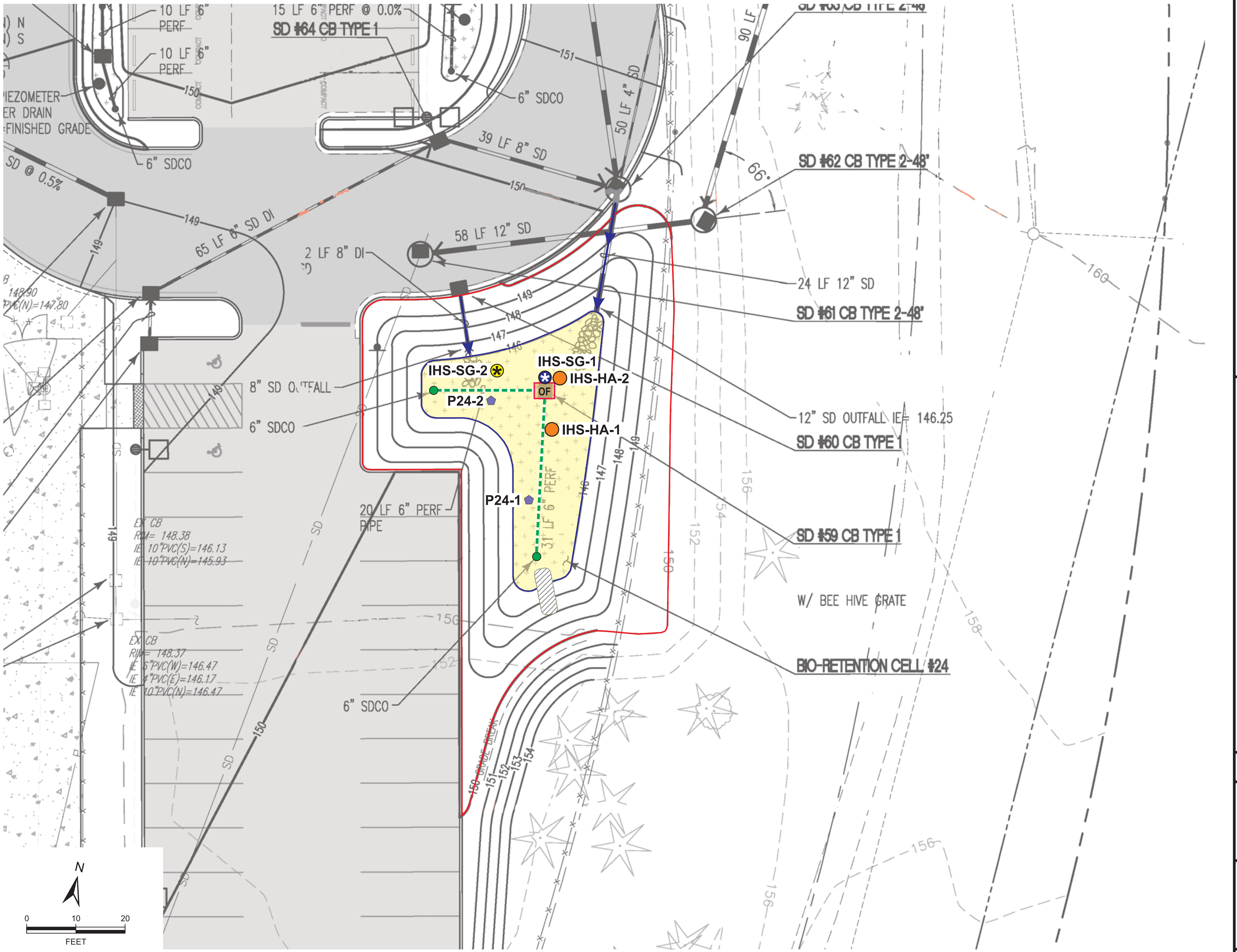
LIDAR BASED TOPOGRAPHY

BIORETENTION HYDROLOGIC
PERFORMANCE STUDY, IHS SITE
ISSAQUAH, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	IHS F2

Document Path: G:\GIS_Projects\aYear2015postJuly2016\150387 Bioretention Hydro Performance Monitoring\mxd\Fig2s\150387 IHS Fig2B LIDAR.mxd



LEGEND:

● HA	HAND AUGER
⊛	TEMPORARY STAFF GAUGE
⊛	PERMANENT STAFF GAUGE
⬭	BASE OF FACILITY
⬭	TOP OF FACILITY SLOPE
→	INFLOW / OVERFLOW DIRECTION
OF	OVERFLOW GRATE
- - -	PERFORATED PIPE
●	STORM DRAIN CLEANOUT
⬟ P	PRE-EXISTING 4 INCH PIEZOMETER
SD	STORM DRAIN
▨	CONCRETE SLURRY DUMP

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:

1. BASE MAP REFERENCE: COUGHLIN PORTER LUNDEEN, ISSAQUAH HIGH SCHOOL, GRADING AND DRAINAGE PLAN, SHEET C-404, 5/16/2014

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FACILITY AND EXPLORATION PLAN
IHS SITE
BIORETENTION HYDROLOGIC PERFORMANCE
ISSAQUAH, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	IHS F3

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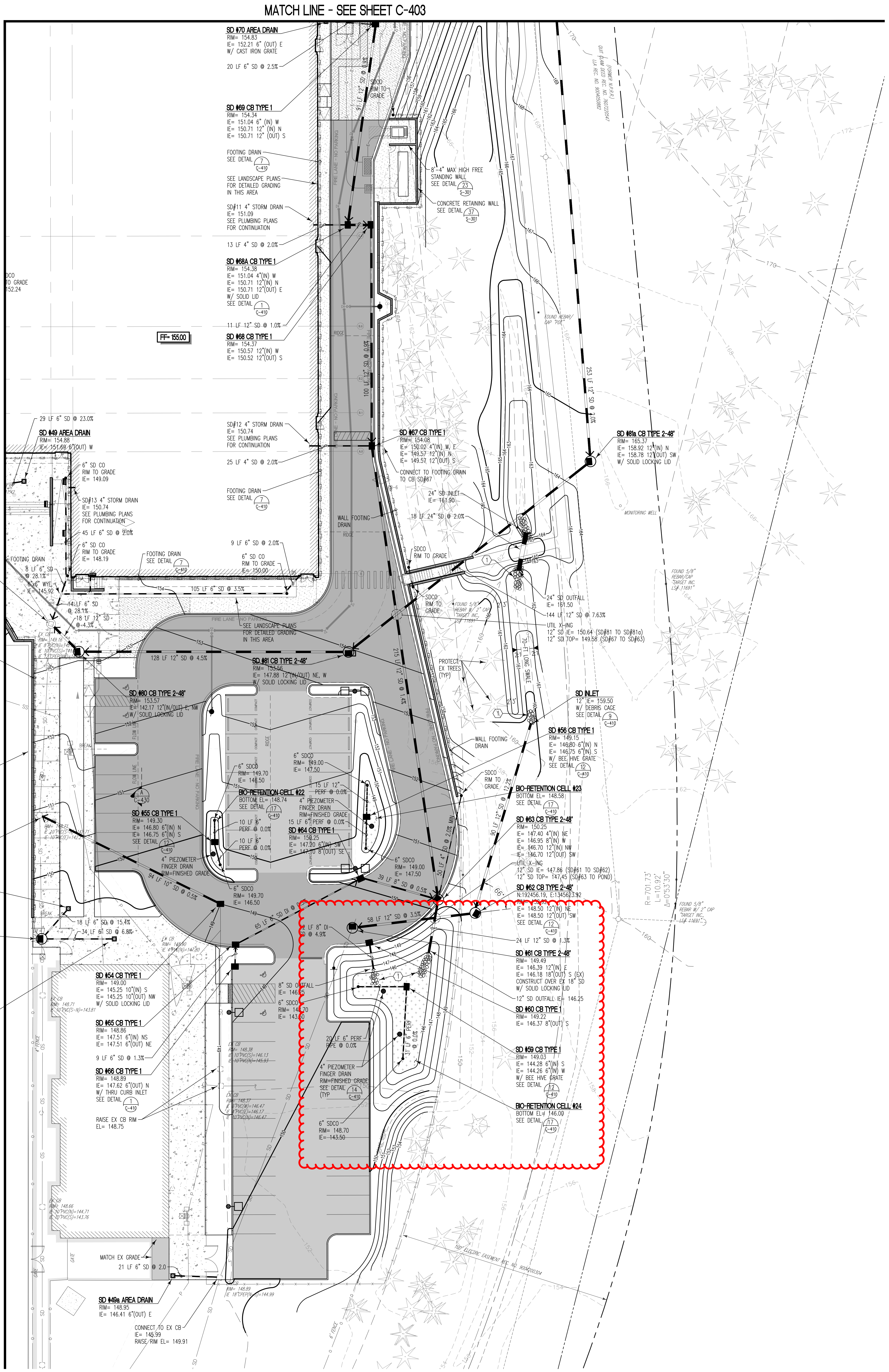
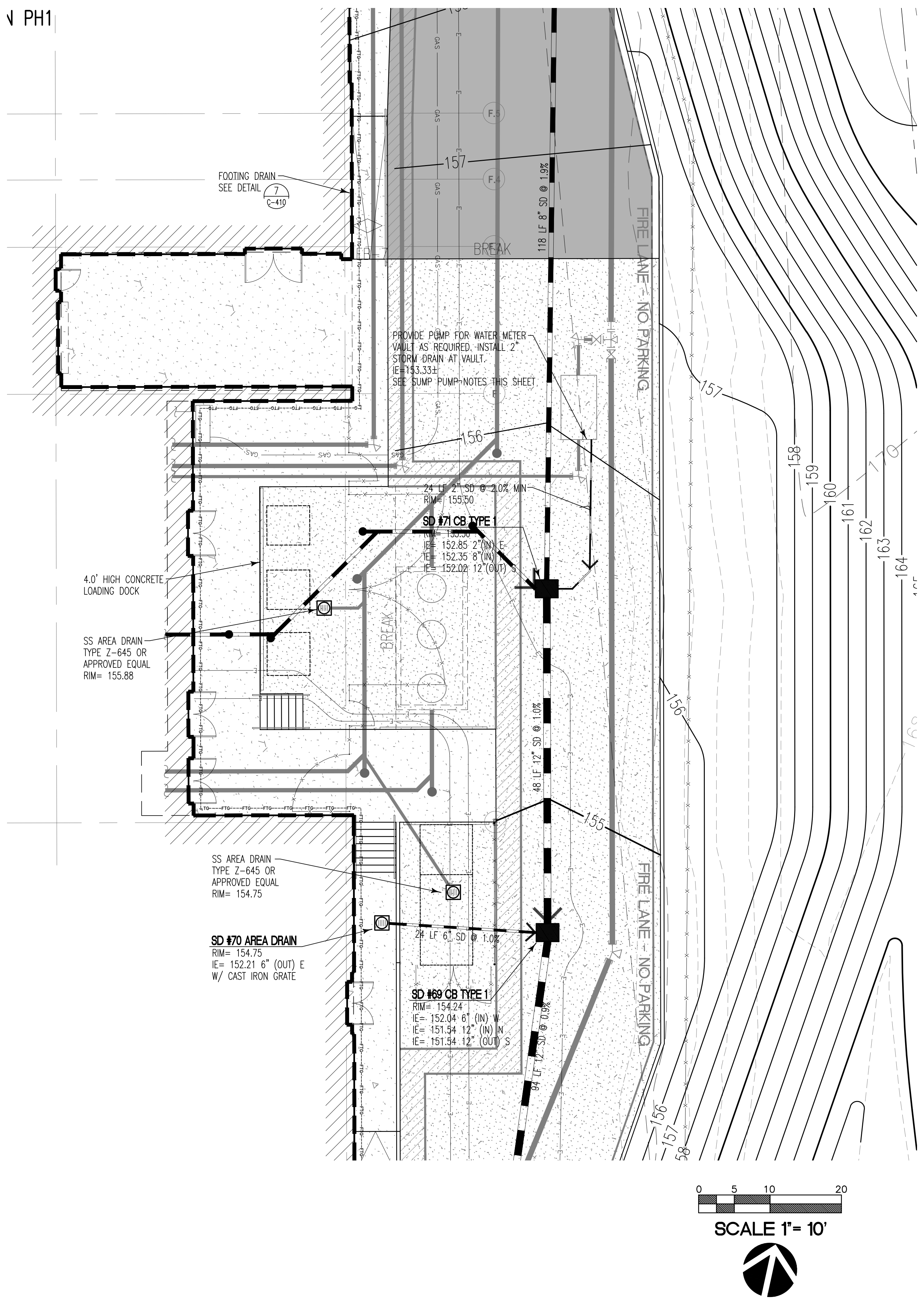
APPENDIX A

Project Civil Plans





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BIORETENTION NOTES

1. CONSTRUCTION OF THE BIO-RETENTION/RAINGARDEN AREAS SHALL ALSO INCORPORATE THE INFILTRATION FACILITIES NOTES ON THIS PAGE.
2. CONTRACTOR SHALL NOT EXCAVATE BIORETENTION AREAS UNTIL THE SITE HAS BEEN STABILIZED AND AUTHORIZATION IS PROVIDED BY THE OWNER'S REPRESENTATIVE.
3. ROUTE ALL SURFACE WATER AWAY FROM FUTURE/EXISTING BIORETENTION AREAS UNTIL THE SITE HAS BEEN STABILIZED PER THE LANDSCAPING AND/OR PAVING PLANS AND THE BIORETENTION AREA HAS BEEN ACCEPTED BY THE ENGINEER AND LANDSCAPE ARCHITECT.
4. CONTRACTOR SHALL HOLD A PRE-CONSTRUCTION MEETING WITH LANDSCAPE ARCHITECT, LANDSCAPE CONTRACTOR, CIVIL ENGINEER, EARTHWORK/CIVIL CONTRACTOR, GEOTECHNICAL ENGINEER AND OWNER'S REPRESENTATIVE PRIOR TO COMMENCING WORK ON BIORETENTION AREAS.
5. SUB-GRADE PREPARATION SHALL BE IN ACCORDANCE WITH THE PROJECT SPECIFICATIONS. THE CONTRACTOR SHALL HAVE ALL PREPARED SUB-GRADE AREAS INSPECTED BY THE GEOTECHNICAL ENGINEER PRIOR TO PLACEMENT OF MATERIAL.
6. GEOTECHNICAL ENGINEER SHALL FIELD VERIFY SPECIFIED INFILTRATION RATE ON APPROVED SOIL MIX AFTER PLACEMENT IN BIO-RETENTION AREAS. TESTING SHALL BE COMPLETED ON TYPICAL INSTALLATION AFTER ALL REQUIRED SUBGRADE PREPARARTION AND FULL DEPTH BIO-RETENTION SOIL PLACEMENT. IF REQUIRED FIELD INFILTRATION PERFORMANCE IS NOT ACHIEVED, CONTRACTOR SHALL ADJUST SOIL MIX COMPONENTS OR PLACEMENT PROCEDURES AND ADDITIONAL TESTING WILL BE COMPLETED UNTIL FIELD INFILTRATION PERFORMANCE CONFORMS TO THESE PROJECT DOCUMENTS.
7. CONSTRUCTION TRAFFIC SHALL NOT BE ALLOWED TO DRIVE OVER BIORETENTION AREAS.
8. IF THE SUB-GRADE BECOMES COMPACTED OR CONTAIMINATED WITH SILTS (OR OTHER DEBRIS) THE CONTRACTOR WILL BE RESPONSIBLE FOR OVER-EXCAVATING UP TO 2-FEET OF MATERIAL BELOW THE SUB-GRADE AND BACKFILLING WITH FREE-DRAINING MATERIAL AS DIRECTED BY THE GEOTECHNICAL ENGINEER AT NO ADDITIONAL COST TO THE OWNER.
9. THE OWNERS GEOTECHNICAL ENGINEER SHALL PROVIDE IN-SITU TESTING OF THE BIORETENTION SOIL MIX TO VERIFY INFILTRATION RATES MEET SPEC'S OF 1-INCH/HR.
10. THE CONTRACTOR SHALL PROVIDE A DETAILED CONSTRUCTION SCHEDULE TO THE OWNER AND DESIGN TEAM AT THE PRECONSTRUCTION MEETING AND ALLOW ADEQUATE TIME FOR SUB-GRADE PREPARATION, IN-SITU TESTING AND INSPECTION.

INFILTRATION FACILITIES

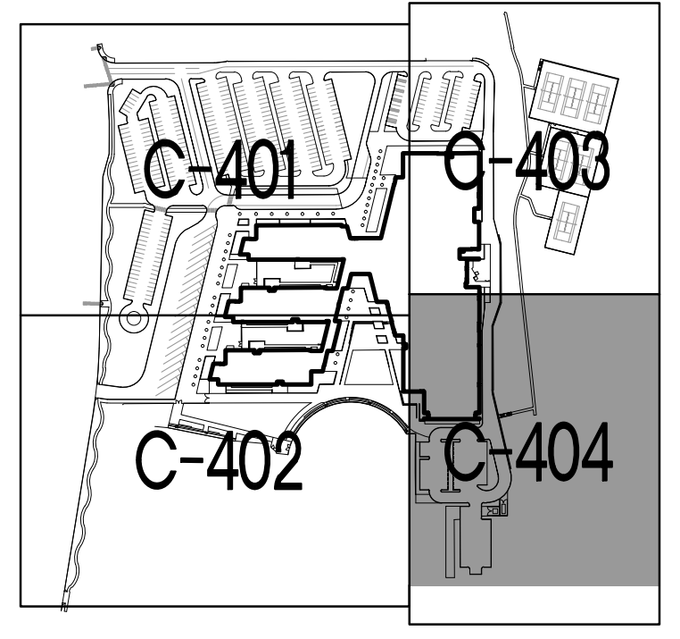
1. CONTRACTOR SHALL NOT EXCAVATE INFILTRATION AREAS UNTIL THE SITE HAS BEEN STABILIZED AND AUTHORIZATION IS PROVIDED BY THE OWNER'S REPRESENTATIVE.
2. ROUTE ALL SURFACE WATER AWAY FROM FUTURE/EXISTING INFILTRATION AREAS UNTIL THE SITE HAS BEEN STABILIZED PER THE LANDSCAPING AND/OR PAVING PLANS AND THE BIORETENTION AREA HAS BEEN ACCEPTED BY THE ENGINEER AND LANDSCAPE ARCHITECT.
3. CONTRACTOR SHALL HOLD A PRE-CONSTRUCTION MEETING WITH CIVIL ENGINEER, EARTHWORK/CIVIL CONTRACTOR, GEOTECHNICAL ENGINEER AND OWNER'S REPRESENTATIVE PRIOR TO COMMENCING WORK ON INFILTRATION AREAS.
4. SUB-GRADE PREPARATION SHALL BE IN ACCORDANCE WITH THE PROJECT SPECIFICATIONS. THE CONTRACTOR SHALL HAVE ALL PREPARED SUB-GRADE AREAS INSPECTED BY THE GEOTECHNICAL ENGINEER PRIOR TO PLACEMENT OF MATERIAL.
5. CONSTRUCTION TRAFFIC SHALL NOT BE ALLOWED TO DRIVE OVER INFILTRATION AREAS EXCEPT WHERE NOTED ON PLANS. IN THE AREAS WHERE CONSTRUCTION TRAFFIC IS ALLOWED TO DRIVE OVER THE INFILTRATION AREAS, THE CONTRACTOR SHALL OVER-EXCAVATE THE UPPER 2-FEET OF THE SUBGRADE AND REPLACE WITH FREE DRAINING MATERIAL AS NOTED IN THE CONTRACT DOCUMENTS.
6. IF THE SUB-GRADE (IN AREAS OTHER THAN THOSE NOTED IN NOTE 5 ABOVE) BECOMES COMPACTED OR CONTAIMINATED WITH SILTS (OR OTHER DEBRIS) THE CONTRACTOR WILL BE RESPONSIBLE FOR OVER-EXCAVATING UP TO 2-FEET OF MATERIAL BELOW THE SUB-GRADE AND BACKFILLING WITH FREE-DRAINING MATERIAL AS DIRECTED BY THE GEOTECHNICAL ENGINEER AT NO ADDITIONAL COST TO THE OWNER.
7. THE OWNERS GEOTECHNICAL ENGINEER TO SHALL PROVIDE IN-SITU TESTING OF THE INFILTRATION BED SUB-GRADE TO VERIFY INFILTRATION RATES MEET DESIGN RATES.
8. THE CONTRACTOR SHALL PROVIDE A DETAILED CONSTRUCTION SCHEDULE TO THE OWNER AND DESIGN TEAM AT THE PRECONSTRUCTION MEETING AND ALLOW ADEQUATE TIME FOR SUB-GRADE PREPARATION, IN-SITU TESTING AND INSPECTION.

SUMP PUMP NOTES

1. PROVIDE SUMP AND PUMP AT BOTTOM OF VAULT.
2. PUMP SHALL BE GCS AUTOMATIC SUMP DRAIN EJECTOR ASSEMBLY MODEL #996633-51-2.
3. ONE GALLON OF SYSTEM WATER WILL BE USED TO REMOVE ONE GALLON FROM THE SUMP.
4. PUMPED DISCHARGE WATER SHALL BE DIRECTED TO STORM SYSTEM PER PLAN.

KEY MAP

NOT TO SCALE



LEGEND

	EXISTING	REMOVE	PROPOSED
LIGHT ASPHALT PAVING	░		▒
HEAVY ASPHALT PAVING			▓
CONCRETE PAVING	░		░
PERMEABLE CONCRETE			░
BUILDINGS	▨		▨
GRAVEL	░		
CURBING	═		═
ROCKERY			
TREE			
WATER LINE	—W—		━
STORM DRAINAGE LINE	—SD—		━
SANITARY SEWER LINE	—SS—		━
POWER	—P—		—E—
GAS LINE	—G—		—GAS—
WATER METER/VALVE/FH	⊞ ⋈		⊞ ⋈
STORM CB/MH			■
SANITARY SEWER MH/CO	○		◎ ●
GAS VALVE/METER	⋈		
STREET LIGHT ASSEMBLY			
CONSTRUCTION LIMITS			
BIO-FILTRATION RAIN GARDEN			

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A CONSULTING
STRUCTURAL AND CIVIL
ENGINEERING CORPORATION

JEFF NOEL PETERSON
36936
05/16/14

ISSAQUAH
SCHOOL DISTRICT 411

ISSAQUAH HIGH SCHOOL
700 SECOND AVE NE
ISSAQUAH, WASHINGTON 98027

CONSTRUCTION RECORD DRAWING
THIS CONSTRUCTION RECORD DRAWING IS A COPY OF A CAD FILE PREPARED BY COUGHLIN PORTER LUNDEEN AND HAS BEEN EDITED TO REFLECT FIELD VERIFIED LOCATIONS OF THE STORM, WATER, AND SANITARY SEWER SYSTEMS. FIELD VERIFIED LOCATIONS OF UTILITIES WERE OBTAINED BY WHITE SHIELD INC. IN NOV/DEC 2011. COUGHLIN PORTER LUNDEEN, INC. DOES NOT PROVIDE ANY WARRANTEE AS TO THE ACCURACY OR COMPLETENESS OF SUCH INFORMATION PROVIDED BY OTHERS.

DATE	DESCRIPTION
	16 MAY 2014
ISSUE:	RECORD DRAWINGS
PROJECT NO.:	C070092-02
DRAWN BY:	SAS
CHECKED BY:	JCF

GRADING AND
DRAINAGE PLAN

C-404

FIELD REPORT

Associated Earth Sciences, Inc.

911 Fifth Avenue, Suite 100
Kirkland, Washington 98033
425-827-7701 FAX 827-5424

Page 1 of 2

Date **4-16-10**	Project Name **New Issaquah High School**	Project No. **KE070373B**
Location **700 2nd Avenue SE**		Weather **Sunny 60°F**
Municipality **City of Issaquah**		Report Number **142**
Engineer/Architect **Coughlin Porter Lundeen / Mahlum Architecture**		
Client/Owner **Issaquah School District**		
General Contractor/Superintendent **Cornerstone**		
Grading Contractor/Superintendent **Continental Dirt**		

TO:
Issaquah School District
555 NW Holly Street
Issaquah, Washington 98027-2899

ATTN: Royce Nouright

AS REQUESTED BY

THE FOLLOWING WAS NOTED:

Pond Excavation

Continental dirt performed excavation of pond number 24 today. The contractor began the excavation by removing the 18 inches of fill over the proposed pond area, this fill consisted of crushed rock and some onsite sand and gravel. The fill that was removed was stockpiled onsite. Once the fill removal was complete Continental dirt began excavating the southern side of the proposed pond. The portion of the pond that was completed today is shown on page two of this report.

Sample Pickup

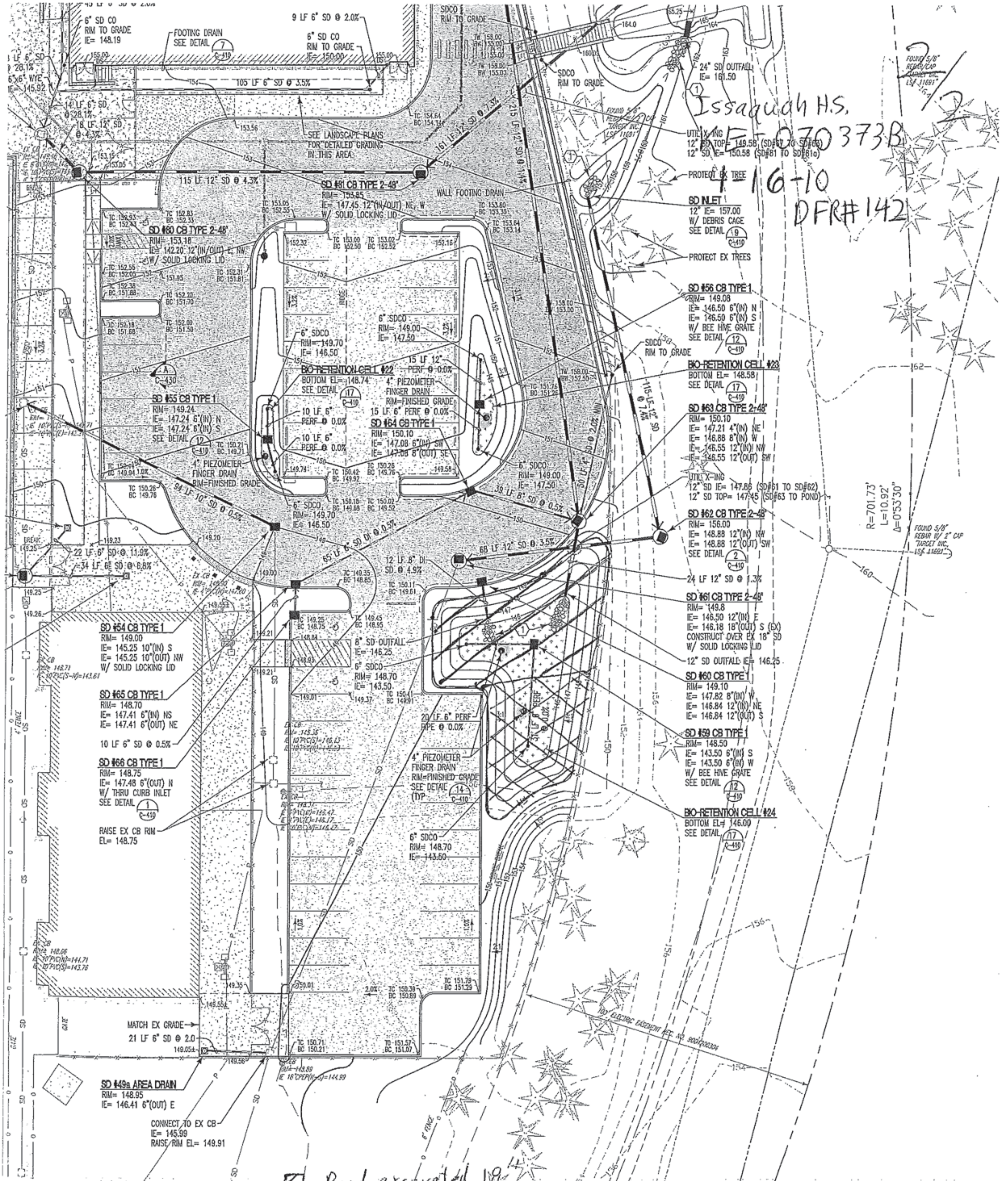
AESI received a sample of the medium sand for use in the pit drains to perform sieve analysis in our laboratory.

COPIES TO:

DATE MAILED: APR 23 2010

FIELD REP.: Michael Place P.E.

PRINCIPAL / PM: Kurt Merriman, P.E.



2/2

Issaquah H.S.
4E-070373B
4-16-10
DFR#142

▨ Pond excavated 18"

⊠ Pond excavated to full depth

FIELD REPORT

Associated Earth Sciences, Inc.

911 Fifth Avenue, Suite 100
Kirkland, Washington 98033
425-827-7701 FAX 827-5424

Page 1 of 3

Date **4-19-10**	Project Name **New Issaquah High School**	Project No. **KE070373B**
Location **700 2nd Avenue SE**		Weather **Sunny 60°F**
Municipality **City of Issaquah**		Report Number **143**
Engineer/Architect **Coughlin Porter Lundeen / Mahlum Architecture**		
Client/Owner **Issaquah School District**		
General Contractor/Superintendent **Cornerstone**		
Grading Contractor/Superintendent **Continental Dirt**		

TO:
Issaquah School District
555 NW Holly Street
Issaquah, Washington 98027-2899

ATTN: Royce Nouright

AS REQUESTED BY

THE FOLLOWING WAS NOTED:

Pond Excavation
Continental Dirt continued excavation of pond number 24 today. Continental Dirt excavated the northern end of the proposed pond down to the proposed grades using a Cat 330 excavator and Cat 312 excavator. The material removed from the base of the pond was noted to be advance outwash deposits consisting of sand and gravel, which was also present at the base of the completed pond. The pond excavation was completed today and the areas worked today are shown on page two of this report.

Footings
The contractor began excavation of two footings along the east side of the triangular shaped outdoor corridor on the south side of the new school. Both footings were excavated to native advance outwash soil, consisting of sand and gravel, and were noted to be firm and unyielding under full body weight when probed using a ½ inch diameter probe rod. In AESI's opinion these footings will maintain the proposed footing loads. See page three for footing locations.

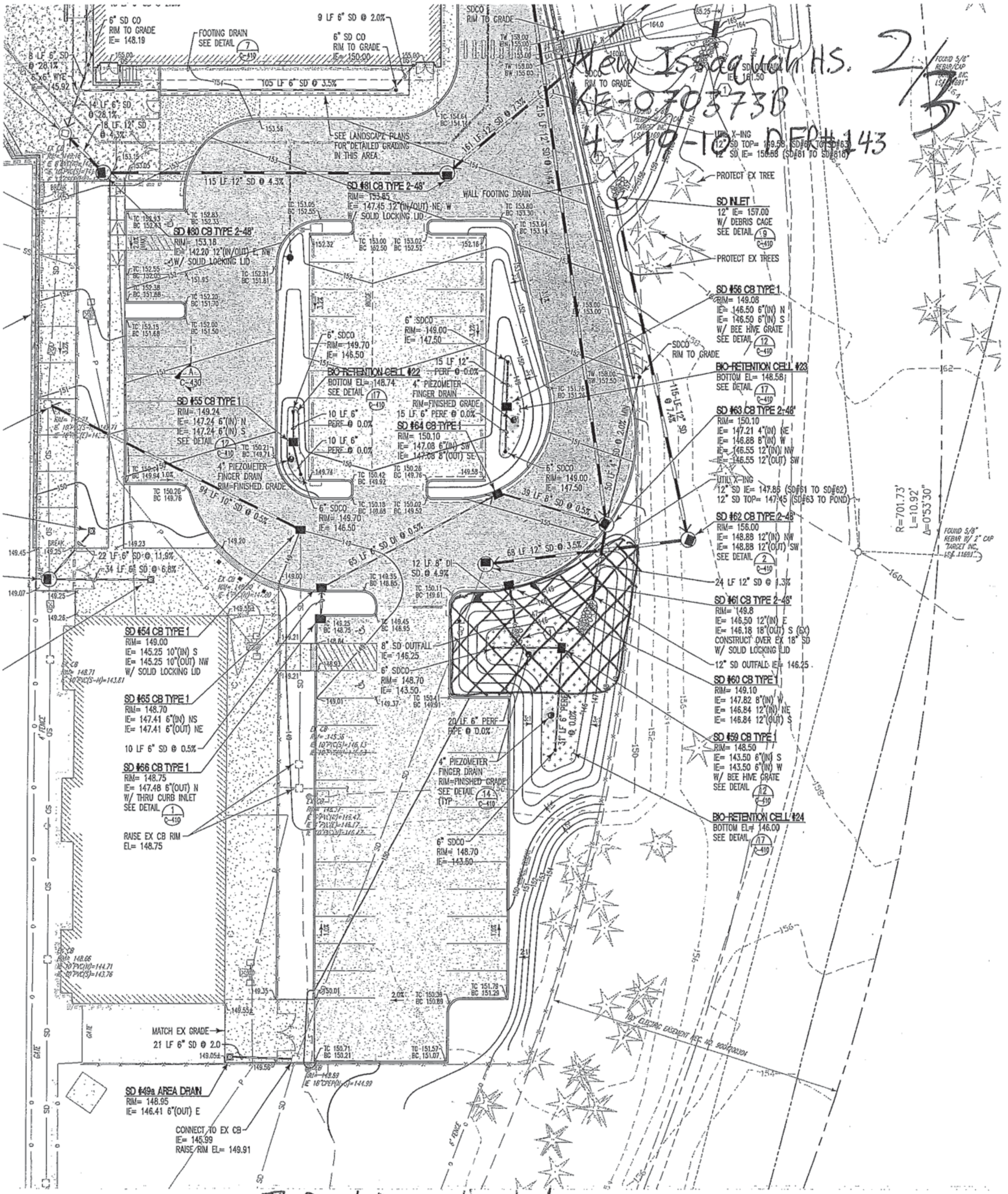
COPIES TO:

DATE MAILED: APR 23 2010

FIELD REP.: Michael Place P.E.

PRINCIPAL / PM: Kurt Merriman, P.E.

New Issaquah H.S. 2/3
KE-070373B
4-19-10 DFR#143

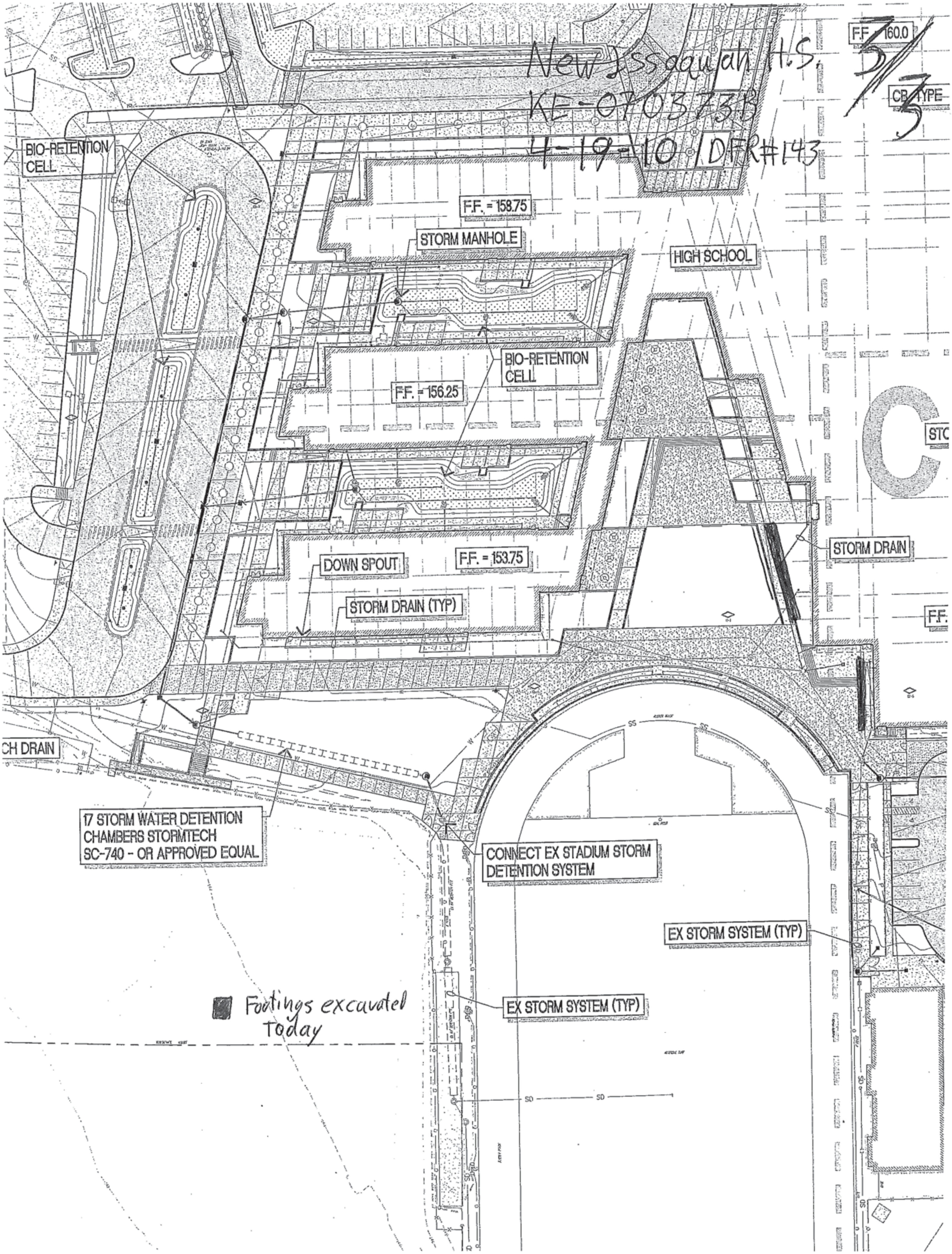


☒ Pond Excavation today

1 2 3

New Issaquah H.S.
KE-070373B
4-19-10 / DFR#143

3/5



■ Footings excavated today

FIELD REPORT

Associated Earth Sciences, Inc.

Celebrating 25 Years of Service

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Page 1 of 2

Date **4/28/2010**	**Project Name** **New Issaquah High School**	**Project No.** **KE070373B**
Location **700 2nd Ave, Pond 24**		Weather **Rain/clouds/sun 40-50s**
Municipality **City of Issaquah**		**Report Number** **150B**
Engineer/Architect **Coughlin Porter Lundeen**		
Client/Owner **Issaquah School District No. 411 / Royce Nourigat**		
General Contractor/Superintendent **Cornerstone Construction/Eric Scott**		
Earthwork Contractor/Superintendent **Continental Dirt Contractors/Jerry Nelson, Jr.**		

TO: **Issaquah School District no. 411**
555 Holly Street
Issaquah, WA 98027

ATTN: **Royce Nourigat**

AS REQUESTED BY **Kurt Merriman**

THE FOLLOWING WAS NOTED:

AESI onsite to perform performance flow testing in pit drains 24-01 and 24-02 constructed in storm water pond #24. General pit drain construction and flow testing procedure described below. A fire hydrant located to the north of the pond is used as a clean water source. Data sheets on file at AESI.

Equipment

- AESI provided equipment: Flow meters Electronic water level meter Electronic pressure transducers (dataloggers) Non-collapsible 2-inch diameter hose
- Equipment from others: Lay-flat 2-inch diameter hose (Continental Dirt Construction), Hydrant meter (Cornerstone)

Pit Drain Construction and Performance Flow Testing Method

Pit drain construction generally consists of excavating pits with the track-mounted excavator to a depth of approximately 10 feet (ft) below pond subgrade. Typical surface area dimensions are a minimum of 3 feet in width and 10 ft in length, with relatively vertical walls and flat bottoms. A 2- to 6-inch diameter polyvinylchloride (PVC) sounding pipe with the bottom 5 ft perforated will be installed in the pit bottom. The pits will be backfilled with washed gravel (WSDOT 9-03.12(4)) to 3 ft below subgrade. Infiltration testing will occur at this stage of pit drain construction. After testing, 18 inches of 4 by 8 sand will be placed on top of the gravel. 18 inches of medium sand will be place on top of the 4 by 8 sand. Pit drain excavation details are presented in separate field reports.

Generally, the infiltration testing method will consist of 3 testing phases. During all phases, readings of the water level, instantaneous flow and total flow will be recorded at regular intervals. The water level in the pits will be monitored in the PVC sounding pipe, placed on the bottom of the pit, with an electronic water level meter, and in some cases a pressure transducer (datalogger) may also be installed to monitor water level. Phase 1, constant rate testing: water will be introduced to the drain through an electronic flow meter with instantaneous and total flow readout. A constant flow rate, generally 45 gpm, will be maintained at a constant rate for roughly 4 hours. Phase 2, the constant head testing: the flow rate will be adjusted to maintain a constant head of water in the gravel pack, which is monitored in the PVC sounding tube. This phase of testing will last approximately 1 hour. Phase 3, falling head testing: water flow is discontinued immediately after the constant head phase. The duration of this phase will vary depending on the infiltration rate. A datalogger may remain to record falling data throughout the evening.

Testing Summary

Pit Drain 24-01
Surface Dimensions: 6 feet x 14 feet; Base Dimensions: 5.5 x 10
Initial static water level from top of PVC: 9.44 feet = 6.09 feet from pond subgrade = 3.91 feet above pit bottom
Constant Rate Duration: 270 minutes
Constant Head Duration: 60 minutes
Falling Head Duration: 30 minutes of manual measurements; datalogger remained in drain overnight
Constant Rate Flow: 45 gpm

COPIES TO:	File	FIELD REP.:	Lara Koger Lara Koger
DATE MAILED:	MAY 0 4 2010	PRINCIPAL / PM:	Kurt D. Merriman, P.E.

FIELD REPORT

FR 150B

Page 2 of 2

To:	Project Name: Issaquah High School
Date: 4/28/2010	Project Number: KE070373B

Constant Head Flow: 43 gpm
Total Head Rise / depth to water: 4.57 ft of rise / depth of water of 1.52 feet below pond subgrade
Total Flow: 14398.3
No appreciable drop in gravel backfill

Pit Drain 24-02
Surface Dimensions: 6.5 feet x 12 feet; Base Dimensions: 6 feet x 9 feet
Initial static water level from top of PVC: 9.41 feet = 6.36 feet from pond subgrade = 4.14 feet above pit bottom
Constant Rate Duration: 240 minutes
Constant Head Duration: 60 minutes
Falling Head Duration: 10 minutes of manual measurements; datalogger remained in drain overnight
Constant Rate Flow: 45 gpm
Constant Head Flow: 45 gpm
Total Head Rise / depth to water: 4.62 ft of rise / depth of water of 1.57 feet below pond subgrade
Total Flow: 13,400.4
No appreciable drop in gravel backfill

Copies To: File	Field Rep: Lara B. Koger Lara Koger
Date Mailed: MAY 04 2010	Principal /PM: Kurt D. Merriman, P.E.

Associated Earth Sciences, Inc.

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2911 ½ Hewitt Avenue • Suite 2
Everett, WA 98201
425-259-0522 FAX 425-252-3408

Job File ☒ **Calculation** ☐

FR 150B

Phone Log ☐ **Memo** ☐ **Conference** ☐ **Info** ☐

Date 4/28/2010 **Project No.** KE070373B

Project New Issaquah High School

Subject Finger Drain Schematic - Pond 24

Person/Company

Phone No. **Page** of

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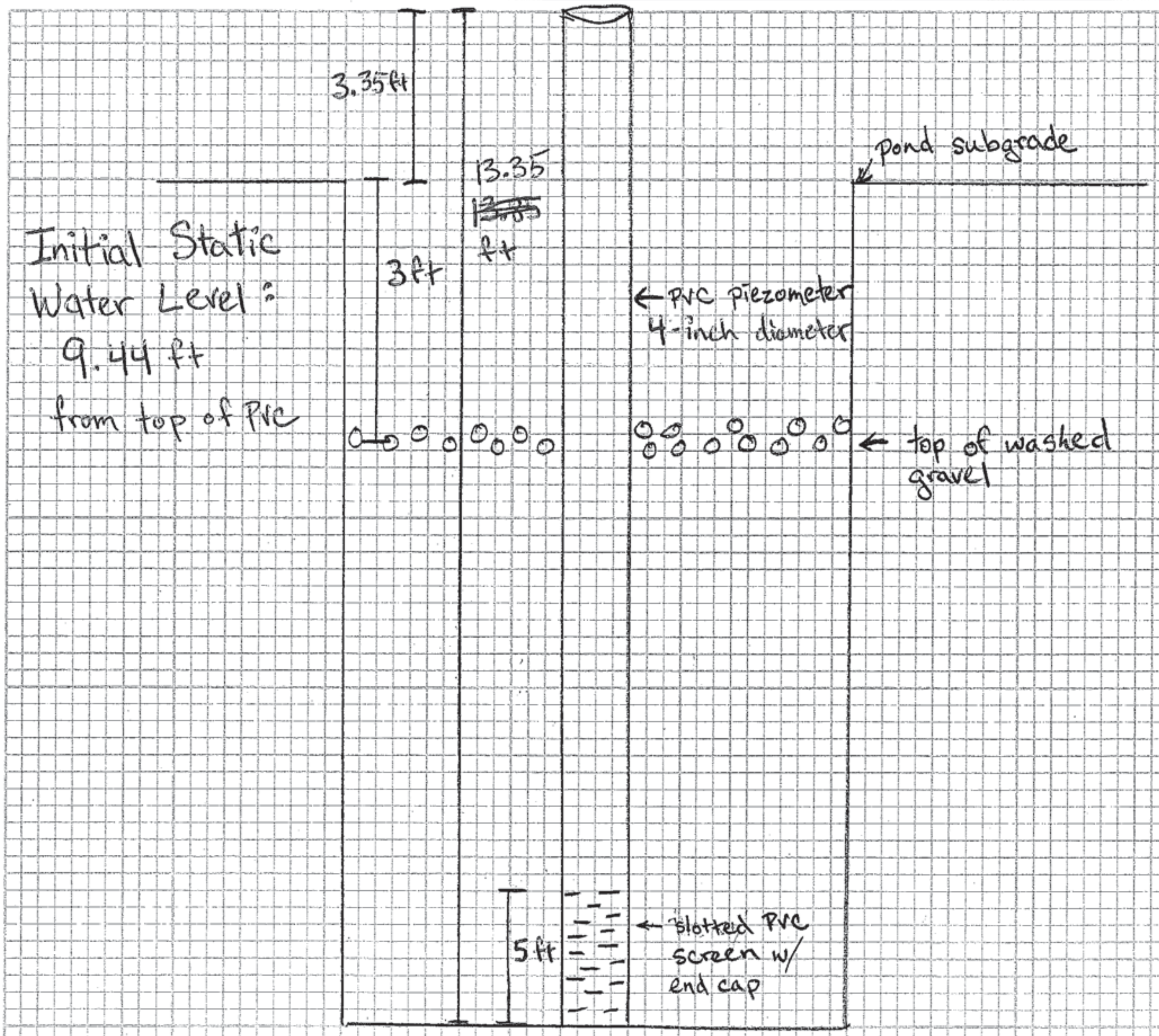

Finger Drain 24-1

Top of Pit Area : 6 feet by 14 feet

Bottom of Pit Area : 5.5 feet by 10 feet

Total Depth from Pond Subgrade : 10 feet

Not to Scale

Signature **Reviewed By**

Associated Earth Sciences, Inc.

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Everett, WA 98201
425-259-0522 FAX 425-252-3408

Job File ☒ **Calculation** ☐ FR 150B

Phone Log ☐ **Memo** ☐ **Conference** ☐ **Info** ☐

Date ______ **Project No.** KE070373B

Project New Issaquah High School

Subject Finger Drain Schematic - Pond 24

Person/Company ______

Phone No. ______ **Page** ______ **of** ______

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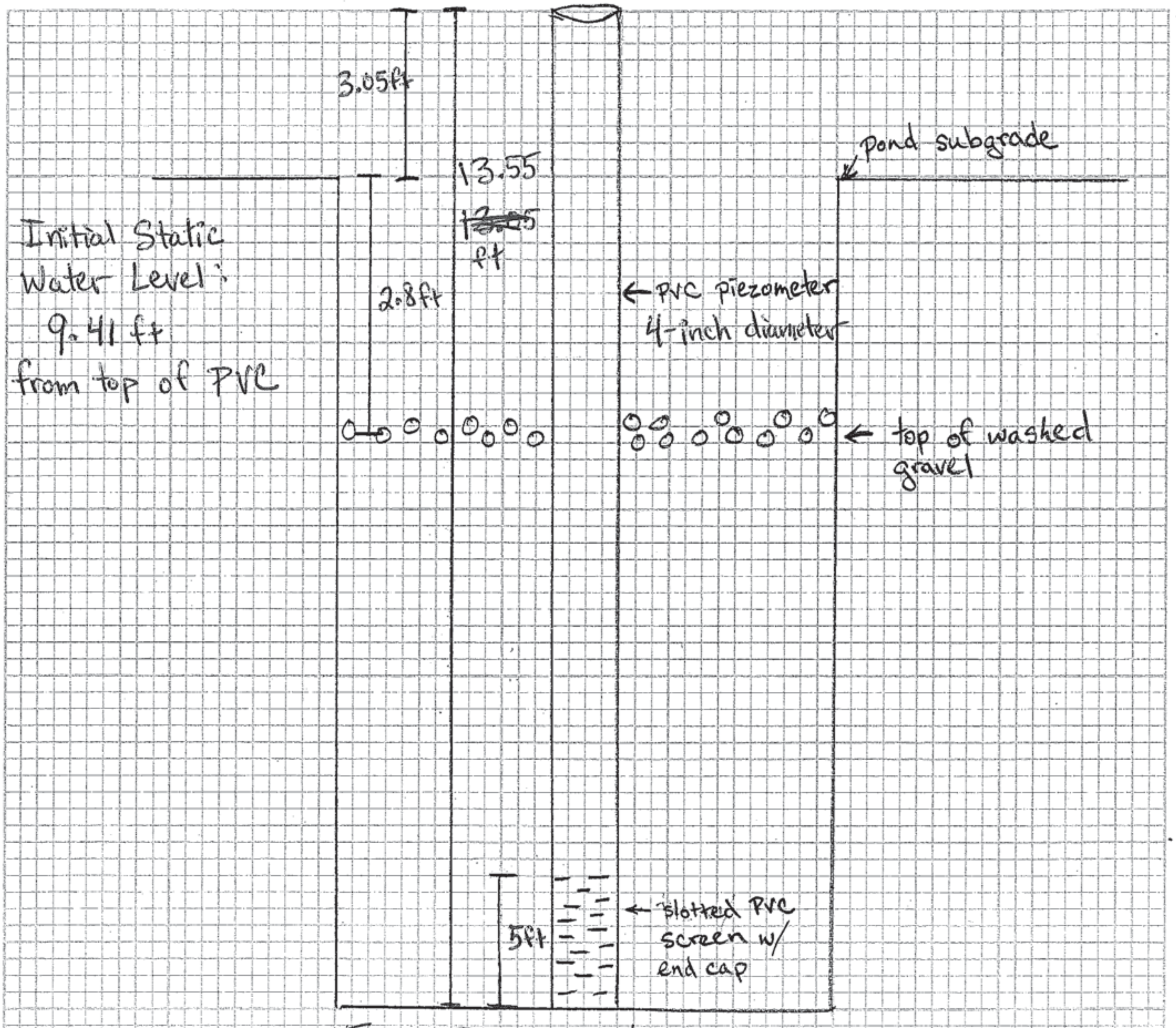


Finger Drain 24-2

Top of Pit Area: 6.5ft by 12ft

Bottom of Pit Area: 6ft by 9ft

Total Depth from Pond Subgrade: 10.5ft

Not to Scale

Signature ______ **Reviewed By** ______

FIELD REPORT

Associated Earth Sciences, Inc.

911 Fifth Avenue, Suite 100
Kirkland, Washington 98033
425-827-7701 FAX 827-5424

Page 1 of 1

Date **4/29/10**	Project Name **New Issaquah High School**	Project No. **KE070373B**
Location **700 2nd Ave**		Weather **Partly sunny/50's**
Municipality **Issaquah**		Field Report No. **151**
Engineer/Architect **Coughlin Porter Lundeen**		
Client/Owner **Issaquah School District No. 411 / Royce Nourigat**		
General Contractor/Superintendent **Cornerstone Construction / Eric Scott**		
Grading Contractor/Superintendent **Continental Dirt Contractors / Jerry Nelson Jr.**		

TO:
Issaquah School District no. 411
555 Holly Street
Issaquah, WA 98027

ATTN: **Royce Nourigat**

AS REQUESTED BY

THE FOLLOWING WAS NOTED:

AESI was onsite today to observe on-going site construction activities as part of continued part-time construction monitoring of the new Issaquah High School building.

Finger Drain Excavation, Installation, and Testing

AESI on site to collect final water levels from finger (pit) drains 24-1 and 24-2, remove the data loggers from the piezometer pipes, and observe installation of the approved 4X8 sand and medium sand.

The water level in drain 24-1 was 5.53 feet bgs (below the existing ground surface) at 0722. The two data loggers were also removed at that time. The water level in drain 24-2 was 5.44 feet bgs at 0735. One data logger was also removed at that time.

AESI observed sand and gravel slough soils on top of the washed drain rock around the base of the excavation sidewalls as the result of performance infiltration testing on 4-28-10. AESI recommended removal of these soils prior to placing the 4X8 sand and medium filter sand. The contractor utilized a mini-excavator to remove most of the soils. The remained of the soils were removed by laborer to expose clean grain rock. The top surface of the drain rock was adequately cleaned in AESI's opinion.

The contractor placed 18 inches of 4X8 sand on top of the drain rock in the finger drains. The 4X8 sand was free of other deleterious soils. The contractor then placed 18 inches of medium filter sand on top of the 4X8 sand. The medium filter sand was free of other deleterious soils. The 4X8 and medium filter sands were placed in general conformance with the project plans and specifications in AESI's opinion.

Following completion of finger drain installation, the contractor installed the storm drainage structure today near the middle of the bio-retention cell. AESI was not present during installation.

The contractor placed the approved drain rock over about 75% of the bottom of the bio-retention cell after the activities noted above were completed.

COPIES TO:

DATE MAILED: MAY 04 2010

FIELD REP.: Frank S. Mocker, L.E.G.

PRINCIPAL / PM: Kurt D. Merriman, P.E.

FIELD REPORT

Associated Earth Sciences, Inc.

911 Fifth Avenue, Suite 100
Kirkland, Washington 98033
425-827-7701 FAX 827-5424

Page 1 of 2

Date **6/14/10**	Project Name **New Issaquah High School**	Project No. **KE070373B**
Location **700 2nd Ave**		Weather **Partly Cloudy/ 60's**
Municipality **Issaquah**		Field Report No. **171**
Engineer/Architect **Coughlin Porter Lundeen**		
Client/Owner **Issaquah School District No. 411 / Royce Nourigat**		
General Contractor/Superintendent **Cornerstone Construction / Eric Scott**		
Grading Contractor/Superintendent **Continental Dirt Contractors / Jerry Nelson Jr.**		

TO:
Issaquah School District no. 411
555 Holly Street
Issaquah, WA 98027
ATTN: **Royce Nourigat**
AS REQUESTED BY

THE FOLLOWING WAS NOTED:

AESI was onsite today to observe on-going site construction activities as part of continued part-time construction monitoring of the new Issaquah High School building.

Bio-Retention Cells #20 and #21
The contractor finished placing approximately 2 inches of compost over the pond slopes in cell #20 and placing bio-retention mix soils at the bottom of both cells today. The bio-retention soils were initially placed at the bottom of the cells using a tele-belt and laborers to minimize compaction of the soils. The contractor then used a small excavator to distribute the soils across the bottom of the cells based on the apparent approval of the design engineer. AESI will perform in place infiltration testing once the cells are completed.

Bio-Retention Cell #24
The contractor used a tele-belt to distribute bio-retention soils over the bottom and east and south slopes of the cell.

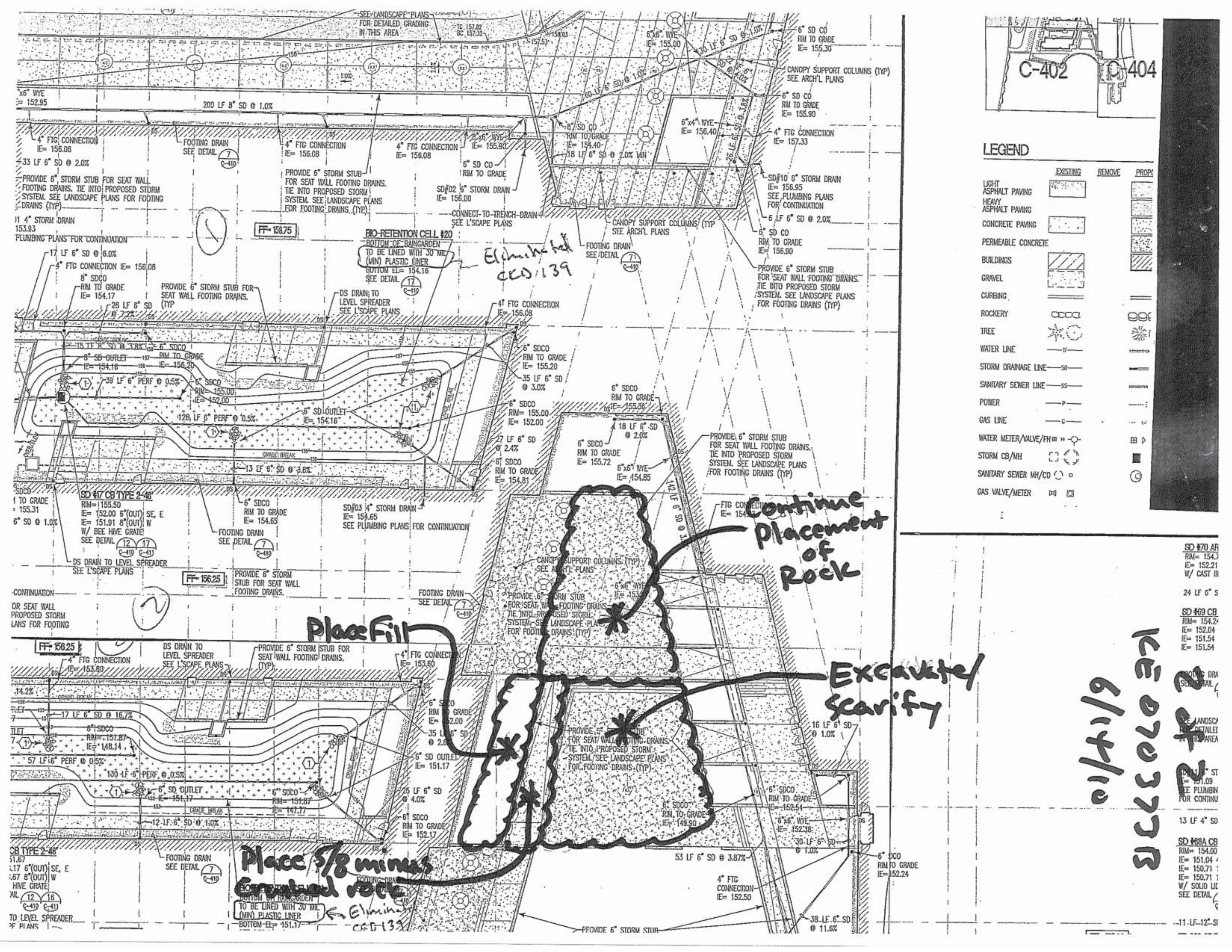
Courtyard Permeable Concrete
The contractor finished placement of washed crushed rock in the approximate area noted on the attached figure. The contractor imported the rock from a different source (Corliss Resources – Puyallup). AESI reviewed the supplier-provided sieve test data, compared the CTI and Corliss materials in the field, and collected a sample for confirmatory testing at AESI's laboratory. AESI noted that the material appears similar to the previously approved CTI material but that formal testing and approval still needs to be acquired. The contractor elected to place the material in the permeable concrete area to the north of the courtyard stairs prior to final approval. AESI completed the sieve analysis and relayed the results to John Farliegh (CPL). In AESI's opinion, the Corliss washed, crushed rock material meets the intent of the specification (WSDOT 9-03.12(3)) for its intended use as choker base below the permeable concrete in the courtyard area. The material was approved by John Farliegh.

AESI observed the contractor excavate to subgrade (6-inches below base of permeable concrete) for the permeable concrete area indicated on the attached figure from the courtyard stairs south to the permeable paver area. The contractor excavated up to about 1 ½ feet to make subgrade elevation for the permeable concrete. The material generally consisted of sand and gravel with a trace ranging to few silt. The subgrade soils are suitable in AESI's opinion. The contractor scarified the subgrade using the teeth of the excavator. No re-compaction was performed on the scarified soils. The contractor informed AESI that base rock will not be placed over the subgrade today.

Planter Fill
The contractor placed a portion of the excavated soils in the planter area in the approximate area indicated on the attached figure. The soils were not compacted.

Pedestrian Ramp Subgrade Preparation
The contractor placed 5/8 inch minus crushed rock over the ramp and compacted to a firm condition using a plate compactor. The compacted rock was firm under foot with penetrations ranging less than 2 inches using a 3/8 inch diameter steel probe. The subgrade is suitable to support the concrete slab in AESI's opinion.

COPIES TO:
DATE MAILED: JUN 15 2010
FIELD REP.: Frank S. Mocker, L.E.G.
PRINCIPAL / PM: Kurt D. Merriman, P.E.



2 of 2
KE 070377B
6/14/10

FIELD REPORT

Associated Earth Sciences, Inc.

911 Fifth Avenue
Kirkland, Washington 98033
425-827-7701 FAX 827-5424

Date	Project Name	Project No.
10/26/10	New Issaquah High School	KE070373B

Location
700 2nd Ave
Weather
Cloudy/rain/50's
Municipality
Issaquah
Report Number
226
Engineer/Architect
Coughlin Porter Lundeen
Client/Owner
Issaquah School District No. 411 / Royce Nourigat
General Contractor/Superintendent
Cornerstone Construction / Eric Scott
Grading Contractor/Superintendent
Continental Dirt Contractors

TO:
Issaquah School District no. 411
555 Holly Street
Issaquah, WA 98027
ATTN: Royce Nourigat
AS REQUESTED BY

THE FOLLOWING WAS NOTED:

TESC Measures

The contractor excavated a TESC pond north of the northeast corner of the Phase 2 building today (see attached figure). The approximate dimensions of the pond are 20 feet long by 15 feet wide by 2.5 feet deep. The pond is located in a depressed area of the site on the south side of a large, covered soils stockpile. The contractor also excavated a few shallow swales to direct water in the local area to the pond. The purpose of the pond is to infiltrate site surface waters in this localized area of the site. The temporary pond appears to be located outside the area of future permanent bio-retention/infiltration ponds.

Amphitheater Vapor Retarder

The contractor has installed vapor retarder plastic sheeting in the approximate area indicated on the attached figure within the lower seating area of the amphitheater. The joints and holes appeared to be sealed with tape.

Bio-Retention Pond Observations

The site has received about 1.5 inches of rain over the last 24 hours according to a local weather station within the limits of Issaquah.

No standing water was observed in the two small bio-retention ponds in the south parking lot (ponds #22 and #23). No water was observed in the piezometer in pond #23.

Standing water was observed over nearly 100% of the bottom of the large pond (pond #24) located at the southeast corner of the south parking lot. The water depth ranged generally between approximately 0.4 and 0.6 feet deep at the time of our site visit. The water depth appeared to be about 0.4 feet deeper prior to AESI's site visit based on the presence of a horizontal line of organics (primarily pine needles) along the slopes of the pond. Continuous water flow was observed into the pond from the 12 inch diameter pipe located at the north end of the pond. The depth of the water flow into the pond within the pipe was about 0.3 feet. AESI measured ground water level in the piezometers installed in the finger drains within the pond. The water level was 9.42 feet below the top of the PVC casing in Piezometer 24-1 located in the south end of the pond. The water level was 9.21 feet below the top of the PVC casing in Piezometer 24-2 located in the northwest end of the pond.

AESI observed water ponded over approximately 15% of the bottom of Pond #20 located between buildings 1 and 2. No water flow was observed into the outflow structure from the pipes that extend across the base of the pond to the east of the structure. The water was mostly ponded along the south side of the pond bottom in the western two-thirds of the pond. A lesser amount of water was observed over the eastern third of the

COPIES TO:
FIELD REP.: Frank S. Mocker, L.E.G
DATE MAILED: NOV - 1 2010
PRINCIPAL / PM: Kurt D. Merriman, P.E.

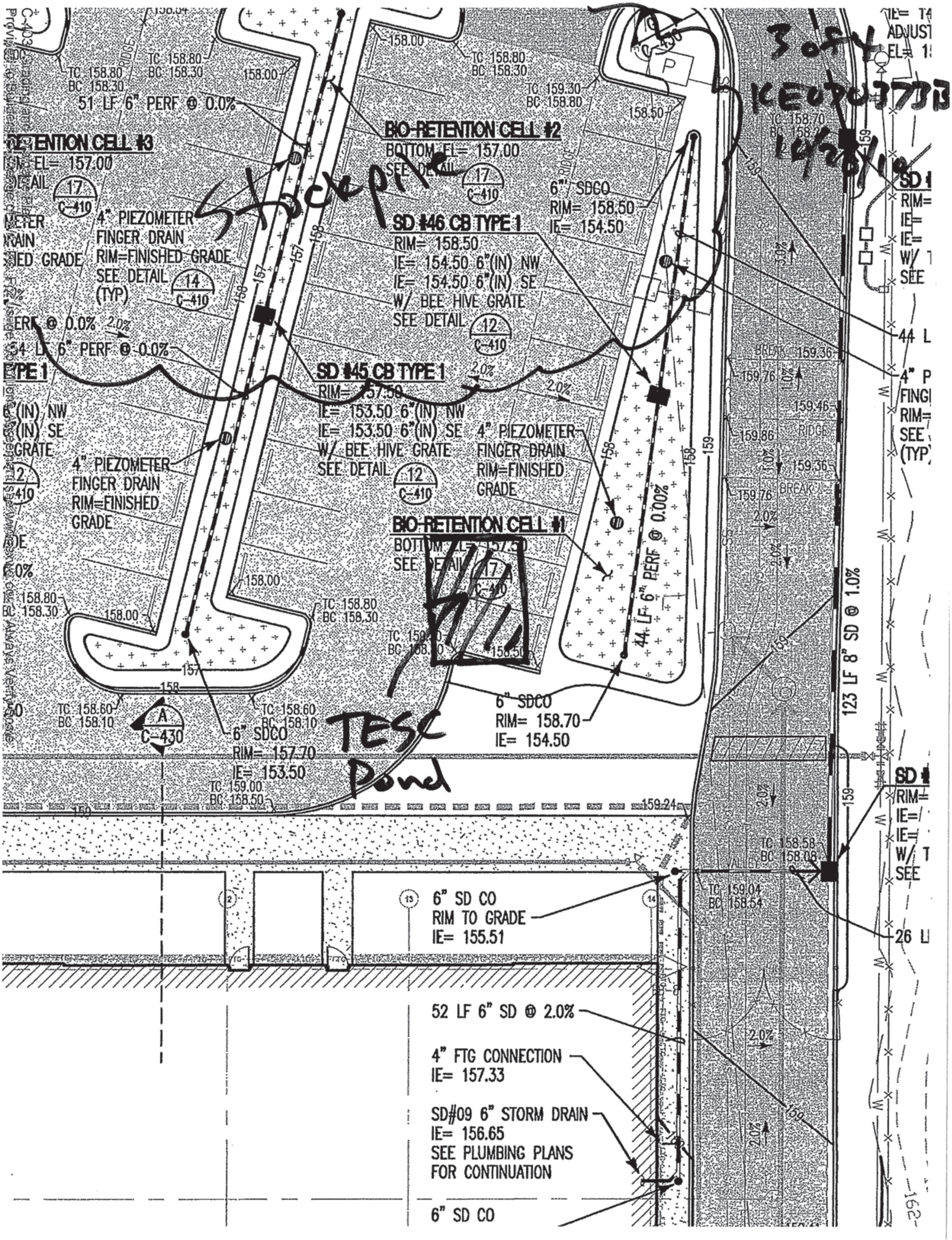
FIELD REPORT

To: Issaquah S.D. No 411
Project Name: New Issaquah H. S.
Date: 10/26/10
Project Number: KE070373B

pond bottom. The water depth in these areas ranged from less than 0.1 feet on the east end of the pond to about 0.1 to 0.2 feet in the middle and west ends of the pond except in a small linear depression to the north of the patio at the southwest side of the pond where the water ranged from 0.5 to 0.7 feet deep. AESI observed some surface water flow to the southeastern corner of the pond where it appeared to infiltrate into the soils.

AESI observed water ponded over approximately 20% to 30% of the bottom of Pond #21 located between buildings 2 and 3. No water flow was observed into the outflow structure from the pipes that extend across the base of the pond to the east of the structure. The water generally occurred in three areas across the west, middle, and eastern thirds of the pond. Most of the water was ponded in the western two-thirds of the pond. A lesser amount of water was observed over the eastern third of the pond bottom. The water depth in these areas ranged from less than 0.1 feet in the eastern side of the pond to about 0.1 to 0.2 feet in the middle and western thirds of the pond except in a small linear depression to the north of the patio at the southwest side of the pond where the water ranged from 0.7 to 0.9 feet deep. AESI observed some surface water flow to the southeastern corner of the pond where it appeared to infiltrate into the soils.

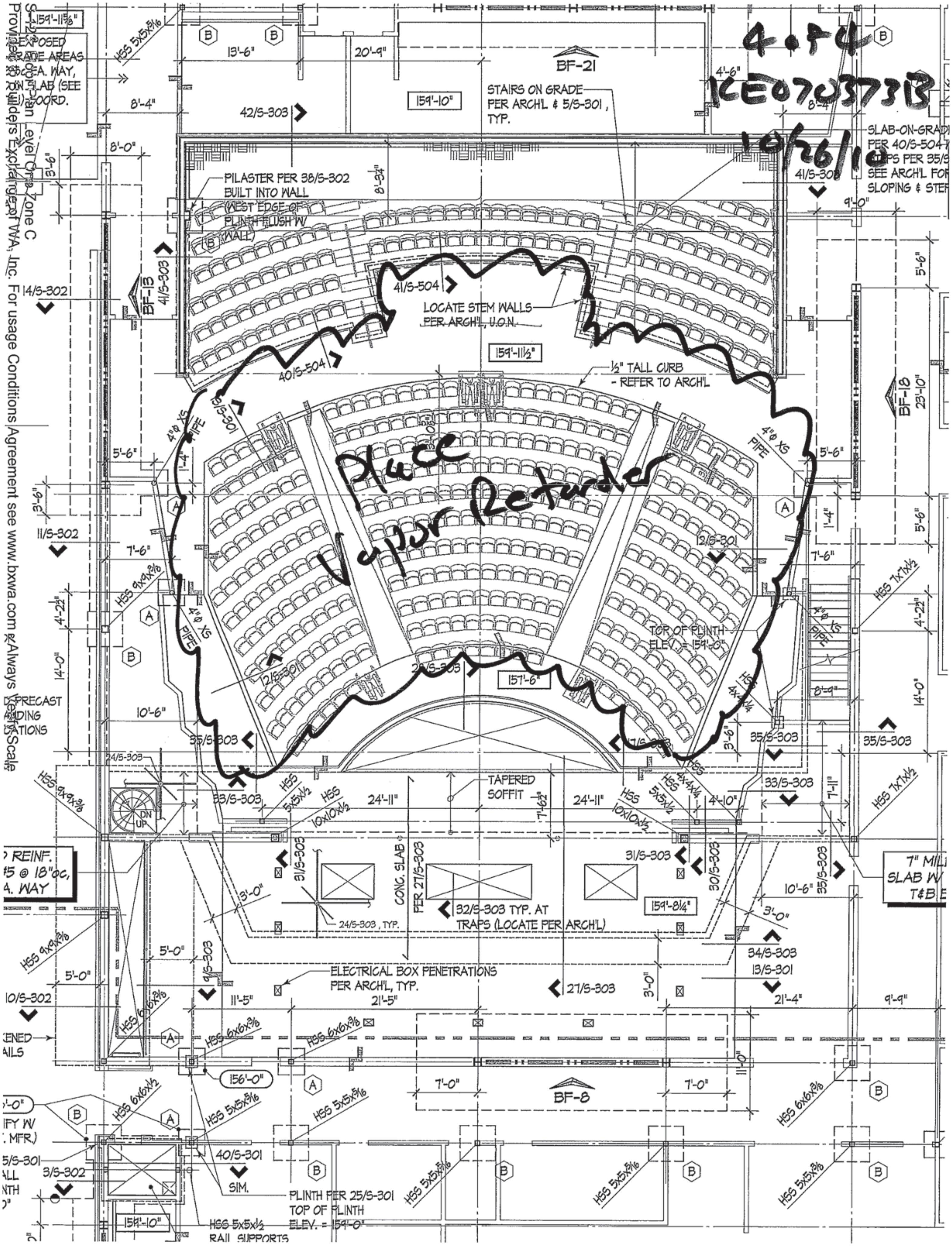
Copies To:
Field Rep: Frank S. Mocker, L.E.G. FSm
Date Mailed: NOV - 1 2010
Principal /PM: Kurt D. Merriman, P.E.



Stockpile

3 of 4
KEUPU3773B
4/28/10

TESC Pond



4.P4
ICE0703713
10/26/10

Place Vapor Retarder

APPENDIX B

Current Study Exploration Logs and Laboratory Testing Data

Cell IHS

Exploration Latitude and Longitude

Exploration	Latitude	Longitude
IHS-HA-1	47.52127	-122.02654

Moisture, Ash, and Organic Matter of Peat and Other Organic Soils - ASTM 2974

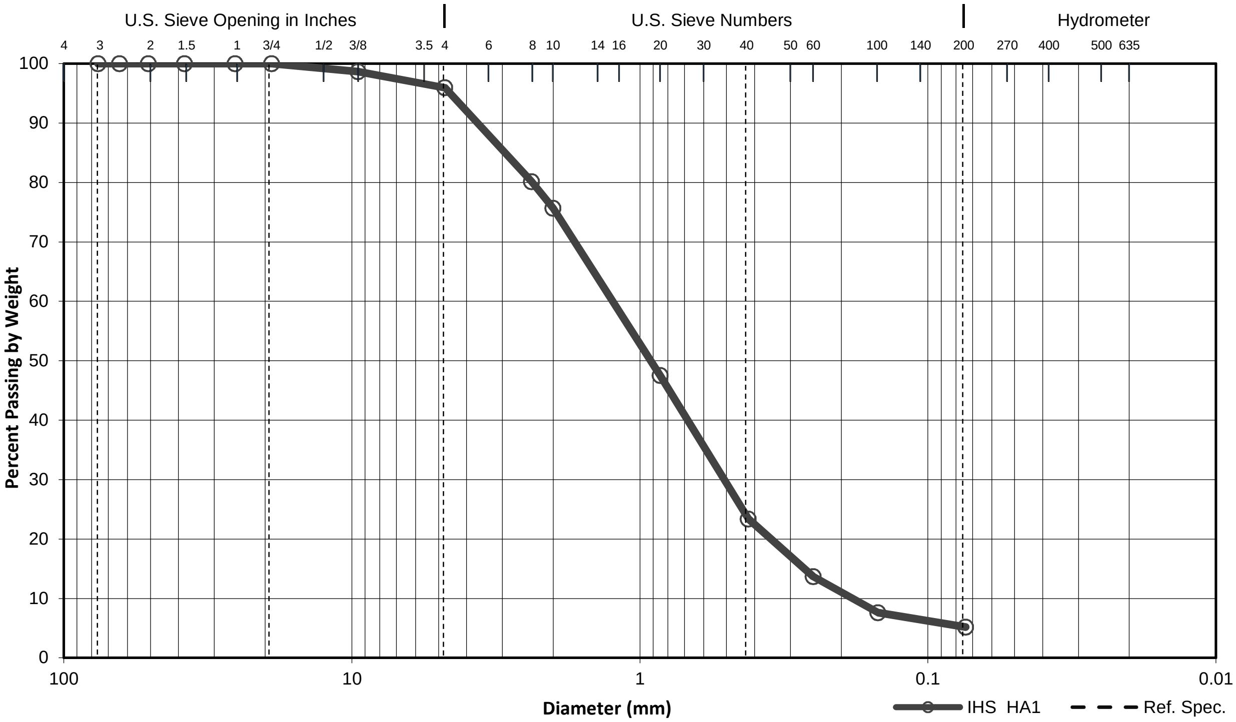
Date Sampled	**Project**	**Project No.**		**Soil Description**
7/6/2016	BHPS	KH150387A		
Tested By	**Location**	**EB/EP No.**	**Depth**	Bioretention soil mix
MS	IHS	IHS		

Moisture Content	**IHS**	**Moisture Content**	**IHS**
Sample ID	**HA1 0.5-0.8**	Sample ID	**HA2 0.1-0.9**
Wet Weight + Pan	**869.3**	Wet Weight + Pan	**616.9**
Dry Weight + Pan	**770.4**	Dry Weight + Pan	**527.6**
Weight of Pan	**334.4**	Weight of Pan	**100.7**
Weight of Moisture	**98.88**	Weight of Moisture	**89.34**
Dry Weight of Soil	**435.97**	Dry Weight of Soil	**426.84**
% Moisture	**22.7**	% Moisture	**20.9**

Organic Matter and Ash Content		**Organic Matter and Ash Content**	
Dry Soil Befor Burn + Pan	**770.4**	Dry Soil Befor Burn + Pan	**775.2**
Dry Soil After Burn + Pan	**744.3**	Dry Soil After Burn + Pan	**751.1**
Weight of Pan	**334.4**	Weight of Pan	**348.5**
Wt. Loss Due to Ignition	**26.13**	Wt. Loss Due to Ignition	**24.10**
Actual Wt. Of Soil After Burr	**409.84**	Actual Wt. Of Soil After Burr	**402.61**
% Organics	**6.0**	% Organics	**5.6**

GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

Project Name	Project Number	Date Sampled	Date Tested	Tested By
IHS	**KH150387A**	**7/6/2016**	**10/7/2016**	**GS**
Sample Source	Sample No.	Depth (ft)	Soil Description	
Onsite	**IHS HA1**	**0.6-1.0**	**SAND, some silt, trace gravel (SW-SM)**	
Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification	
404.7	**0**	**0.182**	**Bioretention soil mix: burned sample**	



Cobb.	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4		0.0	100.0		
3/4	19		0.0	100.0		
3/8	9.51	5.4	1.3	98.7		
#4	4.76	16.4	4.1	95.9		
#8	2.38	80.3	19.8	80.2		
#10	2	98.5	24.3	75.7		
#20	0.85	212.4	52.5	47.5		
#40	0.42	310.2	76.6	23.4		
#60	0.25	349.3	86.3	13.7		
#100	0.149	374.0	92.4	7.6		
#200	0.074	383.7	94.8	5.2		

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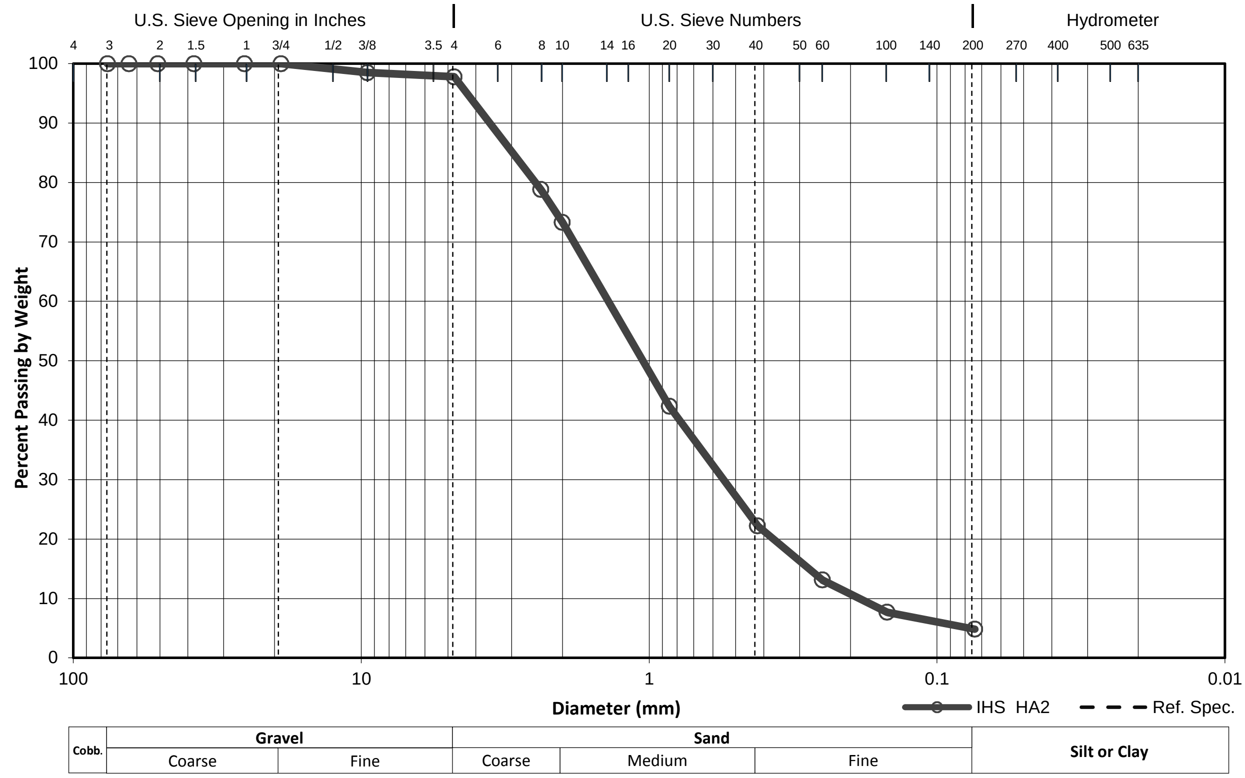
GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

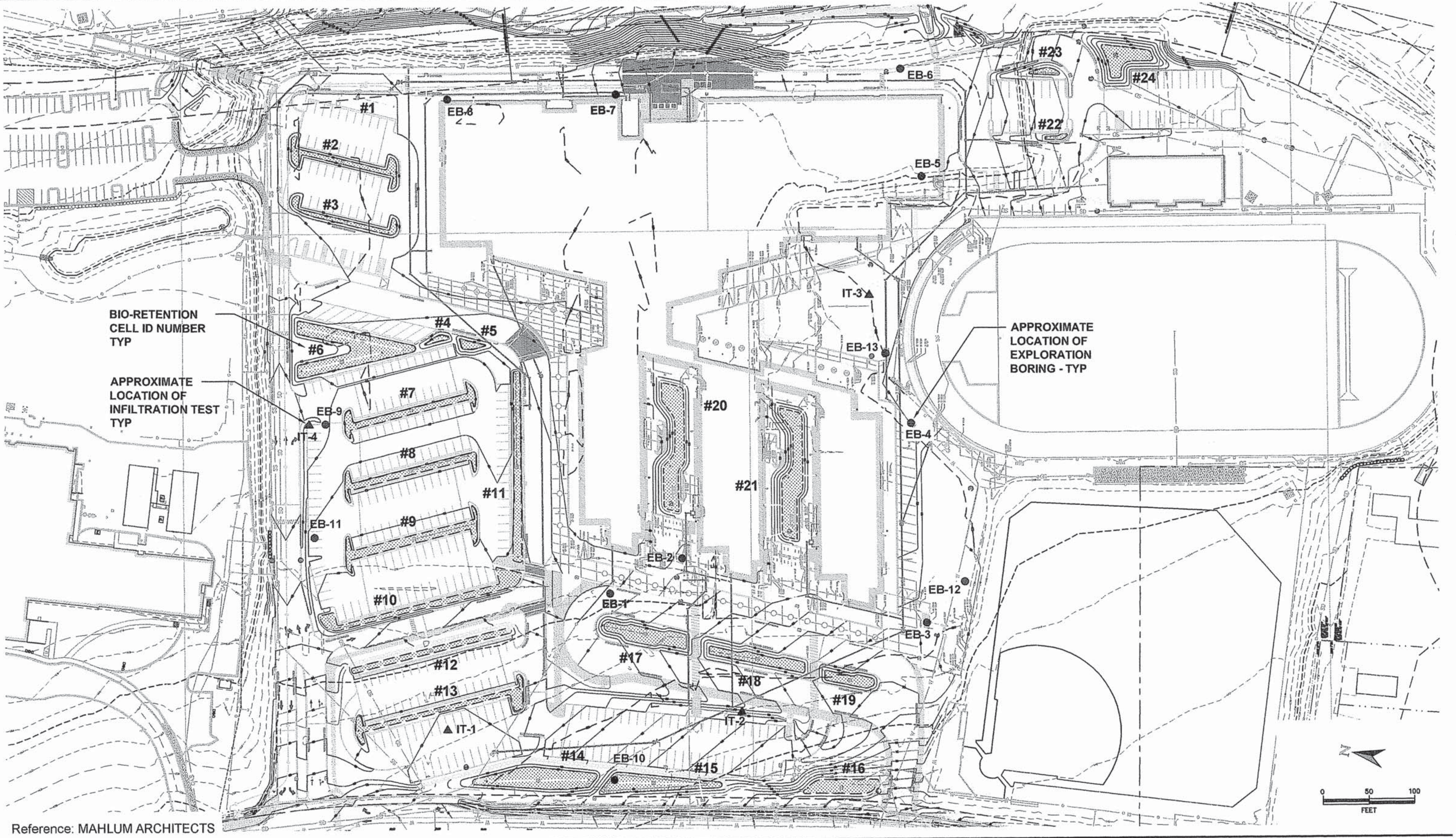
Project Name	Project Number	Date Sampled	Date Tested	Tested By
IHS	**KH150387A**	**7/6/2016**	**10/7/2016**	**GS**
Sample Source	Sample No.	Depth (ft)	Soil Description	
Onsite	**IHS HA2**	**0.1-0.9**	**SAND, trace silt, trace gravel (SW)**	
Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification	
412.3	**0**	**0.185**	**Bioretention soil mix: burned sample**	



Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4		0.0	100.0		
3/4	19		0.0	100.0		
3/8	9.51	6.2	1.5	98.5		
#4	4.76	9.1	2.2	97.8		
#8	2.38	87.3	21.2	78.8		
#10	2	110.1	26.7	73.3		
#20	0.85	237.8	57.7	42.3		
#40	0.42	320.7	77.8	22.2		
#60	0.25	358.2	86.9	13.1		
#100	0.149	380.6	92.3	7.7		
#200	0.074	392.3	95.2	4.8		

APPENDIX C

Background Soil, Geology, and Ground Water Data (Regional Maps, Previous Studies Exploration Logs and Laboratory Testing Data)



Reference: MAHLUM ARCHITECTS

Associated Earth Sciences, Inc.

SITE AND EXPLORATION PLAN
ISSAQUAH HIGH SCHOOL
ISSAQUAH, WASHINGTON

FIGURE 2
DATE 1/09
PROJECT NO. KE070373A

070373 Issaquah High School | 070373 Site and Expl Rev 1-09a.dwg interpreted to be overstated as a result of pounding on cobbles and boulders. The cobbles and boulders created difficult drilling conditions.

Hydrogeology

Ground water was not encountered in any of the explorations completed for this project. In addition, the piezometers installed in EB-4 and EB-10, completed at depths of 16 and 20 feet below ground surface (approximate elevations 134 and 128 feet above mean sea level [amsl]), respectively, were measured following the large storm event on January 8, 2009. No measurable water was observed in either piezometer. For the purposes of the ground water mounding analysis, the bottom of the aquifer and seasonal high ground water elevation were conservatively set at 128 feet and 128.1 feet amsl, respectively. The actual base of the aquifer is not known, but would be lower in elevation than simulated in the model.

Ground Water Mounding Analysis

The soil and ground water input parameters used in the MODRET evaluation were consistent with field/laboratory data and applicable published hydrogeologic literature. The model input parameters are included for each model run in the "Summaries of Unsaturated and Saturated Input Parameters" (attached), and an explanation of the basis for all parameters used is included in Table 1. The 1-month time periods for the hydrographs were selected by CPL. Output data from KCRTS, provided by CPL, are included as attachments to this letter-report.

MODRET simulations indicate that for both the peak flow and maximum volume hydrographs, the infiltration facility will have the capacity to infiltrate all of the storm water runoff routed to the facilities during the design storm time series.

Table 1
Basis for MODRET Input Parameters

Parameter	Value	Basis
Pond Bottom Area	1,690.00 ft^2	CPL.
Pond Volume Between Bottom and DHWL	9,165.00 ft^3	CPL.
Pond Length to Width Ratio	2.00	CPL.
Elevation of Effective Aquifer Base	128.00	AESI – Deepest site exploration, EB-10.
Elevation of Seasonal High Ground Water Table	128.10	AESI – No ground water encountered on-site. Must be higher than effective aquifer base.
Elevation of Starting Water Level	146.00	Facility bottom elevation (CPL).
Elevation of Pond Bottom	146.00	CPL.
Design High Water Level Elevation	148.76	CPL.
Storage Coefficient of Soil for Unsaturated Analysis	0.25	AESI - Within range of published values for the soil types present.
Unsaturated Vertical Hydraulic Conductivity (Kvu) (ft/day)	17.33	Kvs x $^2/_3$. Design infiltration rate, Kvs, conservatively set to 26 ft/day (13 in/hr). Field-measured rates 106 to 134 ft/day.
Factor of Safety	2	Standard value.
Saturated Horizontal Hydraulic Conductivity (Khs) (ft/day)	78.00	3 x Kvs (Kvs = 26 ft/day).

Parameter	Value	Basis
Storage Coefficient of Soil for Saturated Analysis	0.25	AESI - Within range of published values for the soil types present.
Average Effective Storage Coefficient of Pond/Exfiltration Trench	1.00	CPL.
Time Increment During Storm Event	24	Increments match hydrograph time steps.
Time Increment After Storm Event	24	Increments match hydrograph time steps.
Total Number of Increments After Storm Event	6	AESI - Program default.

CPL = Coughlin Porter Lundeen, Inc.
AESI = Associated Earth Sciences, Inc.
DHWL - Design High Water Level
ft^2 = square feet
ft^3 = cubic feet
ft/day = feet per day
in/hr = inches per hour
Kvs = Saturated vertical hydraulic conductivity

For both the peak flow hydrograph and the maximum volume hydrograph, the maximum ground water mound elevation did not reach the bottom of the infiltration facility (146 feet). The design high water elevation for the facility is 148.76 feet. The summaries of results from the MODRET analyses are attached.

Liner Recommendations

Water quality cells or rain gardens constructed adjacent to slopes or buildings should be lined to prevent infiltration. Liners can be either synthetic membranes or low-permeability soils. Synthetic liners should either be HDPE or PVC materials sized and installed in accordance with the manufacturer's recommendations. Soil liner materials should conform to the requirement of Chapter 5 of the King County Manual. Soil liners should be at least 2 feet in thickness and should be compacted at or slightly above the optimum moisture content using a sheepsfoot roller. Liners should extend above the design high water level. Rain gardens with liners should have a perforated pipe underdrain system above the liner.

Recommendations and Conclusions

Based on the infiltration testing, modeling, and analysis, it is the opinion of AESI that the storm water facilities will perform as designed for the storm water hydrographs provided by CPL.

AESI recommends that excavated drains be installed during facility construction, as described in our December 23, 2008 technical memorandum, a copy of which is attached, with a revised "Pit Drain Detail".

Closure

We trust that the information presented in this letter-report meets your current project needs. Should you have any questions, please contact us at your earliest convenience.

Sincerely,
ASSOCIATED EARTH SCIENCES, INC.
Kirkland, Washington

Stanley S. Thompson, P.G., P.Hg.
Senior Project Geologist/Hydrogeologist

KURT D. MERRIMAN
23580
1/21/09

Hydrogeologist
496
Curtis J. Koger
1/21/09

Kurt D. Merriman, P.E.
Principal Engineer

Curtis J. Koger, P.G., P.E.G., P.Hg.
Principal Geologist/Hydrogeologist

Attachments:
1) Vicinity Map
2) Site and Exploration Plan
3) Exploration Logs
4) Summary of Unsaturated and Saturated Input Parameters (Peak Flow)
5) Hydrograph: Issaquah High School – Peak Flow
6) MODRET Summary of Results – Peak Flow
7) Summary of Unsaturated and Saturated Input Parameters (Max Volume)
8) Hydrograph: Issaquah High School – Max Volume
9) MODRET Summary of Results – Max Volume
10) KCRTS Time Series Data, Peak Flow
11) KCRTS Time Series Data, Max Volume
12) December 23, 2008 Technical Memorandum including Infiltration "Pit Drain Detail"

SST/ld
KE070373A7
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Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KE070373A	EB-5	1 of 1

Project Name Issaquah High School
Location Issaquah, WA
Driller/Equipment Davies Drilling/Track Rig
Hammer Weight/Drop 140# / 30"

Ground Surface Elevation (ft) ~156 feet
Datum N/A
Date Start/Finish 6/26/07,6/26/07
Hole Diameter (in) ~6 inches

Depth (ft)	S T	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot 10 20 30 40	Other Tests
				Asphalt					
				Recessional Outwash Moist, light brown, non-stratified, sandy fine to coarse subrounded GRAVEL, few subrounded cobbles, trace silt (GW).					
				Bottom of exploration boring at 2 feet Exploration terminated due to refusal.					
5									
10									
15									
20									
25									
30									
35									

Sampler Type (ST):

▯ 2" OD Split Spoon Sampler (SPT)
▯ 3" OD Split Spoon Sampler (D & M)
☝ Grab Sample

☐ No Recovery
▮ Ring Sample
▱ Shelby Tube Sample

M - Moisture
▽ Water Level ()
▼ Water Level at time of drilling (ATD)

Logged by: JDC
Approved by:

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KE070373A	EB-6	1 of 1

Project Name Issaquah High School
Location Issaquah, WA
Driller/Equipment Davies Drilling/Track Rig
Hammer Weight/Drop 140# / 30"

Ground Surface Elevation (ft) ~156 feet
Datum N/A
Date Start/Finish 6/27/07,6/27/07
Hole Diameter (in) ~6 inches

Depth (ft)	S T	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot 10 20 30 40	Other Tests
				Asphalt					
				Recessional Outwash					
	◫	S-1		Moist, light brown, weakly stratified, fine to coarse SAND, trace silt, trace fine to coarse gravel (SW).			21 40 41	▲81	
5	◫	S-2		Moist, light brown, weakly stratified, fine to coarse SAND, trace silt, trace fine to coarse gravel (SW).			16 22 33	▲55	
10	◫	S-3		Moist, light brown, weakly stratified, fine to coarse SAND, trace silt, few gravel (SW)			17 26 37	▲63	
15	◫	S-4		Moist, light brown, weakly stratified, fine to coarse SAND, trace silt, few gravel (SW)			50/6"	▲50/6"	
				Bottom of exploration boring at 15.5 feet					
20									
25									
30									
35									

Sampler Type (ST):

◫ 2" OD Split Spoon Sampler (SPT)
◫ 3" OD Split Spoon Sampler (D & M)
☐ Grab Sample
☐ No Recovery
▮ Ring Sample
▨ Shelby Tube Sample
M - Moisture
▽ Water Level ()
▼ Water Level at time of drilling (ATD)

Logged by: JDC
Approved by:

LOG OF EXPLORATION PIT NO. IT-3

Depth (ft)	This log is part of the report prepared by Associated Earth Sciences, Inc. (AESI) for the named project and should be read together with that report for complete interpretation. This summary applies only to the location of this trench at the time of excavation. Subsurface conditions may change at this location with the passage of time. The data presented are a simplfication of actual conditions encountered. **DESCRIPTION**
	Crushed Rock
	Recessional Outwash
1	Medium dense to dense, moist, light brown, weakly stratified, sandy GRAVEL and gravelly SAND,
2	few grading to trace silt with depth, few 12-inch boulders (GW/SW).
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	Bottom of exploration pit at depth 14 feet No caving. No ground water seepage.
16	
17	
18	
19	
20	

Issaquah High School
Issaquah, WA

Associated Earth Sciences, Inc.

Logged by: JDC
Approved by:

Project No. KE070373A
7/18/07

FIELD REPORT

Associated Earth Sciences, Inc.

911 Fifth Avenue, Suite 100
Kirkland, Washington 98033
425-827-7701 FAX 827-5424

Date **4/28/10**	Project Name **New Issaquah High School**	Project No. **KE070373B**
Location **700 2nd Ave**		Weather **Partly sunny/50's**
Municipality **Issaquah**		Field Report No. **150A**
Engineer/Architect **Coughlin Porter Lundeen**		
Client/Owner **Issaquah School District No. 411 / Royce Nourigat**		
General Contractor/Superintendent **Cornerstone Construction / Eric Scott**		
Grading Contractor/Superintendent **Continental Dirt Contractors / Jerry Nelson Jr.**		

TO:
Issaquah School District no. 411
555 Holly Street
Issaquah, WA 98027
ATTN: **Royce Nourigat**
AS REQUESTED BY

THE FOLLOWING WAS NOTED:

AESI was onsite today to observe on-going site construction activities as part of continued part-time construction monitoring of the new Issaquah High School building.

Planter Wall Footings
The contractor excavated the planter wall footings on the north and east sides of the courtyard area located generally north of the existing track. The excavations exposed firm sand and gravel soils. The contractor re-compacted to subgrade soils using a small plate compactor. The compacted subgrade was firm under foot. Penetrations ranged less than generally 3 inches using a 3/8 inch diameter steel probe under full body weight. The existing subgrade is suitable to support the walls in AESI's opinion.

Finger Drain Excavation, Installation, and Testing
AESI observed the excavation and construction of two finger (pit) drains located in bio-retention cell number 24. The location of the finger (pit) drains is shown on the attached figure. The contractor utilized a 3 feet wide bucket to excavate the finger (pit) drains. The excavations generally encountered native sand with variable gravel content and a trace of silt from the existing ground surface to a depth of approximately 7 feet. Native gravel with variable sand content and a trace of silt was observed below the sand to depth of approximate 9 feet below the existing ground surface. Finger (pit) drain 24-1 encountered native sand with variable gravel content and a trace of silt below the gravel soils to the bottom of the excavation. Finger (pit) drain 24-2 encountered sand with a variable gravel content and a trace of silt and silt interbeds below the gravel soils to the bottom of the excavation. Ground water seepage was observed in both the excavations at a depth of approximately 6.5 to 7 feet below the existing ground surface. Minor caving of the sidewalls of the excavations occurred particularly in the area of the groundwater seepage noted above. The dimensions of drain 24-1 were 10 feet deep by 5 to 5 ½ feet wide by 10 (at bottom) to 12 (at top) feet long. The dimensions of drain 24-2 were 10.5 feet deep by 5 to 6 feet wide by 9 (at bottom) to 10 (at top) feet long.

After excavation of each of the drains was completed, the contractor installed the 4-inch (nominal diameter), SDR 35 piezometer pipe. The piezometer consisted of two sections of 4 3/16 inch O.D. (outer diameter), 3 15/16 inch I.D. (inner diameter) pipe. The bottom (perforated) sections of pipe were five feet long and had a slip cap fastened at the bottom. The perforations were machine slotted by the pipe manufacturer prior to delivery to the project site. The perforations were 3/16 inch wide by about 3 ½ inches long and spaced about 2 to 3 inches apart on one side of the pipe. The upper section of the piezometer pipe was solid (no perforations) and was fastened to the lower screen section of pipe by a glued, belled, slip coupling. After placing the piezometer pipe in the excavation, the contractor placed clean, approved gravel (WSDOT Spec. 9-03.12 (4)) in the finger (pit) drain excavations to a depth of 3 feet below the existing ground surface. The gravel was placed using an excavator bucket in a clean, continuous column without any intervening, uncontrolled native soil slough layers.

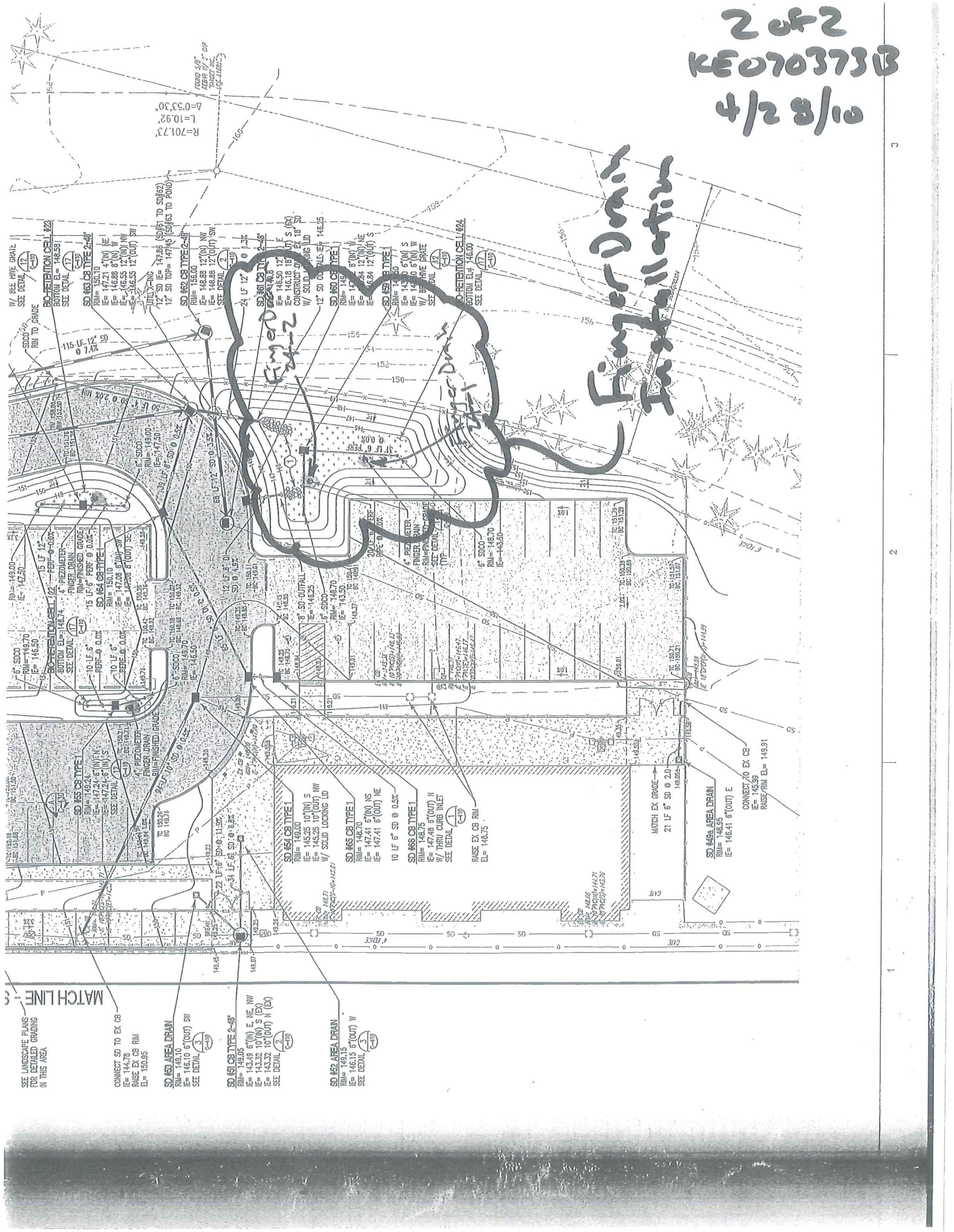
Performance infiltration testing was then performed by AESI (Lara Koger) today and is addressed in a separate field report.

Finger (Pit) Drain Medium Filter Sand Submittal
The contractor imported another load of medium filter sand today for use in the finger (pit) drains. AESI collected a representative sample for the stockpile located at the north end of the track (south end of the courtyard). AESI completed sieve analysis this morning of the collected sample. The medium filter sand delivered to the site today meets the gradation specifications for its intended use in the finger (pit) drains.

COPIES TO:
DATE MAILED: MAY 04 2010

FIELD REP.: Frank S. Mocker, L.E.G.
PRINCIPAL / PM: Kurt D. Merriman, P.E.

2 of 2
KE070373B
4/28/10



Issaquah High School, Pond #24, summer construction.

Top left: 4/19/2010, top right: 4/21/2010; bottom left:4/28/2010; bottom right: 6/22/2010

Issaquah High School, Pond #24, summer construction and start of fall rains.

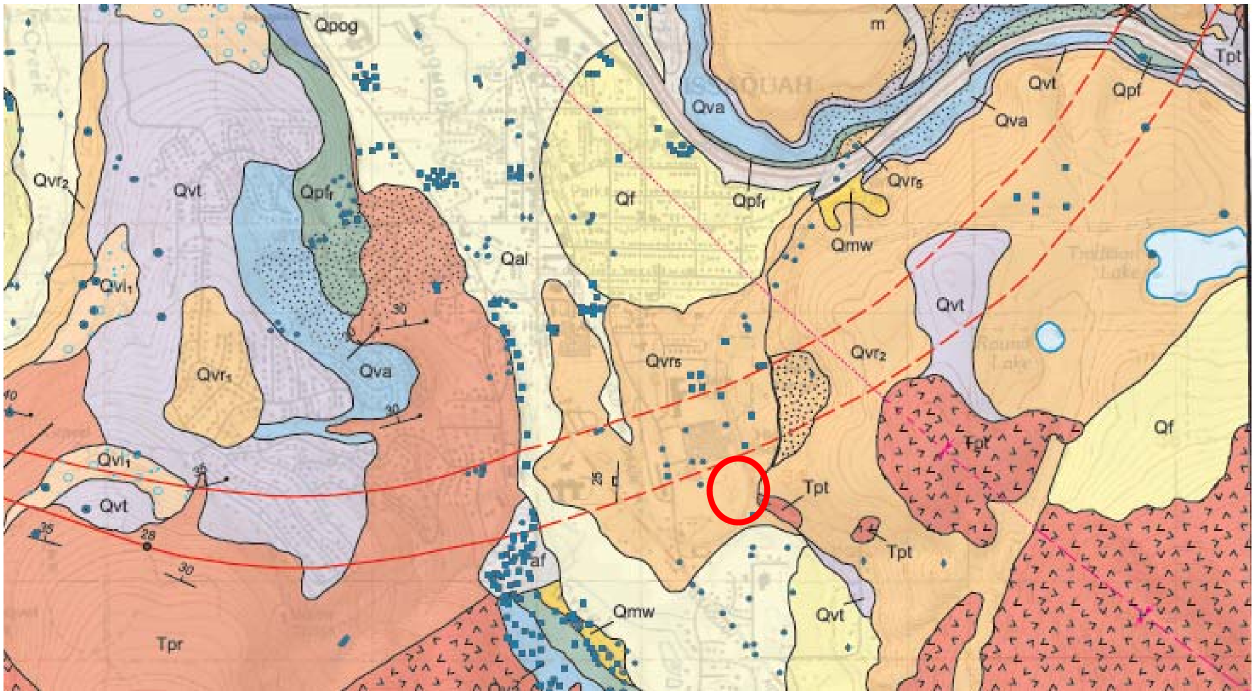
Top left: 7/8/2010, top right: 7/13/2010; bottom left:9/3/2010; bottom right: 10/25/2010

Issaquah High School, Pond #24, Year 1, fall rains.

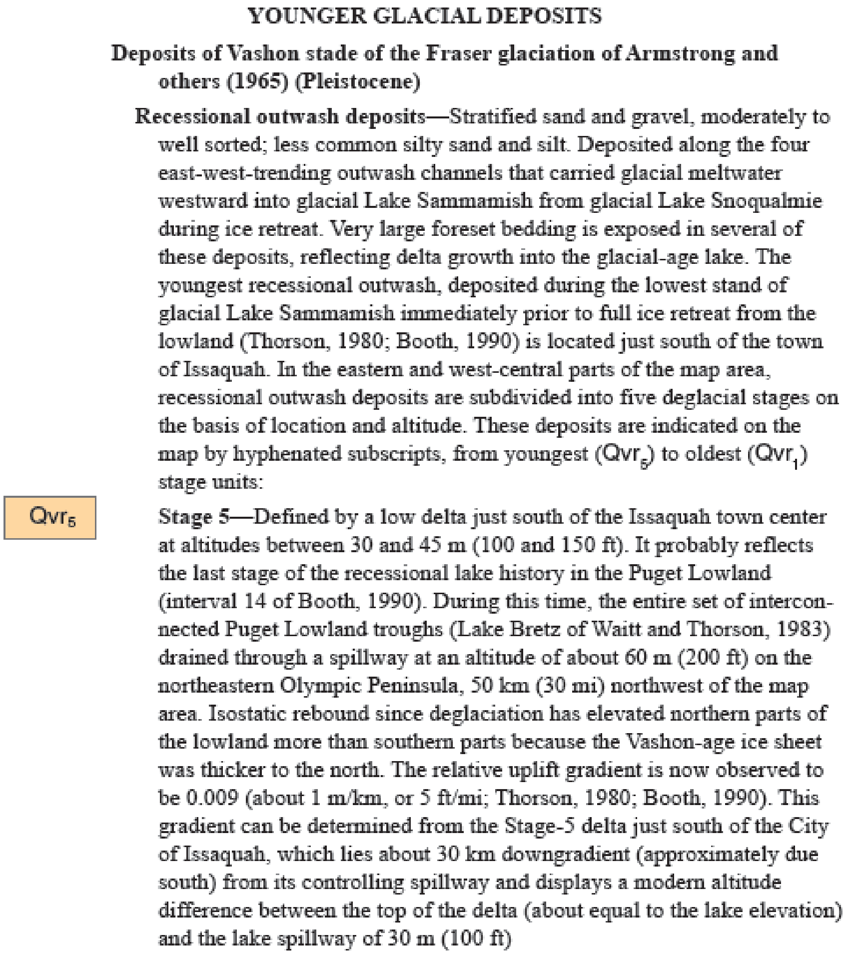
Top left: 10/26/2010, top right: 10/27/2010; bottom left:11/01/2010; bottom right: 11/08/2010

Issaquah High School, Pond #24, Year 1 Winter and Year 2 Spring.

Top left: 12/8/2010, top right: 12/09/2010; bottom left:1/7/2011; bottom right: 4/23/2012



Approximate location of facilities indicated by bold red outline



YOUNGER GLACIAL DEPOSITS

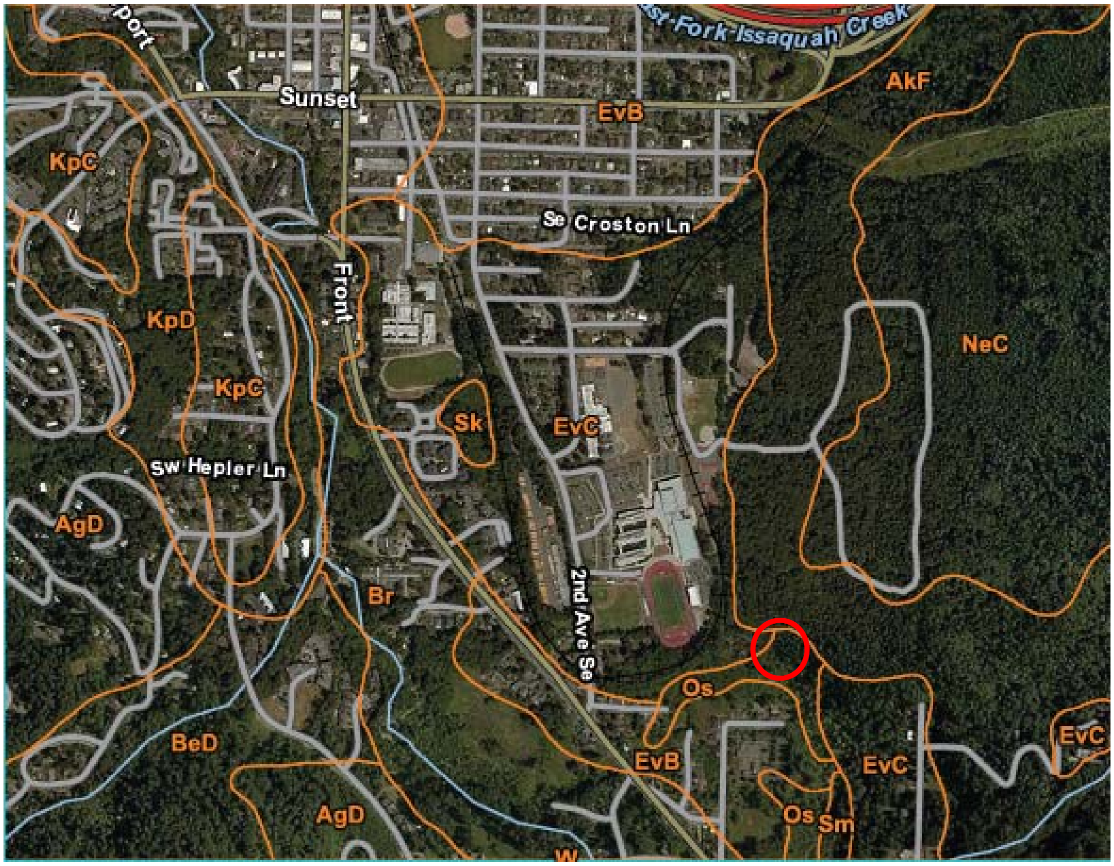
Deposits of Vashon stade of the Fraser glaciation of Armstrong and others (1965) (Pleistocene)

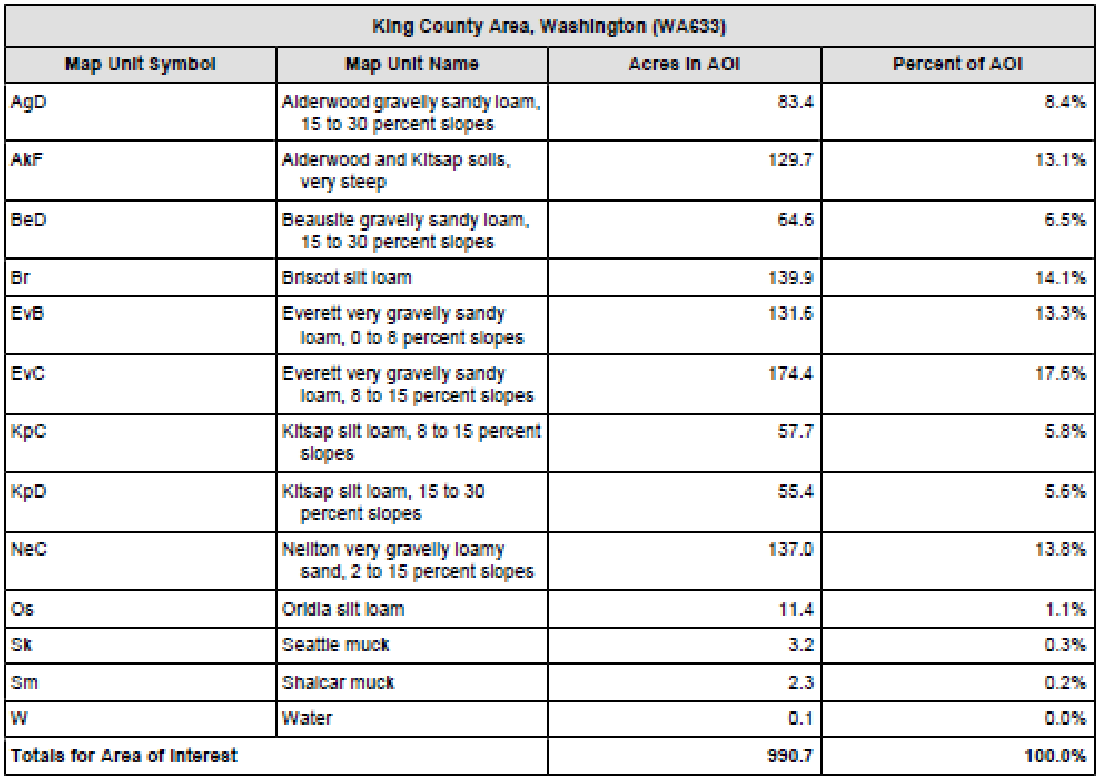
Recessional outwash deposits—Stratified sand and gravel, moderately to well sorted; less common silty sand and silt. Deposited along the four east-west-trending outwash channels that carried glacial meltwater westward into glacial Lake Sammamish from glacial Lake Snoqualmie during ice retreat. Very large foreset bedding is exposed in several of these deposits, reflecting delta growth into the glacial-age lake. The youngest recessional outwash, deposited during the lowest stand of glacial Lake Sammamish immediately prior to full ice retreat from the lowland (Thorson, 1980; Booth, 1990) is located just south of the town of Issaquah. In the eastern and west-central parts of the map area, recessional outwash deposits are subdivided into five deglacial stages on the basis of location and altitude. These deposits are indicated on the map by hyphenated subscripts, from youngest (Qvr_5) to oldest (Qvr_1) stage units:

Qvr_5

Stage 5—Defined by a low delta just south of the Issaquah town center at altitudes between 30 and 45 m (100 and 150 ft). It probably reflects the last stage of the recessional lake history in the Puget Lowland (interval 14 of Booth, 1990). During this time, the entire set of interconnected Puget Lowland troughs (Lake Bretz of Waitt and Thorson, 1983) drained through a spillway at an altitude of about 60 m (200 ft) on the northeastern Olympic Peninsula, 50 km (30 mi) northwest of the map area. Isostatic rebound since deglaciation has elevated northern parts of the lowland more than southern parts because the Vashon-age ice sheet was thicker to the north. The relative uplift gradient is now observed to be 0.009 (about 1 m/km, or 5 ft/mi; Thorson, 1980; Booth, 1990). This gradient can be determined from the Stage-5 delta just south of the City of Issaquah, which lies about 30 km downgradient (approximately due south) from its controlling spillway and displays a modern altitude difference between the top of the delta (about equal to the lake elevation) and the lake spillway of 30 m (100 ft)

Excerpt from Geologic map of the east half of the Belleview South 7.5' x 15' quadrangle, Issaquah area, King County, Washington.





King County Area, Washington (WA633)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
AgD	Alderwood gravelly sandy loam, 15 to 30 percent slopes	83.4	8.4%
AkF	Alderwood and Kitsap soils, very steep	129.7	13.1%
BeD	Beausite gravelly sandy loam, 15 to 30 percent slopes	64.6	6.5%
Br	Briscot silt loam	139.9	14.1%
EvB	Everett very gravelly sandy loam, 0 to 8 percent slopes	131.6	13.3%
EvC	Everett very gravelly sandy loam, 8 to 15 percent slopes	174.4	17.6%
KpC	Kitsap silt loam, 8 to 15 percent slopes	57.7	5.8%
KpD	Kitsap silt loam, 15 to 30 percent slopes	55.4	5.6%
NeC	Neilton very gravelly loamy sand, 2 to 15 percent slopes	137.0	13.8%
Os	Oridia silt loam	11.4	1.1%
Sk	Seattle muck	3.2	0.3%
Sm	Shalcar muck	2.3	0.2%
W	Water	0.1	0.0%
Totals for Area of Interest		**990.7**	**100.0%**

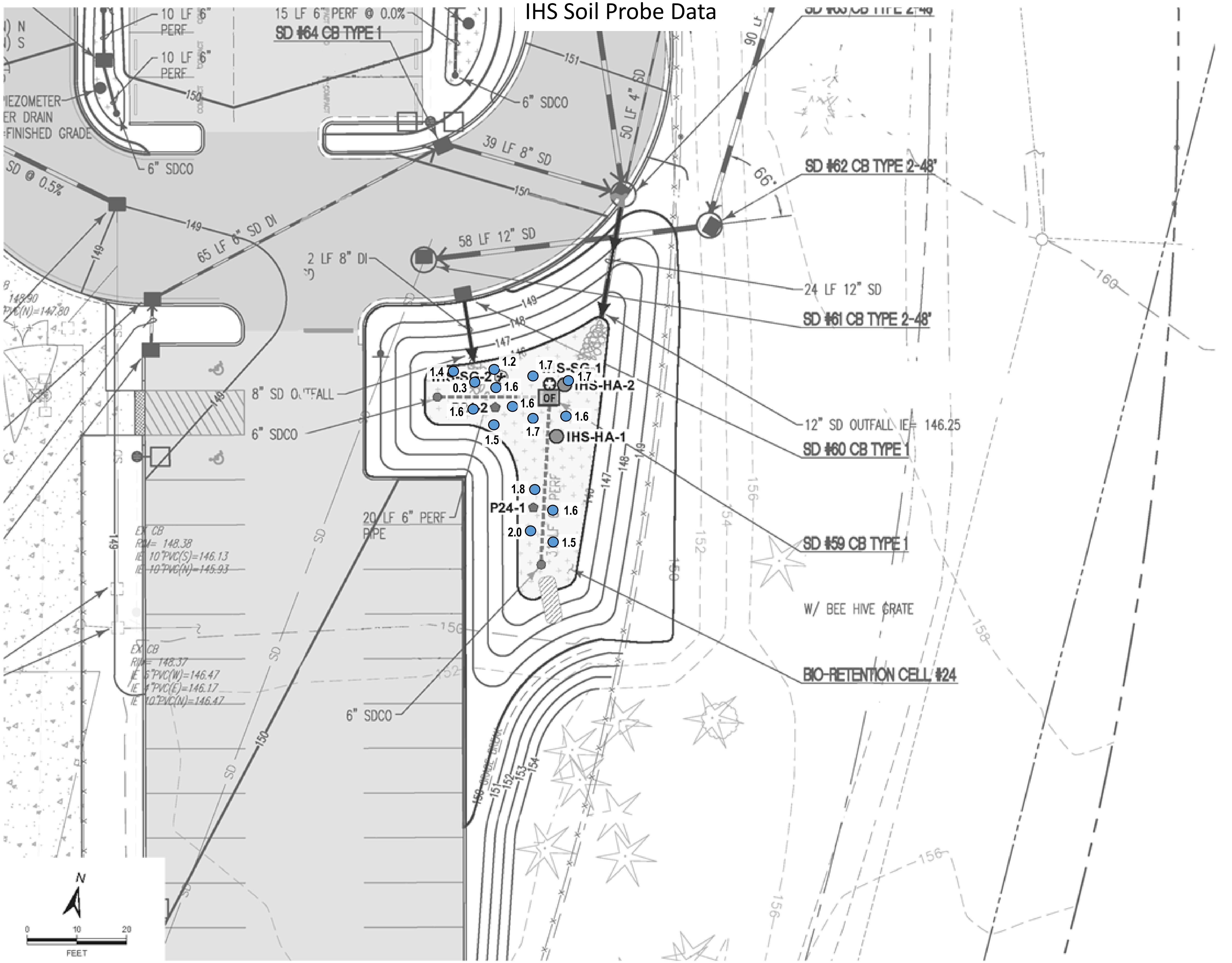
Approximate location of facilities indicated by red outline.

Excerpt from Natural Resources Conservation Service, 2016, Web soil survey

APPENDIX D

Soil Probe, Level Survey, and Field Infiltration Testing Data

IHS Soil Probe Data



LEGEND:

● HA	HAND AUGER
⊛	TEMPORARY STAFF GAUGE
✪	PERMANENT STAFF GAUGE
▭	BASE OF FACILITY
▭	TOP OF FACILITY SLOPE
➔	INFLOW / OVERFLOW DIRECTION
OF	OVERFLOW GRATE
------	PERFORATED PIPE
●	STORM DRAIN CLEANOUT
⬟ P	PRE-EXISTING 4 INCH PIEZOMETER
SD	STORM DRAIN
▨	CONCRETE SLURRY DUMP
● 0.8	Soil Probe and Depth of Loose Soil

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:
1. BASE MAP REFERENCE: COUGHLIN PORTER LUNDEEN, ISSAQUAH HIGH SCHOOL, GRADING AND DRAINAGE PLAN, SHEET C-404, 5/16/2014

BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION.

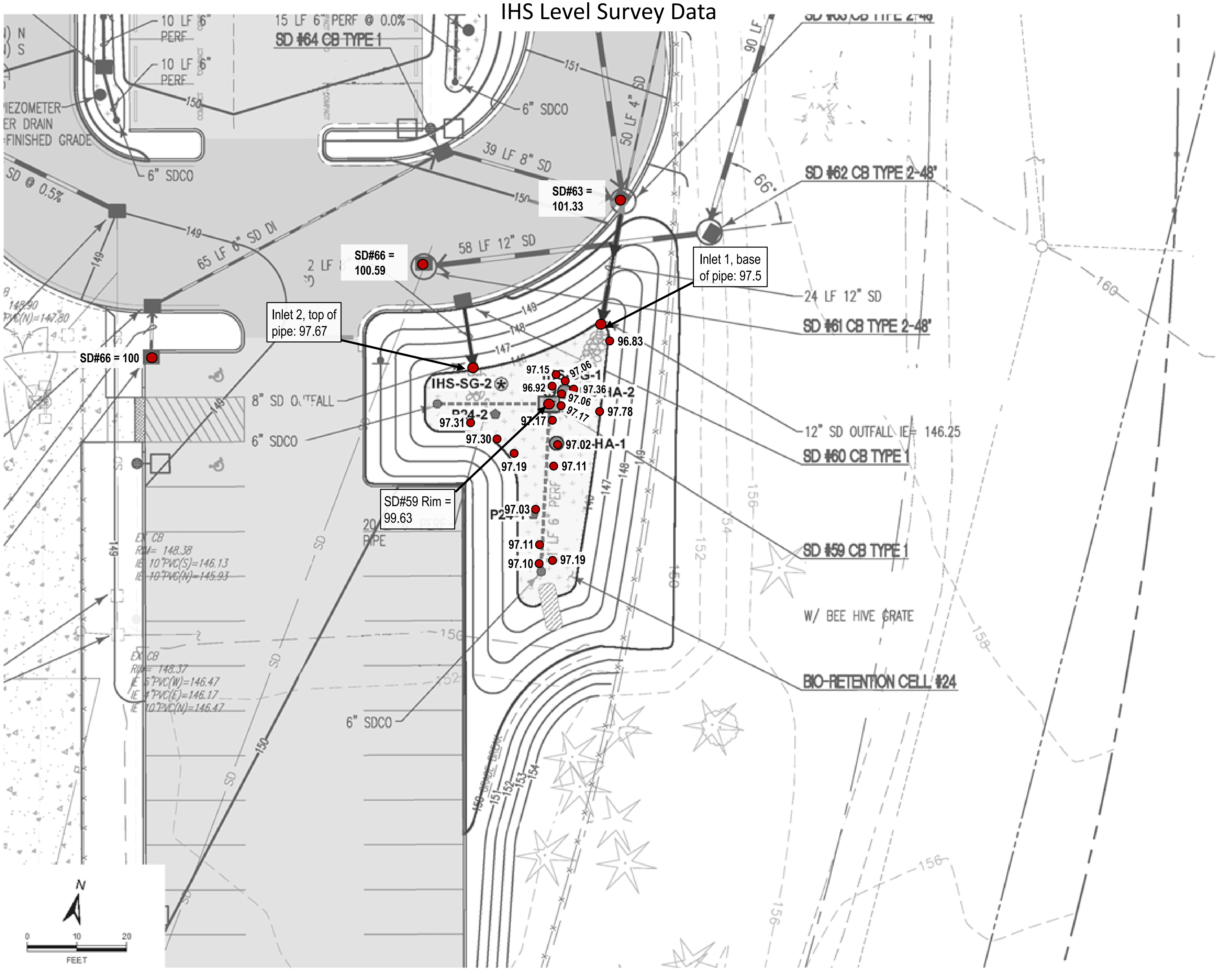
associated
earth sciences
incorporated

SOIL PROBE DATA
IHS SITE
BIORETENTION HYDROLOGIC PERFORMANCE
ISSAQUAH, WASHINGTON

PROJ NO. KH150387A
DATE: 9/16
FIGURE: D1

150387 BHPS MCCA\150387 Site-Explr.cdr PAGE 3: IHS

IHS Level Survey Data



150387 BHPS MCCA\150387 Site-Explr.cdr PAGE 3: IHS

LEGEND:

● HA	HAND AUGER
⊛	TEMPORARY STAFF GAUGE
✪	PERMANENT STAFF GAUGE
▭	BASE OF FACILITY
▭	TOP OF FACILITY SLOPE
➔	INFLOW / OVERFLOW DIRECTION
OF	OVERFLOW GRATE
- - - -	PERFORATED PIPE
●	STORM DRAIN CLEANOUT
⬟ P	PRE-EXISTING 4 INCH PIEZOMETER
SD	STORM DRAIN
▨	CONCRETE SLURRY DUMP
● 98.66	Elevation, Project Datum (see text)

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:
1. BASE MAP REFERENCE: COUGHLIN PORTER LUNDEEN, ISSAQUAH HIGH SCHOOL, GRADING AND DRAINAGE PLAN, SHEET C-404, 5/16/2014

BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION.

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LEVEL SURVEY DATA
IHS SITE
BIORETENTION HYDROLOGIC PERFORMANCE
ISSAQUAH, WASHINGTON

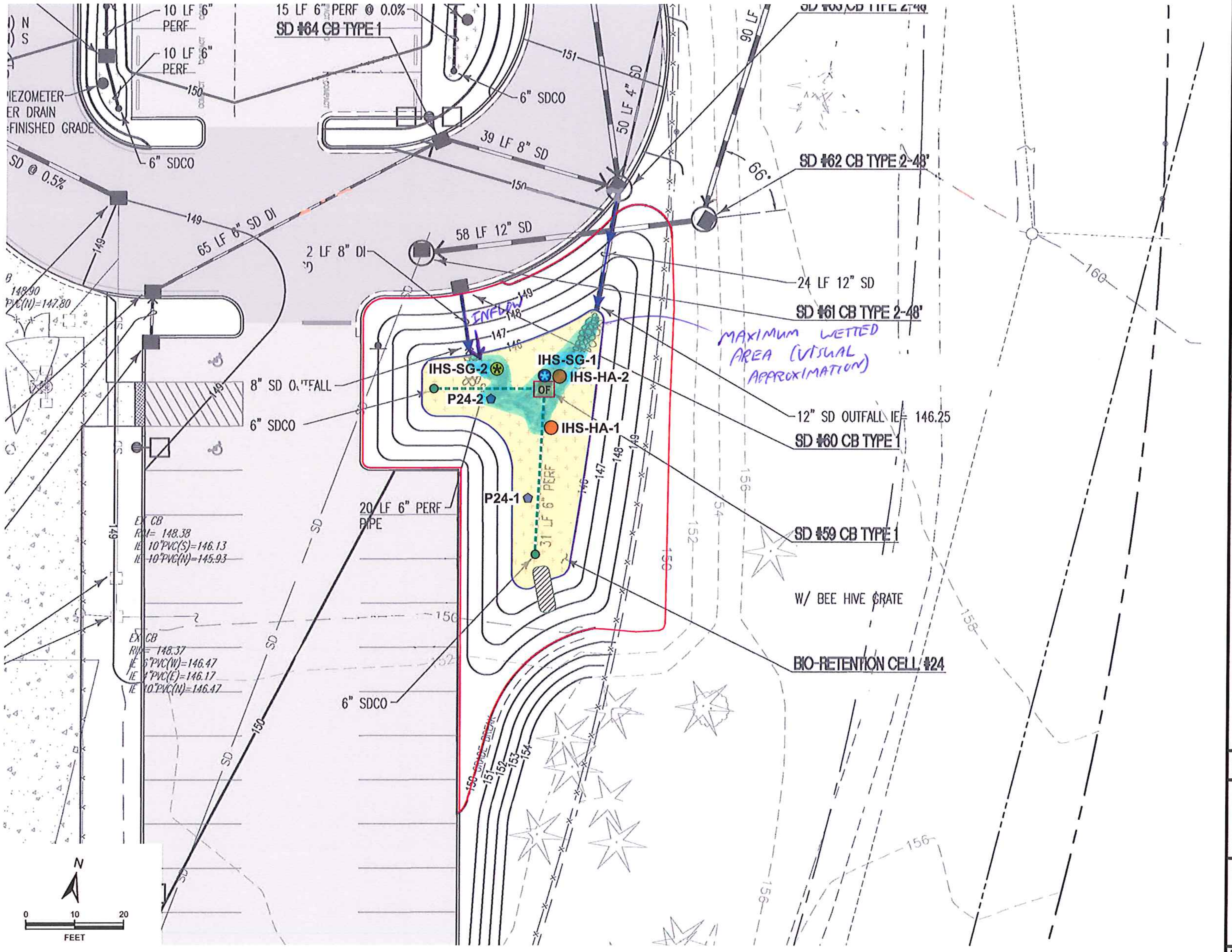
PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	D2

Cell IHS
Level Survey Data

Location	Elevation (feet, project datum)
SD #66	100
SD #61	100.59
SD #63	101.33
Bottom of pipe, inlet 1 (12-inch pipe)	97.5
Top of pipe, inlet 2 (6-inch pipe)	97.67
Piezometer 24-1 top of casing	98.17
SD #59 rim	99.63
Survey points in base of cell	On site plan

Cell IHS
Probe Survey Data List (Excludes Outliers)

Probe Penetration (feet):
1.1
1.2
1.6
1.6
1.7
1.7
1.6
1.5
1.7
1.6
1.8
1.6
2.0
1.5
AVERAGE: 1.6



LEGEND:

● HA	HAND AUGER
⊛	TEMPORARY STAFF GAUGE
⊛	PERMANENT STAFF GAUGE
▭	BASE OF FACILITY
▭	TOP OF FACILITY SLOPE
→	INFLOW / OVERFLOW DIRECTION
OF	OVERFLOW GRATE
- - - -	PERFORATED PIPE
●	STORM DRAIN CLEANOUT
⬟ P	PRE-EXISTING 4 INCH PIEZOMETER
SD	STORM DRAIN
▨	CONCRETE SLURRY DUMP

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:

1. BASE MAP REFERENCE: COUGHLIN PORTER LUNDEEN, ISSAQUAH HIGH SCHOOL, GRADING AND DRAINAGE PLAN, SHEET C-404, 5/16/2014

BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION.

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WETTED AREA

IHS SITE

BIORETENTION HYDROLOGIC PERFORMANCE

ISSAQUAH, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	10/16	APPENDIX D

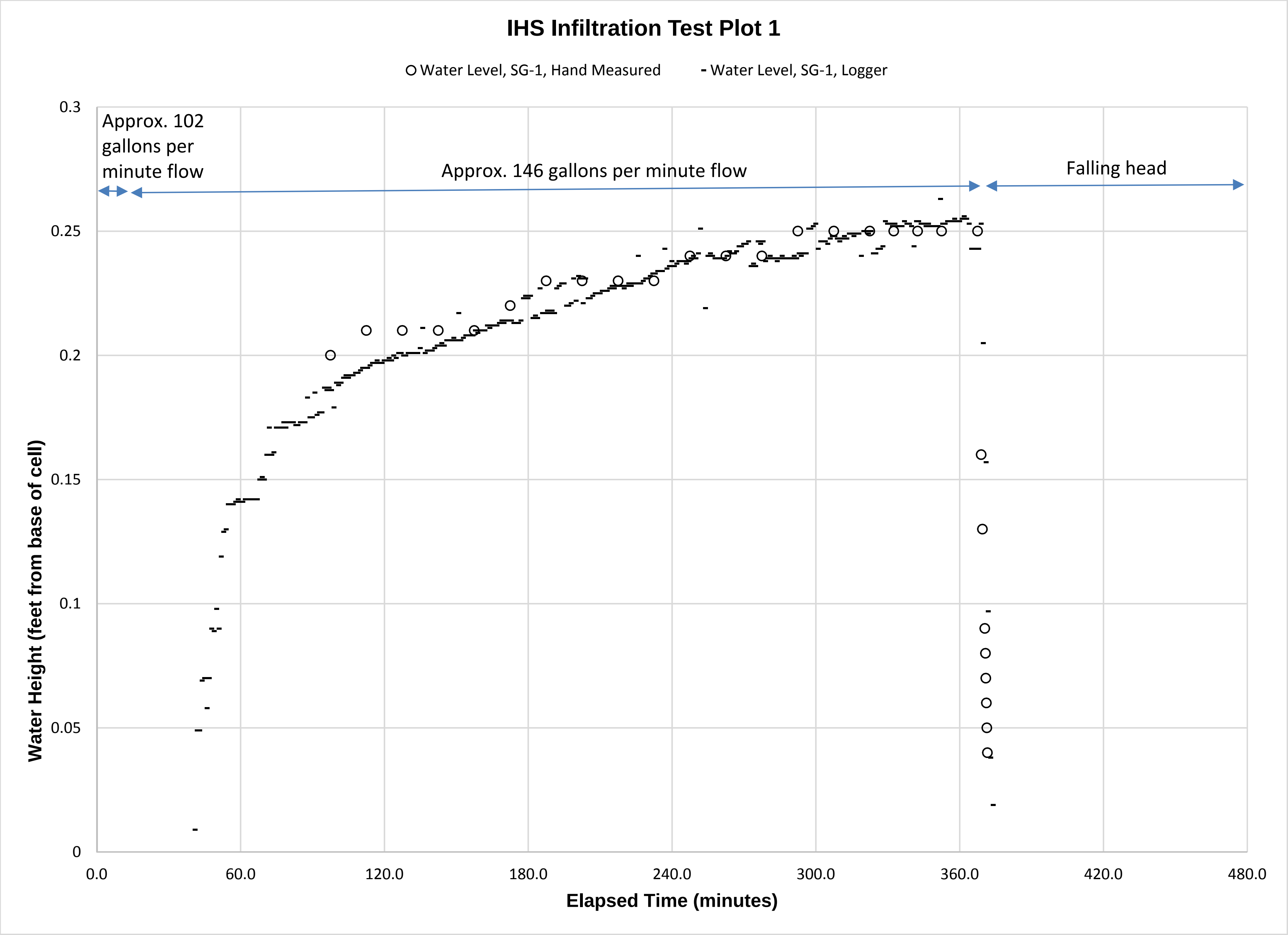
150387 BHPS MCCA | 150387 Site-Explr.cdr PAGE 3: IHS

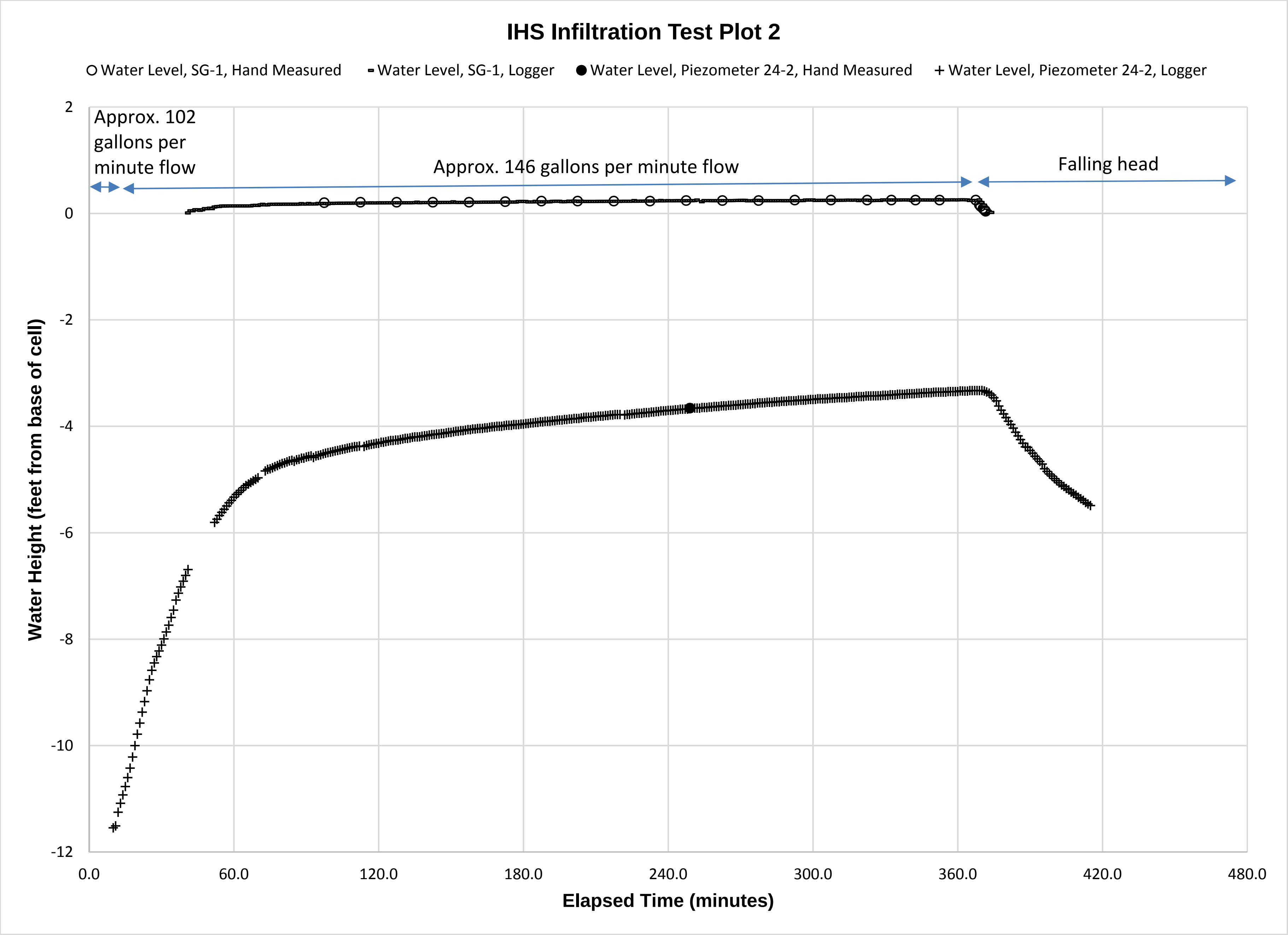
Project Name Bioretention Hydrologic Performance Assessment
Project Number KH150387A
Date 7/27/16
Weather Sunny
Test No. IHS IT-1
Meter FM7
Water Source Hydrant

Receptor Soils Bioretention Soil over Qva
Testing Performed By ADY

Time (24-hr)	Total (min)	Flow Rate (gpm)	Totalizer (gal)	Head (permanent staff gauge SG-1, feet)	Head (temporary staff gauge SG-2, feet)	Wetted area (ft^2)	Piezometer 24-2 Depth to Water from Top of Casing (feet)	Notes
8:37:30	0.0	101.98	0					Flow on
8:50:00	1.0	101.82	1304		0.42			
9:00:00	3.0	101.82	2278		0.42			
9:03:00	9.0	146.38			0.43			Flow increased to maximum
9:15:00	21.0	144.3	4312		0.43			
9:30:00	40.0	145.07	6499		0.43			
9:45:00	66.0	145.38	8763		0.43			
10:00:00	81.0	146.01	10866		0.38			Pool in front of SG-2 drained, no direct correlation to SG-1, SG-1 better represents average water level in cell
10:15:00	96.0	144.6	13129	0.2	0.38			
10:30:00	111.0	145.7	15338	0.21	0.39			
10:45:00	126.0	144.76	17422	0.21	0.38			
11:00:00	141.0	143.37		0.21	0.38			
11:15:00	156.0	144.92	21718	0.21	0.38			
11:30:00	171.0	145.36	23840	0.22	0.38			
11:45:00	181.0	146.01	26071	0.23	0.38			
12:00:00	186.0	146.3	28242	0.23	0.38			
12:15:00	201.0	145.23	30510	0.23	0.38			

Time (24-hr)	Total (min)	Flow Rate (gpm)	Totalizer (gal)	Head (permanent staff gauge SG-1, feet)	Head (temporary staff gauge SG-2, feet)	Wetted area (ft^2)	Piezometer 24-2 Depth to Water from Top of Casing (feet)	Notes
12:30:00	216.0	144.46	32642	0.23	0.38			
12:45:00	231.0	146.62	34763	0.24	0.38		4.67 feet at 12:47	
13:00:00	246.0	146.16	36947	0.24	0.38			
13:15:00	261.0	144.6	39074	0.24	0.38			
13:30:00	276.0	144.46	41301	0.25	0.38			
13:45:00	291.0	145.7	43546	0.25	0.38			
14:00:00	306.0	145.98	45663	0.25	0.38			
14:10:00	321.0	145.86	47226	0.25	0.38			
14:20:00	336.0	146.32	48640	0.25	0.38			
14:30:00	353.0	145.04	50083	0.25	0.38	223		
14:45:00	376.0	0	52277	0.25	0.38			Flow off, begin falling head
14:46:30	386.0	0		0.16				
14:47:00	397.0	0		0.13				
14:48:00	411.0	0		0.09				
14:48:18	426.0	0		0.08				
14:48:27	436.0	0		0.07				
14:48:40	446.0	0		0.06				
14:48:51	456.0	0		0.05				
14:49:07	466.0	0		0.04				End test, retrieve dataloggers


IHS Infiltration Test Plot 1
○ Water Level, SG-1, Hand Measured
- Water Level, SG-1, Logger
Approx. 102 gallons per minute flow
Approx. 146 gallons per minute flow
Falling head
Water Height (feet from base of cell)
0.3
0.25
0.2
0.15
0.1
0.05
0
0.0
60.0
120.0
180.0
240.0
300.0
360.0
420.0
480.0
Elapsed Time (minutes)


IHS Infiltration Test Plot 2
○ Water Level, SG-1, Hand Measured
- Water Level, SG-1, Logger
● Water Level, Piezometer 24-2, Hand Measured
+ Water Level, Piezometer 24-2, Logger
Approx. 102 gallons per minute flow
Approx. 146 gallons per minute flow
Falling head
Water Height (feet from base of cell)
2
0
-2
-4
-6
-8
-10
-12
0.0
60.0
120.0
180.0
240.0
300.0
360.0
420.0
480.0
Elapsed Time (minutes)

APPENDIX E

Site Photos

Cell IHS overflow structure

Cell IHS pre-existing piezometer 24-2

Cell IHS 12-inch inlet

Cell IHS 9-inch inlet

APPENDIX 6

Deliverable 4.5, Site MCCA, Geotechnical/Soils Assessment Design Data and Current Condition, Mill Creek Community Association, Mill Creek, Washington. Associated Earth Sciences, Inc. 10/25/16

associated earth sciences incorporated

Technical Memorandum

Date:	October 25, 2016	**From:**	Jennifer H. Saltonstall, L.G., L.Hg.
To:	Clear Creek Solutions, Inc.	**Project Manager:**	Jennifer H. Saltonstall, L.G., L.Hg.
	15800 Village Green Drive #3 Mill Creek, Washington 98012	**Principal in Charge:**	Curtis J. Koger, L.G., L.E.G., L.Hg.
		Project Name:	Bioretention Hydrologic Performance Study
Attn:	Doug Beyerlein, P.E.	**Project No:**	KH150387A
Subject:	Deliverable 4.5, Site MCCA, Geotechnical/Soils Assessment Design Data and Current Conditions, Mill Creek Community Association, Mill Creek, Washington		

1.0 INTRODUCTION

This technical memorandum documents existing shallow soil and ground water conditions in bioretention cell #1 (MCCA1) and #2 (MCCA2) at the Mill Creek Community Association Office, located in the city of Mill Creek, Washington (Figure MCCA F1). This memorandum was prepared in accordance with Task 4 of the contract scope of work. Associated Earth Sciences, Inc. (AESI) collected shallow soil and ground water conditions data related to bioretention cell function, and documented the current condition of the facility relative to the as-built drawings and available background geotechnical information. The information will be used in the WWHM2012 modeling that will be conducted as part of Task 5 (Data Analysis). In Task 5, the team will compare the previously documented hydrologic design information with our field-collected information and will note where there are significant differences. The purpose of this technical memorandum is to document the collection of current and accurate geotechnical, geologic and hydrogeologic site information for this later work.

The following summary of shallow soil and ground water conditions integrates the observations made during the geotechnical assessment which included site visits on July 8, July 11, July 22, and August 24, 2016, infiltration testing on August 8 and August 26, 2016, and background geotechnical information.

This technical memorandum has been prepared for the exclusive use of Clear Creek Solutions and the City of Bellingham and their agents for specific application to this project. Within the limitations of scope, schedule, and budget, our services have been performed in accordance with generally accepted hydrogeologic and geotechnical engineering practices in effect in this area at the time our document was prepared. No other warranty, express or implied, is made.

2.0 PURPOSE AND SCOPE

The purpose of our work was to perform a shallow soil and ground water conditions assessment and provide baseline documentation data to assess effectiveness of bioretention hydrologic performance.

Specifically, our scope included the following activities:

- Review of project documents.
- Site reconnaissance.
- Visual condition assessment of erosion and deposition features near inlet and outlet.
- Review project plans relative to constructed facility, in particular, the number and location of inlets, energy dissipation devices, outlets, and other flow-related details.
- Survey elevations of inlet, outlet, well point rim, and other observation points relative to a project datum.
- Excavate shallow hand augers through the bioretention soil and into the underlying material, extending one hand auger deeper into the subgrade for installation of a well point.
- Classify sediment according to the Unified Soil Classification System (USCS) and *American Society for Testing and Materials* (ASTM) D2488, “Standard Recommended Practice for Description of Soils.”
- Collect samples for laboratory testing of (1) particle size distribution in accordance with ASTM D422-63, “Standard Test Method for Particle-Size Analysis of Soils”; (2) organic matter content per ASTM D2974.
- Conduct qualitative assessment of bioretention soil compaction via T-probe.
- Conduct infiltration testing.
- Preparation of descriptive exploration logs for each exploration.
- Preparation of this summary document.

Topography of the site and surrounding area is shown on Figure MCCA F2, “LiDAR-Based Topography.” Existing facility features and the locations of hand-auger boreholes completed for this study are shown on Figure MCCA F 3, “Facility and Exploration Plan.” Project civil plans are attached as Appendix A. Exploration logs and laboratory testing data conducted as part of this study are attached as Appendix B. Background soil, geology, and ground water information are attached as Appendix C. Soil probe, level survey, and field infiltration testing data are attached as Appendix D. Site photos are attached as Appendix E.

3.0 SITE DESCRIPTION AND DESIGN BACKGROUND

The project site is the Mill Creek Community Association (MCCA) office and parking lot located at 15524 Country Club Drive in Mill Creek, Washington as shown on the attached “Vicinity Map” (Figure MCCA F1). This project site is bordered by a parking lot to the northwest, by Country Club

Drive to the northeast, by a pedestrian path and single-family residences to the southeast, and by a maintenance area to the southwest. No natural surface water features are present onsite. Penny Creek, an incised perennial stream, is located about 700 feet east of site, and about 100 feet lower in elevation. Per the Washington State Source Water Assessment Program Mapping Application, the nearest water supply well is located approximately ½ mile to the east of the facility. LiDAR topography and other near-site vicinity features are illustrated on Figure MCCA F2, “LiDAR-Based Topography.”

Our specific area of study for this project includes the bioretention facilities located between the MCCA office building and the associated parking lot as shown on Figure MCCA F3, “Facility and Exploration Plan.”

Details of the bioretention facility design and basis were presented in the following documents:

- Plan sheets C1-C6, Harmsen & Associates, Inc., August 20, 2013.
- Stormwater Site Plan for the Mill Creek Community Association Building (Stormwater Site Plan), Harmsen & Associates, Inc., August 20, 2013.
- Subsurface Exploration, Geologic Hazard, and Preliminary Geotechnical Engineering Report, Associated Earth Sciences, Inc., July 9, 2013.

3.1 Summary of Facility Design

From our review of these documents, the bioretention facility design consists of two square-shaped bioretention cells, each with approximately 200 square feet of base area, as shown on Figure MCCA F3, “Facility and Exploration Plan.” We understand that the cells were sized per the 2005 Washington State Department of Ecology (Ecology) *Stormwater Management Manual for Western Washington* (2005 Ecology Manual), and modeled using WWHM3 based on a developed condition drainage basin of about 460 square feet each (representing ¼ of the roof area). Land use within the drainage basin consists of roof area. The facility design includes 1 foot of bioretention soil mix (per the Stormwater Site Plan) overlying native soil and is designed to infiltrate 100 percent of inflow into the subgrade. Emergency overflow from each cell would discharge through an 8-inch-diameter yard drain that connects to the rock reservoir beneath the adjacent porous concrete parking lot. The rim of the yard drain is intended to be 1 foot higher than the cell base to create the 1 foot of ponding. The facility was constructed and began receiving runoff in May 2014 (Email communication, Joan Heath, MCCA, August 23, 2016).

4.0 SITE OBSERVATIONS

During AESI’s site visits, we made notes regarding the physical construction of the bioretention facilities including documenting site inlet/outlet layout relative to site plans and qualitative bioretention soil thickness and compaction. These notes were used to indicate key features of the facilities on Figure MCCA F3, “Facility and Exploration Plan.”

- Level Survey: AESI conducted elevation surveys of the facilities using a Leitz C40 automatic level and a stadia rod. An arbitrary project datum was established for these surveys, with the top of the concrete lamp post base on the northeast side of the parking lot defined as project datum elevation 100 feet for both surveys. All other elevations measured by the surveys are relative to this project datum. Key level data is summarized in Table 1. Additional data points are included in Appendix D to this document. These surveys were not conducted by a licensed surveyor. Surveyed elevations are expected to be sufficiently accurate for this general assessment of facility construction, but may be inaccurate for purposes requiring greater precision.

- Inflow: Both cells contain one inflow to each cell which consists of a 4-inch PVC pipe draining a portion of the roof area. The inlet pipe discharges onto an approximately 3.5-foot by 4-foot (MCCA1) or 4-foot by 4-foot (MCCA2) quarry spall splash pad. No evidence of erosion was noted at either inlet. AESI observed some deposition of leaf litter and sand in the quarry spall at each inlet.

Table 1
Summary of MCCA1 and MCCA2
Level Survey Data

Location	MCCA1 Elevation (feet, project datum)	MCCA2 Elevation (feet, project datum)
Top of cement lamp post base, east side of parking lot	100	
Base of inflow pipe	99.12	99.03
Base of facility, low point	97.71	97.62
Base of 8-inch overflow yard drain grate	97.98	97.80
Base of 4-inch overflow pipe*	~98.1*	~97.9*
Top of well point	99.43	98.52
Base of lowest overflow stub	98.24	
Survey points in base of cell	On site plan in Appendix D to this document	

*Measured height of 4-inch pipe invert at 0.1 feet above base of yard drain grate; unable to survey directly.

- Overflow: Both bioretention cells contain rectangular black plastic yard drain "overflow structures" that do not correlate with planned overflow structure shown on plan sheet C3 (Harmsen & Associates, Inc. [Harmsen], 2013). The yard drain overflow consists of a black plastic box, with a plastic grate cover, measuring approximately 0.7 feet wide by 0.6 feet high set laterally in the cell base and connecting to the 4-inch PVC overflow pipe. Quarry spall was present around the front and sides of the grate. AESI noted some leaf litter collected on the quarry spall, but not collected against the front of the grate.

- The plans indicate that emergency overflow from each cell would discharge through an 8-inch-diameter yard drain that is connected to the adjacent porous parking lot base course/storage reservoir via a 4-inch perforated PVC pipe. The rim of the yard drain was shown on the plans to be 1 foot higher than the cell base to allow for up to 1 foot of ponding within the bioretention cell. We observed that for each cell, water can only pond about 0.3 to 0.4 feet in depth before overflow would occur through the 4-inch overflow pipe. This is because the 8-inch yard drain is not oriented vertically over the 4-inch overflow pipe (see Photo 1).

- AESI notes that bioretention cell discharge pipe (4-inch perforated pipe) is indicated on the plan set to continue from the overflow grates through the porous parking lot rock reservoir, and connect to 4-inch-diameter solid PVC “overflow” pipes, which rise slightly to daylight and discharge to the grass lawn on the east side of the parking lot. Per plans, the overflow pipe stubs have a bottom elevation of 0.5 feet higher than the bioretention cell discharge pipe invert. This differs from the measured height difference of 0.15 to 0.35 feet for MCCA1 and MCCA2, respectively, documented by AESI’s level survey (Table 1).

- AESI understands that, when water pools to sufficient depth in either bioretention cell, the cell would discharge into the overflow structure, then into the perforated overflow pipes, pool in the porous parking lot rock reservoir, and, if sufficient water depth was reached in the rock reservoir, flow out the overflow stubs on the east of the parking lot. It is possible that, under extreme or intense rainfall conditions, water could also flow from the rock reservoir back into the bioretention cells because the overflow pipe stub outlet is 0.1 to 0.3 feet higher than the inlet in the bioretention cells.

Photo 1. *Cell MCCA2, 8-inch “overflow” yard drain grate, oriented sideways instead of vertical.*

- AESI investigated the loose bioretention soil thickness present in the bioretention cells using a geotechnical soil T-probe. This qualitative data was used in conjunction with the hand-auger observations to understand loose soil thickness and relative potential compactness of the bioretention soils at depth. AESI measured the depth of penetration of the soils probe at locations generally arranged in a 5-foot grid pattern spanning the base of each facility. The apparent thickness of bioretention soil generally ranged from approximately 0.6 feet to 1 foot and averaged 0.8 feet in cell MCCA1, and ranged from approximately 0.7 feet to 1.3 feet in cell MCCA2, with an average of 1 foot. Probe penetration data is included in Appendix D to this document.

- MCCA2: AESI noted that public utility locators had placed marks indicating the presence of a gas line crossing from the parking lot toward the building, near or under the southern end of cell MCCA2. This approximate location is indicated on Figure MCCA F3. AESI did not excavate hand-auger borings or use the T-probe in the immediate vicinity of the indicated utility line.
- MCCA2: Cell MCCA2 differed in size from the plan in that the cell base extended farther to the south than shown on the plan; the difference is illustrated on Figure MCCA F3.

- MCCA2: AESI observed cylindrical black plastic objects with grated sides, described as "root wells" by the owner, which were inserted vertically about a foot into the bioretention soil in cell MCCA2 to improve the infiltration of water into the subsurface.

- MCCA2: The owner indicated that historically, ponded water has often been present in cell MCCA2, and that it has typically taken several days to disappear, draining noticeably slower than cell MCCA1.

5.0 SITE SETTING

The text sections below describe our research findings in regards to the topographic, geologic, and hydrogeologic setting of the project site both from regional studies and background site-specific geotechnical and ground water studies. Our sources of information included the following:

- Site-specific documents cited previously under "Project and Site Description."
- *Geologic Map of the Bothell Quadrangle, Snohomish and King Counties, Washington*, United States Geological Survey, 1985.
- *Soil Survey of the Snohomish County area, Washington*, United States Department of Agriculture, Natural Resource Conservation Service (NRCS), 1983.
- Thomas, B.E. et al., *The Ground-Water System and Ground-Water Quality in Western Snohomish County, Washington*, United States Geological Survey Water-Resources Investigations Report 96-4312, 1997.
- Newcomb, R.C., *Ground-Water Resources of Snohomish County, Washington*, United States Geological Survey, Water Supply Paper 1135, 1952.

5.1 Regional Topography and Project Grading

The project site is situated on a rolling upland with elevations generally ranging from 380 to 460 feet as shown on Figure MCCA F2, "LiDAR-Based Topography." The upland is incised by Penny Creek and other shallower drainages. Penny Creek, near the project site, has eroded down about 100 feet, creating relatively steep slopes within about 200 feet of the bioretention cells.

On a closer scale, the site occupies an upland area near a bend in Penny Creek, and is generally level with an elevation of approximately 440 to 444 feet. Prior to bioretention cell construction, the site existing conditions was described as open grass with a several large trees (Harmsen, 2013) that sloped gently to the north and west from a high of 444 feet in the southeast corner to a low of 440 feet along the north and western parts of the site. The proposed improvements (MCCA building, parking lot, and bioretention cells) were described as located in the open grass area. No significant cutting or filling was needed to achieve design bioretention cell grades based on a review of existing topography compared with built topography. Design grades for the adjacent sidewalk, access road, and building foundation would have required about 1 to 2 feet of fill.

5.2 Regional Geology and Background Geotechnical Information

According to the *Geologic Map of the Bothell Quadrangle, Snohomish and King Counties, Washington*, the site vicinity is underlain by Vashon till, which is in turn underlain by advance outwash sediments (mapped as exposed within the Penny Creek ravine). The contact between these units is depicted at an elevation of approximately 410 feet in the vicinity of the site. These sediments are described below.

- *Vashon Lodgement Till (Qvt):* The uppermost geologic unit is a deposit of Vashon lodgement till. This is described in the *Geologic Map of the Bothell Quadrangle, Snohomish and King Counties, Washington* as a "nonsorted mixture of mud, sand, pebbles, cobbles, and boulders, which looks like concrete mix," with some lenses of stratified material within the lower part of the unit. This unit was deposited during the Vashon Stade of the Fraser Glaciation, and was directly overridden by the glacial ice, resulting in a high degree of compaction.

- *Advance Outwash (Qva):* This unit was deposited by streams flowing from the glacier as it advanced, prior to the deposition of the Vashon lodgement till. This unit typically consists of stratified sands and gravels. Advance outwash was subsequently overridden by the Vashon ice sheet, resulting in a high degree of compaction. However, due to deposition by flowing water, the material typically contains few fines, resulting in moderate permeability characteristics.

The 2013 AESI report included four exploration pits advanced within the on-site sediments to evaluate the proposed parking lot. Two of these explorations encountered fill soils to 1 foot below ground surface. All four explorations encountered sediments interpreted as weathered Vashon lodgement till to 3 to 3.5 feet below ground surface, and unweathered Vashon lodgement till to the total depth explored (10 feet below ground surface). These findings are in agreement with the geologic map of the area.

5.3 Regional Soils and Soil Data Used in Site Stormwater Model

AESI reviewed the *Soil Survey of the Snohomish County area, Washington* (Natural Resources Conservation Service [NRCS], 1983), and soils mapping from the NRCS web portal (NRCS, 2016).

The soil survey identifies different soil map units based on parent material, climate, topography (slope), organisms (biota), and time. The soils in the study area formed mostly from young glacial deposits and have not had time to develop the deep weathering profiles present in soils in unglaciated terrains. Instead, they exhibit a direct relationship to the underlying parent material, local climate, topography, and vegetation.

Mapped soils in the project area consist of Alderwood-type soils. Alderwood soils are formed from the weathering of glacial till. NRCS describes the permeability in the undisturbed upper 27 inches of the Alderwood soils as ranging from 2.0 to 6.3 inches per hour (in/hr). However, in developing areas, this upper soil is typically removed or compacted. The lower portion of the soil profile has a low permeability, less than 0.06 in/hr at depth (NRCS, 1983). This is a key limitation for shallow infiltration and can be easily misinterpreted. The very low infiltration rate reflects the permeability of the glacial till "parent" material. These soils commonly become saturated during the winter and typically contain shallow ground water referred to as interflow.

As described in the Stormwater Site Plan (Harmsen, 2013), the pre-developed condition was modeled as Type C soils, consistent with mapped soil and background geotechnical data.

5.4 Regional Hydrogeology and Background Ground Water Data

Regional hydrogeology is described in *The Ground-Water System and Ground-Water Quality in Western Snohomish County, Washington* (Thomas, 1997), and *Groundwater Resources of Snohomish County* (Newcomb, 1952). The area occupied by the site is referred to as the "Intercity Plateau." The United States Geological Survey report describes the Vashon lodgement till as a confining bed, but indicates that it can contain thin lenses of sand and gravel, which can yield usable quantities of water. A very shallow seasonal perched water-bearing zone typically forms in the weathered horizon of the Vashon lodgement till, and is referred to as "interflow." Interflow typically accumulates within the weathered soils on top of the unweathered till and flows laterally generally in the direction of sloping ground. Interflow discharges in low areas forming wetlands, at near-vertical cuts along roadways, walls or in excavations, or slows infiltrates into the underlying unweathered till as diffuse recharge, or along fractures or sandy zones in the till.

No background data on ground water was available. No seepage was encountered in the geotechnical study exploration pits.

6.0 BIORETENTION CELL SUBSURFACE EXPLORATION AND WELL POINT INSTALLATION

Limited information on subsurface conditions was obtained for this study from hand-auger samples and soil probe penetration measurements at about 2-foot increments in each hand-augered borehole. In each bioretention cell, one hand-auger boring was performed in the facility bottom and advanced through the bioretention soil and into the underlying subgrade. Additional hand-auger borings were completed to the base of the bioretention soil. Representative samples were collected, visually classified in the field, stored in water-tight containers and transported to

AESI's offices for additional classification, geotechnical testing and study. At the conclusion of the excavation, each borehole was immediately backfilled with the excavated material, or completed as a well point and the bioretention soil replaced.

The various types of sediments, as well as the depths where characteristics of the sediments changed, are indicated on the exploration logs presented in Appendix B. A detailed record of the observed bioretention soil, subsurface soil, geology, and ground water conditions was made. The sediments were described by visual and textural examination using the soil classification in general accordance with ASTM D2488, "Standard Recommended Practice for Description of Soils." The depths indicated on the logs where conditions changed may represent gradational variations between sediment types in the field. The exploration logs in Appendix B are based on the field observations, inspection of the samples, and where applicable, laboratory grain-size analysis. Our explorations were approximately located in the field relative to known site features, and are shown on Figure MCCA F3, "Facility and Exploration Plan." GPS coordinates for the explorations were taken using a handheld GPS, and are summarized in Appendix B.

The results presented in this document are based on the explorations completed for this study and review of background data. The number, locations, and depths of the explorations were completed within site and budgetary constraints. Because of the nature of exploratory work below ground, interpolation of subsurface conditions between field explorations is necessary. It should be noted that differing subsurface conditions may sometimes be present due to the random nature of deposition and the alteration of topography by past grading and/or filling.

6.1 Hand-Auger Borings in Cell MCCA1

Hand-auger borings in cell MCCA1 were completed on July 8 and July 11, 2016. Light rain was noted upon AESI's arrival, which stopped shortly thereafter. No flow was observed from the inlet pipes.

Hand-auger boring number 1 in cell MCCA1 (MCCA1-HA-1) was completed in the southwest corner of the cell, and encountered approximately 1 foot of bioretention soil, overlying material interpreted as weathered glacial till. The exploration encountered refusal on gravel at 2.2 feet. Seepage was observed in the bottom of the borehole, and water pooled in the borehole to 2 feet below grade. AESI installed a well point in this location.

Hand-auger boring numbers 2 and 3 in cell MCCA1 (MCCA1-HA-2 and MCCA1-HA-3) encountered 1 foot and 1.2 feet, respectively, of bioretention soil, overlying material interpreted as weathered glacial till. MCCA1-HA-2 encountered refusal on an approximately 6-inch cobble at 1.8 feet. MCCA1-HA-3 encountered refusal on gravel at 1.4 feet. No seepage was observed.

6.2 Hand-Auger Borings in Cell MCCA2

Hand-auger borings in cell MCCA2 were completed on July 22 and August 24, 2016. No rain or inflow of water to the facility was observed on these days.

Hand-auger boring number 1 in cell MCCA2 (MCCA2-HA-1) was completed near the center of the cell, in the proximity of the area of lowest elevation. MCCA2-HA-1 encountered approximately 0.9 feet of bioretention soil, overlying material interpreted as fill soils to a depth of 2.2 feet below the facility grade. Below 2.2 feet, the material was interpreted as weathered Vashon till. The exploration reached refusal on a cobble at 2.6 feet. AESI installed a well point in this location.

Hand-auger boring numbers 2 and 3 in cell MCCA2 (MCCA2-HA-2 and MCCA2-HA-3) encountered approximately 0.6 feet and 1.2 feet, respectively, of bioretention soil, overlying silty gravel and silty fine sand with some gravel interpreted as undocumented fill. MCCA2-HA-2 encountered refusal on a cobble of approximately 5 inches in diameter at 1.1 feet below grade. MCCA2-HA-3 encountered refusal on a cobble at 2.1 feet. No seepage or caving was observed.

No explorations were completed on the southern side of the cell near the inflow due to the presence of a buried gas line indicated by utility locators.

6.3 Well Points

Well points were installed in HA-1 in cell MCCA1, and HA-3 in cell MCCA2. Both were dry at the time of installation. Key dimensions of these well points are provided in Table 2, below.

Table 2
Summary of MCCA1 and MCCA2 Well Point Dimensions

Well Point	Exploration in which Well Point was Installed	Total Depth Inside Casing (feet)	Interior Diameter	Stickup Height (feet)	Total Depth Inside Casing Below Ground Surface
MCCA1-WP	MCCA1-HA-1	3.1	1.25 inch nominal	1.6	1.5
MCCA2-WP	MCCA2-HA-3	4.2	1.25 inch nominal	0.8	3.4

7.0 LABORATORY ANALYSIS

Laboratory testing included mechanical grain-size distribution and percent organic matter by weight in accordance with ASTM D422 and D2974, respectively. Two samples of bioretention soil for each cell were first tested for organic matter content and then the burned material was tested for grain-size distribution for comparison with the aggregate fraction of the bioretention soil mix guidance in the Washington State Department of Ecology (Ecology) 2014 *Stormwater Management Manual for Western Washington* (2014Ecology Manual). One sample of the subgrade from each cell was tested for grain-size distribution. The data is summarized in Table 3.

7.1 Bioretention Soil Mix

We compared the organic content and burned fraction gradation against the general guidelines for the bioretention soil mix (Table 4).

The organic content of the tested bioretention soils ranged between 4.0 to 5.3 percent by weight. This is below or on the low range of the recommended organic content by weight of 5 to 8 percent in the 2014 Ecology Manual.

Table 3
Summary of MCCA1 and MCCA2, Organic Content and Grain-Size Data

Exploration Number	Depth (feet)	Soil Type	Organic Content (% by weight)	USCS Soil Description	Fines Content (% passing #200)	Cu	Cc	USDA Soil Texture*
MCCA1-HA-1	0.3-0.9	Bioretention Soil	4.0	SAND (SP)	0.3%	3.6	1.8	SAND
MCCA1-HA-3	0.1-0.7	Bioretention Soil	4.3	SAND (SP)	0.4%	2.8	1.0	SAND
MCCA1-HA-3	1-1.4	Vashon Lodgement Till	Not tested	Silty very gravelly SAND (SM)	16%	1.9	>20	Sandy clay loam to sandy loam
MCCA2-HA-1	0.3-0.5	Bioretention Soil	4.8	SAND (SP)	1.3%	3.0	1.0	SAND
MCCA2-HA-2	0.1-0.6	Bioretention Soil	5.3	SAND (SP)	1.1%	3.0	1.4	SAND
MCCA2-HA-1	1-1.2	Undocumented Fill	Not tested	Silty very gravelly SAND (SM)	33%	19.5	>20	Sandy clay to sandy loam

USCS: Unified Soil Classification System; Cu: coefficient of uniformity; Cc: coefficient of curvature; USDA: U.S. Dept. of Agriculture;
*No hydrometers were performed. USDA soil texture range reflects possible fines consisting entirely of silt to entirely of clay.

Table 4
General Guidelines for Bioretention Soil Mix (2014 Ecology Manual) Compared to Averaged MCCA1 and MCCA2 Site Data

Parameter	Recommended Range	MCCA1	MCCA2
Organic Content (by weight)	5 to 8 percent	4.2 percent by weight	5.1 percent by weight
Cu coefficient of uniformity	4 or greater	3.2	3.0
Cc coefficient of curvature	1 to 3	1.4	1.2
Sieve Size	**Percent Passing**		
3/8” (9.51 mm)	100	100	100
#4 (4.76 mm)	95 to 100	99	99
#10 (2.0 mm)	75 to 90	94	94
#40 (0.42 mm)	25 to 40	11	37
#100 (0.15 mm)	4 to 10	1.1	4.3
#200 (0.074 mm)	2 to 5	0.3	1.2

Note: The general guidelines for mineral aggregate gradation are from Table 7.4.1 of the 2014 Ecology Manual.
mm: millimeter

The grain-size analysis test results on the burned soil fraction indicate that the bioretention soils tested correlate to a “SAND” based on ASTM D2487 USCS. The respective fines content as measured on the No. 200 sieve ranged from approximately 0.3 to 1.3 percent, consistently less than the recommend range of 2 to 5 percent. The coefficient of uniformity ranged from 2.8 to 3.6, consistently less than the recommended value of equal to or greater than 4. The coefficient of curvature ranged from 1.0 to 1.8, consistent with the recommended range of greater than or equal to 1 and less than or equal to 3. For cell MCCA1, the soil mix generally did not meet (contained less than) the recommended range of fine sand and silt fractions. The tested bioretention soil was predominantly medium-grained sand.

7.2 Subgrade

In MCCA1, a sample of native glacial till was sieved. The tested material correlates to a silty, very gravelly SAND with 16 percent by weight of the material passing the No. 200 sieve. In MCCA2, a sample of the undocumented fill material was sieved. The tested material correlates to a gravelly, very silty SAND with 33 percent of the material by weight passing the No. 200 sieve.

The grain-size distribution data were also transformed to describe the United States Department of Agriculture (USDA) soil texture. The grain-size distributions were normalized to the No. 10 sieve—i.e., the coarse sand and gravel fraction of the sample is discounted and the remainder is taken as 100 percent of the sample. The fines were assessed relative to the No. 270 sieve. The respective USDA fines content as measured on the No. 270 sieve after adjusting to remove the weight retained on the #10 sieve was 48 percent for the undocumented fill material and 28 percent for the native glacial till material.

8.0 INFILTRATION TESTING

The infiltration tests were conducted in general accordance with the 2014 Ecology Manual. Each test was conducted by discharging water into the facility for a “soaking period,” to allow the receptor soils to become saturated. After completion of the soaking period, water was discharged into the cell at a rate sufficient to maintain a relatively constant head. This constitutes the “constant head” phase of infiltration testing. Immediately following the constant head phase of infiltration testing, flow into the facilities was discontinued, and the water level was monitored as it dropped. This constitutes the “falling head” portion of the infiltration testing.

The water for testing was obtained from on-site hose bibs, and conveyed to the test area with garden hoses. During infiltration testing, the water was conveyed into the bioretention cell via a digital flow meter with gallons per minute (gpm) and total gallon readouts, and discharged through a flow diffuser onto the rock splash pad by the facility inflow pipe. Water levels were monitored using a temporary metal staff gauge marked in 0.02-foot increments which was installed for the duration of the test, within the well point with a digital water level tape, and with digital pressure transducers. Data from the digital pressure transducers was compensated for barometric response using a separate digital barometer. The area of the pool was measured periodically during testing.

Infiltration tests in each bioretention cell are discussed below, and results are presented in Table 5. Infiltration test data is included in Appendix D to this document.

8.1 Infiltration Test in Cell MCCA1

AESI performed infiltration testing of cell MCCA1 on August 26, 2016. No rainfall was noted during testing, and no flow from the inflow pipes was present.

During this test, after an initial soak period of 5 hours, flow was maintained at approximately 5 gpm for approximately 2 hours, during which the water level in the facility rose slowly from 0.34 to 0.38 feet, as measured on the temporary staff gauge. Water was observed pooling in the base of the overflow pipe during this time, but only trace flow into the pipe was observed. The full duration of flow was approximately 8 hours, during which approximately 3,000 gallons of water were used.

Immediately following the period of constant flow, AESI shut off the flow and monitored water level as it fell. AESI observed a drop in water levels of approximately 0.07 feet during 30 minutes of hand readings. The falling water level was monitored overnight using a digital pressure transducer. As recorded by the digital pressure transducer, the water level fell from 0.38 feet to 0.05 feet over the course of approximately 130 minutes. Below this level, the water did not register on the pressure transducer. The facility was found to contain no ponded water when the digital pressure transducer was removed at a later date. Water built up in the well point within a few minutes of the start of the infiltration test, and was present in the well point throughout the test, generally corresponding to water level within the cell. After testing, water within the well point took approximately 23.5 hours to decrease to the level at which it no longer registered on the data logger, approximately 1.2 feet below ground surface.

8.2 Infiltration Test in Cell MCCA2

AESI performed infiltration testing of cell MCCA2 on August 8, 2016. Upon our arrival onsite, we observed light rain and inflow into the cell but no ponded water. This flow was measured, using a container of known volume and a stopwatch, as approximately 0.05 gpm as the infiltration test began. Shortly after this measurement, the rain ceased and roof inflow stopped. The majority of the infiltration test occurred after roof inflow had ceased.

During this test, after an initial soak period during which flow into the facility was as high as approximately 4.4 gpm to fill the storage capacity, flow was maintained at approximately 1.5 gpm for approximately 3 hours, during which the water level in the facility rose slowly from 0.21 to 0.34 feet, as measured on the temporary staff gauge. A trace of flow (<0.1 gpm) into the overflow of the facility was observed; the flow rate was then decreased to approximately 0.9 gpm, and maintained at this level for an additional 1.5 hours. At the end of this time, a trace of flow was again observed in the overflow. The full duration of flow was approximately 7 hours, during which approximately 700 gallons of water were used.

After about 7 hours, AESI shut off the flow and monitored water level as it fell. AESI observed a drop in water levels of approximately 0.01 feet during 30 minutes or hand readings. The falling water level was monitored overnight using a digital pressure transducer. As recorded by the digital pressure transducer, the water level fell from 0.34 feet to 0.09 feet over the course of approximately 440 minutes. Below this level, the water did not register on the pressure transducer. The facility was found to contain no ponded water the following morning. Water built up in the well point within a few minutes of the start of the infiltration test, and was present in the well point throughout the test, though generally at a lower level than water within the cell. After testing, water level within the well point fell slowly to approximately 1 foot below ground surface at approximately 17.5 hours after the end of the water flow for the test. Water was still present within the well point at this time when the data logger was removed from the well point.

Table 5
MCCA1 and MCCA2 Infiltration Test Results

Test No.	Wetted Surface Area, End of Test	Discharge Time	Total Volume Discharged	Approximate Constant Head Level	Field Infiltration Rates	
					Constant Head Test	Falling Head Test
MCCA1	180 square feet	501 minutes	2,998 gallons	0.37 feet	2.5 in/hr	2.0 in/hr
MCCA2	200 square feet	415 minutes	702 gallons	0.34 feet	0.5 in/hr	0.4 in/hr

in/hr: inches per hour

9.0 FINDINGS AND CONCLUSIONS

The bioretention cells at the MCCA site varied somewhat from the design shown on the civil plan sheets. Variations included the following:

- Bioretention soil
  - Thickness: Both cells contained areas where the bioretention soil was less than the planned 1-foot in thickness. No distinct pattern was apparent in the distribution of bioretention soil thickness throughout the cells. Some variations in loose bioretention soil thickness could be due to foot compaction within the cell during site maintenance, water compaction, or an uneven subgrade.
  - Composition: The soil tested in MCCA1 did not meet the recommended guidelines for organic content and sand gradation. The soil tested in MCCA2 was within the recommended range for organic content and met the recommended gradations for the sand fraction. The soil in both cells did not meet the recommended fraction of silt. We interpret that a different load of bioretention soil was placed in MCCA1 than in MCCA2 illustrating variations from the bioretention soil supplier.

- The overflow in both cells is different than plans in that the ponded water surface can only build up to about 0.3 to 0.4 feet before the cells begin to overflow. Site design documents indicate that the ponding level was designed as 1 foot.

- Cell MCCA2 differed in size from the plan: The cell extended farther to the south than shown on the plan, as indicated on Figure MCCA F3.

- Subgrade conditions: The subgrade conditions were variable, ranging from weathered glacial till (MCCA1) to undocumented fill (MCCA2).

- Review of existing and developed topography indicates that no significant cuts were necessary to achieve bioretention cell subgrade. This is consistent with presence of weathered glacial and undocumented fill remaining beneath the cells instead of being largely stripped away as part of site development.

- Field infiltration rates were measured at about 2 in/hr (MCCA1) and 0.4 in/hr (MCCA2). The infiltration rates were substantially lower in MCCA2 consistent with site observations by the owner. This is also consistent with observations of silty compacted undocumented fill soils beneath MCCA2. Fill would also be associated with the utility line crossing through a portion of MCCA2.

- In MCCA1, during infiltration testing, the water level within the well point corresponded to the water level within the base of the bioretention cell during testing, with a lag on the scale of 10 to 15 minutes during the period of rapid head rise early in testing. This is consistent with the well point screen intersecting bioretention soil.

- In MCCA2, the well point was installed deeper than in MCCA1, and during infiltration testing, the water level did not rise to the level of the ponded water within the base of the cell. The lag in response to inflow was on the scale of several minutes. This is consistent with the well point screen intersecting the low-permeability undocumented fill, and somewhat hydraulically separated from the bioretention soil.

- In both infiltration tests, water readily soaked through the bioretention soil mix and accumulated on the underlying subgrade as indicated by the water level response within the well points. The data indicate that the native subgrade has a lower permeability than the overlying bioretention soil.

- The calculated infiltration rates are interpreted to include a lateral flow component consistent with the 'interflow' setting. This is supported by observed seepage at the time of hand-auger explorations in MCCA1 shortly following light rain events. AESI interprets water as perching within the weathered soil horizon, above the unweathered, low-permeability native Vashon lodgement till. When perched on low-permeability layers, the primary ground water flow direction is lateral rather than vertical.

10.0 CLOSURE

We appreciate the opportunity to be of continued service to you on this project. Should you have any questions regarding this document or other geotechnical/hydrogeologic aspects of the project, please call us at your earliest convenience.

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State of Washington
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2335
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10/25/16

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Jennifer H. Saltonstall, L.G., L.Hg.
Senior Associate Geologist/Hydrogeologist

Attachments:	Figure MCCA F1:	Vicinity Map
	Figure MCCA F2:	LiDAR-Based Topography
	Figure MCCA F3:	Facility and Exploration Plan
	Appendix A:	Project Civil Plans
	Appendix B:	Current Study Exploration Logs and Laboratory Testing Data
	Appendix C:	Background Soil, Geology, and Ground Water Data (Regional Maps, Previous Studies Exploration Logs, and Laboratory Testing Data)
	Appendix D:	Soil Probe, Level Survey, and Field Infiltration Testing Data
	Appendix E:	Site Photos

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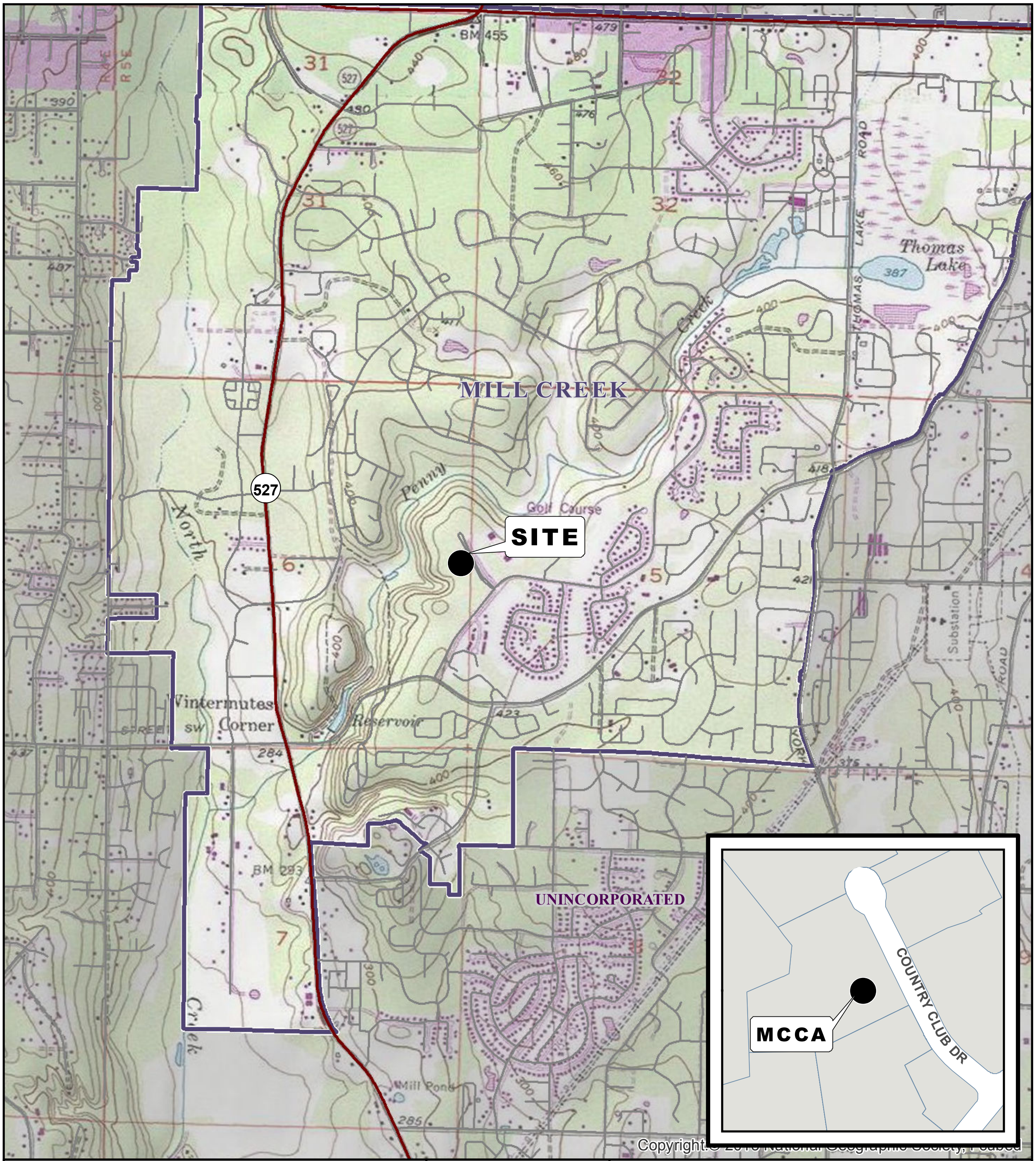

DATA SOURCES / REFERENCES:
USGS: 24K SERIES TOPOGRAPHIC MAPS
SNOHOMISH CO: STREETS, PARCELS 2015

LOCATIONS AND DISTANCES SHOWN ARE APPROXIMATE

N

0 1000 2000
FEET

NOTE: BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION

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VICINITY MAP

BIORETENTION HYDROLOGIC PERFORMANCE STUDY, MCCA SITE MILL CREEK, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	MCCA F1

Document Path: G:\GIS_Projects\aYear2015postJuly2016\150387 Bioretention Hydro Performance Monitoring\mxd\Fig1s\150387 MCCA Fig1 ProjectVicinity.mxd

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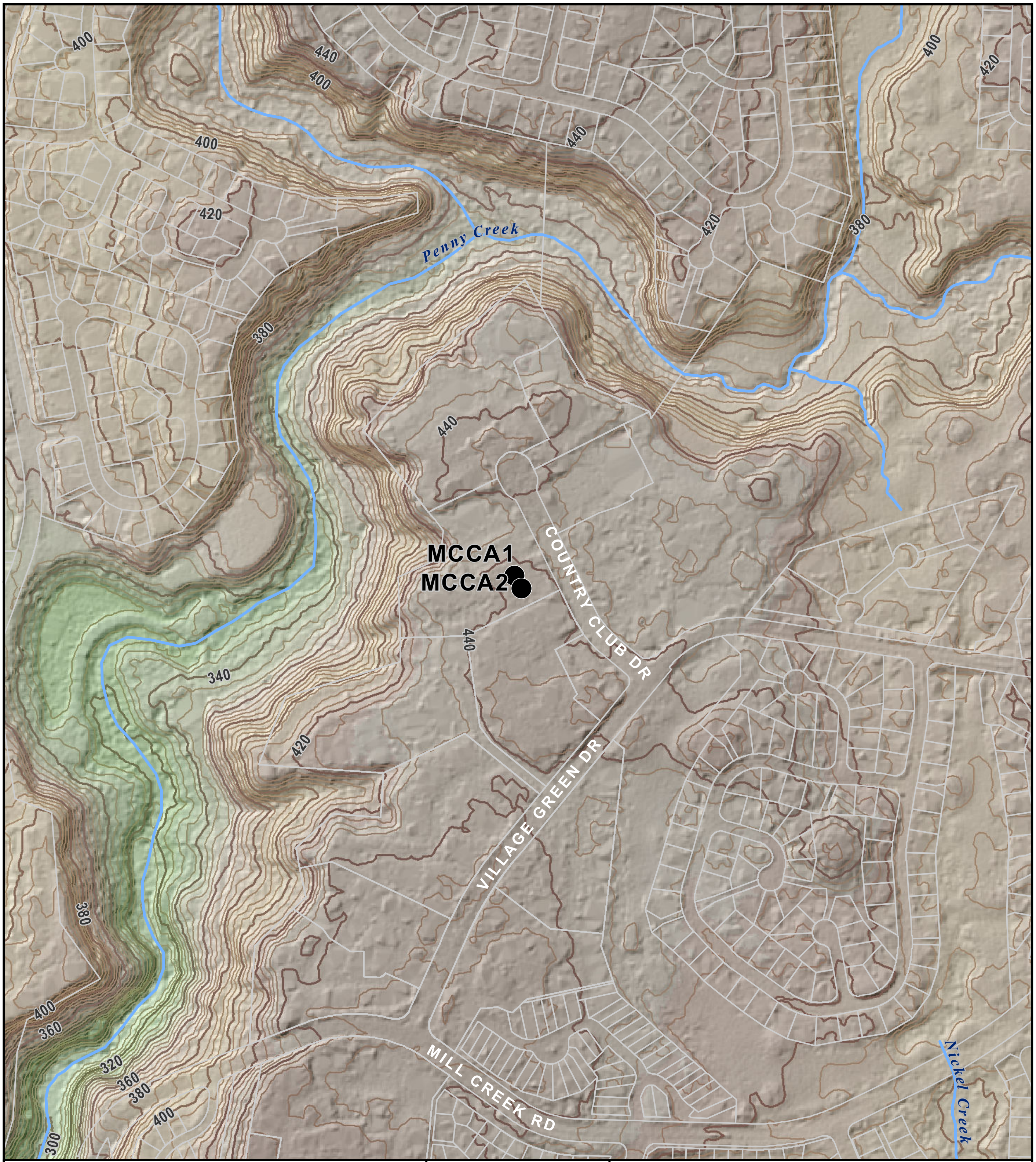

DATA SOURCES / REFERENCES:
PSLC: LIDAR 2000-2005 SUPERMOSAIC, 6' CELL
SNOHOMISH CO: STREETS, PARCELS 2016

LOCATIONS AND DISTANCES SHOWN ARE APPROXIMATE

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NOTE: BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION

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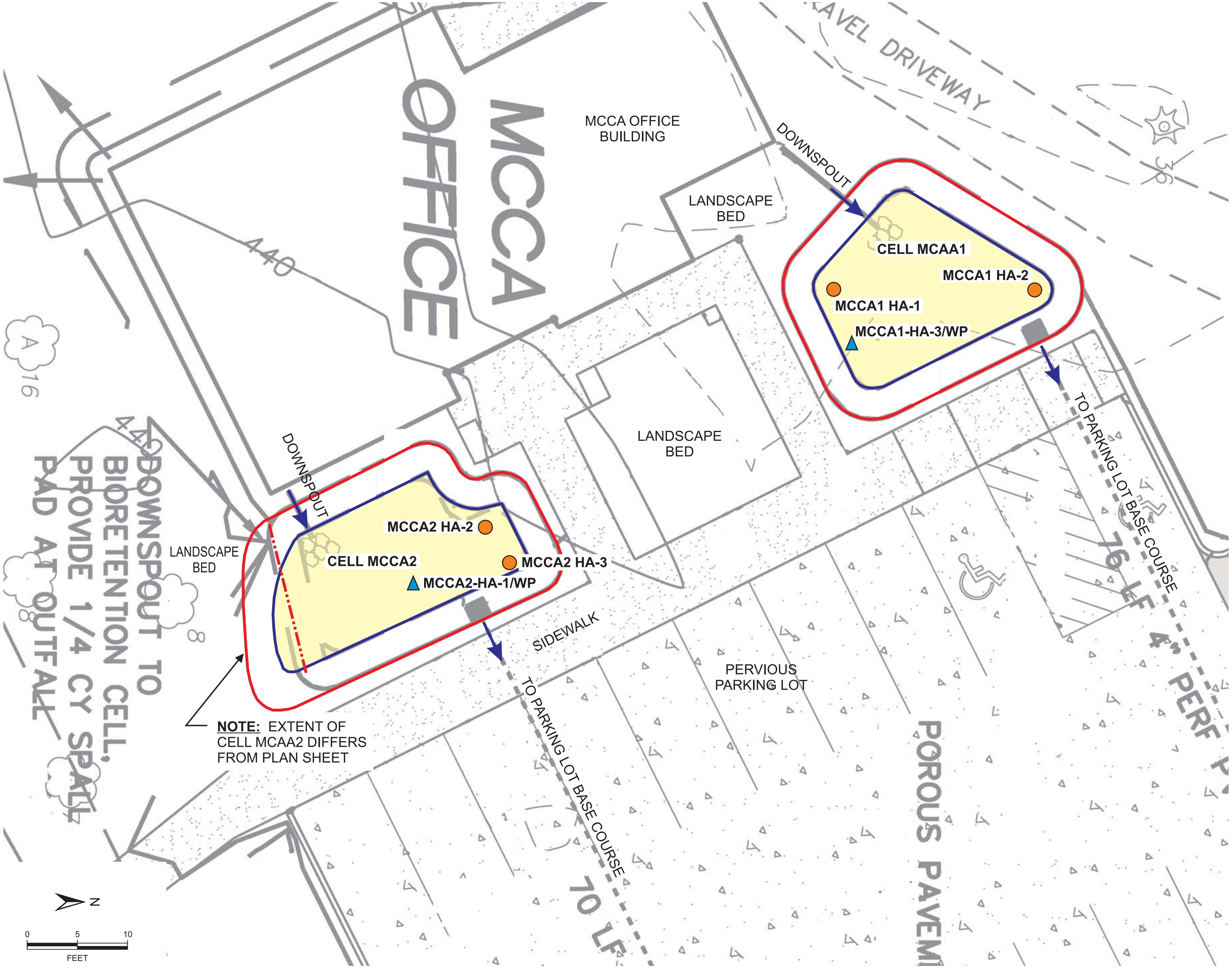
LIDAR BASED TOPOGRAPHY

BIORETENTION HYDROLOGIC
PERFORMANCE STUDY, MCCA1 / MCCA2 SITE
MILL CREEK, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	MCCA F2



NOTE: EXTENT OF CELL MCAA2 DIFFERS FROM PLAN SHEET

LEGEND:

● **HA**	HAND AUGER
▲ **WP**	WELL POINT
▭	BASE OF FACILITY
▭	TOP OF FACILITY SLOPE
→	INFLOW / OVERFLOW DIRECTION
-·-	GAS LINE

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:
1. BASE MAP REFERENCE: HARMSEN & ASSOCIATES INC, MILL CREEK COMMUNITY ASSOCIATION, DRAINAGE & PAVING PLAN, C3, 9/12/2013

associated earth sciences incorporated

FACILITY AND EXPLORATION PLAN
MCCA SITE
BIORETENTION HYDROLOGIC PERFORMANCE
MILL CREEK, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	MCCA F3

150387 BHPS MCCA \ 150387 Site-Expl.cdr PAGE 4: MCCA

APPENDIX A

Project Civil Plans

PROJECT INFORMATION

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425-259-0522

LANDSCAPE ARCHITECT:

LEGAL DESCRIPTION

LOT 2, MILL CREEK 7, ACCORDING TO PLAT RECORDED IN AUDITOR'S FILE NO. 7807280272.

SITUATE IN COUNTY OF SNOHOMISH, STATE OF WASHINGTON.

SHEET INDEX

C1 SITE LAYOUT & COVER SHEET
C2 SWPPP PLAN
C3 DRAINAGE & PAVING PLAN
C4 GRADING SECTIONS & DETAILS
C5 NOTES & DETAILS
C6 NOTES & DETAILS

CONSTRUCTION SEQUENCE

1. ATTEND PRECONSTRUCTION MEETING WITH THE CITY OF MILL CREEK.
2. CALL 811 FOR UNDERGROUND LOCATES.
3. DELINEATE PROJECT LIMITS IN FIELD.
4. INSTALL TEMPORARY EROSION CONTROL MEASURES.
5. BEGIN CLEARING AND GRADING, TAKE CARE TO PROTECT THE SENSITIVE SUBGRADE FROM COMPACTION.
6. FINE GRADE AND PLACE CONCRETE SIDEWALKS AND PERVIOUS CONCRETE PAVING.
7. BEGIN BUILDING CONSTRUCTION INCLUDING UTILITIES.
8. INSTALL PLANTINGS PER THE LANDSCAPE PLAN.
9. SEED AND MULCH ANY OTHER EXPOSED SOILS CAUSED BY CONSTRUCTION ACTIVITY.
10. REMOVE TESC MEASURES ONCE PROJECT WORK IS COMPLETE.

P:\WORK\PROJECTS\2012\12-189 MCCA\CE\DWG\CDS\C3 STORM.DWG 09/12/2013

SECTION 6 TOWNSHIP 27 NORTH, RANGE 5 EAST, W.M.

MILL CREEK COMMUNITY ASSOCIATION BUILDING

BSP #13-64

1" = 20'
0 10 20 40

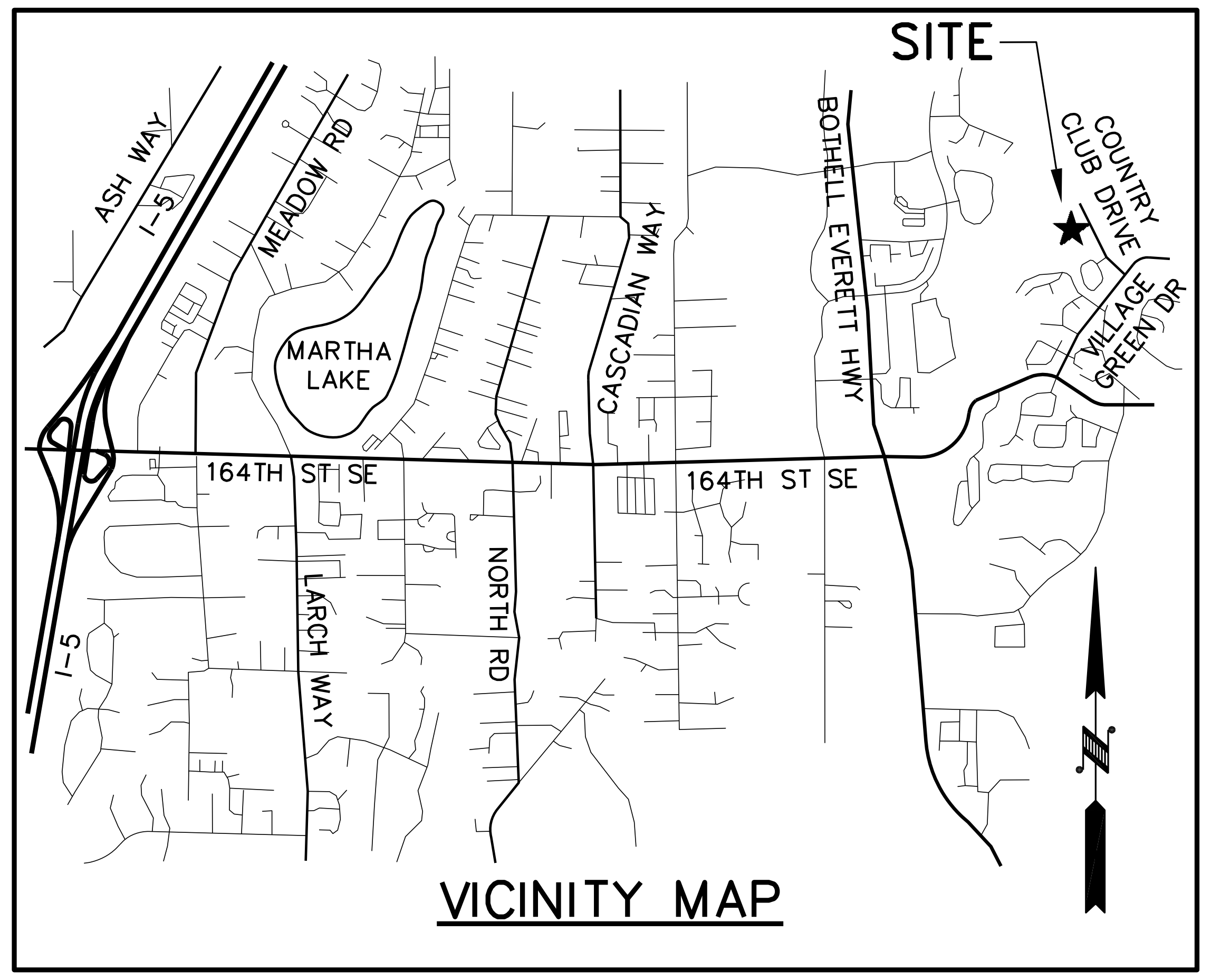
BASIS OF BEARINGS
MONUMENTED CENTERLINE OF VILLAGE GREEN DRIVE BEARS N 39°23'12" E PER PLAT OF MILL CREEK 7

VERTICAL DATUM
NAVD88

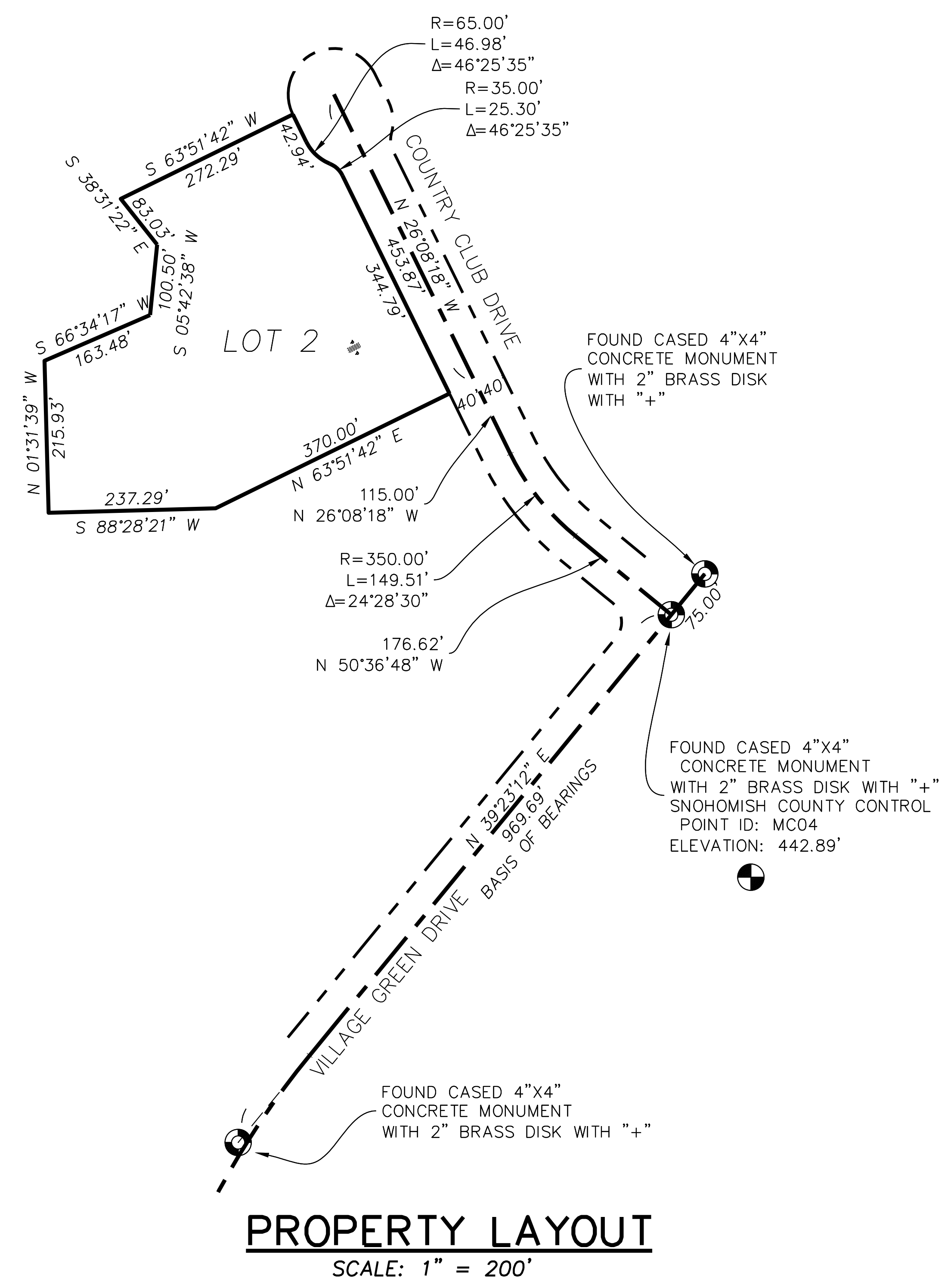
DATUM DERIVED FROM SNOHOMISH COUNTY SURVEY CONTROL DATABASE. POINT ID MC04. CASED MONUMENT AT INTERSECTION OF VILLAGE GREEN DRIVE AND COUNTRY CLUB DRIVE.
ELEVATION: 442.89

TBM #1: PK NAIL SET IN CONCRETE SIDEWALK SEAM, ADJACENT TO N. END OF CONC. BLOCK WALL, W. SIDE OF COUNTRY CLUB DRIVE.
ELEV=440.27'

TBM #2: PK NAIL SET IN CONCRETE SIDEWALK SEAM, 3.5 S OF N. EDGE OF WALK,
ELEV=441.88'

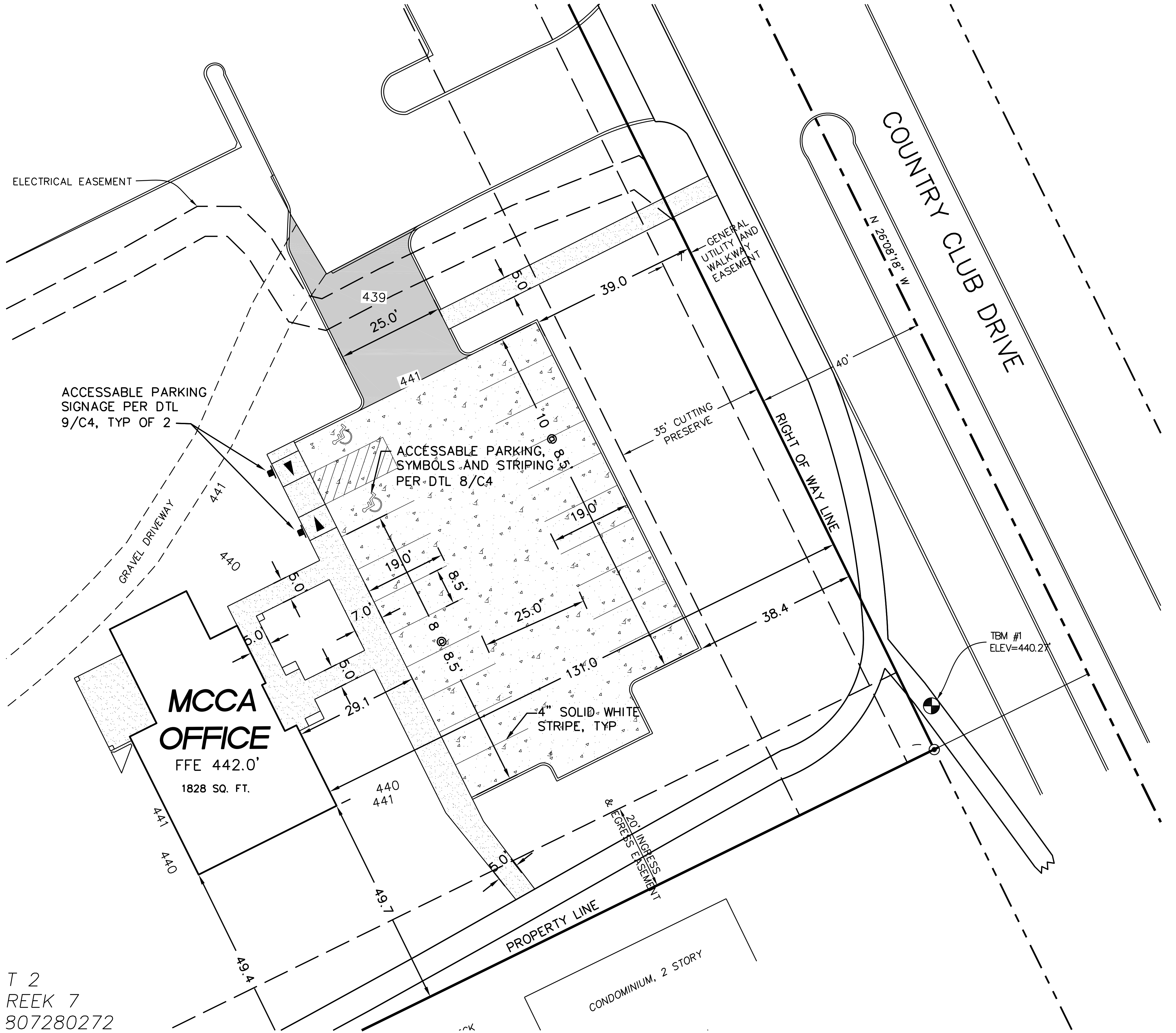


VICINITY MAP



PROPERTY LAYOUT

SCALE: 1" = 200'



1 / C1 SITE LAYOUT PLAN
SCALE: 1" = 20'

LEGEND

◈	FOUND MONUMENT IN CASE
⊙	FOUND IRON PIPE AS NOTED
◐	BENCH MARK
⊟	CATCH BASIN
⋈ W	WATER VALVE
▣	IRRIGATION CONTROL VALVE
○—☼	LUMINAIRE
□ P	POWER VAULT
⊓	SIGN POST
A 12	ALDER TREE, TRUNK DIA INCHES
C	CEDAR TREE
✲	CONIFER TREE
✿	DECIDUOUS TREE
F	FIR TREE
H	HEMLOCK TREE
M	MAPLE TREE
M	DRIPLINE ON TREE
⊡ T	TELEPHONE PEDESTAL
☼	STUMP
—×—×—	FENCE LINE
—SD—	STORM DRAIN LINE
▭	PERVIOUS CONCRETE
▨	ASPHALT PAVEMENT
▭	CONCRETE SIDEWALK
—G—	GAS LINE
—UP—	POWER LINE (UNDERGROUND)
—UT—	TELEPHONE LINE (UNDERGROUND)
—FO—	FIBER OPTIC LINE
—W—	WATER LINE
⚲	BLOWOFF
⊕	FIRE HYDRANT
⊞	WATER METER
○ S	SEWER MANHOLE

811
Know what's below.
Call before you dig.

ACCEPTED FOR CONSTRUCTION
CITY OF MILL CREEK

PUBLIC WORKS DIRECTOR DATE

ACCEPTED AS IN COMPLIANCE
WITH CONDITIONS OF APPROVAL
FOR BS 13-64

COMMUNITY DEVELOPMENT DIRECTOR DATE

REVISIONS

DWN. BY: SRM
CHK. BY: DWH
DATE: 8/20/13
JOB #: 12-189
F/B #: 1029
SCALE: 1" = 20'

HARMSEN & ASSOCIATES INC
ENGINEERS SURVEYORS
LANDSCAPE ARCHITECTS
PLANNERS
16778 146TH STREET SE, SUITE 104
P.O. BOX 516
MONROE, WA 98272
(360) 794-7811
(206) 343-5903
FAX: (360) 805-9732

DAVID W. HARMSEN
33745
9/12/13

MILL CREEK COMMUNITY ASSO.
15624 COUNTRY CLUB DRIVE
MILL CREEK, WA

SITE LAYOUT &
COVER SHEET

DRAWING:
C1

SHEET: 1 OF 6

SECTION 6 TOWNSHIP 27 NORTH, RANGE 5 EAST, W.M.

STABILIZATION BMPS

TEMPORARY BMP's

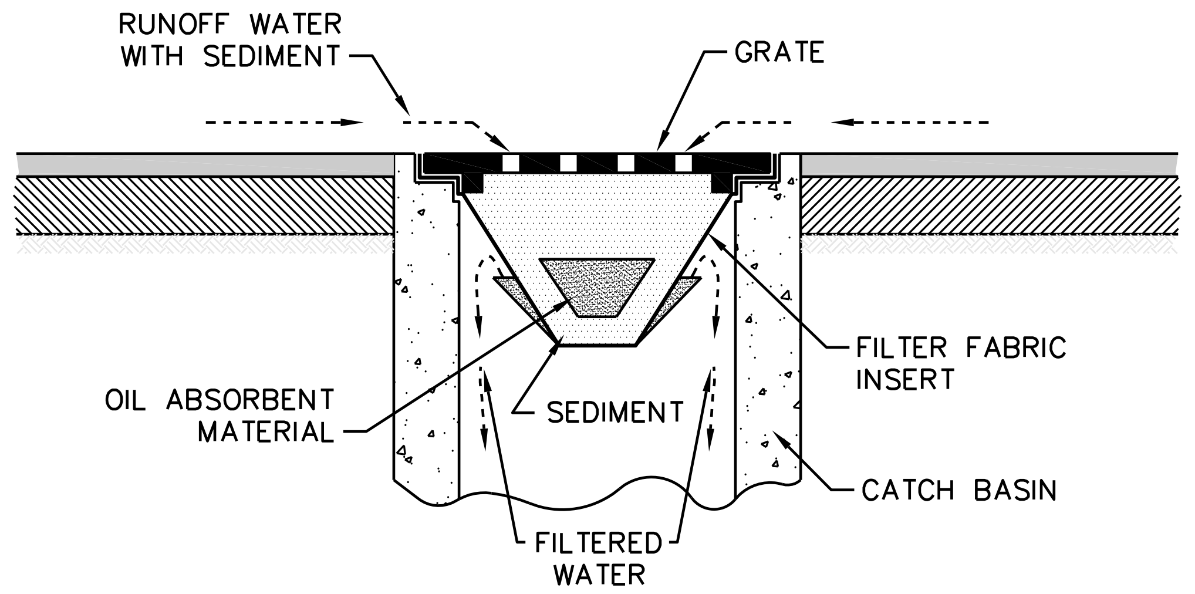
① STABILIZE WITH COURSE OF CRUSHED ROCK. (BMP C107)

② STABILIZE ALL OTHER AREAS WITH SEEDING & 4" STRAW MULCH. (BMP C120, C121)

PERMANENT BMP's

① STABILIZE PAVED AREAS WITH ASPHALT OR CONCRETE PAVING PER APPLICABLE PAVING SECTION

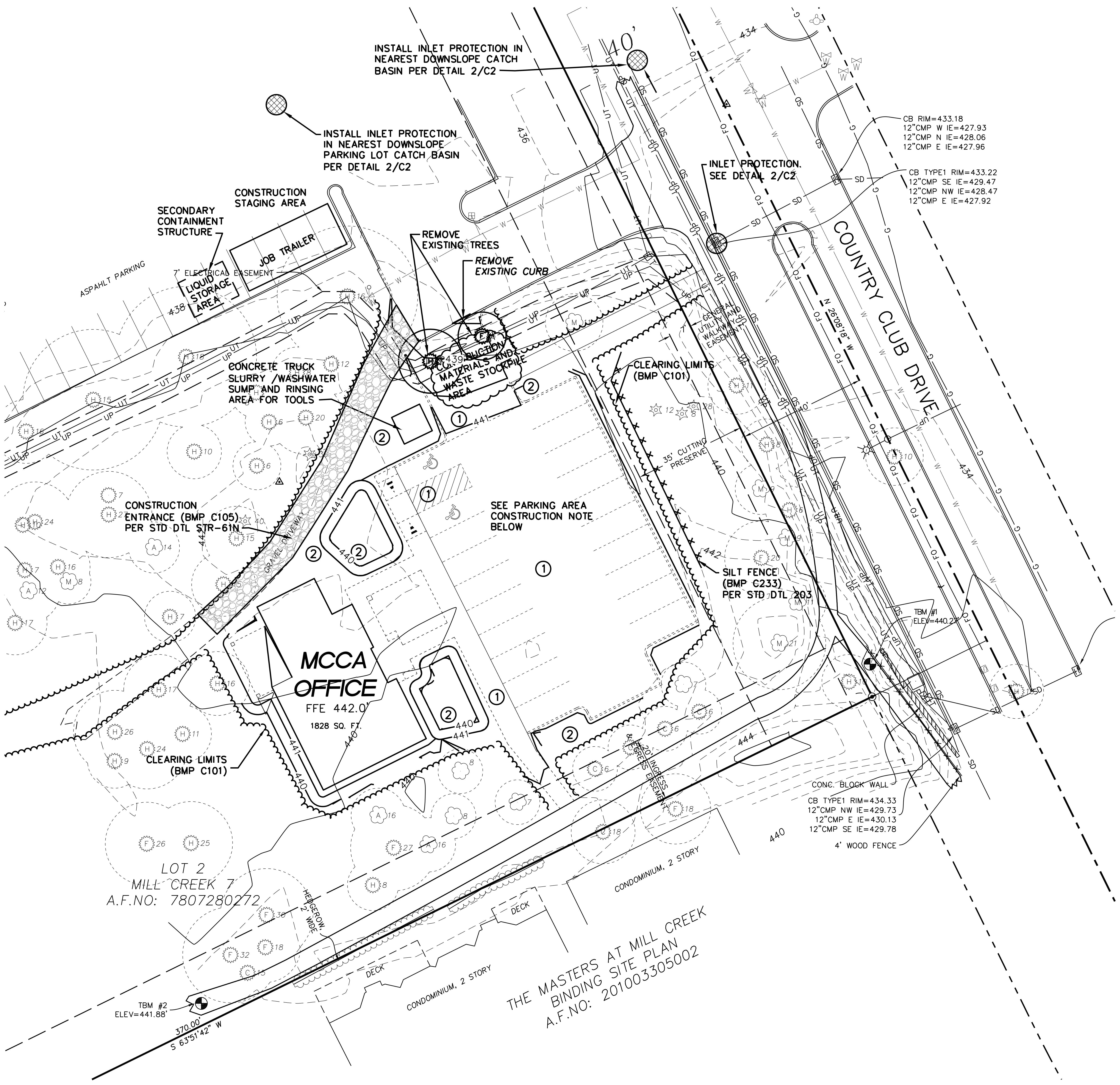
② STABILIZE ALL OTHER AREAS WITH LANDSCAPING & GRASS



"GULLYWASHER", "SILT SACK" OR OTHER APPROVED CATCH BASIN INSERT MAY BE USED FOR INLET PROTECTION. CONTACT: PRICE-MOON ENTERPRISES PH: 360.563.6709, OR "SILTSACK" BY ACF ENVIRONMENTAL AT PH: 1.800.644.9223 (OR APPROVED EQUAL)

(2/C2) TEMPORARY INLET PROTECTION DETAIL

SCALE: NONE



PARKING AREA CONSTRUCTION

DO NOT DISTURB OR UTILIZE THE FUTURE PARKING AREA AS A STAGING AREA UNTIL IMMEDIATELY PRIOR TO INSTALLATION OF THE PARKING AREA. THIS IS TO PREVENT COMPACTION FROM CONSTRUCTION TRAFFIC AND MAINTAIN THE ABILITY OF THE SOIL TO INFILTRATE STORMWATER.

SIMILARLY, DO NOT DISTURB THE RAIN GARDEN AREAS UNTIL THEIR CONSTRUCTION.

TREE PROTECTION NOTE

INSTALL TEMPORARY CLEARING LIMITS FENCING WHERE SHOWN ON PLAN TO PROTECT ADJACENT TREES FROM DAMAGE DURING CONSTRUCTION. REMOVE FENCING UPON COMPLETION.

(1/C2) SWPPP PLAN

SCALE: 1" = 20'

1" = 20'
0 10 20 40

BASIS OF BEARINGS
MONUMENTED CENTERLINE OF VILLAGE
GREEN DRIVE BEARS N 39°23'12" E
PER PLAT OF MILL CREEK 7

VERTICAL DATUM
NAVD88

DATUM DERIVED FROM SNOHOMISH COUNTY SURVEY CONTROL DATABASE. POINT ID MC04. CASED MONUMENT AT INTERSECTION OF VILLAGE GREEN DRIVE AND COUNTRY CLUB DRIVE. ELEVATION: 442.89

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TBM #2: PK NAIL SET IN CONCRETE SIDEWALK SEAM, 3.5 S OF N. EDGE OF WALK, ELEV=441.88'

LEGEND

◍	FOUND MONUMENT IN CASE
◉	FOUND IRON PIPE AS NOTED
◐	BENCH MARK
▤	CATCH BASIN
⋈	WATER VALVE
⊠	IRRIGATION CONTROL VALVE
○—✕	LUMINAIRE
□P	POWER VAULT
⊓	SIGN POST
(A) 12	ALDER TREE, TRUNK DIA INCHES
(C)	CEDAR TREE
○	CONIFER TREE
○	DECIDUOUS TREE
(F)	FIR TREE
(H)	HEMLOCK TREE
(M)	MAPLE TREE
(M)	DRIPLINE ON TREE
□T	TELEPHONE PEDESTAL
☆	STUMP
—×—×—	FENCE LINE
—SD—	STORM DRAIN LINE
▭	PERVIOUS CONCRETE
▨	ASPHALT PAVEMENT
▒	GRAVEL PATHWAY
△	CONTROL POINT
—G—	GAS LINE
—UP—	POWER LINE (UNDERGROUND)
—UT—	TELEPHONE LINE (UNDERGROUND)
—FO—	FIBER OPTIC LINE
—W—	WATER LINE
♀	BLOWOFF
⌖	FIRE HYDRANT
⊞	WATER METER
○S	SEWER MANHOLE
⌒⌒⌒	CLEARING LIMITS (BMP C101)
—×—×—	FILTER FABRIC FENCE (BMP C233)
◍	TEMPORARY INLET PROTECTION (BMP C220)

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CITY OF MILL CREEK

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COMMUNITY DEVELOPMENT DIRECTOR DATE

P:\WORK\PROJECTS\2012\12-189 MCCA\CE\DWG\CDS\C3 STORM.DWG 09/12/2013

REVISIONS

DWN. BY: SRM
CHK. BY: DWH
DATE: 8/20/13
JOB #: 12-189
F/B #: 1029
SCALE: 1" = 20'

HARMSEN & ASSOCIATES INC
ENGINEERS SURVEYORS
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PLANNERS
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FAX: (360) 805-9732

DAVID W. HARMSEN
33745
7/12/13

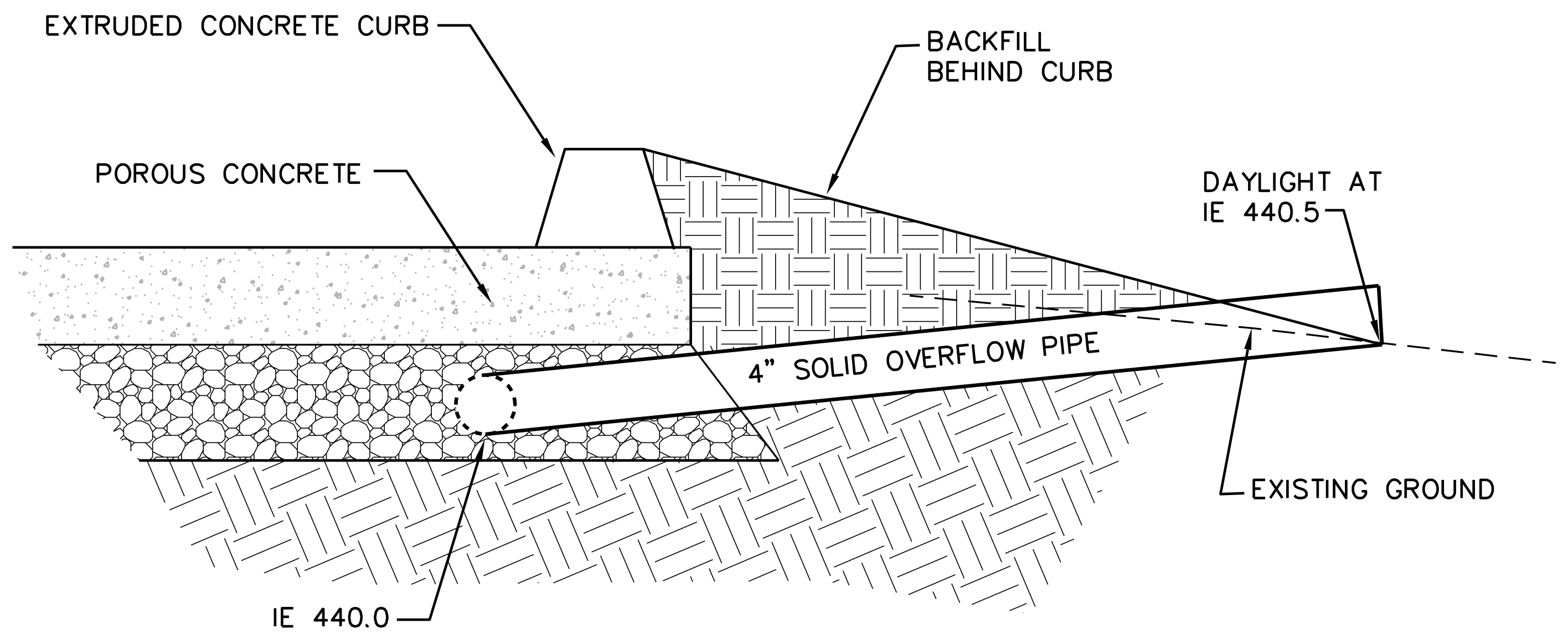
MILL CREEK COMMUNITY ASSO.
15624 COUNTRY CLUB DRIVE
MILL CREEK, WA

SWPPP PLAN

DRAWING:
C2

SHEET: 2 OF 6

SECTION 6 TOWNSHIP 27 NORTH, RANGE 5 EAST, W.M.



2/C3 POROUS CONCRETE OVERFLOW STUB

SCALE: NONE

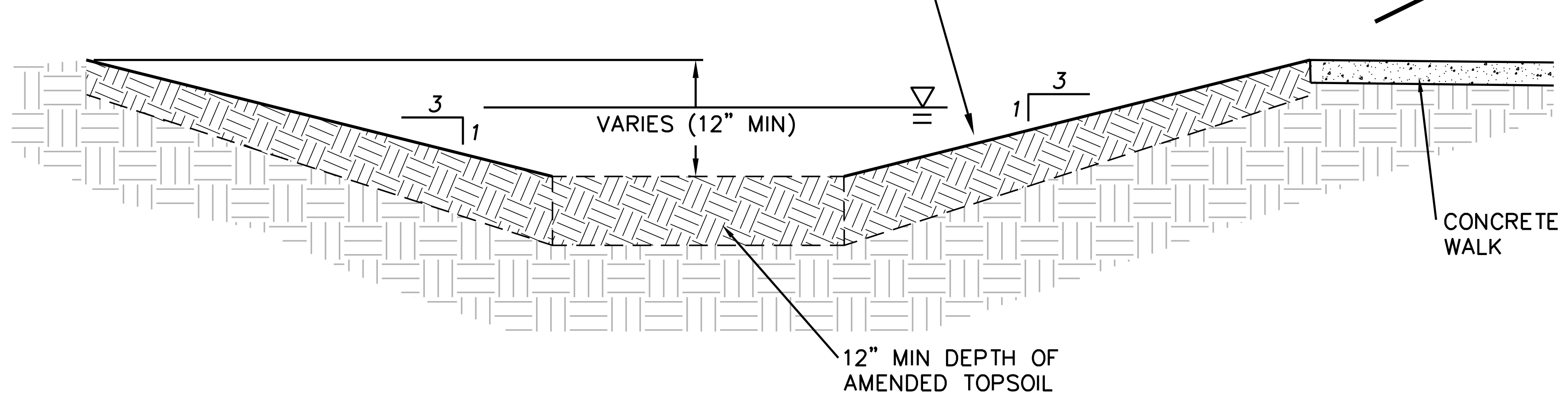
BIO-RETENTION CELL CONSTRUCTION NOTES

1. EXCAVATE BIO-RETENTION CELL TO ELEVATION SHOWN ON PLAN, INSTALL UNDER-DRAIN AND FILL WITH AMENDED SOIL PER LANDSCAPE SPECIFICATIONS.
2. MINIMUM COMPACTION OF SIDEWALLS AND BASE OF BIO-RETENTION CELL IS ESSENTIAL. KEEP HEAVY MACHINERY OUTSIDE OF CELL AREA.
3. SUB-GRADE SHALL BE SCARIFIED, CLEARED OF ALL WEEDS, ROCKS AND DEBRIS AND ROUGH GRADED.
4. EXCAVATION WILL NOT BE ALLOWED DURING WET WEATHER OR IN SATURATED CONDITIONS.
5. FINAL GRADING OF THE CELL SHALL BE DONE BY HAND.
6. SOIL MIXING SHALL BE DONE AT A LOCATION OFF-SITE WHERE TESTING MAY BE DONE FOR UNIFORMITY OF MIX AND COMPLIANCE WITH MIX SPECIFICATIONS.
7. REFER TO LANDSCAPE PLAN FOR PLANTING INFORMATION.
8. PLACE GEOFABRIC UNDER 4" DEPTH OF 1-2 1/2" QUARRY SPALL ARMORING AT OUTFALL DISCHARGE FOR CULVERTS OR WHERE CONCENTRATED FLOW ENTERS CELL. MIRAFI 500X, OR EQUAL.

BIO-RETENTION CELL SOIL MIX SPECIFICATIONS

1. COMPOST MATERIAL MUST BE IN COMPLIANCE WITH WAC CHAPTER 173-350 SECTION 220 AND MEET TYPE 1, 2, 3 OR 4 FEEDSTOCK, CARBON NITROGEN RATIO BETWEEN 20:1 AND 35:1, AND ORGANIC CONTENT BETWEEN 40% AND 50%.
2. THE FINAL SOIL MIX SHALL HAVE A MINIMUM ORGANIC CONTENT OF 10% BY WEIGHT, AND A PH FACTOR BETWEEN 5.5 AND 7.0.
3. THE SOIL MIX SHALL BE AS FOLLOWS: 50% TO 60% CLEAN SAND MEETING ASTM C-33, 20% TO 30% LEAF COMPOST, AND 20% TO 30% TOPSOIL. MAXIMUM CLAY CONTENT NOT TO EXCEED 5%.
4. THE FINAL MIX SHALL BE UNIFORM AND FREE OF STONES, ROOTS, OR SIMILAR MATERIALS THAT ARE GREATER THAN 2 INCHES.
5. BIORETENTION SOIL SHALL HAVE A TESTED & DEMONSTRATED INFILTRATION RATE OF AT LEAST 2"/HR. BY GEOTECHNICAL EVALUATION.

BIO-RETENTION CELL BOTTOM AREAS	
CELL #1:	200 SF MINIMUM
CELL #2:	200 SF MINIMUM



3/C3 BIO-RETENTION CELL SECTION

SCALE: NONE

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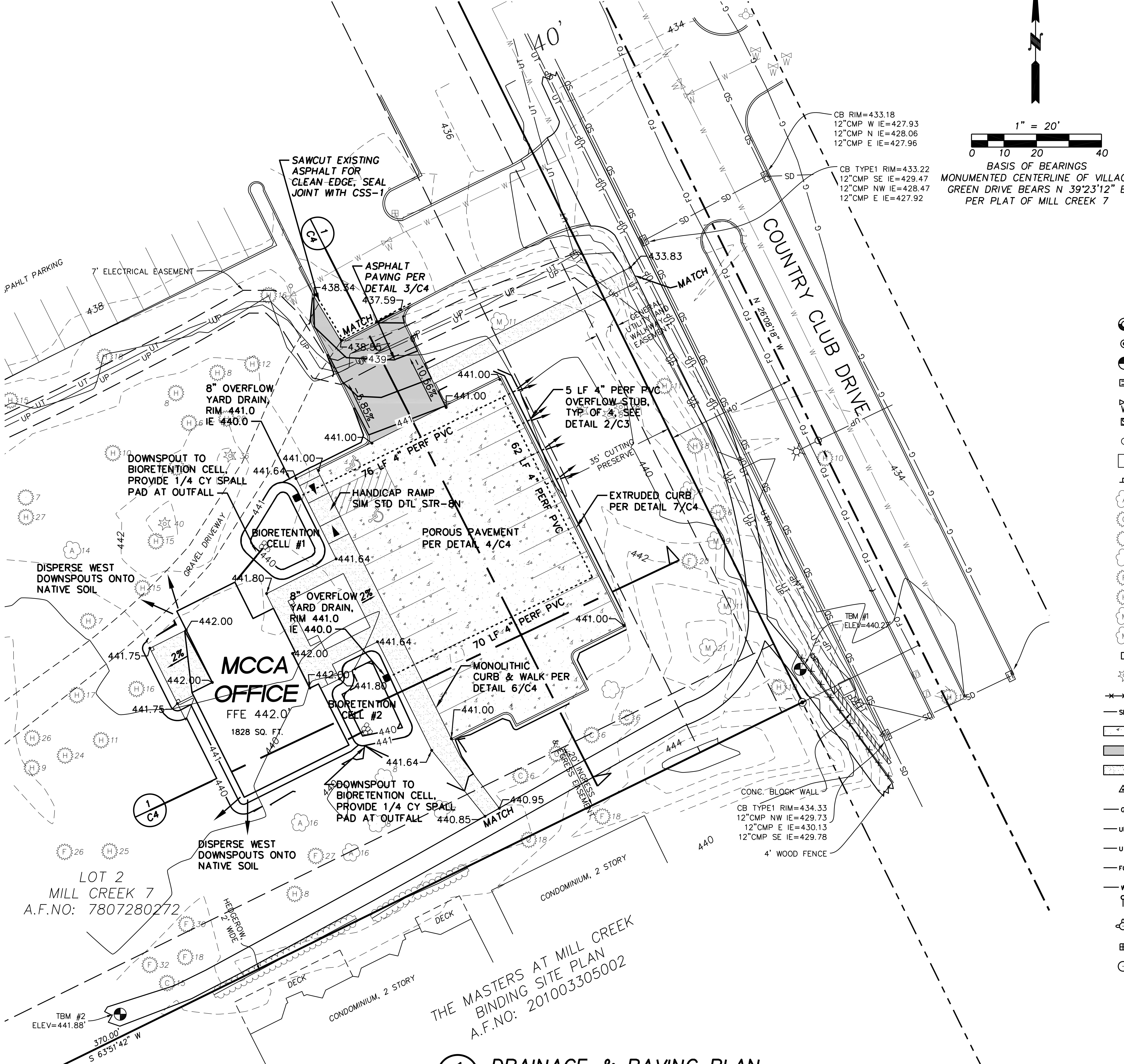

1/C3 DRAINAGE & PAVING PLAN

SCALE: 1" = 20'

INFILTRATION NOTE:

TO ENSURE PROPER FUNCTIONING OF THE RAIN GARDENS AND INFILTRATION TRENCH AREAS IT IS ABSOLUTELY NECESSARY TO AVOID COMPACTION OF THE UNDERLYING SOILS DURING CONSTRUCTION AND SEDIMENT TRANSPORT INTO THE EXCAVATION DURING CONSTRUCTION. NO HEAVY EQUIPMENT SHALL RUN ACROSS THE BASE OF THE POROUS PAVING AREAS TO PREVENT ANY DAMAGE TO THE UNDERLYING SOILS DURING CONSTRUCTION ACTIVITIES.

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⊓	SIGN POST
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M	DRIPLINE ON TREE
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✳	STUMP
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—SD—	STORM DRAIN LINE
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✥	FIRE HYDRANT
⊞	WATER METER
○S	SEWER MANHOLE

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COMMUNITY DEVELOPMENT DIRECTOR DATE

REVISIONS

DWN. BY: SRM
CHK. BY: DWH
DATE: 8/20/13
JOB #: 12-189
F/B #: 1029
SCALE: 1" = 20'

HARMSEN & ASSOCIATES INC
ENGINEERS SURVEYORS
LANDSCAPE ARCHITECTS
PLANNERS
16778 146TH STREET SE, SUITE 104
P.O. BOX 516
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FAX: (360) 805-9732

DAVID W. HARMSEN
33745

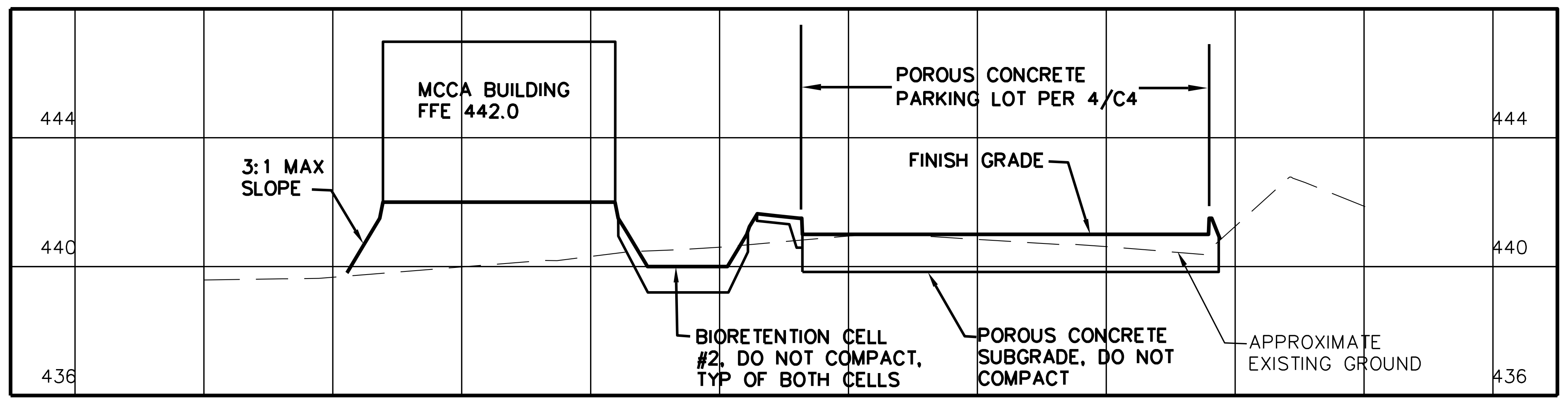
MILL CREEK COMMUNITY ASSO.
15624 COUNTRY CLUB DRIVE
MILL CREEK, WA

DRAINAGE &
PAVING PLAN

DRAWING:
C3

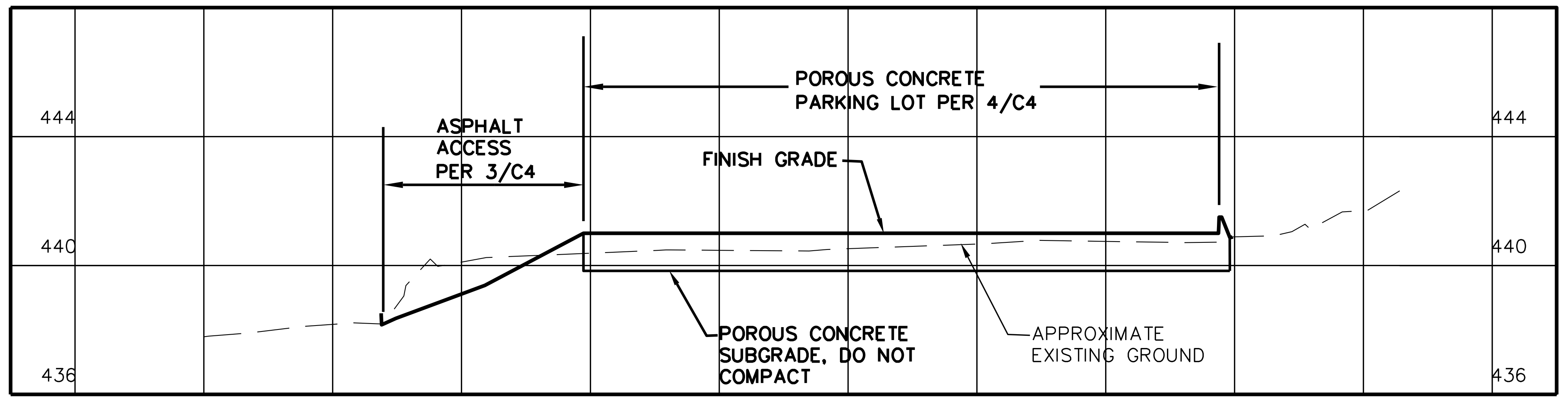
SHEET: 3 OF 6

SECTION 6 TOWNSHIP 27 NORTH, RANGE 5 EAST, W.M.



1/C4 GRADING SECTION

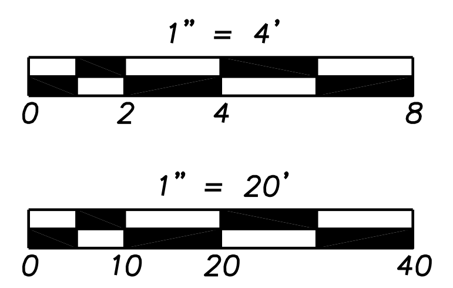
SCALE: H: 1" = 20'
V: 1" = 4'



2/C4 GRADING SECTION

SCALE: H: 1" = 20'
V: 1" = 4'

VERTICAL DATUM
NAVD88



BASIS OF BEARINGS
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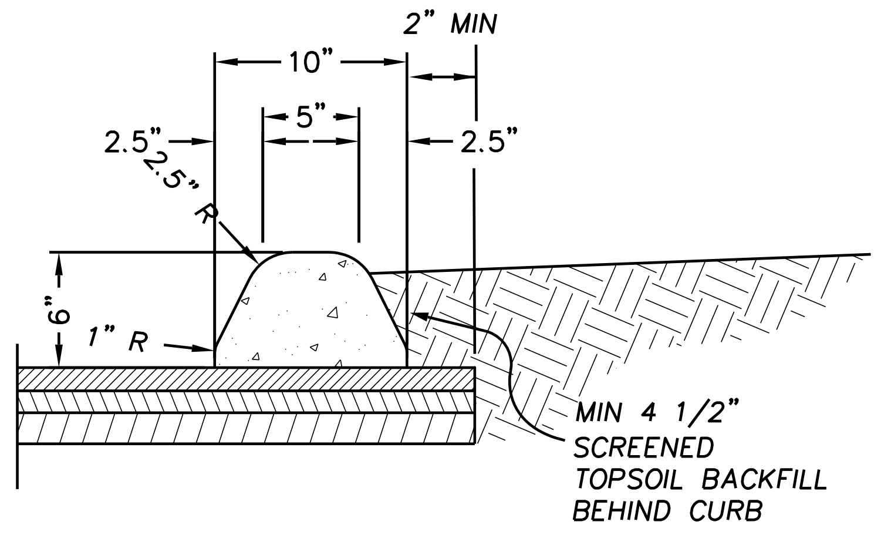
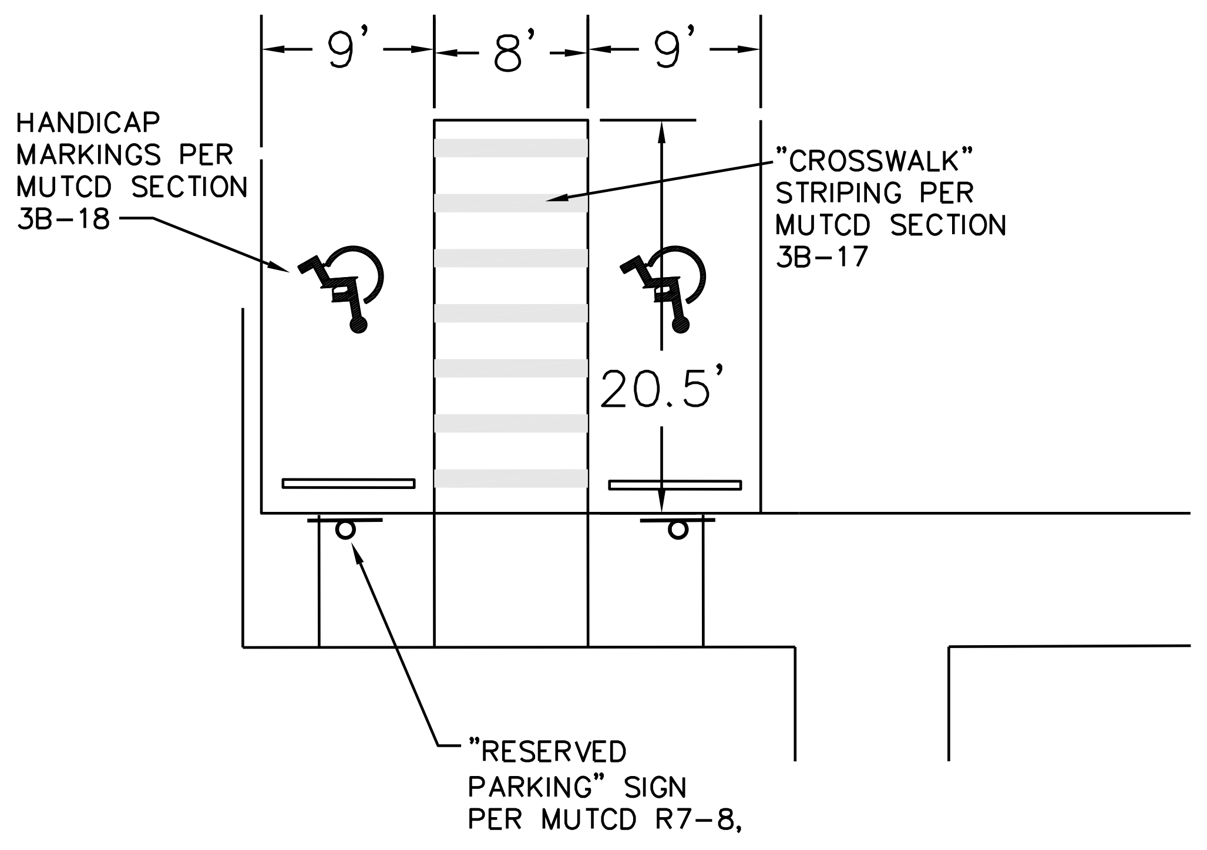


NOTES:

1. EXTRUDED CEMENT CONCRETE CURB SHALL BE BONDED TO THE PAVEMENT WITH TACK COAT OR SLURRY MIXTURE ADHESIVE.
2. JOINTS IN EXTRUDED CEMENT CONCRETE CURB SHALL BE CUT VERTICALLY AT 10' INTERVALS TO A MINIMUM DEPTH OF 5 INCHES. SAWED CUTS SHALL BE 1/8 INCH MINIMUM WIDTH.

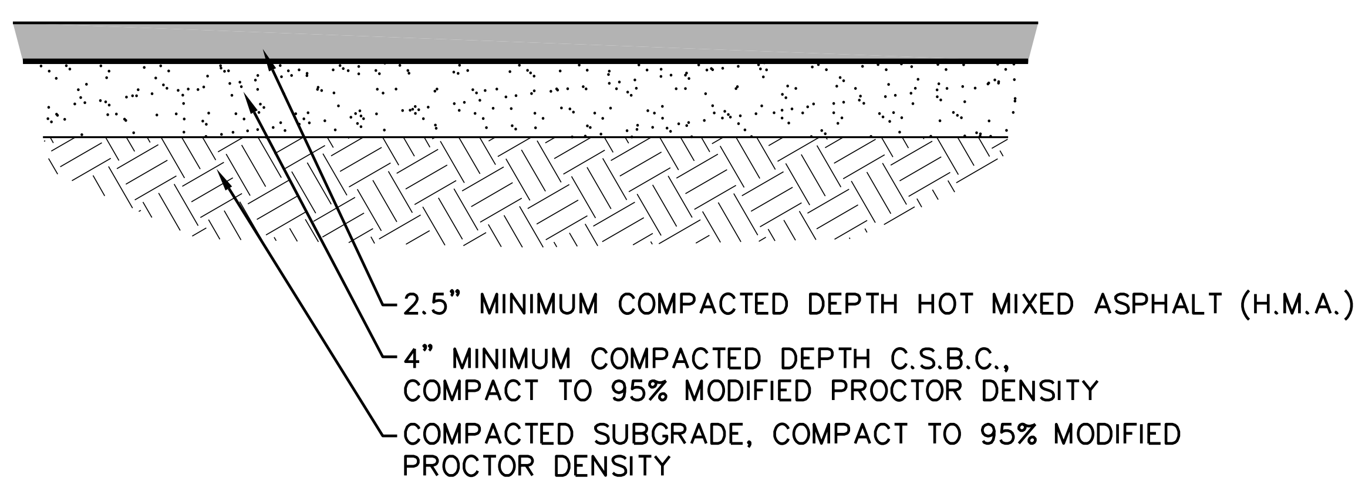
7/C4 EXTRUDED CONCRETE CURB DETAIL

SCALE: NONE



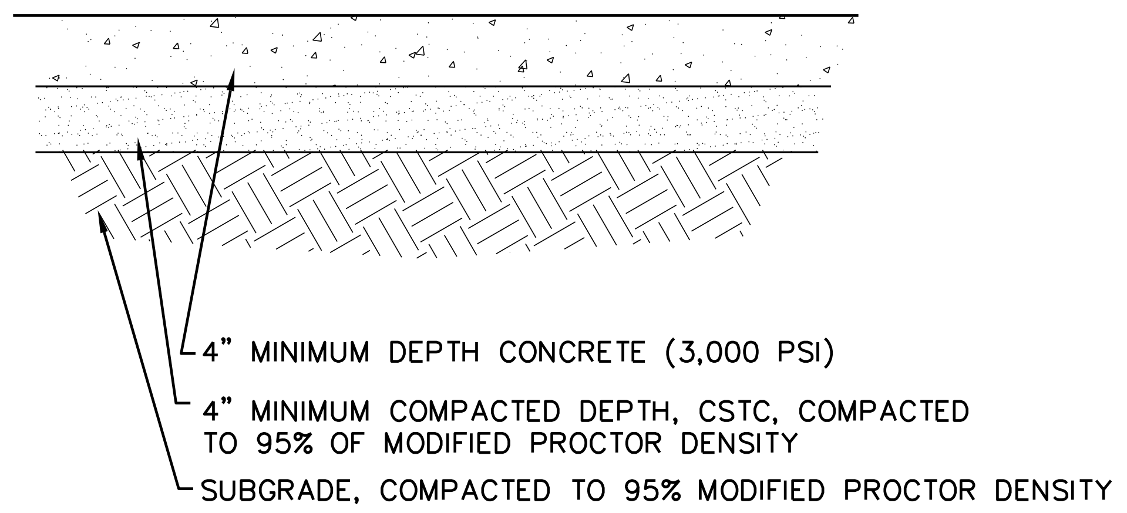
8/C4 ACCESSIBILITY PARKING DETAIL

SCALE: NONE



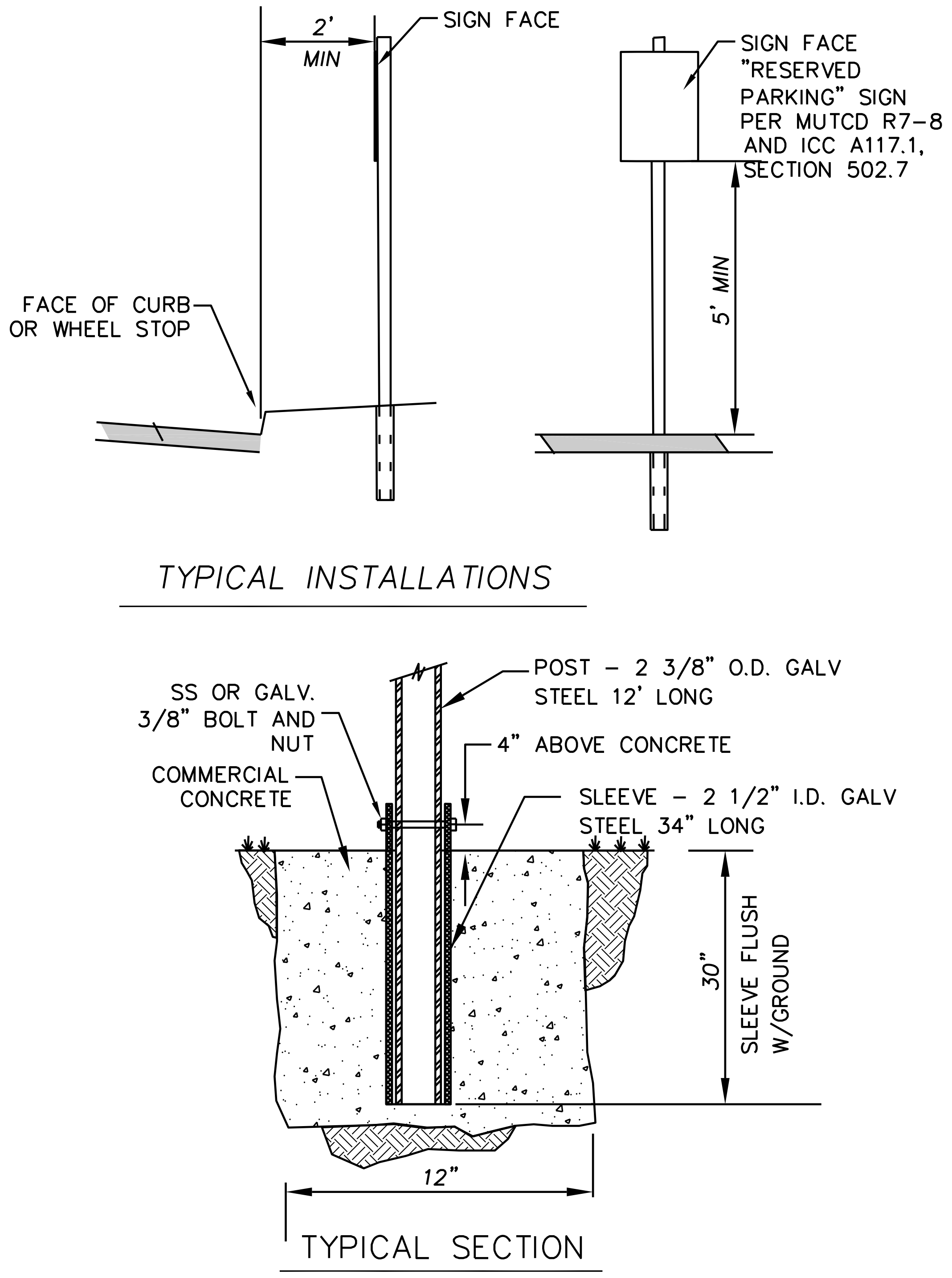
3/C4 REGULAR ASPHALT PAVING SECTION

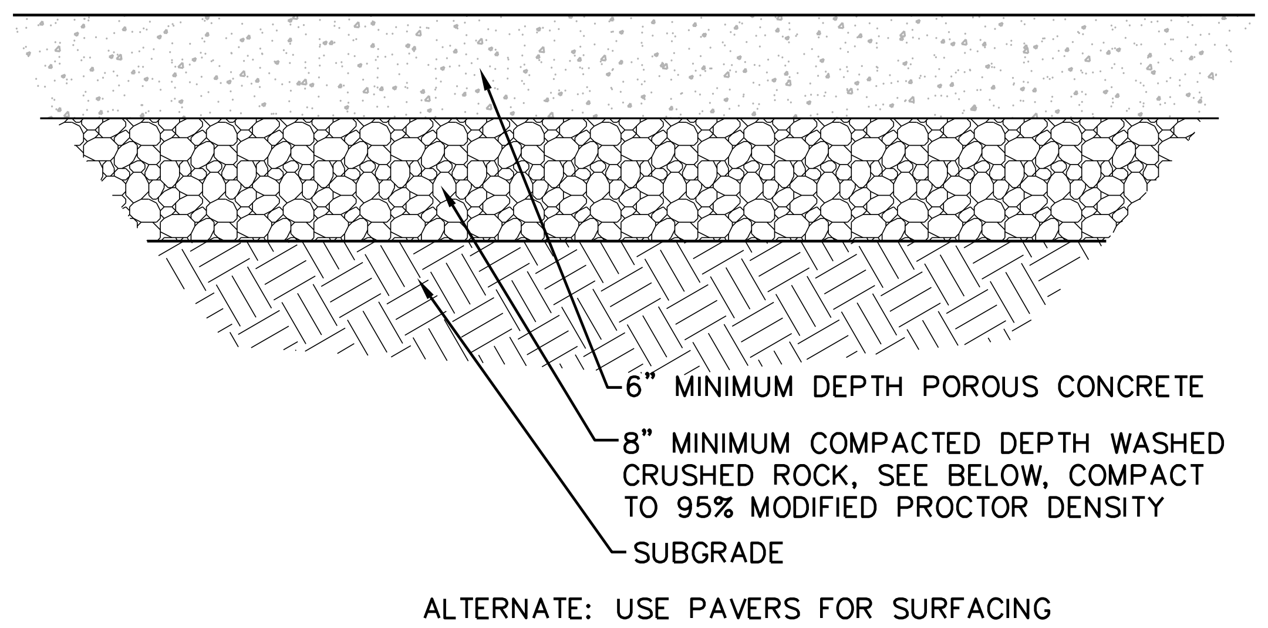
SCALE: NONE



5/C4 CONCRETE WALKWAY SECTION

SCALE: NONE



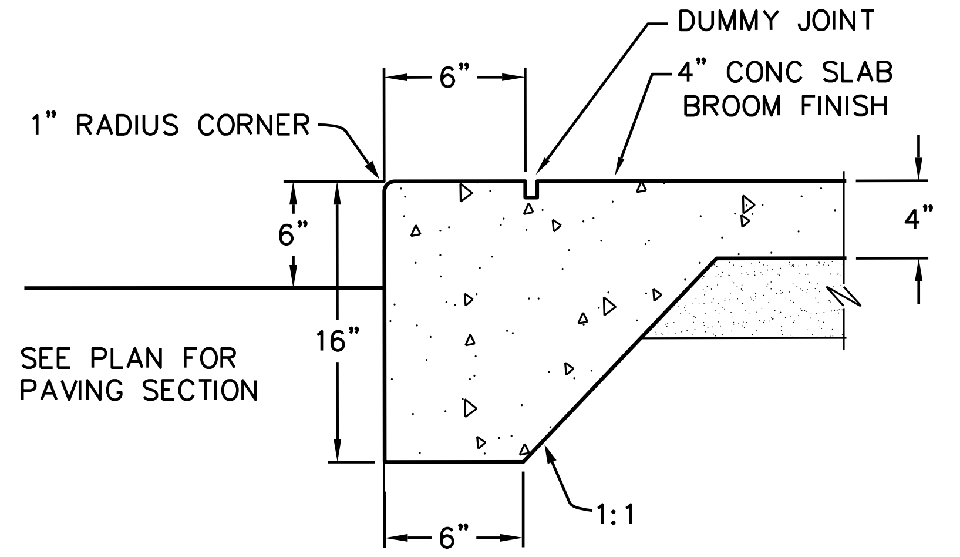


ALTERNATE: USE PAVERS FOR SURFACING

4/C4 POROUS CONCRETE PAVING SECTION

SCALE: NONE

WASHED CRUSHED ROCK: COARSE AGGREGATE SHALL BE 1 ½" TO 2-1/2" UNIFORMLY GRADED CRUSHED COARSE AGGREGATE, WITH A WASH LOSS OF NO MORE THAN 0.05%, AASHTO SIZE NUMBER 3 PER TABLE 4, AASHTO SPECIFICATIONS, PART I, 13TH ED., 1982 OR LATER.



6/C4 THICKENED EDGE SIDEWALK

SCALE: NONE

9/C4 "HANDICAP PARKING" SIGN DETAIL

SCALE: NONE

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P:\WORK\PROJECTS\2012\12-189 MCCA\CE\DWG\CDS\C3 STORM.DWG 09/12/2013

REVISIONS

DWN. BY: SRM
CHK. BY: DWH
DATE: 8/16/13
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SCALE: 1" = 20'

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DAVID W. HARMSEN 33745

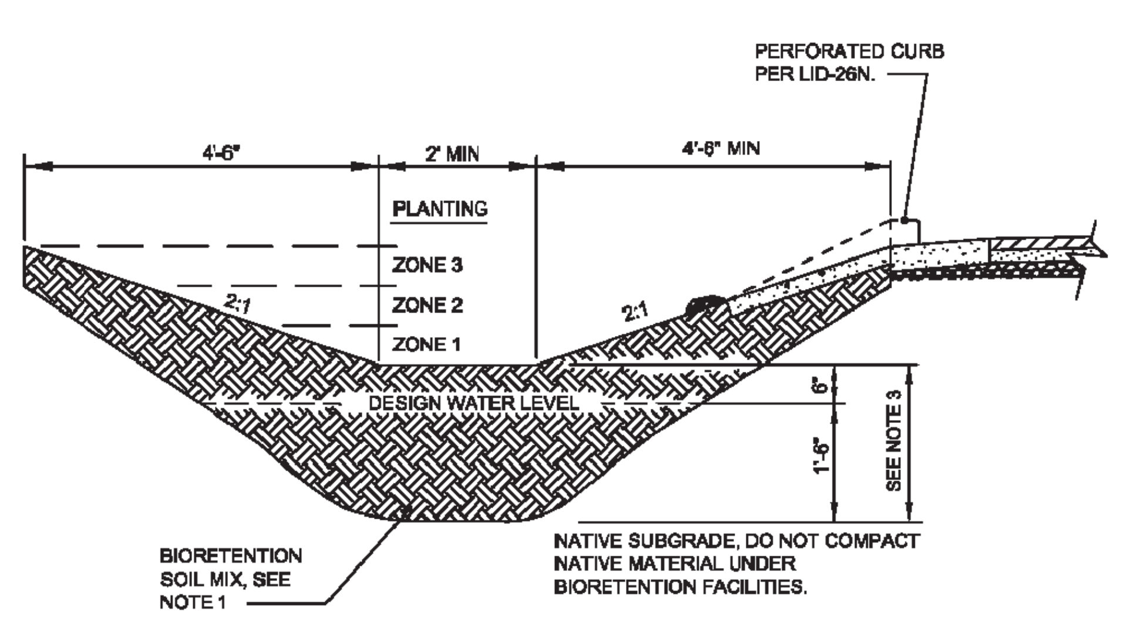
MILL CREEK COMMUNITY ASSO
15624 COUNTRY CLUB DRIVE
MILL CREEK, WA

GRADING SECTIONS
& DETAILS

DRAWING:
C4

SHEET: 4 OF 6

SECTION 6 TOWNSHIP 27 NORTH, RANGE 5 EAST, W.M.



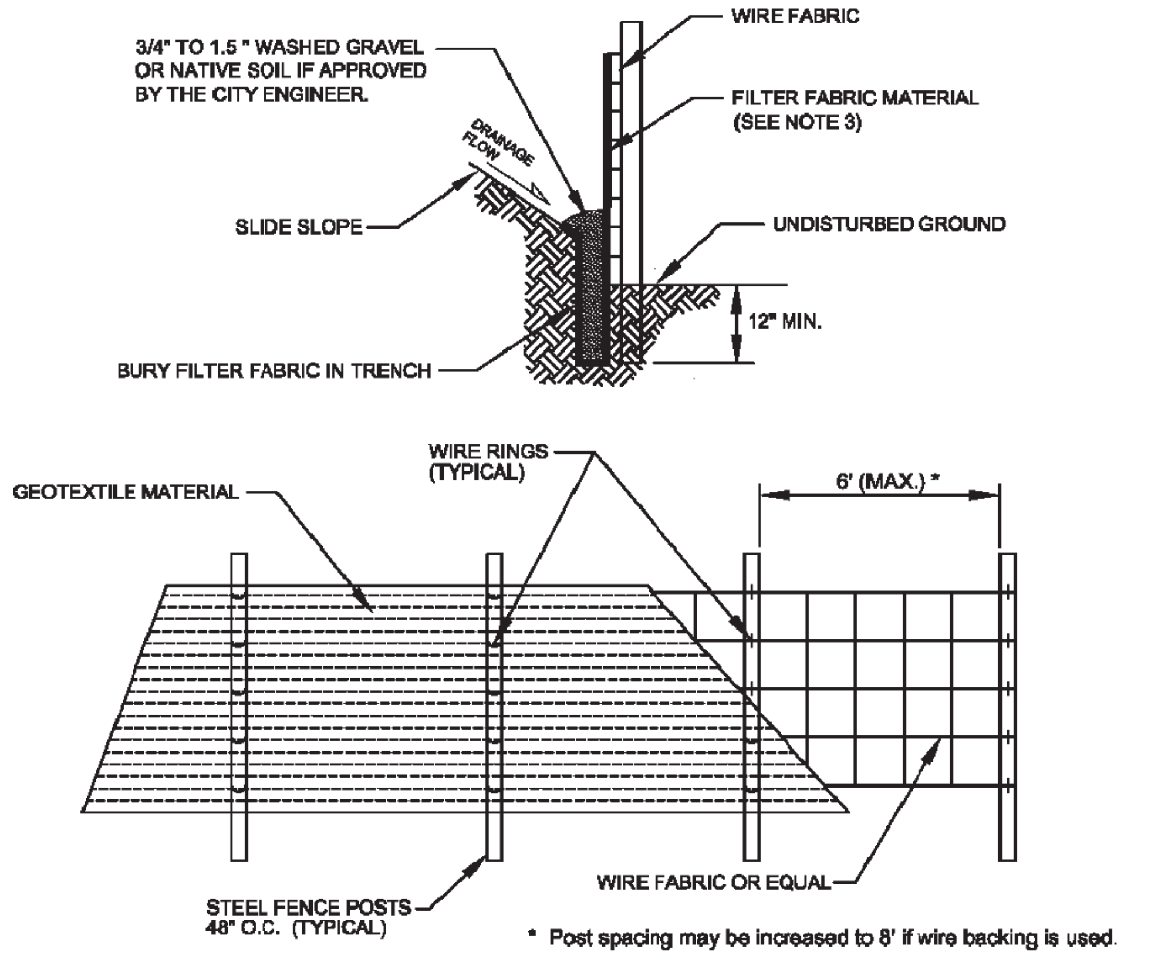
SECTION

LOW IMPACT DEVELOPMENT TYPICAL SWALE BIORETENTION

NOTES:

1. BIORETENTION SOIL, COMPOSITION AND pH LEVELS SHALL MEET THE STANDARDS SET FORTH IN THE *LID TECHNICAL GUIDANCE MANUAL FOR PUGET SOUND* (CURRENT EDITION).
2. PLANTING SHALL CONSIST OF NATIVE SPECIES ABLE TO TOLERATE VARIABLE SOIL MOISTURE CONDITIONS, PONDING WATER FLUCTUATIONS, AND VARIABLE SOIL MOISTURE CONTENT. SEE APPENDIX 3 IN THE *LID TECHNICAL GUIDANCE MANUAL FOR PUGET SOUND* (CURRENT EDITION) FOR A "BIORETENTION PLANT LIST".
3. AT LEAST 18 INCHES OF BIORETENTION SOIL MIX IS REQUIRED BELOW THE DESIGN WATER ELEVATION. ABOVE THIS ELEVATION AT LEAST 6 INCHES OF BIORETENTION SOIL MIX IS REQUIRED. COMPACT SUBSOILS MUST BE SCARIFIED AT 4 INCHES BELOW THE AMENDED LAYER.
4. UNDERDRAINS ARE REQUIRED IN SOILS WITH INFILTRATION RATES INADEQUATE TO MEET MAXIMUM POOL AND SYSTEM DEWATER RATES.
5. ZONE 1 PLANTINGS SHOULD BE USED BELOW THE DESIGN WATER ELEVATION.

CITY OF Mill Creek WASHINGTON
LOW IMPACT DEVELOPMENT
TYPICAL BIORETENTION SWALE
NOT TO SCALE
CITY OF MILL CREEK PUBLIC WORKS
APPROVED: Director of Public Works
STD. DWG. LID-22N
DATE: 8/31/2011

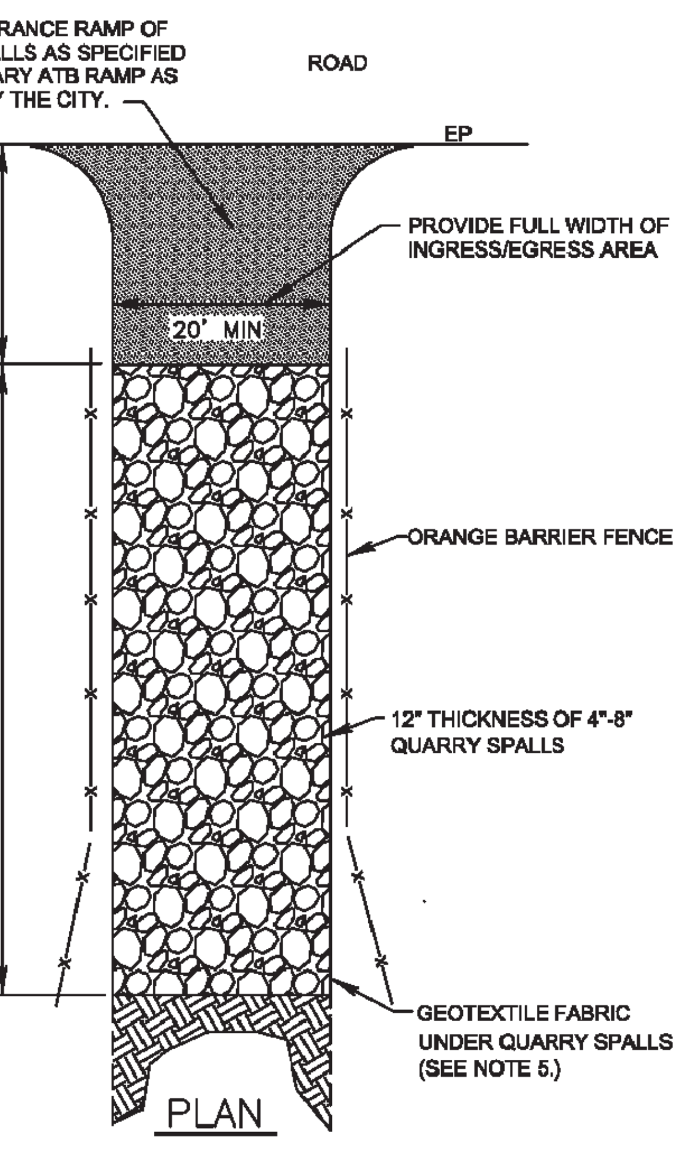


* Post spacing may be increased to 8' if wire backing is used.

NOTES:

1. This detail supplements BMP C233 Silt Fence per the Stormwater Management Manual for Western Washington by Washington State D.O.E.
   The geotextile used shall meet D.O.E. standards per the silt fence design and installation specifications.
2. Silt fence is not intended to treat concentrated flows, nor is it intended to treat substantial amounts of overland flow. Any concentrated flows must be conveyed through the drainage system to a sediment pond.
3. Standard strength fabrics shall be supported with wire mesh, chicken wire, 2-inch x 2-inch wire, safety fence, or jute mesh, or as approved by the city.
   Silt fence materials are available that have synthetic mesh backing attached.
4. The minimum height of the top of silt fence shall be 2 feet and the maximum height shall be 2.5 feet above the original ground surface.
5. The fence posts shall be placed or driven a minimum of 18 inches. Fence posts depths shall be increased by 6 inches if the fence is located on slopes of 3:1 or steeper and the slope is perpendicular to the fence.
6. Silt fence barriers shall be inspected immediately after each rainfall and at least daily during prolonged rainfall.

CITY OF Mill Creek WASHINGTON
SILT FENCE
NOT TO SCALE
CITY OF MILL CREEK PUBLIC WORKS
APPROVED: Director of Public Works
STD. DWG. STM-7N
DATE: 8/26/2011



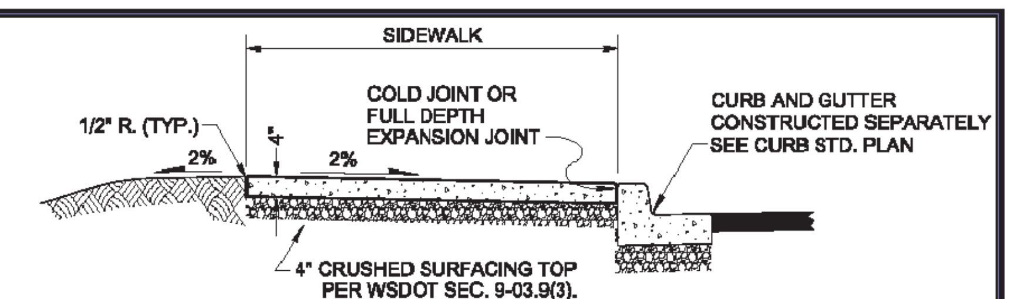
NOTES:

1. 4" TO 8" QUARRY SPALLS AS SPECIFIED IN SECTION 9-13.6 OF THE WSDOT STANDARD SPECIFICATIONS.
2. THE MINIMUM LENGTH SHALL BE LENGTHENED AS NECESSARY TO ENSURE MATERIAL IS NOT TRACKED INTO THE PUBLIC RIGHT-OF-WAY. ALTERNATE CONSTRUCTION ENTRANCES WILL BE ALLOWED WITH APPROVAL OF THE CITY ENGINEER ON A CASE BY CASE BASIS, WHERE PHYSICAL SITE CONDITIONS AND SIZE DICTATE.
3. INSTALL ORANGE BARRIER FENCE TO DIRECT TRAFFIC ONTO CONSTRUCTION ENTRANCE.
4. INSTALLATION: THE AREA OF THE ENTRANCE SHOULD BE CLEARED OF ALL VEGETATION, ROOTS, OTHER OBJECTIONABLE MATERIAL. THE GRAVEL SHALL BE PLACED TO THE SPECIFIED DIMENSIONS.
5. THE GEOTEXTILE SHALL MEET THE REQUIREMENTS FOR BMP C105: STABILIZED CONSTRUCTION ENTRANCE IN THE WA STATE D.O.E. STORMWATER MANAGEMENT MANUAL FOR WESTERN WASHINGTON.

NOTES:

1. SURFACE WATER - ALL SURFACE WATER FLOWING OR DIVERTED TOWARD CONSTRUCTION ENTRANCES SHALL BE PIPED ACROSS THE ENTRANCE. IF PIPING IS IMPRACTICAL, A MOUNTABLE BERM WITH 5:1 SLOPES WILL BE PERMITTED.
2. MAINTENANCE - THE ENTRANCE SHALL BE MAINTAINED IN A CONDITION WHICH WILL PREVENT TRACKING OR FLOWING OF SEDIMENT ONTO PUBLIC RIGHT-OF-WAY. THIS MAY REQUIRE PERIODIC TOP DRESSING WITH ADDITIONAL STONE AS CONDITIONS DEMAND AND REPAIR AND/OR CLEANOUT OF ANY MEASURES USED TO TRAP SEDIMENT. ALL SEDIMENT SPILLED, DROPPED, WASHED OR TRACKED ONTO PUBLIC RIGHT-OF-WAY MUST BE REMOVED IMMEDIATELY BY SWEEPING. NO WASHING STREETS IS ALLOWED.
3. WHEELS SHALL BE CLEANED TO REMOVE SEDIMENT PRIOR TO ENTRANCE ONTO PUBLIC RIGHT-OF-WAY. WHEN WASHING IS USED, IT SHALL BE DONE ON AN AREA STABILIZED WITH STONE AND WHICH DRAINS INTO AN APPROVED SEDIMENT TRAPPING DEVICE.
4. PERIODIC INSPECTION AND NEEDED MAINTENANCE SHALL BE PROVIDED AFTER EACH RAIN.

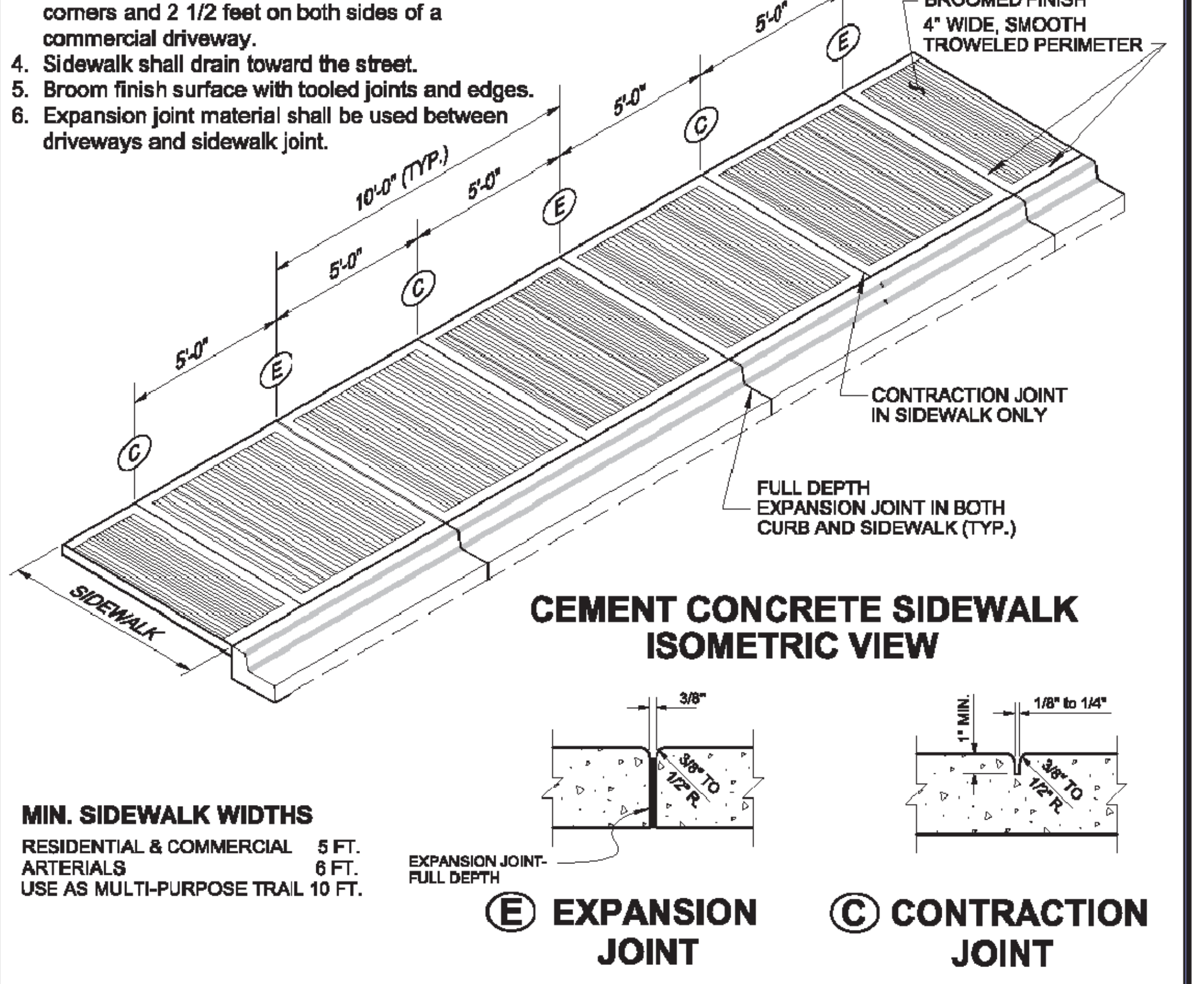
CITY OF Mill Creek WASHINGTON
GRAVEL CONSTRUCTION ENTRANCE
NOT TO SCALE
CITY OF MILL CREEK PUBLIC WORKS
APPROVED: Director of Public Works
STD. DWG. STR-61N
DATE: 8/29/2011



CEMENT CONCRETE SIDEWALK SECTION

NOTES:

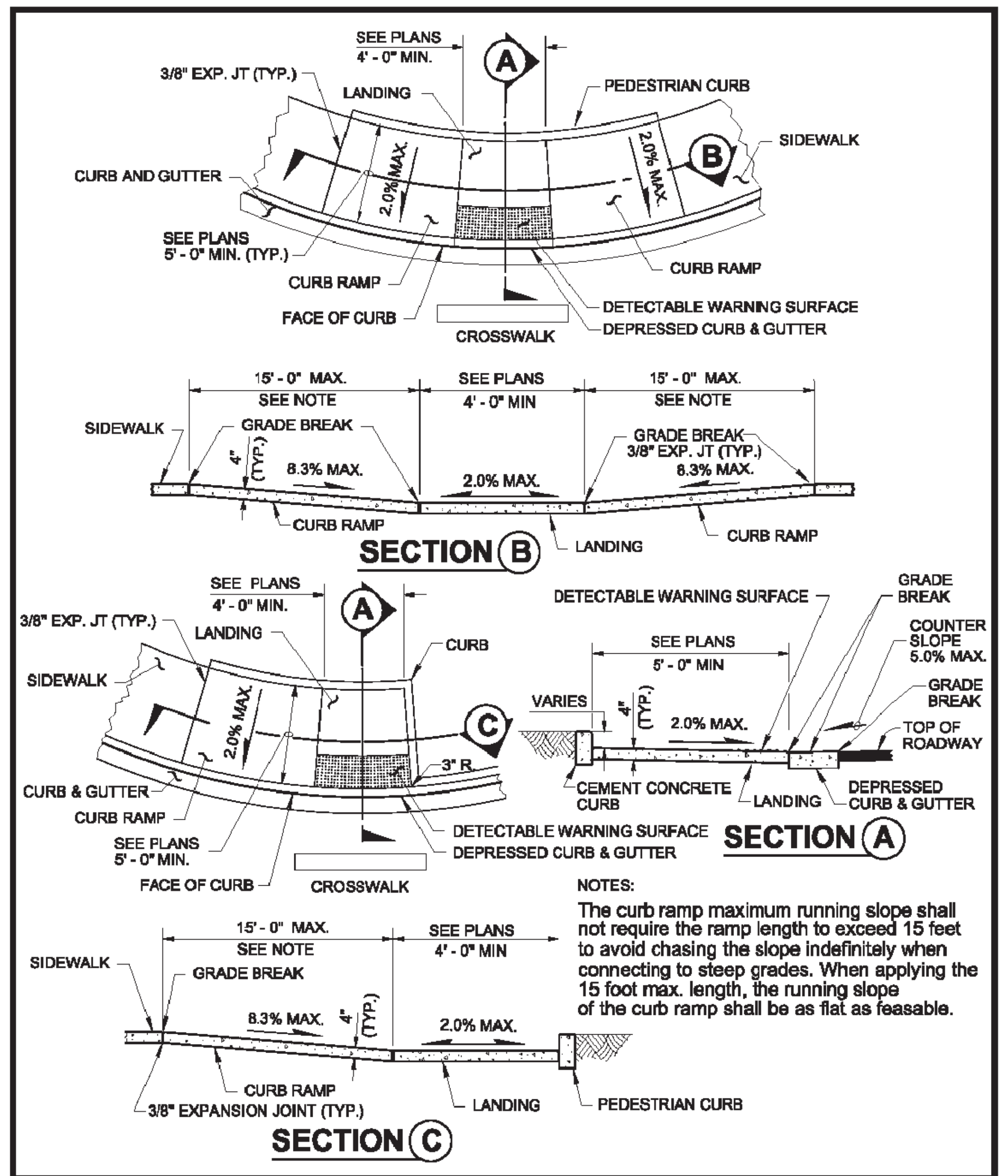
1. Concrete shall be Class 3000 air entrained.
2. Concrete thickness shall be 4" (Typical) except at driveways which shall be 6" thick.
3. Thickened edge shall be used on commercial corners and 2 1/2 feet on both sides of a commercial driveway.
4. Sidewalk shall drain toward the street.
5. Broom finish surface with tooled joints and edges.
6. Expansion joint material shall be used between driveways and sidewalk joint.



MIN. SIDEWALK WIDTHS

RESIDENTIAL & COMMERCIAL	5 FT.
ARTERIALS	6 FT.
USE AS MULTI-PURPOSE TRAIL	10 FT.

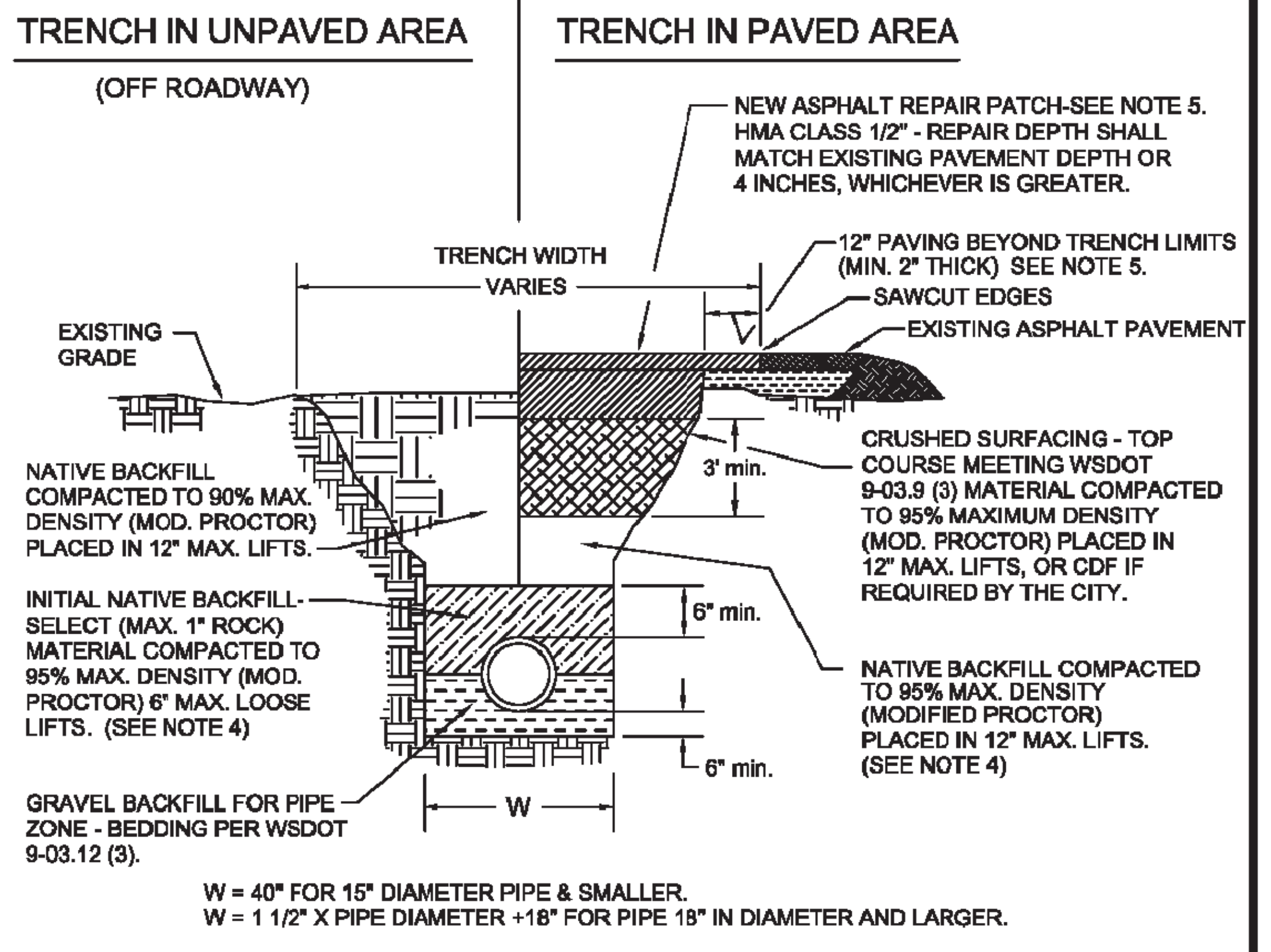
CITY OF Mill Creek WASHINGTON
CEMENT CONCRETE SIDEWALK
NOT TO SCALE
CITY OF MILL CREEK PUBLIC WORKS
APPROVED: Director of Public Works
STD. DWG. STR-3N
DATE: 8/29/2011



NOTES:

The curb ramp maximum running slope shall not require the ramp length to exceed 15 feet to avoid chasing the slope indefinitely when connecting to steep grades. When applying the 15 foot max. length, the running slope of the curb ramp shall be as flat as feasable.

CITY OF Mill Creek WASHINGTON
PARALLEL CURB RAMPS
NOT TO SCALE
CITY OF MILL CREEK PUBLIC WORKS
APPROVED: Director of Public Works
STD. DWG. STR-8N
DATE: 8/29/2011



W = 40" FOR 15" DIAMETER PIPE & SMALLER.
W = 1 1/2" X PIPE DIAMETER +18" FOR PIPE 18" IN DIAMETER AND LARGER.

NOTES:

1. EXISTING ASPHALT PAVEMENT MUST BE SAWCUT TO PROVIDE A CLEAN STRAIGHT EDGE BEFORE PIPE PLACEMENT.
2. EXISTING MATERIAL DISTURBED UNDER THE PIPE SHALL BE REPLACED WITH BEDDING MATERIAL AND COMPACTED TO 95% MAX. DENSITY.
3. BACK MATERIAL SHALL BE INSTALLED IN AN APPROVED MANNER TO ENSURE NO DAMAGES TO THE PIPE.
4. IF NATIVE BACKFILL IS DETERMINED UNSATISFACTORY BY THE CITY, USE CRUSHED SURFACING TOP COURSE PER WSDOT 9-03.9 (3)
5. SEE MILL CREEK MUNICIPAL CODE SECTION 12.18.060 FOR PAVEMENT PATCHING STANDARDS.

CITY OF Mill Creek WASHINGTON
TYPICAL TRENCH DETAIL
NOT TO SCALE
CITY OF MILL CREEK PUBLIC WORKS
APPROVED: Director of Public Works
STD. DWG. STR-62N
DATE: 8/30/2011

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811 Know what's below. Call before you dig.

GENERAL PLAN NOTES

1. ALL WORK AND MATERIALS SHALL BE ACCORDING TO THE LATEST ADDITION OF "STANDARD SPECIFICATIONS FOR ROAD, BRIDGE, AND MUNICIPAL CONSTRUCTION" PREPARED BY WASHINGTON STATE DEPARTMENT OF TRANSPORTATION (WSDOT), CITY OF MILL CREEK STANDARD PLANS, AND ANY CONDITIONS OF APPROVAL. IT SHALL BE THE SOLE RESPONSIBILITY OF THE APPLICANT AND THE PROFESSIONAL CIVIL ENGINEER TO CORRECT ANY ERROR, OMISSIONS, OR VARIATION FROM THE ABOVE REQUIREMENTS FOUND IN THESE PLANS. ALL CORRECTIONS SHALL BE AT NO ADDITIONAL COST OR LIABILITY TO THE CITY OF MILL CREEK.
2. ALL WORK WITHIN THE SITE SHALL BE SUBJECT TO THE INSPECTION OF THE CITY ENGINEER OR DESIGNATED REPRESENTATIVE.
3. PRIOR TO BEGINNING ROAD CONSTRUCTION, THE APPLICANT, THEIR ENGINEER AND ROAD CONTRACTOR SHALL MEET WITH THE DEPARTMENT OF PUBLIC WORKS FOR A PRE-CONSTRUCTION MEETING.
4. A COPY OF THESE APPROVED PLANS MUST BE ON THE SITE WHENEVER CONSTRUCTION IS IN PROGRESS.
5. PRIOR TO ANY SITE CONSTRUCTION THAT INCLUDES CLEARING/LOGGING OR GRADING THE SITE/LOT CLEARING LIMITS SHALL BE LOCATED AND IDENTIFIED BY THE PROJECT SURVEYORJ ENGINEER AS REQUIRED BY THESE PLANS AND APPROVED BY THE CITY.
6. THE TEMPORARY EROSION/SEDIMENTATION CONTROL BMP'S SHALL BE INSTALLED PRIOR TO ANY GRADING OR EXTENSIVE LAND CLEARING IN ACCORDANCE WITH APPROVED CONSTRUCTION STORMWATER POLLUTION PREVENTION PLAN (SWPPP). THESE BMP'S MUST BE SATISFACTORILY MAINTAINED UNTIL CONSTRUCTION AND LANDSCAPING IS COMPLETED AND THE POTENTIAL FOR ON-SITE EROSION HAS PASSED.
7. PUBLIC STREETS SHALL BE CLEANED ONCE PER DAY OR AS DIRECTED BY THE CITY. FLUSHING OF STREETS WITH WATER WILL NOT BE ALLOWED.
8. LOCATIONS OF EXISTING UTILITIES ARE APPROXIMATE. THE CONTRACTOR SHALL BE RESPONSIBLE FOR VERIFYING THE LOCATIONS OF EXISTING UTILITIES PRIOR TO CONSTRUCTION. UTILITIES SHOWN HERE ARE FOR THE PURPOSES OF ASSISTING THE CONTRACTOR IN LOCATING SAID UTILITIES. CONTRACTOR SHALL CONTACT UNDERGROUND UTILITIES LOCATION CENTER (1-800-424-5555) 48 HOURS PRIOR TO BEGINNING OF CONSTRUCTION AND OBTAIN ON-SITE UTILITY LOCATIONS.
9. THE CONTRACTOR SHALL COMPLY WITH ALL OTHER NECESSARY PERMITS AND REQUIREMENTS BY THE CITY OF MILL CREEK GOVERNING AUTHORITYJAGENCY.
10. UNLESS OTHERWISE APPROVED BY THE CITY ENGINEER, FROM OCTOBER 1 THROUGH APRIL 30, NO SOILS SHALL REMAIN EXPOSED AND UNWORKED FOR MORE THAN 2 DAYS AND FROM MAY 1THROUGH SEPTEMBER 30, NO SOILS SHALL REMAIN EXPOSED AND UNWORKED FOR MORE THAN 7 DAYS. ANY UNWORKED SOIL SHALL BE STABILIZED WITH A CITY APPROVED BEST MANAGEMENT PRACTICE (BMP).

STORM DRAINAGE NOTES

1. ALL PIPE SHALL BE PLACED ON STABLE EARTH, OR IF IN THE OPINION OF THE CITY ENGINEER, THE EXISTING FOUNDATION IS UNSATISFACTORY, AND THEN IT SHALL BE EXCAVATED BELOW GRADE AND BACK-FILLED PER STANDARD PLAN STM 01.
2. TRENCH BACK FILL OF NEW UTILITIES AND STORM DRAINAGE FACILITIES SHALL BE COMPACTED TO 95% MAXIMUM DENSITY (MODIFIED PROCTOR)UNDER ROADWAYS AND SIDEWALKS AND 90% MAXIMUM DENSITY (MODIFIED PROCTOR) OFF ROADWAYS.
3. ALL CATCH BASINS TO BE TYPE I UNLESS OTHERWISE NOTED.
4. ALL CATCH BASINS WITH A DEPTH OVER 5.0 FEET TO THE FLOW LINE SHALL BE TYPE II.
5. ALL TYPE II CATCH BASINS AND ALL INLETS AND CATCH BASINS OUTSIDE OF PUBLIC RIGHT OF WAY SHALL HAVE SOLID LOCKING LIDS UNLESS OTHERWISE APPROVED BY THE CITY. CATCH BASINS OUTSIDE THE RIGHT OF WAY COLLECTING SURFACE WATER SHALL HAVE LOCKING GRATES.
6. STANDARD LADDER STEPS SHALL BE PROVIDED IN ALL CATCH BASINS/MANHOLES EXTENDING 5 FEET IN DEPTH.
7. CATCH BASIN FRAME AND GRATES SHALL BE DUCTILE IRON (HS- 25 RATING) VANED GRATE (OLYMPIC FOUNDRY ITEM NUMBER SM50VG OR APPROVED EQUAL). THROUGH CURB INLETS SHALL BE 18" X 24" DUCTILE IRON- DIAGONAL SLOT GRATE WITH 9" HIGH DIAMOND PLATE HOOD, AND HS-25 RATING (OLYMPIC FOUNDRY ITEM NUMBER SMSOVG OR APPROVED EQUAL).
8. THE CONTRACTOR SHALL BE RESPONSIBLE FOR ADJUSTING ALL INLET, AND CATCH BASIN FRAMES AND GRATES JUST PRIOR TO PAVING. DURING OVERLAY PROJECTS, ALL MANHOLES, VALVES, AND MONUMENTS SHALL BE ADJUSTED AFTER PAVING.
9. PRIOR TO SIDEWALK CONSTRUCTION, CONSTRUCT THE LOT DRAINAGE AND/OR STUB OUTS BEHIND SIDEWALK DRAINS AS REQUIRED. POSITIVE DRAINAGE IS TO BE PROVIDED WHERE FEASIBLE WITH CONNECTION TO STORM DRAIN. STUB- OUTS SHALL BE MARKED WITH 2" X 4" AND LABELED "STORM."
10. STORM WATER RETENTION/DETENTION FACILITIES, CONTROL STRUCTURES, STORM DRAINAGE PIPES AND CATCH BASINS SHALL BE JETTED AND CLEANED PRIOR TO ACCEPTANCE.
11. PIPE SPECIFICATION: ALL STORM DRAIN PIPES SHALL BE 12" MIN. DIAMETER. PIPE MATERIAL, JOINTS AND PROTECTIVE TREATMENT, SHALL BE IN ACCORDANCE WITH WSDOT STANDARD SPECIFICATIONS, SECTION 9.05 AND AASHTO AND ASTM DESIGNATIONS AS NOTED BELOW.

MATERIALS ALLOWED FOR STORM DRAIN LINES:

- PLAIN CONCRETE PIPE (CP)
- REINFORCED CONCRETE PIPE (RCP)
- ALUMINUM SPIRAL RI PIPE (ASRP)
- ASTM D3034 PVC
- HIGH DENSITY POLYETHYLENE PIPE (HDPE) SMOOTH INTERIOR -DUAL AND TRIPLE WALL (12"-24" PIPE SHALL BE DUAL WALL)

MATERIALS ALLOWED FOR 6" ROOF DRAIN LINES.

- SDR35 SEWER PIPE (ASTM D3034 PVC) ALLOWABLE

JOINTS:

- CONCRETE PIPE SHALL BE RUBBER GASKETED.
- SPIRAL RIB PIPE SHALL BE "HAT BANDED" WITH NEOPRENE GASKETS
- PVC PIPE SHALL BE RUBBER GASKETED.
- HDPE SHALL BE BELL-AND-SPIGOT, CLEATED BELL, OR SPLIT, INTERNAL AND SNAP COUPLERS.

ACCEPTED FOR CONSTRUCTION
CITY OF MILL CREEK

PUBLIC WORKS DIRECTOR DATE

ACCEPTED AS IN COMPLIANCE
WITH CONDITIONS OF APPROVAL
FOR BS 13-64

COMMUNITY DEVELOPMENT DIRECTOR DATE

REVISIONS

DWN. BY: SRM
CHK. BY: DWH
DATE: 8/20/13
JOB #: 12-189
F/B #: 1029
SCALE: NONE

HARMSEN & ASSOCIATES INC
ENGINEERS SURVEYORS
LANDSCAPE ARCHITECTS
PLANNERS
16778 146TH STREET SE, SUITE 104
P.O. BOX 516
MONROE, WA 98272
(360) 794-7811
(206) 343-5903
FAX: (360) 805-9732

DAVID W. HARMSEN 33745
9/12/13

MILL CREEK COMMUNITY ASSO.
15624 COUNTRY CLUB DRIVE
MILL CREEK, WA

NOTES & DETAILS

DRAWING: C5
SHEET: 5 OF 6

P:\WORK\PROJECTS\2012\12-189 MCCA\CE\DWG\CDS\C3 STORM.DWG 09/12/2013

SECTION 6 TOWNSHIP 27 NORTH, RANGE 5 EAST, W.M.

TEMPORARY EROSION & SEDIMENTATION CONTROL NOTES:

1. ALL TEMPORARY EROSION AND SEDIMENT CONTROL (TESC) MEASURES SHALL BE INSTALLED BY THE CONTRACTOR PRIOR TO ANY GRADING OR LAND CLEARING IN ACCORDANCE WITH THE APPROVED TESC PLAN. THESE FACILITIES MUST BE MAINTAINED DAILY UNTIL FINAL APPROVAL BY THE CITY INSPECTOR.
2. THE TESC FACILITIES SHOWN ON THIS PLAN ARE THE MINIMUM REQUIREMENTS FOR ANTICIPATED SITE CONDITIONS. DURING THE CONSTRUCTION PERIOD, THESE TESC FACILITIES SHALL BE UPGRADED (E.G. ADDITIONAL SUMPS, RELOCATION OF DITCHES AND SILT FENCES, ETC.) AS NEEDED FOR UNEXPECTED STORM EVENTS.
3. CONSTRUCTION ACCESS TO THE SITE SHALL BE ONLY AS SHOWN ON THE APPROVED PLANS. ALL VEHICLES LEAVING THE SITE ONTO PUBLIC RIGHT-OF-WAY SHALL BE CLEANED TO PREVENT TRACKING OF MUD, DIRT, AND OTHER DEBRIS.
4. THE CONTRACTOR SHALL SWEEP AND/OR WASH ACCESS STREETS AT LEAST DAILY OR MORE FREQUENTLY AS MAY BE NECESSARY AND SO DIRECTED BY THE CITY OF MILL CREEK. DUST CONTROL ON SITE WILL BE REQUIRED.
5. INSTALL INLET PROTECTION AT DOWNSTREAM CATCH BASIN GRATES AND AT CATCHBASINS INSTALLED ON-SITE PER DETAIL 2/C2.
6. POLLUTED WATER MAY NOT BE PUMPED INTO THE CITY STORM SYSTEM.
7. ALL DISTURBED AREAS SUCH AS RETENTION FACILITIES, ROADWAY BACK-SLOPES, ETC. SHALL BE SEEDED WITH A PERENNIAL GROUND COVER TO MINIMIZE EROSION. GRASS SEEDING WILL BE DONE USING AN APPROVED HYDROSEEDER.
8. IMMEDIATELY FOLLOWING FINISH GRADING, PERMANENT VEGETATION CONSISTING OF RAPID, PERSISTENT AND LEGUME WILL BE APPLIED AT A MINIMUM #80 PER ACRE. THIS IS TO INCLUDE THE FOLLOWING: 20% ANNUAL, PERENNIAL OR HYDROSEED REQUIRED. PREPARATION OF SUBGRADE MAY BE REQUIRED PRIOR TO HYDROSEEDING.
9. ALL EROSION CONTROL ON SITE MUST COMPLY WITH THE DEPARTMENT OF ECOLOGY STORMWATER MANUAL FOR WESTERN WASHINGTON, 2005 EDITION.
10. EROSION AND SEDIMENTATION CONTROL DEVICES SHALL BE INSPECTED AT REGULAR INTERVALS FOR DAMAGE AND SEDIMENT ACCUMULATION. AT A MINIMUM, THE FACILITIES SHALL BE INSPECTED WEEKLY AND IMMEDIATELY AFTER ANY RUNOFF PRODUCING RAIN EVENT. INSPECTIONS SHALL TAKE PLACE AT THE END OF EACH WORK WEEK AND ANY NEEDED REPAIRS OR MAINTENANCE SHALL BE COMPLETED BEFORE THE JOB IS SHUT DOWN FOR THE WEEKEND. INSPECTIONS SHALL CONTINUE AT THESE INTERVALS DURING PERIODS OF WORK STOPAGES OR UNTIL PERMANENT VEGETATION IS ESTABLISHED.
11. CONTRACTOR SHALL REMOVE EROSION AND SEDIMENTATION CONTROL DEVICES WHEN CONSTRUCTION IS COMPLETE.
12. FROM OCTOBER 1 TO APRIL 30, EXPOSED SOILS TO BE LEFT UNWORKED FOR MORE THAN 2 DAYS SHALL BE STABILIZED. OTHERWISE SOILS TO BE LEFT UNWORKED FOR 7 DAYS SHALL BE STABILIZED.

POLLUTANTS OTHER THAN SEDIMENT

ALL POLLUTANTS, INCLUDING WASTE MATERIALS AND DEMOLITION DEBRIS, THAT OCCUR ONSITE SHALL BE HANDLED AND DISPOSED OF IN A MANNER THAT DOES NOT CAUSE CONTAMINATION OF STORMWATER. GOOD HOUSEKEEPING AND PREVENTATIVE MEASURES WILL BE TAKEN TO ENSURE THAT THE SITE WILL BE KEPT CLEAN, WELL ORGANIZED, AND FREE OF DEBRIS. IF REQUIRED, BMPS TO BE IMPLEMENTED TO CONTROL SPECIFIC SOURCES OF POLLUTANTS ARE DISCUSSED BELOW.

VEHICLES, CONSTRUCTION EQUIPMENT, AND/OR PETROLEUM PRODUCT STORAGE/DISPENSING:

- ALL VEHICLES, EQUIPMENT, AND PETROLEUM PRODUCT STORAGE/DISPENSING AREAS WILL BE INSPECTED REGULARLY TO DETECT ANY LEAKS OR SPILLS, AND TO IDENTIFY MAINTENANCE NEEDS TO PREVENT LEAKS OR SPILLS.
- ON-SITE FUELING TANKS AND PETROLEUM PRODUCT STORAGE CONTAINERS SHALL INCLUDE SECONDARY CONTAINMENT.
- SPILL PREVENTION MEASURES, SUCH AS DRIP PANS, WILL BE USED WHEN CONDUCTING MAINTENANCE AND REPAIR OF VEHICLES OR EQUIPMENT.
- IN ORDER TO PERFORM EMERGENCY REPAIRS ON SITE, TEMPORARY PLASTIC WILL BE PLACED BENEATH AND, IF RAINING, OVER THE VEHICLE.
- CONTAMINATED SURFACES SHALL BE CLEANED IMMEDIATELY FOLLOWING ANY DISCHARGE OR SPILL INCIDENT.

CHEMICAL STORAGE:

- ANY CHEMICALS STORED IN THE CONSTRUCTION AREAS WILL CONFORM TO THE APPROPRIATE SOURCE CONTROL BMPS LISTED IN VOLUME IV OF THE ECOLOGY STORMWATER MANUAL. IN WESTERN WA, ALL CHEMICALS SHALL HAVE COVER, CONTAINMENT, AND PROTECTION PROVIDED ON SITE, PER BMP C153 FOR MATERIAL DELIVERY, STORAGE AND CONTAINMENT IN SWMMWW 2005
- APPLICATION OF AGRICULTURAL CHEMICALS, INCLUDING FERTILIZERS AND PESTICIDES, SHALL BE CONDUCTED IN A MANNER AND AT APPLICATION RATES THAT WILL NOT RESULT IN LOSS OF CHEMICAL TO STORMWATER RUNOFF. MANUFACTURERS' RECOMMENDATIONS FOR APPLICATION PROCEDURES AND RATES SHALL BE FOLLOWED.

DEMOLITION:

- DUST RELEASED FROM DEMOLISHED SIDEWALKS SHALL BE CONTROLLED USING DUST CONTROL MEASURES (BMP C140).
- STORM DRAIN INLETS VULNERABLE TO STORMWATER DISCHARGE CARRYING DUST, SOIL, OR DEBRIS WILL BE PROTECTED USING STORM DRAIN INLET PROTECTION (BMP C220 AS INDICATED ON THE PLAN).
- PROCESS WATER AND SLURRY RESULTING FROM SAWCUTTING AND SURFACING OPERATIONS WILL BE PREVENTED FROM ENTERING THE WATERS OF THE STATE BY IMPLEMENTING SAWCUTTING AND SURFACING POLLUTION PREVENTION MEASURES (BMP C152).
  1. SLURRY AND CUTTING SHALL BE VACUUMED DURING CUTTING AND SURFACING OPERATIONS.
  2. SLURRY AND CUTTINGS SHALL NOT DRAIN TO ANY NATURAL OR CONSTRUCTED DRAINAGE CONVEYANCE.
  3. COLLECTED SLURRY AND CUTTINGS SHALL BE DISPOSED OF IN A MANNER THAT DOES NOT VIOLATE GROUNDWATER OR SURFACE WATER QUALITY STANDARDS.

CONCRETE AND GROUT:

- PROCESS WATER AND SLURRY RESULTING FROM CONCRETE WORK WILL BE PREVENTED FROM ENTERING THE WATERS OF THE STATE BY IMPLEMENTING CONCRETE HANDLING MEASURES (BMP C151).
  1. CONCRETE TRUCK CHUTES, PUMPS, AND INTERNALS SHALL BE WASHED OUT ONLY INTO FORMED AREAS AWAITING INSTALLATION OF CONCRETE OR ASPHALT.
  2. UNUSED CONCRETE REMAINING IN THE TRUCK AND PUMP SHALL BE RETURNED TO THE ORIGINATING BATCH PLANT FOR RECYCLING.
  3. HAND TOOLS INCLUDING, BUT NOT LIMITED TO, SCREEDS, SHOVELS, RAKES, FLOATS, AND TROWELS SHALL BE WASHED OFF ONLY INTO FORMED AREAS AWAITING INSTALLATION OF CONCRETE OR ASPHALT.

  WHEN NO FORMED AREAS ARE AVAILABLE, WASHWATER AND LEFTOVER PRODUCT SHALL BE CONTAINED IN A LINED CONTAINER. CONTAINED CONCRETE SHALL BE DISPOSED OF IN A MANNER THAT DOES NOT VIOLATE GROUNDWATER OR SURFACE WATER QUALITY STANDARDS.

SANITARY WASTEWATER:

- PORTABLE SANITATION FACILITIES WILL BE FIRMLY SECURED, REGULARLY MAINTAINED, AND EMPTIED WHEN NECESSARY.
- SOLID WASTE WILL BE STORED IN SECURE, CLEARLY MARKED CONTAINERS.

OTHER:

- OTHER BMPS WILL BE ADMINISTERED AS NECESSARY TO ADDRESS ANY ADDITIONAL POLLUTANT SOURCES ON SITE.

EROSION CONTROL BMP'S:

THE CONSTRUCTION STAGING AREA AND PARKING IS DIAGRAMATIC ONLY. THE CONTRACTOR IS ALLOWED TO LOCATE THESE FACILITIES ON THE SITE AS NEEDS DICTATE IN COORDINATION WITH THE CITY INSPECTOR.

PRESERVE NATURAL VEGETATION (BMP C101)
DO NOT CLEAR PAST THE DESIGNATED CLEARING LIMITS.

HIGH VISIBILITY FENCING (BMP C103)
USE IN COMBINATION WITH BMP C233, SILT FENCE ALONG THE WEST, NORTH AND EAST BOUNDARIES AS INDICATED ON THE PLANS.

CONSTRUCTION ENTRANCE (BMP C105)
INSTALL CONSTRUCTION ENTRANCE AS LOCATED ON THE PLANS PER STD DETAIL 206.

CONSTRUCTION ROAD/PARKING AREA STABILIZATION (BMP C107)
ONCE GRADING IN FUTURE PAVED AREAS HAS REACHED SUBGRADE, THE GRAVEL BASE COURSE OF MATERIAL INDICATED ON THE APPLICABLE PAVING SECTION IS TO BE PLACED ON THE SUBGRADE TO STABILIZE EXPOSED SURFACES. SURFACES PROTECTED THIS WAY INCLUDE SIDEWALKS, AND THE CONSTRUCTION STAGING AREA AND PARKING.

TEMPORARY & PERMANENT SEEDING (BMP C120)
PERMANENT SEEDING SHALL BE USED TO STABILIZE EXPOSED SOILS AND SHALL BE PERFORMED UNDER THE DIRECTION OF THE LANDSCAPE PLANS AND SPECIFICATIONS.

MULCHING (BMP C121)
STABILIZE EXPOSED SURFACES WITH 4" STERILE STRAW MULCH WHEN SURFACES ARE TO BE UNWORKED FOR THE SEASONAL TIME FRAMES LISTED IN THE TESC NOTES AND SWPPP NARRATIVE. MULCH CAN BE USED TO TEMPORARILY STABILIZE SOILS UNDER FUTURE PAVEMENT, HOWEVER, ALL MULCH MUST BE REMOVED PRIOR TO PLACEMENT OF BASE COURSES. ALTERNATIVELY, CONSTRUCTION ROAD/PARKING STABILIZATION CAN BE USED IN FUTURE PAVED AREAS.

PLASTIC COVERING (BMP C123)
USE PLASTIC SHEATHING TO PROTECT STOCKPILES. ANCHOR WITH ROPED TOGETHER SAND BAGS.

TOPSOILING/COMPOSTING (BMP C125)
STRIP TOPSOIL UNDER PAVEMENT, WALKS AND BUILDING. STOCKPILE SEPARATELY FOR USE ON PROJECT LANDSCAPING.

DUST CONTROL (BMP C140)
CONTRACTOR SHALL IMPLEMENT MEASURES TO PREVENT WIND TRANSPORT OF DUST FROM SOIL SURFACES. SUCH MEASURES CAN INCLUDE BUT ARE NOT LIMITED TO THE FOLLOWING: MULCHING AREAS NOT USED FOR VEHICLE ACCESS, REDUCING SPEEDS ON HAUL ROADS, SPRINKLE EXPOSED SURFACES WITH WATER, SURFACE HAUL ROADS WITH GRAVEL.

STORM INLET PROTECTION (BMP C220)
COUNTRY CLUB DRIVE & AQUATIC PARKING: PLACE INSERTS PER PLAN DETAIL IN EXISTING CATCH BASINS AS INDICATED ON THE PLAN. ONSITE CATCH BASINS: AS NEW CATCH BASINS ARE INSTALLED, THESE SHALL ALSO BE PROTECTED UNTIL THE DRAINAGE AREA IS STABILIZED.

SILT FENCE (BMP C233)
INSTALL SILT FENCE IN LOCATIONS INDICATED ON THE PLAN PER STD DETAIL STM-7N.

MAINTENANCE OF BMP'S

ALL TEMPORARY AND PERMANENT EROSION AND SEDIMENT CONTROL PRACTICES SHALL BE MAINTAINED AND REPAIRED AS NEEDED TO ASSURE CONTINUED PERFORMANCE OF THEIR INTENDED FUNCTION. FACILITIES SHALL BE INSPECTED AT A MINIMUM ON A WEEKLY BASIS AND IMMEDIATELY AFTER ANY RUNOFF PRODUCING RAIN EVENT. ALL MAINTENANCE AND REPAIR SHALL BE CONDUCTED IN ACCORDANCE WITH MARYSVILE STANDARDS. AT A MINIMUM, REPAIRS TO BMP'S SHALL TAKE PRECEDENT OVER OTHER SITE WORK AND COMPLETED PRIOR TO CLOSING THE SITE OF THE NIGHT. TRAPPED SEDIMENT MUST BE REMOVED OR STABILIZED ON SITE. DISTURBED SOIL AREAS RESULTING FROM REMOVAL SHOULD BE PERMANENTLY STABILIZED.

PRESERVING NATURAL VEGETATION (BMP C101)
INSPECT FLAGGED/FENCED AREAS REGULARLY TO MAKE SURE FLAGGING/FENCING HAS NOT BEEN REMOVED. IF TREE ROOTS HAVE BEEN EXPOSED OR INJURED, RE-COVER AND/OR SEAL THEM.

HIGH VISIBILITY FENCING (BMP C103)
INSPECT FENCING AND REPAIR DAMAGED SECTIONS.

STABILIZED CONSTRUCTION ENTRANCE (BMP C105)
THE ENTRANCES SHALL BE MAINTAINED IN A CONDITION WHICH WILL PREVENT TRACKING OR FLOW OF MUD ONTO EXISTING ACCESS ROADS. THIS MAY REQUIRE PERIODIC TOP DRESSING WITH 2-INCH STONE, AS CONDITIONS DEMAND, AND REPAIR AND/OR CLEANOUT OF ANY STRUCTURES USED TO TRAP SEDIMENT. ALL MATERIALS SPILLED, DROPPED, WASHED, OR TRACKED FROM VEHICLES ONTO ROADWAYS OR INTO STORM DRAINS MUST BE REMOVED IMMEDIATELY.

CONSTRUCTION ROAD STABILIZATION (BMP C107)
INSPECT STABILIZED AREAS REGULARLY, ESPECIALLY AFTER LARGE STORM EVENTS. ADD GRAVEL IF NECESSARY AND RESTABILIZE ANY AREAS FOUND TO BE ERODING.

TEMPORARY SEEDING OF STRIPPED AREAS (BMP C120)
SEEDING SHOULD BE SUPPLIED WITH ADEQUATE MOISTURE. SUPPLY WATER AS NEEDED, ESPECIALLY IN ABNORMALLY HOT OR DRY WEATHER OR ON ADVERSE SITES. WATER APPLICATION RATES SHOULD BE CONTROLLED TO PREVENT RUNOFF.
RE-SEEDING – AREAS WHICH FAIL TO ESTABLISH VEGETATIVE COVER ADEQUATE TO PREVENT EROSION SHALL BE RE-SEEDED AS SOON AS SUCH AREAS ARE IDENTIFIED.

MULCHING (BMP C121)
MULCHED AREAS SHOULD BE CHECKED PERIODICALLY, ESPECIALLY FOLLOWING SEVERE STORMS. DAMAGED AREAS OF MULCH OR TIE-DOWN MATERIAL SHALL BE IMMEDIATELY REPAIRED.

PLASTIC COVERING (BMP C123)
CHECK REGULARLY FOR RIPS AND PLACES WHERE THE PLASTIC MAY BE DISLODGED. CONTACT BETWEEN THE PLASTIC AND THE GROUND SHOULD ALWAYS BE MAINTAINED. ANY AIR BUBBLES FOUND SHOULD BE REMOVED IMMEDIATELY OR THE PLASTIC MAY RIP DURING THE NEXT WINDY PERIOD. RE-ANCHOR OR REPLACE THE PLASTIC AS NECESSARY.

TOPSOILING (BMP C125)
INSPECT FOR DAMAGE FROM RAINFALL AND SHEET FLOW. REGRADE AS NECESSARY.

DUST CONTROL (BMP C140)
RESPRAY AREA AS NECESSARY TO PREVENT WIND EROSION.

STORM DRAIN INLET PROTECTION (BMP C220)
FOR SYSTEMS USING FILTER FABRIC: INSPECTIONS SHOULD BE MADE ON A REGULAR BASIS, ESPECIALLY AFTER LARGE STORM EVENTS. IF THE FILTER BAG BECOMES CLOGGED, IT SHOULD BE CLEANED OR REPLACED.

SILT FENCE (BMP C233)
INSPECT IMMEDIATELY AFTER EACH RAINFALL, AND AT LEAST DAILY DURING PROLONGED RAINFALL. REPAIR AS NECESSARY. SEDIMENT MUST BE REMOVED WHEN IT REACHES APPROXIMATELY ONE THIRD THE HEIGHT OF THE FENCE, ESPECIALLY IF HEAVY RAINS ARE EXPECTED.

811
Know what's below.
Call before you dig.

ACCEPTED FOR CONSTRUCTION
CITY OF MILL CREEK

PUBLIC WORKS DIRECTOR DATE

ACCEPTED AS IN COMPLIANCE
WITH CONDITIONS OF APPROVAL
FOR BS 13-64

COMMUNITY
DEVELOPMENT DIRECTOR DATE

P:\WORK\PROJECTS\2012\12-189 MCCA\CE\DWG\CDS\C3 STORM.DWG 09/12/2013

REVISIONS

DWN. BY: SRM
CHK. BY: DWH
DATE: 8/20/13
JOB #: 12-189
F/B #: 1029
SCALE: NONE

HARMSEN
& ASSOCIATES INC
ENGINEERS SURVEYORS
LANDSCAPE ARCHITECTS
PLANNERS
16778 146TH STREET SE, SUITE 104
P.O. BOX 516
MONROE, WA 98272
(360) 794-7811
(206) 343-5903
FAX: (360) 805-9732

DAVID W. HARMSEN
33745

MILL CREEK COMMUNITY ASSO.
15624 COUNTRY CLUB DRIVE
MILL CREEK, WA

NOTES & DETAILS

DRAWING:
C6

SHEET: 6 OF 6

APPENDIX B

Current Study Exploration Logs and Laboratory Testing Data

Cell MCCA1 and MCCA2
Exploration Latitude and Longitude

Exploration	**Latitude**	**Longitude**
MCCA1-HA-1	47.85664	-122.20747
MCCA1-HA-2	47.85671	-122.20746
MCCA1-HA-3	47.85663	-122.20741
MCCA1-HA-1	47.85659	-122.20734
MCCA1-HA-2	47.85654	-122.20737
MCCA1-HA-3	47.85655	-122.20736

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Exploration Log

Project Number	Exploration Number	Sheet
KH150387A	MCCA1-HA-1	1 of 1

Project Name: Bioretention Hydrologic Performance Study
Location: Mill Creek, WA
Driller/Equipment: Hand Auger
Hammer Weight/Drop: N/A

Ground Surface Elevation (ft):
Datum: N/A
Date Start/Finish: 7/8/16,7/8/16
Hole Diameter (in): 4 inches

Depth (ft)	S T	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot 10 20 30 40	Other Tests
				Bioretention Soil Mix Surface: sand, leaf litter Loose, slightly moist, dark brown, SAND, trace silt, trace gravel; organics present; mostly medium sand (~84 percent) (SP).					
				Vashon Lodgement Till Medium dense, slightly moist to moist, brown, silty, very gravelly, SAND; mostly fine to medium sand (SM). Dense, wet, brown, silty GRAVEL, some sand (GM).					
				Bottom of exploration boring at 2.2 feet Refusal on gravel at 2.2 feet. Moderate seepage from 2 to 2.2 feet. Pooling water to 2 feet. No caving.					

Sampler Type (ST):

- ▯ 2" OD Split Spoon Sampler (SPT)
- ▯ 3" OD Split Spoon Sampler (D & M)
- ☐ Grab Sample
- ☐ No Recovery
- ◧ Ring Sample
- ▨ Shelby Tube Sample
- M - Moisture
- ▽ Water Level ()
- ▼ Water Level at time of drilling (ATD)

Logged by: ADY
Approved by: JHS

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Exploration Log

Project Number	Exploration Number	Sheet
KH150387A	MCCA1-HA-2	1 of 1

Project Name: Bioretention Hydrologic Performance Study
Location: Mill Creek, WA
Driller/Equipment: Hand Auger
Hammer Weight/Drop: N/A

Ground Surface Elevation (ft):
Datum: N/A
Date Start/Finish: 7/11/16,7/11/16
Hole Diameter (in): 4 inches

Depth (ft)	S T	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot 10 20 30 40	Other Tests
				Bioretention Soil Mix Surface: sand, leaf litter Loose, slightly moist, dark brown, SAND, trace silt; organics present; mostly medium sand (SP).					
				Vashon Lodgement Till Medium dense to dense, slightly moist to moist, brown, silty, SAND, some gravel; mostly fine to medium sand (SM). Becomes grayish brown with depth.					
				Bottom of exploration boring at 1.8 feet Refusal on ~ 6 inch cobble. No seepage. No caving.					

Sampler Type (ST):

- ▯ 2" OD Split Spoon Sampler (SPT)
- ▯ 3" OD Split Spoon Sampler (D & M)
- ☐ Grab Sample
- ☐ No Recovery
- ◧ Ring Sample
- ▨ Shelby Tube Sample
- M - Moisture
- ▽ Water Level ()
- ▼ Water Level at time of drilling (ATD)

Logged by: ADY
Approved by: JHS

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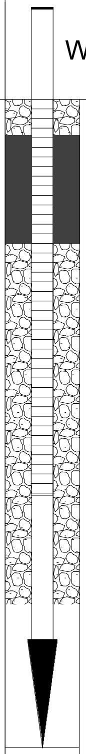
Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KH150387A	-MCCA1-HA-3/WP	1 of 1

Project Name Bioretention Hydrologic Performance Study
Elevation (Top of Well Casing) ~1.6 feet (stick up)
Water Level Elevation
Drilling/Equipment Hand Auger
Hammer Weight/Drop N/A

Location Mill Creek, WA
Surface Elevation (ft)
Date Start/Finish 8/24/16,8/24/16
Hole Diameter (in) 4 inches

Depth (ft)	Water Level	WELL CONSTRUCTION	S T	Blows/ 6"	Graphic Symbol	DESCRIPTION



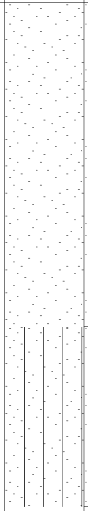
Above ground stick up -1.6 feet
Threaded PVC cap and threaded steep pipe -1.4 to -1.6 feet
Bioretention soil mix at ground surface
Bentonite chips 0.1 to 0.4 foot
Bioretention soil mix 0.4 to 1.4 feet

Stainless steel jacket over stainless steel #60 gauze welded to perforated steel pipe -1.4 to 1.1 feet

Threaded steel pipe, 1 1/4 inch ID and end cap 1.1 to 1.5 feet

Native soils 1.4 to 1.8 feet

Solid drive point -1.5 to -1.8 feet



Bioretention Soil Mix

Surface: sand, leaf litter

Loose, slightly moist, dark brown, SAND, trace silt; organics present; mostly medium sand (SP).

Vashon Lodgement Till

Medium dense to dense, slightly moist, light brown, silty, very gravelly SAND; mostly fine to medium sand (SM).

Boring terminated at 1.4 feet.
Well completed at 1.8 feet on 8/24/16.
Refusal on gravel. No seepage. No caving.

Sampler Type (ST):

▯	2" OD Split Spoon Sampler (SPT)	☐	No Recovery	M -	Moisture	**Logged by:**	ADY
▯	3" OD Split Spoon Sampler (D & M)	▌	Ring Sample	▽	Water Level ()	**Approved by:**	JHS
▯	Grab Sample	▯	Shelby Tube Sample	▼	Water Level at time of drilling (ATD)		

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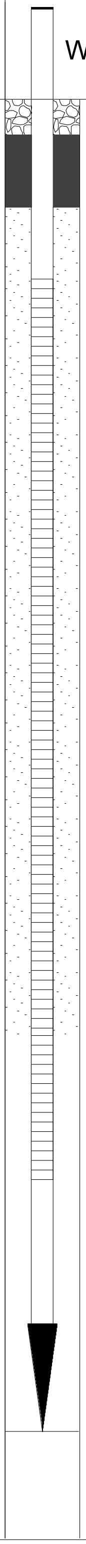
Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KH150387A	-MCCA2-HA-1/WP	1 of 1

Project Name: Bioretention Hydrologic Performance Study
Elevation (Top of Well Casing): ~0.8 feet (stick up)
Water Level Elevation:
Drilling/Equipment: Hand Auger
Hammer Weight/Drop: N/A

Location: Mill Creek, WA
Surface Elevation (ft):
Date Start/Finish: 7/22/16,7/22/16
Hole Diameter (in): 4 inches

Depth (ft)	Water Level	WELL CONSTRUCTION	S T	Blows/ 6"	Graphic Symbol	DESCRIPTION



Above ground stick up -0.8 feet
Bioretention soil mix at ground surface

Threaded PVC cap and threaded steep pipe -0.8 to 0.5 feet

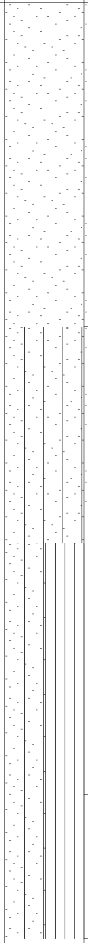
Stainless steel jacket over stainless steel #60 gauze welded to perforated steel pipe 0.5 to 3.0 feet

Medium sand 0.3 to 2.6 feet

Native soils 2.6 to 3.7 feet

Threaded steel pipe, 1 1/4 inch ID and end cap 3 to 3.4 feet

Solid drive point 3.4 to 3.7 feet



Bioretention Soil Mix

Surface: sand, leaf litter

Loose, slightly moist, dark brown, SAND, trace silt; organics present; mostly fine to medium sand (SP).

Fill

Medium dense, slightly moist, gray, gravelly, very silty SAND; cobbles present; mostly fine sand (SM).

Medium dense, slightly moist, brown, gravelly, very silty, SAND to very sandy SILT; cobbles and wood debris present; mostly fine sand (SM-ML).

Vashon Lodgement Till (?)

Medium dense to dense, slightly moist, grayish brown, silty SAND to sandy SILT, some gravel; cobbles present; mostly fine sand (SM/ML).

Boring terminated at 2.6 feet.
Well completed at 3.7 feet on 7/22/16.
Refusal on cobbles. No seepage. No caving.

Sampler Type (ST):

▯ 2" OD Split Spoon Sampler (SPT)	☐ No Recovery	M - Moisture	**Logged by:** ADY
▯ 3" OD Split Spoon Sampler (D & M)	▮ Ring Sample	▽ Water Level ()	**Approved by:** JHS
▯ Grab Sample	▯ Shelby Tube Sample	▼ Water Level at time of drilling (ATD)	

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Exploration Log

Project Number	Exploration Number	Sheet
KH150387A	MCCA2-HA-2	1 of 1

Project Name: Bioretention Hydrologic Performance Study
Location: Mill Creek, WA
Driller/Equipment: Hand Auger
Hammer Weight/Drop: N/A

Ground Surface Elevation (ft):
Datum: N/A
Date Start/Finish: 7/22/16,7/22/16
Hole Diameter (in): 4 inches

Depth (ft)	S T	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot 10 20 30 40	Other Tests
				Bioretention Soil Mix Surface: sand, leaf litter Loose, slightly moist, dark brown, SAND, trace silt; organics present; mostly medium sand (~67 percent) (SP).					
				Fill Medium dense, slightly moist, gray, silty GRAVEL; cobbles present (GM).					
				Bottom of exploration boring at 1.1 feet Refusal on ~5 inch cobble. No seepage. No caving.					

Sampler Type (ST):

- ▯ 2" OD Split Spoon Sampler (SPT)
- ▯ 3" OD Split Spoon Sampler (D & M)
- ☐ Grab Sample
- ☐ No Recovery
- ◧ Ring Sample
- ▱ Shelby Tube Sample
- M - Moisture
- ▽ Water Level ()
- ▼ Water Level at time of drilling (ATD)

Logged by: ADY
Approved by: JHS

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Exploration Log

Project Number	Exploration Number	Sheet
KH150387A	MCCA2-HA-3	1 of 1

Project Name	Bioretention Hydrologic Performance Study	Ground Surface Elevation (ft)	
Location	Mill Creek, WA	Datum	N/A
Driller/Equipment	Hand Auger	Date Start/Finish	8/24/16,8/24/16
Hammer Weight/Drop	N/A	Hole Diameter (in)	4 inches

Depth (ft)	S T	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot 10 20 30 40	Other Tests
				Bioretention Soil Mix Surface: light vegetation, leaf litter Loose, slightly moist, dark brown, SAND, trace silt; organics present; mostly medium sand (SP).					
				Fill Medium dense, slightly moist, brownish gray, silty SAND, some gravel; cobbles present; mostly fine sand (SM).					
				Bottom of exploration boring at 2.1 feet Refusal on cobble. No seepage. No caving.					

Sampler Type (ST):

▯ 2" OD Split Spoon Sampler (SPT)	☐ No Recovery	M - Moisture
▯ 3" OD Split Spoon Sampler (D & M)	◧ Ring Sample	▽ Water Level ()
✋ Grab Sample	▨ Shelby Tube Sample	▼ Water Level at time of drilling (ATD)

Logged by: ADY
Approved by: JHS

Moisture, Ash, and Organic Matter of Peat and Other Organic Soils - ASTM 2974

Date Sampled 7/22/2016	**Project** BHPS	**Project No.** KH150387A		**Soil Description**
Tested By MS	**Location** MCCA	**EB/EP No.** MCCA1 HA3 0.1-0.7	**Depth**	Bioretention soil mix

Moisture Content	**MCCA1**
Sample ID	**HA3 0.1-0.7**
Wet Weight + Pan	**863.76**
Dry Weight + Pan	**829.73**
Weight of Pan	**292.39**
Weight of Moisture	**34.03**
Dry Weight of Soil	**537.34**
% Moisture	**6.3**

Organic Matter and Ash Content

Dry Soil Befor Burn + Pan	**886.23**
Dry Soil After Burn + Pan	**863.09**
Weight of Pan	**348.70**
Wt. Loss Due to Ignition	**23.14**
Actual Wt. Of Soil After Burr	**514.39**
% Organics	**4.3**

a s s o c i a t e d
e a r t h s c i e n c e s
i n c o r p o r a t e d

Moisture, Ash, and Organic Matter of Peat and Other Organic Soils - ASTM 2974

Date Sampled 7/8/2016	**Project** BHPS	**Project No.** KH150387A		**Soil Description**
Tested By MS	**Location** MCCA	**EB/EP No.** MCCA	**Depth**	Bioretention soil mix

Moisture Content	**MCCA1**
Sample ID	**CA HA1 0.3-0.9**
Wet Weight + Pan	**975.42**
Dry Weight + Pan	**915.28**
Weight of Pan	**307.86**
Weight of Moisture	**60.14**
Dry Weight of Soil	**607.42**
% Moisture	**9.9**

Moisture Content	**MCCA2**
Sample ID	**HA1 0.3-0.5**
Wet Weight + Pan	**873.33**
Dry Weight + Pan	**762.53**
Weight of Pan	**296.54**
Weight of Moisture	**110.80**
Dry Weight of Soil	**465.99**
% Moisture	**23.8**

Organic Matter and Ash Content

Dry Soil Befor Burn + Pan	**999.67**
Dry Soil After Burn + Pan	**973.33**
Weight of Pan	**348.69**
Wt. Loss Due to Ignition	**26.34**
Actual Wt. Of Soil After Burr	**624.64**
% Organics	**4.0**

Organic Matter and Ash Content

Dry Soil Befor Burn + Pan	**814.85**
Dry Soil After Burn + Pan	**792.30**
Weight of Pan	**348.68**
Wt. Loss Due to Ignition	**22.55**
Actual Wt. Of Soil After Burr	**443.62**
% Organics	**4.8**

Moisture Content	**MCCA2**
Sample ID	**HA2 0.1-0.6**
Wet Weight + Pan	**904.11**
Dry Weight + Pan	**777.45**
Weight of Pan	**273.38**
Weight of Moisture	**126.66**
Dry Weight of Soil	**504.07**
% Moisture	**25.13**

Organic Matter and Ash Content

Dry Soil Befor Burn + Pan	**896.24**
Dry Soil After Burn + Pan	**869.62**
Weight of Pan	**392.17**
Wt. Loss Due to Ignition	**26.62**
Actual Wt. Of Soil After Burr	**477.45**
% Organics	**5.3**

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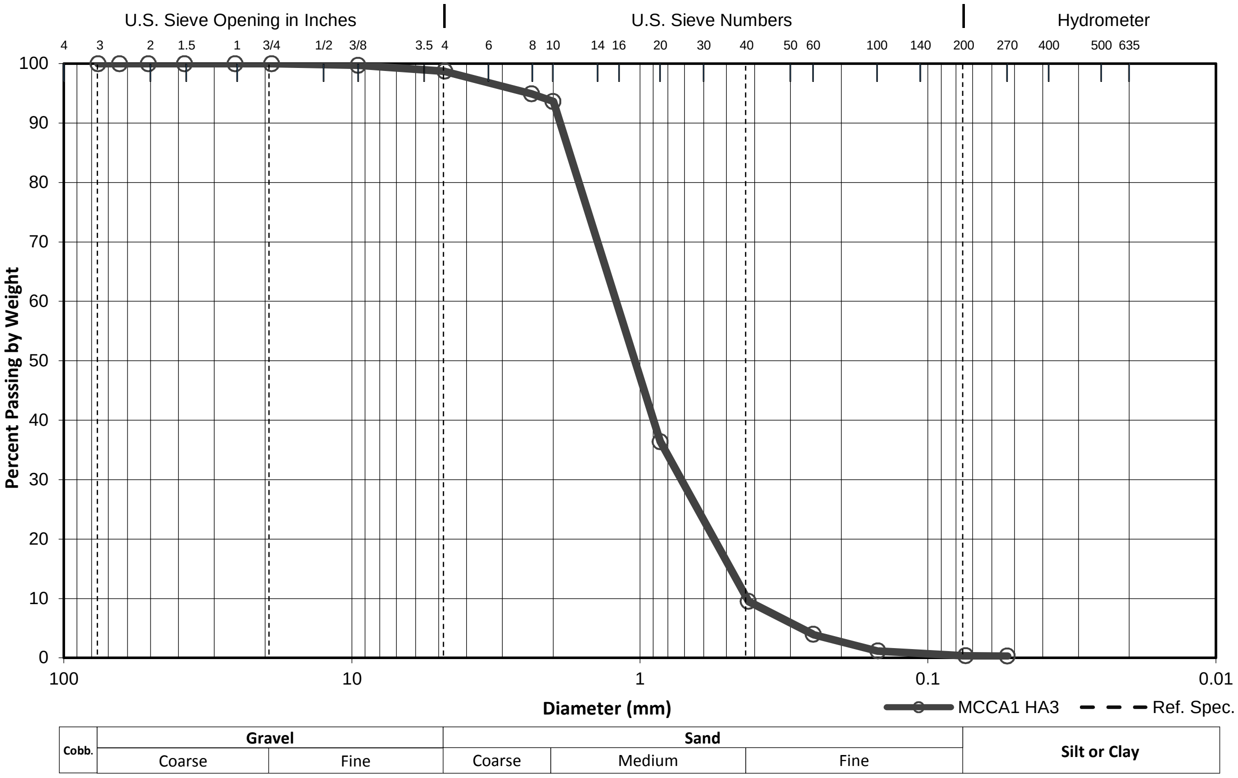
GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

Project Name	Project Number	Date Sampled	Date Tested	Tested By
BHPS	**KH150387A**	**8/24/2016**	**9/15/2016**	**GS**

Sample Source	Sample No.	Depth (ft)	Soil Description
Onsite	**MCCA1 HA3**	**0.1-0.7**	**SAND, trace silt, trace gravel (SP)**

Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification
514.7	**0**	**0.425**	**Bioretention soil mix: burned sample**



Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4		0.0	100.0		
3/4	19		0.0	100.0		
3/8	9.51	1.3	0.2	99.8		
#4	4.76	6.5	1.3	98.7		
#8	2.38	26.0	5.1	94.9		
#10	2	32.6	6.3	93.7		
#20	0.85	327.4	63.6	36.4		
#40	0.42	465.8	90.5	9.5		
#60	0.25	494.4	96.0	4.0		
#100	0.149	508.8	98.8	1.2		
#200	0.074	512.9	99.6	0.4		
#270	0.053	513.1	99.7	0.3		

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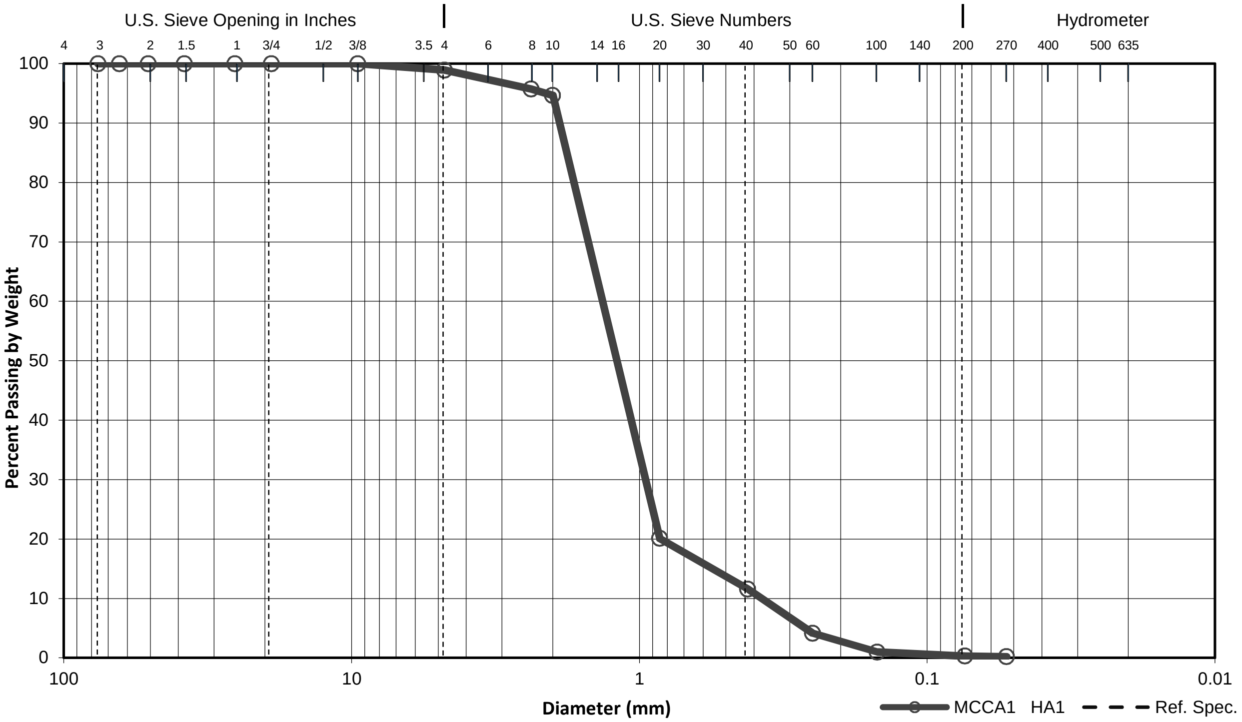
GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

Project Name	Project Number	Date Sampled	Date Tested	Tested By
BHPS	**KH150387A**	**7/8/2016**	**9/1/2016**	**MS**
Sample Source	Sample No.	Depth (ft)	Soil Description	
Onsite	**MCCA1 HA1**	**0.3-0.9**	**SAND, trace silt, trace gravel (SP)**	
Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification	
581.4	**0**	**0.376**	**Bioretention soil mix: burned sample**	



Cobb.	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4		0.0	100.0		
3/4	19		0.0	100.0		
3/8	9.51		0.0	100.0		
#4	4.76	6.2	1.1	98.9		
#8	2.38	24.7	4.3	95.7		
#10	2	31.1	5.3	94.7		
#20	0.85	464.4	79.9	20.1		
#40	0.42	514.1	88.4	11.6		
#60	0.25	557.3	95.9	4.1		
#100	0.149	575.7	99.0	1.0		
#200	0.074	579.5	99.7	0.3		
#270	0.053	580.3	99.8	0.2		

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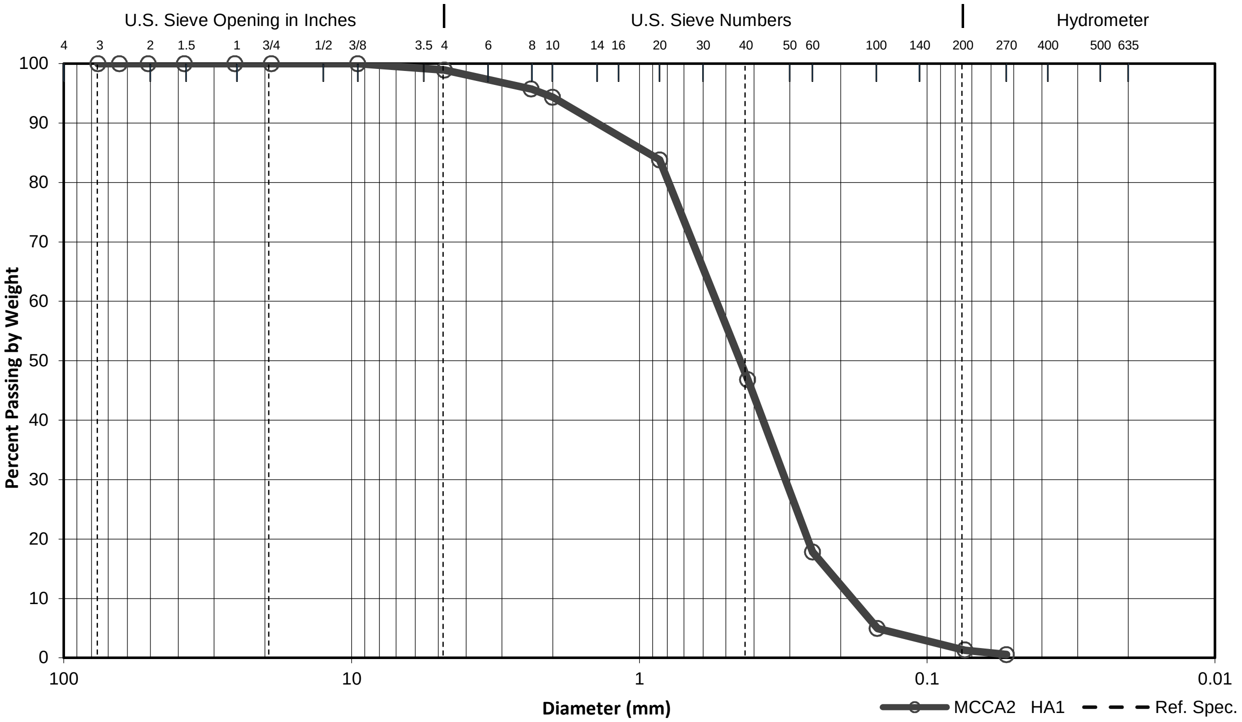
GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

Project Name	Project Number	Date Sampled	Date Tested	Tested By
BHPS	**KH150387A**	**7/22/2016**	**9/1/2016**	**MS**
Sample Source	Sample No.	Depth (ft)	Soil Description	
Onsite	**MCCA2 HA1**	**0.3-0.5**	**SAND, trace silt, trace gravel (SP)**	
Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification	
443.6	**0**	**0.182**	**Bioretention soil mix: burned sample**	



Cobb.	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4		0.0	100.0		
3/4	19		0.0	100.0		
3/8	9.51		0.0	100.0		
#4	4.76	4.7	1.1	98.9		
#8	2.38	18.9	4.3	95.7		
#10	2	25.0	5.6	94.4		
#20	0.85	71.9	16.2	83.8		
#40	0.42	236.0	53.2	46.8		
#60	0.25	364.5	82.2	17.8		
#100	0.149	421.5	95.0	5.0		
#200	0.074	437.6	98.7	1.3		
#270	0.053	441.1	99.4	0.6		

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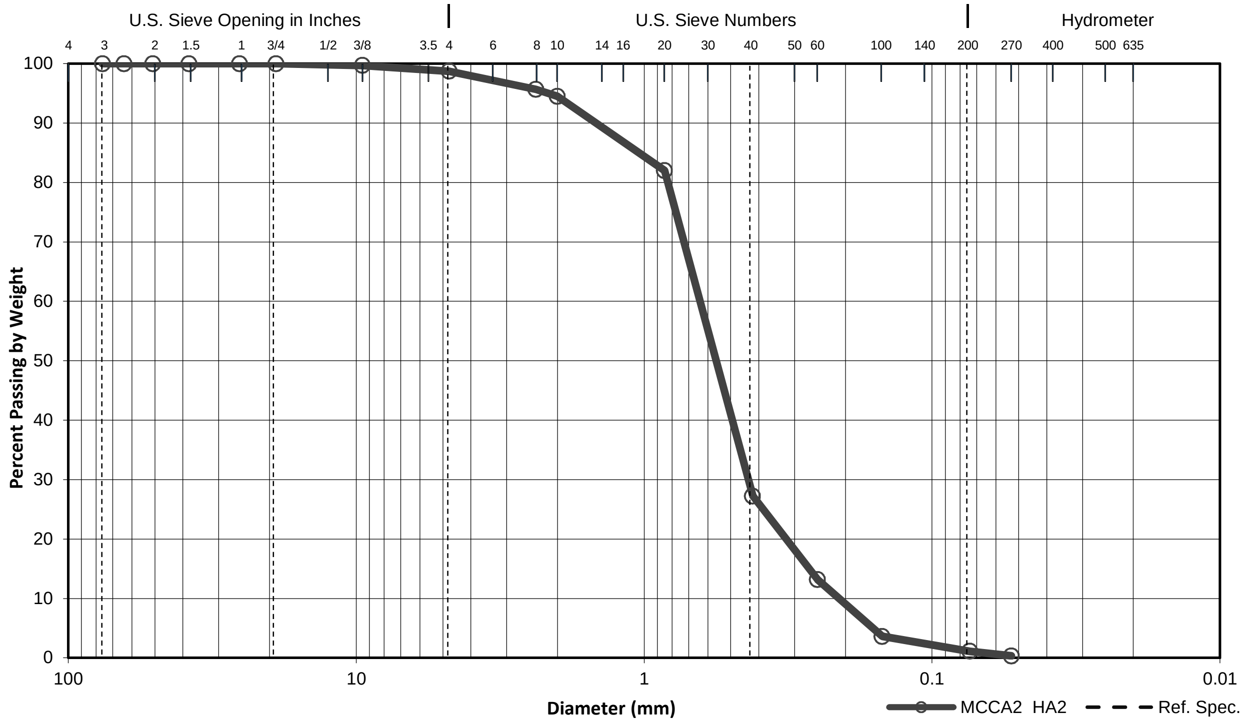
GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

Project Name	Project Number	Date Sampled	Date Tested	Tested By
BHPS	**KH150387A**	**7/22/2016**	**9/1/2016**	**MS**
Sample Source	Sample No.	Depth (ft)	Soil Description	
Onsite	**MCCA2 HA2**	**0.1-0.6**	**SAND, trace silt, trace gravel (SP)**	
Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification	
477.5	**0**	**0.210**	**Bioretention soil mix: burned sample**	



Cobb.	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

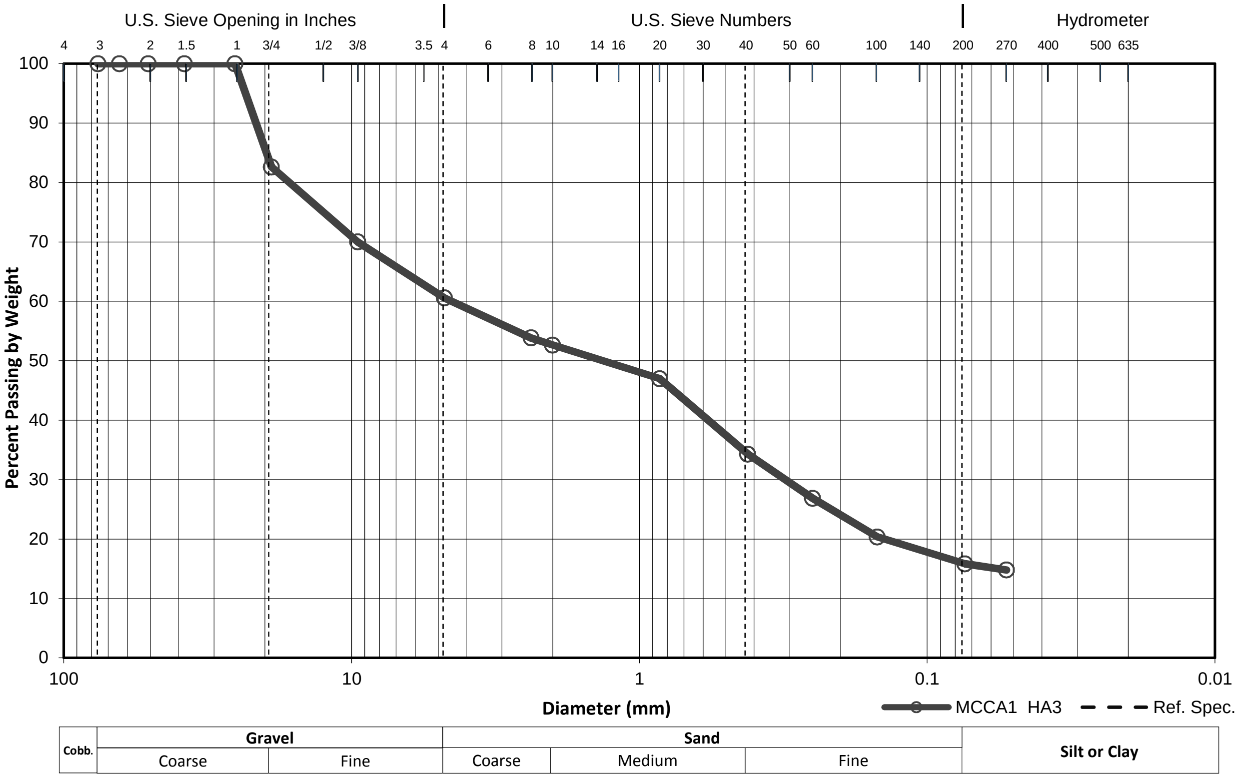
Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4		0.0	100.0		
3/4	19		0.0	100.0		
3/8	9.51	1.4	0.3	99.7		
#4	4.76	6.1	1.3	98.7		
#8	2.38	20.7	4.3	95.7		
#10	2	26.2	5.5	94.5		
#20	0.85	85.9	18.0	82.0		
#40	0.42	347.4	72.8	27.2		
#60	0.25	414.5	86.8	13.2		
#100	0.149	460.2	96.4	3.6		
#200	0.074	472.1	98.9	1.1		
#270	0.053	475.9	99.7	0.3		

GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

Project Name	Project Number	Date Sampled	Date Tested	Tested By
BHPS	**KH150387A**	**8/24/2016**	**9/15/2016**	**GS**

Sample Source	Sample No.	Depth (ft)	Soil Description
Onsite	**MCCA1 HA3**	**1.0-1.4**	**silty, very gravelly SAND (SM)**

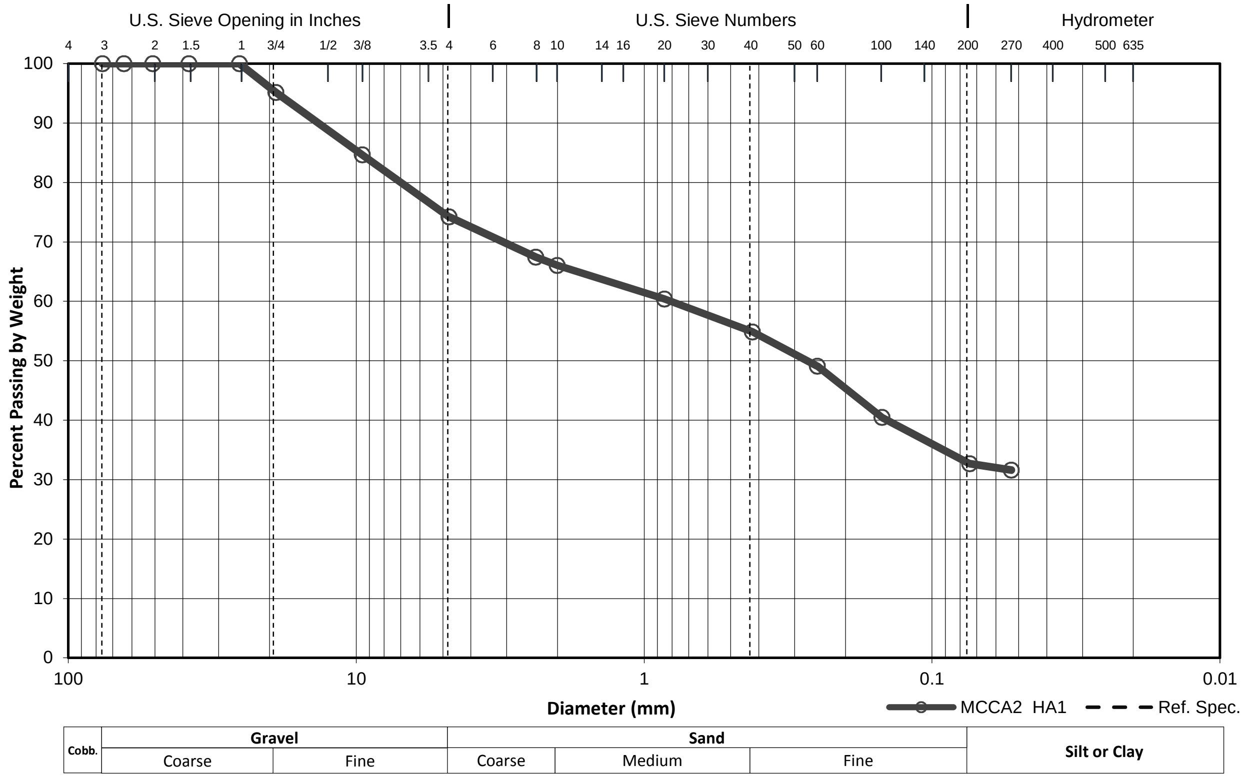
Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification
954.5	**6**	**~0.01**	**Not applicable: native material**



Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4		0.0	100.0		
3/4	19	166.0	17.4	82.6		
3/8	9.51	286.3	30.0	70.0		
#4	4.76	376.2	39.4	60.6		
#8	2.38	440.5	46.2	53.8		
#10	2	451.9	47.3	52.7		
#20	0.85	506.0	53.0	47.0		
#40	0.42	627.1	65.7	34.3		
#60	0.25	698.0	73.1	26.9		
#100	0.149	760.1	79.6	20.4		
#200	0.074	803.5	84.2	15.8		
#270	0.053	813.3	85.2	14.8		

GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

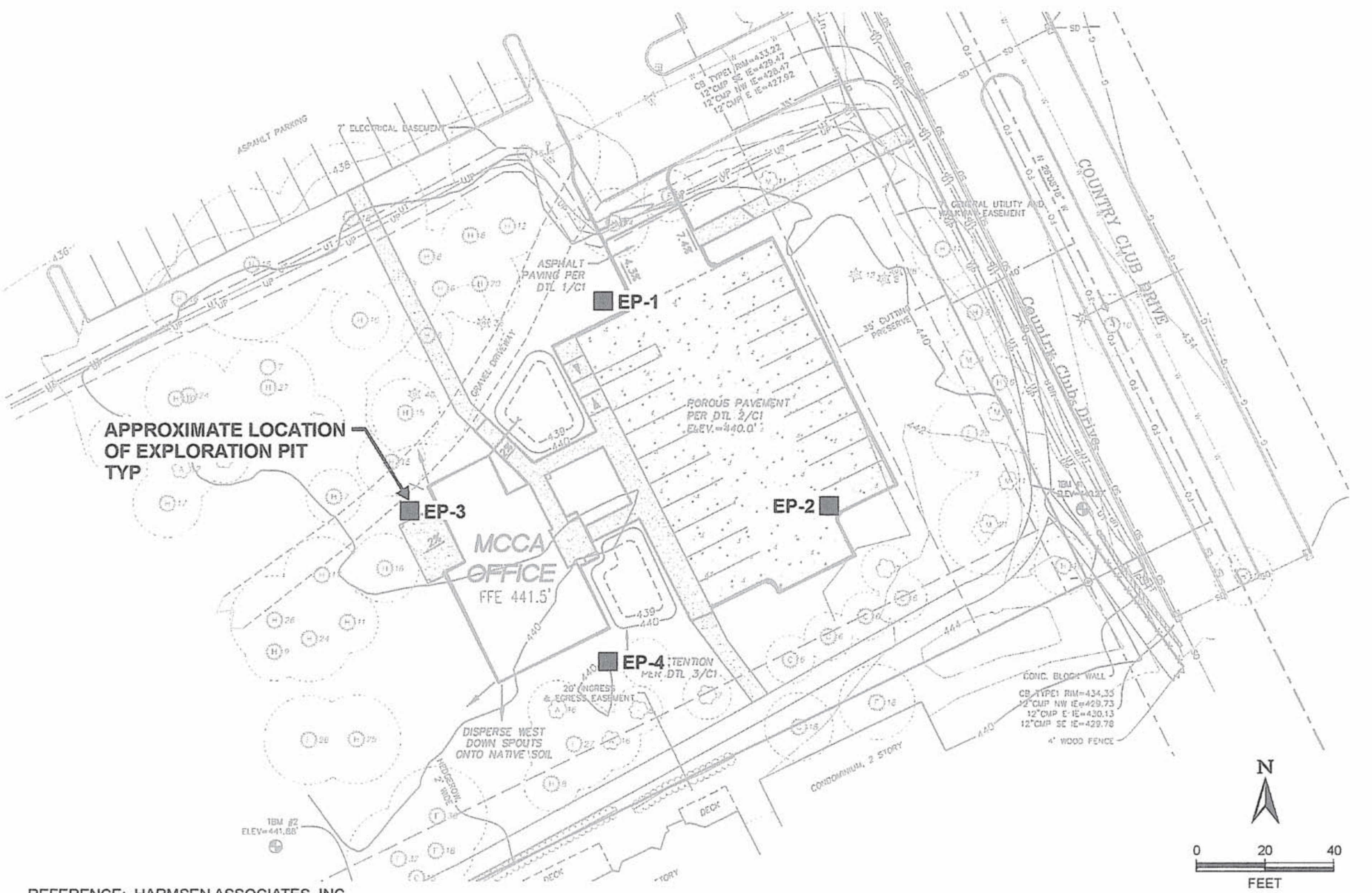
Project Name	Project Number	Date Sampled	Date Tested	Tested By
BHPS	**KH150387A**	**7/22/2016**	**9/15/2016**	**GS**
Sample Source	Sample No.	Depth (ft)	Soil Description	
Onsite	**MCCA2 HA1**	**1-1.2**	**gravelly, very silty SAND (SM)**	
Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification	
522.6	**9**	**<0.01**	**Not applicable: undocumented fill**	



Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4		0.0	100.0		
3/4	19	25.3	4.8	95.2		
3/8	9.51	80.1	15.3	84.7		
#4	4.76	134.8	25.8	74.2		
#8	2.38	170.2	32.6	67.4		
#10	2	177.4	34.0	66.0		
#20	0.85	206.9	39.6	60.4		
#40	0.42	235.9	45.1	54.9		
#60	0.25	266.1	50.9	49.1		
#100	0.149	311.2	59.5	40.5		
#200	0.074	351.8	67.3	32.7		
#270	0.053	357.4	68.4	31.6		

APPENDIX C

Background Soil, Geology, and Ground Water Data (Regional Maps, Previous Studies Exploration Logs and Laboratory Testing Data)



REFERENCE: HARMSEN ASSOCIATES, INC.

Associated Earth Sciences, Inc.

SITE AND EXPLORATION PLAN

MILL CREEK COMMUNITY ASSOCIATION
MILL CREEK, WASHINGTON

FIGURE 2
DATE 6/13
PROJ. NO. KE130200A

LOG OF EXPLORATION PIT NO. EP-1

This log is part of the report prepared by Associated Earth Sciences, Inc. (AESI) for the named project and should be read together with that report for complete interpretation. This summary applies only to the location of this trench at the time of excavation. Subsurface conditions may change at this location with the passage of time. The data presented are a simplification of actual conditions encountered.

Depth (ft)	DESCRIPTION
	Fill Medium dense, very moist, brown, fine to medium SAND, little silt, few fine to coarse gravel (SM).
1	**Weathered Vashon Lodgement Till**
2	Medium dense to dense, very moist, mottled reddish brown, fine to medium SAND, trace coarse sand, little silt, few fine to coarse gravel; diamict; no stratification (SM).
3	
	Vashon Lodgement Till
4	Very dense, very moist, gray, fine SAND, trace medium to coarse sand, little to with silt, few fine to coarse gravel; diamict; no stratification (SM).
5	
6	
7	
8	
9	Dense to very dense, very moist, gray to brown, fine to coarse SAND, little silt, few fine to coarse gravel; interbeds of medium to coarse sand (SM).
10	
11	Bottom of exploration pit at depth 10 feet No seepage. No caving.
12	
13	
14	
15	
16	
17	
18	
19	
20	

Mill Creek Commerciall Association
Mill Creek, WA

Associated Earth Sciences, Inc.

Logged by: LDM
Approved by:

Project No. EE130200A
6/27/13

LOG OF EXPLORATION PIT NO. EP-2

This log is part of the report prepared by Associated Earth Sciences, Inc. (AESI) for the named project and should be read together with that report for complete interpretation. This summary applies only to the location of this trench at the time of excavation. Subsurface conditions may change at this location with the passage of time. The data presented are a simplfication of actual conditions encountered.

Depth (ft)	DESCRIPTION
	Fill Medium dense, very moist, brown, fine to medium SAND, with silt, few fine to coarse gravel (SM).
1	**Weathered Vashon Lodgement Till**
2	Medium dense, very moist, mottled reddish brown, fine to medium SAND, trace coarse sand, little silt, few fine to coarse gravel; diamict; no stratification (SM).
3	**Vashon Lodgement Till**
4	Very dense, very moist, fine SAND, trace medium to coarse sand, little to with silt, little fine to coarse gravel; diamict; no stratification (SM).
5	
6	
7	
8	
9	
10	
11	Bottom of exploration pit at depth 10 feet No seepage. No caving.
12	
13	
14	
15	
16	
17	
18	
19	
20	

Mill Creek Commerciall Association
Mill Creek, WA

Associated Earth Sciences, Inc.

Logged by: LDM
Approved by:

Project No. EE130200A

6/27/13

LOG OF EXPLORATION PIT NO. EP-3

This log is part of the report prepared by Associated Earth Sciences, Inc. (AESI) for the named project and should be read together with that report for complete interpretation. This summary applies only to the location of this trench at the time of excavation. Subsurface conditions may change at this location with the passage of time. The data presented are a simplfication of actual conditions encountered.

Depth (ft)	DESCRIPTION
	Topsoil
1	**Weathered Vashon Lodgement Till**
2	Medium dense, very moist, reddish brown, fine to medium SAND, with silt, few fine gravel; diamict; no stratification (SM).
3	
	Vashon Lodgement Till
4	Very dense, very moist, gray, fine SAND, trace medium to coarse sand, with silt, few fine to coarse gravel; diamict; no stratification (SM).
5	
6	
7	
8	
9	As above.
10	
11	Bottom of exploration pit at depth 10 feet No seepage. No caving.
12	
13	
14	
15	
16	
17	
18	
19	
20	

Mill Creek Commerciall Association
Mill Creek, WA

Associated Earth Sciences, Inc.

Logged by: LDM
Approved by:

Project No. EE130200A

6/27/13

LOG OF EXPLORATION PIT NO. EP-4

Depth (ft)	This log is part of the report prepared by Associated Earth Sciences, Inc. (AESI) for the named project and should be read together with that report for complete interpretation. This summary applies only to the location of this trench at the time of excavation. Subsurface conditions may change at this location with the passage of time. The data presented are a simplfication of actual conditions encountered. **DESCRIPTION**
	Topsoil
1	**Weathered Vashon Lodgement Till**
2	Medium dense, very moist, reddish brown, SAND, trace medium to coarse sand, little silt, few fine to coarse gravel; diamict; no stratification (SM).
3	**Vashon Lodgement Till**
4	Very dense, very moist, gray, fine SAND, trace medium to coarse sand, little silt, few fine to coarse gravel; diamict; no stratification (SM).
5	
6	
7	
8	
9	As above.
10	
11	Bottom of exploration pit at depth 10 feet No seepage. No caving.
12	
13	
14	
15	
16	
17	
18	
19	
20	

Mill Creek Commerciall Association
Mill Creek, WA

Associated Earth Sciences, Inc.

Logged by: LDM

Approved by:

Project No. EE130200A

6/27/13

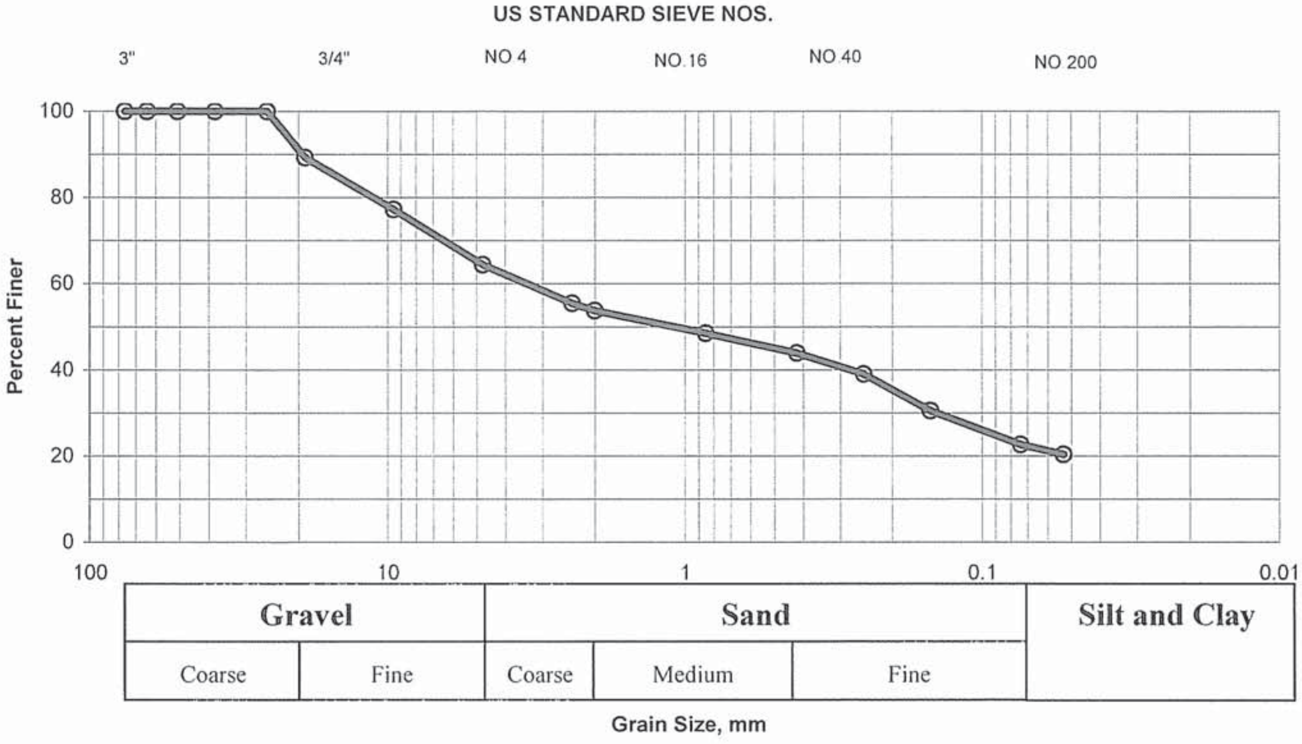
KCTP3 130200.GPJ June 29, 2013

GRAIN SIZE ANALYSIS - MECHANICAL

Date Sampled	Project	Project No.		Soil Description
6/27/2013	**Mill Creek Community Assoc.**	**EE130200A**		**Weathered Till**
Tested By	Location	EB/EP No	Depth	**Reddish brown, fine to coarse SAND little silt with fine to coarse gravel**
BCM	**Onsite**	**EP-2**	**2 ft**	

Wt. of moisture wet sample + Tare	404.44	Total Sample Tare	332.23
Wt. of moisture dry Sample + Tare	371.57	Total Sample wt + tare	1473.67
Wt. of Tare	100.89	Total Sample Wt	1141.4
Wt. of moisture Dry Sample	270.68	Total Sample Dry Wt	1017.8
Moisture %	12%		

					Specification Requirements	
Sieve No.	Diam. (mm)	Wt. Retained (g)	% Retained	% Passing	Minimum	Maximum
3	76.1		0.0	100.0	-	-
2.5	64		0.0	100.0	-	-
2	50.8		0.0	100.0	-	-
1.5	38.1		0.0	100.0	-	-
1	25.4		0.0	100.0	-	-
3/4	19	109.25	10.7	89.3		
3/8	9.51	232.03	22.8	77.2		
#4	4.76	362.38	35.6	64.4		
#8	2.38	453.23	44.5	55.5		
#10	2	470.9	46.3	53.7		
#20	0.85	524.67	51.5	48.5		
#40	0.42	571.13	56.1	43.9		
#60	0.25	621.03	61.0	39.0		
#100	0.149	707.35	69.5	30.5		
#200	0.074	787.41	77.4	22.6		
#270	0.053	810.71	79.7	20.3		



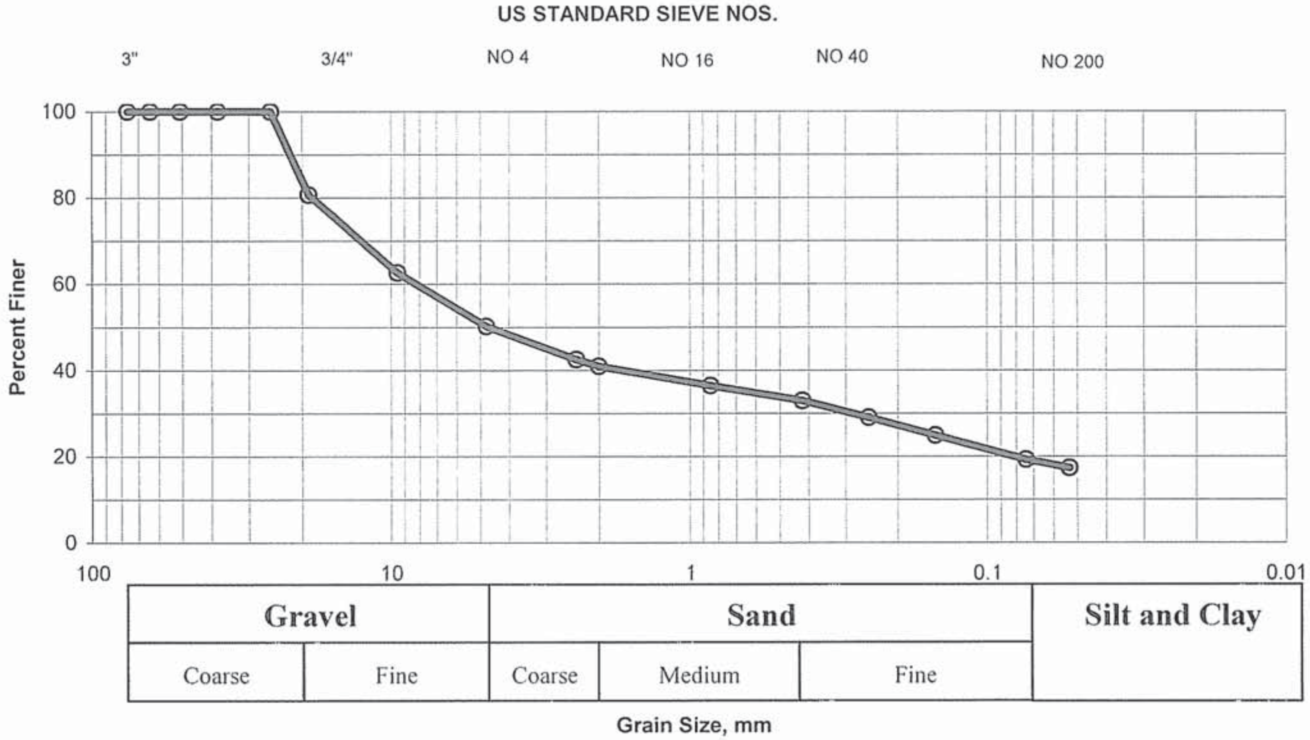
GRAIN SIZE ANALYSIS - MECHANICAL

Date Sampled **6/27/2013**	Project **Mill Creek Community Assoc.**	Project No. **EE130200A**		Soil Description **Weathered Till**
Tested By **BCM**	Location **Onsite**	EB/EP No **EP-1**	Depth **1.5 ft**	**Reddish brown, fine to coarse SAND little silt with fine to coarse gravel**

Wt. of moisture wet sample + Tare	360
Wt. of moisture dry Sample + Tare	332.78
Wt. of Tare	100.9
Wt. of moisture Dry Sample	231.88
Moisture %	12%

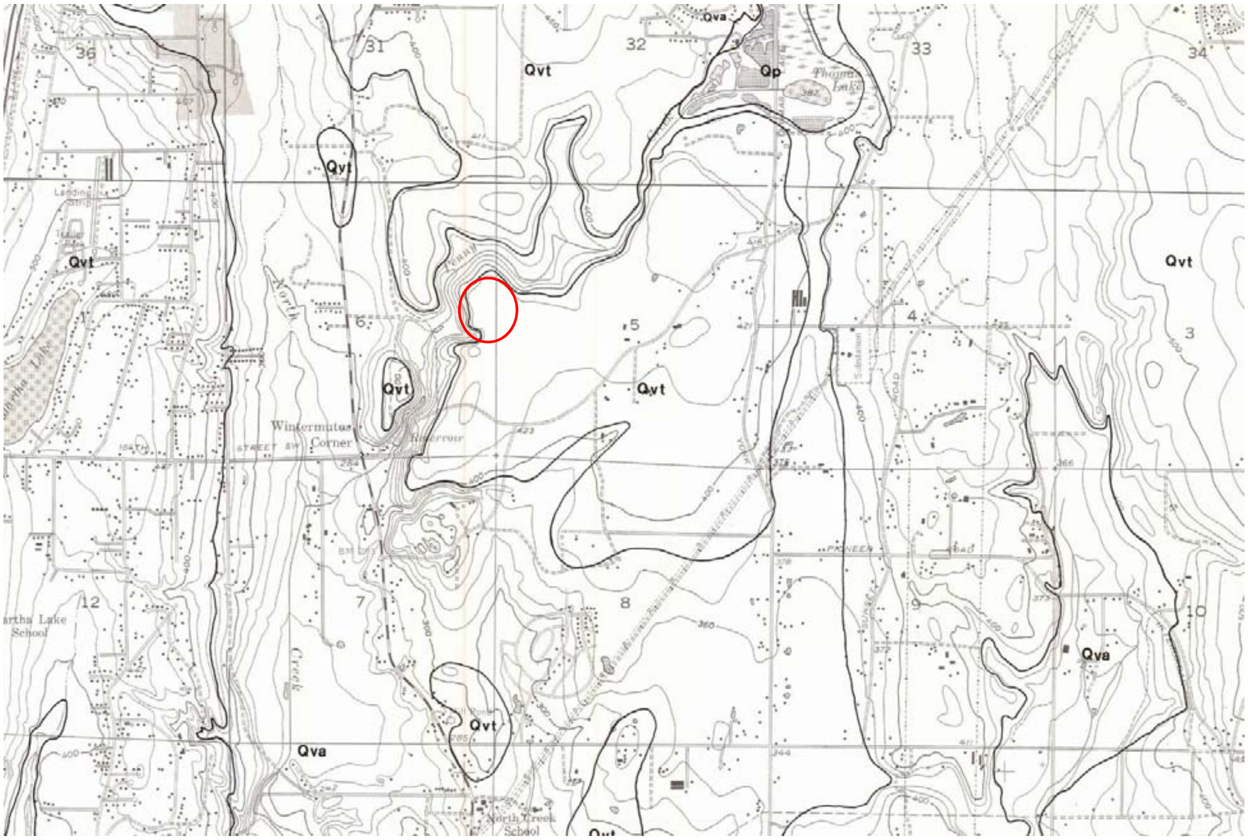
Total Sample Tare	394.25
Total Sample wt + tare	1509.83
Total Sample Wt	1115.6
Total Sample Dry Wt	998.4

					Specification Requirements	
Sieve No.	Diam. (mm)	Wt. Retained (g)	% Retained	% Passing	Minimum	Maximum
3	76.1		0.0	100.0	-	-
2.5	64		0.0	100.0	-	-
2	50.8		0.0	100.0	-	-
1.5	38.1		0.0	100.0	-	-
1	25.4		0.0	100.0	-	-
3/4	19	192.92	19.3	80.7		
3/8	9.51	373.29	37.4	62.6		
#4	4.76	497.5	49.8	50.2		
#8	2.38	573.97	57.5	42.5		
#10	2	590.04	59.1	40.9		
#20	0.85	635.09	63.6	36.4		
#40	0.42	669.68	67.1	32.9		
#60	0.25	709.04	71.0	29.0		
#100	0.149	749.91	75.1	24.9		
#200	0.074	806.08	80.7	19.3		
#270	0.053	825.27	82.7	17.3		

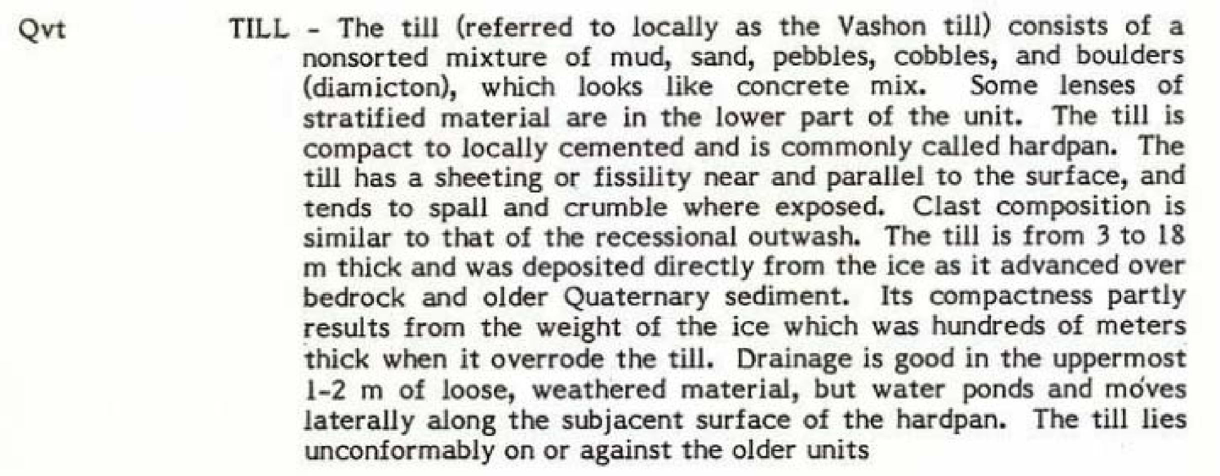


ASSOCIATED EARTH SCIENCES, INC.

911 5th Ave , Suite 100 Kirkland, WA 98033 425-827-7701 FAX 425-827-5424

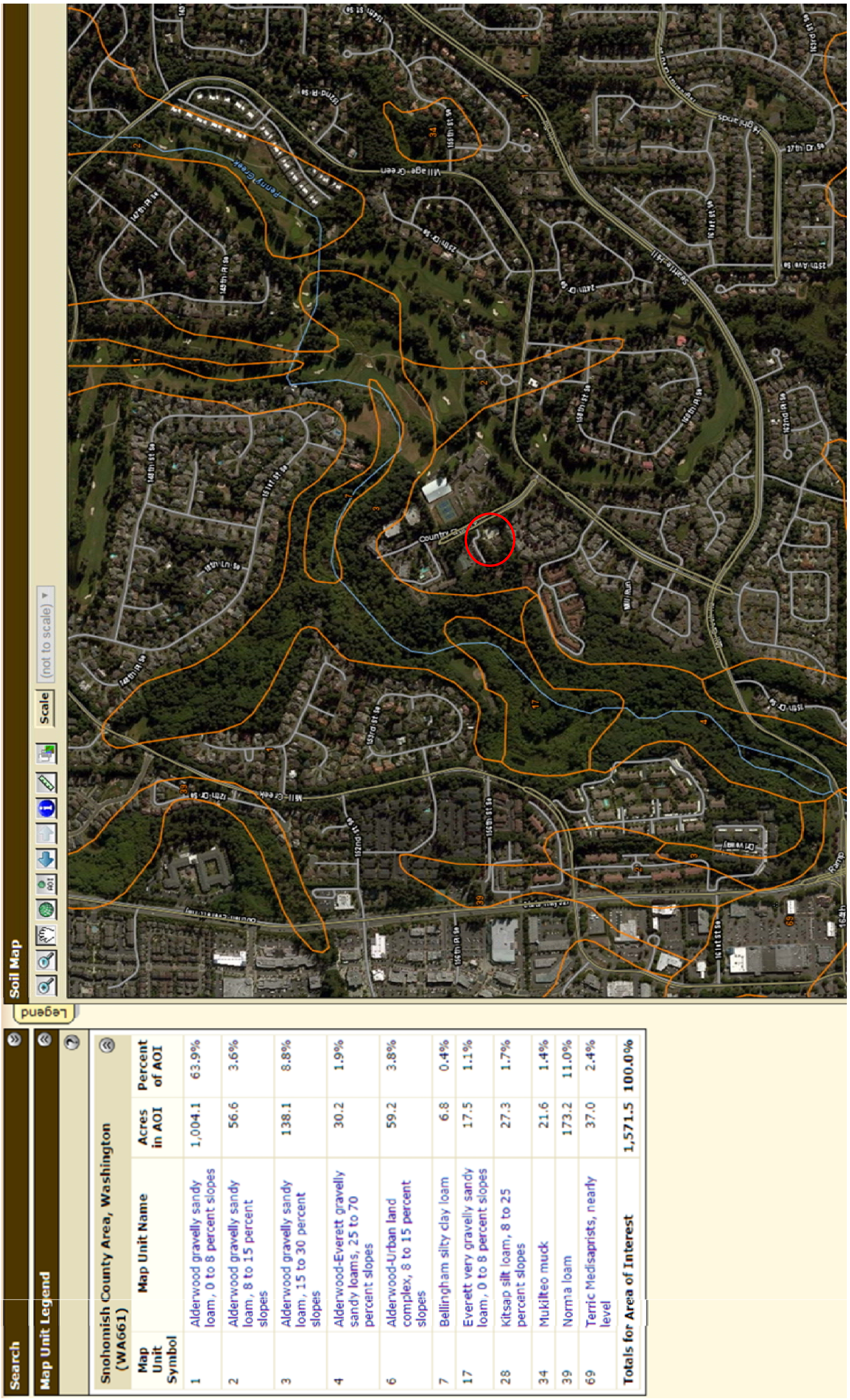


Approximate location of facilities indicated by red outline



Qvt TILL - The till (referred to locally as the Vashon till) consists of a nonsorted mixture of mud, sand, pebbles, cobbles, and boulders (diamicton), which looks like concrete mix. Some lenses of stratified material are in the lower part of the unit. The till is compact to locally cemented and is commonly called hardpan. The till has a sheeting or fissility near and parallel to the surface, and tends to spall and crumble where exposed. Clast composition is similar to that of the recessional outwash. The till is from 3 to 18 m thick and was deposited directly from the ice as it advanced over bedrock and older Quaternary sediment. Its compactness partly results from the weight of the ice which was hundreds of meters thick when it overrode the till. Drainage is good in the uppermost 1-2 m of loose, weathered material, but water ponds and moves laterally along the subjacent surface of the hardpan. The till lies unconformably on or against the older units

Excerpt from Geologic Map of the Bothell quadrangle, Snohomish and King Counties, Washington



Snohomish County Area, Washington (WA661)

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
1	Alderwood gravelly sandy loam, 0 to 8 percent slopes	1,004.1	63.9%
2	Alderwood gravelly sandy loam, 8 to 15 percent slopes	56.6	3.6%
3	Alderwood gravelly sandy loam, 15 to 30 percent slopes	138.1	8.8%
4	Alderwood-Everett gravelly sandy loams, 25 to 70 percent slopes	30.2	1.9%
6	Alderwood-Urban land complex, 8 to 15 percent slopes	59.2	3.8%
7	Bellingham silty clay loam	6.8	0.4%
17	Everett very gravelly sandy loam, 0 to 8 percent slopes	17.5	1.1%
28	Kitsap silt loam, 8 to 25 percent slopes	27.3	1.7%
34	Mukilteo muck	21.6	1.4%
39	Norma loam	173.2	11.0%
69	Terric Medisaprists, nearly level	37.0	2.4%
Totals for Area of Interest		**1,571.5**	**100.0%**

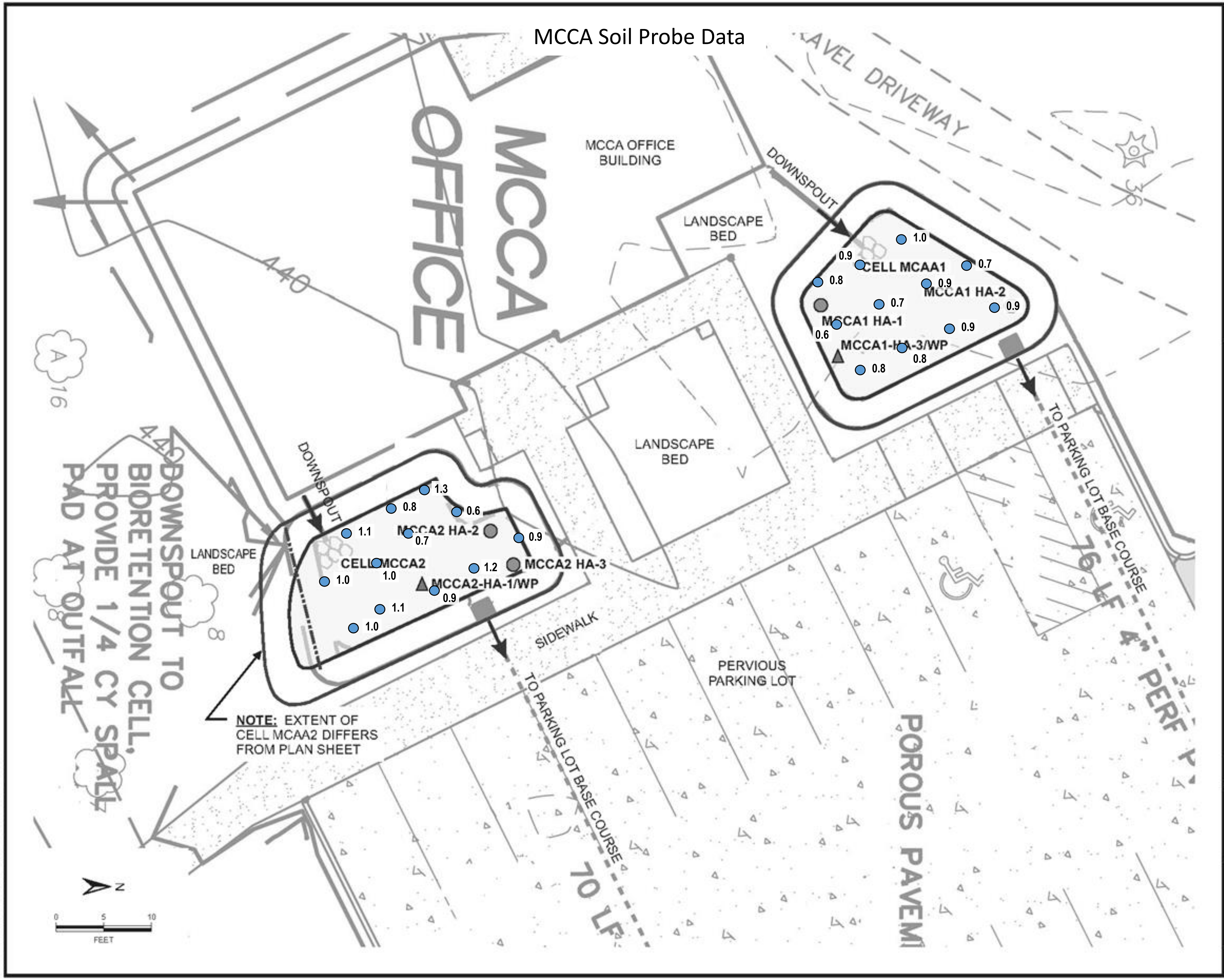
Approximate location of facilities indicated by red outline

Excerpt from Natural Resources Conservation Service, 2016, Web soil survey

APPENDIX D

Soil Probe, Level Survey, and Field Infiltration Testing Data

MCCA Soil Probe Data



LEGEND:

● HA HAND AUGER

▲ WP WELL POINT

BASE OF FACILITY

TOP OF FACILITY SLOPE

INFLOW / OVERFLOW DIRECTION

GAS LINE

● 0.8 Soil Probe and Depth of Loose Soil

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:

1. BASE MAP REFERENCE: HARMSEN & ASSOCIATES INC, MILL CREEK COMMUNITY ASSOCIATION, DRAINAGE & PAVING PLAN, C3, 9/12/2013

BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION.

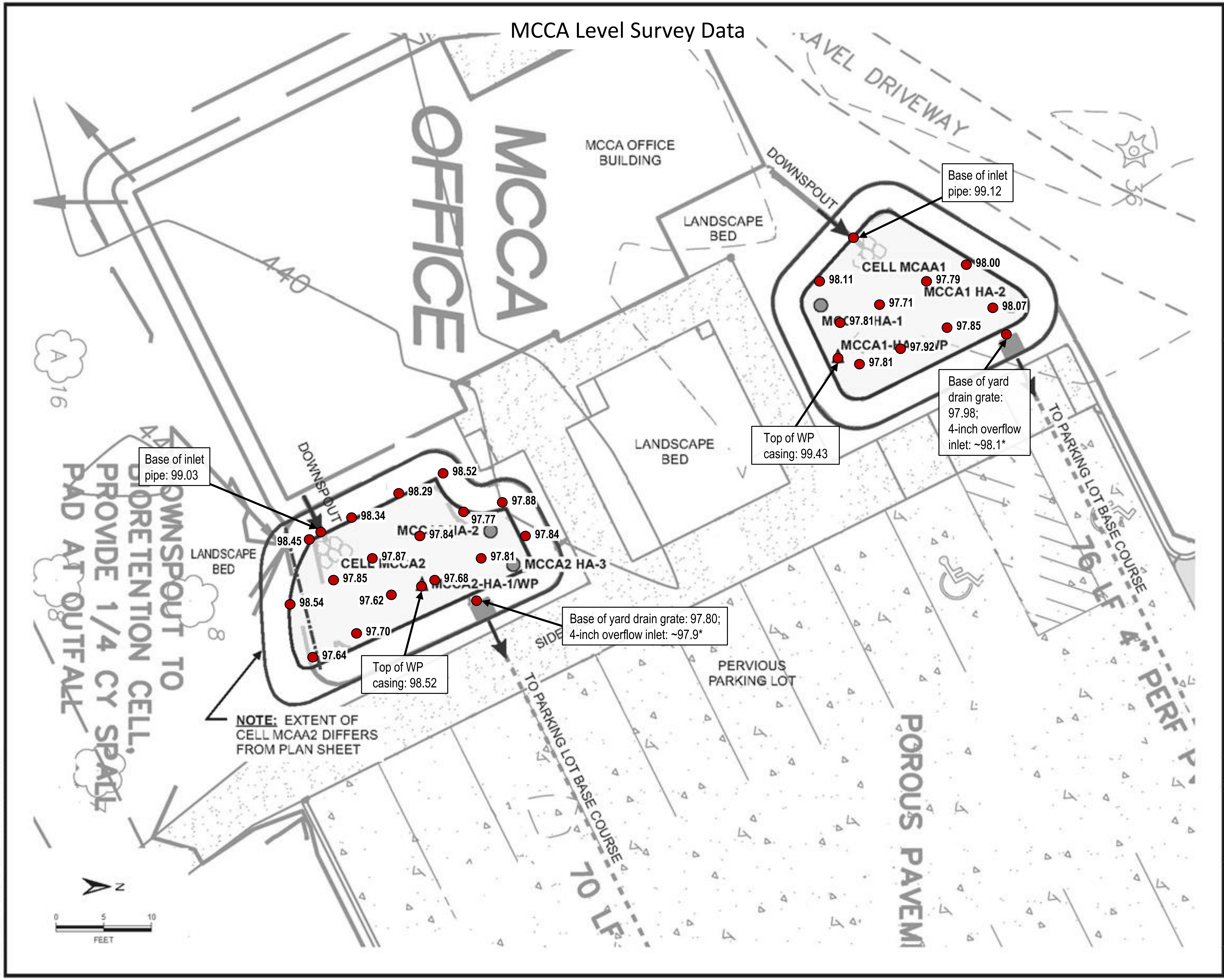
associated earth sciences incorporated

SOIL PROBE DATA
MCCA SITE
BIORETENTION HYDROLOGIC PERFORMANCE
MILL CREEK, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	D1

150387 BHPS MCCA \ 150387 Site-Expl.cdr PAGE 4: MCCA

MCCA Level Survey Data



LEGEND:

- ● HA HAND AUGER
- ▲ WP WELL POINT
- BASE OF FACILITY
- TOP OF FACILITY SLOPE
- INFLOW / OVERFLOW DIRECTION
- GAS LINE
- ● 98.66 Elevation, Project Datum (see text)

*Measured height of 4-inch-pipe invert at 0.1-feet above base of yard drain grate; unable to survey directly.

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

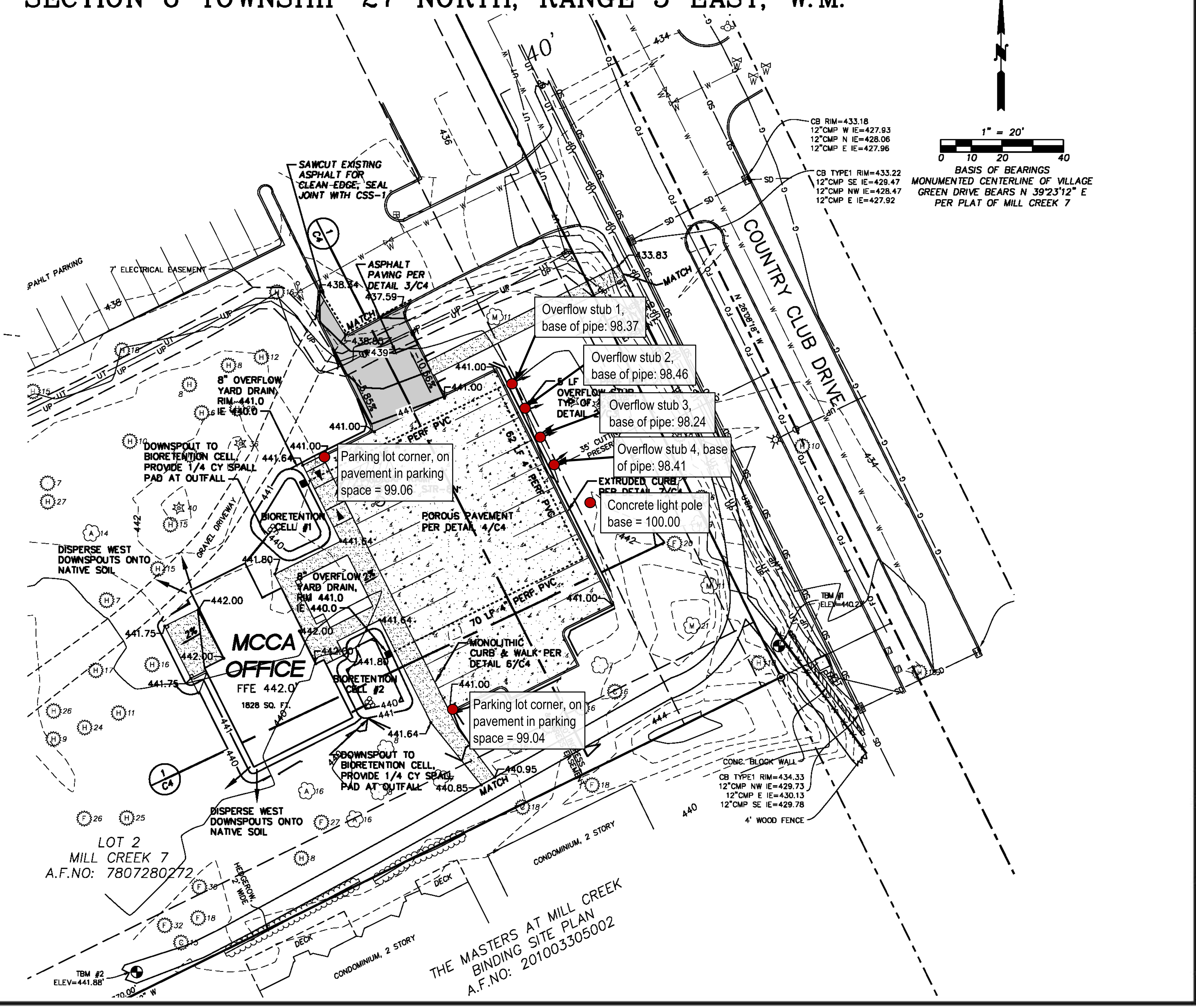
NOTES:
1. BASE MAP REFERENCE: HARMSEN & ASSOCIATES INC, MILL CREEK COMMUNITY ASSOCIATION, DRAINAGE & PAVING PLAN, C3, 9/12/2013

associated earth sciences incorporated

LEVEL SURVEY DATA
MCCA SITE
BIORETENTION HYDROLOGIC PERFORMANCE
MILL CREEK, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	D2

SECTION 6 TOWNSHIP 27 NORTH, RANGE 5 EAST, W.M.



● 98.66 Elevation, Project Datum (see text)

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:
1. BASE MAP REFERENCE: HARMSEN & ASSOCIATES INC, MILL CREEK COMMUNITY ASSOCIATION, DRAINAGE & PAVING PLAN, C3, 9/12/2013

BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION.

associated earth sciences incorporated

LEVEL SURVEY DATA
MCCA SITE
BIORETENTION HYDROLOGIC PERFORMANCE
MILL CREEK, WASHINGTON

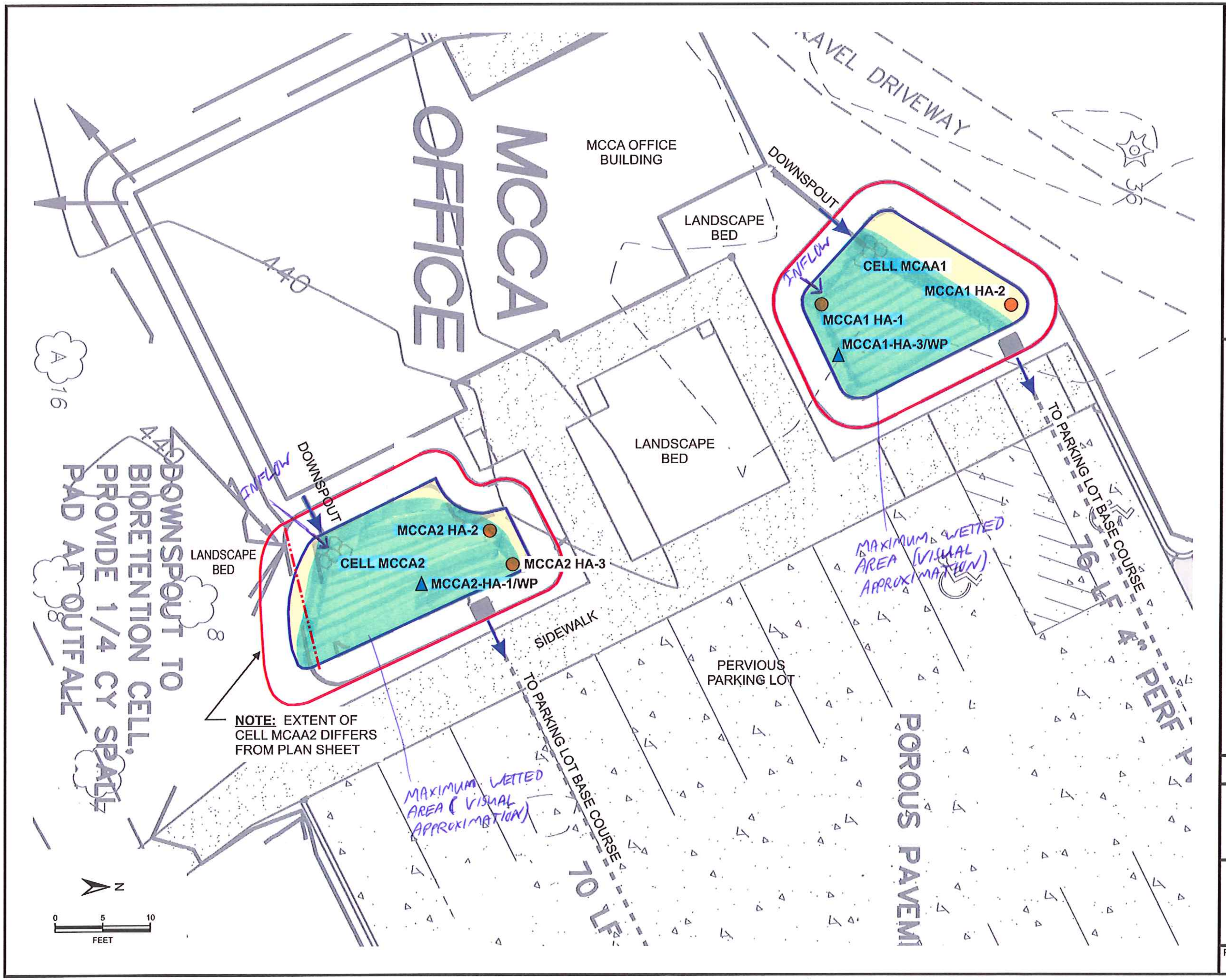
PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	D3

Cell MCCA1 and MCCA2
Level Survey Data

Location	**MCCA1 Elevation (feet, project datum)**	**MCCA2 Elevation (feet, project datum)**
Top of cement lamp post base, east side of parking lot	100	
Base of inflow pipe	99.12	99.03
Base of facility, low point	97.71	97.62
Base of 8-inch overflow yard drain grate	97.98	97.80
Base of 4-inch overflow pipe*	~98.1*	~97.9*
Top of well point	99.43	98.52
Base of lowest overflow stub	98.24	
Points in base of cells	On map	

Cell MCCA1 and MCCA2
Probe Survey Data List (Excludes Outliers)

MCCA1, Probe Penetration (feet):	**MCCA2, Probe Penetration (feet):**
0.9	1.3
0.7	0.8
0.9	1.1
0.9	0.6
1	0.7
0.7	1
0.8	1
0.9	0.9
0.8	1.2
0.8	0.9
0.6	1.1
	1
AVERAGE: 0.8	AVERAGE: 1.0



NOTE: EXTENT OF CELL MCAA2 DIFFERS FROM PLAN SHEET

LEGEND:

● HA	HAND AUGER
▲ WP	WELL POINT
🟨	BASE OF FACILITY
▭	TOP OF FACILITY SLOPE
→	INFLOW / OVERFLOW DIRECTION
— · · —	GAS LINE

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:
1. BASE MAP REFERENCE: HARMSEN & ASSOCIATES INC, MILL CREEK COMMUNITY ASSOCIATION, DRAINAGE & PAVING PLAN, C3, 9/12/2013

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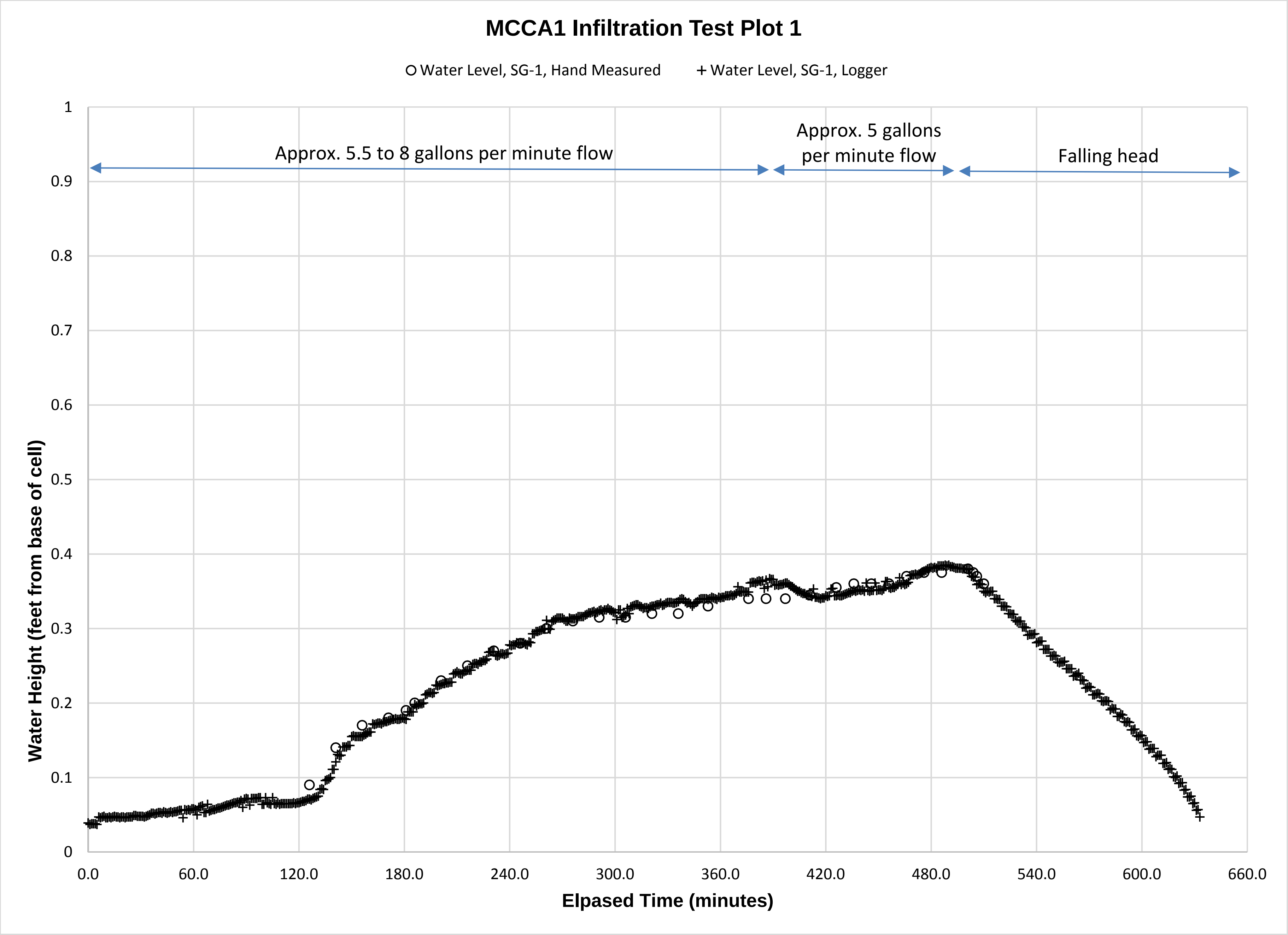
WETTED AREA
MCCA SITE
BIORETENTION HYDROLOGIC PERFORMANCE
MILL CREEK, WASHINGTON

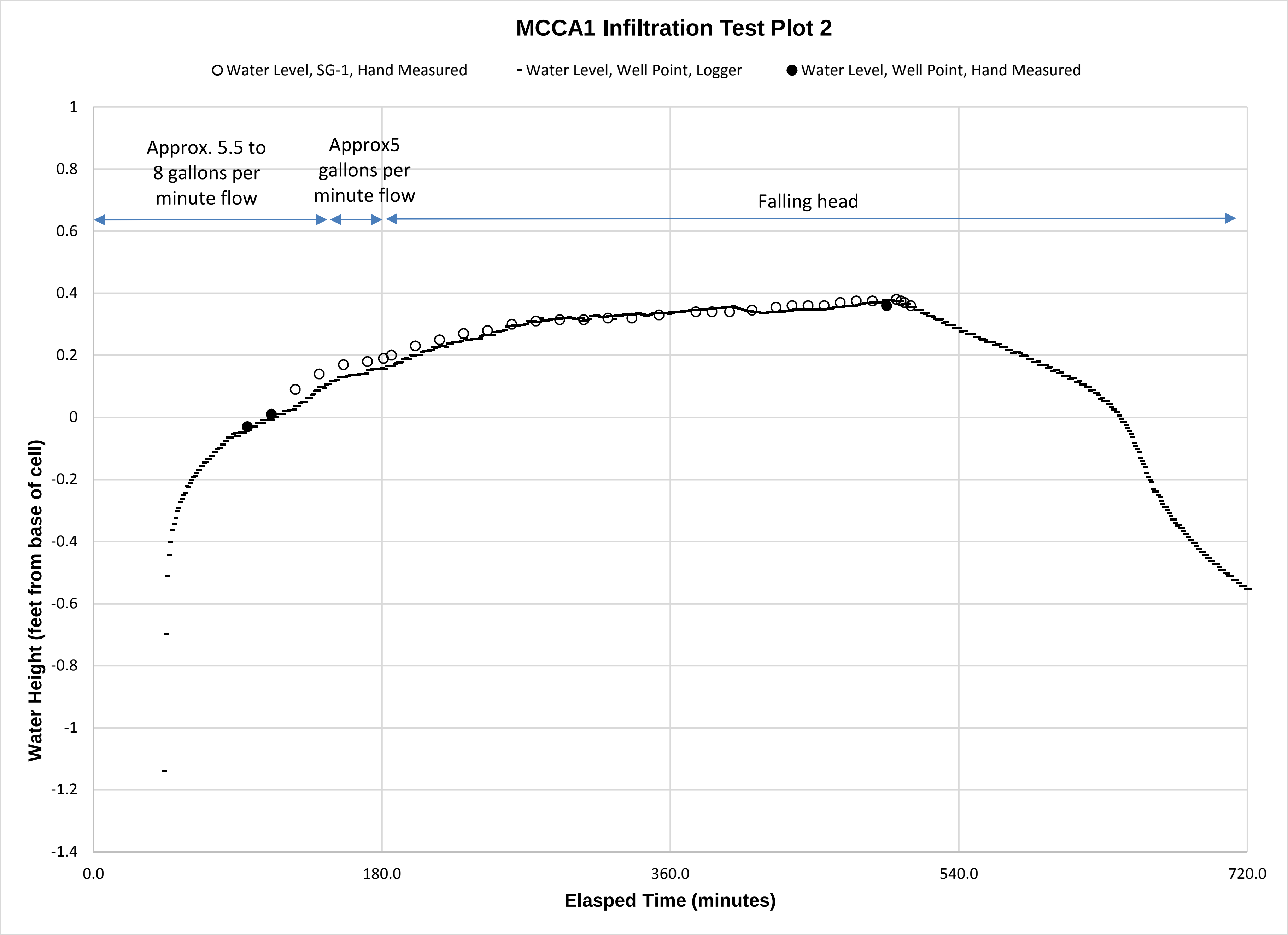
PROJ NO. KH150387A
DATE: 10/16
FIGURE: APPENDIX D

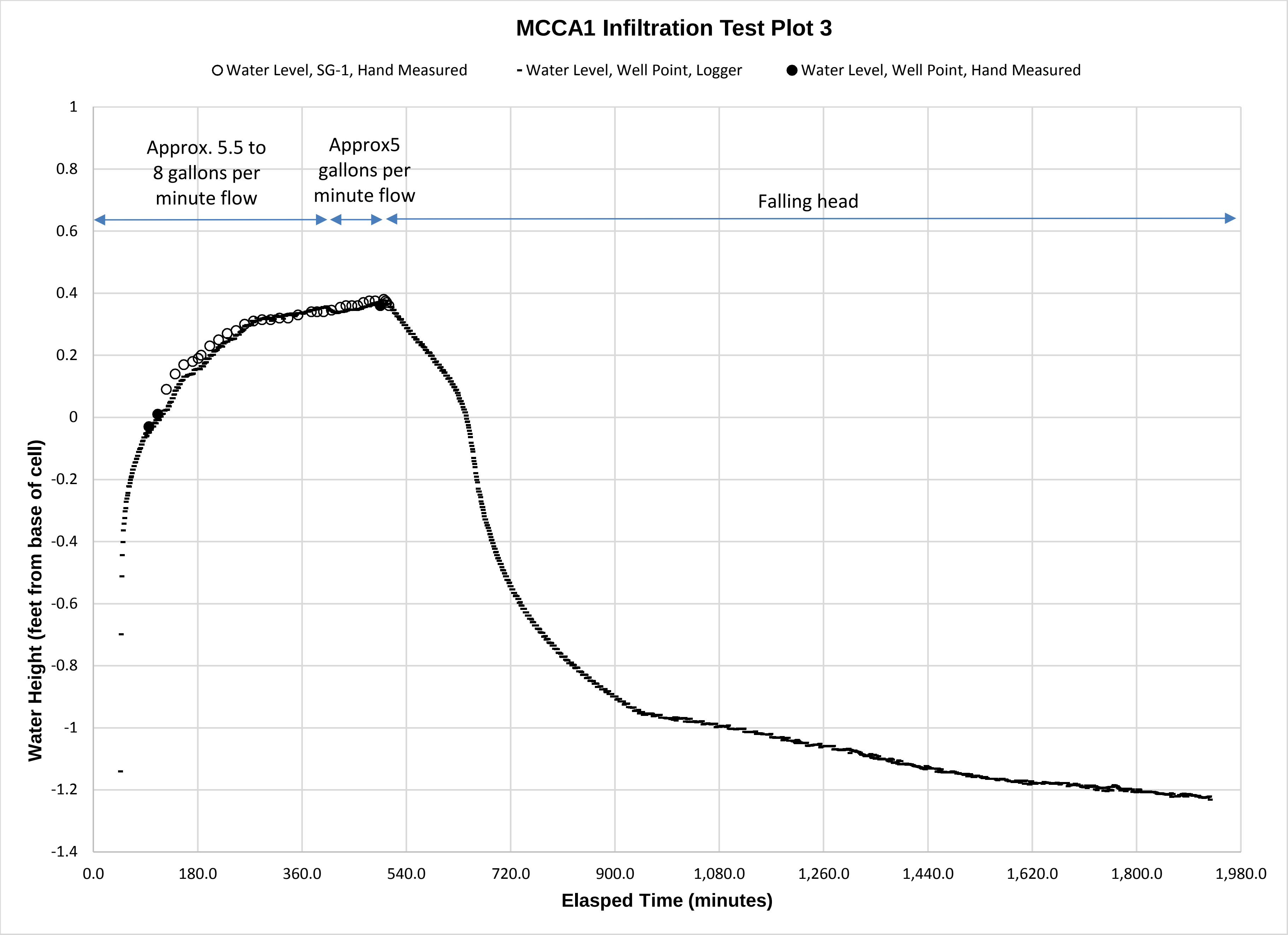
Project Name	Bioretention Hydrologic Performance Assessment	**Receptor Soils**	Bioretention Soil over Qvt
Project Number	KH150387A	**Testing Performed By**	ADY
Date	8/26/16		
Weather	Cloudy		
Test No.	MCCA1 IT-1		
Meter	FM1/FM3		
Water Source	Hose bib		

Time (24-hr)	Total (min)	Flow Rate (gpm)	Totalizer (gal)	Head (temporary staff gauge SG-1, feet)	Wetted area (ft^2)	Depth to water, well point, from top of casing (feet)	Notes
7:54:00	0.0	~5	0			Dry	Flow on
7:55:00	1.0	~5					Flow off, fix hose leaks
7:57:00	3.0	5.7					Flow on
8:03:00	9.0	5.67	39				
8:15:00	21.0	5.82	109				
8:34:00	40.0	5.84	219				
9:00:00	66.0	5.84	372				
9:15:00	81.0	5.59	457				
9:30:00	96.0	5.89	549			1.75	
9:45:00	111.0	6.09	638			1.71	
10:00:00	126.0	6.09	727	0.09			
10:15:00	141.0	6.08	824	0.14			
10:30:00	156.0	6.11	913	0.17			
10:45:00	171.0	6.13	1003	0.18			
10:55:00	181.0	7.82		0.19			
11:00:00	186.0	7.82	1108	0.20			
11:15:00	201.0	7.84	1223	0.23			
11:30:00	216.0	7.82	1342	0.25			
11:45:00	231.0	7.9	1455	0.27			
12:00:00	246.0	7.84	1572	0.28			
12:15:00	261.0	7.84	1690	0.30			

Time (24-hr)	Total (min)	Flow Rate (gpm)	Totalizer (gal)	Head (temporary staff gauge SG-1, feet)	Wetted area (ft^2)	Depth to water, well point, from top of casing (feet)	Notes
12:30:00	276.0	7.87	1805	0.31			
12:45:00	291.0	6.04		0.32			
13:00:00	306.0	5.55	1983	0.32			
13:15:00	321.0	5.55	2064	0.32			
13:30:00	336.0	5.53		0.32			
13:47:00	353.0	5.55	2245	0.33			
14:10:00	376.0	5.55	2377	0.34			
14:20:00	386.0	5.11	2422	0.34			
14:31:00	397.0	5.14	2478	0.34			
14:45:00	411.0	4.99	2546	0.35			
15:00:00	426.0	4.99	2623	0.36	180		
15:10:00	436.0	4.97	2674	0.36			
15:20:00	446.0	4.99	2722	0.36			
15:30:00	456.0	5	2772	0.36			
15:40:00	466.0	4.97	2824	0.37			
15:50:00	476.0	4.99	2872	0.38			
16:00:00	486.0	4.97	2925	0.38	180		
16:15:00	501.0	4.99	2998	0.38		1.36 feet at 16:09	Flow off, beign falling head
16:18:00	504.0			0.38			
16:20:00	506.0			0.37			
16:24:00	510.0			0.36			
16:29:00	515.0			0.35			
16:34:00	520.0			0.34			
16:38:00	524.0			0.33			
16:40:00	526.0			0.33			
16:45:00	531.0			0.32		8/29/2016, dry at 07:00	End test. Well point datalogger retrieved 8/29/2016


MCCA1 Infiltration Test Plot 1
○ Water Level, SG-1, Hand Measured
+ Water Level, SG-1, Logger
Approx. 5.5 to 8 gallons per minute flow
Approx. 5 gallons per minute flow
Falling head
Water Height (feet from base of cell)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.0
60.0
120.0
180.0
240.0
300.0
360.0
420.0
480.0
540.0
600.0
660.0
Elpased Time (minutes)

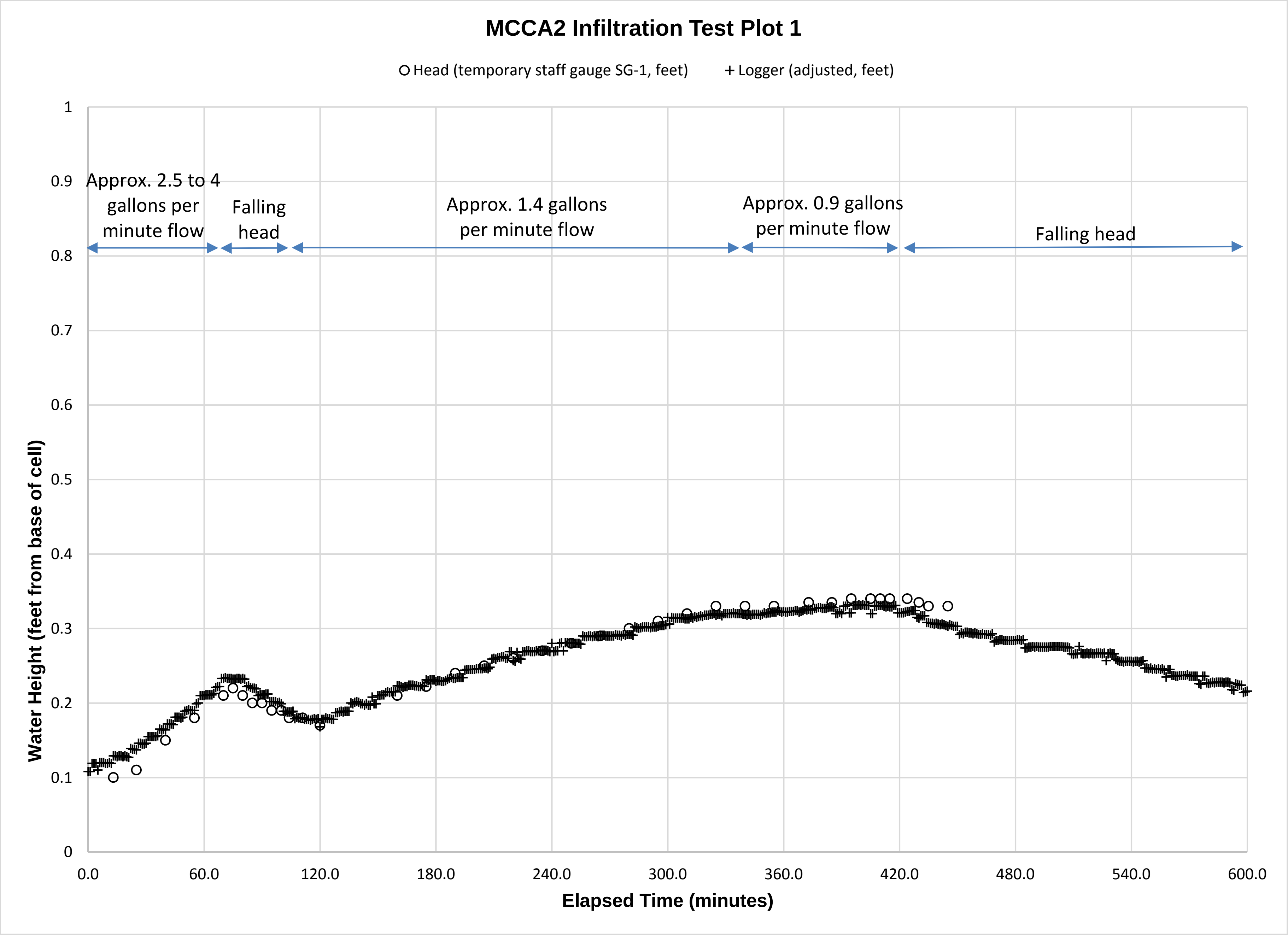

MCCA1 Infiltration Test Plot 2
○ Water Level, SG-1, Hand Measured
- Water Level, Well Point, Logger
● Water Level, Well Point, Hand Measured
Approx. 5.5 to 8 gallons per minute flow
Approx5 gallons per minute flow
Falling head
Water Height (feet from base of cell)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
0.0
180.0
360.0
540.0
720.0
Elasped Time (minutes)


MCCA1 Infiltration Test Plot 3
○ Water Level, SG-1, Hand Measured
- Water Level, Well Point, Logger
● Water Level, Well Point, Hand Measured
Approx. 5.5 to 8 gallons per minute flow
Approx5 gallons per minute flow
Falling head
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
Water Height (feet from base of cell)
0.0
180.0
360.0
540.0
720.0
900.0
1,080.0
1,260.0
1,440.0
1,620.0
1,800.0
1,980.0
Elasped Time (minutes)

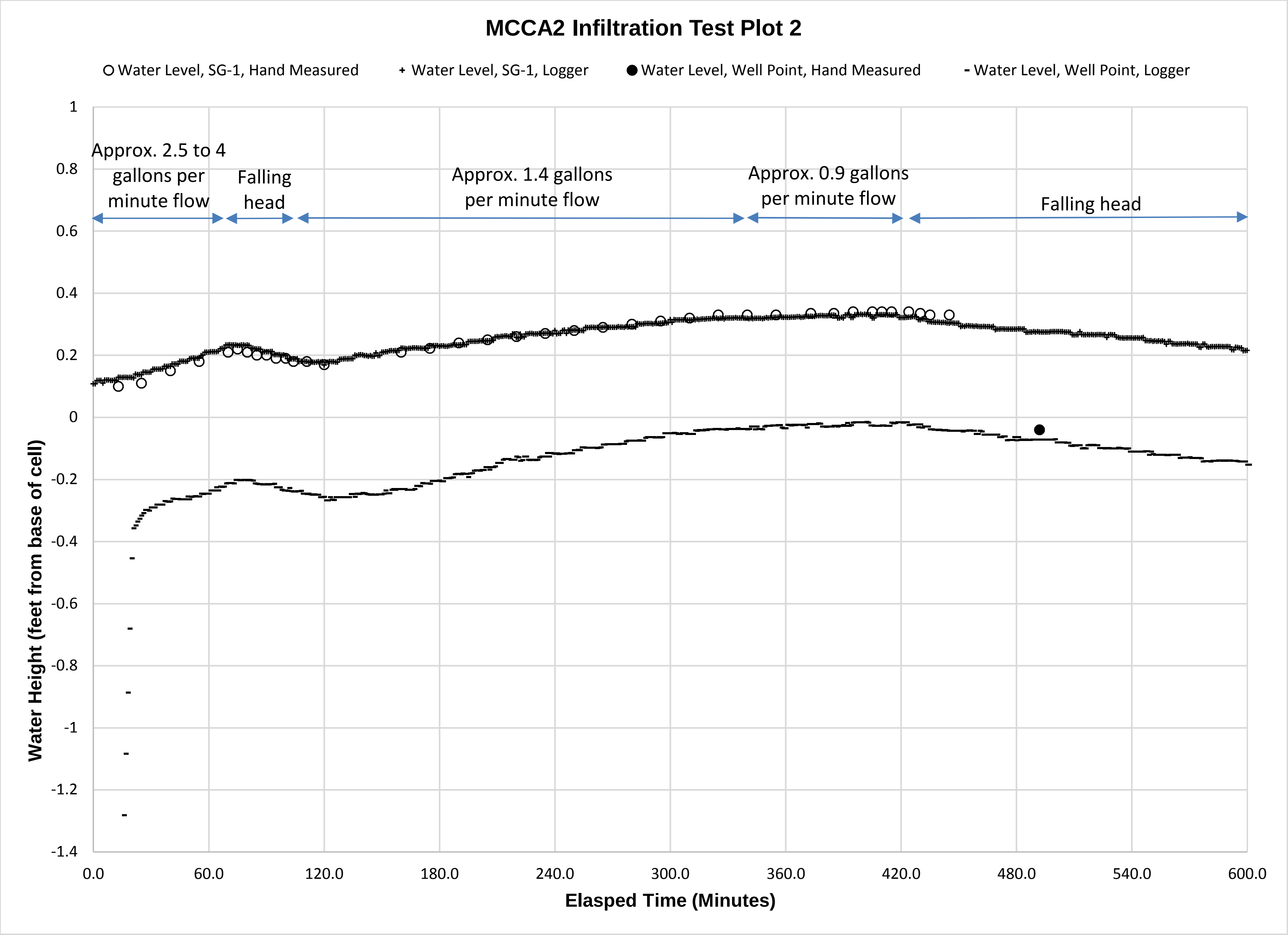
Project Name	Bioretention Hydrologic Performance Assessment	**Receptor Soils**	Bioretention Soil over Qvt/Fill
Project Number	KH150387A	**Testing Performed By**	ADY
Date	8/8/16		
Weather	cloudy, light rain		
Test No.	MCCA2 IT-1		
Meter	FM1/FM3		
Water Source	Hose bib		

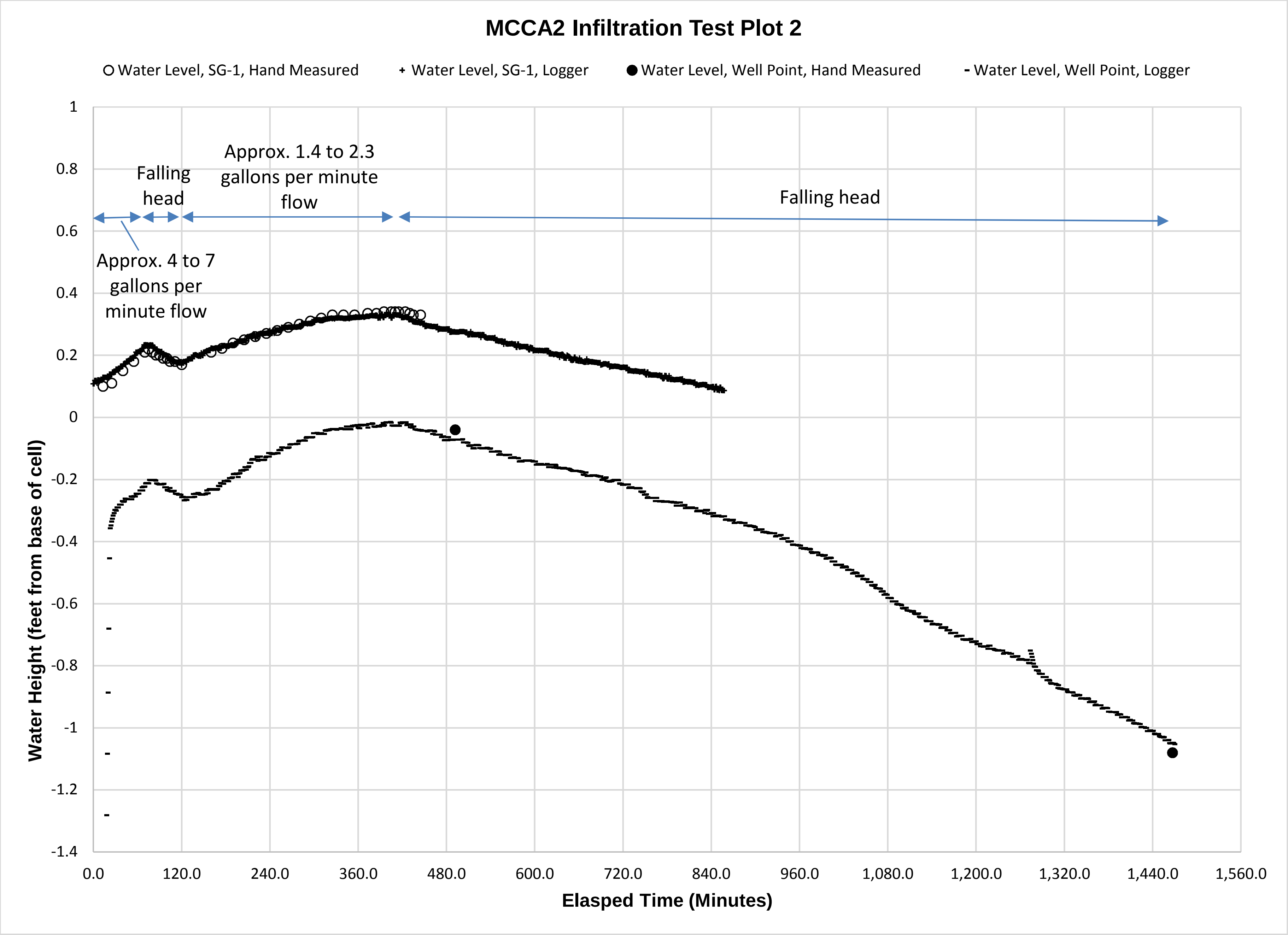
Time (24-hr)	Total (min)	Flow Rate (gpm)	Totalizer (gal)	Head (temporary staff gauge SG-2, feet)	Wetted area (ft^2)	Depth to water, well point, from top of casing, feet	Notes
8:58:00	0.0	2.60	0			Dry	Flow on
8:59:00	0.0						Flow off, fix hose leaks
9:05:00	0.0	2.44					Flow on
9:11:00	6.0	4.18	28				
9:18:00	13.0	4.20	58	0.1			
9:30:00	25.0	4.22	107	0.11			
9:45:00	40.0	4.22	171	0.15			
10:00:00	55.0	4.27	234	0.18			
10:15:00	70.0	4.25	298	0.21			
10:20:00	75.0	2.28	312	0.22			
10:25:00	80.0			0.21			Begin short falling head test
10:30:00	85.0			0.2			
10:35:00	90.0			0.2			
10:40:00	95.0			0.19			
10:45:00	100.0			0.19			
10:49:00	104.0			0.18			
10:56:00	111.0	0.34	315	0.18			End short falling head test, resume flow
11:05:00	120.0	0.63	322	0.17			
11:45:00	160.0	1.48	382	0.21			
12:00:00	175.0	1.47	403	0.222			

Time (24-hr)	Total (min)	Flow Rate (gpm)	Totalizer (gal)	Head (temporary staff gauge SG-2, feet)	Wetted area (ft^2)	Depth to water, well point, from top of casing, feet	Notes
12:15:00	190.0	1.47	426	0.24			
12:30:00	205.0	1.48	447	0.25			
12:45:00	220.0	1.44	469	0.26			
13:00:00	235.0	1.46	491	0.27			
13:15:00	250.0	1.44	513	0.28			
13:30:00	265.0	1.45	534	0.29			
13:45:00	280.0	1.46	556	0.3			
14:00:00	295.0	1.43	579	0.31			
14:15:00	310.0	1.43	600	0.32			
14:30:00	325.0	1.40	621	0.33			
14:45:00	340.0	0.89	635	0.33			
15:00:00	355.0	0.91	649	0.33	192		
15:18:00	373.0	0.90	665	0.335			
15:30:00	385.0	0.90	675	0.335			
15:40:00	395.0	0.89	684	0.34		0.84 feet at 15:37	
15:50:00	405.0	0.90	693	0.34			
15:55:00	410.0	0.89	698	0.34			
16:00:00	415.0	0.89	703	0.34	192		
16:09:00	424.0			0.34			Flow off, begin falling head
16:15:00	430.0			0.335			
16:20:00	435.0			0.33			
16:30:00	445.0			0.33			
16:29:00	444.0			0.35			
16:34:00	449.0			0.34			
16:38:00	453.0			0.33			
16:40:00	455.0			0.33			
16:45:00	460.0			0.32		On 8/9/16 1.88 feet at 09:34	End test. Well point datalogger retrieved 8/9/2016



MCCA2 Infiltration Test Plot 1
○ Head (temporary staff gauge SG-1, feet)
+ Logger (adjusted, feet)
Approx. 2.5 to 4 gallons per minute flow
Falling head
Approx. 1.4 gallons per minute flow
Approx. 0.9 gallons per minute flow
Falling head
Water Height (feet from base of cell)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.0
60.0
120.0
180.0
240.0
300.0
360.0
420.0
480.0
540.0
600.0
Elapsed Time (minutes)


MCCA2 Infiltration Test Plot 2
○ Water Level, SG-1, Hand Measured
+ Water Level, SG-1, Logger
● Water Level, Well Point, Hand Measured
- Water Level, Well Point, Logger
Approx. 2.5 to 4 gallons per minute flow
Falling head
Approx. 1.4 gallons per minute flow
Approx. 0.9 gallons per minute flow
Falling head
Water Height (feet from base of cell)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
0.0
60.0
120.0
180.0
240.0
300.0
360.0
420.0
480.0
540.0
600.0
Elasped Time (Minutes)


MCCA2 Infiltration Test Plot 2
○ Water Level, SG-1, Hand Measured
+ Water Level, SG-1, Logger
● Water Level, Well Point, Hand Measured
- Water Level, Well Point, Logger
Falling head
Approx. 1.4 to 2.3 gallons per minute flow
Falling head
Approx. 4 to 7 gallons per minute flow
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
Water Height (feet from base of cell)
0.0
120.0
240.0
360.0
480.0
600.0
720.0
840.0
960.0
1,080.0
1,200.0
1,320.0
1,440.0
1,560.0
Elasped Time (Minutes)

APPENDIX E

Site Photos

Cell MCCA1 during site visit

Cell MCCA2 during infiltration testing (overflow grate opened for observation)

Flow from inlet to MCCA2 during beginning of infiltration testing, with some flow visible

Overflow structure in Cell MCCA1

APPENDIX 7

Deliverable 4.5, Site NOLL, Geotechnical/Soils Assessment Design Data and Current Conditions, Noll Roundabout, Poulsbo, Washington. Associated Earth Sciences, Inc. 10/25/16

associated earth sciences incorporated

Technical Memorandum

Date:	October 25, 2016	**From:**	Jennifer H. Saltonstall, L.G., L.Hg.
To:	Clear Creek Solutions, Inc.	**Project Manager:**	Jennifer H. Saltonstall, L.G., L.Hg.
	15800 Village Green Drive #3 Mill Creek, WA 98012	**Principal in Charge:**	Curtis J. Koger, L.G., L.E.G., L.Hg.
		Project Name:	Bioretention Hydrologic Performance Study
Attn:	Doug Beyerlein, P.E.	**Project No:**	KH150387A
Subject:	Deliverable 4.5, Site NOL, Geotechnical/Soils Assessment Design Data and Current Conditions, Noll Roundabout, Poulsbo, Washington		

1.0 INTRODUCTION

This technical memorandum documents existing shallow soil and ground water conditions in the bioretention pond (cell NOL) at the Noll Road NE and NE Lincoln Road roundabout, located in Poulsbo, Washington (Figure NOL F1). This memorandum was prepared in accordance with Task 4 of the contract scope of work. Associated Earth Sciences, Inc. (AESI) collected shallow soil and ground water conditions data related to bioretention cell function, and documented the current condition of the facility relative to the as-built drawings and available background geotechnical information. The information will be used in the WWHM2012 modeling that will be conducted as part of Task 5 (Data Analysis). In Task 5, the team will compare the previously documented hydrologic design information with our field-collected information and will note where there are significant differences. The purpose of this technical memorandum is to document the collection of current and accurate geotechnical, geologic and hydrogeologic site information for this later work.

The following summary of shallow soil and ground water conditions integrates the observations made during the geotechnical assessment which included site visits on August 4, 2016, infiltration testing on September 15, 2016, and background geotechnical information.

This technical memorandum has been prepared for the exclusive use of Clear Creek Solutions and the City of Bellingham and their agents for specific application to this project. Within the limitations of scope, schedule, and budget, our services have been performed in accordance with generally accepted hydrogeologic and geotechnical engineering practices in effect in this area at the time our document was prepared. No other warranty, express or implied, is made.

2.0 PURPOSE AND SCOPE

The purpose of our work was to perform a shallow soil and ground water conditions assessment and provide baseline documentation data for use in modeling performance.

Specifically, our scope included the following activities:

- Review of project documents.
- Site reconnaissance.
- Visual condition assessment of erosion and deposition features near inlet and outlet.
- Review project plans relative to constructed facility, in particular, the number and location of inlets, energy dissipation devices, outlets, and other flow-related details.
- Survey elevations of inlet, outlet, well point rim, and other observation points relative to a project datum
- Excavate shallow hand augers through the bioretention soil and into the underlying material, extending one hand auger deeper into the subgrade for installation of a well point.
- Classify sediment according to the Unified Soil Conservation System (USCS) and *American Society for Testing and Materials* (ASTM) D2488, “Standard Recommended Practice for Description of Soils.”
- Collect samples for laboratory testing of (1) particle size distribution in accordance with ASTM D422-63, “Standard Test Method for Particle-Size Analysis of Soils”; (2) organic matter content per ASTM D2974.
- Conduct qualitative assessment of soil compaction via T-probe.
- Conduct infiltration testing.
- Preparation of descriptive exploration logs for each exploration.
- Preparation of this summary document.

Topography of the site and surrounding area is shown on Figure NOL F2, “LiDAR-Based Topography.” Existing facility features and the locations of hand-auger boreholes completed for this study are shown on Figure NOL F3, “Facility and Exploration Plan.” Project civil plans are attached as Appendix A. Exploration logs and laboratory testing data conducted as part of this study are attached as Appendix B. Background soil, geology, and ground water information are attached as Appendix C. Soil probe, level survey, and field infiltration testing data are attached as Appendix D. Site photos are attached as Appendix E.

3.0 SITE DESCRIPTION AND DESIGN BACKGROUND

The project site is the NE Lincoln Road and Noll Road NE roundabout intersection in Poulsbo, Washington, as shown on the attached “Vicinity Map” (Figure NOL F1) and was designed as part of a series of City of Poulsbo drainage improvements to the Noll Road corridor. The Noll Road roundabout is situated on the edge of the City of Poulsbo incorporated area (see Figure NOL F1), and is situated in generally a rural density area. LiDAR topography and other near-site vicinity features are illustrated on Figure NOL F2, "LiDAR-Based Topography." No natural surface water features are present onsite or in the immediate vicinity. An unnamed creek is located about 1,000 feet west of the site. Per the Washington State Source Water Assessment Program Mapping Application, the site is located within the 6-month time of travel area of the Group A City of Poulsbo Lincoln Well #1 (Well tag AAB481), within the 1-year time of travel of the Group A Ashley Lane Well #1 (Well tag AAB595), and within the 10-year time of travel area of the Group A Gala Pines Water Well #1 (Well tag ABP540). Nine Group B wells are displayed within approximately 0.5 miles of the site.

Our specific area of study for this project includes the bioretention facility located on the east side of NE Lincoln Road, just south of the roundabout. This project area is bordered by NE Lincoln Road to the north and west, by a pedestrian path to the south and east, and by a landscaping bed to the south. The attached "Facility and Exploration Plan" (Figure NOL F3) illustrates the bioretention cell area.

Details of the bioretention facility design and basis were presented in the following documents:

- Plan sheets C2, C4, C6, C7, and C9, Parametrix, Inc., May 9, 2012.
- Hydraulic Report Appendix B-2, Soil Survey Map, Soil Logs, and Soil Sieve Test Results. Electronic document titled "Hydraulic Report Appendix B_Soils_optimized.pdf"
- Hydraulic Report Appendix C, Maps and Figures. Electronic document titled "Nol Road Roundabout HydRpt.pdf

3.1 Summary of Facility Design

From our review of these documents, the bioretention facility design for cell NOL consists of approximately 520 square feet of bioretention base area as shown on Figure NOL F3, "Facility and Exploration Plan." We understand that the NOL cell was sized per the 2005 Washington State Department of Ecology (Ecology) *Stormwater Management Manual for Western Washington* (2005 Ecology Manual), and modeled using WWHM3 based on a developed condition drainage basin of 0.68 acres and with a design infiltration rate of 0.5 inches per hour (in/hr). Land use within the drainage basin consists of asphalt road, landscaping, concrete and pervious pathways. Per plan sheet C9 (Parametrix, Inc., May 9, 2010), the facility design includes 1.5 feet of bioretention soil mix overlying a minimum 6-foot-wide rock-filled trench. The rock-filled trench is separated from the overlying bioretention soil mix by a 4- to 6-inch-thick graded filter layer composed of "Gravel Backfill for Drains." The rock-filled trench contains a 6-inch-diameter perforated underdrain pipe bedded in approximately 1.5 feet of "Gravel Backfill for Drywells," which overlies native soil. Cell NOL is designed to infiltrate 96.4 percent of the annual inflow into the subgrade. The facility was constructed in September 2012 and began receiving runoff that month (Email communication, Anja Hart, City of Poulsbo Public Works, September 7, 2016).

Inflow to cell NOL is through a single 12-inch-diameter CPE pipe. Inflow soaks through the bioretention soil mix, collects in the rock-filled trench and either infiltrates into the subgrade or is collected in the underdrain pipe. The underdrain pipe connects to the overflow structure catch basin CB4. CB4 is set about 1 foot above the surface of the bioretention cell and capped with a beehive grate. If ponding in excess of about 1 foot occurs on the bioretention soil, the overflow is also collected within CB4. Another outfall pipe is located within CB4 that will direct stormwater to a series of catch-basin structures, which eventually discharge to a ditch along Noll Road NE via a 12-inch-diameter pipe. Within CB4, the underdrain pipe invert is shown to be 0.12 feet lower in elevation than the overflow pipe invert.

4.0 SITE OBSERVATIONS

During AESI's site visits, we made notes regarding the physical construction of the bioretention facility including documenting site inlet/outlet layout relative to site plans and qualitative bioretention soil thickness and compaction. These notes were used to indicate key features of the facilities on Figure NOL F3, "Facility and Exploration Plan."

- Level Survey: AESI conducted an elevation survey of the facility using a Leitz C40 automatic level and a stadia rod. An arbitrary project datum was established for this survey, with the southeast corner of the cement pad for utility box near the facility inflow defined as project datum elevation 100 feet. All other elevations measured by the survey are relative to this project datum. Key level data is summarized in Table 1. Additional data points are included in Appendix D to this document. These surveys were not conducted by a licensed surveyor. Surveyed elevations are expected to be sufficiently accurate for this general assessment of facility construction, but may be inaccurate for purposes requiring greater precision.

- Inflow: One inflow to the facility is present, which consists of a 12-inch corrugated black plastic pipe, which discharges onto an approximately 4-foot by 6-foot splash pad consisting of angular rock to 0.8 feet in size. No evidence of erosion was noted. AESI observed some deposition of leaf litter and silt in the angular rock and the inflow pipe.

- Overflow: One overflow is present. This overflow, labeled CB4 on plan sheet C4, consists of an approximate 1.6- by 2-foot-wide metal beehive-style grate, with a lip approximately 0.8 feet above the surface of the bioretention soil within the facility in this location. Two pipes are present in the sump beneath this overflow grate. One corresponds with the perforated underdrain pipe underlying the facility, indicated on plan sheet C4 and on the detail drawing on plan sheet C9 (Parametrix, Inc., 2012). As measured by AESI, the base of this underdrain pipe is 3.90 feet below the lip of the overflow grate. The second pipe present is the overflow discharge pipe, which discharges to the ditch along the western side of Noll Road. The base of the overflow discharge pipe is 3.77 feet below the lip of the overflow grate.

- AESI notes that the difference in elevation between the facility base and the top of the eastern side of the facility is approximately 1 foot, rather than the 2 feet indicated on plan sheet C4 (Parametrix, Inc., May 9, 2012).

- AESI investigated the loose bioretention soil thickness present in the bioretention cell using a geotechnical soil T-probe. This qualitative data was used in conjunction with the hand-auger observations to understand loose soil thickness and relative potential compactness of the bioretention soils at depth. AESI measured the depth of penetration of the soils probe at locations generally arranged in a 5-foot spacing in a line along the center of the facility base. The apparent thickness of bioretention soil generally ranged from approximately 1.4 feet to 1.6 feet and averaged 1.5 feet thick. Probe penetration data is included in Appendix D to this document.

Table 1
Summary of Cell NOL
Level Survey Data

Location	Elevation (feet, project datum)
(S-1) Southeast corner of utility pad	100
(S-2) Concrete lamp base	98.41
(S-3) Middle of crosswalk, south side, at curb corner	101.3
Inflow, base of pipe	98.3
Overflow rim	99.45
High point on southeastern embankment of cell, south of center	99.88
High point on southeastern embankment of cell, north of center	99.93
Well point, top of casing	101.01
Survey points in base of cell	On site plan in Appendix D to this document

5.0 SITE SETTING

The text sections below describe our research findings in regards to the topographic, geologic, and hydrogeologic setting of the project site, both from regional studies and background site-specific geotechnical and ground water studies if available. Our sources of information included the following.

- Site-specific documents cited previously under “Project and Site Description.”
- Sceva, J.E., *Geology and Groundwater Resources of Kitsap County, Washington*, United States Geological Survey, Water Supply Paper WSP-1413, scale 1:48,000, 1957.
- *Soil Survey of Kitsap County area, Washington*, United States Department of Agriculture, Natural Resource Conservation Service (NRCS), 1980.
- Natural Resources Conservation Service, Web Soil Survey, United States Department of Agriculture, http://websoilsurvey.nrcs.usda.gov/, accessed September 2016.
- Welch, W.B. et al., *Hydrogeologic Framework, Groundwater Movement, and Water Budget of the Kitsap Peninsula, West-Central Washington*, United States Geological Survey, Scientific Investigations Report 2014-5106, 2014.

5.1 Regional Topography and Project Grading

The project site is situated on a rolling upland with low hills and shallow valleys elongated in the north-south direction, and elevations general range from 310 to 370 feet in the vicinity of the project site as shown on Figure NOL F2, "LiDAR-Based Topography." The upland plateau extends north to Port Gamble and south to Liberty Bay. Surface water features relatively close to the project include intermittent streams within the low valleys west and east of the project.

On a closer scale, the site occupies the eastern flank of a low ridge, and drains southward via a drainage ditch along Noll Road, eventually draining to a stream that discharges to Liberty Bay. The ground surface descends gradually to the south and east in the vicinity of the site. Prior to bioretention cell construction, the site existing condition consisted partially of Noll Road right-of-way and partially of vegetated area. Minor cuts of varying depth, typically on the order of 3 to 5 feet, were necessary to achieve bioretention cell subgrade, and that placement of up to approximately 2 feet of fill soils was required to build up the eastern bank of the cell based on a review of existing topography compared with built topography.

5.2 Regional Geology and Background Geotechnical Information

According to the geologic mapping (Sceva, 1957), the site vicinity is underlain by Vashon lodgement till.

- Vashon Lodgement Till (Qvt): The uppermost soil unit is a deposit of Vashon lodgement till. This is described in the geologic map as a hard gray mixture of clay, silt, sand and gravel as much as 80 feet thick. This unit was deposited during the Vashon Stade of the Fraser Glaciation, and was directly overridden by the glacial ice, resulting in a high degree of compaction.

Three test pits (TP-3, TP-4, and TP-5) were excavated in the proposed footprint of cell NOL and were contained in Appendix B-2 of the hydraulic report. The test pits described "Hard Pan, Gray Cemented Sand" at depths of 3 to 3.5 feet below ground surface prior to construction of the project. Vashon lodgement till is locally referred to as "Hard Pan," and "Hard Pan" descriptions are consistent with the geologic mapping of the area.

5.3 Regional Soils and Soil Data Used in Site Stormwater Model

AESI reviewed the *Soil Survey of Kitsap County Area* (Natural Resources Conservation Service [NRCS], 1980) and soils mapping from the NRCS web portal (NRCS, 2016). The soil survey identifies different soil map units based on parent material, climate, topography (slope), organisms (biota), and time. The soils in the study area formed mostly from young glacial deposits and have not had time to develop the deep weathering profiles present in soils in unglaciated terrains. Instead, they exhibit a direct relationship to the underlying parent material, local climate, topography, and vegetation.

Mapped soils in the project area consist of Poulsbo gravelly sandy loam. Poulsbo soils are formed from the weathering of glacial till. NRCS describes the permeability in the undisturbed upper 24 inches of the Poulsbo soil as moderately well-drained, ranging from 2.0 to 6.3 in/hr. However, in developing areas, this upper soil is typically removed or compacted, as is the case for the majority of the NOL bioretention cell. The lower portion of the soil profile has a low permeability, less than 0.06 in/hr at depth (NRCS , 1980). This is a key limitation for shallow infiltration and can be easily misinterpreted. The very low infiltration rate reflects the permeability of the glacial till "parent" material. These soils commonly become saturated during the winter and typically contain shallow ground water referred to as interflow.

As described in Appendix C of the hydraulic report, the pre-developed condition was modeled as Type C soils, consistent with mapped soil and background geotechnical data.

5.4 Regional Hydrogeology and Background Ground Water Data

Regional hydrogeology is described in *Hydrogeologic Framework, Groundwater movement, and Water Budget of the Kitsap Peninsula, West-Central Washington* (Welch, et al., 2014), which refers to Vashon lodgement till as a confining unit which is present at ground surface throughout much of the area. The Vashon lodgement till is described as somewhat discontinuous due to erosion by streams, and variable in thickness from a thin veneer to more than 185 feet, with an average thickness of 62 feet. A very shallow seasonal perched water-bearing zone typically forms in the weathered horizon of the Vashon lodgement till, and is referred to as "interflow." Interflow typically accumulates within the weathered soils on top of the unweathered till and flows laterally generally in the direction of sloping ground. Interflow discharges in low areas forming wetlands, at near-vertical cuts along roadways, walls or in excavations, or slowly infiltrates into the underlying unweathered till as diffuse recharge, or along fractures or sandy zones in the till.

No background data on ground water was available. The presence or absence of seepage was not described on the soil logs contained Appendix B-2 of the hydraulic report.

6.0 BIORETENTION CELL SUBSURFACE EXPLORATION AND WELL POINT INSTALLATION

Limited information on subsurface conditions was obtained for this study from hand-auger samples and soil probe penetration measurements at about 2-foot increments in each hand-augered borehole. In the bioretention cell, one hand-auger boring was performed in the facility bottom and advanced through the bioretention soil and into the underlying subgrade. Additional hand-auger borings were completed to the base of the bioretention soil. Representative samples were collected, visually classified in the field, stored in water-tight containers and transported to AESI's offices for additional classification, geotechnical testing and study. At the conclusion of the excavation, each borehole was immediately backfilled with the excavated material, or completed as a well point and the bioretention soil replaced.

The various types of sediments, as well as the depths where characteristics of the sediments changed, are indicated on the exploration logs presented in Appendix B. A detailed record of the observed bioretention soil, subsurface soil, geology, and ground water conditions was made. The sediments were described by visual and textural examination using the soil classification in general accordance with ASTM D2488, "Standard Recommended Practice for Description of Soils." The depths indicated on the logs where conditions changed may represent gradational variations between sediment types in the field. The exploration logs in Appendix B are based on the field observations, inspection of the samples, and where applicable, laboratory grain-size analysis. Our explorations were approximately located in the field relative to known site features, and are shown on Figure NOL F3, "Facility and Exploration Plan." GPS coordinates for the explorations were taken using a handheld GPS, and are summarized in Appendix B.

The results presented in this document are based on the explorations completed for this study and review of background data. The number, locations, and depths of the explorations were completed within site and budgetary constraints. Because of the nature of exploratory work below ground, interpolation of subsurface conditions between field explorations is necessary. It should be noted that differing subsurface conditions may sometimes be present due to the random nature of deposition and the alteration of topography by past grading and/or filling.

6.1 Hand-Auger Borings

Hand-auger borings in cell NOL were completed on August 4, 2016. No rain was observed during this time, and no flow was observed from the inlet pipe.

Hand-auger boring number 1 (NOL-HA-1) was completed in the northern portion of the cell, and encountered approximately 1.5 feet of bioretention soil, overlying drain rock. No seepage or caving were observed. Hand-auger boring numbers 2 and 3 (NOL-HA-2 and NOL-HA-3) were completed along the eastern edge of the cell base. They encountered approximately 1.7 feet and 1.9 feet, respectively, of bioretention soil, overlying material interpreted as weathered Vashon lodgement till, to a total depth of 4 feet and 3.5 feet, respectively. No seepage or caving were observed. A well point was installed in NOL-HA-2.

6.2 Well Points

A well point was installed in HA-2. Key dimensions of this well point are provided in Table 1, below.

Table 2
Summary of Cell NOL
Well Point Dimensions

Well Point	Exploration in which Well Point was installed	Total Length of Casing (feet)	Interior Diameter	Stickup Height (feet)	Total Depth Inside Casing Below Ground Surface (feet)
NOL-WP	NOL-HA-2	5.3	1.25 inch nominal	1.7	3.6

7.0 LABORATORY ANALYSIS

Laboratory testing included mechanical grain-size distribution and percent organic matter by weight in accordance with the ASTM D422 and D2974, respectively. Two samples of bioretention soil for each cell were first tested for organic matter content and then the burned material was tested for grain-size distribution for comparison with the aggregate fraction of the bioretention soil mix guidance in the Washington State Department of Ecology (Ecology) 2014 *Stormwater Management Manual for Western Washington* (2014 Ecology Manual). One sample of the subgrade from each cell was tested for grain-size distribution. The data is summarized in Table 3.

Table 3
Summary of Cell NOL
Organic Content and Grain Size Data

Exploration Number	Depth (feet)	Soil Type	Organic Content (% by weight)	USCS Soil Description	Fines Content (% passing #200)	Cu	Cc	USDA Soil Texture*
NOL-HA-1	0.6-0.9	Bioretention Soil	3.5	SAND, trace silt, trace gravel (SP)	0.8%	3.6	0.9	Sand
NOL-HA-3	0.6-0.9	Bioretention Soil	3.8	SAND, trace silt, trace gravel (SP)	0.4%	3.9	0.9	Sand
NOL-HA-3	3-3.3	Vashon Lodgement Till	Not tested	Silty, gravelly SAND (SM)	14%	39	0.6	Sandy loam to loamy sand

USCS: Unified Soil Classification System; Cu: coefficient of uniformity; Cc: coefficient of curvature; USDA: US Dept. of Agriculture;
*No hydrometers were performed. USDA soil texture range assumes fines consist entirely of silt to entirely of clay.

7.1 Bioretention Soil Mix

We compared the organic content and burned fraction gradation against the general guidelines for the bioretention soil mix (Table 4).

The organic content of the tested bioretention soils ranged between 3.5 and 3.8 percent by weight. This is below the recommended organic content by weight of 5 to 8 percent in the 2014 Ecology Manual.

The grain-size analysis test results on the burned soil fraction indicate that the bioretention soils tested correlate to a “SAND” based on ASTM D2487 USCS. The respective fines content as measured on the No. 200 sieve ranged from approximately 0.4 to 0.8 percent, less than the recommended range of 2 to 5 percent the 2014 Ecology Manual. The coefficient of uniformity ranged from 3.6 to 3.9, less than the recommended value of equal to or greater than 4. The coefficient of curvature was 0.9 for both samples tested, consistently lower than the recommended range of greater than or equal to 1 and less than or equal to 3. The soil mix generally did not meet (contained less than) the recommended range of fine sand and silt fractions. The tested bioretention soil was predominantly medium-grained sand.

Table 4
General Guidelines for Bioretention Soil Mix (2014 Ecology Manual)
Compared to Averaged Cell NOL Site Data

Parameter	Recommended Range	NOL
Organic Content (by weight)	5 to 8 percent	3.6 percent by weight
Cu coefficient of uniformity	4 or greater	3.7
Cc coefficient of curvature	1 to 3	0.9
Sieve Size	**Percent Passing**	
3/8” (9.51 mm)	100	99
#4 (4.76 mm)	95 to 100	96
#10 (2.0 mm)	75 to 90	76
#40 (0.42 mm)	25 to 40	14
#100 (0.15 mm)	4 to 10	1.6
#200 (0.074 mm)	2 to 5	0.6

Note: The general guidelines for mineral aggregate gradation are from Table 7.4.1 of the 2014 Ecology Manual.
mm: millimeter

7.2 Subgrade

In cell NOL, a sample of native glacial till was sieved. The tested material correlates to a silty, gravelly SAND with 14 percent by weight of the material passing the No. 200 sieve

The grain size distribution data were also transformed to describe the United States Department of Agriculture soil texture. The grain-size distributions were normalized to the No. 10 sieve—i.e., the coarse sand and gravel fraction of the sample is discounted and the remainder is taken as 100 percent of the sample. The fines were assessed relative to the No. 270 sieve. The respective United States Department of Agriculture fines content as measured on the No. 270 sieve after adjusting to remove the weight retained on the #10 sieve was 18 percent for the native glacial till material.

8.0 INFILTRATION TESTING

8.1 General Infiltration Test Method

An infiltration test was conducted in general accordance with the 2014 Ecology Manual. The test was conducted by discharging water into the facility for a “soaking period,” to allow the receptor soils to become saturated. After completion of the soaking period, water was discharged into the cell at a rate sufficient to maintain a relatively constant head. This constitutes the “constant head” phase of infiltration testing. Immediately following the constant head phase of infiltration testing, flow into the facility was discontinued, and the water level was monitored as it dropped. This constitutes the “falling head” portion of the infiltration testing.

The water for testing was obtained from a fire hydrant located on Noll Road, and conveyed to cell NOL with fire hoses. During infiltration testing, the water was conveyed into the bioretention cell via a digital flow meter with gallons per minute (gpm) and total gallon readouts, and discharged through a flow diffuser. Water levels were monitored using a temporary metal staff gauge marked in 0.02-foot increments which was installed for the duration of the test adjacent to the well point (SG-1), a second temporary metal staff gauge marked in 0.01-foot increments installed near the test discharge (SG-2), within the well point and within the overflow structure (CB4) with a digital water level tape, and with digital pressure transducers. Data from the digital pressure transducers was compensated for barometric response using a separate digital barometer. The area of the pool was measured periodically during testing.

The infiltration test in cell NOL is discussed below, and results are presented in Table 5. Infiltration test data is included in Appendix D to this document.

8.2 Infiltration Test in Cell NOL

AESI performed infiltration testing on September 15, 2016. No rainfall was noted during testing, and no flow from the inflow pipes was present.

During this test, flow was initially maintained at about 150 gpm. Inflow to the facility for the infiltration test was directed, through a diffuser, onto the splash pad by the facility inflow pipe, noted on Figure NOL F3. After approximately 25 minutes, AESI noted that water was flowing back into the inflow pipe and storm drain grates. To avoid backflow, AESI turned flow off and moved the test inflow to the southern end of the facility, away from the facility inflow, and restarted the test. The flow was maintained at approximately 150 gpm (the maximum flow off of the fire hydrant) for approximately 7 hours, during which the water level in the facility rose slowly to 0.32 feet as measured on SG-2 over the course of approximately 2 hours, and was stable at this level for approximately 5 hours. The wetted pool extended across about half of the facility base at this flow rate and pool level. No water was observed within the well point during or after the infiltration test, or wetting SG-1 (adjacent to the well point) at any point during the test. Approximately 66,000 gallons of water were used. During the constant flow portion of the testing, AESI noted flow entering the overflow structure CB4 from the perforated pipe underdrain. The height of the water above the inlet of the underdrain pipe stabilized at about 0.42 feet. The water readily flowed out of CB4 at this height and into a series of storm drain pipes and catch basins, eventually discharging into the ditch along the western edge of Noll Road.

The flow rate at the ultimate discharge pipe into the Noll drainage ditch could not be directly measured, however AESI measured the depth of water flowing within the 12-inch corrugated plastic discharge pipe as ranging from 0.40 to 0.42 feet during the course of testing.

After about 7 hours, AESI shut off the flow and monitored water level as it fell. AESI observed that the pooled water in the base of the facility dropped from 0.32 feet to 0.04 feet over the course of approximately 3 minutes. Flow at the discharge pipe into the Noll drainage ditch was also monitored. The flow rate began to diminish readily after about 4 minutes, and slowed to a trickle after about 25 minutes.

After completion of the infiltration test and once flow into the Noll drainage ditch had decreased to trace flow, AESI conducted a comparative flow test to estimate flow rates into the into the Noll drainage ditch during testing. AESI directed water into the nearest upstream catch basin (CB7), set known flow rates using the digital flow meter, and measured the corresponding depth of water flowing within the discharge pipe into the Noll drainage ditch. AESI found that the depth of water observed in the overflow pipe during the infiltration test correlated closely with the depth of water observed with approximately 150 gpm of flow in the pipe. AESI therefore interprets that the majority of water used during testing infiltrated through the bioretention soil, but flowed to the overflow rather than infiltrating into the native subsurface. The relationship between inflow and outflow will be better approximated after reviewing the planned flow monitoring data.

Table 5
Cell NOL
Infiltration Test Results

Test No.	**Surface Area (square feet)**	**Discharge Time (minutes)**	**Total Volume Discharged (gallons)**	**Approximate Constant Head Level (feet)**	**Field Infiltration Rates**	
					Constant Head Test (in/hr)	**Falling Head Test (in/hr)**
NOL (bioretention soil)	250	419	66,049	0.32	58	65
NOL (subgrade)	Unknown, estimated area of rock-filled trench was filled with water, at 360 SF				nil	nil

in/hr: inches per hour

9.0 FINDINGS AND CONCLUSIONS

The bioretention area at the NOL site varied somewhat from the design shown on the civil plan sheets. Variations included the following:

- Bioretention soil
    - Thickness: Apparent thickness of bioretention soil present appeared to vary somewhat. However, overall apparent average thickness was similar to the planned thickness of 1.5 feet.
    - Composition: The soil tested in NOL did not meet (contained less than) the recommended guidelines for organic content and fines content. The soil tested did not meet the recommended fraction of fine sand and silt, was essentially a well-sorted medium sand.

  - Facility Base Depth: Per AESI's level survey, the southern wall of the facility rises only approximately 1 foot above the base of the facility. This differs from the 2-foot difference shown on plan sheet C4 and detail shown on plan sheet C9 (Parametrix, Inc., 2012).

- The overflow is different than the plan in that the ponded water surface can only build up to about 0.7 feet before the cells begin to overflow. Site design documents indicate that the ponding level was designed as 1 foot. However, given the high infiltration rate of the bioretention soil, direct overflow through the beehive grate is unlikely to occur.

- Subgrade conditions: The subgrade appeared to consist of Vashon lodgement till, consistent with geologic and soils mapping of the area.

- Review of existing and developed topography (plan sheet C4, Parametrix, Inc., 2012) indicates that cuts of varying depth, typically on the order of 3 to 5 feet, were necessary to achieve bioretention cell subgrade, and that placement of up to approximately 2 feet of fill soils would have been required to build up the eastern bank of the cell. This is consistent with the presence of weathered glacial till beneath the cell in the vicinity of NOL-HA-2 and NOL-HA-3, on the eastern edge of the cell. In the case of deeper cuts, such as those on the western side of the cell or beneath the rock-filled trench, this weathered glacial till would be largely stripped away as part of site development.

- The field infiltration rate was measured at about 60 in/hr. During the infiltration test, water readily soaked through the bioretention soil mix and accumulated on the underlying subgrade as indicated by the water level response within the overflow system (CB4). The data indicate that the native subgrade has a lower permeability than the overlying bioretention soil. The calculated infiltration rates are interpreted to apply to the bioretention soil through which the water appeared to infiltrate rapidly, and not to the underlying native subsurface, which we conclude water pooled on top of before flowing to the overflow system.

- Based on the similarity between water levels in the overflow discharge pipe during the infiltration test with 150 gpm directed into the bioretention cell, and with 150 gpm directed directly into the overflow, AESI interprets that the majority of flow during the infiltration testing was discharged via the overflow, and that little infiltration into the native subsurface occurred. The relationship between inflow and outflow will be better approximated after reviewing the planned flow monitoring data.

- Shallow ground water was not encountered at the time of exploration or testing. Ground water may mound up during the winter months. The ongoing monitoring data will be reviewed during the coming months for ground water influence.

10.0 CLOSURE

We appreciate the opportunity to be of continued service to you on this project. Should you have any questions regarding this document or other geotechnical/hydrogeologic aspects of the project, please call us at your earliest convenience.

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Staff Geologist

Curtis J. Koger, L.G., L.E.G., L.Hg.
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Licensed Geologist
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10/25/16

Jennifer H. Saltonstall, L.G., L.Hg.
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Attachments:	Figure NOL F1:	Vicinity Map
	Figure NOL F2:	LiDAR-Based Topography
	Figure NOL F3:	Facility and Exploration Plan
	Appendix A:	Project Civil Plans
	Appendix B:	Current Study Exploration Logs and Laboratory Testing Data
	Appendix C:	Background Soil, Geology, and Ground Water Data (Regional Maps, Previous Studies Exploration Logs and Laboratory Testing Data)
	Appendix D:	Soil Probe, Level Survey, and Field Infiltration Testing Data
	Appendix E:	Site Photos

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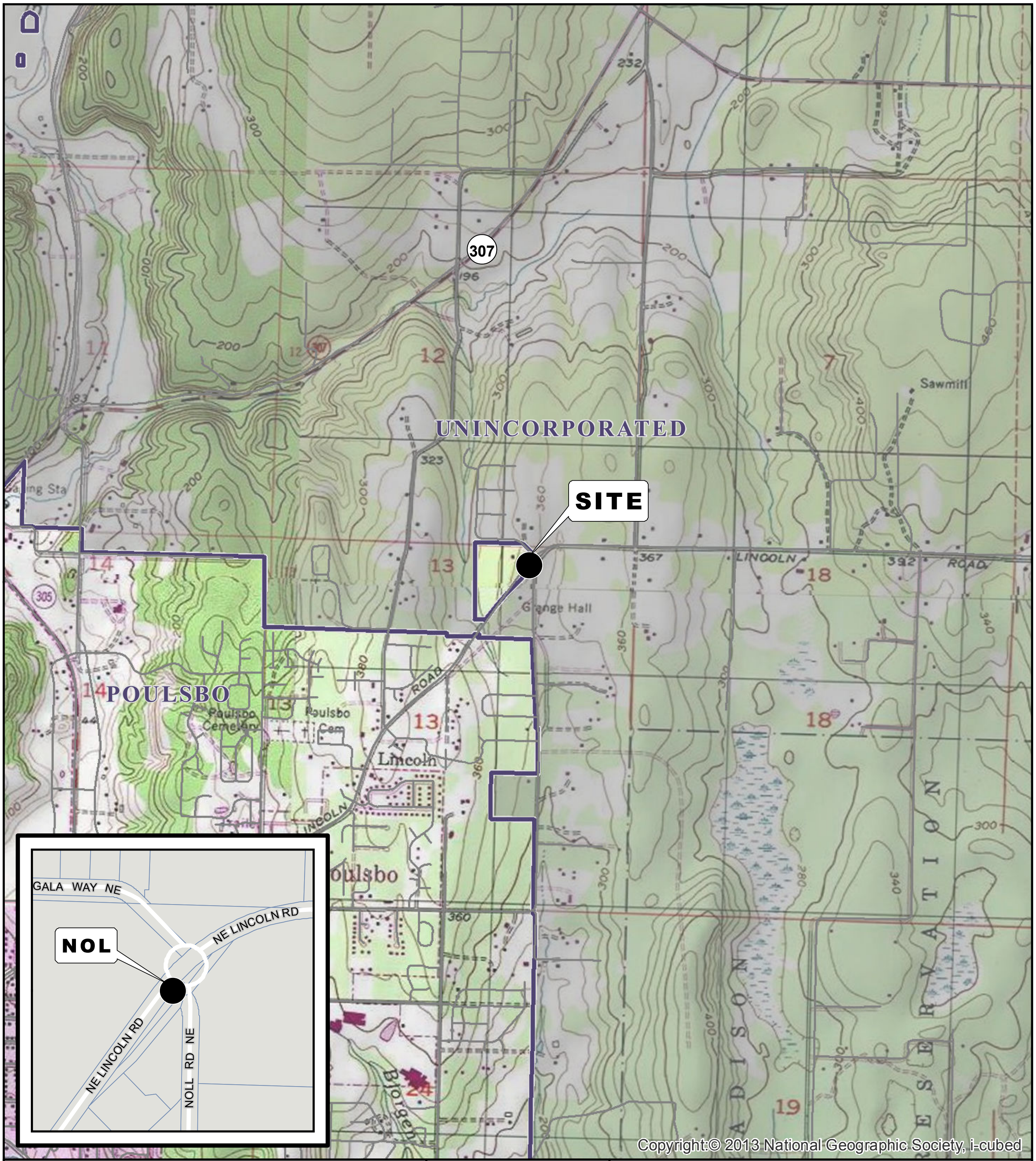

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DATA SOURCES / REFERENCES:
USGS: 24K SERIES TOPOGRAPHIC MAPS
KITSAP CO: STREETS, PARCELS 2015

LOCATIONS AND DISTANCES SHOWN ARE APPROXIMATE

N

0 1000 2000
FEET

NOTE: BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION

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VICINITY MAP

BIORETENTION HYDROLOGIC PERFORMANCE STUDY, NOL SITE
POULSBO, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	NOL F1

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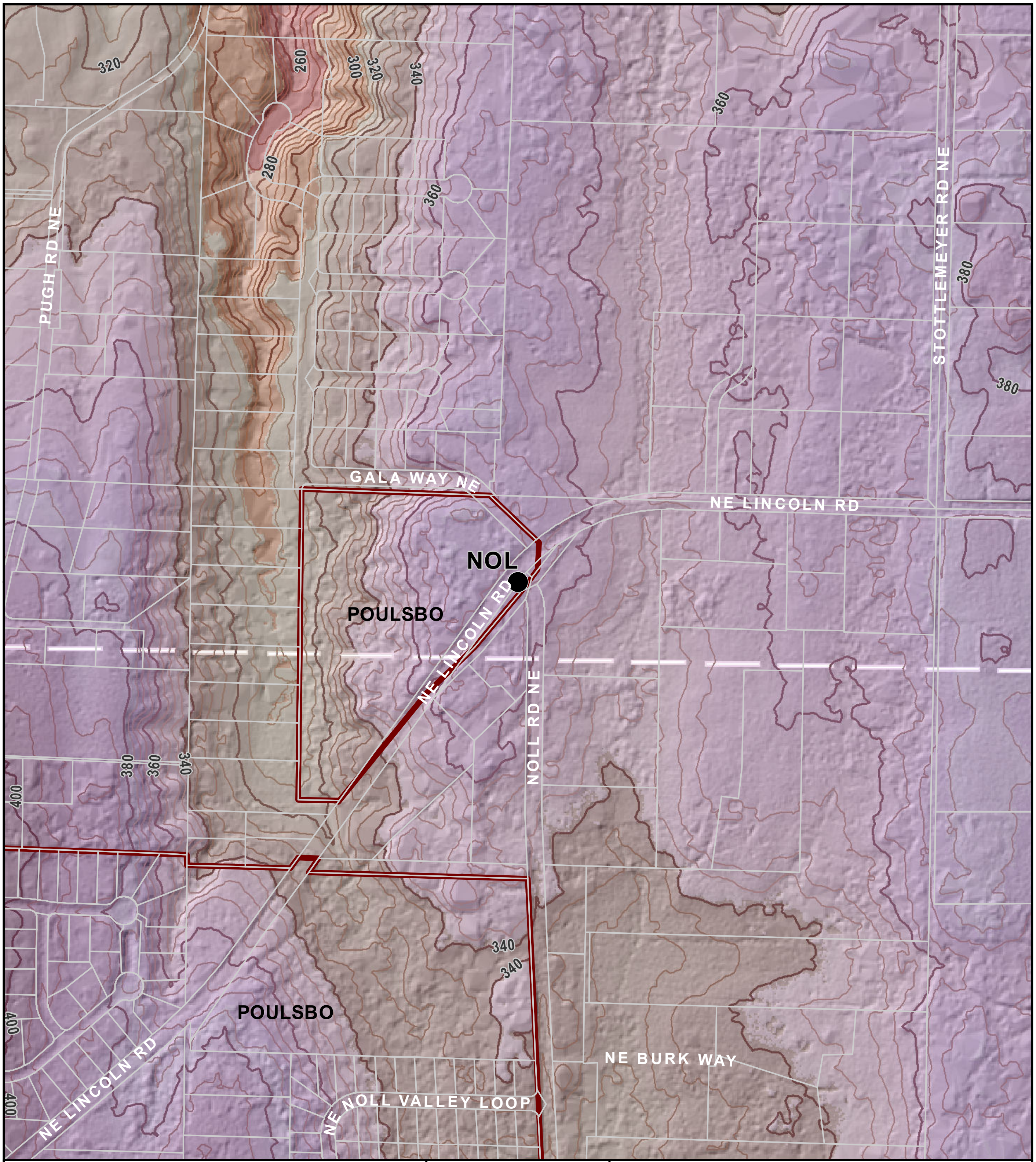

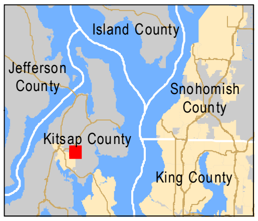

DATA SOURCES / REFERENCES:
PSLC: LIDAR 2000-2005 SUPERMOSAIC, 6' CELL
KITSAP CO: STREETS, PARCELS 2016

LOCATIONS AND DISTANCES SHOWN ARE APPROXIMATE

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LIDAR BASED TOPOGRAPHY

BIORETENTION HYDROLOGIC
PERFORMANCE STUDY, NOL SITE
POULSBO, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	NOL F2

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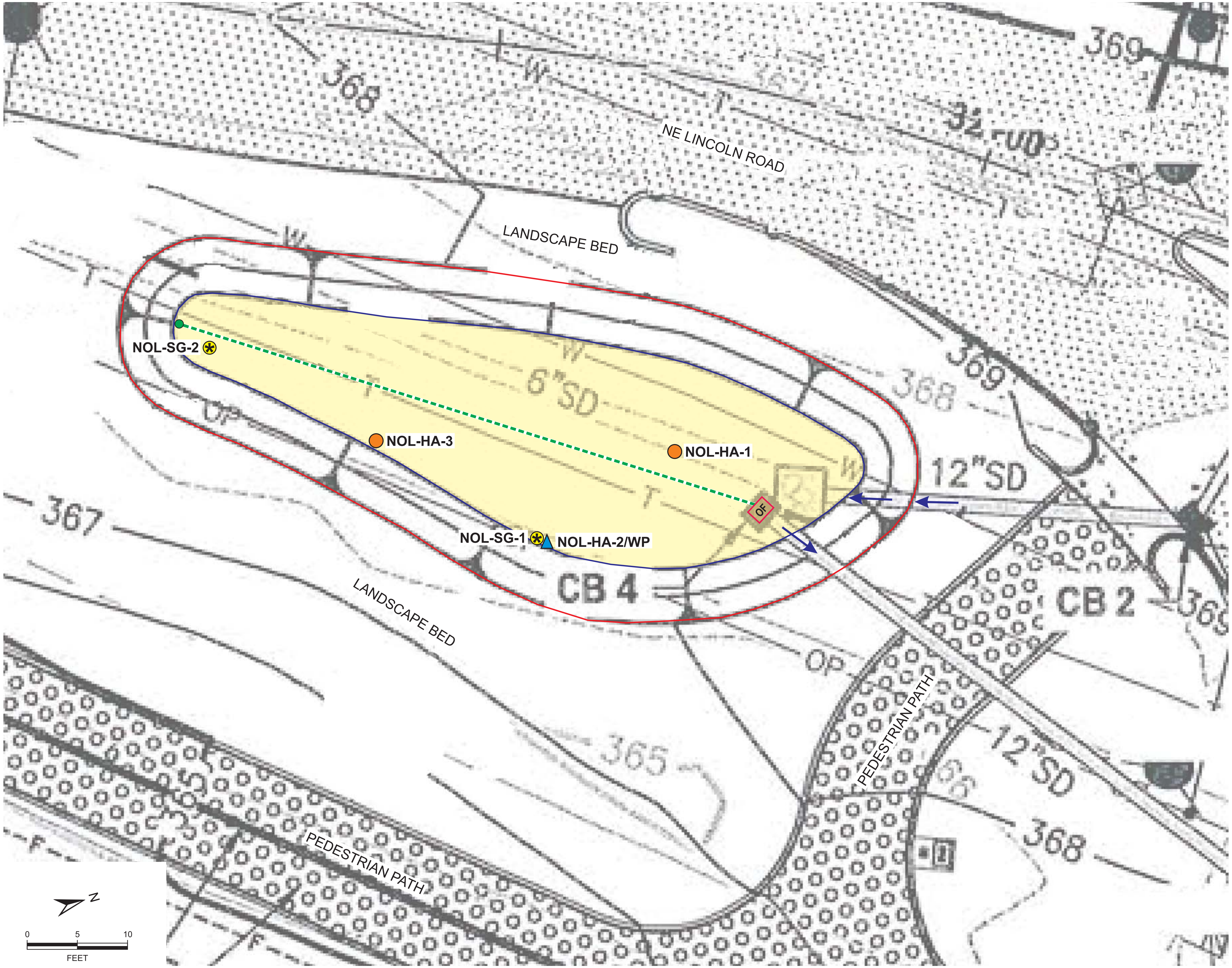

LEGEND:

● HA	HAND AUGER
▲ WP	WELL POINT
⊛	TEMPORARY STAFF GAUGE
▭	BASE OF FACILITY
▭	TOP OF FACILITY SLOPE
→	INFLOW / OVERFLOW DIRECTION
OF	OVERFLOW GRATE
- - - -	UNDERDRAIN
●	STORM DRAIN CLEANOUT

CONTOUR INTERVAL = 1'

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:
1. BASE MAP REFERENCE: PARAMETRIX, NOLL ROAD ROUNDABOUT, POULSBO, WASHINGTON, GRADING, DRAINAGE AND SANITARY SEWER PLAN, C4, 5/9/2012

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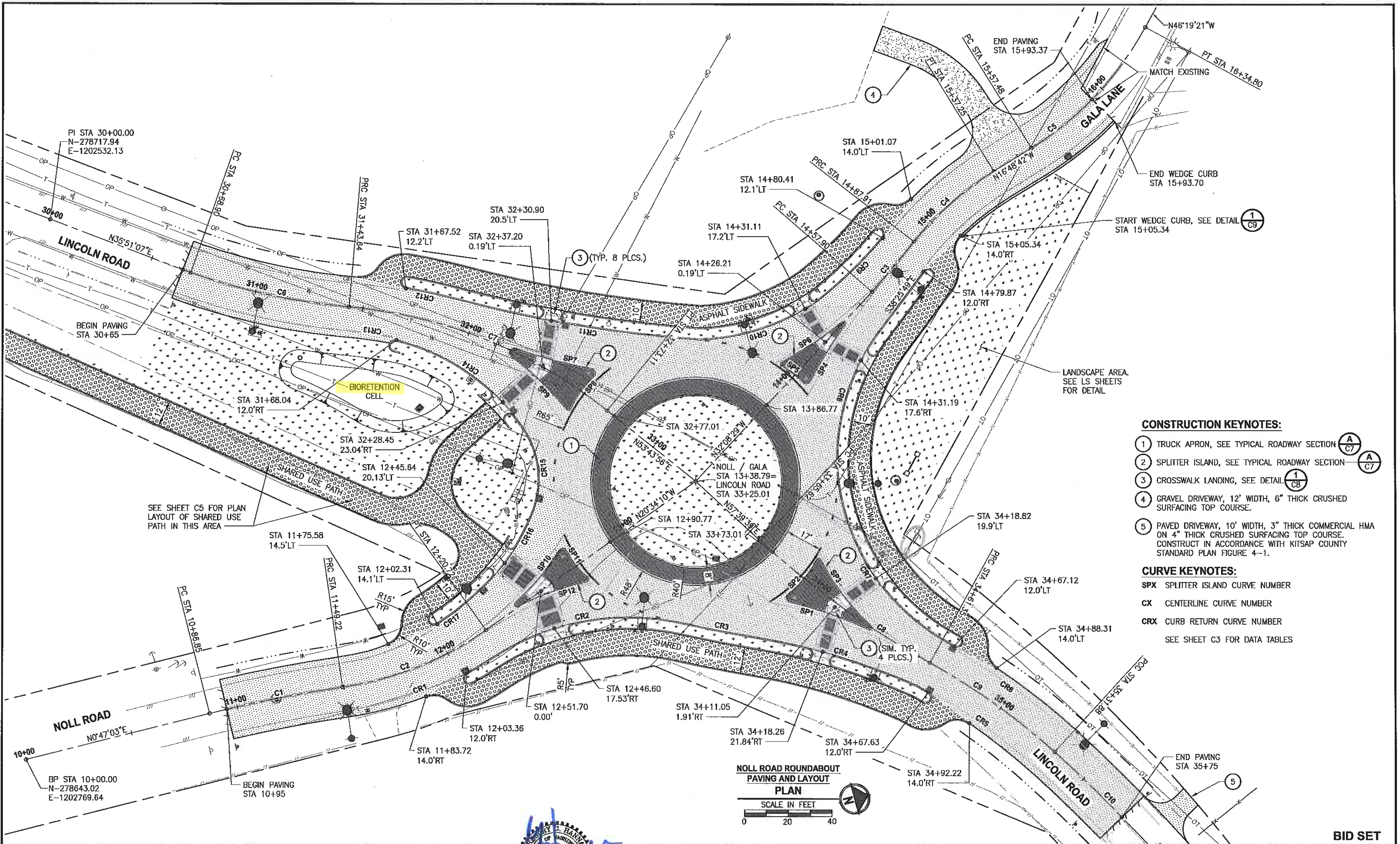
FACILITY AND EXPLORATION PLAN
NOL SITE
BIORETENTION HYDROLOGIC PERFORMANCE
POULSBO, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	NOL F3

150387 BHPS MCCA | 150387 Site-Expl.cdr PAGE 5: NOL

APPENDIX A

Project Civil Plans



CONSTRUCTION KEYNOTES:

① TRUCK APRON, SEE TYPICAL ROADWAY SECTION A/C7

② SPLITTER ISLAND, SEE TYPICAL ROADWAY SECTION A/C7

③ CROSSWALK LANDING, SEE DETAIL 1/C8

④ GRAVEL DRIVEWAY, 12' WIDTH, 6" THICK CRUSHED SURFACING TOP COURSE.

⑤ PAVED DRIVEWAY, 10' WIDTH, 3" THICK COMMERCIAL HMA ON 4" THICK CRUSHED SURFACING TOP COURSE. CONSTRUCT IN ACCORDANCE WITH KITSAP COUNTY STANDARD PLAN FIGURE 4–1.

CURVE KEYNOTES:

SPX	SPLITTER ISLAND CURVE NUMBER
CX	CENTERLINE CURVE NUMBER
CRX	CURB RETURN CURVE NUMBER
	SEE SHEET C3 FOR DATA TABLES

BID SET

REVISIONS	DATE	BY

DESIGNED G. HANNAN & S. RASMUSSEN
DRAWN S. RASMUSSEN
CHECKED K. HOUSE
APPROVED P. STRUCK

ONE INCH AT FULL SCALE. IF NOT, SCALE ACCORDINGLY
FILE NAME BR2237027P07T02–C02
JOB No. 234–2237–027
DATE May 2012

GREGORY L. HANNAN
37389
9 MAY 12

Parametrix
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BREMERTON, WASHINGTON 98312
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www.parametrix.com

PROJECT NAME
CITY OF POULSBO
NOLL ROAD ROUNDABOUT
POULSBO, WASHINGTON

PAVING AND LAYOUT PLAN

SHEET NO.
4 OF 22
C2

DATE: May 09, 2012 – 12:00pm LAYOUT: C-2
PLOTTED BY: rasmuste

IMAGES:
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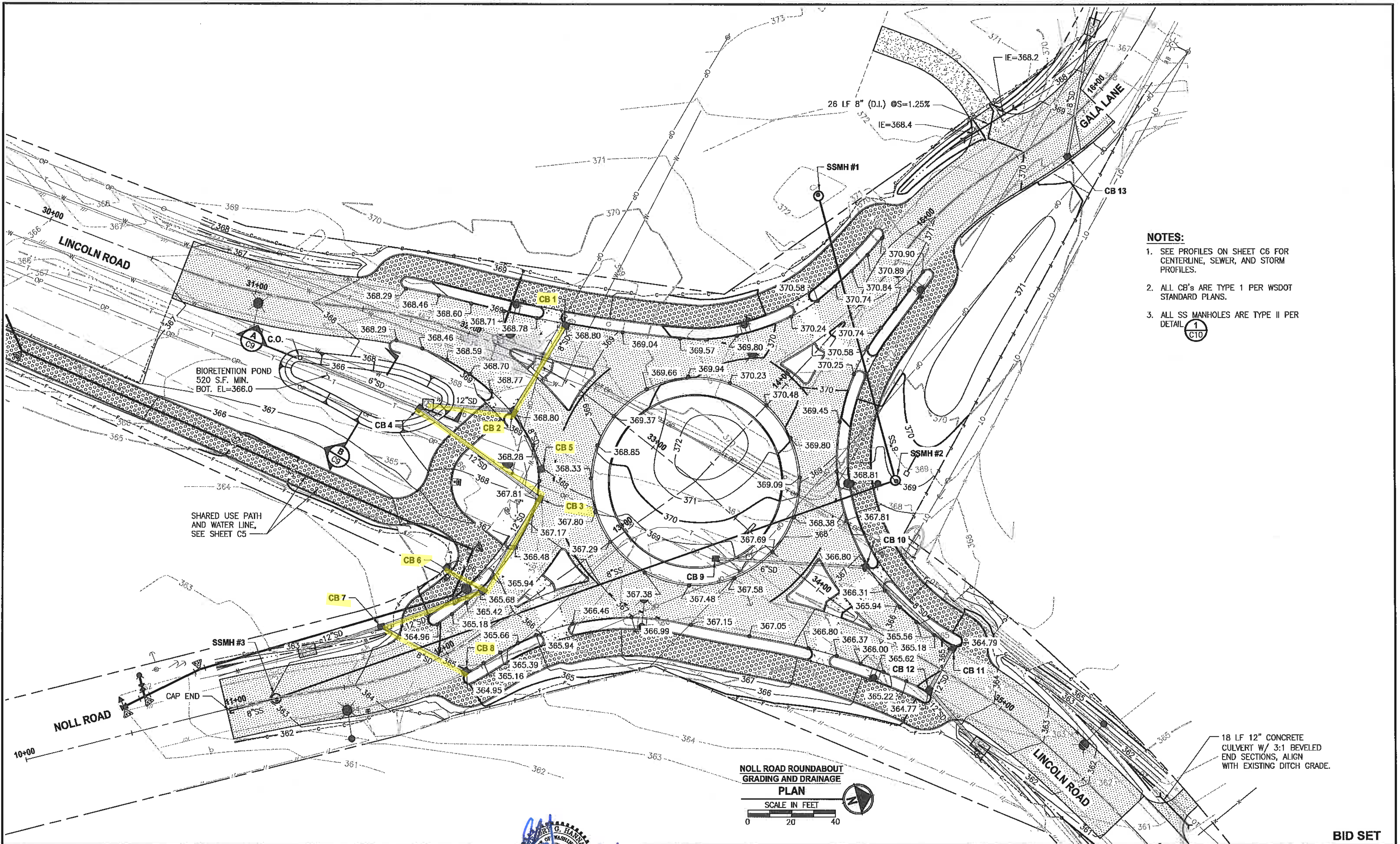

NOLL ROAD ROUNDABOUT GRADING AND DRAINAGE PLAN

SCALE IN FEET
0 20 40

NOTES:

1. SEE PROFILES ON SHEET C6 FOR CENTERLINE, SEWER, AND STORM PROFILES.
2. ALL CB's ARE TYPE 1 PER WSDOT STANDARD PLANS.
3. ALL SS MANHOLES ARE TYPE II PER DETAIL 1/C10

BID SET

IMAGES:
XREFS: PUX 22x34 Bremerton-PH3 | XBR2237027P05-DE-Road | XBR2237027P05-BA | XBR2237027P05-Aerial | XBR2237027P07T02-HA | XBR2237015-LincolnRd-Surv | GGH-PE

DATE: May 09, 2012 - 12:00pm LAYOUT: C-4
PLOTTED BY: rasmuste

REVISIONS	DATE	BY	
			DESIGNED S. RASMUSSEN & D. ZAVACK
			DRAWN S. RASMUSSEN
			CHECKED K. HOUSE
			APPROVED P. STRUCK

ONE INCH AT FULL SCALE.
IF NOT, SCALE ACCORDINGLY
FILE NAME BR2237027P07T02-C02
JOB No. 234-2237-027
DATE May 2012

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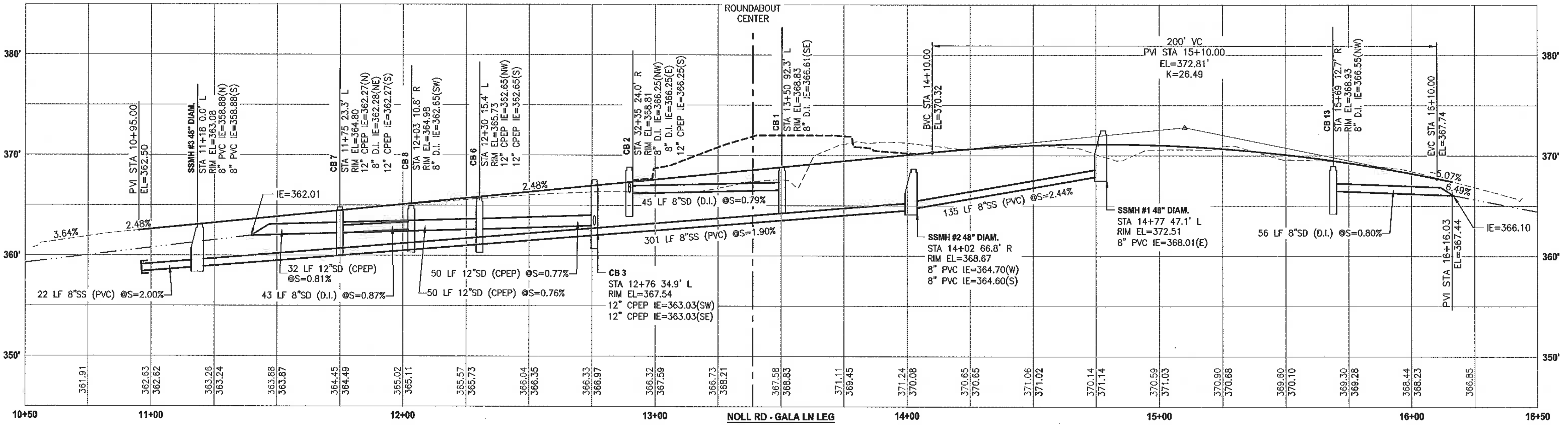
PROJECT NAME
CITY OF POULSBO
NOLL ROAD ROUNDABOUT
POULSBO, WASHINGTON

GRADING, DRAINAGE, AND SANITARY SEWER PLAN

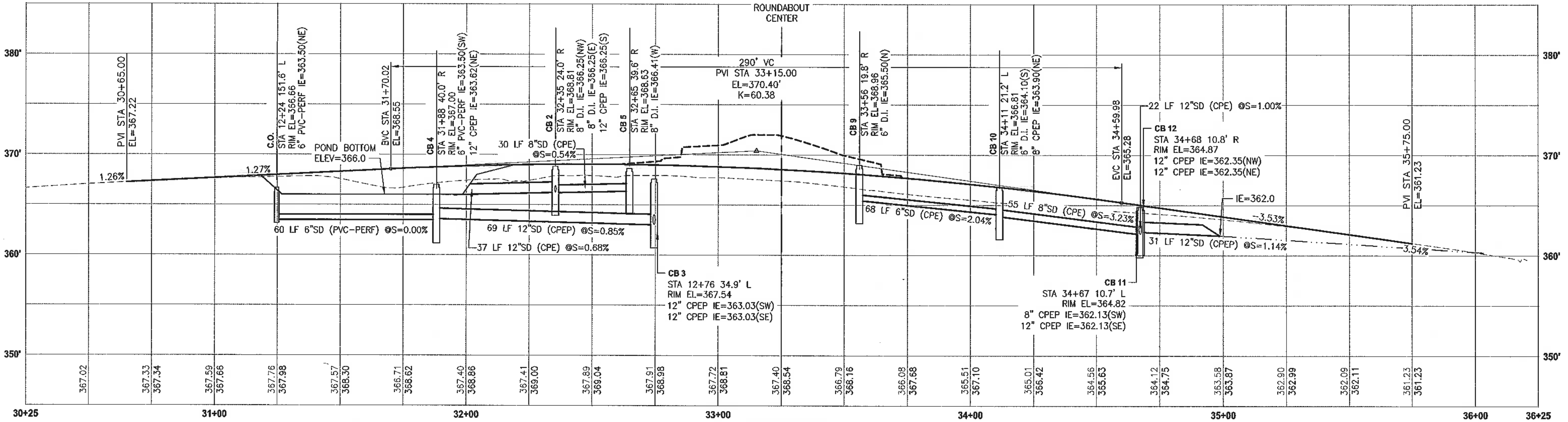
SHEET NO.
6 OF 22
C4



NOLL RD - GALA LN LEG

PROFILE

HORIZ: 1"=20'
VERT: 1"=5'



LINCOLN ROAD LEG

PROFILE

HORIZ: 1"=20'
VERT: 1"=5'

BID SET

▷	REVISIONS	DATE	BY

DESIGNED G. HANNAN & D. ZAVACK
DRAWN S. RASMUSSEN
CHECKED K. HOUSE
APPROVED P. STRUCK

ONE INCH AT FULL SCALE. IF NOT, SCALE ACCORDINGLY
FILE NAME BR2237027P07T02-C03
JOB No. 234-2237-027
DATE May 2012

GREGORY G. HANNAN
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9 MAY 12

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www.parametrix.com

PROJECT NAME
CITY OF POULSBO
NOLL ROAD ROUNDABOUT

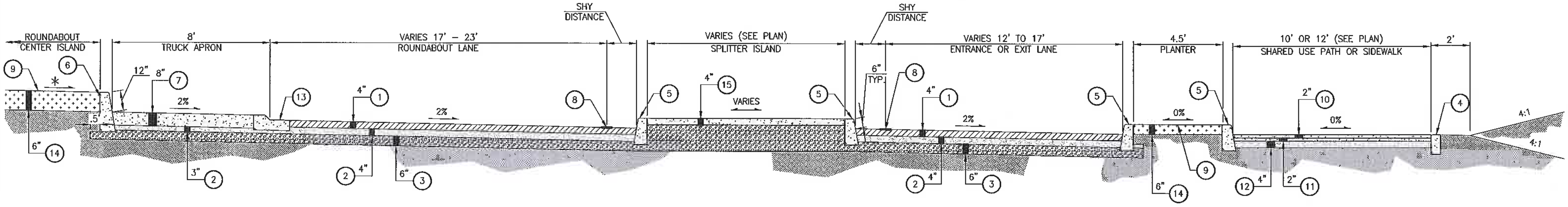
POULSBO, WASHINGTON

PAVING, DRAINAGE, AND SANITARY SEWER PROFILES

SHEET NO.
8 OF 22

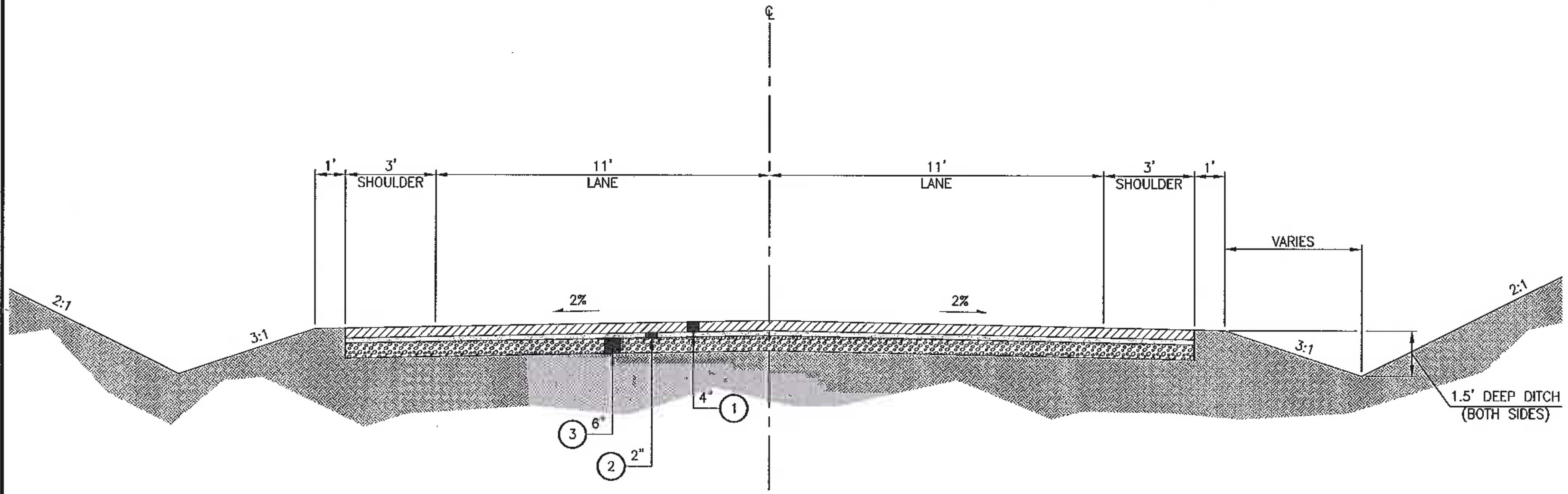
C6

LAYOUT: C-7 PATH: U:\Brem\Projects\Clients\2237-City of Poulsbo\234-2237-027 Noll Road Improvements\99Svcs\CADD\DWG\ PLOTTED BY: rasmuste DATE: Wednesday, May 09, 2012 11:09:22 AM



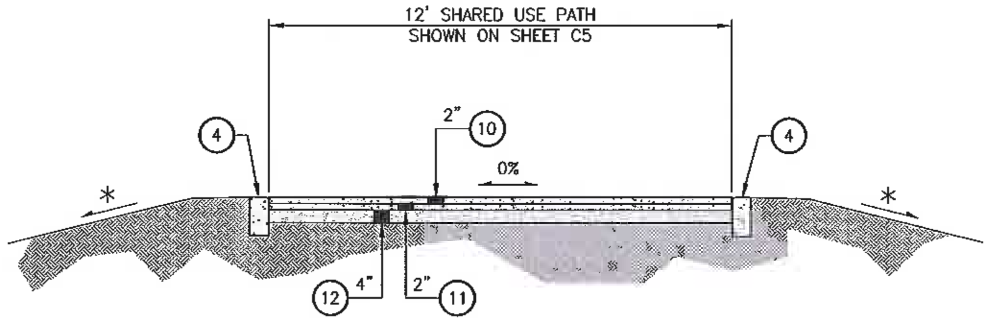
ROUNDABOUT
TYPICAL ROADWAY SECTION A

NO SCALE



APPROACH LEGS
NOLL ROAD, GALA LANE, AND LINCOLN ROAD
TYPICAL ROADWAY SECTION B

NO SCALE



TYPICAL SHARED USE PATH SECTION C

NO SCALE

CONSTRUCTION KEYNOTES:

① HMA CL ½ INCH PG 64–22.
② CRUSHED SURFACING TOP COURSE.
③ GRAVEL BASE.
④ CEMENT CONCRETE PEDESTRIAN CURB.
⑤ CEMENT CONCRETE TRAFFIC CURB.
⑥ ROUNDABOUT CENTRAL ISLAND CEMENT CONCRETE CURB.
⑦ STAMPED CEMENT CONCRETE TRUCK APRON.
⑧ 4" PAINTED WHITE SOLID EDGE LINE.
⑨ SEE LANDSCAPE PLANS FOR MATERIAL REQUIREMENTS.
⑩ PERVIOUS ASPHALT.
⑪ CHOKER COURSE, AASHTO NO. 57 PER WSDOT SECTION 9–03.1(4)C, STATIC ROLL ONLY.
⑫ RECHARGE BED PER WSDOT SECTION 9–03.9(2), STATIC ROLL ONLY.
⑬ ROUNDABOUT TRUCK APRON CEMENT CONCRETE CURB AND GUTTER.
⑭ TOPSOIL TYPE A.
⑮ STAMPED CEMENT CONCRETE SPLITTER ISLAND.

NOTES:

1. CONSTRUCT ALL CURBS IN ACCORDANCE WITH WSDOT STD PLAN F–10.12–01 (06–03–10 VERSION).

* SEE GRADING PLAN.

BID SET

REVISIONS	DATE	BY

DESIGNED G. HANNAN
DRAWN S. RASMUSSEN
CHECKED K. HOUSE
APPROVED P. STRUCK

ONE INCH AT FULL SCALE. IF NOT, SCALE ACCORDINGLY
FILE NAME BR2237027P07T02–C04
JOB No. 234–2237–027
DATE May 2012

GREGORY G. HANNAN
37369
9 MAY 12

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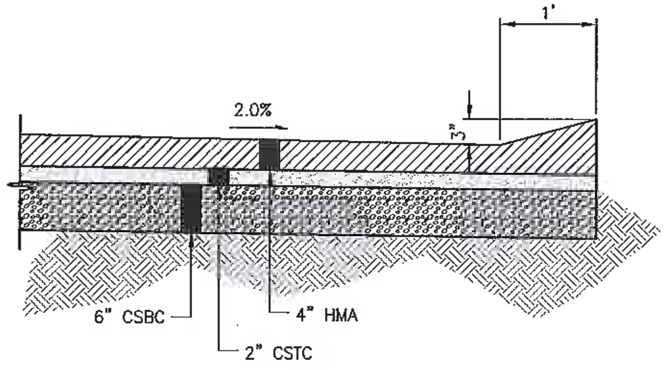
www.parametrix.com

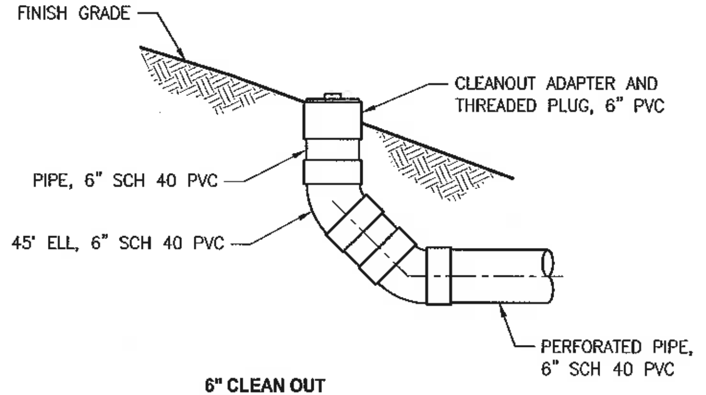
PROJECT NAME
CITY OF POULSBO
NOLL ROAD ROUNDABOUT
POULSBO, WASHINGTON

TYPICAL ROADWAY SECTIONS

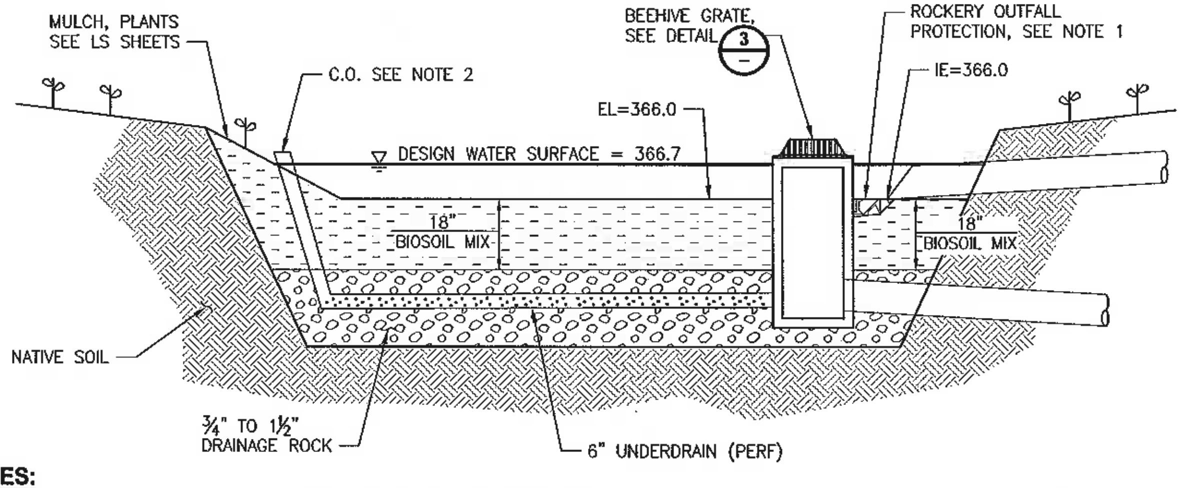
SHEET NO.
9 OF 22
C7



WEDGE CURB
DETAIL 1 C2
NO SCALE



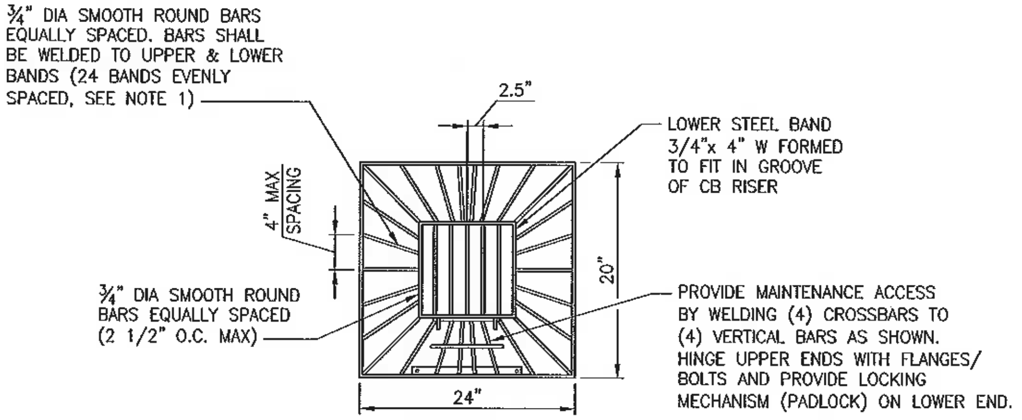
6" CLEAN OUT
DETAIL 2 C4
NO SCALE



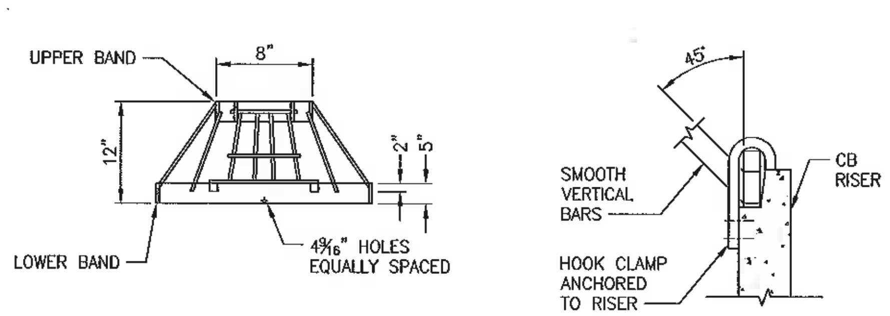
NOTES:

1. OUTFALL ROCKERY PAD 4' WIDEx6' LONGx1' DEEP WITH THE FOLLOWING GRADATION:
   MAX = 12"
   MIN = 4"
   MEDIAN = 8"
2. CLEAN OUT RIM MUST BE 6" ABOVE DESIGN WATER SURFACE ELEVATION.

BIORETENTION POND
SECTION A C4
NO SCALE



PLAN

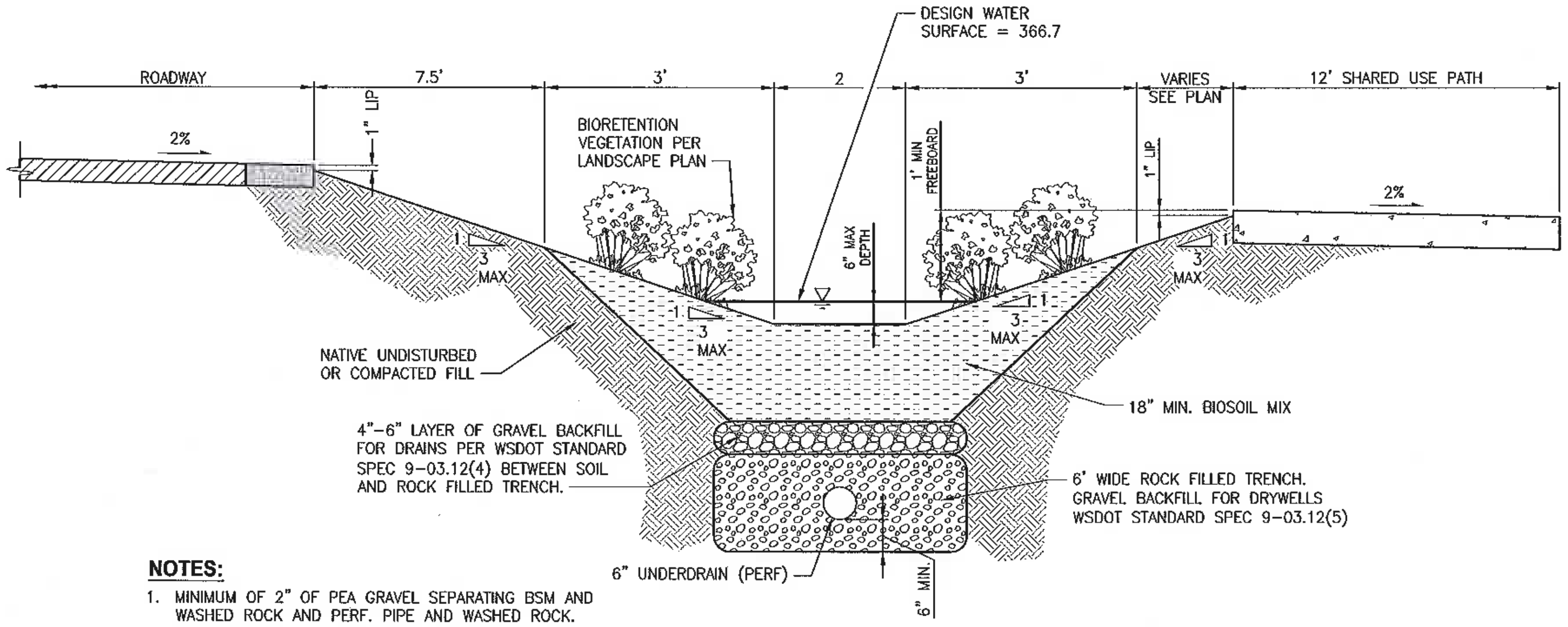


ELEVATION

NOTES:

1. ALL MATERIALS SHALL BE BLACK ALUMINIZED STEEL.

BEEHIVE GRATE
DETAIL 3 TYP
NO SCALE



NOTES:

1. MINIMUM OF 2" OF PEA GRAVEL SEPARATING BSM AND WASHED ROCK AND PERF. PIPE AND WASHED ROCK.
2. BIORETENTION SOIL MIX (BSM) TO 2012 DOE SMWW SPECIFICATIONS. MINIMUM INFILTRATION RATE OF 4"/HOUR. BSM PLACED UP TO DESIGN WATER SURFACE AS A MINIMUM.

BIORETENTION POND
SECTION B C4
NO SCALE

BID SET

LAYOUT: C-9 PATH: U:\Brem\Projects\Clients\2237-City of Poulsbo\234-2237-027 Noll Road Improvements\99Svcs\CADD\DWG\ PLOTTED BY: rasmuste DATE: Wednesday, May 09, 2012 11:09:50 AM

▷	REVISIONS	DATE	BY

DESIGNED D. ZAVACK
DRAWN S. RASMUSSEN
CHECKED K. HOUSE
APPROVED P. STRUCK

ONE INCH AT FULL SCALE. IF NOT, SCALE ACCORDINGLY
FILE NAME BR2237027P07T02-C06
JOB No. 234-2237-027
DATE May 2012

9 MAY 12

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PROJECT NAME
CITY OF POULSBO
NOLL ROAD ROUNDABOUT
POULSBO, WASHINGTON

STORMWATER AND DRAINAGE DETAILS

SHEET NO.
11 OF 22
C9

APPENDIX B

Current Study Exploration Logs and Laboratory Testing Data

Cell NOL
Exploration Latitude and Longitude

Exploration	Latitude	Longitude
NOL-HA-1	47.75057	-122.61301
NOL-HA-2	47.75054	-122.61298
NOL-HA-3	47.75049	-122.61304

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Exploration Log

Project Number	Exploration Number	Sheet
KH150387A	NOL-HA-1	1 of 1

Project Name: Bioretention Hydrologic Performance Study
Location: Poulsbo, WA
Driller/Equipment: Hand Auger
Hammer Weight/Drop: N/A
Ground Surface Elevation (ft):
Datum: Not Surveyed
Date Start/Finish: 8/4/16,8/4/16
Hole Diameter (in): 4 inches

Depth (ft)	S T	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot 10 20 30 40	Other Tests
				Bioretention Soil Mix Surface; leaf litter Loose, dry, brown, SAND, trace silt; organics present; mostly medium sand (~61 percent) (SP).					
				Drain Rock Loose, medium to coarse GRAVEL, some sand (GP).					
				Bottom of exploration boring at 1.6 feet Refusal due to caving. No seepage.					

Sampler Type (ST):

- ▯ 2" OD Split Spoon Sampler (SPT)
- ▯ 3" OD Split Spoon Sampler (D & M)
- ☐ Grab Sample
- ☐ No Recovery
- ◧ Ring Sample
- ▨ Shelby Tube Sample
- M - Moisture
- ▽ Water Level ()
- ▼ Water Level at time of drilling (ATD)

Logged by: ADY
Approved by: JHS

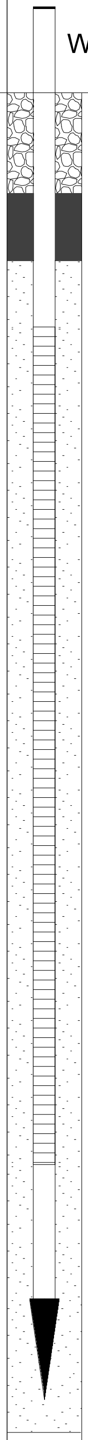
associated earth sciences incorporated

Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KH150387A	NOL-HA-2/WP	1 of 1

Project Name: Bioretention Hydrologic Performance Study
Elevation (Top of Well Casing): ~1.7 feet (stick up)
Water Level Elevation:
Drilling/Equipment: Hand Auger
Hammer Weight/Drop: N/A
Location: Poulsbo, WA
Surface Elevation (ft):
Date Start/Finish: 8/4/16,8/4/16
Hole Diameter (in): 4 inches

Depth (ft) | Water Level | WELL CONSTRUCTION | S T | Blows/ 6" | Graphic Symbol | DESCRIPTION



Above ground stick up -1.7 feet
Threaded PVC cap
Bioretention soil mix 0 to 0.3 foot
Bentonite chips 0.3 to 0.5 foot

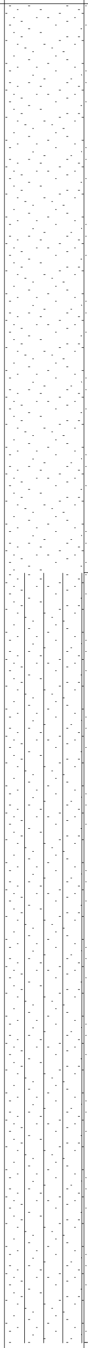
Threaded steel pipe -1.7 to 0.7 feet

Medium sand 0.5 to 4 feet

Stainless steel jacket over stainless steel #60 gauze welded to perforated steel pipe 0.7 to 3.2 feet

Threaded steel pipe, 1 1/4 inch ID and end cap 3.2 to 3.6 feet

Solid drive point 3.6 to 3.9 feet



Bioretention Soil Mix

Loose, dry, brown, SAND, trace gravel, trace silt; organics present; mostly medium sand (SP). Minor leaf litter present at ground surface.

Vashon Lodgement Till

Medium dense to dense, dry, light brown, silty, gravelly SAND; unsorted (SM).

Becomes gray at 3.9 feet.

Boring terminated at 4 feet.
Well completed at 4 feet on 8/4/16.
Refusal due to cobbles. No seepage. No caving.

Sampler Type (ST):

▯ 2" OD Split Spoon Sampler (SPT)	▯ No Recovery	M - Moisture
▯ 3" OD Split Spoon Sampler (D & M)	▮ Ring Sample	▽ Water Level ()
▯ Grab Sample	▯ Shelby Tube Sample	▼ Water Level at time of drilling (ATD)

Logged by: ADY
Approved by: JHS

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Exploration Log

Project Number	Exploration Number	Sheet
KH150387A	NOL-HA-3	1 of 1

Project Name: Bioretention Hydrologic Performance Study
Location: Poulsbo, WA
Driller/Equipment: Hand Auger
Hammer Weight/Drop: N/A

Ground Surface Elevation (ft):
Datum: Not Surveyed
Date Start/Finish: 8/4/16,8/4/16
Hole Diameter (in): 4 inches

Depth (ft)	S T	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot 10 20 30 40	Other Tests
				Bioretention Soil Mix Surface; leaf litter Loose, dry, brown, SAND,trace silt; organics present; mostly medium sand (~63 percent) (SP).					
				Vashon Lodgement Till Medium dense to dense, dry, light brown, silty, gravelly SAND; cobbles (4 inches) present (SM).					
				Bottom of exploration boring at 3.5 feet Refusal due to cobbles. No seepage. No caving.					

Sampler Type (ST):

▯ 2" OD Split Spoon Sampler (SPT)
▯ 3" OD Split Spoon Sampler (D & M)
✋ Grab Sample
☐ No Recovery
◧ Ring Sample
▨ Shelby Tube Sample
M - Moisture
▽ Water Level ()
▼ Water Level at time of drilling (ATD)

Logged by: ADY
Approved by: JHS

Moisture, Ash, and Organic Matter of Peat and Other Organic Soils - ASTM 2974

Date Sampled	**Project**	**Project No.**		**Soil Description**
8/4/2016	BHPS	KH150387A		
Tested By	**Location**	**EB/EP No.**	**Depth**	Bioretention soil mix
MS	NOL	NOL		

Moisture Content	**NOL**	**Moisture Content**	**NOL**
Sample ID	**HA1 0.6-0.9**	Sample ID	**HA3 0.6-0.9**
Wet Weight + Pan	**875.30**	Wet Weight + Pan	**995.30**
Dry Weight + Pan	**851.07**	Dry Weight + Pan	**965.72**
Weight of Pan	**307.12**	Weight of Pan	**306.95**
Weight of Moisture	**24.23**	Weight of Moisture	**29.58**
Dry Weight of Soil	**543.95**	Dry Weight of Soil	**658.77**
% Moisture	**4.5**	% Moisture	**4.5**

Organic Matter and Ash Content		**Organic Matter and Ash Content**	
Dry Soil Befor Burn + Pan	**906.78**	Dry Soil Befor Burn + Pan	**1056.52**
Dry Soil After Burn + Pan	**887.72**	Dry Soil After Burn + Pan	**1031.43**
Weight of Pan	**358.19**	Weight of Pan	**392.16**
Wt. Loss Due to Ignition	**19.06**	Wt. Loss Due to Ignition	**25.09**
Actual Wt. Of Soil After Burr	**529.53**	Actual Wt. Of Soil After Burr	**639.27**
% Organics	**3.5**	% Organics	**3.8**

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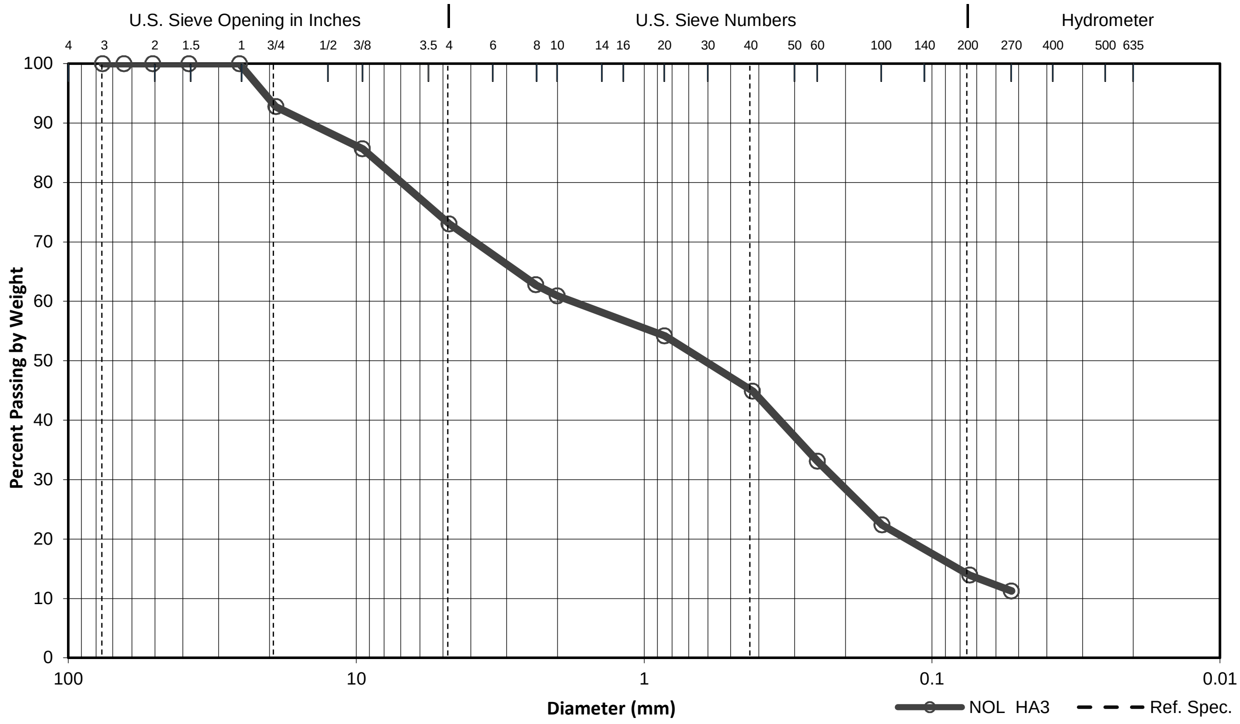
GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

Project Name	Project Number	Date Sampled	Date Tested	Tested By
BHPS	**KH150387A**	**8/4/2016**	**9/1/2016**	**MS**

Sample Source	Sample No.	Depth (ft)	Soil Description
Onsite	**NOL HA3**	**3-3.3**	**silty, gravelly SAND (SM)**

Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification
1019.9	**7**	**~0.04**	**Not applicable: native material**



Cobb.	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4		0.0	100.0		
3/4	19	73.9	7.2	92.8		
3/8	9.51	146.1	14.3	85.7		
#4	4.76	274.9	27.0	73.0		
#8	2.38	379.5	37.2	62.8		
#10	2	398.6	39.1	60.9		
#20	0.85	467.0	45.8	54.2		
#40	0.42	562.1	55.1	44.9		
#60	0.25	682.3	66.9	33.1		
#100	0.149	791.8	77.6	22.4		
#200	0.074	878.0	86.1	13.9		
#270	0.053	905.0	88.7	11.3		

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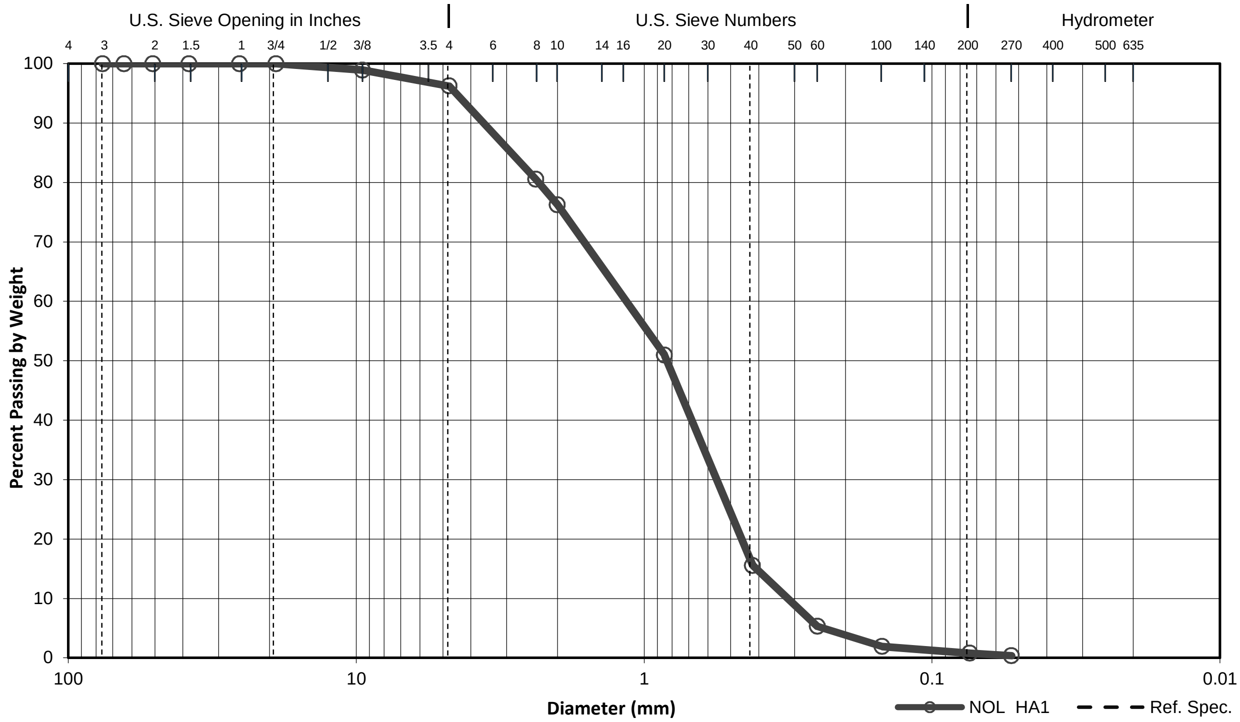
GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

Project Name	Project Number	Date Sampled	Date Tested	Tested By
BHPS	**KH150387A**	**8/4/2016**	**9/1/2016**	**MS**
Sample Source	Sample No.	Depth (ft)	Soil Description	
Onsite	**NOL HA1**	**0.6-0.9**	**SAND, trace silt, trace gravel (SP)**	
Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification	
529.9	**0**	**0.316**	**Bioretention soil mix: burned sample**	

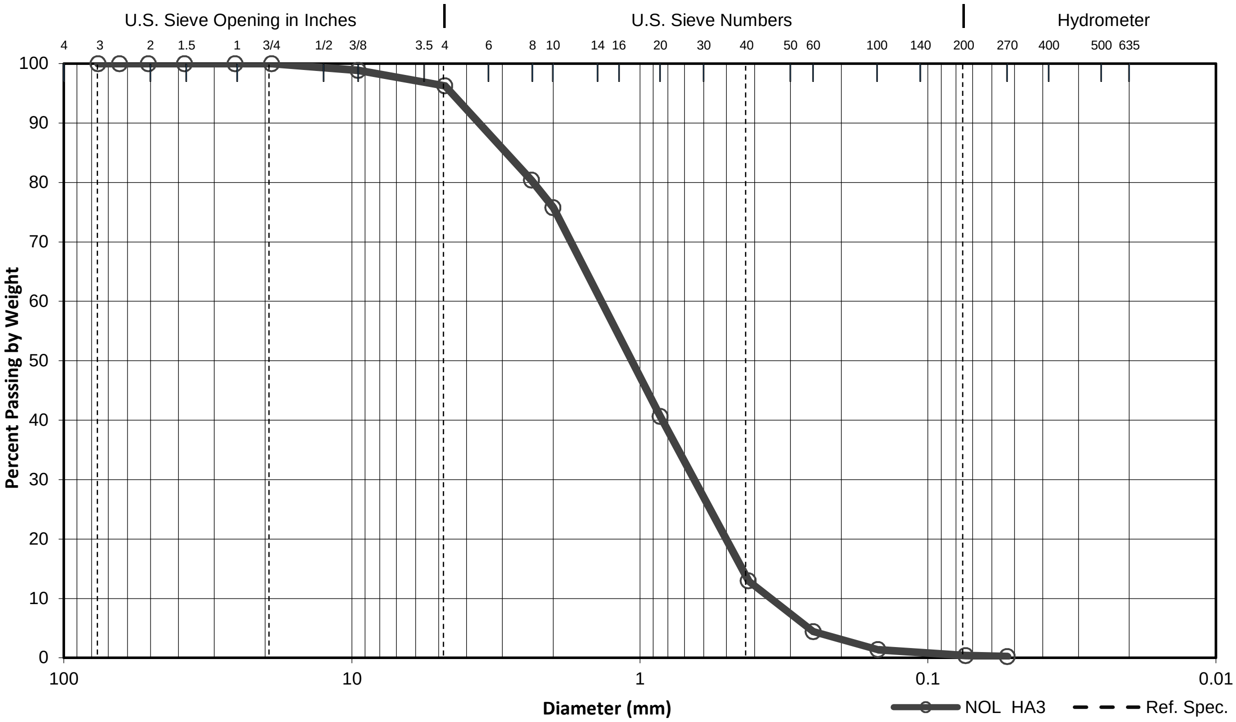


Cobb.	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4		0.0	100.0		
3/4	19		0.0	100.0		
3/8	9.51	5.8	1.1	98.9		
#4	4.76	19.8	3.7	96.3		
#8	2.38	103.1	19.5	80.5		
#10	2	125.8	23.7	76.3		
#20	0.85	259.8	49.0	51.0		
#40	0.42	447.3	84.4	15.6		
#60	0.25	501.7	94.7	5.3		
#100	0.149	519.7	98.1	1.9		
#200	0.074	525.7	99.2	0.8		
#270	0.053	527.9	99.6	0.4		

GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

Project Name	Project Number	Date Sampled	Date Tested	Tested By
BHPS	**KH150387A**	**8/4/2016**	**9/1/2016**	**MS**
Sample Source	Sample No.	Depth (ft)	Soil Description	
Onsite	**NOL HA3**	**0.6-0.9**	**SAND, trace silt, trace gravel (SP)**	
Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification	
639.7	**0**	**0.351**	**Bioretention soil mix: burned sample**	



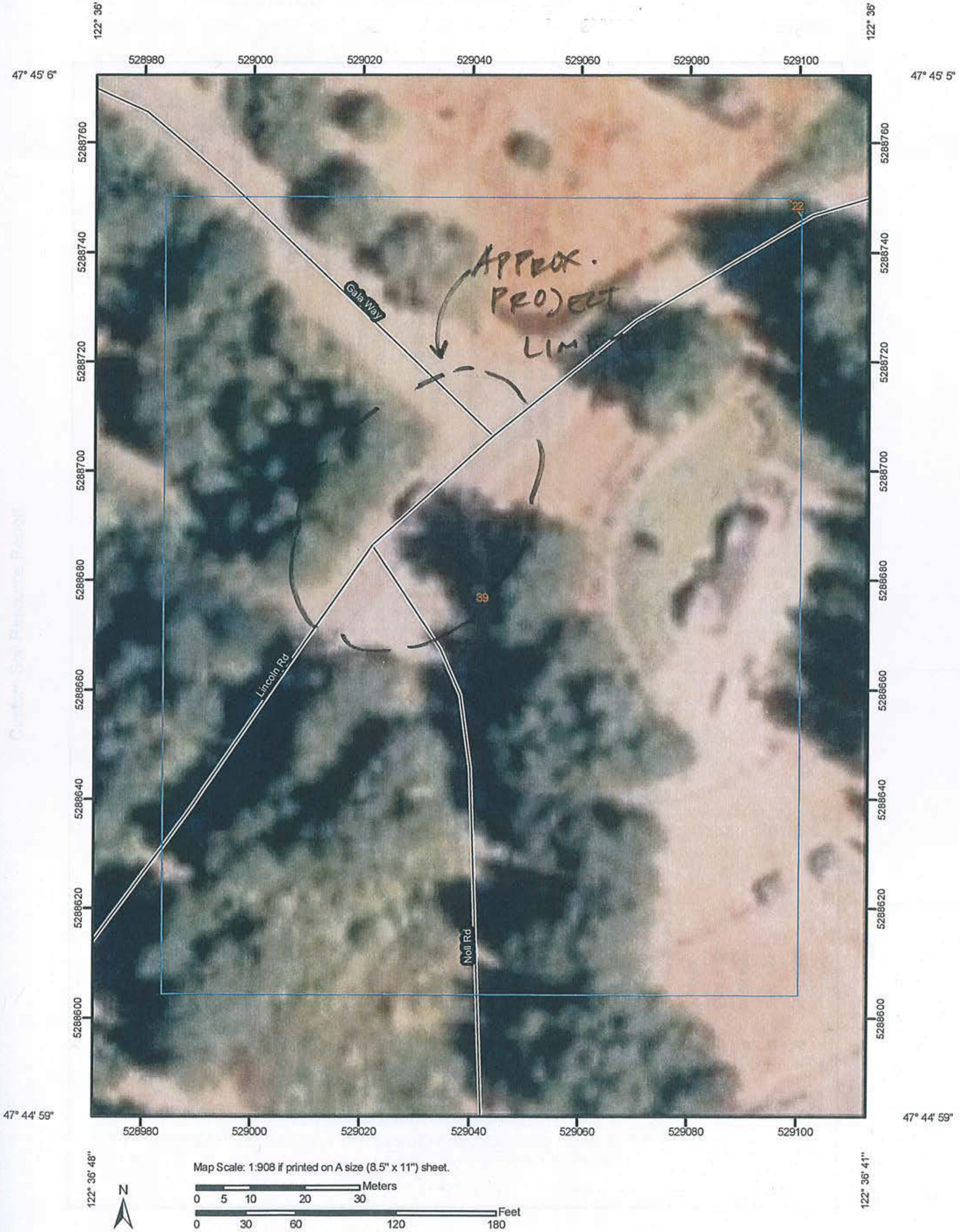
Cobb.	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4		0.0	100.0		
3/4	19		0.0	100.0		
3/8	9.51	7.1	1.1	98.9		
#4	4.76	23.6	3.7	96.3		
#8	2.38	125.5	19.6	80.4		
#10	2	154.9	24.2	75.8		
#20	0.85	379.6	59.3	40.7		
#40	0.42	556.8	87.0	13.0		
#60	0.25	611.4	95.6	4.4		
#100	0.149	630.9	98.6	1.4		
#200	0.074	637.2	99.6	0.4		
#270	0.053	638.3	99.8	0.2		

APPENDIX C

Background Soil, Geology, and Ground Water Data (Regional Maps, Previous Studies Exploration Logs and Laboratory Testing Data)

Custom Soil Resource Report
Soil Map (Noll Road Turnabout)



Map Scale: 1:908 if printed on A size (8.5" x 11") sheet.

MAP LEGEND

Area of Interest (AOI)
- ☐ Area of Interest (AOI)

Soils
- ☐ Soil Map Units

Special Point Features
- ʊ Blowout
- ☒ Borrow Pit
- ⋇ Clay Spot
- ◆ Closed Depression
- ⚒ Gravel Pit
- ∴ Gravelly Spot
- ⊘ Landfill
- ʎ Lava Flow
- ⩩ Marsh or swamp
- ⚒ Mine or Quarry
- ◎ Miscellaneous Water
- ◉ Perennial Water
- ∨ Rock Outcrop
- + Saline Spot
- ⁘ Sandy Spot
- ⩧ Severely Eroded Spot
- ◇ Sinkhole
- ⥽ Slide or Slip
- ⌀ Sodic Spot
- ≋ Spoil Area
- ◊ Stony Spot
- ω Very Stony Spot
- ⚲ Wet Spot
- ▲ Other

Special Line Features
- ∼ Gully
- ⋯ Short Steep Slope
- ⌃ Other

Political Features
- ● Cities

Water Features
- ▇ Oceans
- ∼ Streams and Canals

Transportation
- ┼┼┼ Rails
- ∼ Interstate Highways
- ∼ US Routes
- ∼ Major Roads
- ∼ Local Roads

MAP INFORMATION

Map Scale: 1:908 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 10N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Kitsap County Area, Washington
Survey Area Data: Version 6, Sep 22, 2009

Date(s) aerial images were photographed: 7/21/2006

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend (Noll Road Turnabout)

Kitsap County Area, Washington (WA635)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
22	Kapowsin gravelly loam, 0 to 6 percent slopes	0.0	0.0%
39	Poulsbo gravelly sandy loam, 0 to 6 percent slopes	4.2	100.0%
Totals for Area of Interest		**4.2**	**100.0%**

Map Unit Descriptions (Noll Road Turnabout)

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments

Kitsap County Area, Washington

22—Kapowsin gravelly loam, 0 to 6 percent slopes

Map Unit Setting

Elevation: 50 to 900 feet
Mean annual precipitation: 30 to 50 inches
Mean annual air temperature: 48 to 52 degrees F
Frost-free period: 150 to 220 days

Map Unit Composition

Kapowsin and similar soils: 100 percent

Description of Kapowsin

Setting

Landform: Terraces
Parent material: Basal till with volcanic ash in the upper part

Properties and qualities

Slope: 0 to 6 percent
Depth to restrictive feature: 20 to 35 inches to dense material
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
Depth to water table: About 12 to 24 inches
Frequency of flooding: None
Frequency of ponding: None
Available water capacity: Low (about 4.3 inches)

Interpretive groups

Land capability (nonirrigated): 3s

Typical profile

0 to 5 inches: Gravelly loam
5 to 23 inches: Gravelly loam
23 to 60 inches: Very gravelly sandy loam

Minor Components

Norma

Percent of map unit:
Landform: Depressions

39—Poulsbo gravelly sandy loam, 0 to 6 percent slopes

Map Unit Setting

Mean annual precipitation: 35 inches
Mean annual air temperature: 50 degrees F
Frost-free period: 210 days

Map Unit Composition

Poulsbo and similar soils: 100 percent

Description of Poulsbo

Setting

Landform: Terraces, moraines
Parent material: Basal till with volcanic ash in the upper part

Properties and qualities

Slope: 0 to 6 percent
Depth to restrictive feature: 20 to 40 inches to dense material
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
Depth to water table: About 12 to 30 inches
Frequency of flooding: None
Frequency of ponding: None
Available water capacity: Very low (about 2.9 inches)

Interpretive groups

Land capability (nonirrigated): 4s

Typical profile

0 to 2 inches: Gravelly sandy loam
2 to 24 inches: Gravelly sandy loam
24 to 60 inches: Very gravelly sandy loam

Minor Components

Norma

Percent of map unit:
Landform: Depressions

ROPOSED ROUNDABOUT

ROPOSED STRIPING

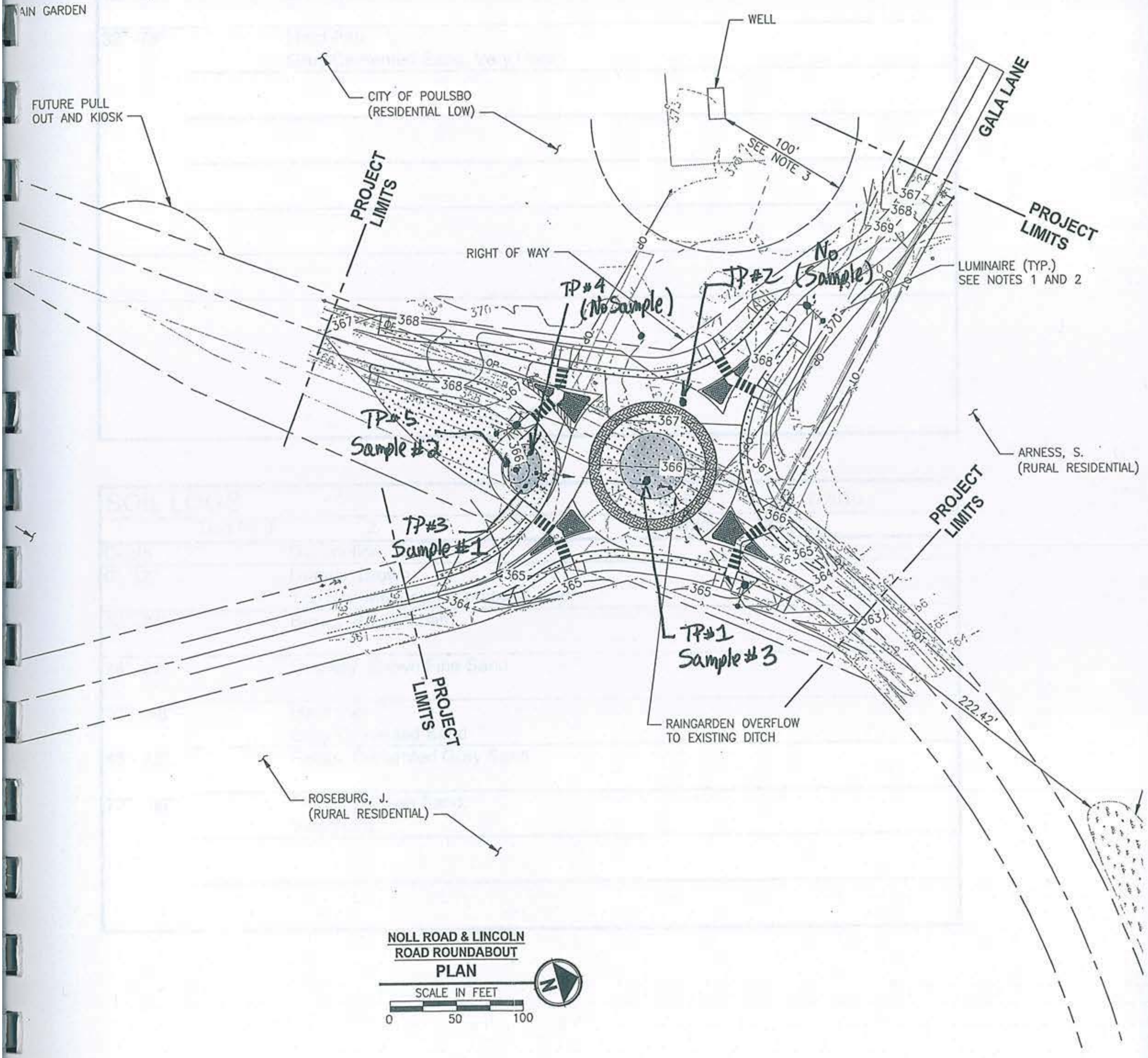
PROPOSED MAJOR CONTOUR (5')

ROPOSED MINOR CONTOUR (1')

LANDSCAPE AREA

AIN GARDEN

TEST PITS



NOLL ROAD & LINCOLN ROAD ROUNDABOUT

PLAN

SCALE IN FEET

0 50 100

ONE INCH AT FULL SCALE. IF NOT, SCALE ACCORDINGLY

FILE NAME BR2237027P05T03-C02a

JOB No. 234-2237-027

DATE MAY 13, 2010

Parametrix

ENGINEERING . PLANNING . ENVIRONMENTAL SCIENCES

4660 KITSAP WAY, SUITE A
BREMERTON, WASHINGTON 98312
T. 360.377.0014 F. 360.479.5961
www.parametrix.com

PROJECT NAME

CITY OF POULSBO
NOLL ROAD IMPROVEMENTS
PRELIMINARY DESIGN
POULSBO, WASHINTON

SOIL LOGS

DHZ 3/17/2010

Test Pit # 1

Sample # 3 30" deep

Depth	Description
0 - 12"	Humus, Brown Top Soil with organic material, dark
12"- 30"	Brown, Sandy Loam
32" -78"	Hard Pan Grey Cemented Sand, Very Hard

SOIL LOGS

DHZ 3/17/2010

Test Pit # 2

Sample # None

Depth	Description
0 - 12"	Humus, Brown Top Soil with organic material, dark
12"- 24"	Brown, Sandy Loam
24" -32"	Gravelly, Brown Fine Sand
32" - 48"	Hard Pan Grey Cemented Sand
48"- 72"	Rocks, Cemented Grey Sand
72" - 96"	Gravelly Brown Sand, Very Hard

SOIL LOGS

DHZ 3/17/2010

Test Pit # 3

Sample # 1 _96"deep

Depth	Description
0 - 12".	Brown Humus/Duff Top Soil with organic material, dark
12"- 24"	Brown, Sandy Loam
24" -36"	Big Rocks, brown gravelly, sandy loam
36" -72"	Hard Pan, Cemented Gray Sand
72" - 96"	Fine Gray Sandy Loam

SOIL LOGS

DHZ 3/17/2010

Test Pit # 4

Sample # None

Depth	Description
0 - 12"	Dark Brown Humus/Duff Top Soil with organic material, dark
12"- 42"	Brown, Sandy Loam
42" -72"	Hard Pan, Grey Cemented Sand
72" -84"	Hard Pan, Cemented Gray Sand with large rocks
84" - 100"	Fine Gray Sandy Loam

SOIL LOGS

DHZ 3/17/2010

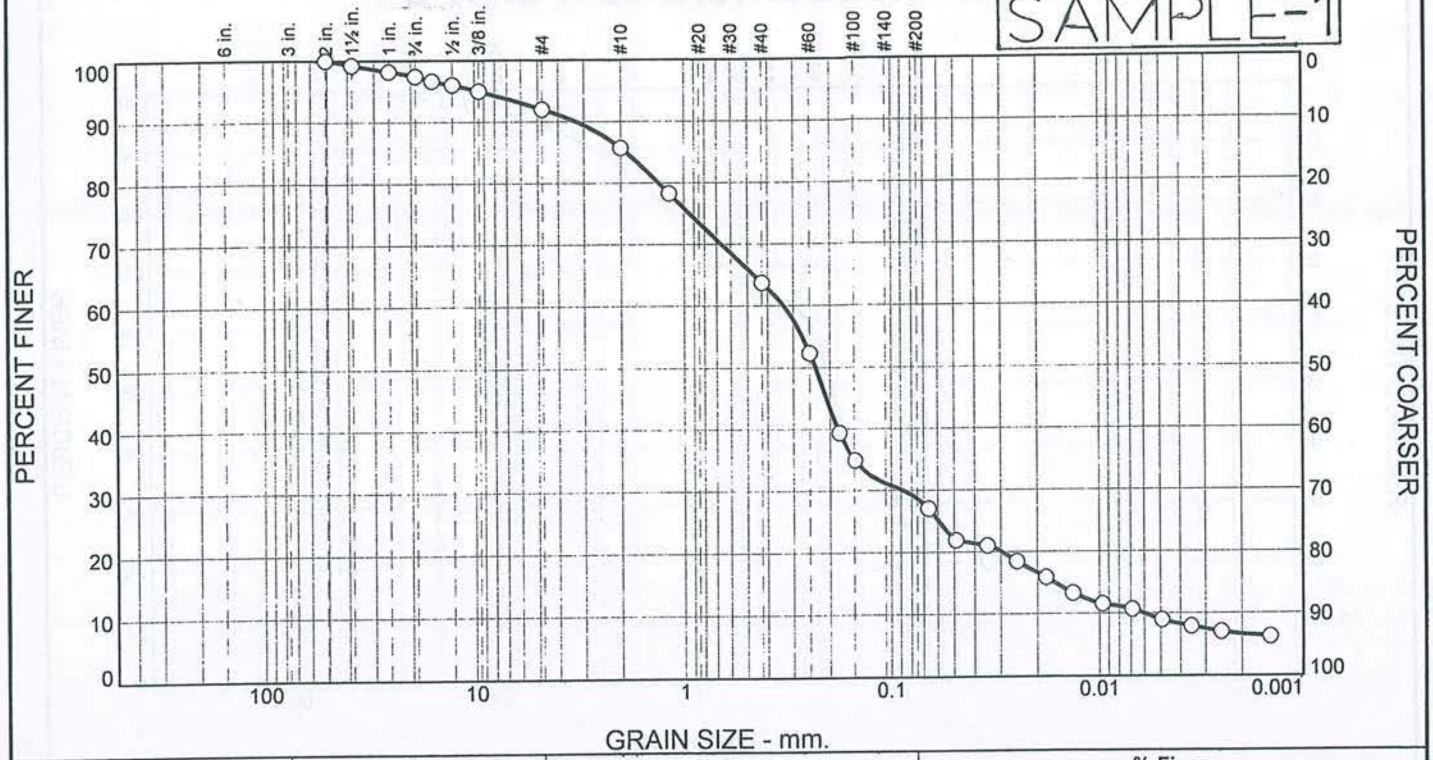
Test Pit # 5

Sample # 2 120" deep

Depth	Description
0 - 12"	Brown Humus Top Soil with organic material, dark
12"- 40"	Brown, Sandy Loam
40" -60"	Hard Pan, Grey Cemented Sand
60"-72"	Very Hard Grey Sand with Rocks
72"-120"	Fine Gray Loamy Sand, Hard

Particle Size Distribution Report

SAMPLE-1



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	2.6	5.4	6.3	21.9	35.1	19.7	9.0

Test Results (ASTM C 136 & ASTM C 117)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
2	100.0		
1.5	99.2		
1	98.2		
.75	97.4		
.625	96.7		
.5	96.0		
.375	95.0		
#4	92.0		
#10	85.7		
#16	78.3		
#40	63.8		
#60	52.4		
#80	39.4		
#100	34.9		
0.0663 mm.	27.0		
0.0489 mm.	21.9		
0.0348 mm.	21.0		
0.0251 mm.	18.5		
0.0181 mm.	15.9		
0.0135 mm.	13.3		
0.0097 mm.	11.6		
0.0069 mm.	10.7		
0.0049 mm.	9.0		
0.0035 mm.	8.0		
0.0025 mm.	7.0		
0.0014 mm.	6.3		

* (no specification provided)

Material Description

SILTY SAND

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SM **AASHTO (M 145)=** A-2-4(0)

Coefficients

D_{90}= 3.2557	D_{85}= 1.8805	D_{60}= 0.3340
D_{50}= 0.2350	D_{30}= 0.0878	D_{15}= 0.0164
$\boxed{D_{10}= 0.0060}$	C_u= 55.81	C_c= 3.86

Remarks

REPORT:119616
FIELD DESCRIPTION: GRAY POORLY GRADED SILTY SAND W/GRAVEL

Date Received: 3-24-10 **Date Tested:** 3-24-10

Tested By: ZL

Checked By: AARON CLYDE

Title: LABORATORY MANAGER

Location: NOEL RD TP 1
Sample Number: P17554

Date Sampled: 3-24-10

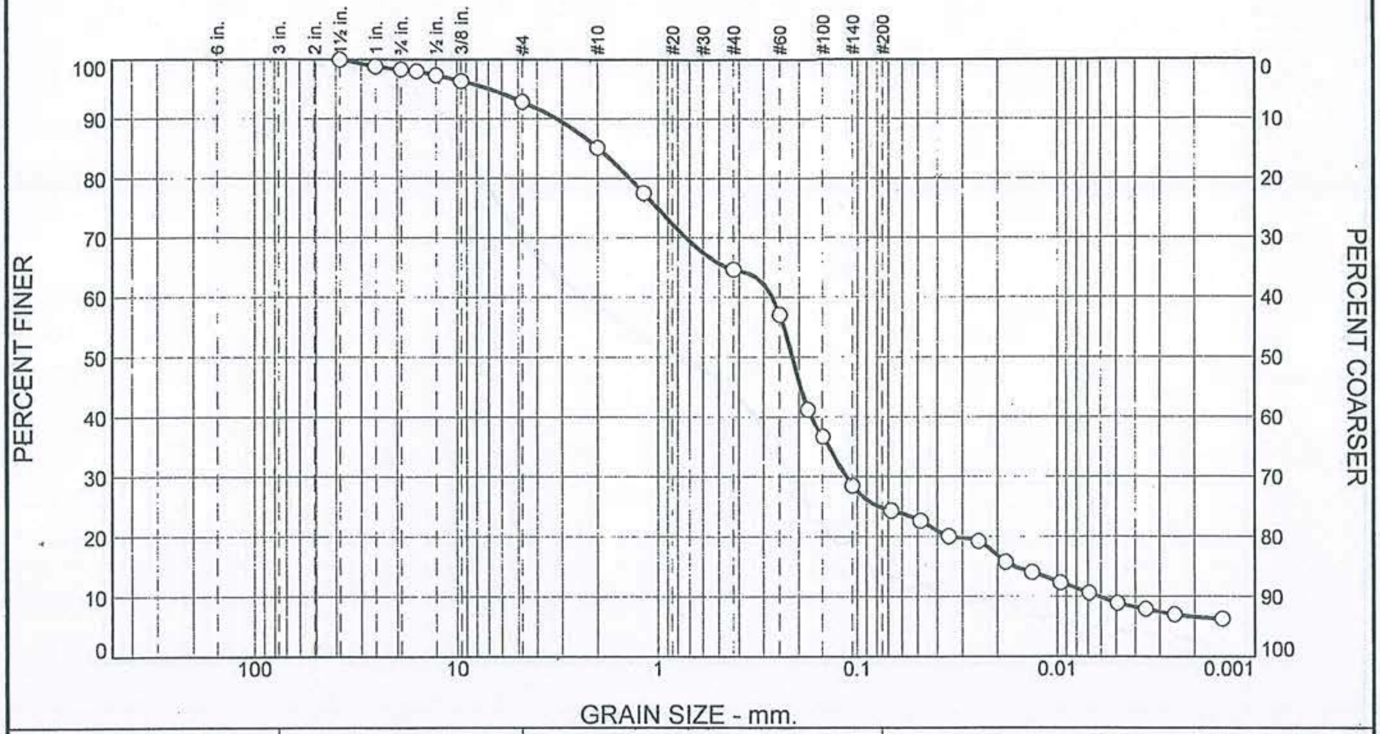
Krazan

Client: CITY OF POULSBO
Project: POULSBO MISC LAB TESTING

Project No: 106-09120 **Figure** K

SAMPLE-2

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	1.7	5.4	7.7	20.6	39.8	15.8	9.0

Test Results (ASTM C 136 & ASTM C 117)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1.5	100.0		
1	98.9		
.75	98.3		
.625	98.0		
.5	97.4		
.375	96.4		
#4	92.9		
#10	85.2		
#16	77.6		
#40	64.6		
#60	57.1		
#80	41.2		
#100	36.7		
#140	28.5		
0.0677 mm.	24.3		
0.0485 mm.	22.6		
0.0350 mm.	20.1		
0.0249 mm.	19.2		
0.0181 mm.	15.8		
0.0134 mm.	14.1		
0.0096 mm.	12.3		
0.0069 mm.	10.6		
0.0049 mm.	8.9		
0.0035 mm.	7.9		
0.0025 mm.	7.0		
0.0014 mm.	6.3		

* (no specification provided)

Material Description

SILTY SAND

Atterberg Limits (ASTM D 4318)

PL= NP LL= NV PI= NP

Classification

USCS (D 2487)= SM AASHTO (M 145)= A-2-4(0)

Coefficients

D_{90}= 3.1832	D_{85}= 1.9634	D_{60}= 0.2721
D_{50}= 0.2165	D_{30}= 0.1137	D_{15}= 0.0163
D_{10}= 0.0061	C_u= 44.40	C_c= 7.76

Remarks

REPORT:119616
FIELD DESCRIPTION: GRAY POORLY GRADED SILTY SAND W/ GRAVEL

Date Received: 3-24-10 **Date Tested:** 3-25-10

Tested By: ZL

Checked By: AARON CLYDE

Title: LABORATORY MANAGER

Location: NOEL RD TP 2
Sample Number: P17553

Date Sampled: 3-24-10

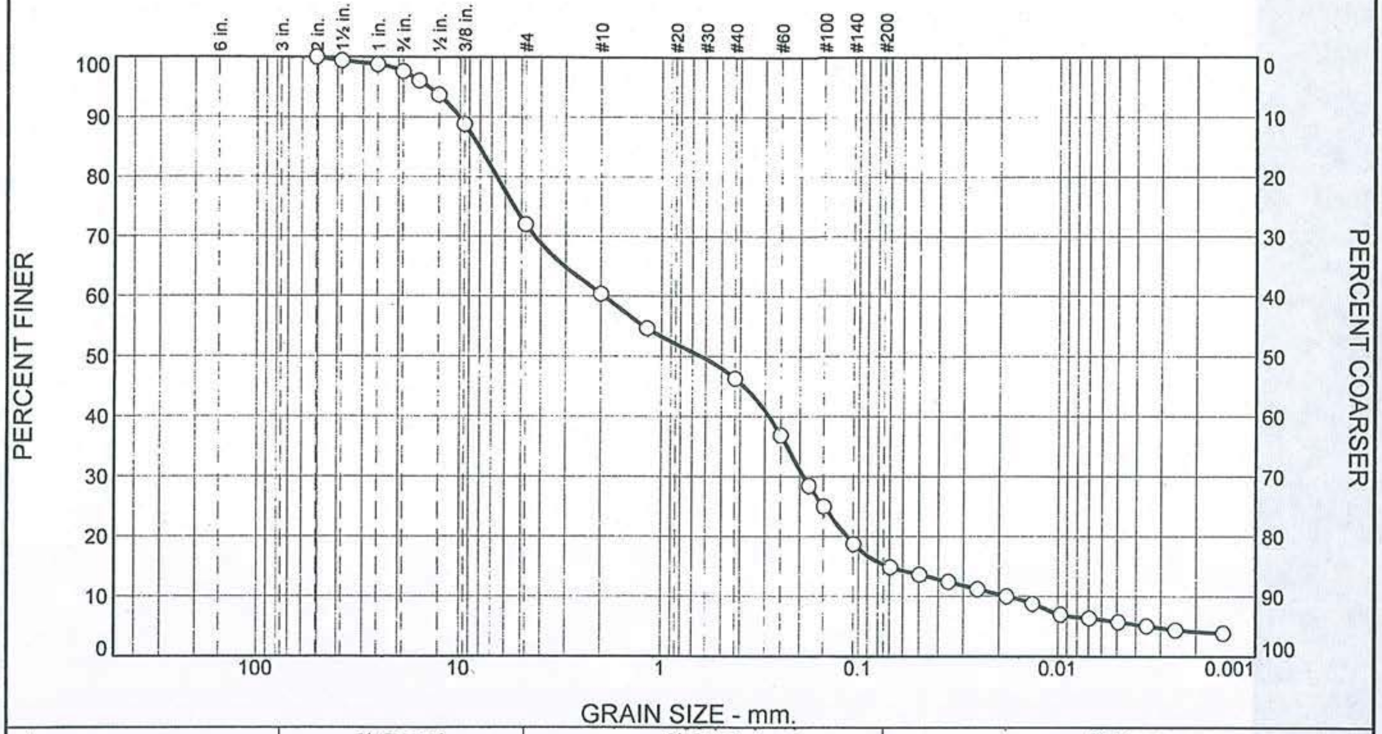
Krazan

Client: CITY OF POULSBO
Project: POULSBO MISC LAB TESTING

Project No: 106-09120 **Figure**

SAMPLE-3

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	2.4	25.6	11.6	14.1	31.0	9.6	5.7

Test Results (ASTM C 136 & ASTM C 117)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
2	100.0		
1.5	99.4		
1	98.7		
.75	97.6		
.625	96.1		
.5	93.7		
.375	88.8		
#4	72.0		
#10	60.4		
#16	54.6		
#40	46.3		
#60	36.9		
#80	28.5		
#100	25.0		
#140	18.7		
0.0695 mm.	14.8		
0.0498 mm.	13.6		
0.0357 mm.	12.4		
0.0256 mm.	11.2		
0.0183 mm.	10.0		
0.0135 mm.	8.8		
0.0097 mm.	7.0		
0.0069 mm.	6.3		
0.0049 mm.	5.7		
0.0035 mm.	5.0		
0.0025 mm.	4.4		
0.0015 mm.	3.9		

* (no specification provided)

Material Description

SILTY SAND W/ GRAVEL

Atterberg Limits (ASTM D 4318)

PL= NP LL= NV PI= NP

Classification

USCS (D 2487)= SM AASHTO (M 145)= A-1-b

Coefficients

D_{90}= 10.0891 D_{85}= 8.0595 D_{60}= 1.9321

D_{50}= 0.6353 D_{30}= 0.1923 D_{15}= 0.0718

$\boxed{D_{10}= 0.0183}$ C_u= 105.30 C_c= 1.04

Remarks

REPORT:119616

FIELD DESCRIPTION: BROWN POORLY GRADED SITLY SAND

Date Received: 3-25-10 **Date Tested:** 3-25-10

Tested By: ZL

Checked By: AARON CLYDE

Title: LABORAOTRY MANAGER

Location: NOEL RD TP3

Sample Number: P17552

Date Sampled: 3-24-10

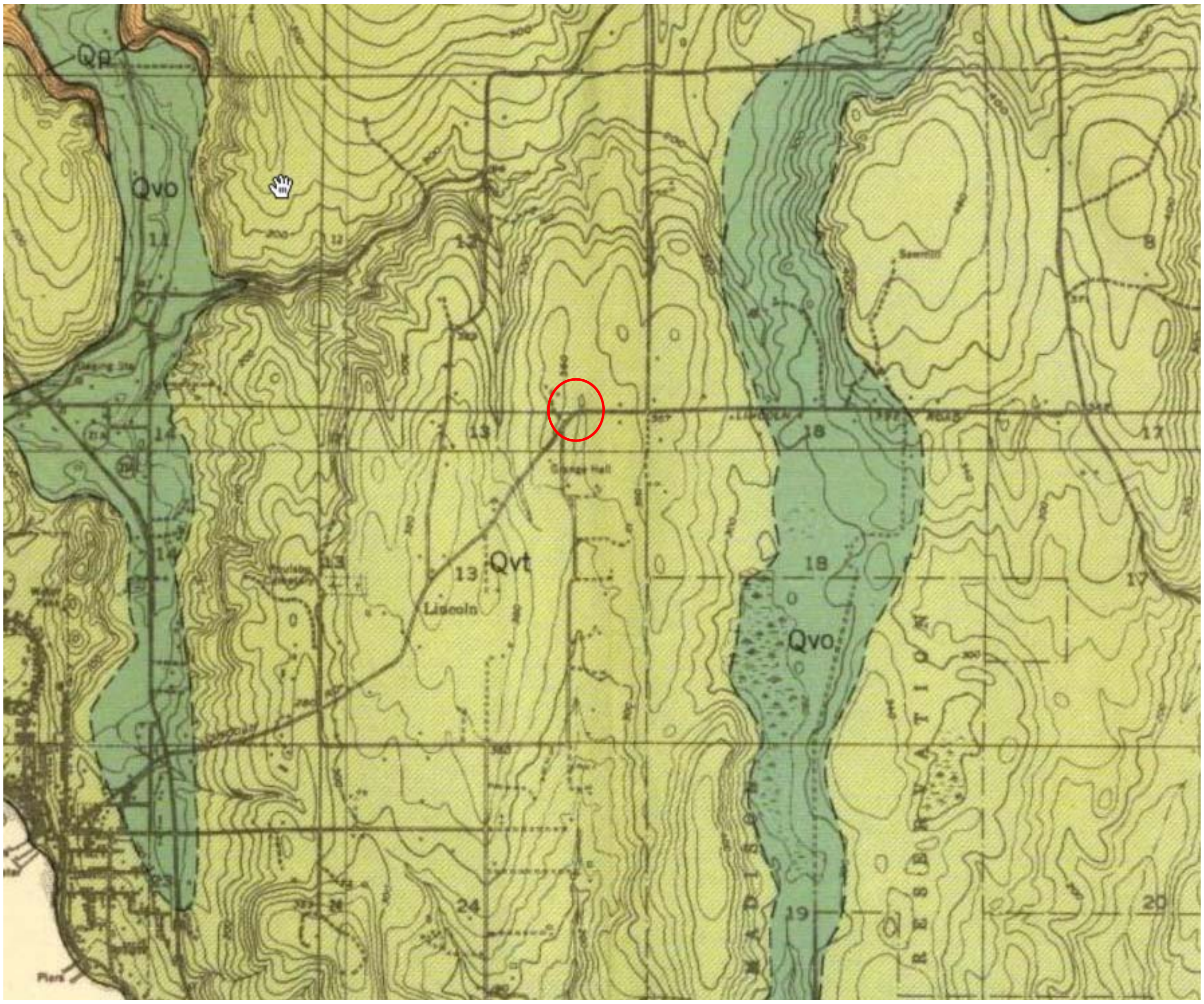
Krazan

Client: CITY OF POULSBO

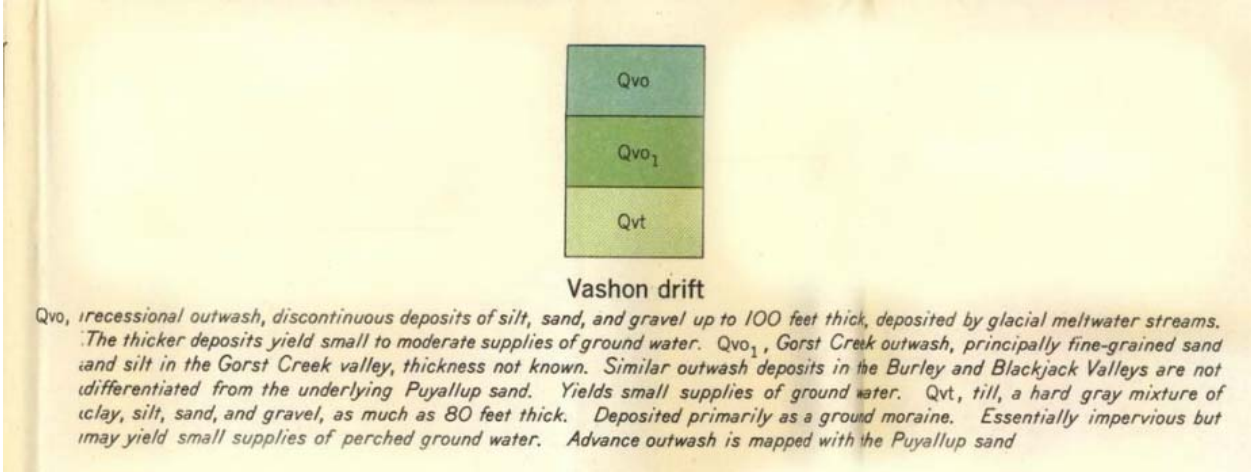
Project: POULSBO MISC LAB TESTING

Project No: 106-09120

Figure



Approximate location of site indicated by red outline



Vashon drift

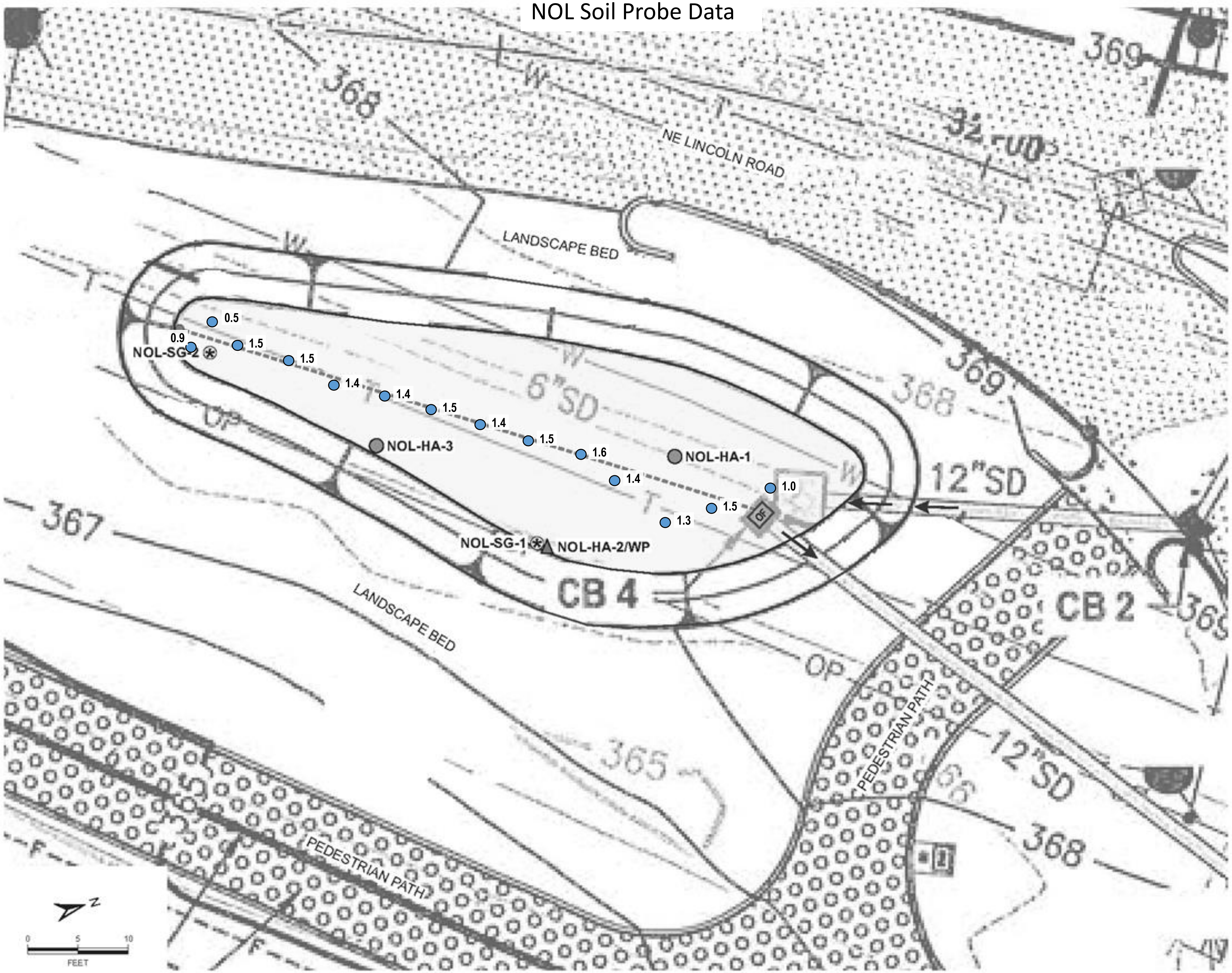
Qvo, recessional outwash, discontinuous deposits of silt, sand, and gravel up to 100 feet thick, deposited by glacial meltwater streams. The thicker deposits yield small to moderate supplies of ground water. Qvo_1, Gorst Creek outwash, principally fine-grained sand and silt in the Gorst Creek valley, thickness not known. Similar outwash deposits in the Burley and Blackjack Valleys are not differentiated from the underlying Puyallup sand. Yields small supplies of ground water. Qvt, till, a hard gray mixture of clay, silt, sand, and gravel, as much as 80 feet thick. Deposited primarily as a ground moraine. Essentially impervious but may yield small supplies of perched ground water. Advance outwash is mapped with the Puyallup sand

Excerpt from Sceva, J. E., 1957, Geology and ground-water resources of Kitsap County, Washington

APPENDIX D

Soil Probe, Level Survey, and Field Infiltration Testing Data

NOL Soil Probe Data



LEGEND:

- ● HA HAND AUGER
- ▲ WP WELL POINT
- ⊛ TEMPORARY STAFF GAUGE
- ▢ BASE OF FACILITY
- ▢ TOP OF FACILITY SLOPE
- → INFLOW / OVERFLOW DIRECTION
- OF OVERFLOW GRATE
- ---- UNDERDRAIN
- ● STORM DRAIN CLEANOUT

CONTOUR INTERVAL = 1'

● 0.8 Soil Probe and Depth of Loose Soil

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:
1. BASE MAP REFERENCE: PARAMETRIX, NOLL ROAD ROUNDABOUT, POULSBO, WASHINGTON, GRADING, DRAINAGE AND SANITARY SEWER PLAN, C4, 5/9/2012

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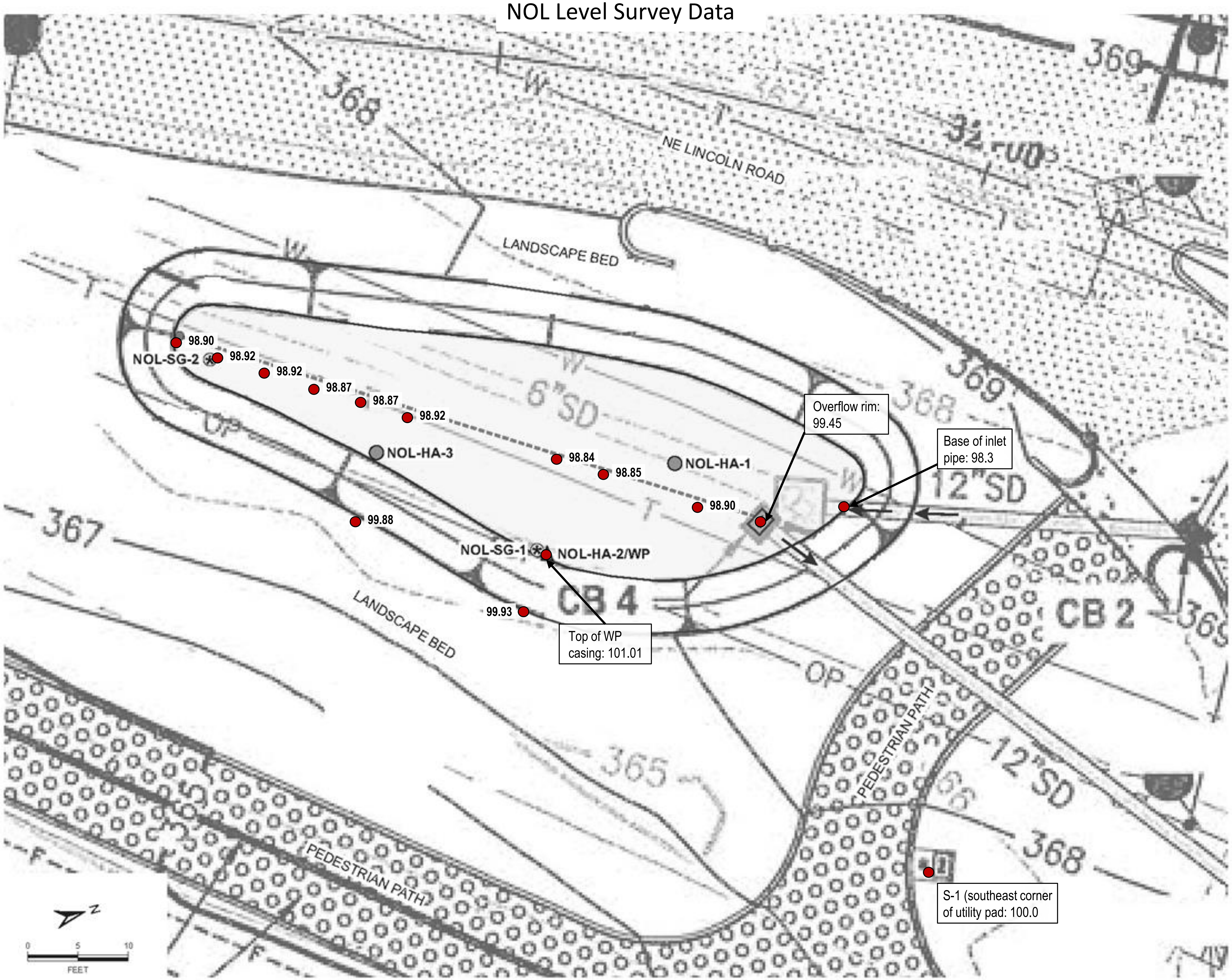
SOIL PROBE DATA
NOL SITE
BIORETENTION HYDROLOGIC PERFORMANCE
POULSBO, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	D1

150387 BHPS MCCA \ 150387 Site-Expl.cdr PAGE 5: NOL

NOL Level Survey Data



Overflow rim: 99.45

Base of inlet pipe: 98.3

Top of WP casing: 101.01

S-1 (southeast corner of utility pad: 100.0

LEGEND:

● **HA**	HAND AUGER
▲ **WP**	WELL POINT
⊛	TEMPORARY STAFF GAUGE
▢	BASE OF FACILITY
▢	TOP OF FACILITY SLOPE
→	INFLOW / OVERFLOW DIRECTION
OF	OVERFLOW GRATE
------	UNDERDRAIN
●	STORM DRAIN CLEANOUT

CONTOUR INTERVAL = 1'

● **98.66** Elevation, Project Datum (see text)

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:
1. BASE MAP REFERENCE: PARAMETRIX, NOLL ROAD ROUNDABOUT, POULSBO, WASHINGTON, GRADING, DRAINAGE AND SANITARY SEWER PLAN, C4, 5/9/2012

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LEVEL SURVEY DATA
NOL SITE
BIORETENTION HYDROLOGIC PERFORMANCE
POULSBO, WASHINGTON

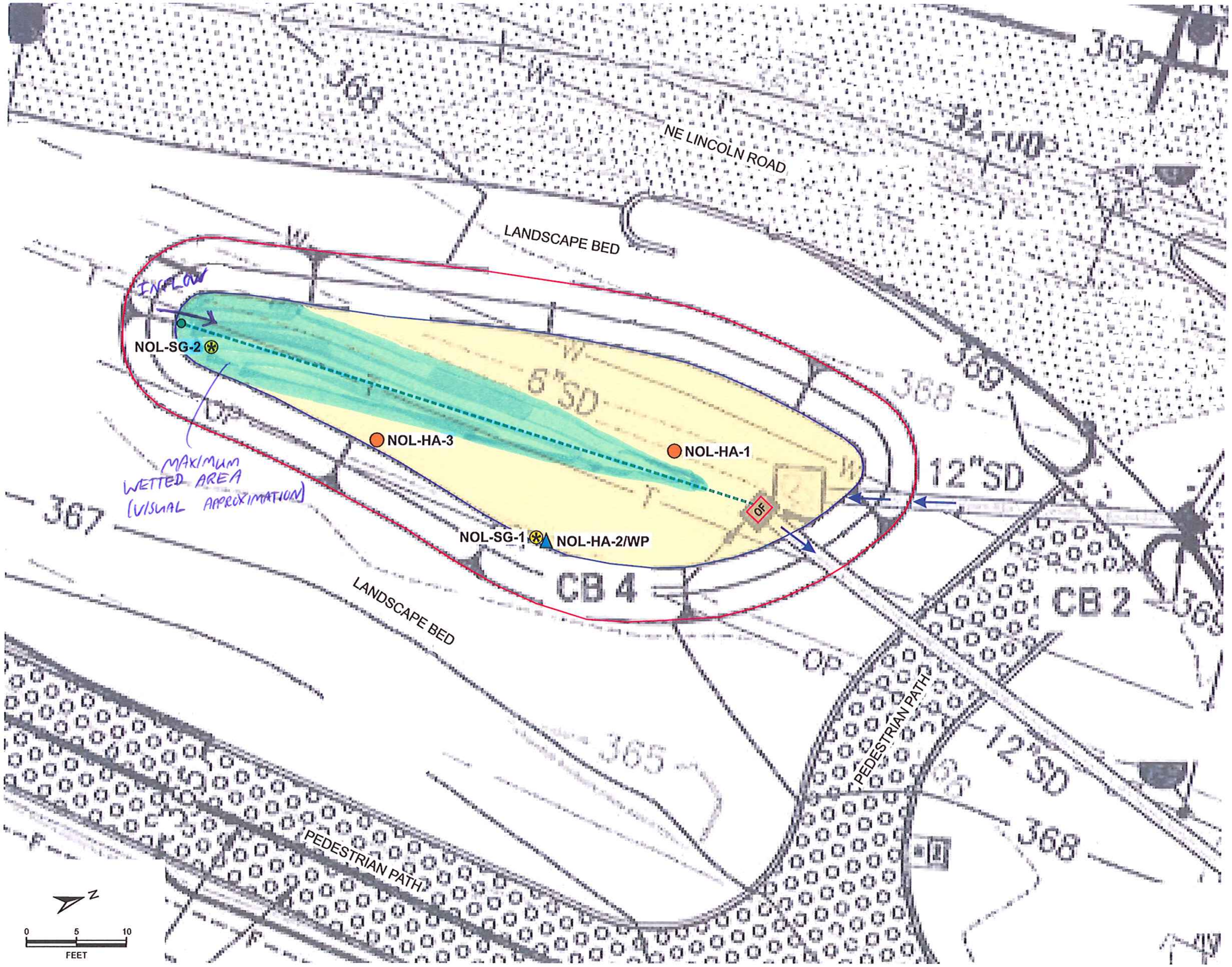
PROJ NO. KH150387A
DATE: 9/16
FIGURE: D2

Cell NOL
Level Survey Data

Location	Elevation (feet, project datum)
(S-1) South east corner of utility pad	100
(S-2) Concrete lamp base	98.41
(S-3) Middle of Crosswalk, south side, at curb corner	101.3
Inflow, base of pipe	98.3
Overflow rim	99.45
High point on south eastern embankment of cell, south of center	99.88
High point on south eastern embankment of cell, north of center	99.93
Well point, top of casing	101.01
Survey points in base of cell	On map

Cell NOL
Probe Survey Data List (Excludes Outliers)

Probe Penetration (feet):
1.5
1.5
1.4
1.4
1.5
1.4
1.5
1.6
1.4
1.3
1.5
AVERAGE: 1.5



LEGEND:

● HA	HAND AUGER
▲ WP	WELL POINT
⊛	TEMPORARY STAFF GAUGE
🟨	BASE OF FACILITY
⬭	TOP OF FACILITY SLOPE
→	INFLOW / OVERFLOW DIRECTION
OF	OVERFLOW GRATE
-------	UNDERDRAIN
●	STORM DRAIN CLEANOUT

CONTOUR INTERVAL = 1'

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:

1. BASE MAP REFERENCE: PARAMETRIX, NOLL ROAD ROUNDABOUT, POULSBO, WASHINGTON, GRADING, DRAINAGE AND SANITARY SEWER PLAN, C4, 5/9/2012

BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION.

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WETTED AREA

NOL SITE

BIORETENTION HYDROLOGIC PERFORMANCE

POULSBO, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	10 /16	APPENDIX D

150387 BHPS MCCA \ 150387 Site-Explr.cdr PAGE 5: NOL

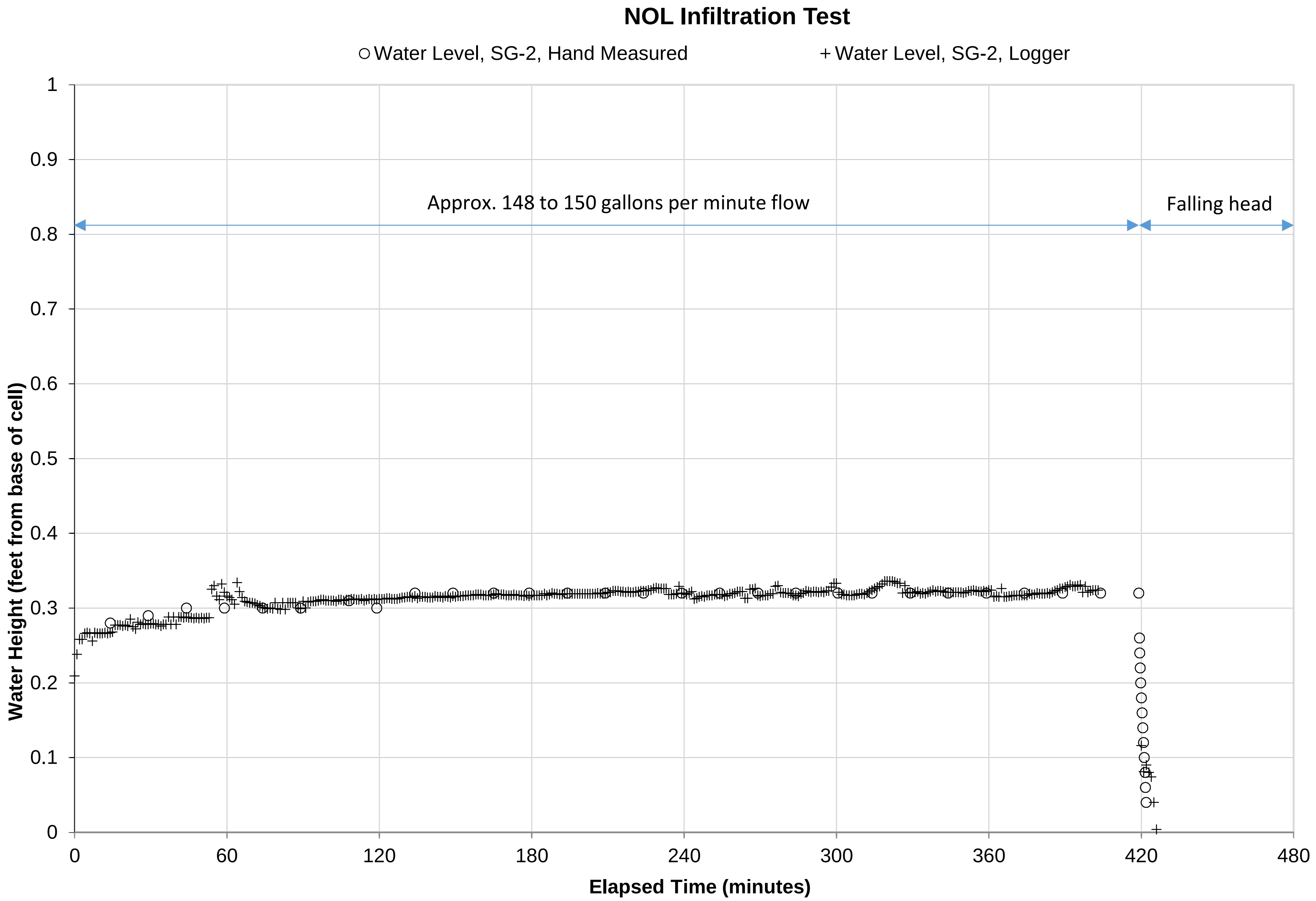
Project Name	Bioretention Hydrologic Performance Assessment
Project Number	KH150387A
Date	9/15/16
Weather	Cloudy
Test No.	NOL IT-1
Meter	FM7
Water Source	Hydrant

Receptor Soils	Bioretention Soil over Qvt
Testing Performed By	ADY

Time (24-hr)	Total (min)	Flow Rate (gpm)	Totalizer (gal)	Head (temporary staff gauge SG-1, feet)	Head (temporary staff gauge SG-2, feet)	Wetted area (ft^2)	Depth to water, well point, from top of casing (feet)	Depth to water, overflow structure (feet below rim)	Flow depth, overflow discharge pipe, end at ditch (feet)	Notes
7:45:00							Dry			Water level below level of undrain pipe in overflow structure upon arrival to site
7:48:00		154								Water on, trace flow in overflow structure between cement casing (leakage)
8:04:30		152.78	2462	0			Dry			0.28 ft head by overflow structure. Backflow into facility inflow pipe and storm drain system observed
8:11:30		153	3554	0						0.28 ft head by overflow structure
8:12:20		0								Flow off; Install SG-2 in south end of pond
8:31:00	0.0	152.7								Flow on; no flow in overflow structure, time zero
8:45:00	14.0	151.08	5903	0	0.28		Dry			No backflow into facility inflow and storm drain system
9:00:00	29.0	148.31	8150	0	0.29		Dry	3.50	0.42	
9:15:00	44.0	148.15	10377	0	0.30					
9:30:00	59.0	147.84	12636	0	0.30					
9:45:00	74.0	148.64	14815	0	0.30	250.00				
10:00:00	89.0	149.7	17037	0	0.30		Dry	3.47	0.40	

Time (24-hr)	Total (min)	Flow Rate (gpm)	Totalizer (gal)	Head (temporary staff gauge SG-1, feet)	Head (temporary staff gauge SG-2, feet)	Wetted area (ft^2)	Depth to water, well point, from top of casing (feet)	Depth to water, overflow structure (feet below rim)	Flow depth, overflow discharge pipe, end at ditch (feet)	Notes
10:19:00	108.0	149.99	19876	0	0.31		Dry			
10:30:00	119.0	149.54	21530	0	0.30		Dry			
10:45:00	134.0	149.5	23769	0	0.32	262.00	Dry			
11:00:00	149.0	148.46	26001	0	0.32		Dry	3.50	0.41	
11:16:00	165.0	148.78	28396	0	0.32		Dry			
11:30:00	179.0	148.15	30491	0	0.32		Dry			
11:45:00	194.0	148.62	32694	0	0.32	303.00	Dry			
12:00:00	209.0	148.62	34940	0	0.32		Dry	3.48	0.41	
12:15:00	224.0	148.15	37147	0	0.32		Dry			
12:30:00	239.0	148.15	39369		0.32		Dry			
12:45:00	254.0	148	41829		0.32	303.00				
13:00:00	269.0	148	43851	0	0.32		Dry	3.48	0.41	
13:15:00	284.0	148.5	46016	0	0.32		Dry			
13:31:30	300.5	148.62	48520		0.32					
13:45:00	314.0	148.15	50490		0.32	337.50				
14:00:00	329.0	148	52678		0.32			3.48	0.40	
14:15:00	344.0	148.46	55007		0.32					
14:30:00	359.0	148.62	57218		0.32					
14:45:00	374.0	148.46	59369		0.32	337.50				
15:00:00	389.0	148.15	61624	0	0.32		Dry	3.48	0.42	
15:15:00	404.0	147.8	63832		0.32					
15:30:00	419.0	~148	~66049		0.32					Water off, begin falling head. Final flow rate and totalizer value estimated based on previous value and rate.
15:30:18	419.3				0.26					
15:30:25	419.4				0.24					
15:30:30	419.5								0.39	
15:30:33	419.6				0.22					
15:30:45	419.8				0.20					

Time (24-hr)	Total (min)	Flow Rate (gpm)	Totalizer (gal)	Head (temporary staff gauge SG-1, feet)	Head (temporary staff gauge SG-2, feet)	Wetted area (ft^2)	Depth to water, well point, from top of casing (feet)	Depth to water, overflow structure (feet below rim)	Flow depth, overflow discharge pipe, end at ditch (feet)	Notes
15:31:00	420.0				0.18					
15:31:21	420.4				0.16					
15:31:36	420.6				0.14					
15:31:50	420.8								0.38	
15:31:55	420.9				0.12					
15:32:10	421.2				0.10					
15:32:30	421.5				0.08					
15:32:40	421.7				0.06					
15:32:54	421.9				0.04					
15:34:00	423.0								0.36	
15:34:30	423.5								0.35	
15:36:00	425.0								0.33	
15:37:45	426.8								0.30	
15:39:30	428.5								0.27	
15:42:30	431.5								0.23	
15:48:00	437.0								0.21	
15:55:00	444.0								0.18	End test. Retrieve dataloggers.


NOL Infiltration Test
○ Water Level, SG-2, Hand Measured
+ Water Level, SG-2, Logger
Approx. 148 to 150 gallons per minute flow
Falling head
Water Height (feet from base of cell)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
60
120
180
240
300
360
420
480
Elapsed Time (minutes)

APPENDIX E

Site Photos

Cell NOL, viewed from next to Lincoln Road NE

Cell NOL inlet

Cell NOL overflow structure

Cell NOL SG-2 during infiltration testing, with nearby underdrain cleanout (white PVC octagonal cap)

Discharge from overflow pipe during infiltration testing

APPENDIX 8

Deliverable 4.5, Site ORLA, Geotechnical/Soils Assessment Design Data and Current Conditions, Olympia Regional Learning Academy, Thurston County, Washington. Associated Earth Sciences, Inc. 10/25/16

associated earth sciences incorporated

Technical Memorandum

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		Project Name:	Bioretention Hydrologic Performance Study
Attn:	Doug Beyerlein, P.E.	**Project No:**	KH150387A
Subject:	Deliverable 4.5, Site ORLA, Geotechnical/Soils Assessment Design Data and Current Conditions, Olympia Regional Learning Academy, Thurston County, Washington		

1.0 INTRODUCTION

This technical memorandum documents existing shallow soil and ground water conditions in bioretention cell 1-B and 2-B (cell ORLA 1-B and cell ORLA 2-B) at the Olympia Regional Learning Academy, located in unincorporated Thurston County, Washington (Figure ORLA F1). This memorandum was prepared in accordance with Task 4 of the contract scope of work. Associated Earth Sciences, Inc. (AESI) collected shallow soil and ground water conditions data related to bioretention cell function, and documented the current condition of the facility relative to the as-built drawings and available background geotechnical information. The information will be used in the WWHM2012 modeling that will be conducted as part of Task 5 (Data Analysis). In Task 5, the team will compare the previously documented hydrologic design information with our field-collected information and will note where there are significant differences. The purpose of this technical memorandum is to document the collection of current and accurate geotechnical, geologic and hydrogeologic site information for this later work.

The following summary of shallow soil and ground water conditions integrates the observations made during the geotechnical assessment which included site visits on July 26 and August 25, 2016, infiltration testing on August 30 and August 31, 2016, and background geotechnical information.

This technical memorandum has been prepared for the exclusive use of Clear Creek Solutions and the City of Bellingham and their agents for specific application to this project. Within the limitations of scope, schedule, and budget, our services have been performed in accordance with generally accepted hydrogeologic and geotechnical engineering practices in effect in this area at the time our document was prepared. No other warranty, express or implied, is made.

2.0 PURPOSE AND SCOPE

The purpose of our work was to perform a shallow soil and ground water conditions assessment and provide baseline documentation data to assess effectiveness of bioretention hydrologic performance.

Specifically, our scope included the following activities:

- Review of project documents.
- Site reconnaissance.
- Visual condition assessment of erosion and deposition features near inlet and outlet.
- Review project plans relative to constructed facility, in particular, the number and location of inlets, energy dissipation devices, outlets, and other flow-related details.
- Survey elevations of inlet, outlet, well point rim, and other observation points relative to a project datum.
- Rough survey of facility ponding area, focused on identifying low areas where inflow water would initially pool.
- Excavate shallow hand augers through the bioretention soil and into the underlying material.
- Excavate one moderately deep hand-auger to 8 to 10 feet or refusal, through the bioretention soil and several feet into the underlying native soil and install one well point.
- Classify sediment according to the Unified Soil Classification System (USCS) and *American Society for Testing and Materials* (ASTM) D2488, “Standard Recommended Practice for Description of Soils.”
- Collect samples for laboratory testing of (1) particle size distribution in accordance with ASTM D422-63, “Standard Test Method for Particle-Size Analysis of Soils”; (2) organic matter content per ASTM D2974.
- Conduct qualitative assessment of soil compaction via T-probe.
- Conduct infiltration testing.
- Preparation of descriptive exploration logs for each exploration.
- Preparation of this summary document.

Topography of the site and surrounding area is shown on Figure ORLA F2, “LiDAR-Based Topography.” Existing facility features and the locations of hand-auger boreholes completed for this study are shown on Figure ORLA F3 and ORLA F4, “Facility and Exploration Plan - ORLA 1-B,” and “Facility and Exploration Plan, ORLA 2-B.” Project civil plans are attached as Appendix A. Exploration logs and laboratory testing data for current study are attached as Appendix B. Background soil, geology, and ground water information are attached as Appendix C. Soil probe, level survey, and field infiltration testing data are attached as Appendix D. Site photos are attached as Appendix E.

3.0 SITE DESCRIPTION AND DESIGN BACKGROUND

The project site is the Olympia Regional Learning Academy located at 2400 15th Avenue SE, in unincorporated Thurston County, Washington as shown on the attached "Vicinity Map" (Figure ORLA F1). The project site is within the Urban Growth Boundary of the city of Olympia. This project site is roughly delineated by Boulevard Road SE to the west, by 15th Avenue SE to the south, by 12th Avenue SE to the north, and by multi-family residences to the east. The site is located about 200 feet southeast of Indian Creek, which flows to the southwest in the vicinity of the site. A wetland is located offsite to the northeast. No on-site surface water features are present. As described in the Drainage Report (LPD Engineering, PLLC [LPD], 2013) the site is in the Extreme Class of Critical Aquifer Recharge Areas. LiDAR topography and other near-site vicinity features are illustrated on Figure ORLA F2, "LiDAR-Based Topography."

Our specific area of study for this project includes two bioretention cells (ORLA 1-B and ORLA 2-B) located on the south of the school building, between the school building and the associated parking lot as shown on the attached "Facility and Exploration Plan" figures (Figure ORLA F3 and Figure ORLA F4).

Details of the bioretention facility design and basis were presented in the following documents:

- Report, Geotechnical Engineering Services, Proposed ORLA Facility," Insight Geologic, Inc., Project No. 566-001-01, April 5, 2012.
- Revised Report, Geotechnical Engineering Services – Stormwater Infiltration, OSD ORLA Facility," Insight Geologic, Inc., Project No. 566-001-03, February 27, 2013.
- Record Drawing, Olympia Regional Learning Academy, LPD Engineering, PLLC, May 18, 2015.
- Drainage Report, ORLA, Olympia School District, LPD Engineering, PLLC, August 20, 2013, Revised September 9, 2013.

3.1 Summary of Facility Design

From our review of site drainage report and record drawings referenced above, cell ORLA 1-B has about 2,450 square feet of base area and cell ORLA 2-B has about 2,800 square feet of base area as shown on Figure ORLA F3, "Facility and Exploration Plan, ORLA 1-B," and Figure ORLA F4, "Facility and Exploration Plan, ORLA 2-B." We understand that the cells were sized per the 2009 *Drainage Design and Erosion Control Manual for City of Olympia*, and modeled using WWHM4 based on developed condition drainage basins of 0.64 and 0.55 acres, respectively, for cells ORLA 1-B and ORLA 2-B. Land uses within the drainage basins consist of roof area, landscaping, and walkways. The facility design includes an 18-inch bioretention soil mix layer and a 12-inch-thick layer of drain rock overlying native soil, and is designed to infiltrate 99.12 percent of inflow into the subgrade for cell ORLA 1-B, and 99.89 percent of the inflow into the subgrade for cell ORLA 2-B. A perforated underdrain pipe is present within the drain rock, and is discussed as part of the overflow system, below.

Inflow to cells ORLA 1-B and ORLA 2-B is from roof drains. If ponding occurs on the bioretention soil, the overflow is collected by an area drain in each cell that will directly discharge to the 12-inch drain rock layer beneath the bioretention soil via perforated underdrain for infiltration. The area drain in each cell is set at an elevation 6 inches above the top of the bioretention soil layer to ensure that the area drains do not clog and a channel is not created through the bioretention area to the drain. In the case of emergency overflow situations, another overflow outfall pipe is located within the area drain above the perforated underdrain that will direct stormwater to a separate infiltration trench located in the parking lot south of the bioretention cells.

4.0 SITE OBSERVATIONS

During AESI's site visits, we made notes regarding the physical construction of the bioretention facilities including documenting site inlet/outlet layout relative to site plans and qualitative bioretention soil thickness and compaction. These notes were used to indicate key features of the facilities in Figure ORLA F3 and Figure ORLA F4.

- Level Survey: AESI conducted elevation surveys of the facilities using a Leitz C40 automatic level and a stadia rod. An arbitrary project datum was established for these surveys with, for each facility, the top of a nearby concrete lamp post base (indicated on the survey data map included in the Appendices) defined as project datum elevation 100 feet. A separate project datum was used for each facility on the ORLA site. All other elevations measured by the surveys are relative to these project datum. Key level data is summarized in Table 1 and Table 2. Additional data points are included in Appendix D to this document.

Table 1
Summary of ORLA 1-B Level Survey Data

Location	Elevation (feet, project datum)
(S-1) Crosswalk corner	99.80
(S-2) Lamp post base (E end cell ORLA 1-B)	100.00
(S-3) Lamp post base (middle of cell)	99.97
Inlet 1 base of pipe	97.63
Inlet 2 base of pipe	98.33
Inlet 3 base of pipe	98.28
Inlet 4 base of pipe	98.1
Overflow rim	98.79
Well point, top of casing	102.05
Survey points in base of cell	On site plan in Appendix D to this document

Table 2
Summary of ORLA 2-B Level Survey Data

Location	Elevation (feet, project datum)
(S-1) Top of cement base of lamp post, near cell ORLA 2-B bridge	100.00
(S-2) Sidewalk next to corner of wall	100.23
(S-3) Top of cement base of lamp post, near fire hydrant	100.08
Inlet 1 base of pipe	98.08
Inlet 2 base of pipe (approximate)	98.08
Inlet 3 base of pipe	98.15
Inlet 4 base of pipe	98.19
Overflow rim	98.70
Well point, top of casing	100.14
Survey points in base of cell	On site plan in Appendix D to this document

- Inflow: Four inlets to each facility are present, referred to as Inlet 1 through Inlet 4 for each facility as indicated on Figures ORLA F3 and ORLA F4. These consisted of 6-inch PVC pipes surrounded by rounded cobbles, forming an approximately 1-foot by 1-foot to 2-foot by 2-foot pad. No erosion was noted, however heavy vegetation and a variable quantity of leaf litter were observed in and below the inlets. AESI noted that in cell ORLA 2-B, Inlet 2 was buried in cobbles to 8 inches, and that Inlet 4 was approximately 80 percent buried in cobbles to 6 inches and landscaping bark.

- Overflow: Both bioretention cells contain round 12-inch diameter PVC area drains covered with metal beehive-style overflow grates. The lip of the grate is approximately 7 inches above the base of the facility in cell ORLA 1-B, and 6 inches above the base of the facility in cell ORLA 2-B. The vertical 12-inch PVC pipe beneath this grate has a closed bottom end, creating a sump, into which two pipes connect. One of these pipes is the perforated underdrain pipe which extends horizontally through the drain rock layer. The other pipe is the overflow pipe, which discharges to an infiltration trench located south of the cell in the parking lot. The overflow pipe is situated at a higher elevation within the sump than the perforated pipe, such that water will not flow into the overflow pipe until it has backed up within the perforated pipe and drain rock layer.

- AESI notes that during infiltration testing in cell ORLA 2-B, water was observed to flow from the underdrain pipe into the overflow grate sump rather than from the overflow grate sump into the underdrain, as discussed under "Infiltration Testing."

- Existing observation wells noted on the plan sheets had total depths of approximately 2.8 feet (in ORLA 1-B) and 3 feet (in ORLA 2-B) and had flush mount monuments which required a $^{5}/_{16}$ hex to open, and had PVC caps which required a 2-inch wrench to remove. These observation wells were screened within the drain rock layer.

- AESI investigated the loose bioretention soil thickness present in the bioretention cells using a geotechnical soil T-probe. This qualitative data was used in conjunction with the hand-auger observations to understand loose soil thickness and relative potential compactness of the bioretention soils at depth. AESI measured the depth of penetration of the soils probe at locations generally arranged in a 10-foot spacing in a line approximately down the center of each facility. The apparent thickness of bioretention soil generally ranged from approximately 1 foot to 1.7 feet and averaged 1.3 feet in cell ORLA 1-B. In cell ORLA 2-B the apparent thickness of bioretention soil generally ranged from approximately 1 to 1.6 feet, and AESI noted that in several locations east of the existing pedestrian bridge, probe penetration was lower than this range, to a minimum of 0.1 feet. AESI qualitatively interprets these lower probe penetration values in ORLA 2-B as due to the presence of zones of gravel mixed into the bioretention soil mix in the base of the facility. This gravel was generally not visible on the surface. The average apparent thickness of bioretention in cell ORLA 2-B, excluding measurements interpreted as being anomalously shallow due to the presence of gravel within the bioretention soil, is 1.3 feet. Probe penetration data is included in Appendix D to this document.

- ORLA 2-B: AESI noted that a buried gas line was present under the western part of the cell, as indicated by utility locators. The approximate location of this gas line is indicated on Figure ORLA F4.

- ORLA 2-B: AESI noted a worn foot path crosses the base of the eastern portion of the cell. Gravel was present on the base of the cell in the vicinity of this foot path.

- ORLA 2-B: AESI was unable to locate the easternmost cleanout for the perforated underdrain pipe; it may be buried under landscaping bark and vegetation.

5.0 SITE SETTING

The text sections below describe our research findings in regards to the topographic, geologic, and hydrogeologic setting of the project site, both from regional studies and background site-specific geotechnical and ground water studies. Our sources of information included the following.

- Site-specific documents cited previously under “Project and Site Description.”
- Logan, R.L. et al., *Geologic Map of the Lacey 7.5 Minute Quadrangle, Thurston County, Washington*, Washington Division of Geology and Earth Resources Open File Report 2003—9, 2003, scale 1:24,000.
- *Soil Survey of Thurston County, Washington*, United States Department of Agriculture, Natural Resource Conservation Service (NRCS), 1990.
- Natural Resources Conservation Service, Web Soil Survey, United States Department of Agriculture, http://websoilsurvey.nrcs.usda.gov/, accessed September 2016.

- Drost, B.W. et al., *Hydrology and Quality of Ground Water in Northern Thurston County, Washington*, United States Geological Survey, Water-Resources Investigations Report 92-4109 [Revised], 1998.

5.1 Regional Topography and Project Grading

The project site is situated on an upland with elevations generally ranging from 160 to 200 feet as shown on Figure ORLA F2, "LiDAR-Based Topography." Glacial meltwater scoured the upland surface and created level outwash terrain surfaces. Indian Creek, a modern stream, has incised the outwash terrain north and northeast of the site about 30 to 40 feet, creating relatively steep slopes within about 500 feet west of the bioretention cells.

On a closer scale, the site is relatively level, situated on an outwash terrace at about elevation 185 feet to 190 feet. The northeastern portion of the site slopes downward to the northeast and off-site properties by approximately 20 feet, with a slopes on the order of 20 percent.

The project site was previously developed as McKinley Elementary School which was demolished in 1991. Since then and prior to the current construction of ORLA, the site was used as a playfield with a small developed area in the north-central portion of the site. The site topography is relatively flat with a gradual slope from northwest to southeast with an overall grade change of 8 feet.

Minor cutting (about 2 to 4 feet in ORLA 1-B and about 2 feet in ORLA 2-B) was needed to achieve design bioretention cell grades based on a review of existing topography compared with built topography.

5.2 Regional Geology and Background Geotechnical Data

According to the *Geologic Map of the Lacey 7.5 Minute Quadrangle, Thurston County, Washington*, the site vicinity is underlain by Vashon recessional outwash described as latest Vashon recessional sand and minor silt (map unit Qgos), described below.

- <u>Vashon recessional sand and minor silt (Qgos)</u>: This material is described as moderately well sorted fine to medium sand with minor silt; non-cohesive and highly permeable. This material was deposited during the retreat of the most recent glaciation period in Puget Sound and is not glacially consolidated.

The project geotechnical reports (Insight Geologic, Inc., 2012 and 2013) included several rounds of explorations on the site. These explorations generally encountered loose to medium dense sand with variable silt content underlain by a medium stiff to very stiff sandy silt perching layer at depths of about 14 to 23 feet. Insight Geologic, Inc. interpreted the upper sand as recessional outwash, which is consistent with the geologic mapping in the area. Shallow fill soils were encountered in some explorations, to depths of up to 4 feet.

5.3 Regional Soils and Soil Data Used in Site Stormwater Model

AESI reviewed the *Soil Survey of Thurston County, Washington* (Natural Resources Conservation Service [NRCS], 1990) and soils mapping from the NRCS web portal (NRCS, 2016). The soil survey identifies different soil map units based on parent material, climate, topography (slope), organisms (biota), and time. The soils in the study area formed mostly from young glacial deposits and have not had time to develop the deep weathering profiles present in soils in unglaciated terrains. Instead, they exhibit a direct relationship to the underlying parent material, local climate, topography, and vegetation.

Mapped soils in the project area consist of primarily of Cagey loamy sand with a small area of Yelm fine sandy loam located northeast of the bioretention cells. Both Cagey and Yelm soils are typically situated on terraces and formed from the weathering of glacial outwash. NRCS describes the permeability as rapid (6 to 20 inches per hour [in/hr]) in Cagey loamy sand and moderately rapid (2 to 6 in/hr) in Yelm fine sandy loam (NRCS, 1990).

As described in the LPD 2003 Drainage Report, the pre-developed condition was modeled as Type C soils. This is not consistent with mapped soil and background geotechnical data, which indicates that the site is underlain by Type A soils.

5.4 Regional Hydrogeology and Background Ground Water Data

Regional hydrogeology is described in *Hydrology and Quality of Ground Water in Northern Thurston County, Washington* (Drost et al., 1998). Drost et al. (1998) indicates that recessional outwash and end moraine deposits can be an aquifer where saturated, and that perched ground water conditions can occur locally within these units. This unit typically overlies Vashon lodgement till, which is described by Drost et al (1998) as typically a confining bed.

On a closer scale, the site is within two threshold discharge areas of the Thurston County sub-basin “I-2” of the Indian-Moxley Creek Basin. As described in the Drainage Report (LPD, 2013), both of these sub-basins discharge ultimately to Indian Creek. Limited background ground water level data was collected at three on-site monitoring wells; ground water ranged from approximately 24 to 28 feet below ground surface in March, 2012 (Insight Geologic, Inc., 2012). However, these wells were completed at depths below the perching layer (present at about 14 to 23 feet below ground surface). Ground water is expected to perch at this shallower depth under the developed conditions due to stormwater infiltration from the bioretention cells and other site infiltration features.

6.0 BIORETENTION CELL SUBSURFACE EXPLORATION AND WELL POINT INSTALLATION

Limited information on subsurface conditions was obtained from hand-auger samples and soil probe penetration measurements at about 2-foot increments in each hand-augered borehole. In each bioretention cell, one hand-auger boring was performed in the facility bottom and advanced through the bioretention soil and into the underlying subgrade. Additional hand-auger borings were completed to the base of the bioretention soil. Representative samples were collected, visually classified in the field, stored in water-tight containers and transported to AESI's offices for additional classification, geotechnical testing and study. At the conclusion of the excavation, each borehole was immediately backfilled with the excavated material, or completed as a well point and the bioretention soil replaced.

The various types of sediments, as well as the depths where characteristics of the sediments changed, are indicated on the exploration logs presented in Appendix B. A detailed record of the observed bioretention soil, subsurface soil, geology, and ground water conditions was made. The sediments were described by visual and textural examination using the soil classification in general accordance with ASTM D2488, "Standard Recommended Practice for Description of Soils." The depths indicated on the logs where conditions changed may represent gradational variations between sediment types in the field. The exploration logs in Appendix B are based on the field observations, inspection of the samples, and where applicable, laboratory grain-size analysis. Our explorations were approximately located in the field relative to known site features, and are shown on the "Facility and Exploration Plan," Figure ORLA F3 and Figure ORLA F4. GPS coordinates for the explorations were taken using a handheld GPS, and are summarized in Appendix B.

The results presented in this document are based on the explorations completed for this study and review of background data. The number, locations, and depths of the explorations were completed within site and budgetary constraints. Because of the nature of exploratory work below ground, interpolation of subsurface conditions between field explorations is necessary. It should be noted that differing subsurface conditions may sometimes be present due to the random nature of deposition and the alteration of topography by past grading and/or filling.

6.1 Hand-Auger Borings in Cell ORLA 1-B

Hand-auger borings in cell ORLA 1-B were completed on July 26 and August 25, 2016. No rain was noted during these site visits, and no flow was observed from the inlet pipes.

Hand-auger boring number 1 and 2 (ORLA1-B-HA-1 and ORLA1-B-HA-2) encountered 2 feet, and 1.6 feet, respectively, of bioretention soil, overlying drain rock. Hand-auger boring number 4 (ORLA1-B-HA-4) was completed immediately adjacent to ORLA1-B-HA-2, and was completed to obtain an additional bioretention soil sample for laboratory testing. No seepage or caving was observed.

Hand-auger boring number 3 (ORLA1-B-HA-3) was completed on the west end of the cell, near the overflow, and encountered approximately 1.6 feet of bioretention soil, overlying 0.4 feet of drain rock. Beneath the drain rock layer, we encountered sand interpreted as native Vashon recessional outwash. The borehole encountered refusal due to caving from the drain rock layer at a total depth of 3 feet. No seepage was observed. AESI installed a well point in this location.

6.2 Hand-Auger Borings in Cell ORLA 2-B

Hand-auger borings in cell ORLA 2-B were completed on August 25, 2016. No rain or inflow of water to the facility was observed on this day.

Hand-auger boring number 1 (ORLA2-B-HA-1) was completed near the center of the facility, and encountered approximately 1.9 feet of bioretention soil, overlying 0.6 feet of drain rock. Below the drain rock, we encountered sand interpreted as Vashon recessional outwash, and minor oxidation was observed. The exploration reached refusal on a large gravel/cobble at 3.1 feet. No seepage or caving was observed. AESI installed a well point in this location.

Hand-auger boring number 2 and 3 (ORLA2-B-HA-2 and ORLA2-B-HA-3) encountered 1.1 feet and 1.4 feet, respectively, of bioretention soil overlying drain rock. No seepage or caving was observed.

6.3 Well Points

Well points were installed in ORLA1-B-HA-1 in cell ORLA1-B, and ORLA2-B-HA-1 in cell ORLA2-B. Key dimensions of these well points are provided in Table 3, below.

Table 3
Summary of ORLA 1-B and ORLA 2-B
Well Point Dimensions

Well Point	Exploration in which Well Point was installed	Total Length of Casing (feet)	Interior Diameter	Stickup Height (feet)	Total Depth Inside Casing Below Ground Surface
ORLA1-B-WP	ORLA1-HA-1	7.2	1.25 inch nominal	3.6	3.6
ORLA2-B-WP	ORLA2-HA-3	8.3	1.25 inch nominal	2	6.3

7.0 LABORATORY ANALYSIS

Laboratory testing included mechanical grain-size distribution and percent organic matter by weight in accordance with the ASTM D422 and D2974, respectively. Two samples of bioretention soil for each cell were first tested for organic matter content and then the burned material was tested for grain-size distribution for comparison with the aggregate fraction of the bioretention soil mix guidance in the Washington State Department of Ecology (Ecology) 2014 *Stormwater Management Manual for Western Washington* (2014 Ecology Manual). One sample of the subgrade from each cell was tested for grain-size distribution. The data is summarized in Table 4.

7.1 Bioretention Soil Mix

We compared the average organic content and burned fraction gradation against the general guidelines for the bioretention soil mix (Table 5).

The organic content of the tested bioretention soils ranged between 4.1 to 7.3 percent by weight. The recommended range of organic content by weight is 5 to 8 percent in the 2014 Ecology Manual.

The grain-size analysis test results on the burned soil fraction indicate that the bioretention soils tested correlate to a "SAND" based on ASTM D2487. The respective fines content as measured on the No. 200 sieve ranged from about 0.5 to 4.1 percent. The recommended range of fines is 2 to 5 percent. The coefficient of uniformity ranged from 2.9 to 3.9, consistently less than the recommended value of equal to or greater than 4. The coefficient of curvature ranged from 1 to 1.8, consistent with the recommended range of greater than or equal to 1 and less than or equal to 3.

Table 4
Summary of ORLA 1-B and ORLA 2-B
Organic Content and Grain-Size Data

Exploration Number	Depth (feet)	Soil Type	Organic Content (% by weight)	USCS Soil Description	Fines Content (% passing #200)	Cu	Cc	USDA Soil Texture*
ORLA 1B HA1	0.4-0.8	Bioretention Soil	7.3	SAND	1.8	3.3	1.5	SAND
ORLA 1B HA4	0-0.5	Bioretention Soil	5.1	SAND	3.2	3.9	1.8	SAND
ORLA 2B HA1	0.6-0.9	Bioretention Soil	4.0	Gravelly SAND	2.8	3.6	1.0	SAND
ORLA 2B HA2	0.1-0.7	Bioretention Soil	3.1	SAND	0.5	2.9	1.3	SAND
ORLA 2B HA3	0.7-1.1	Bioretention Soil	5.6	SAND	4.1	3.6	1.2	SAND
ORLA 2B HA1	2.5-2.9	Recessional Outwash	Not Tested	Silty SAND	17.4			Loamy Sand to Sandy Loam

USCS: Unified Soil Classification System; Cu: coefficient of uniformity; Cc: coefficient of curvature; USDA: US Dept. of Agriculture;
*No hydrometers were performed. USDA soil texture range assumes fines consist entirely of silt to entirely of clay.

Table 5
General Guidelines for Bioretention Soil Mix (2014 Ecology Manual)
Compared to Averaged ORLA 1-B and ORLA 2-B Site Data

Parameter	Recommended Range	ORLA 1-B	ORLA 2-B
Organic Content (by weight)	5 to 8 percent	6.2 percent by weight	4.2 percent by weight
Cu coefficient of uniformity	4 or greater	3.6	1.7
Cc coefficient of curvature	1 to 3	3.4	1.1
Sieve Size	**Percent Passing**		
3/8" (9.51 mm)	100	99.8	96.8
#4 (4.76 mm)	95 to 100	98.5	91.9
#10 (2.0 mm)	75 to 90	94.6	87.7
#40 (0.42 mm)	25 to 40	23.1	39.8
#100 (0.15 mm)	4 to 10	6.5	7.7
#200 (0.074 mm)	2 to 5	2.5	2.5

Note: The general guidelines for mineral aggregate gradation are from Table 7.4.1 of the 2014 Ecology Manual.
mm: millimeter

7.2 Subgrade

In ORLA 2-B, a sample of native recessional outwash was sieved. The tested material correlates to a silty SAND, trace gravel with 17 percent by weight of the material passing the No. 200 sieve.

The grain-size distribution data were also transformed to describe the United States Department of Agriculture soil texture. The grain-size distributions were normalized to the No. 10 sieve—i.e., the coarse sand and gravel fraction of the sample is discounted and the remainder is taken as 100 percent of the sample. The fines were assessed relative to the No. 270 sieve. The respective United States Department of Agriculture fines content as measured on the No. 270 sieve after adjusting to remove the weight retained on the #10 sieve was 18 percent for the native recessional outwash material.

8.0 INFILTRATION TESTING

The infiltration tests were conducted in general accordance with the 2014Ecology Manual. Each test was conducted by discharging water into the facility for a “soaking period,” to allow the receptor soils to become saturated. After completion of the soaking period, water was discharged into the cell at a rate sufficient to maintain a relatively constant head. This constitutes the “constant head” phase of infiltration testing. Immediately following the constant head phase of infiltration testing, flow into the facilities was discontinued, and the water level was monitored as it dropped. This constitutes the “falling head” portion of the infiltration testing.

The water for testing was obtained from an on-site fire hydrant, and conveyed to the test area with fire hoses. During infiltration testing, the water was conveyed into the bioretention cell via a digital flow meter with gpm and total gallon readouts, and discharged through a flow diffuser onto the base of the facilities. Water levels were monitored using a temporary metal staff gauge marked in 0.02-foot increments which was installed for the duration of the test, with a digital water level tape, and with digital pressure transducers. Data from the digital pressure transducers was compensated for barometric response using a separate digital barometer. The area of the pool was measured periodically during testing.

Infiltration tests in each bioretention cell are discussed below, and results are presented in Table 6. Infiltration test data is included in Appendix D to this document.

8.1 Infiltration Test in Cell ORLA 1-B

AESI performed infiltration testing of cell ORLA 1-B on August 30, 2016. No rainfall was noted during testing, and no flow from the inflow pipes was present. A staff gauge (SG-1) was installed at the well point prior to testing and a second staff gauge (SG-2) was installed near the inflow to the facility during testing. Water levels were measured by hand and by data logger in the well point and the wetted pool. The overflow structure (SD-31) was observed periodically during testing. No water was present in the well point or pooled in the cell prior to the start of testing.

During this test, both the soaking period and the constant head period consisted of the maximum possible flow from the on-site fire hydrant. Flow was maintained at approximately 190 gpm for approximately 7 hours, during which approximately 80,000 gallons of water were used. The discharge flow diffuser was placed on the eastern end of the facility, nearest to the fire hydrant, in order to limit head loss through the firehose and maximize flow rate. As the test began, water was observed to pool up to approximately 0.3 feet deep on the eastern end of the facility and then flow west, with intermittent minor damming occurring against accumulated leaf litter and plant debris. The wetted area in the facility began to stabilize once approximately 110 linear feet of the facility base (measured from the east end) was wetted. The staff gauge near the well point was never wetted during testing, and no water was observed in the well point. Over the course of the last 2 hours of testing, the ponded water level in the facility was relatively stable at 0.51 to 0.52 feet, as measured at staff gauge SG-2. During testing, AESI monitored the end of the perforated pipe visible in the sump beneath the beehive grate overflow structure. Stagnant water was present in the sump prior to the start of the test. No flow was observed from pipe into the sump, and stagnant water level within the sump remained constant throughout the test.

After 7 hours, AESI shut off the flow and monitored water level as it fell. AESI observed a drop in water level of approximately 0.44 feet during approximately 14 minutes. The well point was monitored overnight with a pressure transducer; the well point remained dry.

Table 6
ORLA 1-B and ORLA 2-B
Infiltration Test Results

Test No. and Depth	Wetted Surface Area (square feet)	Discharge Time (minutes)	Total Volume Discharged (gallons)	Approximate Constant Head Level (feet)	Field Infiltration Rates	
					Constant Head Test (in/hr)	Falling Head Test (in/hr)
ORLA1-B bioretention soil	710	425	80,164	0.52	25	23
ORLA 1-B subgrade	Interpreted to be similar to wetted area				Assumed to be similar to the bioretention soil rate as no flow was observed out of the underdrain	
ORLA2-B subgrade	~1,900 surface pool; ~2,800 (wetted drain rock layer area)	474	43,071	0.40	~4 to 7 Actual pooled area unknown	~7

in/hr: inches per hour

8.2 Infiltration Test in Cell ORLA 2-B

AESI performed infiltration testing of cell ORLA 2-B on August 31, 2016. Some rainfall and subsequent inflow from the inlets to the facility was noted initially during testing, but no inflow from the inlets was observed during the final 2 hours of testing. A staff gauge (SG-1) was installed at the well point prior to testing, and a second staff gauge (SG-2) was installed next to the infiltration test inflow to the facility during testing. Water levels were measured by hand and by data logger in the well point and the wetted pool. The overflow structure (SD-21) and underdrain cleanout ports were observed periodically during testing. No water was present in the well point or pooled in the cell prior to the start of testing.

During this test, flow was initially maintained at 130 to 190 gpm. Inflow to the facility for the infiltration test was directed, through a diffuser, on the gravel of the walking path which crosses the east side of the facility, noted on Figure ORLA F4. After approximately 1 hour, AESI noted that water was flowing from the underdrain pipe into SD-21 (the overflow area drain). AESI interpreted this to indicate that the native subgrade was draining slower than the bioretention soil, causing water to pool within the drain rock layer, above the native material. Water within SD-21 approached but did not reach the discharge pipe inlet (discharges overflow from the sump to the infiltration trenches to the south). AESI briefly stopped inflow to the facility and monitored the rate of water level drop within SD-21. AESI then resumed inflow to the facility at approximately 84 gpm. At this flow rate, after several hours, water had pooled at SG-1 and SG-2, and the pool of water extended across about two-thirds of the cell base. However, we had observed water within underdrain cleanout at the western edge of the cell, beyond the surface wetted pool area. This indicates that water spread out in the drain rock layer. Over the course of the last 2 hours of testing, the ponded surface water level was stable, and was measured at staff gauge SG-1 at 0.21 to 0.22 feet and SG-2 at 0.40 feet. The full duration of flow was approximately 8 hours, during which approximately 43,000 gallons of water were used.

After about 8 hours, AESI shut off the flow and monitored water level as it fell. AESI observed a drop in water levels of approximately 0.40 feet during approximately 40 minutes of hand readings. Water level in the well point was monitored, but no appreciable change was observed beyond trapped water in the end cap.

9.0 FINDINGS AND CONCLUSIONS

Cells ORLA 1-B and ORLA 2-B varied somewhat from the design shown on the civil plan sheets. Variations included the following:

- Bioretention soil
  - Thickness: Both cells contained areas where the bioretention soil was less than the planned 1.5 feet in thickness.
  - Composition: The soil tested in ORLA 2-B did not meet (contained less than) the recommended guidelines for organic content. The soil tested in ORLA 1-B was within the recommended range for organic content. The soil tested from both cells has higher gravel content than the recommended range. The soil tested from ORLA

2-B had higher coarse sand content than the recommended range. Based on our observations with a geotechnical T-probe, some higher gravel content was present within the bioretention soil in some locations.

- A foot path was present, crossing cell ORLA 2-B toward the east end. Gravel was in place across the base of the facility in this location, and it had been compacted into the surface of the bioretention soil. The foot path did not create a dam within the cell during infiltration testing.

- The subgrade conditions encountered were somewhat finer-grained than what was described as recessional outwash in the geotechnical report for the project (Insight Geologic, Inc., 2012). The native subgrade contained about 17 percent fines where sampled under cell ORLA 2-B compared to typically 2 to 8 percent fines reported in the geotechnical report.

- Review of existing and developed topography indicates that cuts of about 2 to 4 feet were necessary to achieve bioretention cell subgrade. This is important to note because topsoil and fill were present across the site, encountered at depths of up to 4 feet. Fill soil is present in the vicinity of the buried gas line under cell ORLA 2-B. The extent of this fill soil is expected to be limited to a minor portion of the overall area of the facility, but its actual extent is unknown. Oxidation was observed in the native material underlying cell ORLA 2-B in ORLA2-B-HA-1, and was not observed in the native material underlying cell ORLA 1-B in ORLA1-B-HA-3. Oxidation is common in the upper weathered horizon of soils.

- Field infiltration rates were measured at about 25 in/hr (ORLA 1-B) and 4 in/hr (ORLA 2-B). The infiltration rates were substantially lower in ORLA 2-B. Additional subsurface exploration would be necessary to determine if the lower infiltration rate is due to soil variability.

- In both infiltration tests, water readily soaked through the bioretention soil mix. In ORLA 1-B, no ponded within the underdrain was observed. The native soil infiltration rate is interpreted to be similar to that of the bioretention soil. In ORLA 2-B, the water was interpreted to accumulate on the underlying subgrade as indicated by the water level response within the underdrain. The data indicate that for ORLA 2-B, the native subgrade has a lower permeability than the overlying bioretention soil.
- Shallow ground water was not encountered at the time of exploration or testing. Ground water may mound up during the winter months. The ongoing monitoring data will be reviewed during the coming months for ground water influence.

10.0 CLOSURE

We appreciate the opportunity to be of continued service to you on this project. Should you have any questions regarding this document or other geotechnical/hydrogeologic aspects of the project, please call us at your earliest convenience.

Anton Ypma
Staff Geologist

State of Washington
Licensed Geologist
Hydrogeologist
2335
Jennifer H. Saltonstall

Jennifer Saltonstall
10/25/16

Curtis J. Koger, L.G., L.E.G., L.Hg.
Senior Principal Geologist/Hydrogeologist

Jennifer H. Saltonstall, L.G., L.Hg.
Senior Associate Geologist/Hydrogeologist

Attachments:	Figure ORLA F1:	Vicinity Map
	Figure ORLA F2:	LiDAR-Based Topography
	Figure ORLA F3:	Facility and Exploration Plan - ORLA1-B
	Figure ORLA F4:	Facility and Exploration Plan - ORLA 2-B
	Appendix A:	Project Civil Plans
	Appendix B:	Current Study Exploration Logs and Laboratory Testing Data
	Appendix C:	Background Soil, Geology, and Ground Water Data (Regional Maps, Previous Studies Exploration Logs and Laboratory Testing Data)
	Appendix D:	Soil Probe, Level Survey, and Field Infiltration Testing Data
	Appendix E:	Site Photos

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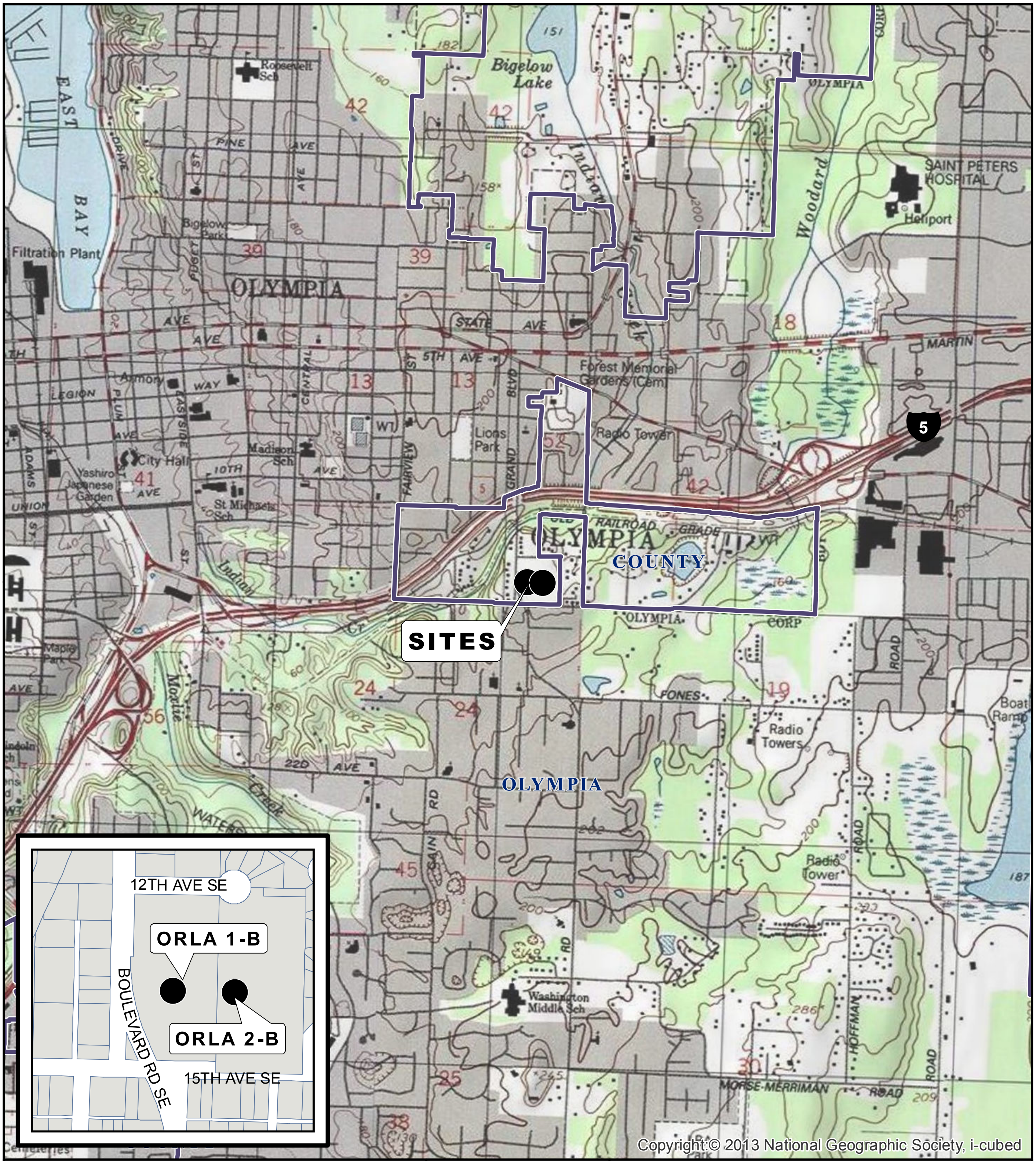

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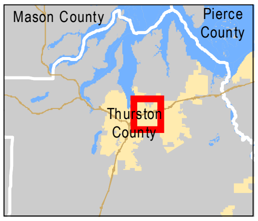
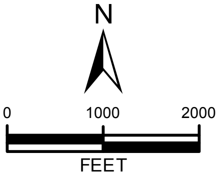


DATA SOURCES / REFERENCES:
USGS: 24K SERIES TOPOGRAPHIC MAPS
PIERCE CO: STREETS, PARCELS 2015

LOCATIONS AND DISTANCES SHOWN ARE APPROXIMATE



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VICINITY MAP

BIORETENTION HYDROLOGIC PERFORMANCE STUDY, ORLA SITE
THURSTON COUNTY, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	ORLA F1

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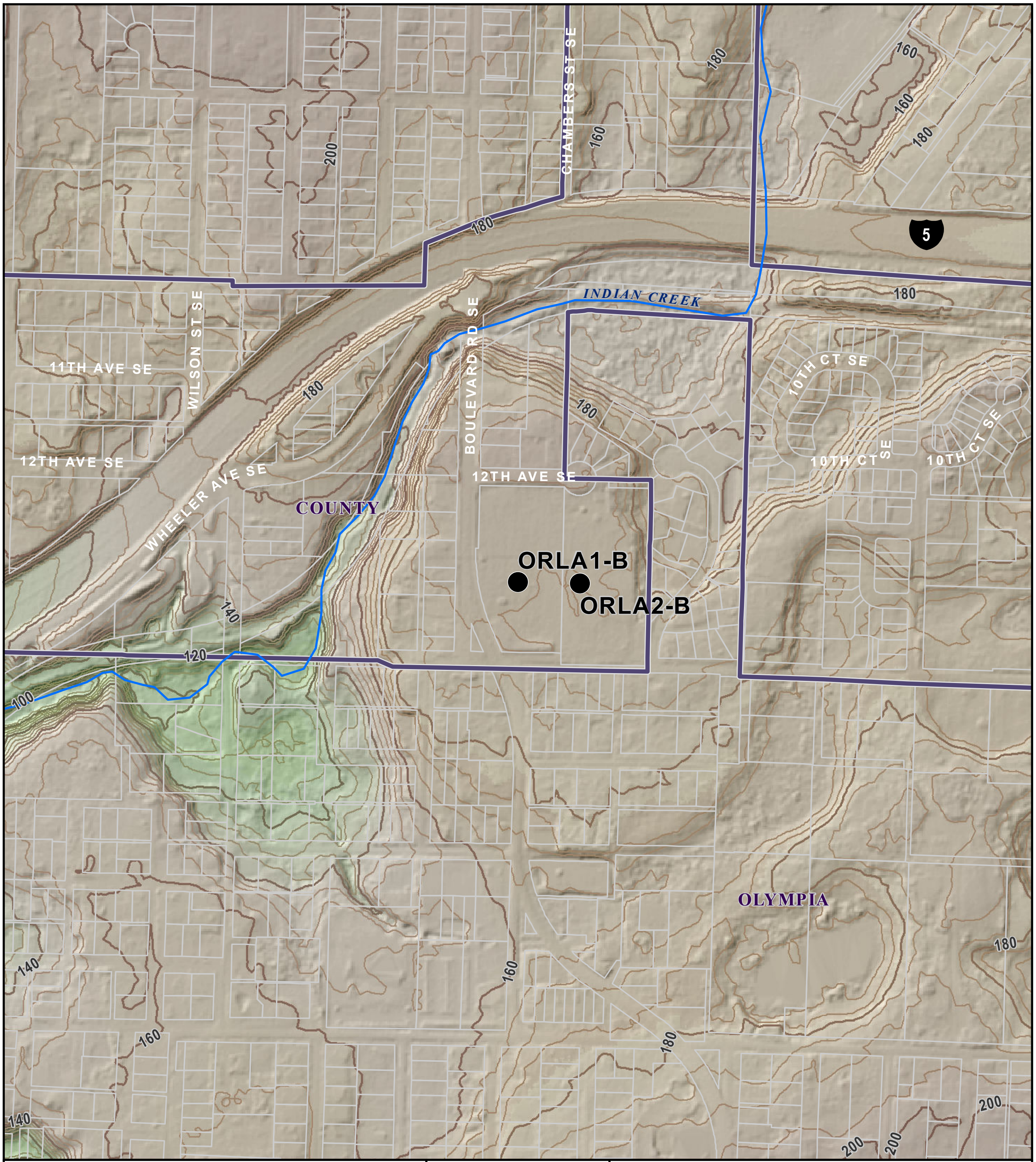

DATA SOURCES / REFERENCES:
PSLC: LIDAR 2000-2005 SUPERMOSAIC, 6' CELL
THURSTON CO: STREETS, PARCELS 2013

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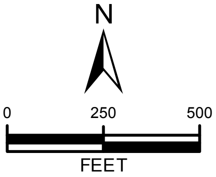

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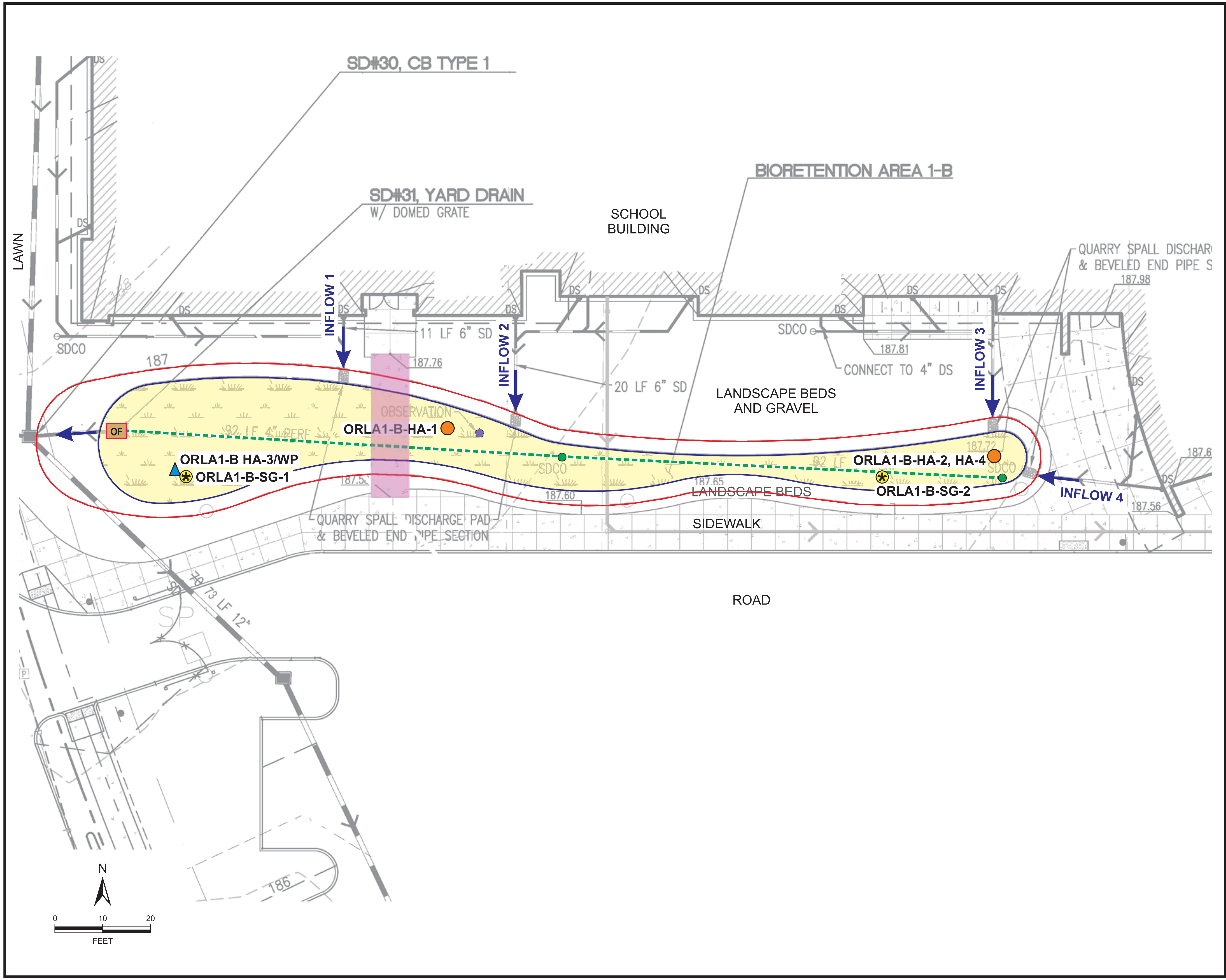
LIDAR BASED TOPOGRAPHY

BIORETENTION HYDROLOGIC
PERFORMANCE STUDY, ORLA SITE
THURSTON COUNTY, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	ORLA F2

Document Path: G:\GIS_Projects\aYear2015postJuly2016\150387 Bioretention Hydro Performance Monitoring\mxd\Fig2s\150387 ORLA Fig2B LIDAR.mxd



LEGEND:

● HA	HAND AUGER
▲ WP	WELL POINT
⊛	TEMPORARY STAFF GAUGE
▭	BASE OF FACILITY
▭	TOP OF FACILITY SLOPE
→	INFLOW / OVERFLOW DIRECTION
OF	OVERFLOW GRATE
- - -	UNDERDRAIN
●	STORM DRAIN CLEANOUT
⬟	PRE-EXISTING OBSERVATION WELL
▨	PEDESTRIAN BRIDGE

CONTOUR INTERVAL = 1'

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:
1. BASE MAP REFERENCE: LPD ENGINEERING, OLYMPIA REGIONAL LEARNING ACADEMY, GRADING DRAINAGE PLAN, C2.3, 5/18/2015

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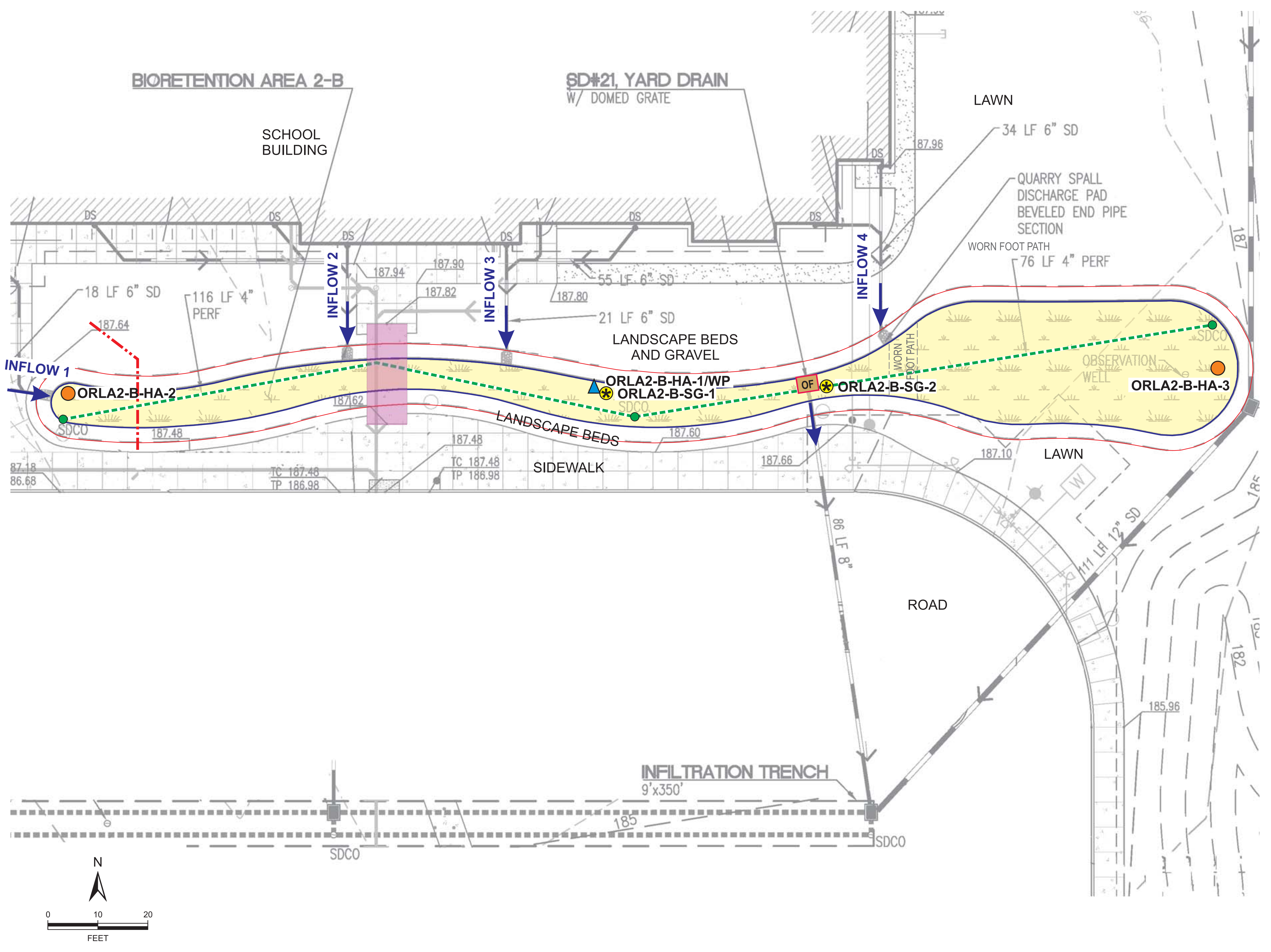
FACILITY AND EXPLORATION PLAN
ORLA1-B SITE
BIORETENTION HYDROLOGIC PERFORMANCE
THURSTON COUNTY, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	ORLA F3



LEGEND:

● **HA**	HAND AUGER
▲ **WP**	WELL POINT
⊛	TEMPORARY STAFF GAUGE
🟨	BASE OF FACILITY
○	TOP OF FACILITY SLOPE
→	INFLOW / OVERFLOW DIRECTION
OF	OVERFLOW GRATE
-----	UNDERDRAIN
●	STORM DRAIN CLEANOUT
-·-·-	GAS LINE
🟪	PEDESTRIAN BRIDGE

CONTOUR INTERVAL = 1'

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:
1. BASE MAP REFERENCE: LPD ENGINEERING, OLYMPIA REGIONAL LEARNING ACADEMY, GRADING / DRAINAGE PLAN, SHEET C2.4, 5/18/2015

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FACILITY AND EXPLORATION PLAN
ORLA2-B SITE
BIORETENTION HYDROLOGIC PERFORMANCE
THURSTON COUNTY, WASHINGTON

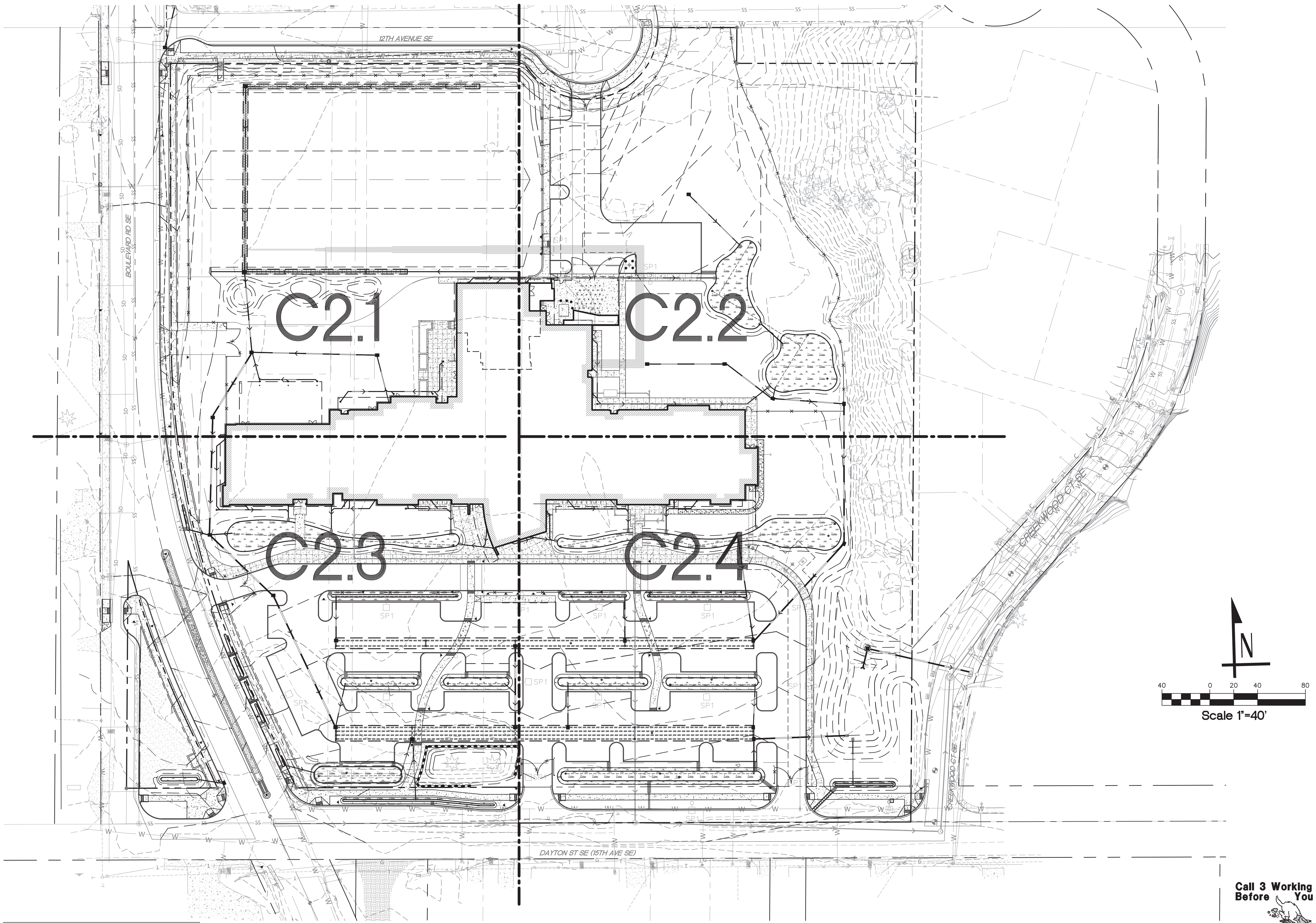
PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	ORLA F4

150387 BHPS MCCA \ 150387 Site-Expl.cdr PAGE 7: ORLA 2B

APPENDIX A

Project Civil Plans

SEC 24, T 18N, R 2W, WM



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LAURIE J. PEARR
30766
5-18-2015

PHASE 1 - SITE & BUILDING
PREP RECORD DRAWINGS

Project Title
OLYMPIA REGIONAL
LEARNING ACADEMY
(ORLA)

OLYMPIA OSD SCHOOL DISTRICT

Project Numbers
TCF: 2010-010

Issue & Revision Dates

17 JANUARY 2013	100% SD
20 MARCH 2013	LAND USE
13 MAY 2013	DD COST ESTIMATE
31 MAY 2013	100% DD SET
18 JUNE 2013	LAND USE RESUBMITTAL
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31 JULY 2013	PHASE 1 - BID SET
9 SEPT 2013	PHASE 1 - SITE & BUILDING PREPARATION PERMIT RESUBMITTAL
20 SEPT 2013	PHASE 1 - SITE & BUILDING PREP FINAL PERMIT SET
18 MAY 2015	RECORD DRAWINGS

RECORD DRAWINGS HAVE BEEN PREPARED BASED UPON INFORMATION FURNISHED BY THE CONTRACTOR AND THE CONTRACTOR'S SURVEYOR.

Sheet Title
Grading/ Drainage Plan Overall

RECORD DRAWING

Drawn By	Design By	Checked By
SN	JS	LJP

Sheet Number
C2.0

Sheet Number Of

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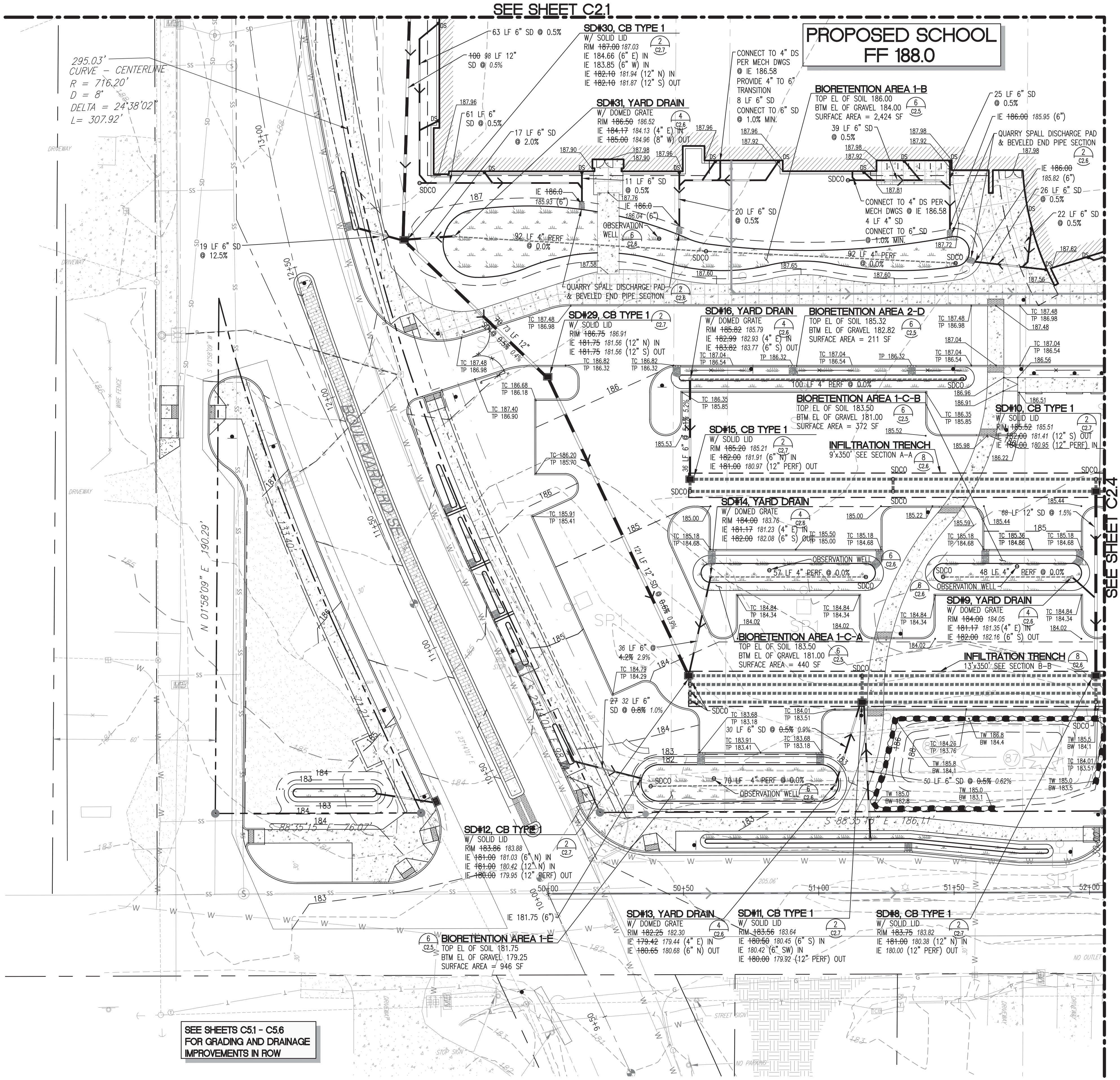
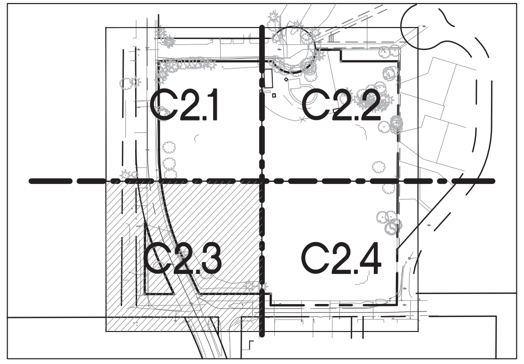
BY: ____________________ DATE: ____________
ENGINEERING PLANS EXAMINER
APPROVAL EXPIRES: ____________________

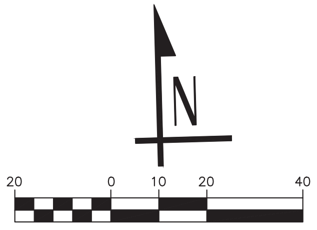


SEE SHEETS C5.1 - C5.6 FOR GRADING AND DRAINAGE IMPROVEMENTS IN ROW

SEC 24, T 18N, R 2W, WM

KEY MAP





Scale 1"=20'

LEGEND

	PROPERTY LINE
230	EX CONTOUR (INDEX)
	EX CONTOUR
230	PROPOSED CONTOUR (INDEX)
231	PROPOSED CONTOUR
xxx.x	SPOT ELEVATION
	EX BUILDING
FF 78.0	FINISHED FLOOR ELEVATION
	PROPOSED BUILDING
	CONCRETE PAVEMENT
	HEAVY DUTY CONCRETE
	SCORED CONCRETE
	ASPHALT (AC) PAVEMENT
	HEAVY DUTY OR ALT ASPHALT (AC) PAVEMENT
	GRIND AND OVERLAY
	GRAVEL SURFACING
	VERTICAL CURB
	CURB AND GUTTER
	BIORETENTION SWALE
	GRADE DIRECTION
	TRUNCATED DOMES

	QUARRY SPALL DISCHARGE PAD
	CATCH BASIN TYPE 1
	STORM DRAINAGE PIPE
DS	DOWNSPOUT
SDCO	CLEANOUT
	YARD DRAIN
	BOLLARD
	FIRE HYDRANT
	WATER FITTINGS
	WATER SERVICE LINES
	WATER METER
	WATER SERVICE LINES
	FIRE SERVICE LINE
	SANITARY SEWER PIPE
	SEWER CLEANOUT
	SIDE SEWER CONNECTION
	SSMH
SP1	LIGHT POLE PER ELECT DWGS
	LIGHT FIXTURE PER ELECT DWGS
	PULL BOX PER ELECT DWGS
	4" CONDUIT FOR FUTURE GAS
	GROUND LOOP PIPING PER MECH DWGS

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PHASE 1 - SITE & BUILDING PREP RECORD DRAWINGS

Project Title
OLYMPIA REGIONAL LEARNING ACADEMY (ORLA)

OLYMPIA OSD SCHOOL DISTRICT

Project Numbers
TCF: 2010-010

Issue & Revision Dates

17 JANUARY 2013	100% SD
20 MARCH 2013	LAND USE
13 MAY 2013	DD COST ESTIMATE
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20 SEPT 2013	PHASE 1 - SITE & BUILDING PREP FINAL PERMIT SET
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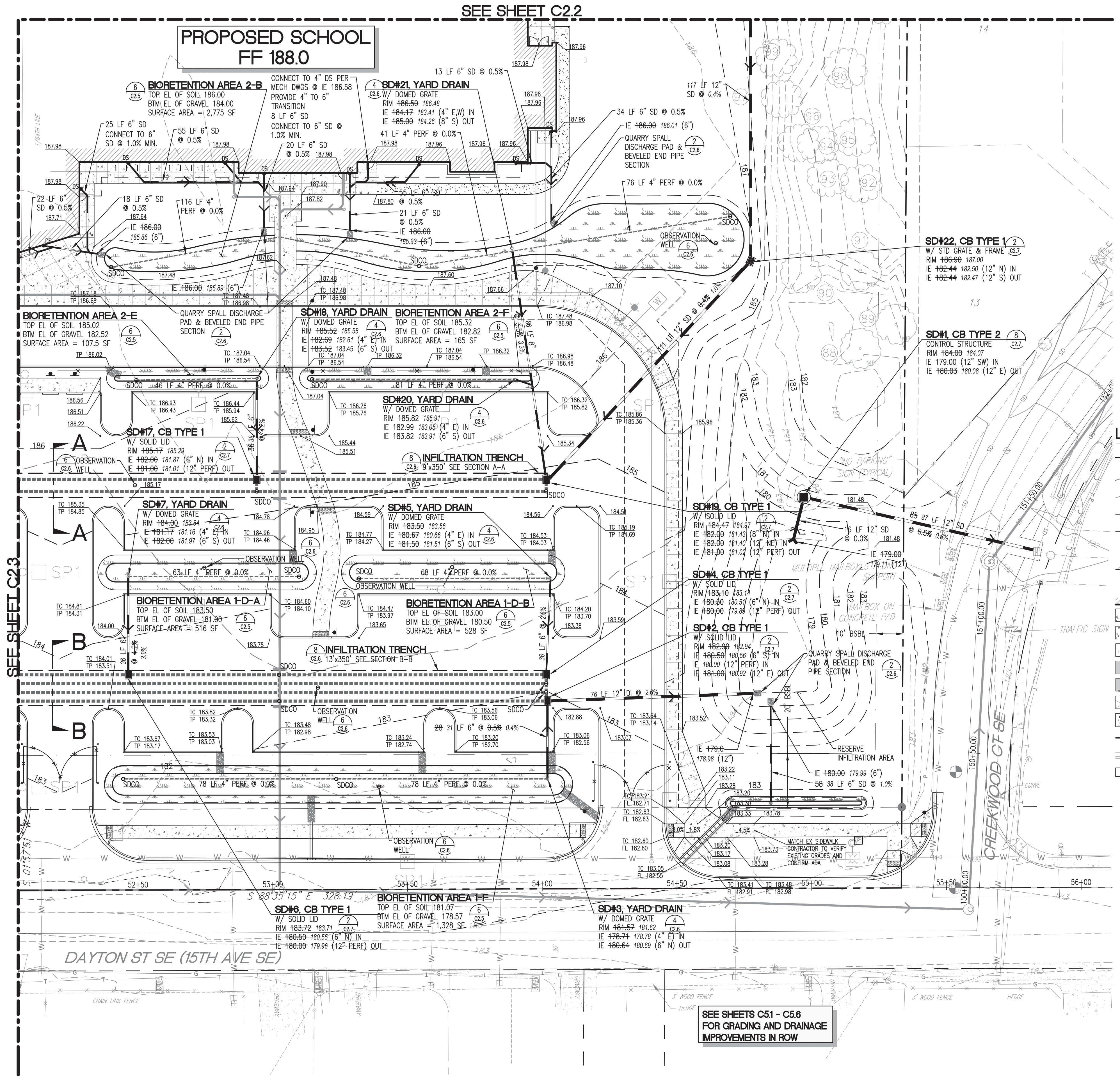
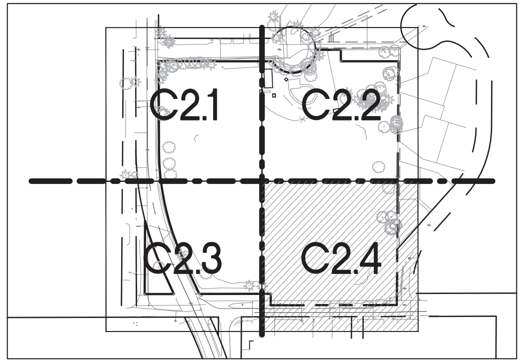
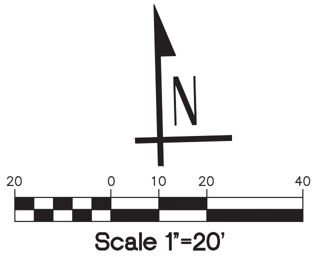


SEC 24, T 18N, R 2W, WM

KEY MAP





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LEGEND

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	EX CONTOUR		STORM DRAINAGE PIPE
230	PROPOSED CONTOUR (INDEX)	DS	DOWNSPOUT
231	PROPOSED CONTOUR	SDCO	CLEANOUT
XXX.X	SPOT ELEVATION		YARD DRAIN
	EX BUILDING		BOLLARD
FF 78.0	FINISHED FLOOR ELEVATION		FIRE HYDRANT
	PROPOSED BUILDING		WATER FITTINGS
	CONCRETE PAVEMENT		WATER SERVICE LINES
	HEAVY DUTY CONCRETE		WATER METER
	SCORED CONCRETE		WATER SERVICE LINES
	ASPHALT (AC) PAVEMENT		FIRE SERVICE LINE
	HEAVY DUTY OR ALT ASPHALT (AC) PAVEMENT		SANITARY SEWER PIPE
	GRIND AND OVERLAY		SEWER CLEANOUT
	GRAVEL SURFACING		SIDE SEWER CONNECTION
	VERTICAL CURB		SSMH
	CURB AND GUTTER	SP1	LIGHT POLE PER ELECT DWGS
	BIORETENTION SWALE		LIGHT FIXTURE PER ELECT DWGS
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LAURIE J. PFARR 30766 5-18-2015

PHASE 1 - SITE & BUILDING
PREP RECORD DRAWINGS

Project Title

OLYMPIA REGIONAL LEARNING ACADEMY (ORLA)

OLYMPIA OSD SCHOOL DISTRICT

Project Numbers
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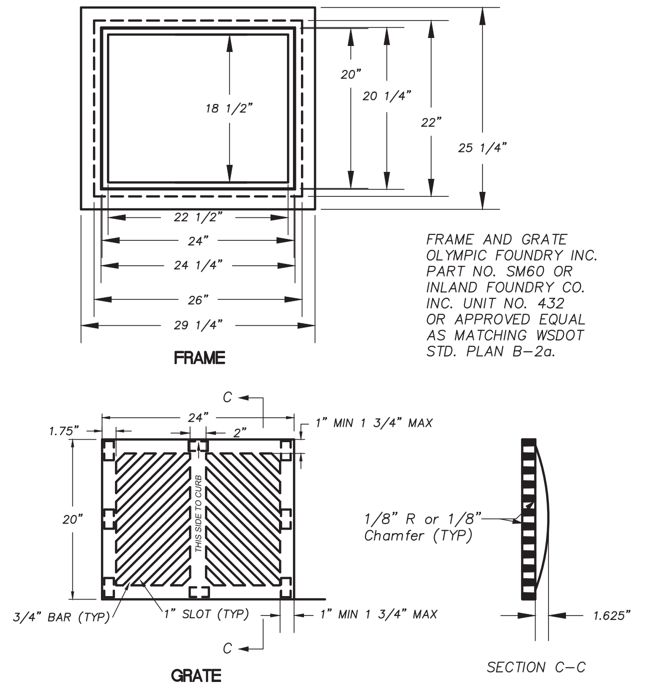
Sheet Number

C2.4

Sheet Number Of



FRAME AND GRATE
OLYMPIC FOUNDRY INC.
PART NO. SM60 OR
INLAND FOUNDRY CO.
INC. UNIT NO. 432
OR APPROVED EQUAL
AS MATCHING WSDOT
STD. PLAN B–2a.

NOTES:

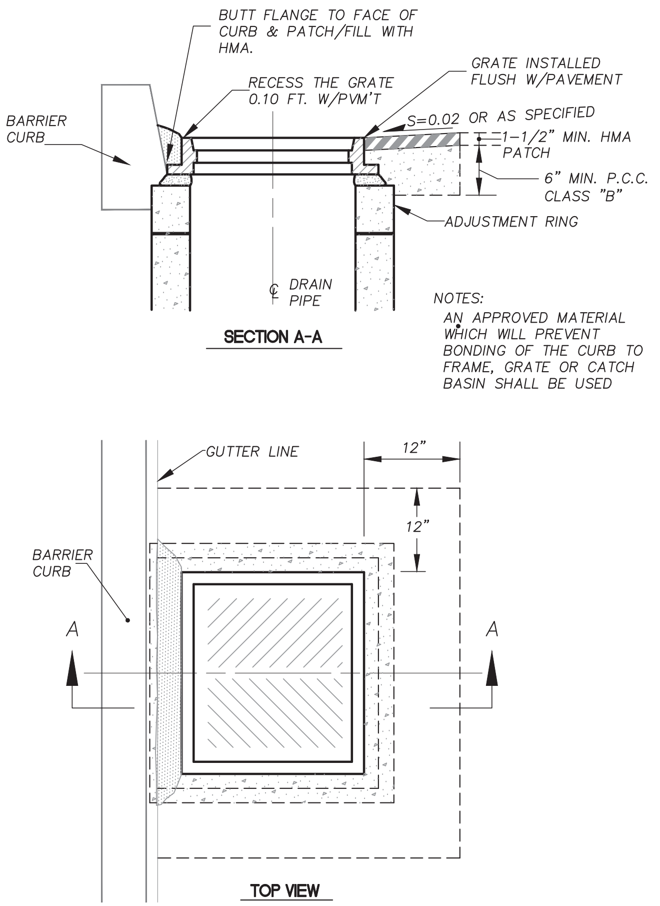
GRATE SHALL COMPLY WITH OR EXCEED A.S.T.M. SPECIFICATIONS A536–72 GRADE 65–45–12 DUCTILE IRON.

WEIGHT	
FRAME	158 LBS ±5%
GRATE	118 LBS ±5%

TOLERANCE ON ALL DIMENSIONS SHALL BE ± 1/16" UNLESS OTHERWISE NOTED.

NTS

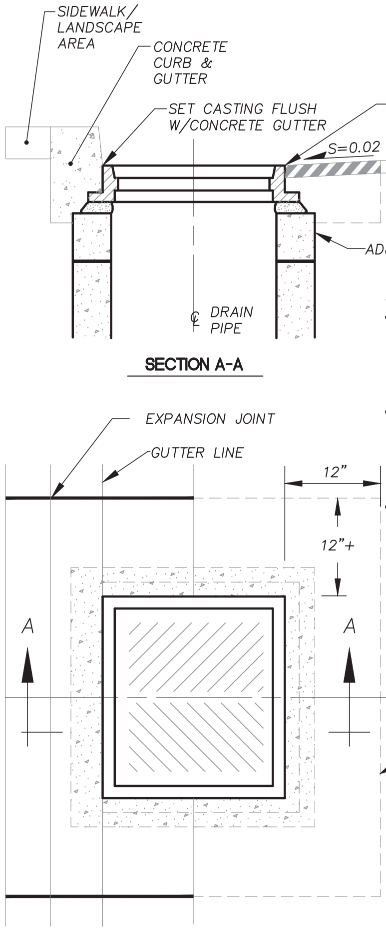
COO 5-5 STANDARD GRATE AND FRAME 1



NOTES:
AN APPROVED MATERIAL WHICH WILL PREVENT BONDING OF THE CURB TO FRAME, GRATE OR CATCH BASIN SHALL BE USED

NTS

COO 5-6 CATCH BASIN INSTALLATION BARRIER CURB 2



NOTES:

- SEE CITY OF OLYMPIA STANDARD PLANS FOR STANDARD CONCRETE WEDGE CURB & GUTTER CONSTRUCTION.
- AN APPROVED MATERIAL WHICH WILL PREVENT BONDING OF THE CURB TO FRAME, GRATE OR CATCH BASIN SHALL BE USED.
- PLACE CURB & GUTTER AROUND CATCH BASIN USING CEMENT CONCRETE CLASS 'B'.

NTS

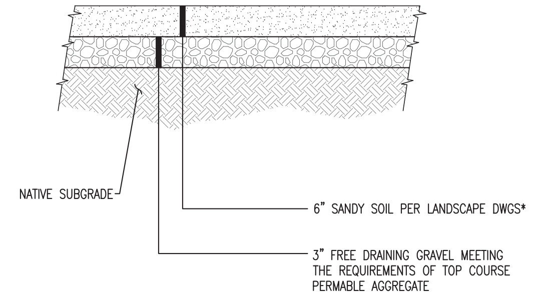
COO 5-7A CATCH BASIN INSTALLATION CONCRETE CURB & GUTTER 3

APPROVED FOR CONSTRUCTION

BY: ______________________ DATE: __________

ENGINEERING PLANS EXAMINER

APPROVAL EXPIRES: ______________________



TOP COURSE PERMEABLE AGGREGATE SPECIFICATION:

SIEVE SIZE	PERCENT PASSING BY WEIGHT
$\frac{3}{4}$"	100
$\frac{1}{2}$"	90–100
$\frac{3}{8}$"	80–100
No. 4	55–75
No. 8	30–50
No. 30	5–25
No. 100	2–10
No. 200 (WET SIEVE)	0–2.0
No. 270 (WET SIEVE)	0–1.0

*ALTERNATIVE

NTS

PLAY FIELD SECTION 4

THE CITY OF OLYMPIA ACCEPTS THE EXECUTION OF THE FOLLOWING PROCEDURES TO MEET THE REQUIREMENTS OF STORMWATER MANUAL BMP T5.13.

PREPARATION METHOD

1. TILL THE SUB GRADE SOIL TO AN 8–INCH DEPTH; THOSE AREAS SUBJECTED TO VEHICLE TRAFFIC SHALL BE TILLED TO A DEPTH OF 12 INCHES. DO NOT SCARIFY OR TILL WITHIN THE DRIP LINE OF EXISTING TREES THAT WILL BE RETAINED.
2. PLACE 3 INCHES OF COMPOST MATERIAL AND TILL INTO 5 INCHES OF SOIL (A TOTAL AMENDED DEPTH OF ABOUT 9.5 INCHES, FOR A SETTLED DEPTH OF 8 INCHES).
3. RAKE THE AREA SMOOTH AND REMOVE SURFACE ROCKS LARGER THAN 1 INCH IN DIAMETER.
4. PLACE 2 INCHES OF AA COMPOST AND RAKE.

COMPOST AMENDMENT QUALITY STANDARDS

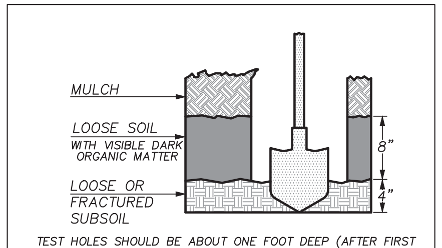
1. THE ORGANIC CONTENT FOR "PRE–APPROVED" AMENDMENT RATES CAN BE MET ONLY BY USING COMPOST THAT MEETS THE DEFINITION FOR "COMPOSTED MATERIALS" IN WAC 173–350–220, AVAILABLE ONLINE AT http://www.ecy.wa.gov/programs/swfa/compost/
2. THE COMPOST MUST ALSO HAVE AN ORGANIC MATTER CONTENT OF 35 TO 65 PERCENT, CARBON TO NITROGEN RATIO BELOW 25:1.
3. THE CARBON TO NITROGEN RATIO MAY BE AS HIGH AS 35:1 FOR PLANTINGS COMPOSED ENTIRELY OF PLANTS NATIVE TO THE PUGET SOUND LOWLANDS REGION.

FOR SINGLE FAMILY RESIDENTIAL LOTS: PREPARATION FOR INSPECTION

- PROVIDE SIX HOLES PER SITE; TWO FOR THE FRONT YARD, ONE EACH FOR SIDE YARDS, AND TWO FOR THE BACKYARD. ALL HOLES SHALL BE EVENLY PLACED THROUGHOUT THE PROPERTY TO DEMONSTRATE AUGMENTATION HAS BEEN COMPLETED.
- TEST HOLES SHALL BE A MINIMUM OF 1 FOOT DEEP AND 1 FOOT SQUARE.
- PERMITTEE SHALL PROVIDE DOCUMENTS FOR THE AA COMPOST VOLUME DELIVERED TO THE SITE TO CONFIRM COMPOST ORIGIN AND QUALITY.

INSPECTION VERIFICATION

- 2 INCHES OF COMPOST ON ALL DISTURBED SURFACES.
- LOOSE SOIL FOR 8 INCHES WITH VISIBLE DARK ORGANIC MATTER.
- LOOSE FRACTURED SUB SOILS SHOULD NOT BE EASY TO PENETRATE WITH A SHOVEL 4 INCHES BELOW THE 8 INCHES. TOTAL DEPTH OF AUGMENTED AND LOOSENED SOIL SHALL BE 12 INCHES.



TEST HOLES SHOULD BE ABOUT ONE FOOT DEEP (AFTER FIRST SCRAPING AWAY ANY MULCH) AND ABOUT ONE FOOT SQUARE.
NTS

NTS

COO 5-11 POST-CONSTRUCTION SOIL QUALITY AND DEPTH 5

CONSTRUCTION SEQUENCE FOR BIORETENTION AREA

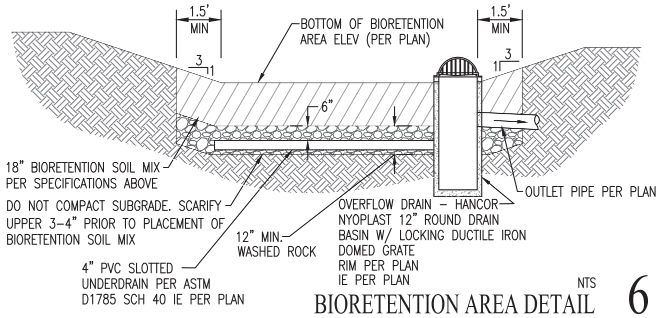
1. INSTALL TEMPORARY SEDIMENT CONTROL BMPS AS SHOWN ON PLAN.
2. COMPLETE SITE GRADING. IF APPLICABLE, CONSTRUCT CURB CUTS OR OTHER INFLOW ENTRANCE BUT PROVIDE PROTECTION SO THAT DRAINAGE IS PROHIBITED FROM ENTERING BIORETENTION CONSTRUCTION AREA.
3. STABILIZE GRADING WITHIN THE LIMIT OF DISTURBANCE EXCEPT WITHIN THE BIORETENTION AREA. BIORETENTION AREAS THAT ARE USED AS TEMPORARY SEDIMENT TRAPS SHOULD BE EXCAVATED 6 INCHES BELOW THE BOTTOM OF THE SEDIMENT TRAP.
4. EXCAVATE BIORETENTION AREA TO PROPOSED DEPTH AND SCARIFY THE TOP 3"–4" OF EXISTING SOIL SURFACES. DO NOT COMPACT NATIVE SUBGRADE.
5. INSTALL PVC SLOTTED UNDERDRAIN PIPE PER PLAN.
6. BACKFILL BIORETENTION AREA WITH BIORETENTION SOIL MIX AND WASHED ROCK AS SHOWN ON PLANS AND SPECIFICATIONS. OVERFILLING IS RECOMMENDED TO ACCOUNT FOR SETTLEMENT. LIGHT HAND TAMPING IS ACCEPTABLE IF NECESSARY.
7. PRESOAK THE PLANTING SOIL PRIOR TO PLANTING VEGETATION TO AID IN SETTLEMENT.
8. COMPLETE FINAL GRADING TO ACHIEVE PROPOSED DESIGN ELEVATIONS. LEAVE SPACE FOR UPPER LAYER OF COMPOST, MULCH OR TOPSOIL AS SPECIFIED ON PLANS.
9. PLANT VEGETATION ACCORDING TO PLANTING PLAN.
10. MULCH AND INSTALL EROSION PROTECTION AT SURFACE FLOW ENTRANCES WHERE NECESSARY UNTIL ENTIRE SITE IS STABILIZED.

BIORETENTION SOIL MIX SPECIFICATIONS

1. HYDRAULIC CONDUCTIVITY INITIAL RATE LESS THAN 12 INCHES PER HOUR AND A LONG–TERM RATE MORE THAN 1 INCH PER HOUR
2. 4–8% (BY DRY WEIGHT) ORGANIC MATTER CONTENT
3. RATIO OF OXALATE PHOSPHOROUS AND OXALATE IRON AND ALUMINUM < 0.25
4. CATION EXCHANGE CAPACITY (CEC)≥ 5 MEQ/100 GRAMS OF DRY SOIL
5. 60% MINERAL AGGREGATE: 40% COMPOST
    a. MINERAL AGGREGATE
        i. AGGREGATE GRADATION

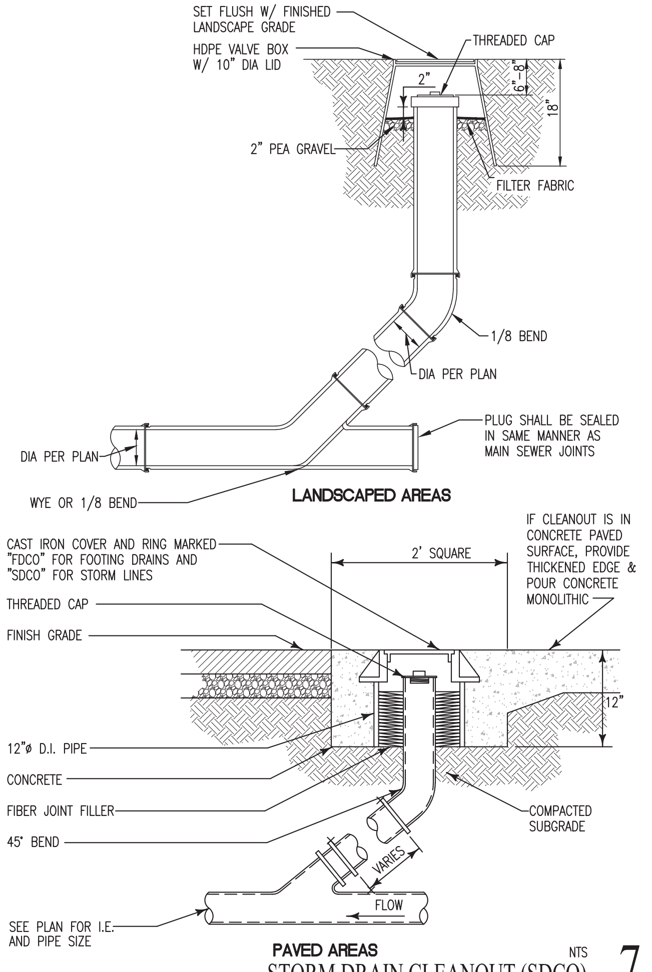
Sieve Size	Percent
3/8 inch	100
No. 4	95–100
No. 10	75–90
No. 40	25–40
No. 100	4–10
No. 200	2–5

        ii. COEFFICIENT OF UNIFORMITY ≥ 4
    b. COMPOST
        i. CARBON NITROGEN RATIO OF 25 CARBON: 1 NITROGEN
        ii. INERT MATERIAL ≤ 4%
        iii. 40–65% (BY DRY WEIGHT) ORGANIC CONTENT
        iv. RESTRICT LARGE PIECES OF COMPOST: 100% PASSING 1" SIEVE
        v. FEED STOCK COMPOSITION: ≤ 35% TYPE III STOCK, ≥ TYPE I STOCK (WAC 173–350–100)
        vi. MATURITY INDICATOR > 80%
        vii. STABILITY INDICATOR ≤ 7
        viii. COPPER CONTENT < 750 mg/kg
        ix. ZINC CONTENT < 1400 mg/kg
        x. SOLUBLE SALT < 4 mmhos/cm



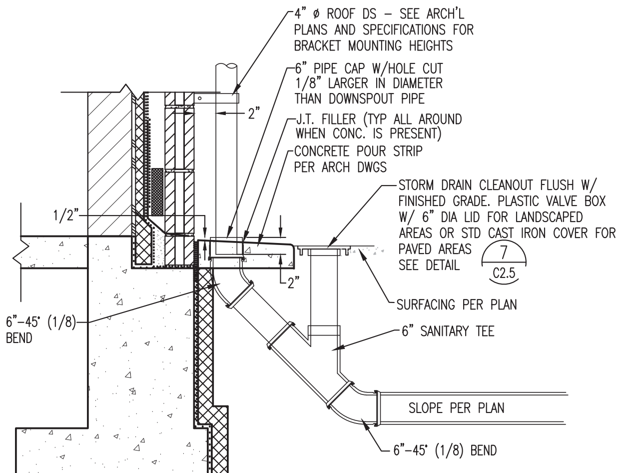
NTS

BIORETENTION AREA DETAIL 6



NTS

STORM DRAIN CLEANOUT (SDCO) 7



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ROOF DOWNSPOUT (DS) CONNECTION 8

TCF Architecture
902 North Second Street
Tacoma, Washington 98403

P. 253.572.3993
F. 253.572.1445

www.tcfarchitecture.com

TCF Architecture, PLLC

LPD engineering pllc
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Suite 420
Seattle, WA 98104
p. 206.725.1211
f. 206.973.5344
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LAURIE J. PEARR
30766
5-18-2015

PHASE 1 - SITE & BUILDING
PREP RECORD DRAWINGS

Project Title

OLYMPIA REGIONAL
LEARNING ACADEMY
(ORLA)

OLYMPIA OSD SCHOOL DISTRICT

Project Numbers
TCF: 2010-010

Issue & Revision Dates

17 JANUARY 2013	100% SD
20 MARCH 2013	LAND USE
13 MAY 2013	DD COST ESTIMATE
31 MAY 2013	100% DD SET
18 JUNE 2013	LAND USE RESUBMITTAL
21 JUNE 2013	PHASE 1 - SITE & BUILDING PREPARATION PERMIT SUBMITTAL
31 JULY 2013	PHASE 1 - BID SET
9 SEPT 2013	PHASE 1 - SITE & BUILDING PREPARATION PERMIT RESUBMITTAL
20 SEPT 2013	PHASE 1 - SITE & BUILDING PREP FINAL PERMIT SET
18 MAY 2015	RECORD DRAWINGS

RECORD DRAWINGS HAVE BEEN PREPARED BASED UPON INFORMATION FURNISHED BY THE CONTRACTOR AND THE CONTRACTOR'S SURVEYOR.

Sheet Title

Grading/ Drainage Details

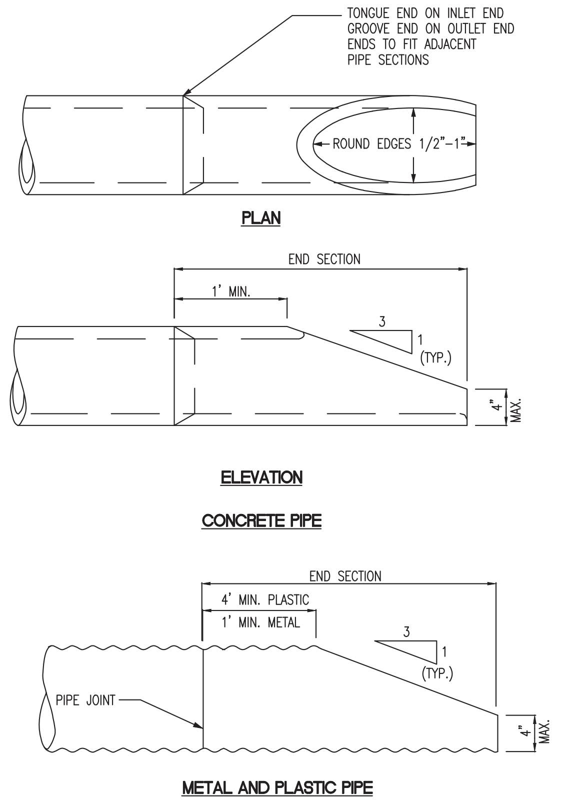
RECORD DRAWING

Drawn By	Design By	Checked By
SN	JS	LJP

Sheet Number

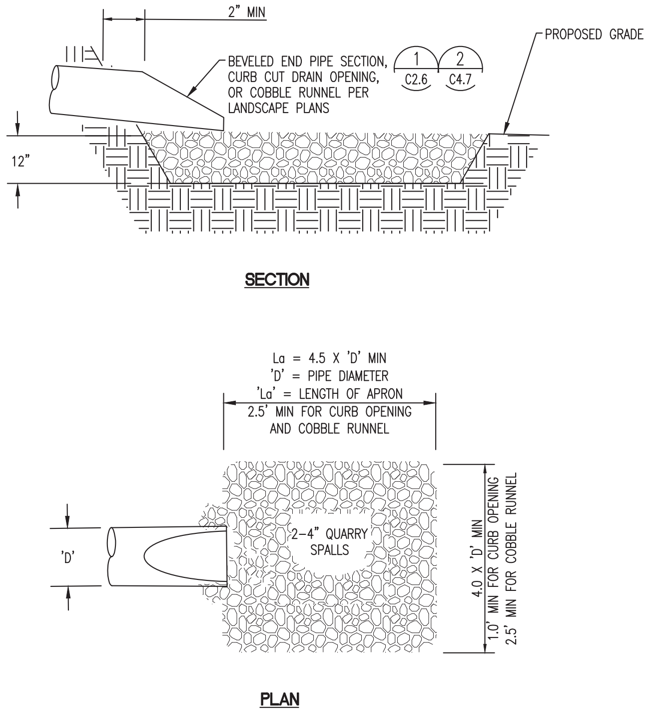
C2.5

Sheet Number Of

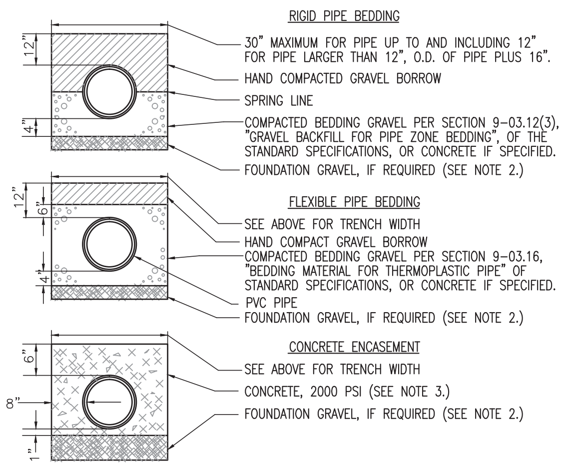


NOTE:
SIDE SLOPE SHALL BE WARPED TO MATCH THE BEVELED PIPE END. WHEN CULVERT IS ON SKEW, BEVELED END SHALL BE ROTATED TO CONFORM TO SLOPE. IF SLOPE DIFFERS FROM 3:1, PIPE SHALL BE BEVELED TO MATCH SLOPE.

NTS
BEVELED END PIPE SECTION DETAIL 1



NTS
QUARRY SPALL DISCHARGE PAD 2

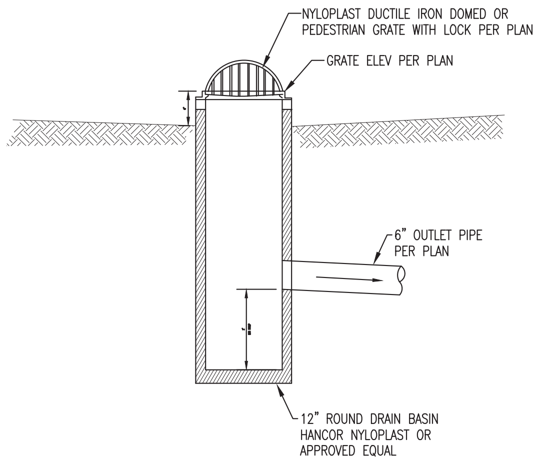


NOTES:

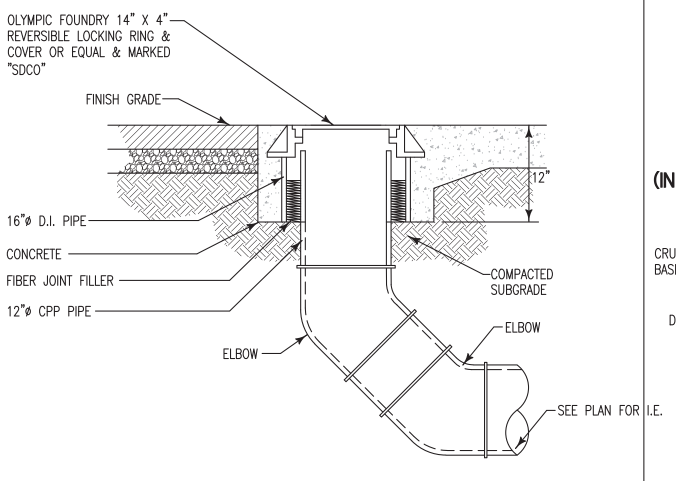
1. COMPACTED CRUSHED SURFACING TOP COURSE PER SECTION 9-03.9(3), "CRUSHED SURFACING", OF THE STANDARD SPECIFICATIONS CAN ALSO BE USED AS BEDDING GRAVEL.
2. EXCAVATE UNSTABLE MATERIAL DOWN TO FIRM SOIL AND REPLACE WITH FOUNDATION GRAVEL PER SECTION 9-03.9(1), "BALLAST", OF THE STANDARD SPECIFICATIONS
3. THE CONTRACTOR SHALL BE RESPONSIBLE FOR ANCHORING PIPE TO PREVENT FLOTATION DURING CONCRETE PLACEMENT.

NTS
PIPE BEDDING 3

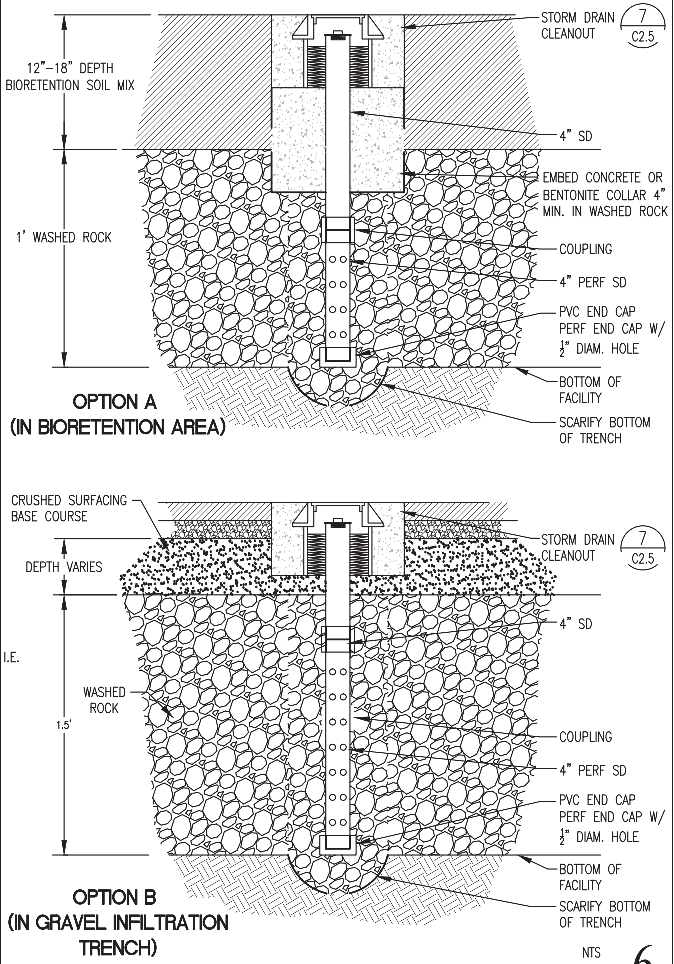
APPROVED FOR CONSTRUCTION
BY: ______________________ DATE: __________
ENGINEERING PLANS EXAMINER
APPROVAL EXPIRES: ______________________



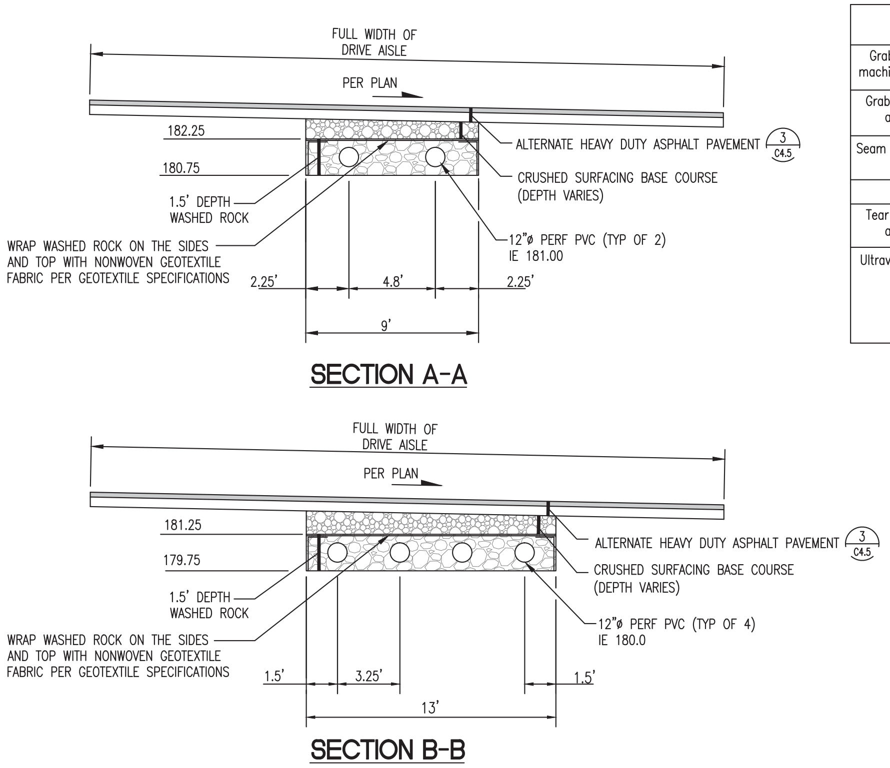
NTS
YARD DRAIN 4



NTS
INFILTRATION TRENCH FITTING CONFIGURATION 5



NTS
OBSERVATION WELL 6



GEOTEXTILE SPECIFICATIONS

Geotextile Property	Woven
Grab Tensile Strength, min. in machine and x-machine direction	160 lbs min.
Grab Failure Strain, in machine and x-machine direction	>50%
Seam Breaking Strength (if seams present)	140 lbs min.
Puncture Resistance	50 lbs min.
Tear Strength, min. in machine and x-machine direction	50 lbs min.
Ultraviolet (UV) Radiation stability	50% strength retained min., after 500 hrs. in weatherometer

NTS
INFILTRATION TRENCH 8

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Sheet Title
Grading/ Drainage Details

RECORD DRAWING

Drawn By	Design By	Checked By
SN	JS	LJP

Sheet Number
C2.6

Sheet Number Of

APPENDIX B

Current Study Exploration Logs and Laboratory Testing Data

Cell ORLA1-B and ORLA2-B
Exploration Latitude and Longitude

Exploration	Latitude	Longitude
ORLA1-B-HA-1	47.03693	-122.86800
ORLA1-B-HA-2	47.03693	-122.86800
ORLA1-B-HA-3	47.03698	-122.86871
ORLA1-B-HA-4	47.03695	-122.86800
ORLA2-B-HA-1	47.03691	-122.86722
ORLA2-B-HA-2	47.03692	-122.86758
ORLA2-B-HA-3	-47.03693	-122.86670

associated earth sciences incorporated

Exploration Log

Project Number	Exploration Number	Sheet
KH150387A	ORLA1-B-HA-1	1 of 1

Project Name: Bioretention Hydrologic Performance Study
Location: Thurston County, WA
Driller/Equipment: Hand Auger
Hammer Weight/Drop: N/A

Ground Surface Elevation (ft):
Datum: N/A
Date Start/Finish: 7/26/16,7/26/16
Hole Diameter (in): 4 inches

Depth (ft)	S T	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot 10 20 30 40	Other Tests
				Bioretention Soil Mix Surface: sand, leaf litter, vegetation Loose, slightly moist, light brown, SAND, trace silt; becomes brown with depth; organics present; mostly medium sand (~71 percent) (SP).					
				Drain Rock Loose rounded gravel (~1 inch diameter) (GP).					
				Bottom of exploration boring at 2.1 feet Refusal on gravel. No seepage. No caving.					

Sampler Type (ST):

▯ 2" OD Split Spoon Sampler (SPT)	☐ No Recovery	M - Moisture
▯ 3" OD Split Spoon Sampler (D & M)	◧ Ring Sample	▽ Water Level ()
☐ Grab Sample	▱ Shelby Tube Sample	▼ Water Level at time of drilling (ATD)

Logged by: ADY
Approved by: JHS

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earth sciences
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Exploration Log

Project Number	Exploration Number	Sheet
KH150387A	ORLA1-B-HA-2	1 of 1

Project Name: Bioretention Hydrologic Performance Study
Location: Thurston County, WA
Driller/Equipment: Hand Auger
Hammer Weight/Drop: N/A

Ground Surface Elevation (ft):
Datum: N/A
Date Start/Finish: 7/26/16,7/26/16
Hole Diameter (in): 4 inches

Depth (ft)	ST	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot 10 20 30 40	Other Tests
				Bioretention Soil Mix Surface: sand, leaf litter, vegetation Loose, moist, dark brown, SAND, trace silt; organics present; mostly medium sand (SP).					
				Bottom of exploration boring at 1.4 feet Refusal on rounded gravel (~1 inch diameter). No seepage. No caving.					

Sampler Type (ST):

▯ 2" OD Split Spoon Sampler (SPT)
▯ 3" OD Split Spoon Sampler (D & M)
✋ Grab Sample
☐ No Recovery
◧ Ring Sample
▨ Shelby Tube Sample
M - Moisture
▽ Water Level ()
▼ Water Level at time of drilling (ATD)

Logged by: ADY
Approved by: JHS

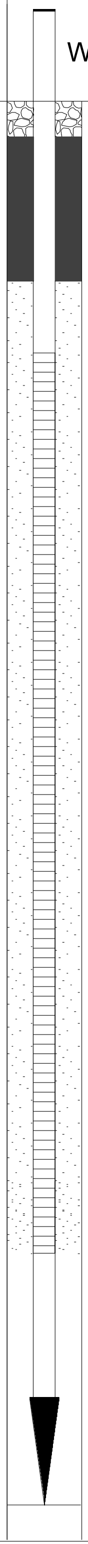
associated earth sciences incorporated

Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KH150387A	-ORLA-1-B-HA-3/WP	1 of 1

Project Name: Bioretention Hydrologic Performance Study
Elevation (Top of Well Casing): ~3.6 feet (stick up)
Water Level Elevation:
Drilling/Equipment: Hand Auger
Hammer Weight/Drop: N/A
Location: Thurston County, WA
Surface Elevation (ft):
Date Start/Finish: 7/26/16,7/26/16
Hole Diameter (in): 4 inches

Depth (ft)	Water Level	WELL CONSTRUCTION	ST	Blows/ 6"	Graphic Symbol	DESCRIPTION



Above ground stick up -3.6 feet

Threaded PVC cap

Bioretention soil mix 0 to 0.1 foot

Bentonite chips 0.1 to 0.5 foot

Threaded steel pipe -3.6 to 0.7 feet

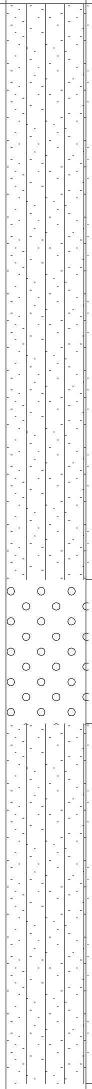
Medium sand 0.5 to 3 feet

Stainless steel jacket over stainless steel #60 gauze welded to perforated steel pipe 0.7 to 3.2 feet

Native soils 3 to 3.9 feet

Threaded steel pipe, 1 1/4 inch ID and end cap 3.2 to 3.6 feet

Solid drive point 3.6 to 3.9 feet



Bioretention Soil Mix

Surface: sand, leaf litter, vegetation

Loose, slightly moist, light brown, SAND, trace silt; organics present; mostly medium sand (~71 percent) (SP).

Drain Rock

Loose rounded gravel (~1 inch diameter) (GP).

Vashon Recessional Outwash

Medium dense, slightly moist, light brown, silty SAND; mostly fine sand (SM).

Boring terminated at 3 feet.
Well completed at 3.9 feet on 7/26/16.
Refusal at 3 feet due to heavy caving from layer of drain rock. No seepage.

Sampler Type (ST):

▯ 2" OD Split Spoon Sampler (SPT)	▯ No Recovery	M - Moisture
▯ 3" OD Split Spoon Sampler (D & M)	▮ Ring Sample	▽ Water Level ()
▯ Grab Sample	▯ Shelby Tube Sample	▼ Water Level at time of drilling (ATD)

Logged by: ADY
Approved by: JHS

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Exploration Log

Project Number	Exploration Number	Sheet
KH150387A	ORLA1-B-HA-4	1 of 1

Project Name Bioretention Hydrologic Performance Study
Location Thurston County, WA
Driller/Equipment Hand Auger
Hammer Weight/Drop N/A

Ground Surface Elevation (ft)
Datum N/A
Date Start/Finish 8/25/16,8/25/16
Hole Diameter (in) 4 inches

Depth (ft)	S T	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot 10 20 30 40	Other Tests
			⁘	**Bioretention Soil Mix** Surface: dry grass, sand Loose, slightly moist, brown, SAND, trace silt; organics present; mostly medium sand (~72 percent) (SP).					
				Bottom of exploration boring at 0.5 feet No seepage. No caving.					

Sampler Type (ST):

▯ 2" OD Split Spoon Sampler (SPT)	☐ No Recovery	M - Moisture
▯ 3" OD Split Spoon Sampler (D & M)	◧ Ring Sample	▽ Water Level ()
✋ Grab Sample	▨ Shelby Tube Sample	▼ Water Level at time of drilling (ATD)

Logged by: ADY
Approved by: JHS

AESIBOR 150387ORLA.GPJ October 24, 2016

associated earth sciences incorporated

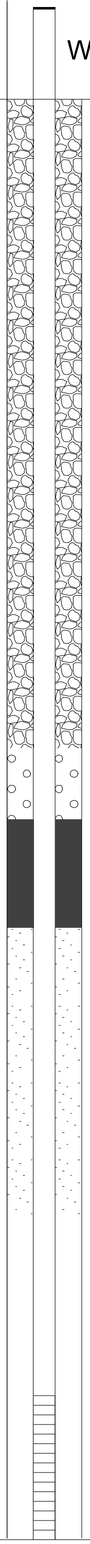
Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KH150387A	-ORLA2-B-HA-1/WP	1 of 2

Project Name Bioretention Hydrologic Performance Study
Elevation (Top of Well Casing) ~2 feet (stick up)
Water Level Elevation
Drilling/Equipment Hand Auger
Hammer Weight/Drop N/A

Location Thurston County, WA
Surface Elevation (ft)
Date Start/Finish 8/25/16,8/25/16
Hole Diameter (in) 4 inches

Depth (ft)	Water Level	WELL CONSTRUCTION	ST	Blows/ 6"	Graphic Symbol	DESCRIPTION



Above ground stick up -2.0 feet
Threaded PVC cap
Bioretention soil mix 0 to 1.8 foot

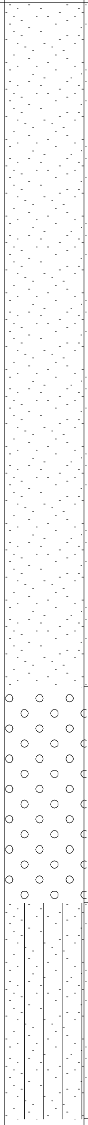
Threaded steel pipe -2.0 to 3.6 feet

Drain rock 1.8 to 2 feet

Bentonite chips 2.0 to 2.3 feet

Medium sand 2.3 to 3.1 feet

Native soils 3.1 to 6.6 feet



Bioretention Soil Mix

Surface: leaf litter, sand

Loose, slightly moist, brown, gravelly (0.5 to 1 inch, rounded) SAND, trace silt; organics present; mostly fine sand (~50 percent) (SP).

Drain Rock

Loose rounded gravel (~0.5 to 1 inch diameter); some sandy intervals (GP).

Vashon Recessional Outwash

Medium dense, slightly moist, brown, silty SAND, trace gravel; oxidation visible; mostly fine sand (~51 percent) (SM).

Boring terminated at 3.1 feet.
Well completed at 6.6 feet on 8/25/16.
Refusal on cobble. No seepage. Moderate caving of drain rock.

Sampler Type (ST):

▯ 2" OD Split Spoon Sampler (SPT)	▯ No Recovery	M - Moisture
▯ 3" OD Split Spoon Sampler (D & M)	▮ Ring Sample	▽ Water Level ()
▯ Grab Sample	▯ Shelby Tube Sample	▼ Water Level at time of drilling (ATD)

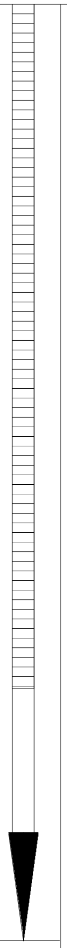
Logged by: ADY
Approved by: JHS

Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KH150387A	-ORLA2-B-HA-1/WP	2 of 2

Project Name	Bioretention Hydrologic Performance Study	Location	Thurston County, WA
Elevation (Top of Well Casing)	~2 feet (stick up)	Surface Elevation (ft)	
Water Level Elevation		Date Start/Finish	8/25/16,8/25/16
Drilling/Equipment	Hand Auger	Hole Diameter (in)	4 inches
Hammer Weight/Drop	N/A		

Depth (ft)	Water Level	WELL CONSTRUCTION	S T	Blows/ 6"	Graphic Symbol	DESCRIPTION
5						



Stainless steel jacket over stainless steel #60 gauze welded to perforated steel pipe 3.6 to 5.9 feet

Threaded steel pipe, 1 1/4 inch ID and end cap 5.9 to 6.3 feet

Solid drive point 6.3 to 6.6 feet

Sampler Type (ST):

▯ 2" OD Split Spoon Sampler (SPT)	☐ No Recovery	M - Moisture	**Logged by:**	ADY
▯ 3" OD Split Spoon Sampler (D & M)	▌ Ring Sample	▽ Water Level ()	**Approved by:**	JHS
▯ Grab Sample	▱ Shelby Tube Sample	▼ Water Level at time of drilling (ATD)		

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Exploration Log

Project Number	Exploration Number	Sheet
KH150387A	ORLA2-B-HA-2	1 of 1

Project Name: Bioretention Hydrologic Performance Study
Location: Thurston County, WA
Driller/Equipment: Hand Auger
Hammer Weight/Drop: N/A

Ground Surface Elevation (ft):
Datum: N/A
Date Start/Finish: 8/25/16,8/25/16
Hole Diameter (in): 4 inches

Depth (ft)	S T	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot 10 20 30 40	Other Tests
				Bioretention Soil Mix Surface: bare sand Loose, slightly moist, brown, SAND, trace silt; organics present; mostly medium sand (~85 percent) (SP).					
				Drain Rock Loose rounded gravel (~0.5 to 1 inch diameter) (GP).					
				Bottom of exploration boring at 1.2 feet No seepage. No caving.					

Sampler Type (ST):

- ▯ 2" OD Split Spoon Sampler (SPT)
- ▯ 3" OD Split Spoon Sampler (D & M)
- ✋ Grab Sample
- ☐ No Recovery
- ◧ Ring Sample
- ▨ Shelby Tube Sample
- M - Moisture
- ▽ Water Level ()
- ▼ Water Level at time of drilling (ATD)

Logged by: ADY
Approved by: JHS

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Exploration Log

Project Number	Exploration Number	Sheet
KH150387A	ORLA2-B-HA-3	1 of 1

Project Name: Bioretention Hydrologic Performance Study
Location: Thurston County, WA
Driller/Equipment: Hand Auger
Hammer Weight/Drop: N/A

Ground Surface Elevation (ft):
Datum: N/A
Date Start/Finish: 8/25/16,8/25/16
Hole Diameter (in): 4 inches

Depth (ft)	S T	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot 10 20 30 40	Other Tests
				Bioretention Soil Mix Surface: dry grass, sand Loose, slightly moist, brown, SAND, trace silt; organics present; mostly fine to medium sand (SP).					
				Drain Rock Loose rounded gravel (~0.5 to 1 inch diameter) (GP).					
				Bottom of exploration boring at 1.5 feet No seepage. No caving.					

Sampler Type (ST):

▯ 2" OD Split Spoon Sampler (SPT)	☐ No Recovery	M - Moisture	**Logged by:**	ADY
▯ 3" OD Split Spoon Sampler (D & M)	◧ Ring Sample	▽ Water Level ()	**Approved by:**	JHS
☐ Grab Sample	▨ Shelby Tube Sample	▼ Water Level at time of drilling (ATD)		

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Moisture, Ash, and Organic Matter of Peat and Other Organic Soils - ASTM 2974

Date Sampled	**Project**	**Project No.**		**Soil Description**
7/26/2016	BHPS	KH150387A		Bioretention soil mix
Tested By	**Location**	**EB/EP No.**	**Depth**	
MS	ORLA1-B	ORLA1-B		

Moisture Content	**ORLA1-B**	**Moisture Content**	**ORLA1-B**
Sample ID	**HA1 0.4-0.8**	Sample ID	**HA4 0-0.5**
Wet Weight + Pan	**620.22**	Wet Weight + Pan	**956.41**
Dry Weight + Pan	**585.48**	Dry Weight + Pan	**901.14**
Weight of Pan	**291.69**	Weight of Pan	**273.49**
Weight of Moisture	**34.74**	Weight of Moisture	**55.27**
Dry Weight of Soil	**293.79**	Dry Weight of Soil	**627.65**
% Moisture	**11.8**	% Moisture	**8.8**

Organic Matter and Ash Content		**Organic Matter and Ash Content**	
Dry Soil Befor Burn + Pan	**690.06**	Dry Soil Befor Burn + Pan	**976.33**
Dry Soil After Burn + Pan	**668.21**	Dry Soil After Burn + Pan	**944.08**
Weight of Pan	**392.15**	Weight of Pan	**348.78**
Wt. Loss Due to Ignition	**21.85**	Wt. Loss Due to Ignition	**32.25**
Actual Wt. Of Soil After Burr	**276.06**	Actual Wt. Of Soil After Burr	**595.30**
% Organics	**7.3**	% Organics	**5.1**

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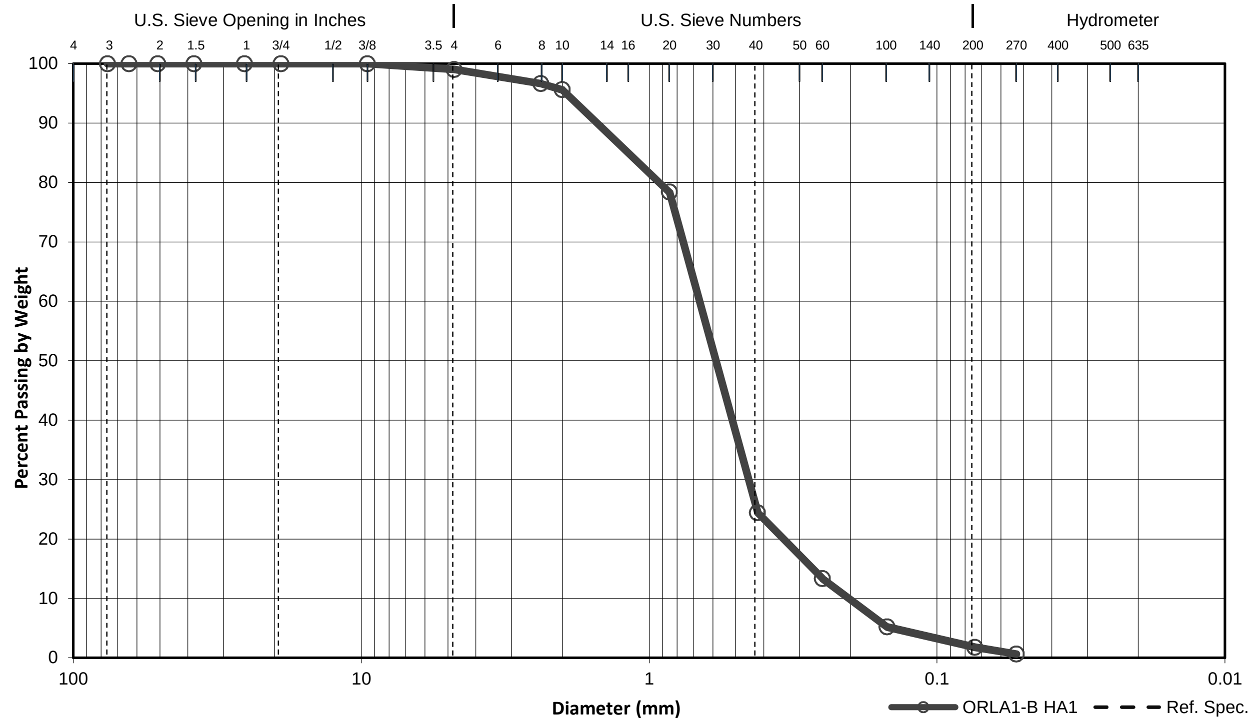
GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

Project Name	Project Number	Date Sampled	Date Tested	Tested By
BHPS	**KH150387A**	**7/26/2016**	**9/1/2016**	**MS**
Sample Source	Sample No.	Depth (ft)	Soil Description	
Onsite	**ORLA1-B HA1**	**0.4-0.8**	**SAND, trace silt, trace gravel (SP)**	
Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification	
276.2	**0**	**0.202**	**Bioretention soil mix: burned sample**	



Cobb.	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4		0.0	100.0		
3/4	19		0.0	100.0		
3/8	9.51		0.0	100.0		
#4	4.76	2.7	1.0	99.0		
#8	2.38	9.2	3.3	96.7		
#10	2	12.1	4.4	95.6		
#20	0.85	59.7	21.6	78.4		
#40	0.42	208.8	75.6	24.4		
#60	0.25	239.3	86.6	13.4		
#100	0.149	261.9	94.8	5.2		
#200	0.074	271.3	98.2	1.8		
#270	0.053	274.5	99.4	0.6		

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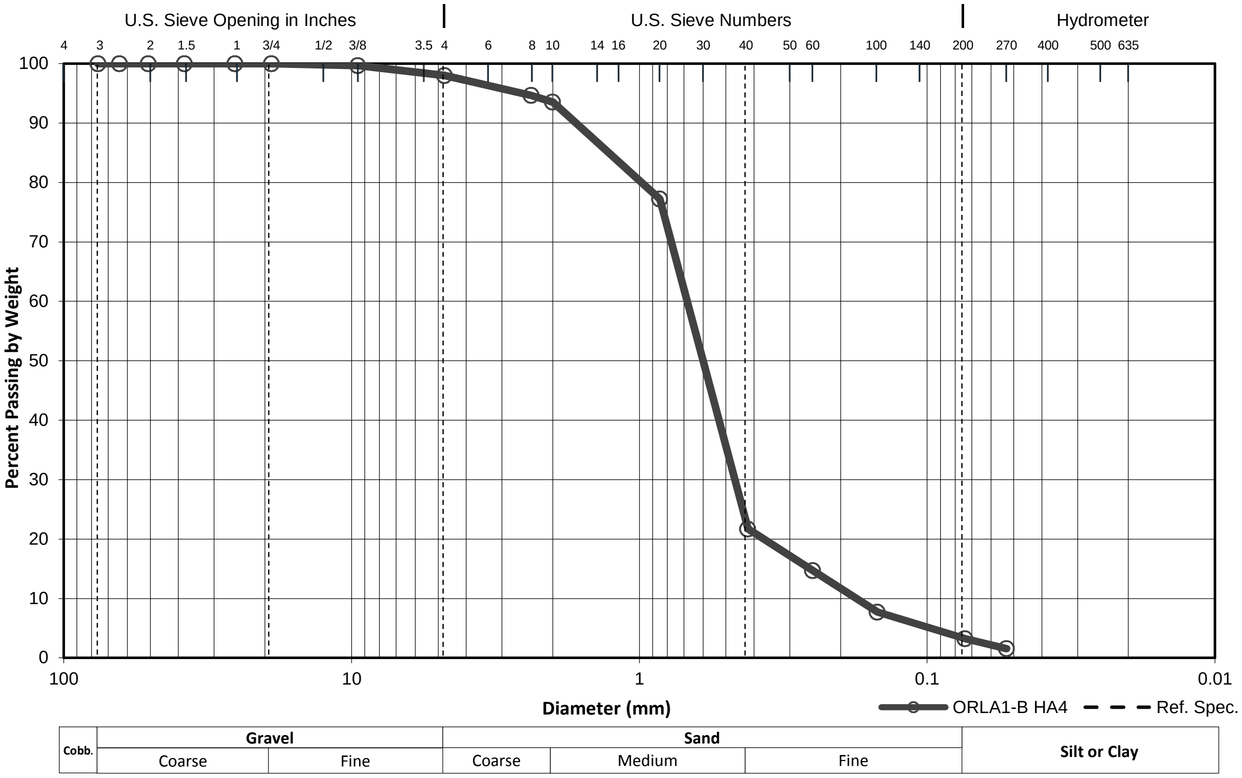
GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

Project Name	Project Number	Date Sampled	Date Tested	Tested By
BHPS	**KH150387A**	**8/25/2016**	**9/1/2016**	**MS**
Sample Source	Sample No.	Depth (ft)	Soil Description	
Onsite	**ORLA1-B HA4**	**0-0.5**	**SAND, trace silt, trace gravel (SP)**	
Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification	
595.4	**0**	**0.176**	**Bioretention soil mix: burned sample**	



Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4		0.0	100.0		
3/4	19		0.0	100.0		
3/8	9.51	2.0	0.3	99.7		
#4	4.76	11.9	2.0	98.0		
#8	2.38	31.7	5.3	94.7		
#10	2	38.4	6.5	93.5		
#20	0.85	135.7	22.8	77.2		
#40	0.42	466.2	78.3	21.7		
#60	0.25	507.8	85.3	14.7		
#100	0.149	549.4	92.3	7.7		
#200	0.074	576.0	96.8	3.2		
#270	0.053	586.0	98.4	1.6		

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Moisture, Ash, and Organic Matter of Peat and Other Organic Soils - ASTM 2974

Date Sampled 8/25/2016	**Project** BHPS	**Project No.** KH150387A		**Soil Description**
Tested By MS	**Location** ORLA2-B	**EB/EP No.** ORLA2-B	**Depth**	Bioretention soil mix

Moisture Content	**ORLA2-B**
Sample ID	**CA HA1 0.6-0.9**
Wet Weight + Pan	**905.09**
Dry Weight + Pan	**818.24**
Weight of Pan	**272.57**
Weight of Moisture	**86.85**
Dry Weight of Soil	**545.67**
% Moisture	**15.9**

Organic Matter and Ash Content

Dry Soil Befor Burn + Pan	**894.21**
Dry Soil After Burn + Pan	**872.54**
Weight of Pan	**348.71**
Wt. Loss Due to Ignition	**21.67**
Actual Wt. Of Soil After Burr	**523.83**
% Organics	**4.0**

Moisture Content	**ORLA2-B**
Sample ID	**HA2 0.1-0.7**
Wet Weight + Pan	**968.78**
Dry Weight + Pan	**916.30**
Weight of Pan	**299.12**
Weight of Moisture	**52.48**
Dry Weight of Soil	**617.18**
% Moisture	**8.5**

Organic Matter and Ash Content

Dry Soil Befor Burn + Pan	**975.14**
Dry Soil After Burn + Pan	**956.17**
Weight of Pan	**358.16**
Wt. Loss Due to Ignition	**18.97**
Actual Wt. Of Soil After Burr	**598.01**
% Organics	**3.1**

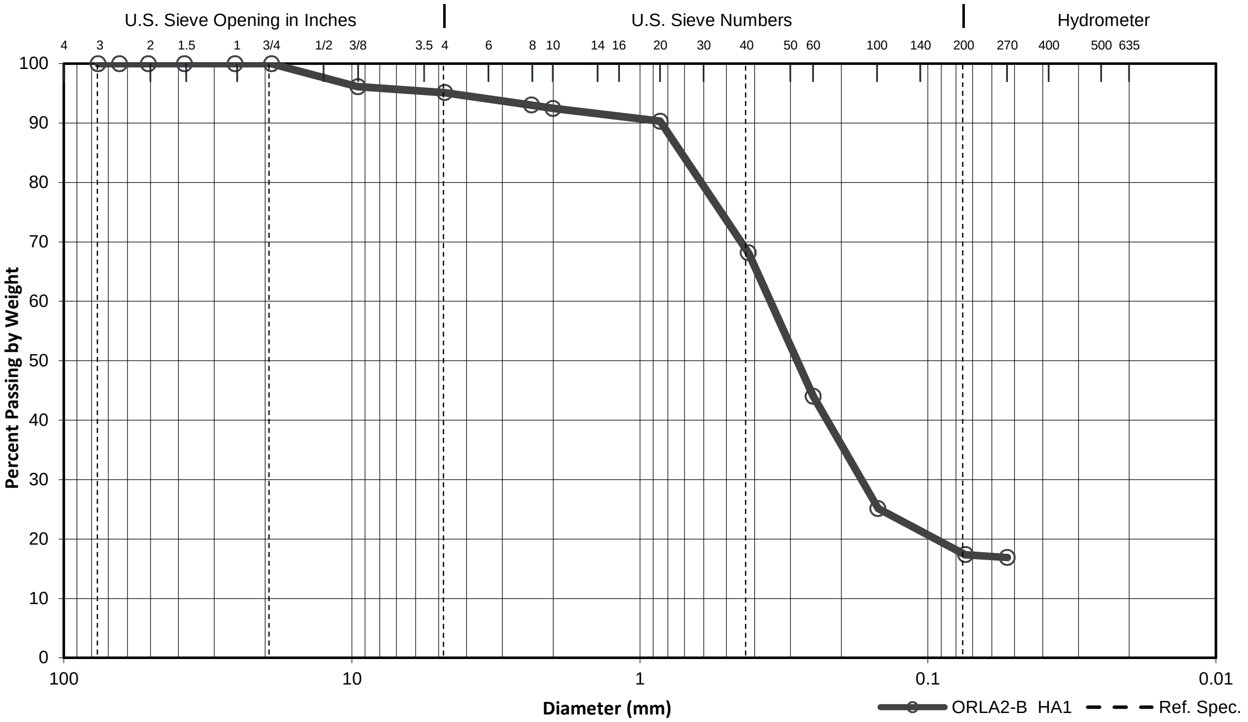
Moisture Content	**ORLA2-B**
Sample ID	**HA3 0.7-1.1**
Wet Weight + Pan	**890.82**
Dry Weight + Pan	**838.41**
Weight of Pan	**292.12**
Weight of Moisture	**52.41**
Dry Weight of Soil	**546.29**
% Moisture	**9.6**

Organic Matter and Ash Content

Dry Soil Befor Burn + Pan	**938.33**
Dry Soil After Burn + Pan	**907.62**
Weight of Pan	**392.18**
Wt. Loss Due to Ignition	**30.71**
Actual Wt. Of Soil After Burr	**515.44**
% Organics	**5.6**

GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

Project Name	Project Number	Date Sampled	Date Tested	Tested By
BHPS	**KH150387A**	**8/25/2016**	**9/15/2016**	**GS**
Sample Source	Sample No.	Depth (ft)	Soil Description	
Onsite	**ORLA2-B HA1**	**2.5-2.9**	**silty SAND, trace gravel (SM)**	
Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification	
448.3	**13**	**<0.01**	**Not applicable: native material**	

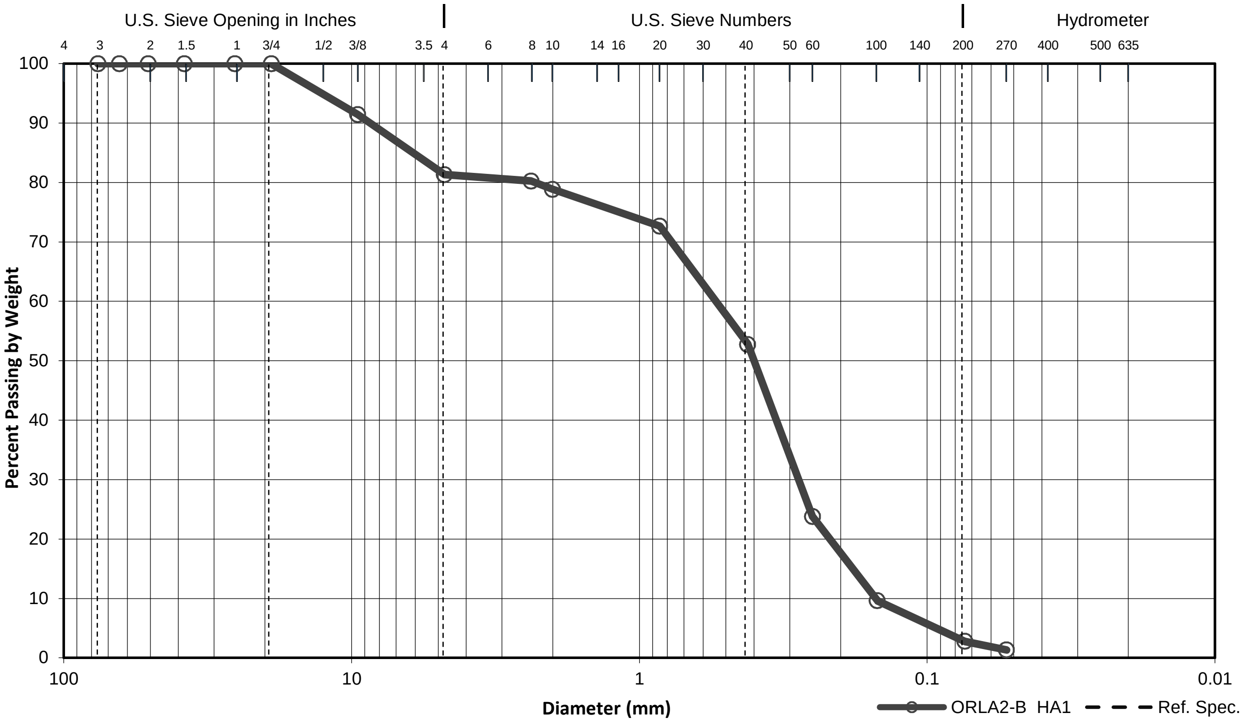


Cobb.	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4		0.0	100.0		
3/4	19		0.0	100.0		
3/8	9.51	17.5	3.9	96.1		
#4	4.76	21.8	4.9	95.1		
#8	2.38	31.3	7.0	93.0		
#10	2	33.8	7.5	92.5		
#20	0.85	43.5	9.7	90.3		
#40	0.42	142.7	31.8	68.2		
#60	0.25	250.9	56.0	44.0		
#100	0.149	335.6	74.9	25.1		
#200	0.074	370.4	82.6	17.4		
#270	0.053	372.5	83.1	16.9		

GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

Project Name	Project Number	Date Sampled	Date Tested	Tested By
BHPS	**KH150387A**	**8/25/2016**	**9/15/2016**	**GS**
Sample Source	Sample No.	Depth (ft)	Soil Description	
Onsite	**ORLA2-B HA1**	**0.6-0.9**	**gravelly SAND, trace silt (SP)**	
Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification	
523.7	**0**	**0.151**	**Bioretention soil mix: burned sample**	



Cobb.	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4		0.0	100.0		
3/4	19		0.0	100.0		
3/8	9.51	44.8	8.5	91.5		
#4	4.76	97.7	18.7	81.3		
#8	2.38	103.5	19.8	80.2		
#10	2	110.8	21.2	78.8		
#20	0.85	143.1	27.3	72.7		
#40	0.42	247.5	47.3	52.7		
#60	0.25	399.3	76.2	23.8		
#100	0.149	473.3	90.4	9.6		
#200	0.074	509.1	97.2	2.8		
#270	0.053	516.8	98.7	1.3		

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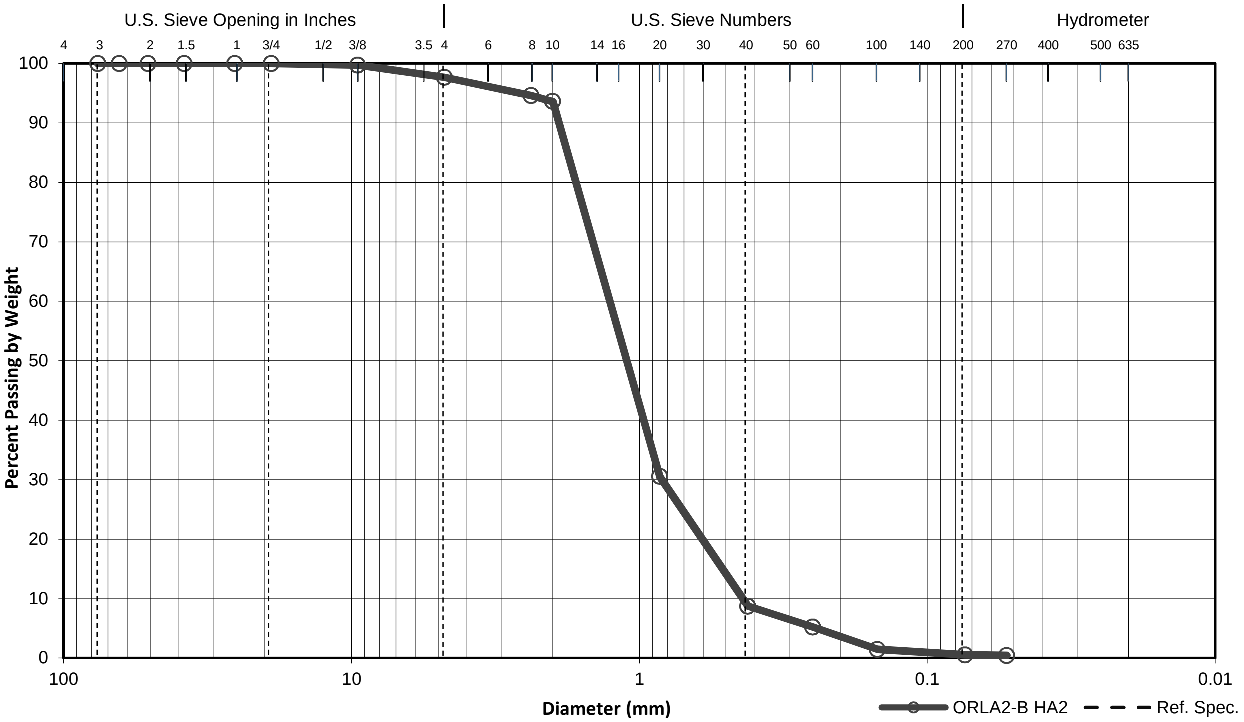
GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

Project Name	Project Number	Date Sampled	Date Tested	Tested By
BHPS	**KH150387A**	**8/25/2016**	**9/15/2016**	

Sample Source	Sample No.	Depth (ft)	Soil Description
Onsite	**ORLA2-B HA2**	**0.1-0.7**	**SAND, trace silt, trace gravel (SP)**

Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification
515.5	**0**	**0.437**	**Bioretention soil mix: burned sample**



Cobb.	**Gravel**		**Sand**			**Silt or Clay**
	Coarse	Fine	Coarse	Medium	Fine	

Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4		0.0	100.0		
3/4	19		0.0	100.0		
3/8	9.51	1.4	0.3	99.7		
#4	4.76	12.0	2.3	97.7		
#8	2.38	27.8	5.4	94.6		
#10	2	32.9	6.4	93.6		
#20	0.85	358.0	69.4	30.6		
#40	0.42	470.6	91.3	8.7		
#60	0.25	488.5	94.8	5.2		
#100	0.149	507.9	98.5	1.5		
#200	0.074	512.7	99.5	0.5		
#270	0.053	513.2	99.6	0.4		

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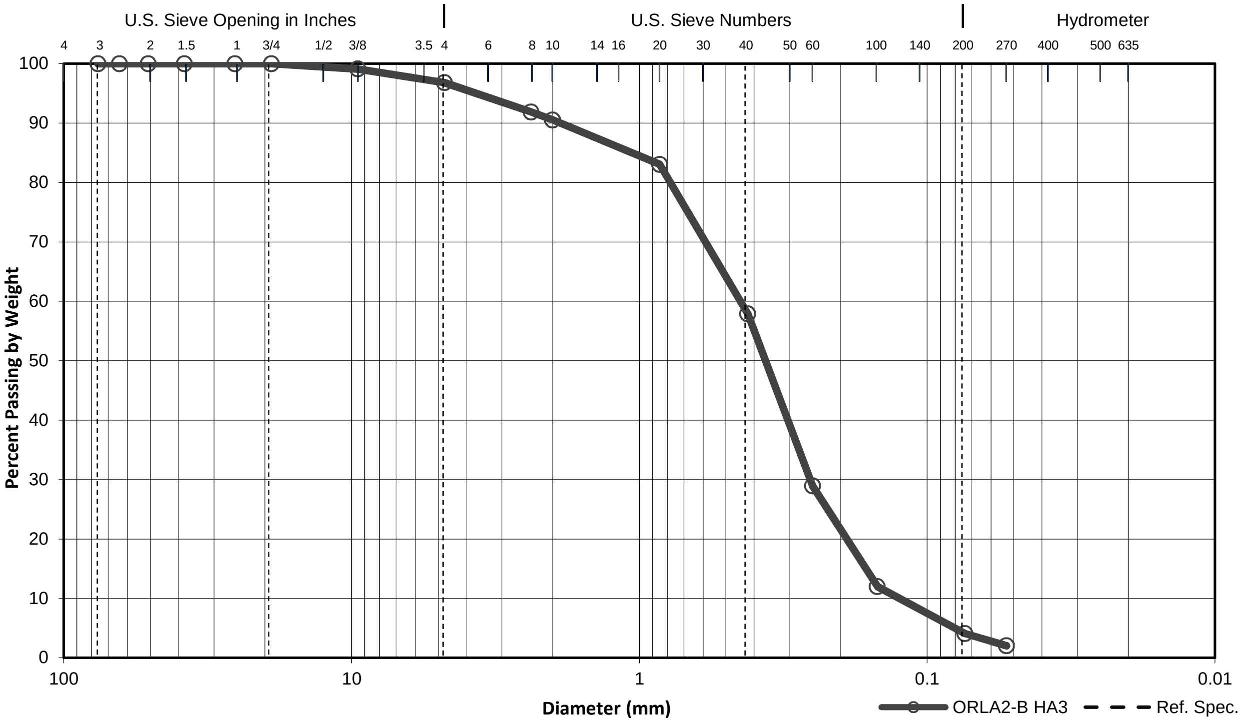
GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

Project Name	Project Number	Date Sampled	Date Tested	Tested By
BHPS	**KH150387A**	**8/25/2016**	**9/15/2016**	**GS**
Sample Source	Sample No.	Depth (ft)	Soil Description	
Onsite	**ORLA2-B HA3**	**0.7-1.1**	**SAND, trace silt, trace gravel (SP)**	
Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification	
598.0	**0**	**0.124**	**Bioretention soil mix: burned sample**	

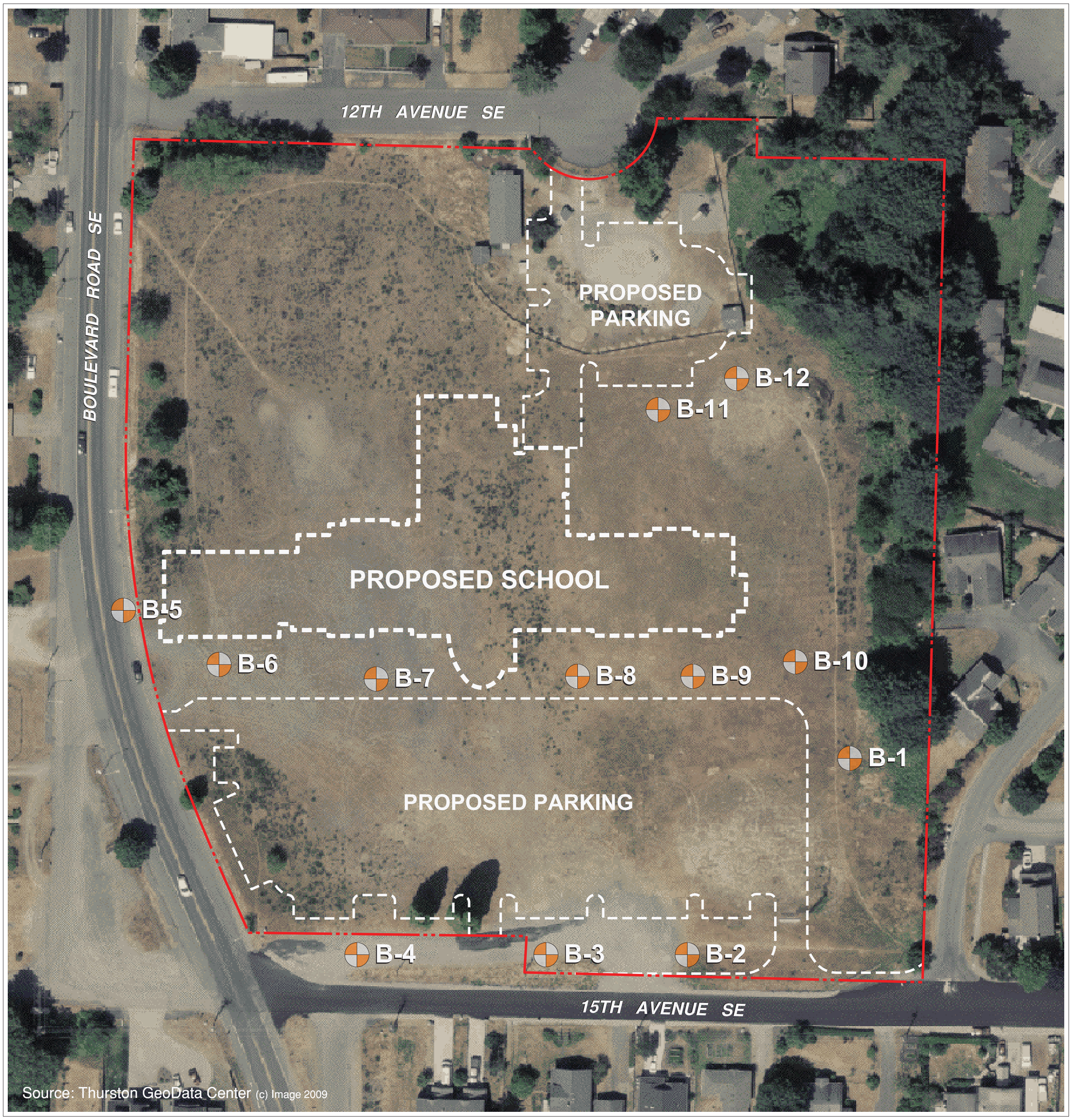


Cobb.	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt. Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4		0.0	100.0		
3/4	19		0.0	100.0		
3/8	9.51	5.3	0.9	99.1		
#4	4.76	19.1	3.2	96.8		
#8	2.38	48.6	8.1	91.9		
#10	2	56.6	9.5	90.5		
#20	0.85	101.4	17.0	83.0		
#40	0.42	251.8	42.1	57.9		
#60	0.25	424.8	71.0	29.0		
#100	0.149	526.1	88.0	12.0		
#200	0.074	573.5	95.9	4.1		
#270	0.053	585.8	98.0	2.0		

APPENDIX C

Background Soil, Geology, and Ground Water Data (Regional Maps, Previous Studies Exploration Logs and Laboratory Testing Data)



Source: Thurston GeoData Center (c) Image 2009

LEGEND:

B-1 APPROXIMATE BORING LOCATION

-·-·- APPROXIMATE PROJECT BOUNDARY

0 30 60 120

SCALE: 1" = 120'

OSD ORLA FACILITY

OLYMPIA, WASHINGTON

INSIGHT GEOLOGIC, INC.

Figure 2
Site Plan

ATTACHMENT A

EXPLORATION LOGS

B-1

DEPTH (FEET)	SAMPLE NUMBER AND DEPTH	INCHES DRIVEN/ RECOVERED	U.S.G.S.	LITHOLOGY	SOIL DESCRIPTION	REMARKS AND LABORATORY TEST RESULTS
0	1	48/19	SM		Orange brown silty fine to medium sand, loose, moist	Groundwater not encountered
1						
2						
3						
4	2	48/30			Brown fine to medium sand with trace silt, loose, moist	
5			SP			
6						
7						
8	3	48/36			Light brown silty fine sand, loose, moist	
9			SM			
10					Brown fine to medium sand with silt, loose, moist	MC:9%
11						
12	4	48/40	SP-SM			
13						
14						
15						
16						

LEGEND:

PROJECT: OSD ORLA FACILITY
PROJECT NO.: 566-001-03
DATE: JANUARY 12, 2013
TOTAL DEPTH: 16 FEET

DRILLING CONTRACTOR: HOLOCENE DRILLING
DRILLING EQUIPMENT: AMS POWER PROBE 9500
DRILLING METHOD: DIRECT PUSH
LOGGED BY: KEVIN VANDEHEY

OSD ORLA FACILITY

OLMYPIA, WASHINGTON

INSIGHT GEOLOGIC, INC.

Exploration Log B-1

B-2

DEPTH (FEET)	SAMPLE NUMBER AND DEPTH	INCHES DRIVEN/ RECOVERED	U.S.G.S.	LITHOLOGY	SOIL DESCRIPTION	REMARKS AND LABORATORY TEST RESULTS
0	1	48/37	SM		Brown silty fine to medium sand, loose, moist	Groundwater not encountered
1						
2						
3			SP		Brown fine to medium sand with trace silt and occasional fine gravel, loose, moist	MC:9%
4	2	48/37				
5						
6						
7						
8	3	48/43				
9						
10						
11						
12	4	48/38				
13						
14						
15						
16						

LEGEND:

PROJECT: OSD ORLA FACILITY
PROJECT NO.: 566-001-03
DATE: JANUARY 12, 2013
TOTAL DEPTH: 16 FEET

DRILLING CONTRACTOR: HOLOCENE DRILLING
DRILLING EQUIPMENT: AMS POWER PROBE 9500
DRILLING METHOD: DIRECT PUSH
LOGGED BY: KEVIN VANDEHEY

OSD ORLA FACILITY

OLMYPIA, WASHINGTON

INSIGHT GEOLOGIC, INC.

Exploration Log B-2

B-3

DEPTH (FEET)	SAMPLE NUMBER AND DEPTH	INCHES DRIVEN/ RECOVERED	U.S.G.S.	LITHOLOGY	SOIL DESCRIPTION	REMARKS AND LABORATORY TEST RESULTS
0	1	48/37	SM		Brown silty fine to medium sand, loose, moist	Groundwater not encountered
1						
2			SP		Brown fine to medium sand with trace silt and occasional fine gravel, loose, moist	MC:5%
3						
4	2	48/37				
5						
6						
7						
8	3	48/43				
9						
10						
11						
12	4	48/38				MC:8%
13						
14						
15						
16						

LEGEND:

PROJECT: OSD ORLA FACILITY
PROJECT NO.: 566-001-03
DATE: JANUARY 12, 2013
TOTAL DEPTH: 16 FEET

DRILLING CONTRACTOR: HOLOCENE DRILLING
DRILLING EQUIPMENT: AMS POWER PROBE 9500
DRILLING METHOD: DIRECT PUSH
LOGGED BY: KEVIN VANDEHEY

OSD ORLA FACILITY
OLMYPIA, WASHINGTON

INSIGHT GEOLOGIC, INC.

Exploration Log B-3

B-4

DEPTH (FEET)	SAMPLE NUMBER AND DEPTH	INCHES DRIVEN/ RECOVERED	U.S.G.S.	LITHOLOGY	SOIL DESCRIPTION	REMARKS AND LABORATORY TEST RESULTS
0	1	48/31	GP		6 Inches of black crushed rock	Groundwater not encountered
1					Brown fine to medium sand with trace silt, loose, moist	
2						MC:12%
3						
4	2	48/41			Grades to include occasional fine to medium gravel	MC:7%
5						
6						
7						
8	3	48/40	SP			
9						
10						
11						
12	4	48/44				MC:12%
13						
14						
15						
16						

LEGEND:

PROJECT: OSD ORLA FACILITY
PROJECT NO.: 566-001-03
DATE: JANUARY 12, 2013
TOTAL DEPTH: 16 FEET

DRILLING CONTRACTOR: HOLOCENE DRILLING
DRILLING EQUIPMENT: AMS POWER PROBE 9500
DRILLING METHOD: DIRECT PUSH
LOGGED BY: KEVIN VANDEHEY

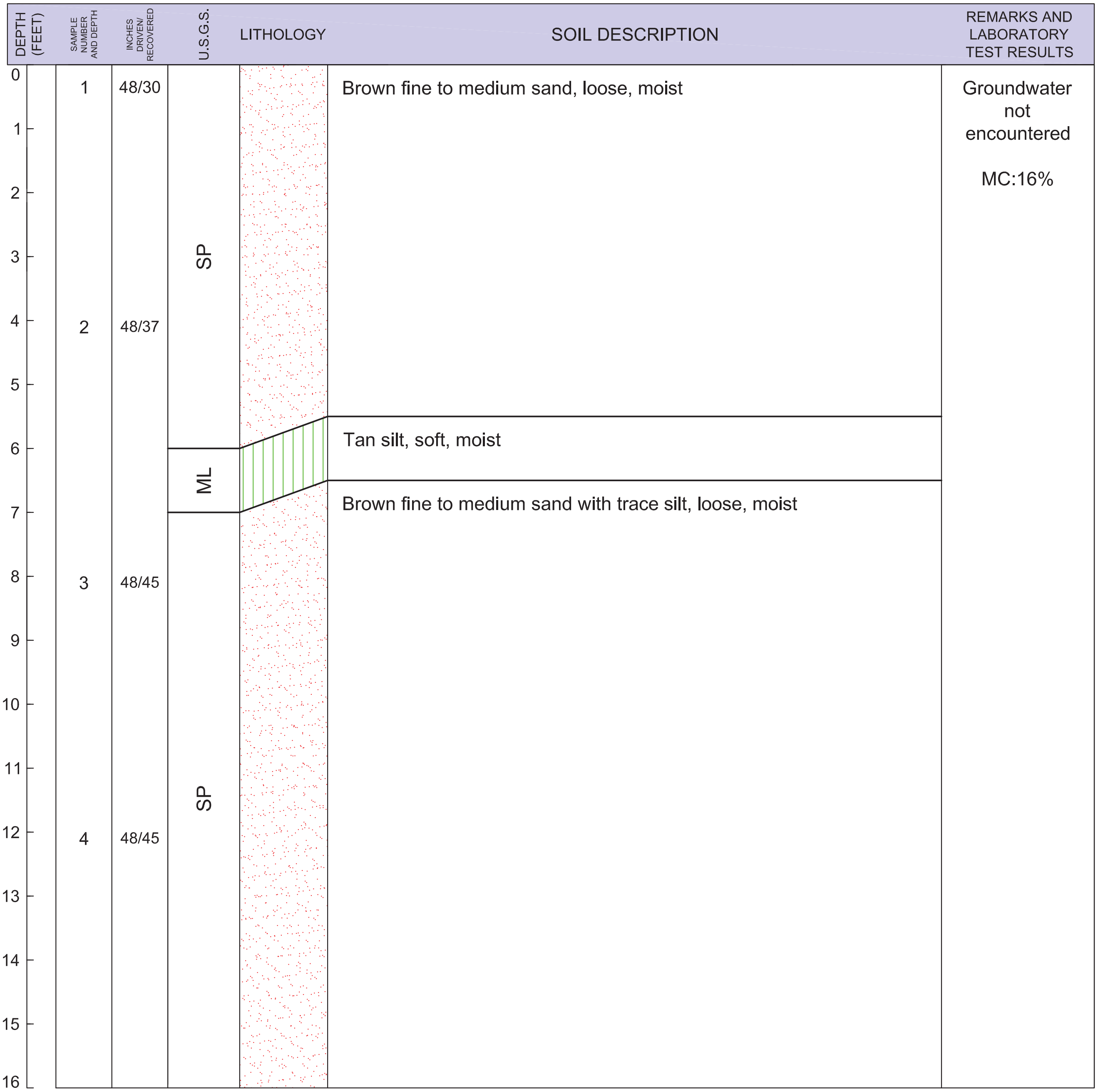
OSD ORLA FACILITY

OLMYPIA, WASHINGTON

INSIGHT GEOLOGIC, INC.

Exploration Log B-4

B-5



DEPTH (FEET)	SAMPLE NUMBER AND DEPTH	INCHES DRIVEN/ RECOVERED	U.S.G.S.	LITHOLOGY	SOIL DESCRIPTION	REMARKS AND LABORATORY TEST RESULTS
0	1	48/30	SP		Brown fine to medium sand, loose, moist	Groundwater not encountered MC:16%
4	2	48/37				
6			ML		Tan silt, soft, moist	
7			SP		Brown fine to medium sand with trace silt, loose, moist	
8	3	48/45				
12	4	48/45				
16						

LEGEND:

PROJECT: OSD ORLA FACILITY
PROJECT NO.: 566-001-03
DATE: JANUARY 12, 2013
TOTAL DEPTH: 16 FEET

DRILLING CONTRACTOR: HOLOCENE DRILLING
DRILLING EQUIPMENT: AMS POWER PROBE 9500
DRILLING METHOD: DIRECT PUSH
LOGGED BY: KEVIN VANDEHEY

OSD ORLA FACILITY

OLMYPIA, WASHINGTON

INSIGHT GEOLOGIC, INC.

Exploration Log B-5

B-6

DEPTH (FEET)	SAMPLE NUMBER AND DEPTH	INCHES DRIVEN/ RECOVERED	U.S.G.S.	LITHOLOGY	SOIL DESCRIPTION	REMARKS AND LABORATORY TEST RESULTS
0	1	48/38			Orange brown fine to medium sand with silt, loose, moist	Groundwater not encountered
1						
2					Grades brown	MC:12%
3						
4	2	48/43				
5						
6						
7						
8	3	48/43	SP-SM			
9						
10						
11						
12	4	48/43				
13						
14						
15						
16						

LEGEND:

PROJECT: OSD ORLA FACILITY
PROJECT NO.: 566-001-03
DATE: JANUARY 12, 2013
TOTAL DEPTH: 16 FEET

DRILLING CONTRACTOR: HOLOCENE DRILLING
DRILLING EQUIPMENT: AMS POWER PROBE 9500
DRILLING METHOD: DIRECT PUSH
LOGGED BY: KEVIN VANDEHEY

OSD ORLA FACILITY
OLMYPIA, WASHINGTON

INSIGHT GEOLOGIC, INC.

Exploration Log B-6

B-7

DEPTH (FEET)	SAMPLE NUMBER AND DEPTH	INCHES DRIVEN/ RECOVERED	U.S.G.S.	LITHOLOGY	SOIL DESCRIPTION	REMARKS AND LABORATORY TEST RESULTS
0	1	48/32			Brown fine to medium sand with trace silt, loose, moist	Groundwater not encountered
1						
2						MC:11%
3					Grades to include occasional fine gravel	
4	2	48/39				
5						
6						
7						
8	3	48/40	SP			
9						
10						
11						
12	4	48/38				
13						
14						
15						
16						

LEGEND:

PROJECT: OSD ORLA FACILITY
PROJECT NO.: 566-001-03
DATE: JANUARY 12, 2013
TOTAL DEPTH: 16 FEET

DRILLING CONTRACTOR: HOLOCENE DRILLING
DRILLING EQUIPMENT: AMS POWER PROBE 9500
DRILLING METHOD: DIRECT PUSH
LOGGED BY: KEVIN VANDEHEY

OSD ORLA FACILITY

OLMYPIA, WASHINGTON

INSIGHT GEOLOGIC, INC.

Exploration Log B-7

B-8

DEPTH (FEET)	SAMPLE NUMBER AND DEPTH	INCHES DRIVEN/ RECOVERED	U.S.G.S.	LITHOLOGY	SOIL DESCRIPTION	REMARKS AND LABORATORY TEST RESULTS
0	1	48/38	SP-SM		Brown fine to medium sand with silt, loose, moist	Groundwater not encountered
1						
2			SP		Brown fine to medium sand with trace silt, loose, moist	
3						
4	2	48/45				
5						
6						
7						
8	3	48/45				
9						
10						
11						
12	4	48/44			Grades to fine to coarse sand with trace silt and fine gravel	MC:5%
13						
14						
15						
16						

LEGEND:

PROJECT: OSD ORLA FACILITY
PROJECT NO.: 566-001-03
DATE: JANUARY 12, 2013
TOTAL DEPTH: 16 FEET

DRILLING CONTRACTOR: HOLOCENE DRILLING
DRILLING EQUIPMENT: AMS POWER PROBE 9500
DRILLING METHOD: DIRECT PUSH
LOGGED BY: KEVIN VANDEHEY

OSD ORLA FACILITY

OLMYPIA, WASHINGTON

INSIGHT GEOLOGIC, INC.

Exploration Log B-8

B-9

DEPTH (FEET)	SAMPLE NUMBER AND DEPTH	INCHES DRIVEN/ RECOVERED	U.S.G.S.	LITHOLOGY	SOIL DESCRIPTION	REMARKS AND LABORATORY TEST RESULTS
0	1	48/36	SP-SM		Brown fine to medium sand with silt, loose, moist	Groundwater not encountered
1						
2			SP		Brown fine to medium sand with trace silt and occasional fine gravel, loose, moist	
3						
4	2	48/38				
5						
6						
7						
8	3	48/39				
9						
10						
11						
12	4	48/39				
13						
14						
15						
16						

LEGEND:

PROJECT: OSD ORLA FACILITY
PROJECT NO.: 566-001-03
DATE: JANUARY 12, 2013
TOTAL DEPTH: 16 FEET

DRILLING CONTRACTOR: HOLOCENE DRILLING
DRILLING EQUIPMENT: AMS POWER PROBE 9500
DRILLING METHOD: DIRECT PUSH
LOGGED BY: KEVIN VANDEHEY

OSD ORLA FACILITY

OLMYPIA, WASHINGTON

INSIGHT GEOLOGIC, INC.

Exploration Log B-9

B-10

DEPTH (FEET)	SAMPLE NUMBER AND DEPTH	INCHES DRIVEN/ RECOVERED	U.S.G.S.	LITHOLOGY	SOIL DESCRIPTION	REMARKS AND LABORATORY TEST RESULTS
0	1	48/31	SP-SM		Brown fine to medium sand with silt, loose, moist	Groundwater not encountered
1						
2						MC:12%
3						
4	2	48/40	SP		Brown fine to coarse sand with trace silt and occasional fine gravel, loose, moist	MC:7%
5						
6						
7						
8	3	48/41				
9						
10						
11						
12	4	48/41				
13						
14						
15						
16						

LEGEND:

PROJECT: OSD ORLA FACILITY
PROJECT NO.: 566-001-03
DATE: JANUARY 12, 2013
TOTAL DEPTH: 16 FEET

DRILLING CONTRACTOR: HOLOCENE DRILLING
DRILLING EQUIPMENT: AMS POWER PROBE 9500
DRILLING METHOD: DIRECT PUSH
LOGGED BY: KEVIN VANDEHEY

OSD ORLA FACILITY

OLMYPIA, WASHINGTON

INSIGHT GEOLOGIC, INC.

Exploration Log B-10

B-11

DEPTH (FEET)	SAMPLE NUMBER AND DEPTH	INCHES DRIVEN/ RECOVERED	U.S.G.S.	LITHOLOGY	SOIL DESCRIPTION	REMARKS AND LABORATORY TEST RESULTS
0	1	48/40	SP-SM		Brown fine to medium sand with silt, loose, moist	Groundwater not encountered
1					Brown fine to coarse sand with trace silt and occasional fine gravel, loose, moist	MC:7%
2						
3						
4	2	48/42				
5						
6						
7						
8	3	48/41	SP			
9						
10						
11						
12	4	48/33				
13						
14						
15						
16						

LEGEND:

PROJECT: OSD ORLA FACILITY
PROJECT NO.: 566-001-03
DATE: JANUARY 12, 2013
TOTAL DEPTH: 16 FEET

DRILLING CONTRACTOR: HOLOCENE DRILLING
DRILLING EQUIPMENT: AMS POWER PROBE 9500
DRILLING METHOD: DIRECT PUSH
LOGGED BY: KEVIN VANDEHEY

OSD ORLA FACILITY

OLMYPIA, WASHINGTON

INSIGHT GEOLOGIC, INC.

Exploration Log B-11

B-12

DEPTH (FEET)	SAMPLE NUMBER AND DEPTH	INCHES DRIVEN/ RECOVERED	U.S.G.S.	LITHOLOGY	SOIL DESCRIPTION	REMARKS AND LABORATORY TEST RESULTS
0	1	48/27	SP-SM		Brown fine to medium sand with silt, loose, moist	Groundwater not encountered
1					Brown fine to coarse sand with trace silt and occasional fine gravel, loose, moist	
2						
3						
4	2	48/27				
5						
6						
7						
8	3	48/42	SP			
9						
10						
11						
12	4	48/30				MC:7%
13						
14						
15						
16						

LEGEND:

PROJECT: OSD ORLA FACILITY
PROJECT NO.: 566-001-03
DATE: JANUARY 12, 2013
TOTAL DEPTH: 16 FEET

DRILLING CONTRACTOR: HOLOCENE DRILLING
DRILLING EQUIPMENT: AMS POWER PROBE 9500
DRILLING METHOD: DIRECT PUSH
LOGGED BY: KEVIN VANDEHEY

OSD ORLA FACILITY

OLMYPIA, WASHINGTON

INSIGHT GEOLOGIC, INC.

Exploration Log B-12

ATTACHMENT B

LABORATORY TEST RESULTS

Gradation Analysis Summary Data

Job Name: OSD ORLA Facility
Job Number: 566-001-03
Date Tested: 1/17/13
Tested By: Kevin Vandehey

Sample Name: B-1 10'-16'
Sample #: B-1 10'-16'
Depth: 10'-16'

Moisture Content (%) 8.7%
Organic Content (%) N/A ASTM Method D 2974 - 87

Sieve Size	Percent Passing
3.0 in. (75.0)	100.0
1.5 in. (37.5)	100.0
3/4 in. (19.0)	100.0
3/8 in. (9.5-mm)	100.0
No. 4 (4.75-mm)	99.8
No. 10 (2.00-mm)	99.7
No. 20 (.850-mm)	99.5
No. 40 (.425-mm)	96.8
No. 60 (.250-mm)	53.0
No. 100 (.150-mm)	22.8
No. 200 (.075-mm)	6.4

Size Fraction	Percent by Weight
Coarse Gravel	0.0
Fine Gravel	0.2
Coarse Sand	0.1
Medium Sand	2.9
Fine Sand	90.4
Fines	6.4
Total	**100.0**

LL	- -
PL	- -
PI	- -
D_{10}	0.089
D_{30}	0.170
D_{60}	0.260
D_{90}	0.390
Cc	1.249
Cu	2.921

ASTM Classification
Group Name: **Poorly-Graded Sand with Silt**
Symbol: **SP-SM**

Insight Geologic, Inc.

Gradation Analysis Summary Data

Job Name: OSD ORLA Facility
Job Number: 566-001-03
Date Tested: 1/17/13
Tested By: Kevin Vandehey

Sample Name: B-2 3'-12'
Sample #: B-2 3'-12'
Depth: 3'-12'

Moisture Content (%) 9.1%
Organic Content (%) N/A ASTM Method D 2974 - 87

Sieve Size	Percent Passing
3.0 in. (75.0)	100.0
1.5 in. (37.5)	100.0
3/4 in. (19.0)	100.0
3/8 in. (9.5-mm)	100.0
No. 4 (4.75-mm)	98.7
No. 10 (2.00-mm)	97.9
No. 20 (.850-mm)	96.7
No. 40 (.425-mm)	91.8
No. 60 (.250-mm)	53.6
No. 100 (.150-mm)	14.0
No. 200 (.075-mm)	3.0

Size Fraction	Percent by Weight
Coarse Gravel	0.0
Fine Gravel	1.3
Coarse Sand	0.8
Medium Sand	6.1
Fine Sand	88.7
Fines	3.0
Total	**100.0**

LL - -
PL - -
PI - -

D_{10} 0.130
D_{30} 0.190
D_{60} 0.270
D_{90} 0.420

Cc 1.028
Cu 2.077

ASTM Classification
Group Name: **Poorly-Graded Sand**
Symbol: **SP**

Gradation Analysis Summary Data

Job Name: OSD ORLA Facility
Job Number: 566-001-03
Date Tested: 1/17/13
Tested By: Kevin Vandehey

Sample Name: B-3 2'-12'
Sample #: B-3 2'-12'
Depth: 2'-12'

Moisture Content (%) 5.0%
Organic Content (%) N/A ASTM Method D 2974 - 87

Sieve Size	**Percent Passing**
3.0 in. (75.0)	100.0
1.5 in. (37.5)	100.0
3/4 in. (19.0)	100.0
3/8 in. (9.5-mm)	98.9
No. 4 (4.75-mm)	96.0
No. 10 (2.00-mm)	92.0
No. 20 (.850-mm)	86.9
No. 40 (.425-mm)	74.2
No. 60 (.250-mm)	34.4
No. 100 (.150-mm)	8.2
No. 200 (.075-mm)	1.8

Size Fraction	**Percent by Weight**
Coarse Gravel	0.0
Fine Gravel	4.0
Coarse Sand	4.1
Medium Sand	17.8
Fine Sand	72.4
Fines	1.8
Total	**100.0**

LL - -
PL - -
PI - -

D_{10} 0.170
D_{30} 0.240
D_{60} 0.370
D_{90} 1.400

Cc 0.916
Cu 2.176

ASTM Classification
Group Name: **Poorly-Graded Sand**
Symbol: **SP**

Gradation Analysis Summary Data

Job Name: OSD ORLA Facility
Job Number: 566-001-03
Date Tested: 1/17/13
Tested By: Kevin Vandehey

Sample Name: B-3 12'-16'
Sample #: B-3 12'-16'
Depth: 12'-16'

Moisture Content (%)	7.7%	
Organic Content (%)	N/A	ASTM Method D 2974 - 87

Sieve Size	Percent Passing
3.0 in. (75.0)	100.0
1.5 in. (37.5)	100.0
3/4 in. (19.0)	95.3
3/8 in. (9.5-mm)	94.6
No. 4 (4.75-mm)	93.9
No. 10 (2.00-mm)	91.7
No. 20 (.850-mm)	85.8
No. 40 (.425-mm)	72.9
No. 60 (.250-mm)	37.9
No. 100 (.150-mm)	10.1
No. 200 (.075-mm)	2.7

Size Fraction	Percent by Weight
Coarse Gravel	4.7
Fine Gravel	1.4
Coarse Sand	2.1
Medium Sand	18.8
Fine Sand	70.2
Fines	2.7
Total	**100.0**

LL	- -
PL	- -
PI	- -
D_{10}	0.160
D_{30}	0.230
D_{60}	0.350
D_{90}	1.500
Cc	0.945
Cu	2.188

ASTM Classification
Group Name: **Poorly-Graded Sand**
Symbol: **SP**

INSIGHT GEOLOGIC, INC.

Gradation Analysis Summary Data

Job Name:	OSD ORLA Facility	**Sample Name:**	B-4 0'-4'
Job Number:	566-001-03	**Sample #:**	B-4 0'-4'
Date Tested:	1/17/13	**Depth:**	0'-4'
Tested By:	Kevin Vandehey		

Moisture Content (%)	11.6%	
Organic Content (%)	N/A	ASTM Method D 2974 - 87

Sieve Size	Percent Passing
3.0 in. (75.0)	100.0
1.5 in. (37.5)	100.0
3/4 in. (19.0)	100.0
3/8 in. (9.5-mm)	99.2
No. 4 (4.75-mm)	99.0
No. 10 (2.00-mm)	97.8
No. 20 (.850-mm)	95.5
No. 40 (.425-mm)	84.3
No. 60 (.250-mm)	38.2
No. 100 (.150-mm)	12.8
No. 200 (.075-mm)	4.3

Size Fraction	Percent by Weight
Coarse Gravel	0.0
Fine Gravel	1.0
Coarse Sand	1.2
Medium Sand	13.5
Fine Sand	79.9
Fines	4.3
Total	**100.0**

LL	- -
PL	- -
PI	- -
D_{10}	0.140
D_{30}	0.210
D_{60}	0.330
D_{90}	0.610
Cc	0.955
Cu	2.357

ASTM Classification
Group Name: **Poorly-Graded Sand**
Symbol: **SP**

INSIGHT GEOLOGIC, INC.

Gradation Analysis Summary Data

Job Name: OSD ORLA Facility
Job Number: 566-001-03
Date Tested: 1/17/13
Tested By: Kevin Vandehey

Sample Name: B-4 4'-12'
Sample #: B-4 4'-12'
Depth: 4'-12'

Moisture Content (%) 6.6%
Organic Content (%) N/A ASTM Method D 2974 - 87

Sieve Size	Percent Passing
3.0 in. (75.0)	100.0
1.5 in. (37.5)	100.0
3/4 in. (19.0)	100.0
3/8 in. (9.5-mm)	95.3
No. 4 (4.75-mm)	94.0
No. 10 (2.00-mm)	93.0
No. 20 (.850-mm)	89.3
No. 40 (.425-mm)	68.9
No. 60 (.250-mm)	21.7
No. 100 (.150-mm)	5.7
No. 200 (.075-mm)	1.7

Size Fraction	Percent by Weight
Coarse Gravel	0.0
Fine Gravel	6.0
Coarse Sand	1.0
Medium Sand	24.1
Fine Sand	67.1
Fines	1.7
Total	**100.0**

LL - -
PL - -
PI - -

D_{10} 0.190
D_{30} 0.280
D_{60} 0.380
D_{90} 0.900

Cc 1.086
Cu 2.000

ASTM Classification
Group Name: **Poorly-Graded Sand**
Symbol: **SP**

Insight Geologic, Inc.

Gradation Analysis Summary Data

Job Name: OSD ORLA Facility
Job Number: 566-001-03
Date Tested: 1/17/13
Tested By: Kevin Vandehey

Sample Name: B-4 12'-16'
Sample #: B-4 12'-16'
Depth: 12'-16'

Moisture Content (%)	7.9%	
Organic Content (%)	N/A	ASTM Method D 2974 - 87

Sieve Size	**Percent Passing**
3.0 in. (75.0)	100.0
1.5 in. (37.5)	100.0
3/4 in. (19.0)	100.0
3/8 in. (9.5-mm)	100.0
No. 4 (4.75-mm)	99.5
No. 10 (2.00-mm)	99.2
No. 20 (.850-mm)	96.2
No. 40 (.425-mm)	70.0
No. 60 (.250-mm)	21.9
No. 100 (.150-mm)	6.1
No. 200 (.075-mm)	2.0

Size Fraction	**Percent by Weight**
Coarse Gravel	0.0
Fine Gravel	0.5
Coarse Sand	0.3
Medium Sand	29.2
Fine Sand	68.0
Fines	2.0
Total	**100.0**

LL - -
PL - -
PI - -

D_{10} 0.190
D_{30} 0.290
D_{60} 0.390
D_{90} 0.670

Cc 1.135
Cu 2.053

ASTM Classification
Group Name: **Poorly-Graded Sand**
Symbol: **SP**

INSIGHT GEOLOGIC, INC.

Gradation Analysis Summary Data

Job Name: OSD ORLA Facility
Job Number: 566-001-03
Date Tested: 1/17/13
Tested By: Kevin Vandehey

Sample Name: B-5 0'-6'
Sample #: B-5 0'-6'
Depth: 0'-6'

Moisture Content (%) 16.1%
Organic Content (%) N/A ASTM Method D 2974 - 87

Sieve Size	Percent Passing
3.0 in. (75.0)	100.0
1.5 in. (37.5)	100.0
3/4 in. (19.0)	100.0
3/8 in. (9.5-mm)	100.0
No. 4 (4.75-mm)	99.5
No. 10 (2.00-mm)	99.0
No. 20 (.850-mm)	98.1
No. 40 (.425-mm)	92.8
No. 60 (.250-mm)	59.6
No. 100 (.150-mm)	39.7
No. 200 (.075-mm)	23.1

Size Fraction	Percent by Weight
Coarse Gravel	0.0
Fine Gravel	0.5
Coarse Sand	0.5
Medium Sand	6.2
Fine Sand	69.6
Fines	23.1
Total	**100.0**

LL - -
PL - -
PI - -

D_{10} 0.000
D_{30} 0.110
D_{60} 0.250
D_{90} 0.400

Cc - -
Cu - -

ASTM Classification
Group Name: **Poorly-Graded Sand**
Symbol: **SP**

INSIGHT GEOLOGIC, INC.

Gradation Analysis Summary Data

Job Name: OSD ORLA Facility
Job Number: 566-001-03
Date Tested: 1/17/13
Tested By: Kevin Vandehey

Sample Name: B-6 0'-2'
Sample #: B-6 0'-2'
Depth: 0'-2'

Moisture Content (%) 12.2%
Organic Content (%) N/A ASTM Method D 2974 - 87

Sieve Size	Percent Passing
3.0 in. (75.0)	100.0
1.5 in. (37.5)	100.0
3/4 in. (19.0)	100.0
3/8 in. (9.5-mm)	98.3
No. 4 (4.75-mm)	97.5
No. 10 (2.00-mm)	96.3
No. 20 (.850-mm)	93.9
No. 40 (.425-mm)	84.3
No. 60 (.250-mm)	36.6
No. 100 (.150-mm)	15.4
No. 200 (.075-mm)	6.4

Size Fraction	Percent by Weight
Coarse Gravel	0.0
Fine Gravel	2.5
Coarse Sand	1.2
Medium Sand	12.0
Fine Sand	77.9
Fines	6.4
Total	**100.0**

LL	- -
PL	- -
PI	- -
D_{10}	0.110
D_{30}	0.240
D_{60}	0.330
D_{90}	0.550
Cc	1.587
Cu	3.000

ASTM Classification
Group Name: **Poorly-Graded Sand with Silt**
Symbol: **SP-SM**

INSIGHT GEOLOGIC, INC.

Gradation Analysis Summary Data

Job Name:	OSD ORLA Facility	**Sample Name:**	B-6 2'-12'
Job Number:	566-001-03	**Sample #:**	B-6 2'-12'
Date Tested:	1/17/13	**Depth:**	2'-12'
Tested By:	Kevin Vandehey		

Moisture Content (%) 11.5%

Organic Content (%) N/A ASTM Method D 2974 - 87

Sieve Size	**Percent Passing**
3.0 in. (75.0)	100.0
1.5 in. (37.5)	100.0
3/4 in. (19.0)	100.0
3/8 in. (9.5-mm)	100.0
No. 4 (4.75-mm)	99.6
No. 10 (2.00-mm)	99.4
No. 20 (.850-mm)	98.8
No. 40 (.425-mm)	94.6
No. 60 (.250-mm)	67.0
No. 100 (.150-mm)	28.4
No. 200 (.075-mm)	7.9

Size Fraction	**Percent by Weight**
Coarse Gravel	0.0
Fine Gravel	0.4
Coarse Sand	0.3
Medium Sand	4.8
Fine Sand	86.7
Fines	7.9
Total	**100.0**

LL - -

PL - -

PI - -

D_{10} 0.081

D_{30} 0.160

D_{60} 0.240

D_{90} 0.380

Cc 1.317

Cu 2.963

ASTM Classification

Group Name: **Poorly-Graded Sand with Silt**

Symbol: **SP-SM**

Gradation Analysis Summary Data

Job Name: OSD ORLA Facility
Job Number: 566-001-03
Date Tested: 1/17/13
Tested By: Kevin Vandehey

Sample Name: B-7 0'-3'
Sample #: B-7 0'-3'
Depth: 0'-3'

Moisture Content (%) 10.5%
Organic Content (%) N/A ASTM Method D 2974 - 87

Sieve Size	Percent Passing
3.0 in. (75.0)	100.0
1.5 in. (37.5)	100.0
3/4 in. (19.0)	100.0
3/8 in. (9.5-mm)	100.0
No. 4 (4.75-mm)	97.8
No. 10 (2.00-mm)	96.6
No. 20 (.850-mm)	95.2
No. 40 (.425-mm)	89.2
No. 60 (.250-mm)	55.6
No. 100 (.150-mm)	20.4
No. 200 (.075-mm)	4.7

Size Fraction	Percent by Weight
Coarse Gravel	0.0
Fine Gravel	2.2
Coarse Sand	1.3
Medium Sand	7.3
Fine Sand	84.5
Fines	4.7
Total	**100.0**

LL - -
PL - -
PI - -

D_{10} 0.100
D_{30} 0.180
D_{60} 0.270
D_{90} 0.440

Cc 1.200
Cu 2.700

ASTM Classification
Group Name: **Poorly-Graded Sand**
Symbol: **SP**

INSIGHT GEOLOGIC, INC.

Gradation Analysis Summary Data

Job Name: OSD ORLA Facility
Job Number: 566-001-03
Date Tested: 1/17/13
Tested By: Kevin Vandehey

Sample Name: B-8 12'-16'
Sample #: B-8 12'-16'
Depth: 12'-16'

Moisture Content (%) 4.7%
Organic Content (%) N/A ASTM Method D 2974 - 87

Sieve Size	Percent Passing
3.0 in. (75.0)	100.0
1.5 in. (37.5)	100.0
3/4 in. (19.0)	96.8
3/8 in. (9.5-mm)	95.0
No. 4 (4.75-mm)	91.4
No. 10 (2.00-mm)	86.5
No. 20 (.850-mm)	77.7
No. 40 (.425-mm)	53.0
No. 60 (.250-mm)	19.9
No. 100 (.150-mm)	6.2
No. 200 (.075-mm)	1.8

Size Fraction	Percent by Weight
Coarse Gravel	3.2
Fine Gravel	5.4
Coarse Sand	4.9
Medium Sand	33.5
Fine Sand	51.2
Fines	1.8
Total	**100.0**

LL - -
PL - -
PI - -

D_{10} 0.190
D_{30} 0.300
D_{60} 0.500
D_{90} 3.500

Cc 0.947
Cu 2.632

ASTM Classification
Group Name: **Poorly-Graded Sand**
Symbol: **SP**

INSIGHT GEOLOGIC, INC.

Gradation Analysis Summary Data

Job Name:	OSD ORLA Facility	**Sample Name:**	B-10 0'-4'
Job Number:	566-001-03	**Sample #:**	B-10 0'-4'
Date Tested:	1/17/13	**Depth:**	0'-4'
Tested By:	Kevin Vandehey		

Moisture Content (%) 12.3%

Organic Content (%) N/A ASTM Method D 2974 - 87

Sieve Size	Percent Passing
3.0 in. (75.0)	100.0
1.5 in. (37.5)	100.0
3/4 in. (19.0)	97.2
3/8 in. (9.5-mm)	94.9
No. 4 (4.75-mm)	93.8
No. 10 (2.00-mm)	92.4
No. 20 (.850-mm)	89.8
No. 40 (.425-mm)	79.5
No. 60 (.250-mm)	42.8
No. 100 (.150-mm)	18.2
No. 200 (.075-mm)	7.8

Size Fraction	Percent by Weight
Coarse Gravel	2.8
Fine Gravel	3.3
Coarse Sand	1.5
Medium Sand	12.9
Fine Sand	71.7
Fines	7.8
Total	**100.0**

LL - -

PL - -

PI - -

D_{10} 0.090

D_{30} 0.190

D_{60} 0.320

D_{90} 0.890

Cc 1.253

Cu 3.556

ASTM Classification

Group Name: **Poorly-Graded Sand with Silt**

Symbol: **SP-SM**

Insight Geologic, Inc.

Gradation Analysis Summary Data

Job Name: OSD ORLA Facility
Job Number: 566-001-03
Date Tested: 1/17/13
Tested By: Kevin Vandehey

Sample Name: B-10 4'-12'
Sample #: B-10 4'-12'
Depth: 4'-12'

Moisture Content (%) 6.9%
Organic Content (%) N/A ASTM Method D 2974 - 87

Sieve Size	Percent Passing
3.0 in. (75.0)	100.0
1.5 in. (37.5)	100.0
3/4 in. (19.0)	98.7
3/8 in. (9.5-mm)	96.1
No. 4 (4.75-mm)	93.5
No. 10 (2.00-mm)	90.4
No. 20 (.850-mm)	84.3
No. 40 (.425-mm)	56.7
No. 60 (.250-mm)	15.4
No. 100 (.150-mm)	4.2
No. 200 (.075-mm)	1.5

Size Fraction	Percent by Weight
Coarse Gravel	1.3
Fine Gravel	5.2
Coarse Sand	3.1
Medium Sand	33.7
Fine Sand	55.2
Fines	1.5
Total	**100.0**

LL - -
PL - -
PI - -

D_{10} 0.220
D_{30} 0.310
D_{60} 0.460
D_{90} 2.000

Cc 0.950
Cu 2.091

ASTM Classification
Group Name: **Poorly-Graded Sand**
Symbol: **SP**

Insight Geologic, Inc.

Gradation Analysis Summary Data

Job Name: OSD ORLA Facility
Job Number: 566-001-03
Date Tested: 1/17/13
Tested By: Kevin Vandehey

Sample Name: B-11 1'-12'
Sample #: B-11 1'-12'
Depth: 1'-12'

Moisture Content (%)	7.4%	
Organic Content (%)	N/A	ASTM Method D 2974 - 87

Sieve Size	Percent Passing
3.0 in. (75.0)	100.0
1.5 in. (37.5)	100.0
3/4 in. (19.0)	100.0
3/8 in. (9.5-mm)	100.0
No. 4 (4.75-mm)	99.7
No. 10 (2.00-mm)	99.1
No. 20 (.850-mm)	97.1
No. 40 (.425-mm)	80.9
No. 60 (.250-mm)	32.1
No. 100 (.150-mm)	9.5
No. 200 (.075-mm)	1.9

Size Fraction	Percent by Weight
Coarse Gravel	0.0
Fine Gravel	0.3
Coarse Sand	0.5
Medium Sand	18.3
Fine Sand	78.9
Fines	1.9
Total	**100.0**

LL	- -
PL	- -
PI	- -
D_{10}	0.170
D_{30}	0.250
D_{60}	0.340
D_{90}	0.550
Cc	1.081
Cu	2.000

ASTM Classification
Group Name: **Poorly-Graded Sand**
Symbol: **SP**

INSIGHT GEOLOGIC, INC.

Gradation Analysis Summary Data

Job Name: OSD ORLA Facility
Job Number: 566-001-03
Date Tested: 1/17/13
Tested By: Kevin Vandehey

Sample Name: B-12 12'-16'
Sample #: B-12 12'-16'
Depth: 12'-16'

Moisture Content (%) 7.2%
Organic Content (%) N/A ASTM Method D 2974 - 87

Sieve Size	Percent Passing
3.0 in. (75.0)	100.0
1.5 in. (37.5)	100.0
3/4 in. (19.0)	100.0
3/8 in. (9.5-mm)	98.2
No. 4 (4.75-mm)	97.1
No. 10 (2.00-mm)	95.9
No. 20 (.850-mm)	91.4
No. 40 (.425-mm)	72.6
No. 60 (.250-mm)	30.1
No. 100 (.150-mm)	8.1
No. 200 (.075-mm)	1.9

Size Fraction	Percent by Weight
Coarse Gravel	0.0
Fine Gravel	2.9
Coarse Sand	1.2
Medium Sand	23.3
Fine Sand	70.7
Fines	1.9
Total	**100.0**

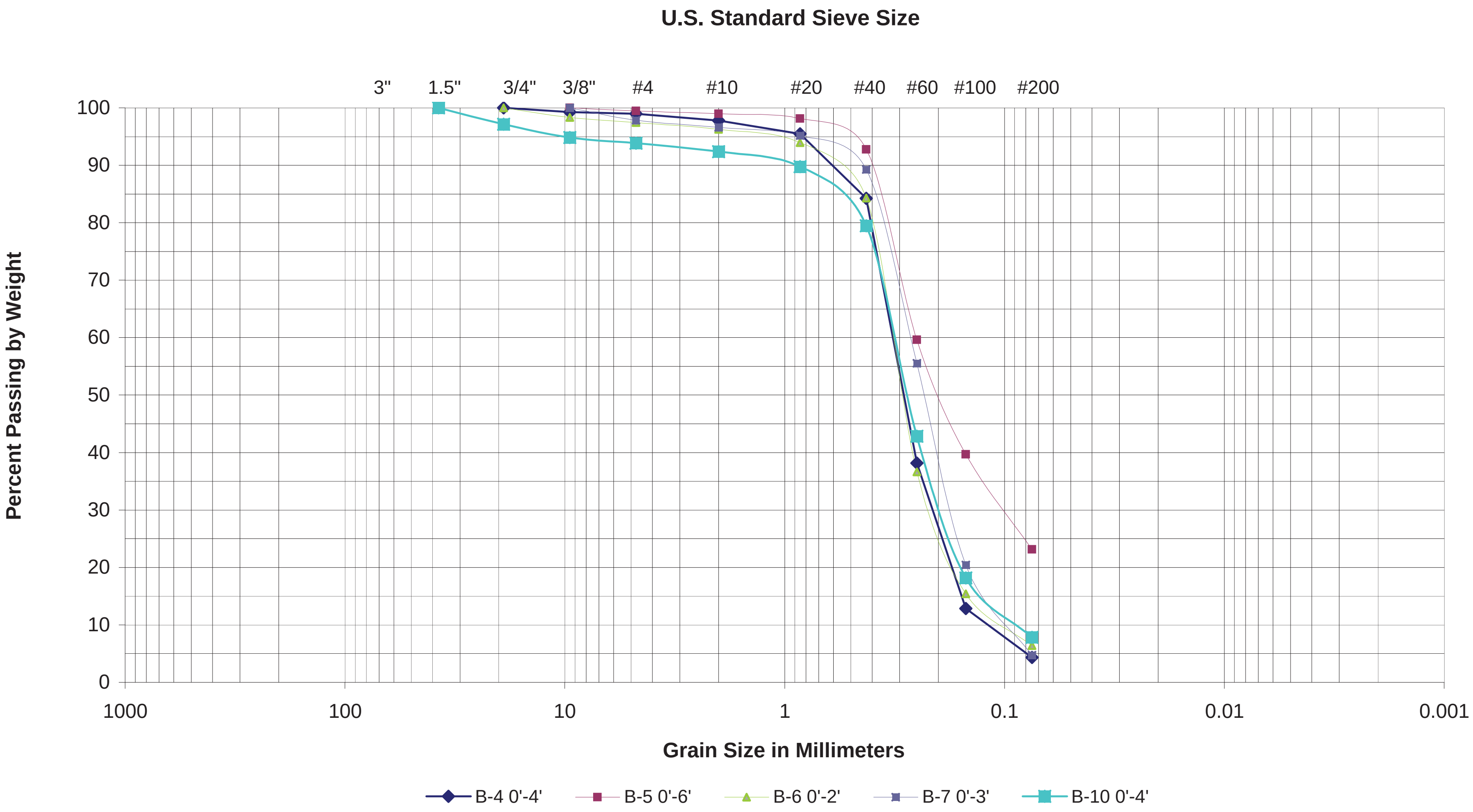
LL - -
PL - -
PI - -

D_{10} 0.160
D_{30} 0.260
D_{60} 0.360
D_{90} 0.790

Cc 1.174
Cu 2.250

ASTM Classification
Group Name: **Poorly-Graded Sand**
Symbol: **SP**

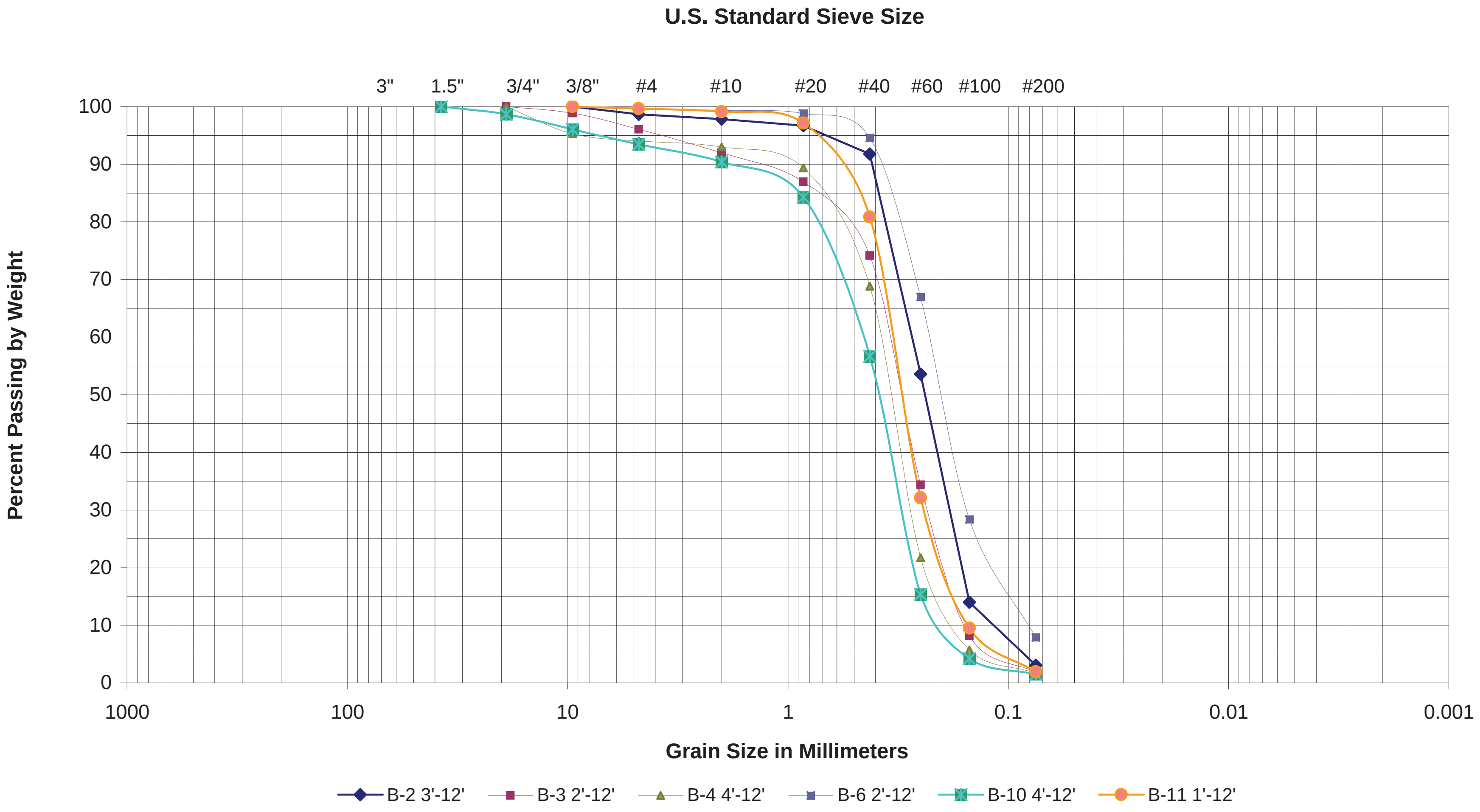
INSIGHT GEOLOGIC, INC.



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

INSIGHT GEOLOGIC, INC.

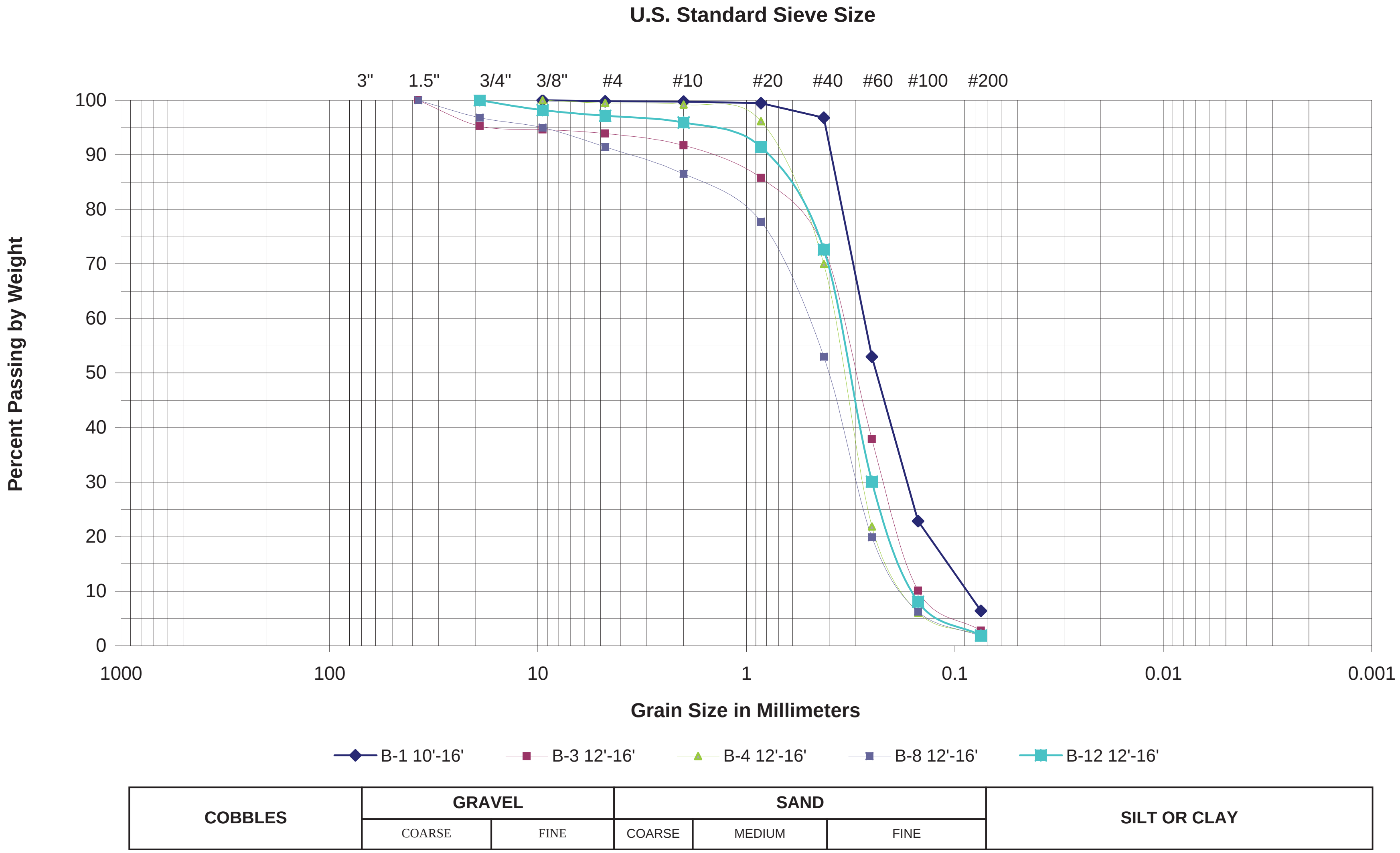
Graph 1
Gradation Analysis Results



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

INSIGHT GEOLOGIC, INC.

Graph 2
Gradation Analysis Results



INSIGHT GEOLOGIC, INC.

Graph 3
Gradation Analysis Results

INSIGHT GEOLOGIC, INC.

August 9, 2012

Olympia School District
1113 Legion Way SE
Olympia, Washington 98501
Attention: Timothy Byrne, AIA

Report
Groundwater Monitoring Services
Proposed ORLA Facility
Olympia, Washington
Project No. 566-001-01

INTRODUCTION

Insight Geologic is pleased to present the results of our groundwater monitoring services in support of the proposed Olympia Regional Learning Academy (ORLA) facility located at the intersection of Boulevard Road SE and 12th Avenue SE in Olympia, Washington. The project is located at the site of the former McKinley Elementary School and is shown relative to surrounding physical features in the Vicinity Map, Figure 1. Our services have been provided in accordance with the signed agreement between Insight Geologic and the Olympia School District (OSD) dated March 7, 2012.

We previously prepared and submitted our report titled "Geotechnical Evaluation Services" dated April 6, 2012, wherein we described the geotechnical conditions on the site and presented stormwater infiltration rates based on the preliminary groundwater measurements at the site. This report provides supplemental information regarding groundwater conditions beneath the site.

PROJECT UNDERSTANDING AND BACKGROUND

Our project understanding is based on conversations with OSD and information provided. We understand that conceptual plans for the new ORLA facility include a two-story, 70,000 square foot masonry structure. The proposed structure overlaps portions of the demolished McKinley Elementary School footprint. Additional site improvements include a playfield and paved parking for roughly 200 vehicles. If practical, stormwater disposal will consist of on-site soil infiltration.

SCOPE OF SERVICES

The purpose of our services was to evaluate seasonal high groundwater levels at the site that could be a factor in the design of the stormwater infiltration system. Our specific scope of services included the following tasks:

1. Review available information for the subsurface conditions including geologic maps and existing plans provided by OSD.

2. Install three groundwater monitoring wells at the site using a truck-mounted drill rig fitted with hollow-stem augers. The wells consist of 1-inch diameter PVC casing and well screen. The monitoring wells were completed inside locking steel covers installed flush with the surrounding grade.
3. Estimate the wellhead elevations based on local ground surface elevations provided by the Thurston County GeoData Center.
4. Monitor site groundwater levels throughout one winter season in general accordance with the 2009 SW Manual.

FINDINGS

We installed programmable pressure transducers in each of the three monitoring wells at the site following the installation of the groundwater monitoring wells on March 8, 2012. The transducers were programmed to collect water level readings twice a day during the monitoring period between March 8 and June 20, 2012. We also collected manual groundwater measurements twice monthly during the monitoring period as a backup against transducer malfunction. Our manual water level measurements are shown in Table 1. Transducer measurements, corrected for changes in barometric pressure, are contained in Attachment A.

The groundwater monitoring data for each well is shown graphically in the hydrographs, Figures 3 through 5. Our groundwater monitoring indicates that high groundwater elevations occurred this season around mid-April. Seasonal high groundwater ranged between 23 and 26 feet below ground surface during this monitoring period. Based on our review of the hydrographs, it appears that the seasonal high groundwater conditions were captured during the monitoring period.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of our groundwater monitoring activities at the site, seasonal high groundwater can be expected between 23 and 26 feet below ground surface during the winter months. A hypothetical stormwater infiltration pond depth of five feet results in a vertical separation of over 18 feet during the winter. It is unlikely that groundwater mounding beneath the stormwater disposal system will be a potential concern.

LIMITATIONS

We have prepared this groundwater monitoring report for the exclusive use of Olympia School District and their authorized agents, for the proposed ORLA facility in Olympia, Washington.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in the field of geotechnical engineering in this area at the time this report was prepared. No warranty or other conditions, expressed or implied, should be understood.

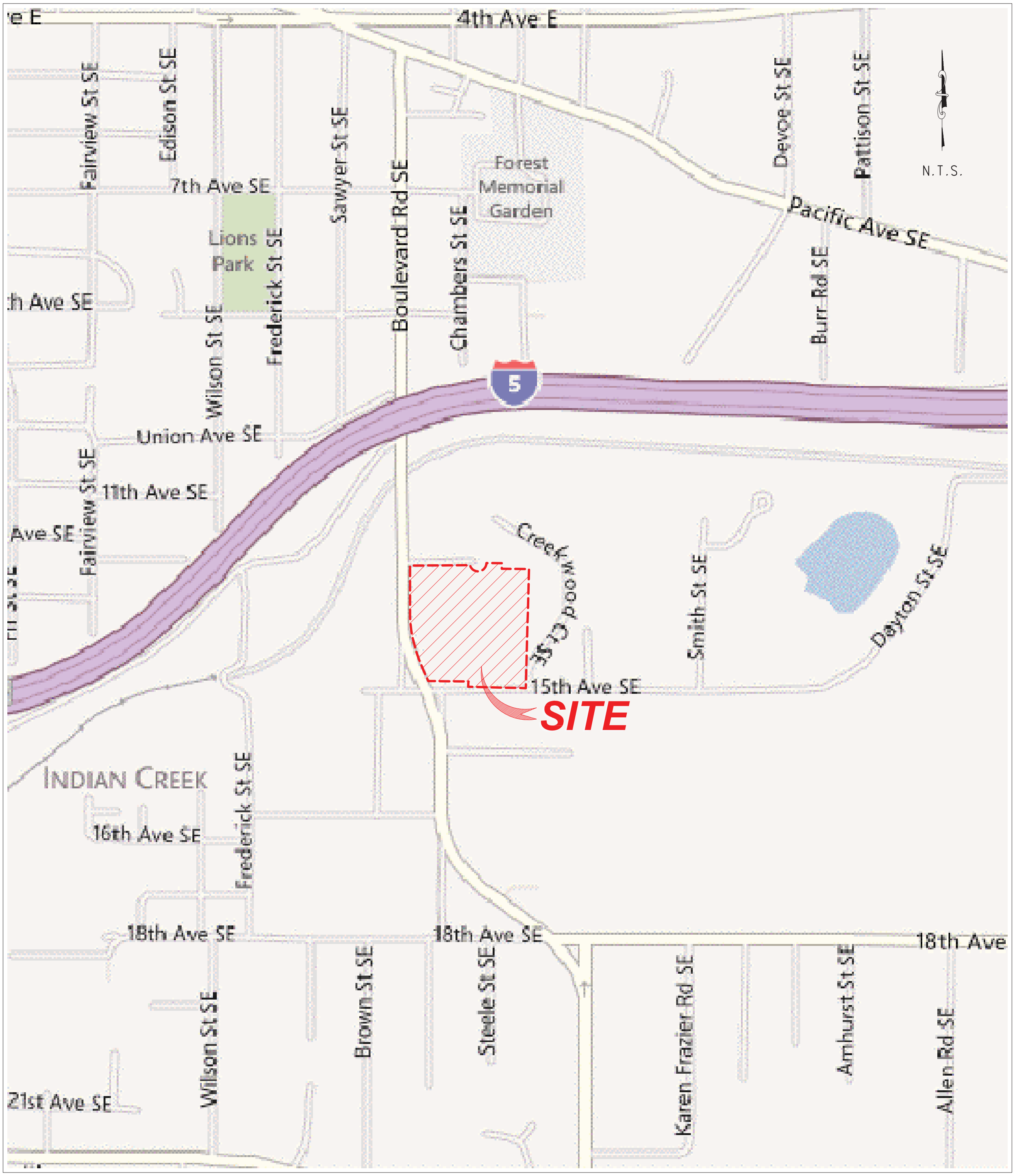
Please refer to Attachment B titled "Report Limitations and Guidelines for Use" for additional information pertaining to use of this report.

We trust this report meets your current needs. Please contact us if you have question, or if you require additional information. We appreciate the opportunity to be of service to the Olympia School District on this project.

Respectfully Submitted,
INSIGHT GEOLOGIC, INC.

William E. Halbert L.HG., L.E.G.
Principal Hydrogeologist

FIGURES



Source: Microsoft (C) 2011

PROPOSED ORLA FACILITY

OLYMPIA, WASHINGTON

INSIGHT GEOLOGIC, INC.

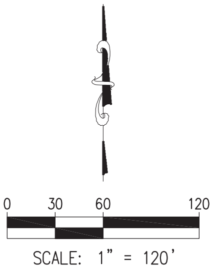
Figure 1
Vicinity Map

FILE INFO: \\ig-s01\company\Insight\566-001-01 OSD - McKinley School\Figures\Figure 1 - Vicinity Map.dwg PLOTTED: Mar 28, 2012 3:56pm BY:reneeb

Source: Thurston GeoData Center (c) Image 2009

LEGEND:

◍ PW-1	APPROXIMATE PROBE WELL LOCATION
—·-·—	APPROXIMATE PROJECT BOUNDARY



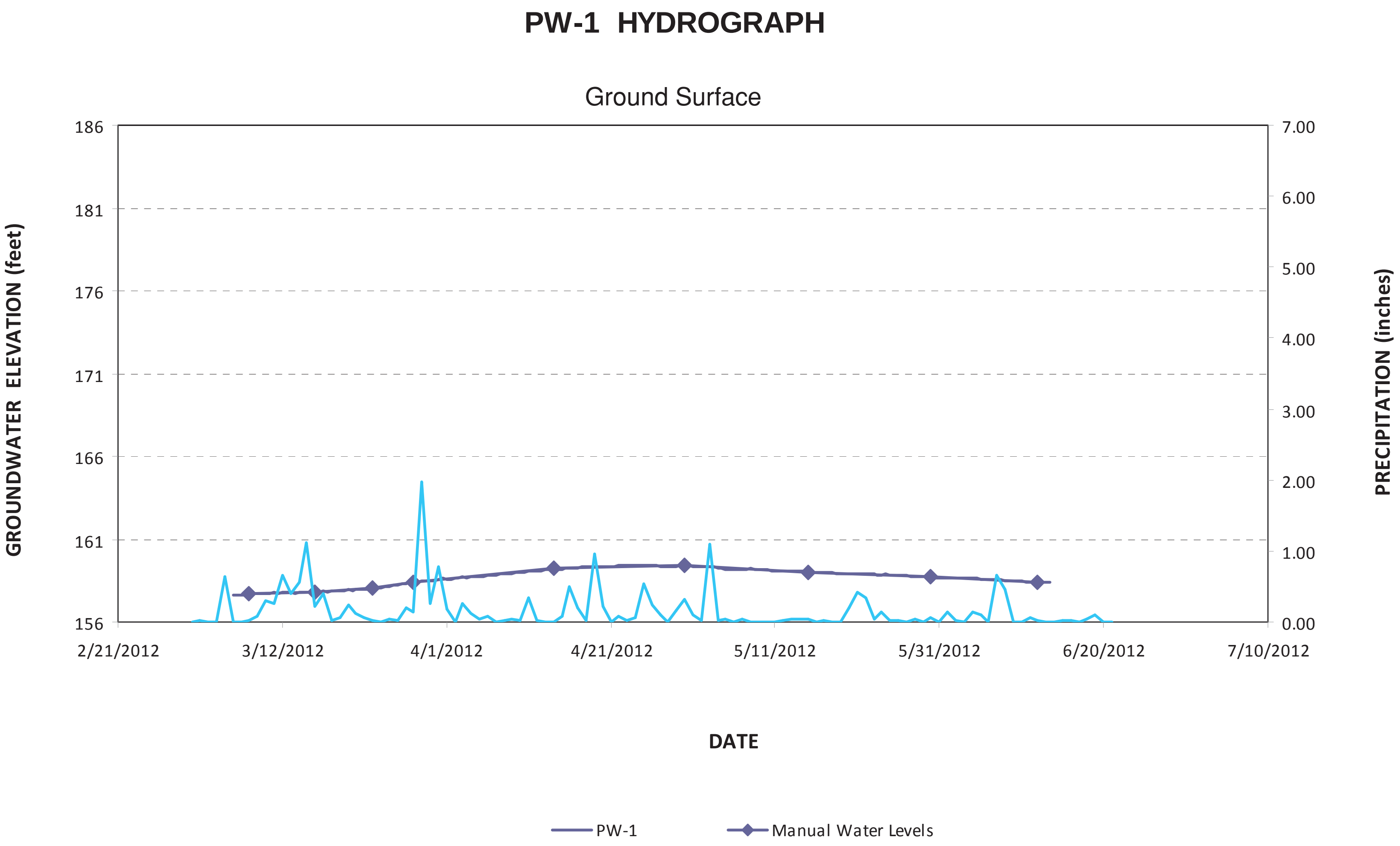
PROPOSED ORLA FACILITY

OLYMPIA, WASHINGTON

INSIGHT GEOLOGIC, INC.

Figure 2

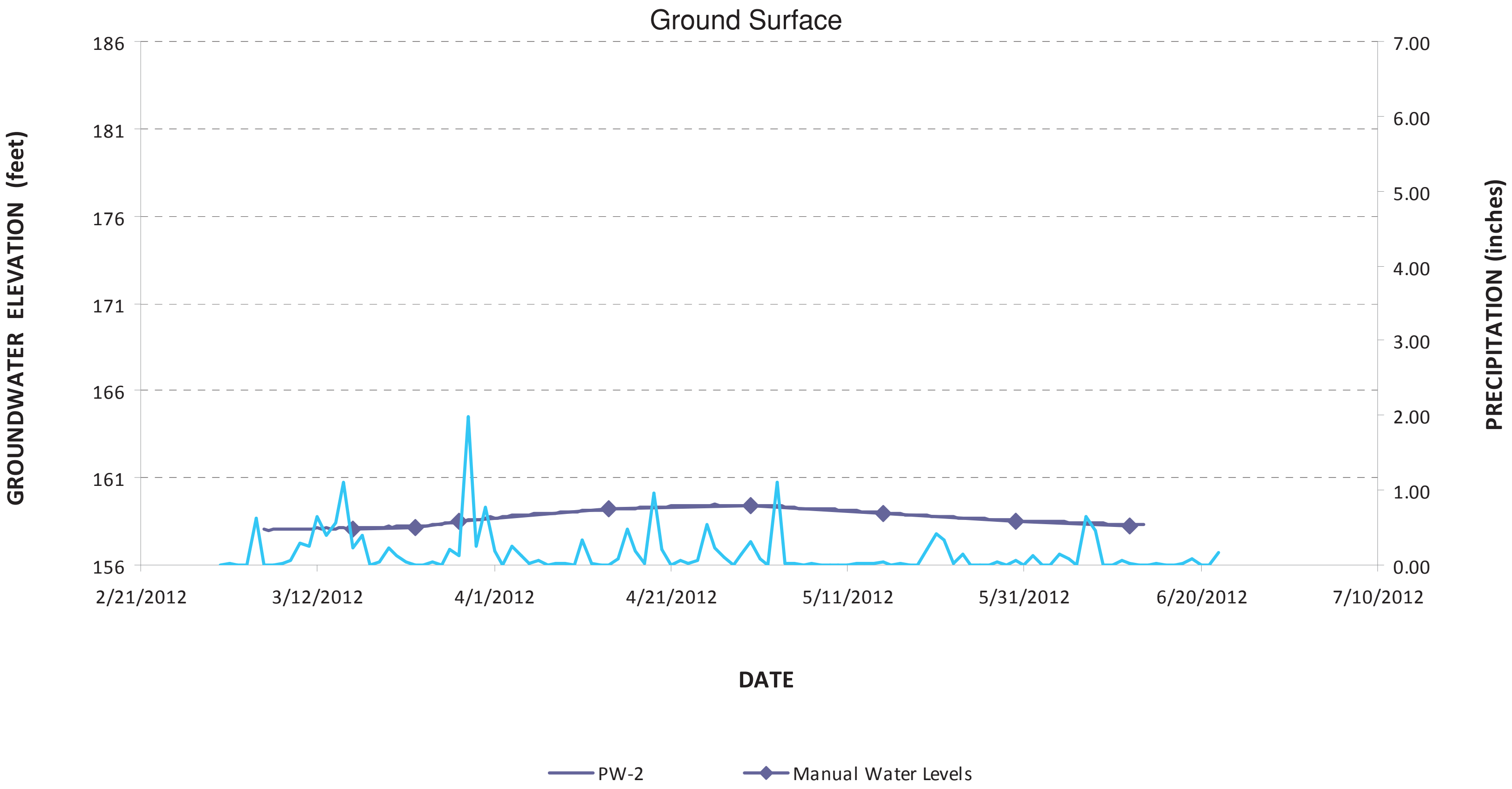
Probe Well Location Map



INSIGHT GEOLOGIC, INC.

Figure 3
PW-1 Hydrograph

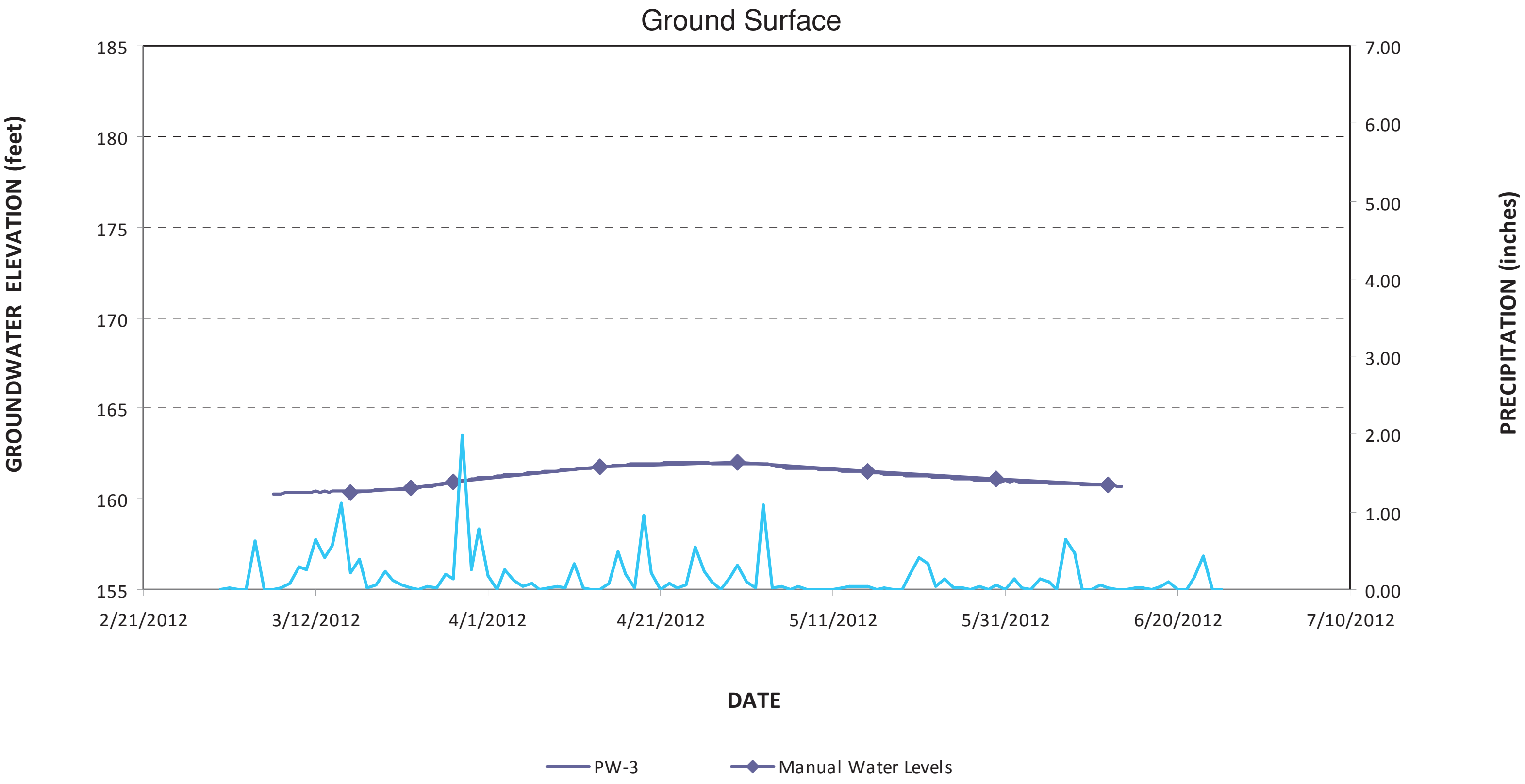
PW-2 HYDROGRAPH



INSIGHT GEOLOGIC, INC.

Figure 4
PW-2 Hydrograph

PW-3 HYDROGRAPH



INSIGHT GEOLOGIC, INC.

Figure 5
PW-3 Hydrograph

TABLE

TABLE 1

MONITORING WELL DETAILS AND MANUAL DATA

Olympia School District, ORLA Facility

Olympia, Washington

Well Number	Casing Elevation (Feet)	Total Depth of Well (Feet)	Transducer Elevation (Feet)	Ecology Tag Number	Transducer ID Number	Measurement Date	Groundwater Elevations
PW-1	185.00	33.80	151.2	BHC 052	20827	3/8/2012	156.69
				200.94		3/16/2012	156.79
				200.94		3/23/2012	157.03
						3/28/2012	157.38
						4/14/2012	158.22
						4/30/2012	158.41
						5/15/2012	158.03
						5/30/2012	157.71
						6/12/2012	157.36
PW-2	184.00	33.04	150.96	BHC 053	20307	3/8/2012	156.01
				198.40		3/16/2012	156.07
						3/23/2012	156.19
						3/28/2012	156.50
						4/14/2012	157.26
						4/30/2012	157.41
						5/15/2012	156.98
						5/30/2012	156.55
						6/12/2012	156.23
PW-3	183.00	39.36	143.64	BHC 051	18714	3/8/2012	158.39
				192.73		3/16/2012	158.36
						3/23/2012	158.61
						3/28/2012	158.96
						4/14/2012	159.81
						4/30/2012	159.98
						5/15/2012	159.48
						5/30/2012	159.08
						6/12/2012	158.76

ATTACHMENT A

TRANSDUCER WATER LEVELS

TABLE 1-A

TRANSDUCER WATER LEVELS CORRECTED FOR BAROMETRIC PRESSURE

Olympia School District, ORLA Facility

Olympia, Washington

DATE	PW-1	PW-2	PW-3
3/6/2012	156.66	156.05	143.76
3/6/2012	156.61	156.01	143.60
3/7/2012	156.65	156.03	158.30
3/7/2012	156.65	156.02	158.29
3/8/2012	156.66	156.02	158.29
3/8/2012	156.68	156.04	158.32
3/9/2012	156.68	156.04	158.33
3/9/2012	156.70	156.05	158.34
3/10/2012	156.71	156.07	158.35
3/10/2012	156.73	156.07	158.36
3/11/2012	156.76	156.09	158.37
3/11/2012	156.73	156.07	158.36
3/12/2012	156.79	156.11	158.39
3/12/2012	156.77	156.09	158.38
3/13/2012	156.79	156.11	158.41
3/13/2012	156.75	156.07	158.38
3/14/2012	156.79	156.10	158.41
3/14/2012	156.80	156.12	158.41
3/15/2012	156.83	156.13	158.42
3/15/2012	156.78	156.10	158.40
3/16/2012	156.84	156.14	158.44
3/16/2012	156.83	156.14	158.43
3/17/2012	156.87	156.18	158.45
3/17/2012	156.83	156.13	158.43
3/18/2012	156.88	156.17	158.46
3/18/2012	156.86	156.16	158.46
3/19/2012	156.88	156.17	158.49
3/19/2012	156.89	156.18	158.48
3/20/2012	156.95	156.22	158.52
3/20/2012	156.87	156.16	158.48
3/21/2012	156.93	156.19	158.52
3/21/2012	156.95	156.21	158.52
3/22/2012	156.98	156.23	158.55
3/22/2012	156.99	156.21	158.55
3/23/2012	157.04	156.25	158.58
3/23/2012	157.04	156.24	158.58
3/24/2012	157.09	156.27	158.62
3/24/2012	157.13	156.28	158.65
3/25/2012	157.16	156.31	158.69
3/25/2012	157.21	156.34	158.72
3/26/2012	157.22	156.35	158.75
3/26/2012	157.27	156.39	158.79
3/27/2012	157.30	156.42	158.82

TABLE 1-A

TRANSDUCER WATER LEVELS CORRECTED FOR BAROMETRIC PRESSURE

Olympia School District, ORLA Facility

Olympia, Washington

DATE	PW-1	PW-2	PW-3
3/27/2012	157.35	156.46	158.88
3/28/2012	157.35	156.47	158.89
3/28/2012	157.38	156.49	158.93
3/29/2012	157.47	156.57	159.00
3/29/2012	157.50	156.61	159.05
3/30/2012	157.51	156.63	159.09
3/30/2012	157.52	156.64	159.10
3/31/2012	157.60	156.71	159.18
3/31/2012	157.61	156.74	159.21
4/1/2012	157.58	156.72	159.19
4/1/2012	157.59	156.73	159.21
4/2/2012	157.62	156.76	159.23
4/2/2012	157.68	156.81	159.28
4/3/2012	157.70	156.84	159.31
4/3/2012	157.68	156.83	159.31
4/4/2012	157.74	156.88	159.36
4/4/2012	157.74	156.88	159.36
4/5/2012	157.77	156.91	159.39
4/5/2012	157.78	156.92	159.40
4/6/2012	157.80	156.94	159.43
4/6/2012	157.81	156.94	159.44
4/7/2012	157.84	156.97	159.47
4/7/2012	157.87	156.98	159.48
4/8/2012	157.87	156.99	159.49
4/8/2012	157.90	157.01	159.52
4/9/2012	157.92	157.02	159.53
4/9/2012	157.97	157.05	159.58
4/10/2012	158.00	157.07	159.61
4/10/2012	158.01	157.07	159.60
4/11/2012	158.04	157.10	159.62
4/11/2012	158.07	157.11	159.65
4/12/2012	158.08	157.13	159.67
4/12/2012	158.10	157.13	159.68
4/13/2012	158.14	157.16	159.72
4/13/2012	158.15	157.17	159.73
4/14/2012	158.16	157.17	159.74
4/14/2012	158.17	157.18	159.76
4/15/2012	158.19	157.20	159.78
4/15/2012	158.22	157.23	159.82
4/16/2012	158.26	157.26	159.86
4/16/2012	158.23	157.23	159.83
4/17/2012	158.25	157.26	159.86
4/17/2012	158.30	157.31	159.91

TABLE 1-A

TRANSDUCER WATER LEVELS CORRECTED FOR BAROMETRIC PRESSURE

Olympia School District, ORLA Facility

Olympia, Washington

DATE	PW-1	PW-2	PW-3
4/18/2012	158.32	157.33	159.93
4/18/2012	158.30	157.30	159.90
4/19/2012	158.32	157.33	159.93
4/19/2012	158.34	157.35	159.95
4/20/2012	158.33	157.34	159.93
4/20/2012	158.33	157.35	159.95
4/21/2012	158.36	157.37	159.97
4/21/2012	158.38	157.39	159.99
4/22/2012	158.38	157.39	159.99
4/22/2012	158.40	157.41	160.01
4/23/2012	158.39	157.40	159.99
4/23/2012	158.41	157.42	160.02
4/24/2012	158.39	157.41	159.99
4/24/2012	158.40	157.41	160.01
4/25/2012	158.42	157.43	160.02
4/25/2012	158.44	157.45	160.04
4/26/2012	158.44	157.45	160.03
4/26/2012	158.40	157.42	159.99
4/27/2012	158.33	157.38	159.93
4/27/2012	158.33	157.38	159.95
4/28/2012	158.34	157.40	159.95
4/28/2012	158.35	157.40	159.95
4/29/2012	158.36	157.41	159.95
4/29/2012	158.38	157.42	159.97
4/30/2012	158.43	157.45	160.01
4/30/2012	158.38	157.41	159.95
5/1/2012	158.34	157.38	159.90
5/1/2012	158.35	157.39	159.92
5/2/2012	158.34	157.39	159.90
5/2/2012	158.34	157.38	159.90
5/3/2012	158.38	157.41	159.93
5/3/2012	158.37	157.40	159.90
5/4/2012	158.27	157.33	159.82
5/4/2012	158.23	157.31	159.79
5/5/2012	158.20	157.28	159.75
5/5/2012	158.16	157.25	159.72
5/6/2012	158.18	157.25	159.72
5/6/2012	158.17	157.24	159.71
5/7/2012	158.19	157.26	159.71
5/7/2012	158.19	157.24	159.71
5/8/2012	158.22	157.26	159.71
5/8/2012	158.19	157.23	159.69
5/9/2012	158.18	157.22	159.66

TABLE 1-A

TRANSDUCER WATER LEVELS CORRECTED FOR BAROMETRIC PRESSURE

Olympia School District, ORLA Facility

Olympia, Washington

DATE	PW-1	PW-2	PW-3
5/9/2012	158.14	157.18	159.64
5/10/2012	158.12	157.16	159.61
5/10/2012	158.10	157.13	159.59
5/11/2012	158.10	157.13	159.57
5/11/2012	158.09	157.10	159.56
5/12/2012	158.10	157.11	159.55
5/12/2012	158.08	157.08	159.53
5/13/2012	158.08	157.08	159.52
5/13/2012	158.06	157.04	159.50
5/14/2012	158.07	157.05	159.49
5/14/2012	158.05	157.02	159.48
5/15/2012	158.04	157.01	159.45
5/15/2012	158.02	156.98	159.44
5/16/2012	158.01	156.97	159.41
5/16/2012	157.99	156.94	159.40
5/17/2012	157.99	156.93	159.38
5/17/2012	157.97	156.90	159.37
5/18/2012	157.96	156.89	159.34
5/18/2012	157.93	156.85	159.32
5/19/2012	157.94	156.85	159.32
5/19/2012	157.93	156.83	159.30
5/20/2012	157.93	156.82	159.29
5/20/2012	157.92	156.81	159.27
5/21/2012	157.92	156.80	159.27
5/21/2012	157.93	156.80	159.26
5/22/2012	157.90	156.77	159.23
5/22/2012	157.88	156.74	159.23
5/23/2012	157.88	156.75	159.20
5/23/2012	157.85	156.71	159.18
5/24/2012	157.85	156.72	159.17
5/24/2012	157.87	156.71	159.16
5/25/2012	157.84	156.70	159.12
5/25/2012	157.83	156.68	159.12
5/26/2012	157.82	156.67	159.10
5/26/2012	157.81	156.66	159.09
5/27/2012	157.78	156.64	159.06
5/27/2012	157.76	156.62	159.05
5/28/2012	157.75	156.61	159.04
5/28/2012	157.74	156.59	159.03
5/29/2012	157.72	156.58	159.01
5/29/2012	157.71	156.57	159.00
5/30/2012	157.71	156.58	158.99
5/30/2012	157.68	156.54	158.97

TABLE 1-A

TRANSDUCER WATER LEVELS CORRECTED FOR BAROMETRIC PRESSURE

Olympia School District, ORLA Facility

Olympia, Washington

DATE	PW-1	PW-2	PW-3
5/31/2012	157.69	156.55	158.98
5/31/2012	157.67	156.53	158.97
6/1/2012	157.69	156.54	158.98
6/1/2012	157.67	156.53	158.95
6/2/2012	157.67	156.52	158.96
6/2/2012	157.65	156.51	158.93
6/3/2012	157.63	156.49	158.92
6/3/2012	157.62	156.49	158.91
6/4/2012	157.63	156.49	158.91
6/4/2012	157.62	156.49	158.90
6/5/2012	157.59	156.46	158.88
6/5/2012	157.55	156.42	158.86
6/6/2012	157.54	156.42	158.85
6/6/2012	157.54	156.42	158.86
6/7/2012	157.55	156.42	158.87
6/7/2012	157.57	156.46	158.85
6/8/2012	157.51	156.40	158.83
6/8/2012	157.50	156.39	158.81
6/9/2012	157.48	156.38	158.79
6/9/2012	157.46	156.37	158.78
6/10/2012	157.44	156.34	158.76
6/10/2012	157.43	156.33	158.76
6/11/2012	157.42	156.34	158.76
6/11/2012	157.41	156.32	158.75
6/12/2012	157.41	156.32	158.74
6/12/2012	157.40	156.31	158.73
6/13/2012	157.39	156.31	158.71
6/13/2012	157.36	156.28	158.69
6/13/2012	193.29	154.06	177.26
6/14/2012	193.29	154.05	177.25
6/14/2012	193.29	154.02	177.23
6/15/2012	193.23	154.00	177.21
6/15/2012	193.23	154.00	177.19
6/16/2012	193.21	153.98	177.19
6/16/2012	193.19	153.98	177.17
6/17/2012	193.18	153.99	177.14
6/17/2012	193.13	153.95	177.13
6/18/2012	193.15	153.91	177.08
6/18/2012	193.13	197.38	177.09
6/19/2012	193.12	197.36	177.05
6/19/2012	193.08	197.34	177.05
6/20/2012	193.04	197.30	177.08
6/20/2012	193.06	197.32	177.02

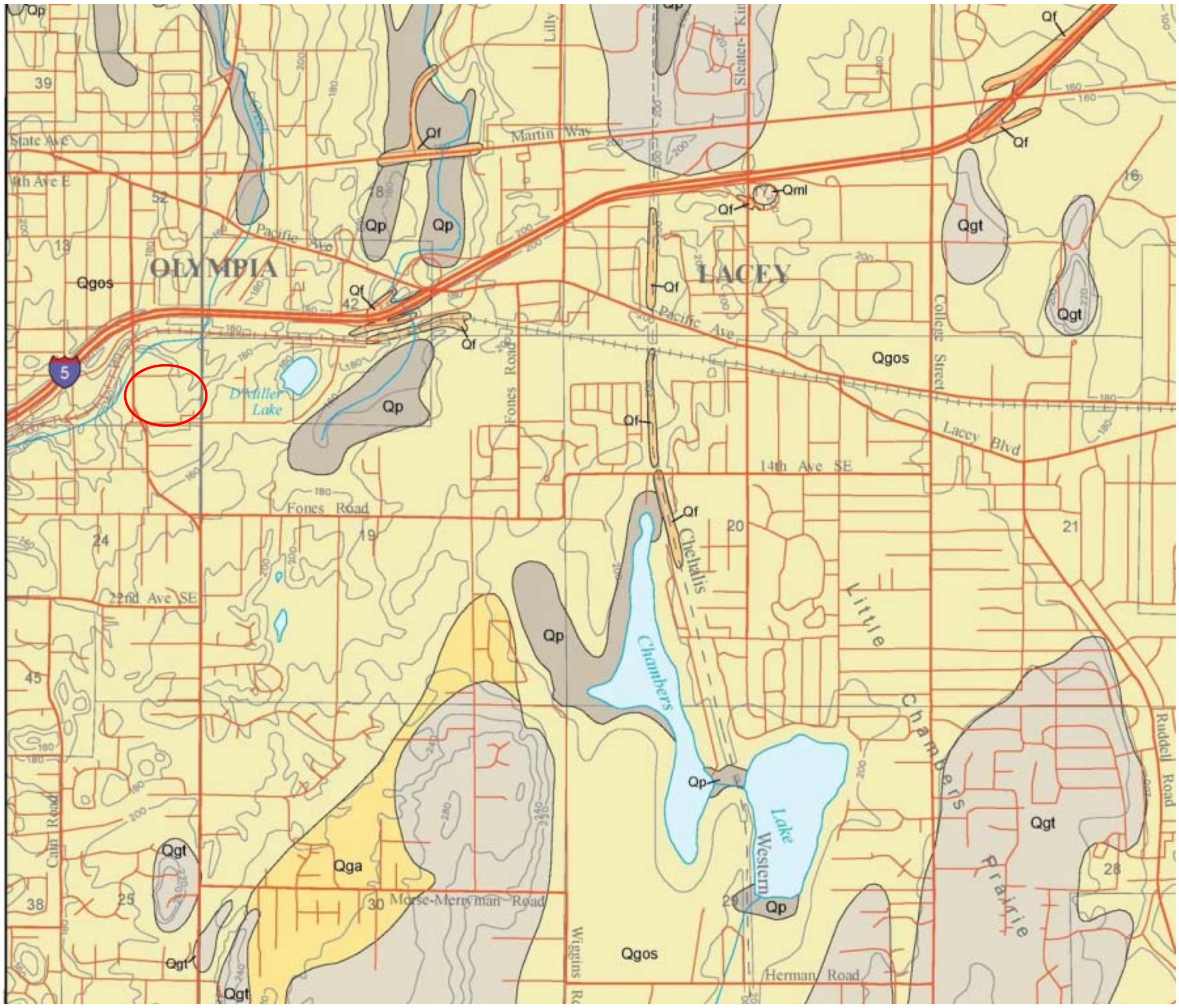
TABLE 1-A

TRANSDUCER WATER LEVELS CORRECTED FOR BAROMETRIC PRESSURE

Olympia School District, ORLA Facility

Olympia, Washington

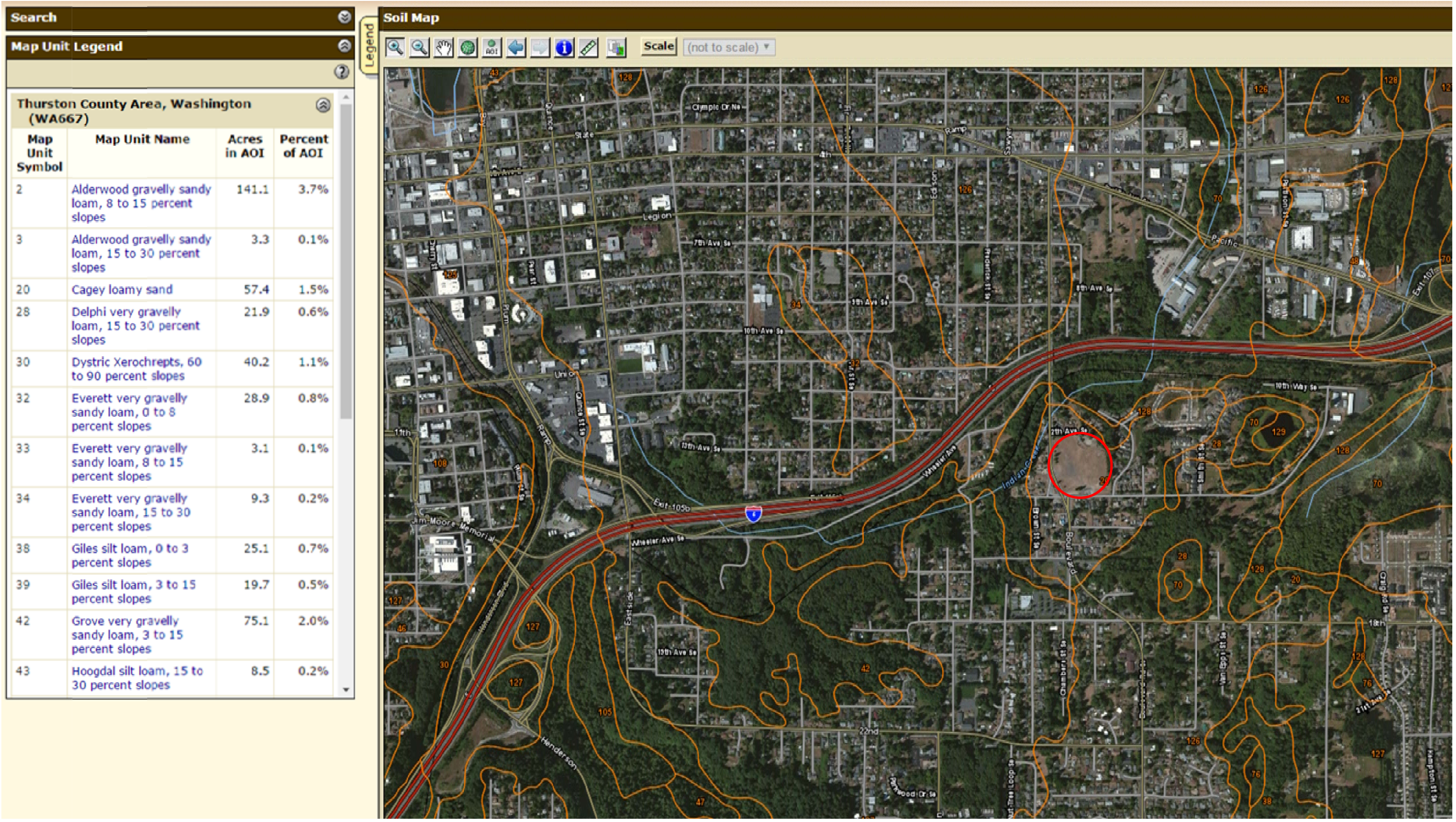
DATE	PW-1	PW-2	PW-3
6/21/2012	193.01	197.28	177.04
6/21/2012	193.02	197.28	177.00
6/22/2012	192.99	197.25	176.99
6/22/2012	192.38	196.64	176.36
6/22/2012	192.58	196.83	176.48
6/23/2012	192.68	196.97	176.68
6/23/2012	192.89	197.18	176.86
6/24/2012	192.97	197.27	176.99
6/24/2012	192.92	197.22	176.92
5/30/2012	350.91	251.84	224.47
5/31/2012	351.02	251.95	224.55
5/31/2012	350.91	251.86	224.35
6/1/2012	351.01	251.98	224.40
6/1/2012	351.07	252.06	224.38
6/2/2012	351.18	252.18	224.46
6/2/2012	351.14	252.15	224.43
6/3/2012	351.08	252.09	224.37
6/3/2012	350.88	251.90	224.18
6/4/2012	350.83	251.86	224.13
6/4/2012	351.02	252.06	224.32
6/5/2012	351.27	252.34	224.55
6/5/2012	351.05	252.11	224.31
6/6/2012	350.80	251.85	224.00
6/6/2012	350.72	251.77	223.89
6/7/2012	350.69	251.82	223.86
6/7/2012	351.26	252.53	224.22
6/8/2012	351.21	252.48	224.00
6/8/2012	351.51	253.38	224.11
6/9/2012	351.77	253.57	224.09
6/9/2012	351.78	253.34	224.09
6/10/2012	351.60	253.09	223.94
6/10/2012	351.41	252.74	223.82
6/11/2012	351.32	252.59	223.76
6/11/2012	351.21	252.45	223.74
6/12/2012	351.17	252.41	223.75
6/12/2012	351.19	252.44	223.83
6/13/2012	351.22	252.48	223.90



Approximate location of facilities indicated by red outline

Qgos	**Latest Vashon recessional sand and minor silt**—Moderately well-sorted, moderately to well-rounded, fine- to medium-grained sand with minor silt; noncohesive and highly permeable; thickness inferred from wells reaches up to 100 ft; deposited in and around the margins of glacial lakes; surrounds numerous steep-walled lakes and depressions (kettles), evidence that this unit was largely deposited during deglaciation when there was stagnant ice occupying much of the southern Puget Lowland.

Excerpt from Logan, R. L., et. al., Geologic Map of the Lacey 7.5 Minute Quadrangle, Thurston County, Washington



Map Unit Legend

Thurston County Area, Washington (WA667)

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
2	Alderwood gravelly sandy loam, 8 to 15 percent slopes	141.1	3.7%
3	Alderwood gravelly sandy loam, 15 to 30 percent slopes	3.3	0.1%
20	Cagey loamy sand	57.4	1.5%
28	Delphi very gravelly loam, 15 to 30 percent slopes	21.9	0.6%
30	Dystric Xerochrepts, 60 to 90 percent slopes	40.2	1.1%
32	Everett very gravelly sandy loam, 0 to 8 percent slopes	28.9	0.8%
33	Everett very gravelly sandy loam, 8 to 15 percent slopes	3.1	0.1%
34	Everett very gravelly sandy loam, 15 to 30 percent slopes	9.3	0.2%
38	Giles silt loam, 0 to 3 percent slopes	25.1	0.7%
39	Giles silt loam, 3 to 15 percent slopes	19.7	0.5%
42	Grove very gravelly sandy loam, 3 to 15 percent slopes	75.1	2.0%
43	Hoogdal silt loam, 15 to 30 percent slopes	8.5	0.2%

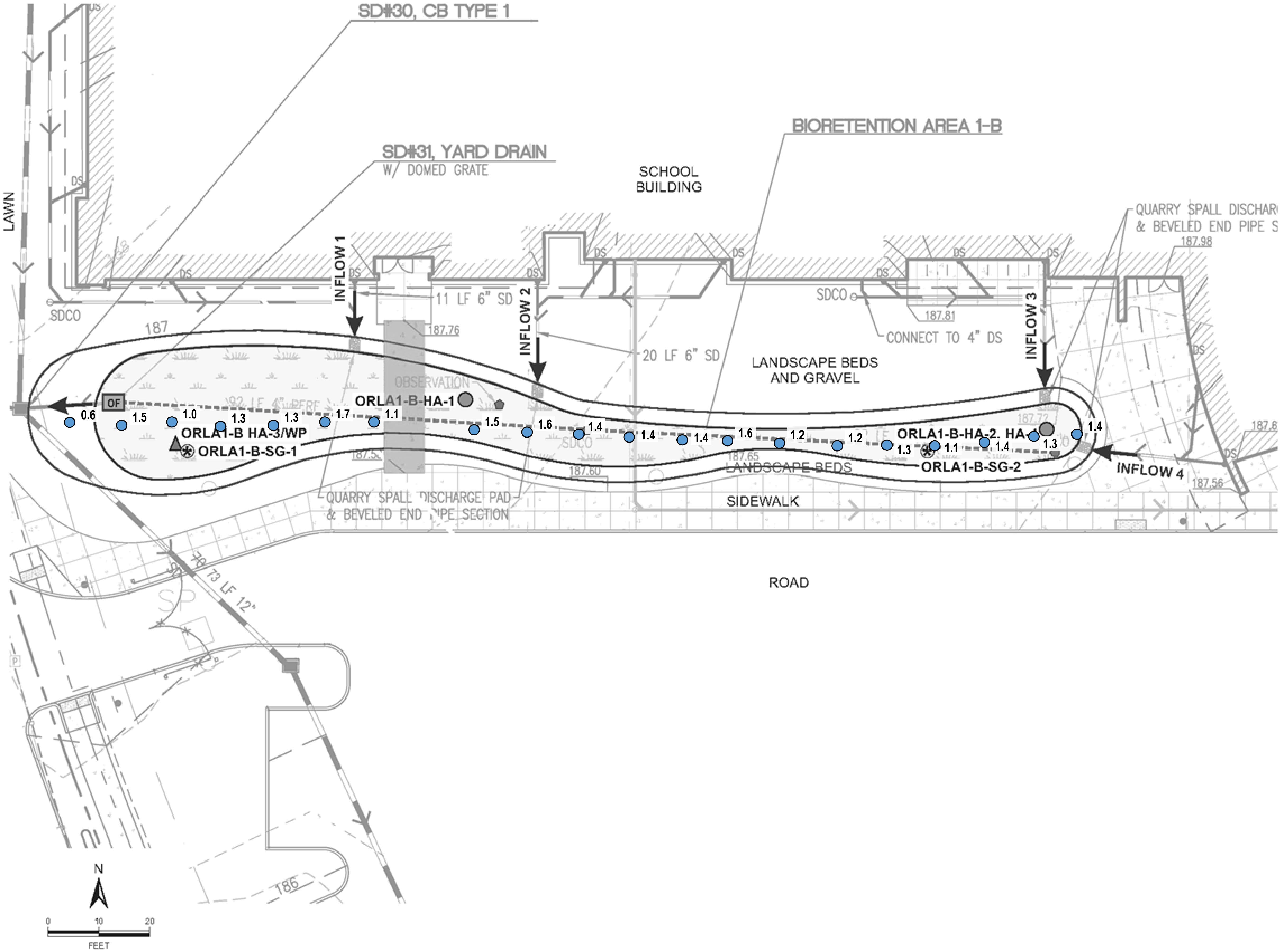
Approximate location of facilities indicated by red outline

Excerpt from Natural Resources Conservation Service, 2016, Web soil survey

APPENDIX D

Soil Probe, Level Survey, and Field Infiltration Testing Data

ORLA1-B Soil Probe Data



LEGEND:

● HA	HAND AUGER
▲ WP	WELL POINT
⊛	TEMPORARY STAFF GAUGE
▭	BASE OF FACILITY
▭	TOP OF FACILITY SLOPE
➞	INFLOW / OVERFLOW DIRECTION
OF	OVERFLOW GRATE
------	UNDERDRAIN
●	STORM DRAIN CLEANOUT
⬟	PRE-EXISTING OBSERVATION WELL
▨	PEDESTRIAN BRIDGE
● 0.8	Soil Probe and Depth of Loose Soil

CONTOUR INTERVAL = 1'

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:
1. BASE MAP REFERENCE: LPD ENGINEERING, OLYMPIA REGIONAL LEARNING ACADEMY, GRADING DRAINAGE PLAN, C2.3, 5/18/2015

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SOIL PROBE DATA
ORLA1-B SITE
BIORETENTION HYDROLOGIC PERFORMANCE
THURSTON COUNTY, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	D1

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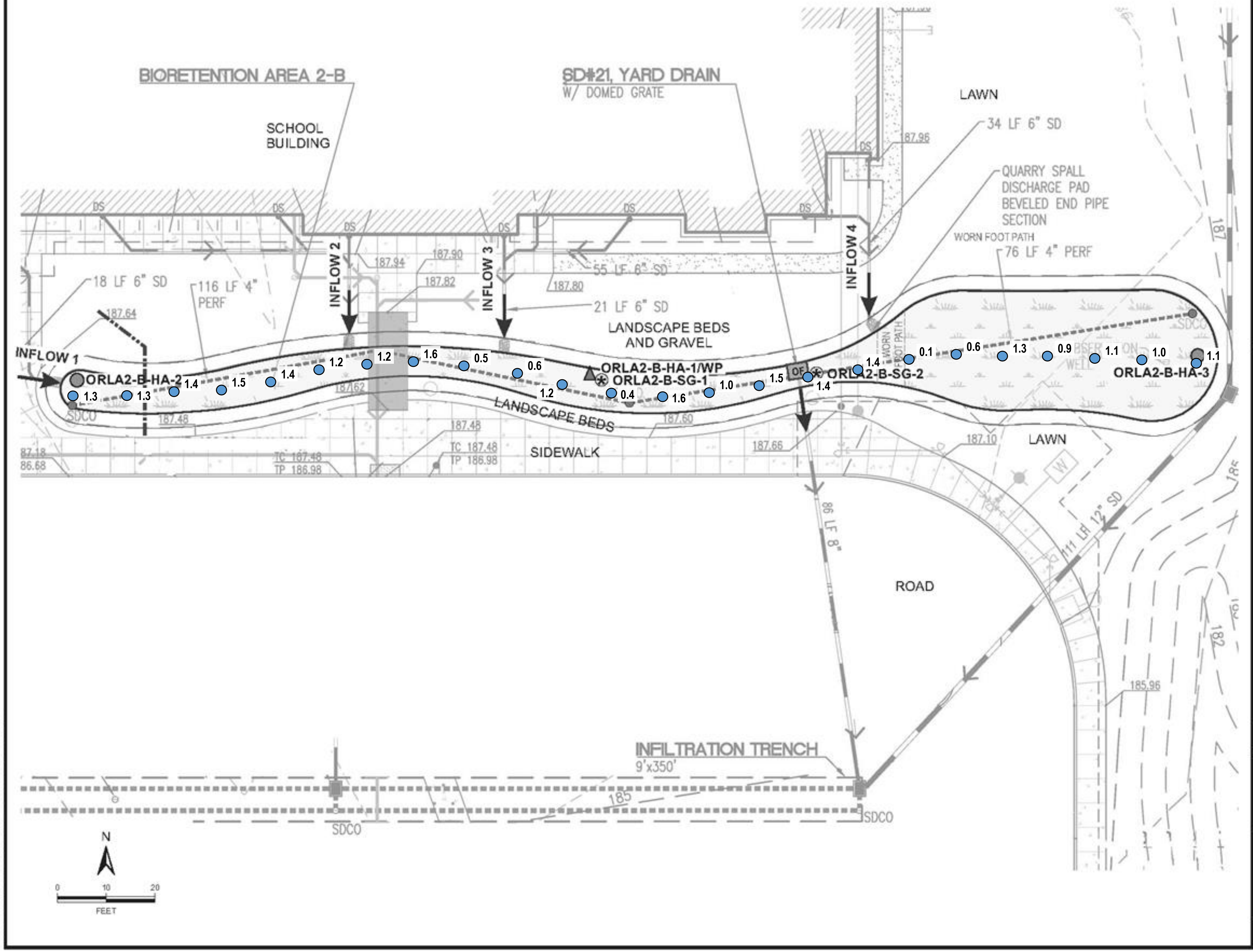
ORLA2-B Soil Probe Data



150387 BHPS MCCA \ 150387 Site-Expl.cdr PAGE 7 ORLA 2B

LEGEND:

● HA	HAND AUGER
▲ WP	WELL POINT
⊛	TEMPORARY STAFF GAUGE
▭	BASE OF FACILITY
▭	TOP OF FACILITY SLOPE
→	INFLOW / OVERFLOW DIRECTION
OF	OVERFLOW GRATE
- - - -	UNDERDRAIN
●	STORM DRAIN CLEANOUT
— · · —	GAS LINE
▨	PEDESTRIAN BRIDGE
● 0.8	Soil Probe and Depth of Loose Soil

CONTOUR INTERVAL = 1'

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:
1. BASE MAP REFERENCE: LPD ENGINEERING, OLYMPIA REGIONAL LEARNING ACADEMY, GRADING / DRAINAGE PLAN, SHEET C2.4, 5/18/2015

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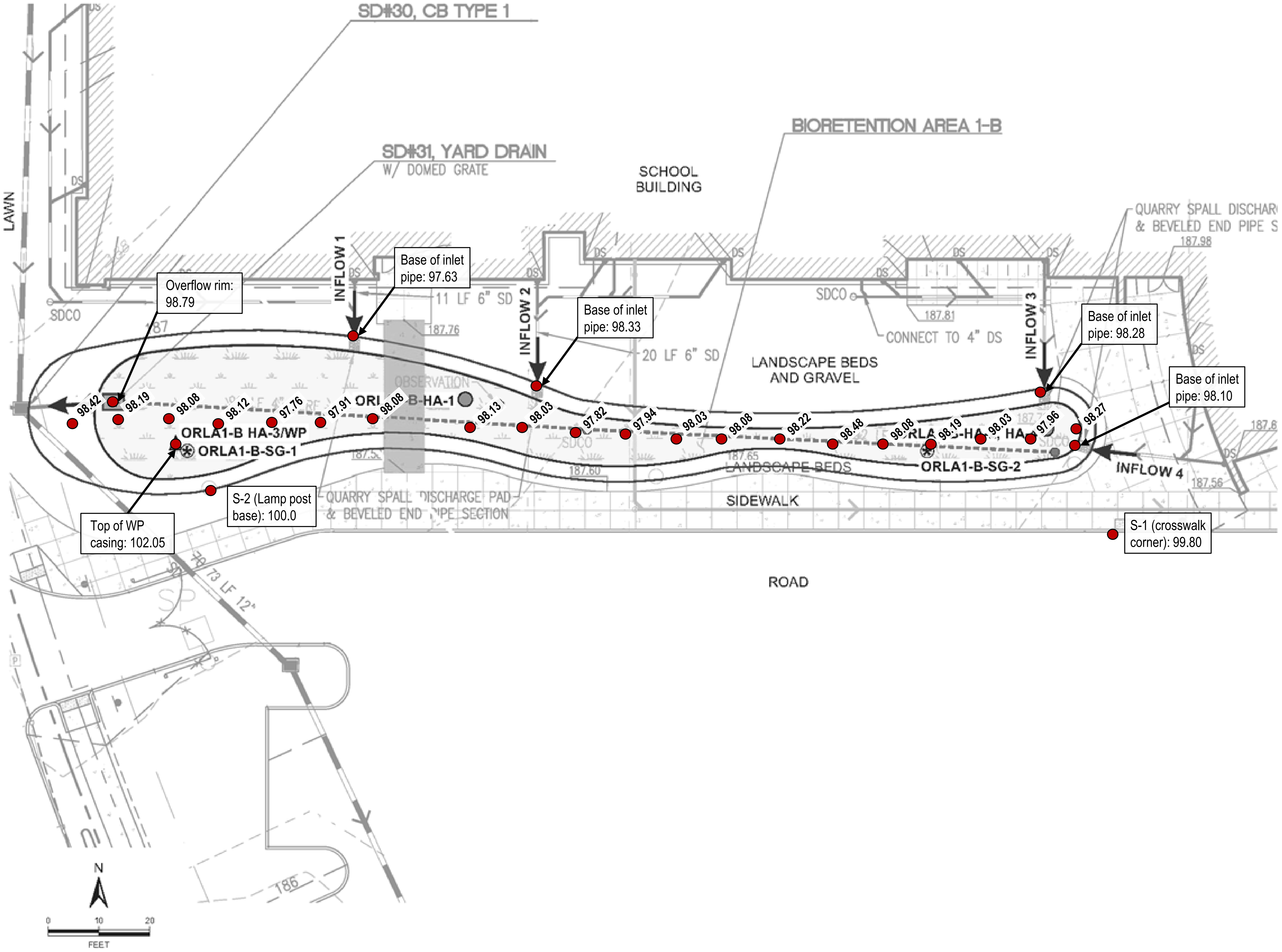
SOIL PROBE DATA
ORLA2-B SITE
BIORETENTION HYDROLOGIC PERFORMANCE
THURSTON COUNTY, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	D1

ORLA1-B Level Survey Data



Overflow rim: 98.79

Base of inlet pipe: 97.63

Base of inlet pipe: 98.33

Base of inlet pipe: 98.28

Base of inlet pipe: 98.10

Top of WP casing: 102.05

S-2 (Lamp post base): 100.0

S-1 (crosswalk corner): 99.80

LEGEND:

● HA	HAND AUGER
▲ WP	WELL POINT
⊛	TEMPORARY STAFF GAUGE
▭	BASE OF FACILITY
▭	TOP OF FACILITY SLOPE
➔	INFLOW / OVERFLOW DIRECTION
OF	OVERFLOW GRATE
-----	UNDERDRAIN
●	STORM DRAIN CLEANOUT
⬟	PRE-EXISTING OBSERVATION WELL
▨	PEDESTRIAN BRIDGE
● 98.66	Elevation, Project Datum (see text)

CONTOUR INTERVAL = 1'

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:

1. BASE MAP REFERENCE: LPD ENGINEERING, OLYMPIA REGIONAL LEARNING ACADEMY, GRADING DRAINAGE PLAN, C2.3, 5/18/2015

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LEVEL SURVEY DATA
ORLA1-B SITE
BIORETENTION HYDROLOGIC PERFORMANCE
THURSTON COUNTY, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	D2

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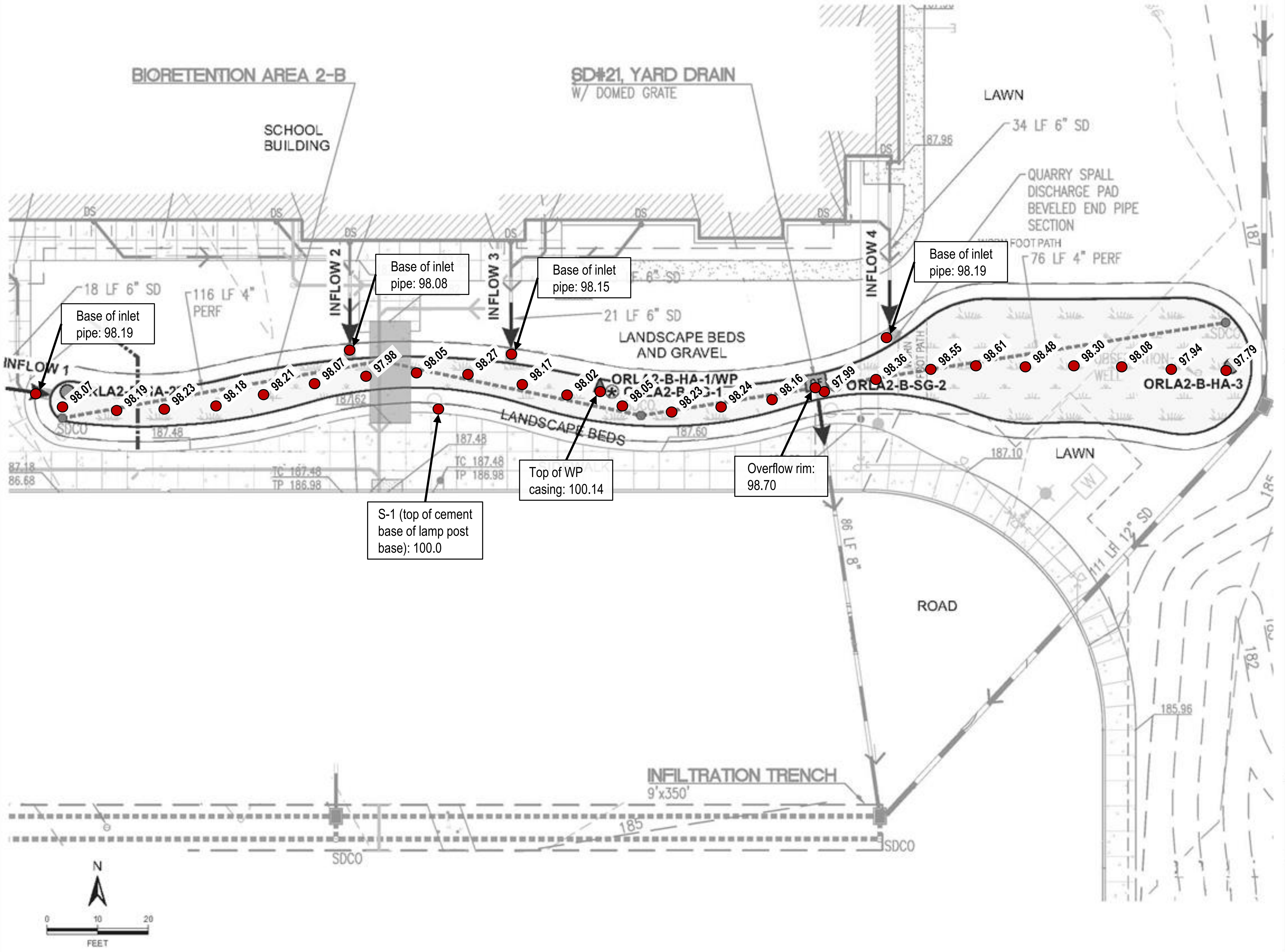
ORLA2-B Level Survey Data



LEGEND:

● HA	HAND AUGER
▲ WP	WELL POINT
⊛	TEMPORARY STAFF GAUGE
▭	BASE OF FACILITY
▭	TOP OF FACILITY SLOPE
➔	INFLOW / OVERFLOW DIRECTION
OF	OVERFLOW GRATE
------	UNDERDRAIN
●	STORM DRAIN CLEANOUT
—··—	GAS LINE
▨	PEDESTRIAN BRIDGE
● 98.66	Elevation, Project Datum (see text)

CONTOUR INTERVAL = 1'

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:
1. BASE MAP REFERENCE: LPD ENGINEERING, OLYMPIA REGIONAL LEARNING ACADEMY, GRADING / DRAINAGE PLAN, SHEET C2.4, 5/18/2015

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LEVEL SURVEY DATA
ORLA2-B SITE
BIORETENTION HYDROLOGIC PERFORMANCE
THURSTON COUNTY, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	D2

Cell ORLA1-B
Level Survey Data

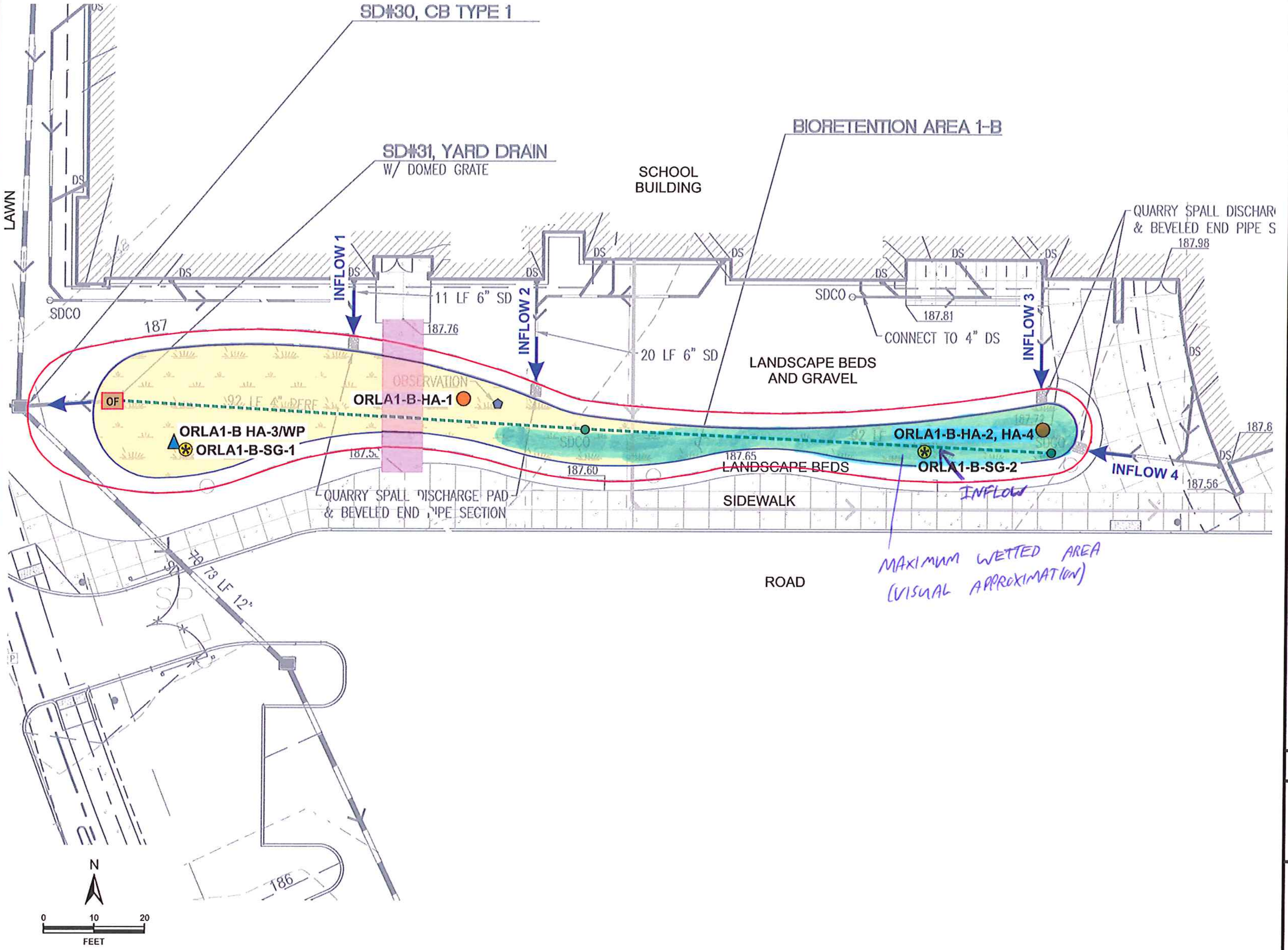
Location	Elevation (feet, project datum)
(S-1) Crosswalk corner	99.80
(S-2) Lamp post base (E end cell ORLA 1-B)	100.00
(S-3) Lamp post base (middle of cell)	99.97
Inlet 1 base of pipe	97.63
Inlet 2 base of pipe	98.33
Inlet 3 base of pipe	98.28
Inlet 4 base of pipe	98.1
Overflow rim	98.79
Well point, top of casing	102.05
Survey points in base of cell	On site plan

Cell ORLA2-B
Level Survey Data

Location	Elevation (feet, project datum)
(S-1) Top of cement base of lamp post, near Cell ORLA 2-B bridge	100.00
(S-2) Sidewalk next to corner of wall	100.23
(S-3) Top of cement base of lamp post, near fire hydrant	100.08
Inlet 1 base of pipe	98.08
Inlet 2 base of pipe (approx)	98.08
Inlet 3 base of pipe	98.15
Inlet 4 base of pipe	98.19
Overflow rim	98.70
Well point, top of casing	100.14
Survey points in base of cell	On site plan

Cell ORLA1-B and ORLA2-B
Probe Survey Data List (Excludes Outliers)

ORLA1-B, Probe Penetration (feet):	ORLA2-B, Probe Penetration (feet):
1.5	1.3
1	1.3
1.3	1.4
1.3	1.5
1.5	1.4
1.1	1.2
1.5	1.2
1.6	1.6
1.4	0.5
1.4	0.6
1.4	1.2
1.6	0.4
1.2	1.6
1.2	1
1.3	1.5
1.1	1.4
1.4	1.4
1.3	0.1
1.4	0.6
	1.3
	0.9
	1.1
	1
	1.1
AVERAGE: 1.3	AVERAGE: 1.1



LEGEND:

● **HA** HAND AUGER

▲ **WP** WELL POINT

⊛ TEMPORARY STAFF GAUGE

🟨 BASE OF FACILITY

⬭ TOP OF FACILITY SLOPE

→ INFLOW / OVERFLOW DIRECTION

OF OVERFLOW GRATE

┅ UNDERDRAIN

● STORM DRAIN CLEANOUT

⬟ PRE-EXISTING OBSERVATION WELL

🟪 PEDESTRIAN BRIDGE

CONTOUR INTERVAL = 1'

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:

1. BASE MAP REFERENCE: LPD ENGINEERING, OLYMPIA REGIONAL LEARNING ACADEMY, GRADING DRAINAGE PLAN, C2.3, 5/18/2015

BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION.

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WETTED AREA

ORLA1-B SITE

BIORETENTION HYDROLOGIC PERFORMANCE
THURSTON COUNTY, WASHINGTON

PROJ NO. KH150387A

DATE: 10/16

FIGURE: APPENDIX D

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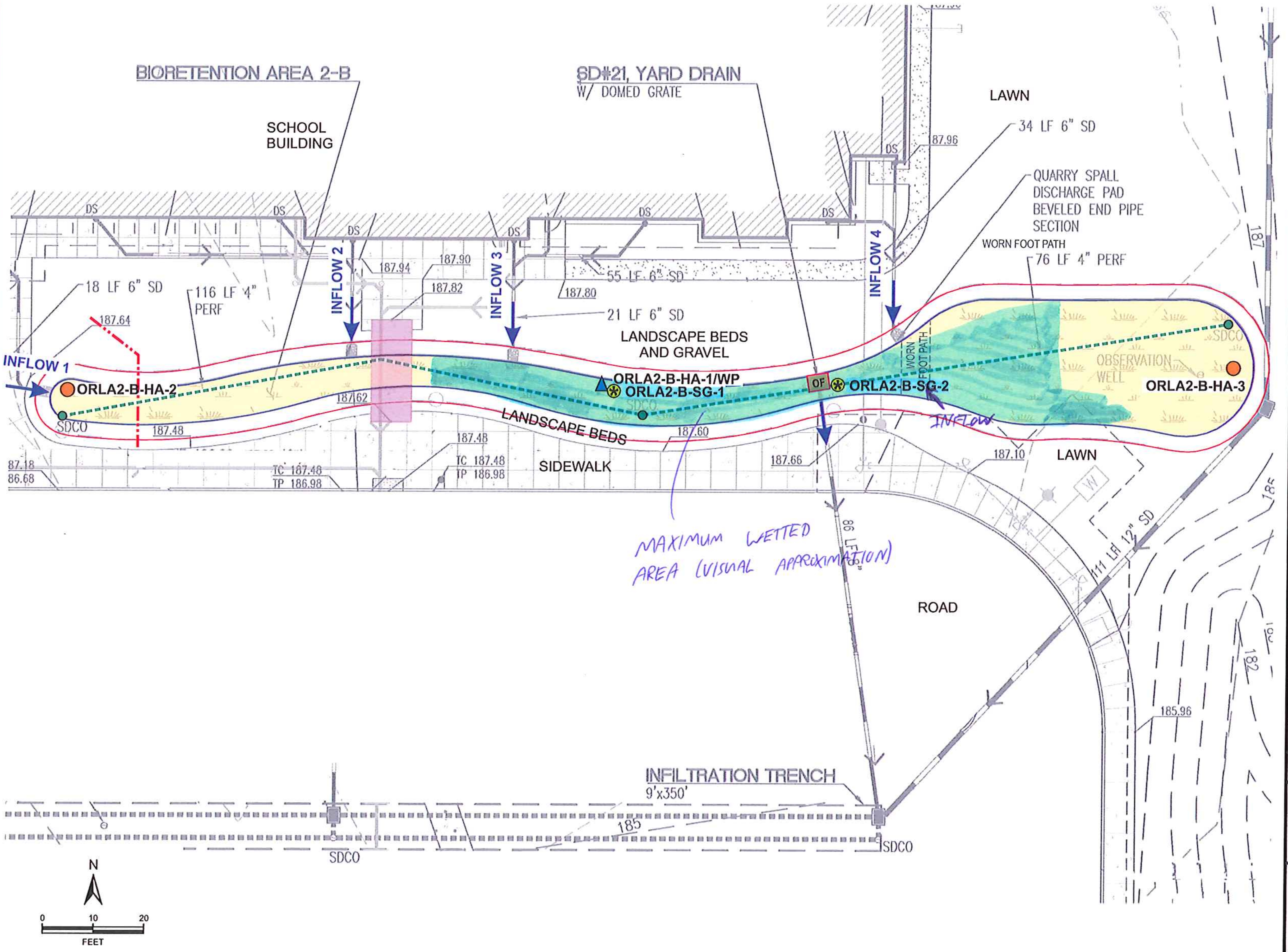

LEGEND:

●	HA	HAND AUGER
▲	WP	WELL POINT
⊛		TEMPORARY STAFF GAUGE
⬭		BASE OF FACILITY
⬭		TOP OF FACILITY SLOPE
→		INFLOW / OVERFLOW DIRECTION
OF		OVERFLOW GRATE
······		UNDERDRAIN
●		STORM DRAIN CLEANOUT
-·-·-		GAS LINE
▨		PEDESTRIAN BRIDGE

CONTOUR INTERVAL = 1'

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:
1. BASE MAP REFERENCE: LPD ENGINEERING, OLYMPIA REGIONAL LEARNING ACADEMY, GRADING / DRAINAGE PLAN, SHEET C2.4, 5/18/2015

BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION.

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WETTED AREA

ORLA2-B SITE
BIORETENTION HYDROLOGIC PERFORMANCE
THURSTON COUNTY, WASHINGTON

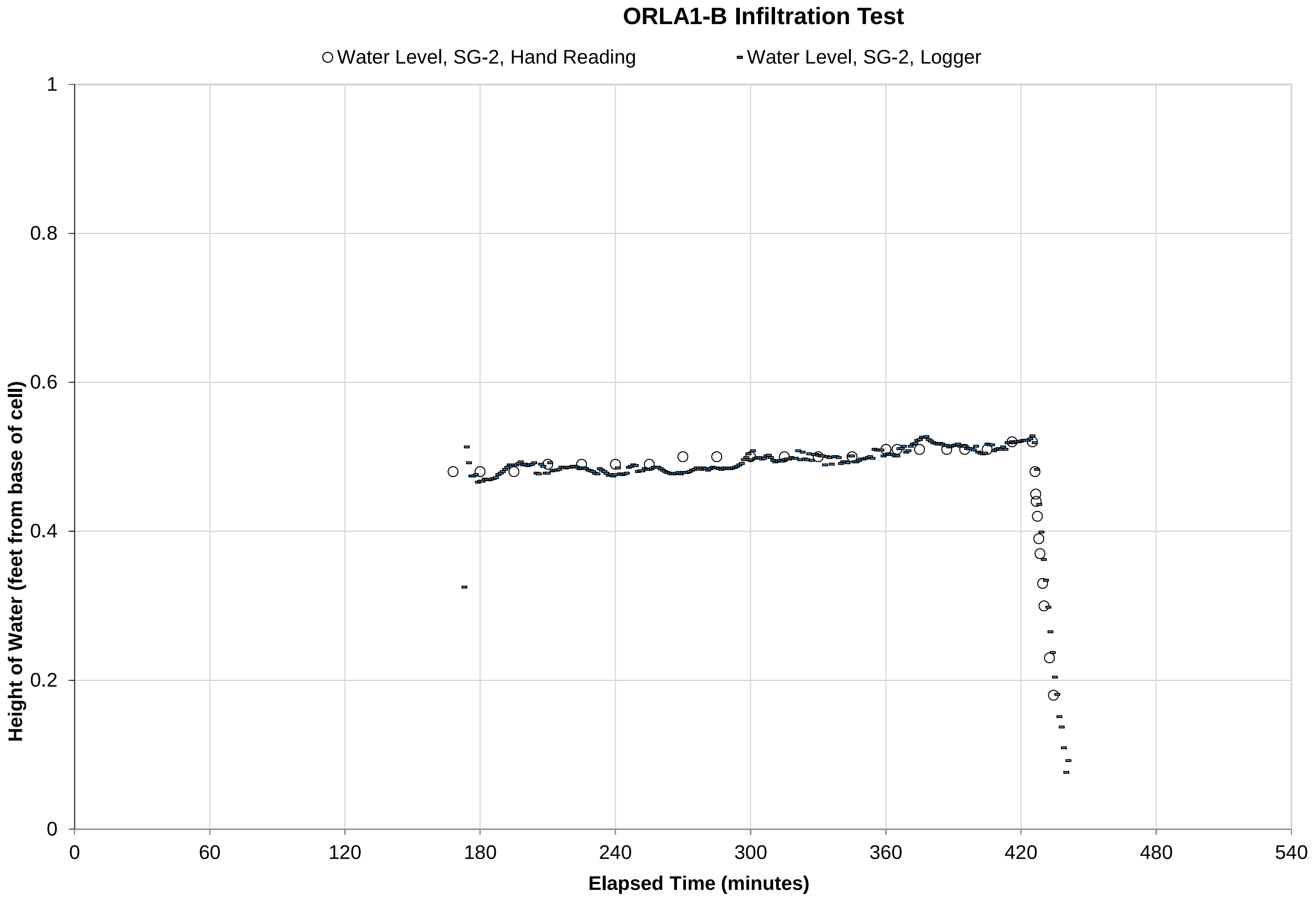
PROJ NO.	DATE:	FIGURE:
KH150387A	10/16	APPENDIX D

150387 BHPS MCCA \ 150387 Site-Expl.cdr PAGE 7: ORLA 2B

Project Name	Bioretention Hydrologic Performance Assessment	**Receptor Soils**	Bioretention Soil over Qvr
Project Number	KH150387A	**Testing Performed By**	ADY
Date	8/30/16		
Weather	Clear		
Test No.	ORLA1-B IT-1		
Meter	FM7		
Water Source	Hydrant		

Time (24-hr)	Total (min)	Flow Rate (gpm)	Totalizer (gallons)	SG-1 Stage (ft)	SG-2 Stage (ft)	Depth to water, well point (feet)	Depth to water, below rim of overflow grate (ft)	Wetted area (ft^2)	Notes
9:15:00	0.0	68.00	0	0.00					Flow on
9:21:00	6.0	185.12	751	0.00					
9:30:00	15.0	191.68	2459	0.00					
9:51:00	36.0	190.28	6468	0.00		Dry	2.40		
10:00:00	45.0	189.85	8185	0.00					
10:15:00	60.0	189.83	11035	0.00		Dry	2.40	440	
10:30:00	75.0	189.98	13908	0.00					
10:45:00	90.0	190.14	16734	0.00					
11:00:00	105.0	190.61	19654	0.00					
11:15:00	120.0	191.53	22496	0.00		Dry	2.40		
11:30:00	135.0	191.68	25365	0.00					
12:03:00	168.0	190.76	31622	0.00	0.48				
12:15:00	180.0	190.44	33957	0.00	0.48				
12:30:00	195.0	190.44	36739	0.00	0.48				
12:45:00	210.0	191.06	39649	0.00	0.49				
13:00:00	225.0	188.17	42530	0.00	0.49				
13:15:00	240.0	190.60	45298	0.00	0.49	Dry	2.40		
13:30:00	255.0	188.79	48062	0.00	0.49				
13:45:00	270.0	187.24	50912	0.00	0.50				
14:00:00	285.0	187.40	53736	0.00	0.50				
14:15:00	300.0	188.17	56681	0.00	0.50				

Time (24-hr)	Total (min)	Flow Rate (gpm)	Totalizer (gallons)	SG-1 Stage (ft)	SG-2 Stage (ft)	Depth to water, well point (feet)	Depth to water, below rim of overflow grate (ft)	Wetted area (ft^2)	Notes
14:30:00	315.0	186.94	59387	0.00	0.50	Dry	2.40		
14:45:00	330.0	189.39	62265	0.00	0.50				
15:00:00	345.0	188.48	65035	0.00	0.50				
15:15:00	360.0	188.17	67853	0.00	0.51	Dry	2.40		
15:20:00	365.0	188.17	68821	0.00	0.51				
15:30:00	375.0	188.17	70753	0.00	0.51				
15:42:00	387.0	187.39	72948	0.00	0.51				
15:50:00	395.0	189.26	74456	0.00	0.51				
16:00:00	405.0	188.94	76344	0.00	0.51				
16:11:00	416.0	188.02	78435	0.00	0.52				
16:20:00	425.0	188.92	80164	0.00	0.52			710	Flow off, begin falling head
16:21:15	426.3			0.00	0.48				
16:21:30	426.5			0.00	0.45				
16:21:45	426.8			0.00	0.44				
16:22:14	427.2			0.00	0.42				
16:22:56	427.9			0.00	0.39				
16:23:27	428.5			0.00	0.37				
16:24:31	429.5			0.00	0.33				
16:25:14	430.2			0.00	0.30				
16:27:35	432.6			0.00	0.23				
16:29:22	434.4			0.00	0.18				
	439.0				0.08	Dry			End test, retrieve dataloggers


ORLA1-B Infiltration Test
○ Water Level, SG-2, Hand Reading
▬ Water Level, SG-2, Logger
Height of Water (feet from base of cell)
1
0.8
0.6
0.4
0.2
0
0
60
120
180
240
300
360
420
480
540
Elapsed Time (minutes)

Project Name	Bioretention Hydrologic Performance Assessment	**Receptor Soils**	Bioretention Soil over Qvs
Project Number	KH150387A	**Testing Performed By**	ADY/LSN
Date	8/31/16		
Weather	Cloudy, rain		
Test No.	ORLA2-B IT-1		
Meter	FM7		
Water Source	Hydrant		

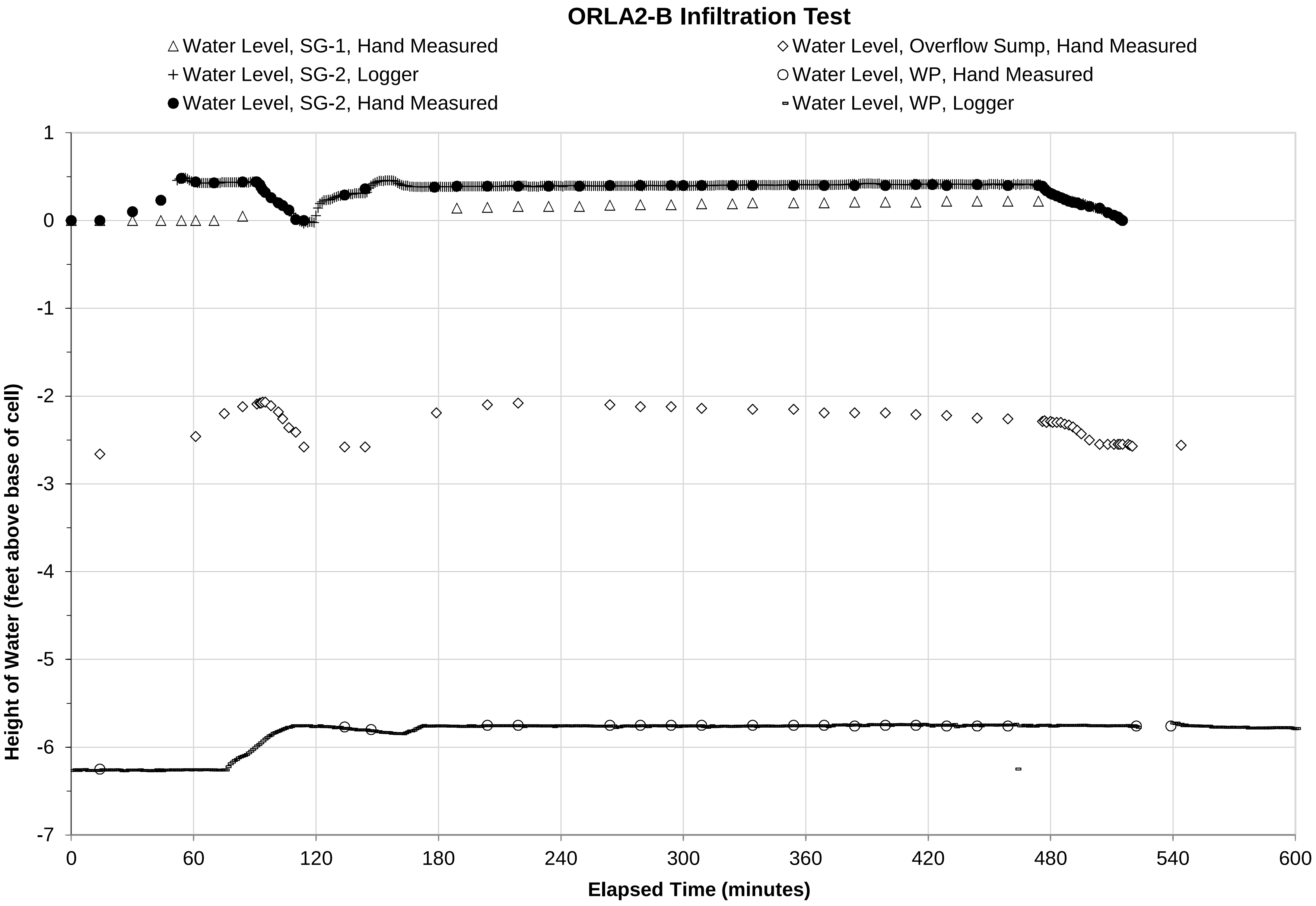
Time (24-hr)	Total (min)	Flow Rate (gpm)	Totalizer (gallons)	SG-1 Stage (feet)	SG-2 Stage (feet)	Depth to water, well point (feet)	Depth to water, from overflow rim (feet)	Wetted area (ft^2)	Inlet 1 status	Inlet 2 status	Inlet 3 status	Inlet 4 status	West underdrain cleanout, depth to water below rim (feet)	Notes
8:06:00	0.0	126.00	0	0.00	0.00									Cloudy, flow on; 08:19 base is wet at SG-2
8:20:00	14.0	127.18	1874	0.00	0.00	8.25	3.16							08:15 no flow into overflow from underdrain pipe
8:36:00	30.0	127.18	3945	0.00	0.10									Flow increased
8:50:00	44.0	191.53	6548	0.00	0.23									08:58 place datalogger at SG-2
9:00:00	54.0	190.13	8336	0.00	0.48									09:02 flow decreased
9:07:00	61.0	130.00	9614	0.00	0.44		2.96							Flow observed from underdrain pipe into overflow structure; 09:06 surface is wet at SG-1
9:16:00	70.0	131.00	10609	0.00	0.43									

Time (24-hr)	Total (min)	Flow Rate (gpm)	Totalizer (gallons)	SG-1 Stage (feet)	SG-2 Stage (feet)	Depth to water, well point (feet)	Depth to water, from overflow rim (feet)	Wetted area (ft^2)	Inlet 1 status	Inlet 2 status	Inlet 3 status	Inlet 4 status	West underdrain cleanout, depth to water below rim (feet)	Notes
9:20:00	74.0	130.00						890						When flow at 190 gpm, east end of facility generally saturated; when flow at 130 gpm, east end of facility partially dried
9:21:00	75.0						2.70							
9:30:00	84.0	130.00	12443	0.05	0.44		2.62							
9:36:30	90.5	131.00	13370		0.44									Flow off, begin short falling head test
9:37:00	91.0	0.00	13370		0.44		2.59							
9:38:25	92.4	0.00	13370		0.41		2.58							
9:39:02	93.0	0.00	13370		0.38		2.58							
9:39:50	93.8	0.00	13370		0.35		2.57							
9:41:05	95.1	0.00	13370		0.32		2.57							
9:43:54	97.9	0.00	13370		0.26		2.61							
9:47:30	101.5	0.00	13370		0.20		2.68							
9:49:40	103.7	0.00	13370		0.17		2.76							
9:52:40	106.7	0.00	13370		0.12		2.86							
9:56:05	110.1	0.00	13370		0.01		2.91							
10:00:00	114.0	0.00	13370		0.00		3.08							
10:02:00	116.0	0.00	13370											Flow on, resume constant head test
10:20:00	134.0	0.00	14324		0.29	7.77	3.08							
10:30:00	144.0	0.00	15057		0.36		3.08							
10:33:00	147.0	0.00				7.80								
10:42:00	156.0	0.00												Flow decreased

Time (24-hr)	Total (min)	Flow Rate (gpm)	Totalizer (gallons)	SG-1 Stage (feet)	SG-2 Stage (feet)	Depth to water, well point (feet)	Depth to water, from overflow rim (feet)	Wetted area (ft^2)	Inlet 1 status	Inlet 2 status	Inlet 3 status	Inlet 4 status	West underdrain cleanout, depth to water below rim (feet)	Notes
11:04:00	178.0	0.00			0.38									SG-2 water is ~3-INCHES below top of lip of overflow
11:05:00	179.0	0.00					2.69							
11:15:00	189.0	84.28	19226	0.14	0.39									
11:30:00	204.0	84.76	20480	0.15	0.39	7.75	2.60	1026	1.75 in of head in pipe; 1 gpm flow	buried but water visible	rocks in pipe; 1 gpm flow	mostly submerged	dry	Rain begins
11:45:00	219.0	83.97	21770	0.16	0.39	7.75	2.58							Decreasing rain
12:00:00	234.0	83.97	23076	0.16	0.39									
12:15:00	249.0	83.50	24339	0.16	0.39									
12:30:00	264.0	83.65	2559	0.18	0.40	7.75	2.60	1044	trace flow	trace water visible	trace flow	mostly submerged	2.13 ft to water from toc	Light sprinkle
12:45:00	279.0	83.49	26794	0.18	0.40	7.75	2.62							
13:00:00	294.0	83.97	28041	0.18	0.40	7.75	2.62							
13:06:00	300.0				0.40									SG-2 water is ~2.75 INCHES below top of lip of overflow
13:15:00	309.0	83.65	29318	0.19	0.40	7.75	2.64							
13:30:00	324.0	83.65	30558	0.19	0.40									
13:40:00	334.0	83.34	31374	0.20	0.40	7.75	2.65	1044	no flow/no water	no flow/no water	no flow/no water	mostly submerged	2	Cloudy
14:00:00	354.0	84.28	33060	0.20	0.40	7.75	2.65							
14:15:00	369.0	83.65	34322	0.20	0.40	7.75	2.69							
14:30:00	384.0	84.44	35586	0.21	0.40	7.76	2.69	1059.0	no flow/no water	no flow/no water	no flow/no water	mostly submerged	2.1	Cloudy, SG-2 water is ~3 INCHES below top of lip of overflow

Time (24-hr)	Total (min)	Flow Rate (gpm)	Totalizer (gallons)	SG-1 Stage (feet)	SG-2 Stage (feet)	Depth to water, well point (feet)	Depth to water, from overflow rim (feet)	Wetted area (ft^2)	Inlet 1 status	Inlet 2 status	Inlet 3 status	Inlet 4 status	West underdrain cleanout, depth to water below rim (feet)	Notes
14:45:00	399.0	83.65	36836	0.21	0.40	7.75	2.69							
15:00:00	414.0	83.65	38097	0.21	0.41	7.75	2.71							
15:08:00	422.0				0.41									SG-2 water is ~2.88 INCHES below top of lip of overflow
15:15:00	429.0	80.73	39354	0.22	0.40	7.76	2.72							
15:30:00	444.0	82.26	40523	0.22	0.41	7.76	2.75							
15:45:00	459.0	81.90	41849	0.22	0.40	7.76	2.76	1059.0	no flow/no water	no flow/no water	no flow/no water	mostly submerged	2.1	Light sprinkle
16:00:00	474.0	82.20	43071	0.22	0.40									Flow off, begin falling head
16:02:00	476.0				0.39		2.79							
16:03:00	477.0				0.36		2.78							
16:04:00	478.0				0.34		2.80							
16:06:00	480.0				0.31		2.79							
16:07:00	481.0				0.30		2.80							
16:09:00	483.0				0.28		2.80							
16:11:00	485.0				0.26		2.80							
16:13:00	487.0				0.24		2.82							
16:15:00	489.0				0.22		2.83							
16:17:00	491.0				0.21		2.85							
16:19:00	493.0				0.20		2.89							
16:21:00	495.0				0.18		2.93							
16:25:00	499.0				0.16		3.00							
16:30:00	504.0				0.14		3.05							
16:34:00	508.0				0.09		3.05							
16:37:00	511.0				0.06		3.05							
16:39:00	513.0				0.04		3.05							
16:40:00	514.0				0.02		3.05							

Time (24-hr)	Total (min)	Flow Rate (gpm)	Totalizer (gallons)	SG-1 Stage (feet)	SG-2 Stage (feet)	Depth to water, well point (feet)	Depth to water, from overflow rim (feet)	Wetted area (ft^2)	Inlet 1 status	Inlet 2 status	Inlet 3 status	Inlet 4 status	West underdrain cleanout, depth to water below rim (feet)	Notes
16:41:15	515.3				0.00		3.05							16:43 move logger from SG2 , install in overflow sump
16:44:00	518.0						3.05							
16:45:00	519.0						3.06							
16:46:00	520.0						3.07							Remove logger from overflow sump
16:48:00	522.0					7.76								Remove logger from well point
17:05:00	539.0					7.76								Replace logger in well point (retrieved at later date)
17:10:00	544.0						3.06							Replace logger in overflow sump (retrieved at later date)


ORLA2-B Infiltration Test
△ Water Level, SG-1, Hand Measured
+ Water Level, SG-2, Logger
● Water Level, SG-2, Hand Measured
◇ Water Level, Overflow Sump, Hand Measured
○ Water Level, WP, Hand Measured
- Water Level, WP, Logger
Height of Water (feet above base of cell)
1
0
-1
-2
-3
-4
-5
-6
-7
0
60
120
180
240
300
360
420
480
540
600
Elapsed Time (minutes)

APPENDIX E

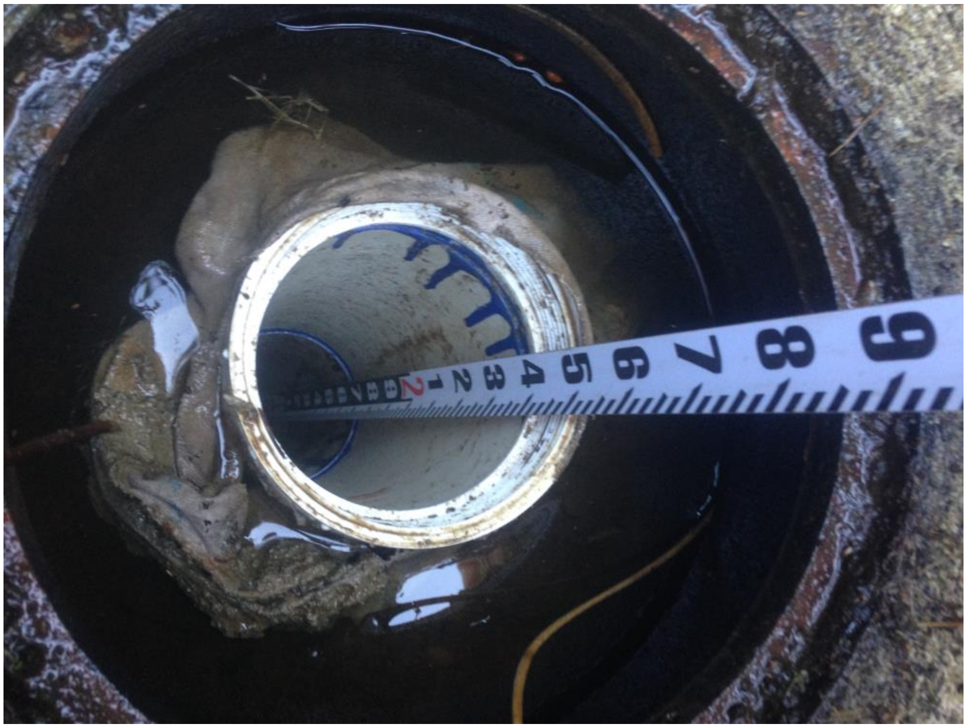
Site Photos

Cell ORLA1-B, western end

Cell ORLA1-B, eastern end

Cell ORLA2-B during infiltration testing, with SG-1 affixed to well point

Overflow structure in Cell ORLA1-B



Pre-existing observation well in Cell ORLA2-B

An inflow pipe to ORLA 2-B.

APPENDIX 9

Deliverable 4.5, Site SLP, Geotechnical/Soils Assessment Design Data and Current Conditions, Spanaway Lake Park, Pierce County, Washington. Associated Earth Sciences, Inc. 10/25/16

associated earth sciences incorporated

Technical Memorandum

Date:	October 25, 2016	**From:**	Jennifer H. Saltonstall, L.G., L.Hg.
To:	Clear Creek Solutions, Inc.	**Project Manager:**	Jennifer H. Saltonstall, L.G., L.Hg.
	15800 Village Green Drive #3 Mill Creek, WA 98012	**Principal in Charge:**	Curtis J. Koger, L.G., L.E.G., L.Hg.
		Project Name:	Bioretention Hydrologic Performance Study
Attn:	Doug Beyerlein, P.E.	**Project No:**	KH150387A
Subject:	Deliverable 4.5, Site SLP, Geotechnical/Soils Assessment Design Data and Current Conditions, Spanaway Lake Park, Pierce County, Washington		

1.0 INTRODUCTION

This technical memorandum documents existing shallow soil and ground water conditions in bioretention cells I (SLP "I") and J (SLP "J") at Spanaway Lake Park, located in Pierce County, Washington (Figure SLP F1). This memorandum was prepared in accordance with Task 4 of the contract scope of work. Associated Earth Sciences, Inc. (AESI) collected shallow soil and ground water conditions data related to bioretention cell function, and documented the current condition of the facility relative to the as-built drawings and available background geotechnical information. The information will be used in the WWHM2012 modeling that will be conducted as part of Task 5 (Data Analysis). In Task 5, the team will compare the previously documented hydrologic design information with our field-collected information and will note where there are significant differences. The purpose of this technical memorandum is to document the collection of current and accurate geotechnical, geologic and hydrogeologic site information for this later work.

The following summary of shallow soil and ground water conditions integrates the observations made during the geotechnical assessment which included site visits on July 28 and August 19, 2016, and infiltration testing on September 13 and 14, 2016.

This technical memorandum has been prepared for the exclusive use of Clear Creek Solutions and the City of Bellingham and their agents for specific application to this project. Within the limitations of scope, schedule, and budget, our services have been performed in accordance with generally accepted hydrogeologic and geotechnical engineering practices in effect in this area at the time our document was prepared. No other warranty, express or implied, is made.

2.0 PURPOSE AND SCOPE

The purpose of our work was to perform a shallow soil and ground water conditions assessment and provide baseline documentation data to assess effectiveness of bioretention hydrologic performance.

Specifically, our scope included the following activities:

- Review of project documents.
- Site reconnaissance.
- Visual condition assessment of erosion and deposition features near inlet and outlet.
- Review project plans relative to constructed facility, in particular, the number and location of inlets, energy dissipation devices, outlets, and other flow-related details.
- Survey elevations of inlet, outlet, well point rim, and other observation points relative to a project datum.
- Excavate shallow hand augers through the bioretention soil and into the underlying material, extending one hand auger deeper into the subgrade for installation of a well point.
- Classify sediment according to the Unified Soil Conservation System (USCS) and *American Society for Testing and Materials* (ASTM) D2488, "Standard Recommended Practice for Description of Soils."
- Collect samples for laboratory testing of (1) particle size distribution in accordance with ASTM D422-63, "Standard Test Method for Particle-Size Analysis of Soils"; (2) organic matter content per ASTM D2974.
- Conduct qualitative assessment of bioretention soil compaction via T-probe.
- Conduct infiltration testing.
- Preparation of descriptive exploration logs for each exploration.
- Preparation of this summary document.

Topography of the site and surrounding area is shown on Figure SLP F2, "LiDAR-Based Topography." Existing facility features and the locations of hand-auger boreholes completed for this study are shown on Figure SLP F3, "Facility and Exploration Plan I" and Figure SLP F4, "Facility and Exploration Plan J." Project civil plans are attached as Appendix A. Exploration logs and laboratory testing data for current study are attached as Appendix B. Background soil, geology, and ground water information are attached as Appendix C. Soil probe, level survey, and field infiltration testing data are attached as Appendix D. Site photos are attached as Appendix E.

3.0 SITE DESCRIPTION AND DESIGN BACKGROUND

The project site is the Pierce County Spanaway Lake Park Stormwater Retrofit Project, located at 14905 Bresemann Boulevard South, in the Spanaway area of unincorporated Pierce County, Washington, as shown on the attached "Vicinity Map" (Figure SLP F1). Spanaway Lake Park is about 135 acres in size, and is roughly delineated by Military Road South to the north, by Bresemann Boulevard South and the Lake Spanaway Golf Course to the east, by 160th Street South and single-family residential homes to the south, and by Spanaway Lake to the west. Spanaway Lake is the largest surface water feature onsite. The lake discharges to the north via Spanaway Creek. Per the Washington State Source Water Assessment Program Mapping Application, the Park is within the 5- and 10-year time of travel area of the Parkland Light and Water Company Well #12 water supply system (Well ID ACY102). LiDAR topography and other near-site vicinity features are illustrated on Figure SLP F2, "LiDAR-Based Topography."

Our specific area of study for this project includes two bioretention areas located in the southern portion of the park area. The cells are referred to as Bioretention Area I and Bioretention Area J, and for this study are referenced as cell SLP "I" and cell SLP "J". Cell SLP "I" is located on the east side of Bresemann Boulevard South, between the road on the east and the Lake Spanaway Golf Course on the west. Cell SLP "J" is located adjacent to a large parking lot, between the parking lot on the east and a natural area with slopes leading down to Spanaway Lake on the west. The attached "Facility and Exploration Plan I" (Figure SLP F3) and "Facility and Exploration Plan J" (Figure SLP F4) illustrates the cell area and some of the surrounding site features and utilities.

Details of the bioretention facility design and basis were presented in the following documents:

- *Spanaway Lake Park Stormwater Retrofit Preliminary Design Report*, The State of Washington Department of Ecology and Pierce County Surface Water Management, January 10, 2013.
- Spanaway Lake Park L.I.D. Retrofit – Phase 1, C.I.P. #D415-006, 2015, Pierce County Surface Water Management, undated.

3.1 Summary of Facility Design

From our review of these documents, the bioretention facility design for cell SLP "I" consists of approximately a square bioretention cell with approximately 1,100 square feet of base area, as shown on Figure SLP F3, "Facility and Exploration Plan I," and modeled using WWHM3 Pro based on a developed condition basin of about 0.43 acres. Land use within the drainage basin to cell SLP "I" is primarily impervious access road. The bioretention facility design for cell SLP "J" consists of approximately a square bioretention cell with approximately 1,080 square feet of base area, as shown on Figure SLP F4, "Facility and Exploration Plan J," and modeled using WWHM3 Pro based on a developed condition basin of about 0.62 acres. Land use within the drainage basin to cell SLP "J" is primarily impervious parking lot. Both facilities were sized using WWHM-3 with a design infiltration rate of 1.5 inches per hour (in/hr) and a factor of safety of 4, and both cells include 3 inches of bark or wood chip mulch overlying 2 feet of bioretention soil mix, overlying native soil. Cell SLP "I" is designed to infiltrate 100 percent of the annual inflow into the subgrade. Cell SLP "J" is designed to infiltrate about 99.9 percent of the annual inflow into the subgrade. Based on the infiltration rate assumptions, the design report indicates that cell SLP "J" will infiltrate up to the 15-year peak flow. The facilities were constructed and began receiving runoff in November 2013 (Email communication, Dawn Anderson, Pierce County, September 6, 2016).

Inflow to cell SLP "I" is from a curb cut in Bresemann Boulevard. Water can pond up to about 1.8 feet before overflow back through the curb cut would occur. There is no designed emergency overflow structure in cell SLP "I".

Inflow to cell SLP "J" is from two curb cuts on the northeast side of the cell. One of the curb cuts includes a small forebay area. If ponding occurs in cell SLP "J", the ponded water would discharge into an overflow structure. The rim of the overflow structure is about 1.8 feet above the base of the cell. The overflow structure discharges to Spanaway Lake.

4.0 SITE OBSERVATIONS

During AESI's site visits, we made notes regarding the physical construction of the bioretention facilities including documenting site inlet/outlet layout relative to site plans and qualitative bioretention soil thickness and compaction. These notes were used to indicate key features of the facilities in Figure SLP F3 and Figure SLP F4.

- AESI conducted elevation surveys of the facilities using a Leitz C40 automatic level and a stadia rod. An arbitrary project datum was established for these surveys; for each facility a nearby feature (indicated on the survey data map included in the Appendices) was defined as project datum elevation 100 feet. All other elevations measured by the surveys are relative to these project datum. Key level data are summarized in Table 1 and Table 2. Additional data points are included in Appendix D to this document. These surveys were not conducted by a licensed surveyor. Surveyed elevations are expected to be sufficiently accurate for this general assessment of facility construction, but may be inaccurate for purposes requiring greater precision.

- AESI investigated the loose bioretention soil thickness present in the bioretention cells using a geotechnical soil T-probe. This qualitative data was used in conjunction with the hand-auger observations to understand loose soil thickness and relative potential compactness of the bioretention soils at depth. AESI measured the depth of penetration of the soils probe at locations generally arranged in a 5-foot spacing along several lines spanning the base of each facility. The apparent thickness of bioretention soil generally ranged from approximately 1.9 feet to 2.1 feet and averaged 2 feet in cell SLP "I", and ranged from approximately 2 feet to 2.4 feet in cell SLP "J", with an average of 2.2 feet. Probe penetration data is included in Appendix D to this document.

- <u>Cell SLP "I" Inflow</u>: One inflow to the facility is present, which consists of a 2.8-foot-wide curb cut, which discharges onto an approximately 8-foot-long by 5-foot-wide round-bottomed trench lined with angular rock up to 1 foot in size. No evidence of erosion was noted. AESI observed heavy deposition of leaf litter up to 0.3 feet thick which continued in a thick layer to approximately 16 feet beyond the end of the rock-lined trench, and terminated abruptly at this point.

- Cell SLP "I" Ponding Depth and Overflow: No overflows are present for this facility. Water can pool up to the level of the curb cut and then overflow. The ponding depth, based on the curb cut and level survey shots of cell base, ranges from 0.9 to 1.1, with the surface of the cell slightly sloping downward to the northeast.
- Cell SLP "I": Pierce County Parks personnel (Rebecca Little, conversation onsite, September 14, 2016) indicated that historically, ponded water has often been observed in Bioretention Area I during winter storms, but typically disappears within the day.

- Cell SLP "J" Inflow: Two inflows to the facility are present. These are referred to in this report as Inflow 1 (to the south) and Inflow 2 (to the north) as indicated on Figure SLP F4. Inflow 1 consists of an approximately 2.1-foot-wide curb cut, which discharges onto an approximately 4.5-foot by 8.5-foot pad consisting of angular cobbles to 1 foot. Leaf litter was observed in this inflow and in the vicinity of the discharge area. A channel up to about 1 foot wide and 0.15 foot deep was noted eroded in the surface of the facility base below the rock pad. AESI noted that this inflow was located farther south than shown on plan sheet 11 (Pierce County Surface Water Management, undated plan set). Inflow 2 consists of a curb cut leading to a small forebay area, where a second approximately 2-foot-wide curb cut discharges onto an approximately 4.5-foot by 6.5-foot pad consisting of angular cobbles to 1 foot. Leaf litter was observed in this inflow and in the vicinity of the discharge area. A channel up to 0.65-foot wide and 0.15-foot deep was noted eroded in the surface of the facility base below the rock pad, extending approximately 2.5 feet beyond the rock.

- Cell SLP "J" Overflow: One overflow is present, as indicated on the civil plans. This overflow consists of a cement structure with a metal beehive grate which is approximately 1.65 feet by 1.4 feet. AESI observed no indicators of recent flow into this structure. Stagnant water was present in the sump at 2.89 feet below the rim of the overflow grate, below the inlet of the overflow pipe within the sump.

Table 1
Cell SLP "I"
Summary of Level Survey Data

Location	Elevation (feet, project datum)
(S-1) East corner of northern tree cell	100
(S-2) South corner of southern tree cell	99.9
(S-3) Center of curb side of eastern storm grate	99.36
(S-4) Center of inflow	99.29
Well point, top of casing	101
Survey points in base of cell	On site plan in Appendix D to this document

Table 2
Cell SLP "J"
Summary of Level Survey Data

Location	Elevation (feet, project datum)
(S-1) Curb corner (indicated on figure)	100
(S-2) Curb corner (indicated on figure)	99.88
(S-3) Curb corner (indicated on figure)	99.93
Inlet 2	99.65
Inlet 1	99.84
Well point, top of casing	98.98
Overflow rim	99.33
Survey points in base of cell	On site plan in Appendix D to this document

5.0 SITE SETTING

The text sections below describe our research findings in regards to the topographic, geologic, and hydrogeologic setting of the project site. Our sources of information included the following.

- Site-specific documents cited previously under "Project and Site Description."
- Walsh, T.J., *Geologic Map of the South Half of the Tacoma Quadrangle, Washington*, Washington Division of Geology and Earth Resources, Open File Report 87-3, scale 1:100,000, 1987.
- Geomap NW, *Draft Geologic Map for the Tacoma South 7.5-Minute Quadrangle*, Pacific Northwest Center for Geologic Mapping Studies, University of Washington, 2006.
- Natural Resources Conservation Service, Web Soil Survey, United States Department of Agriculture, http://websoilsurvey.nrcs.usda.gov/, accessed September 2016.
- *Soil Survey of Pierce County area, Washington*, United States Department of Agriculture, Natural Resource Conservation Service (NRCS), 1979.
- Savoca, M.E., Welch, W.B., Johnson, K.H., Lane, R.C., Clothier, B.G., and Fasser, E.T. (Savoca, et al.), *Hydrogeologic Framework, Groundwater Movement, and Water Budget in the Chambers-Clover Creek Watershed and Vicinity, Pierce County, Washington*, United States Geological Survey Scientific Investigations Report 2010–5055, 46 p., 2010.

5.1 Regional Topography and Project Grading

The project site is located on a low, broad topographic plateau within central Pierce County. Regional surface grades are moderately undulating or hummocky, which is typical for a post-glacial landscape. Local surface grades are fairly flat across the site, with an elevation of approximately 350 feet (United States Geological Survey [USGS] datum). Spanaway Lake borders the site on the west and a moderate to steep slope is present at the grade change from the plateau down to lake level.

Maximum elevation within the park is approximately 350 feet above mean sea level; elevation of Spanaway Lake is approximately 320 feet above mean sea level. Cutting to a depth of approximately 4 feet was needed to achieve design bioretention cell grades based on a review of existing topography compared with built topography.

5.2 Regional Geology and Background Geotechnical Information

According to the *Draft Geologic Map of the Tacoma South 7.5-Minute Quadrangle*, the site vicinity is underlain by Vashon recessional outwash, specifically the outburst channel deposits of Vashon-age Steilacoom Gravel (designated Qvs). Steilacoom Gravel (map unit Qvs) as described below:

- Vashon Recessional Outwash - Steilacoom Gravel: This deposit has been described as "sandy gravel and openwork cobbly gravel; clean to silty; poorly to well sorted; horizontally to cross bedded; loose to dense; distinctive black color." Thicknesses can range from 3 feet to 80 feet, with a typical value of about 25 feet. The unit is highly permeable.

No background geotechnical information specific to Spanaway Lake Park was made available to us. The geologic mapping is consistent with our general experience in the area and with the material encountered in our hand-auger explorations, discussed later in this document.

5.3 Regional Soils and Soil Data Used in Site Stormwater Model

AESI reviewed the *Soil Survey of Pierce County Area* (Natural Resources Conservation Service [NRCS], 1979) and soils mapping from the NRCS web portal (NRCS, 2016). The soil survey identifies different soil map units based on parent material, climate, topography (slope), organisms (biota), and time. The soils in the study area formed mostly from young glacial deposits and have not had time to develop the deep weathering profiles present in soils in unglaciated terrains. Instead, they exhibit a direct relationship to the underlying parent material, local climate, topography, and vegetation.

Mapped soils in the project area consist of primarily of Spanaway gravelly sandy loam, which is formed in glacial outwash. NRCS describes the permeability as moderately rapid (2 to 6 in/hr) in the subsoil (from about 15 to 20 in/hr) and very rapid (greater than 20 in/hr) in the substratum.

As described in the *Spanaway Lake Park Stormwater Retrofit Preliminary Design Report* (2013), the pre-developed condition was modeled as Type A and B soils. This is generally consistent with the mapped soil and geology data, which indicates that the site is underlain by Type A soils.

5.4 Regional Hydrogeology and Background Ground Water Data

Regional hydrogeology is described in Savoca et al. (2010), *Hydrogeologic Framework, Groundwater Movement, and Water Budget in Chambers-Clover Creek Watershed and Vicinity, Pierce County, Washington*, USGS Scientific Investigations Report 2010-5055. Savoca et al. (2010)

indicates that the recessional outwash typically forms a shallow unconfined aquifer across most of southwestern Pierce County. The thickness of the recessional outwash aquifer typically ranges from a thin veneer of less than 35 feet to about 150 feet, but is mapped up to about 80 feet thick in the project vicinity.

On a closer scale, the project is located in the Spanaway Creek sub-basin of Clover Creek. Spanaway Lake discharges via Spanaway Creek flowing northward, splitting into Morey Creek and Spanaway Creek, both of which join Clover Creek. Ground water in the vicinity of the site is mapped between elevations of 320 feet (lake level) and 330 feet.

No site background data on ground water was available.

6.0 BIORETENTION CELL SUBSURFACE EXPLORATION AND WELLPOINT INSTALLATION

Limited information on subsurface conditions was obtained for this study from hand-auger samples and soil probe penetration measurements at about 2-foot increments in each hand-augered borehole. In each bioretention cell, two hand-auger borings were performed in the facility bottom and advanced through the bioretention soil to the underlying subgrade. An additional hand-auger boring was completed outside the cell, to obtain a sample of the native material. Representative samples were collected, visually classified in the field, stored in water-tight containers and transported to AESI’s offices for additional classification, geotechnical testing and study. At the conclusion of the excavation, each borehole was immediately backfilled with the excavated material, or completed as a well point and the bioretention soil replaced.

The various types of sediments, as well as the depths where characteristics of the sediments changed, are indicated on the exploration logs presented in Appendix B. A detailed record of the observed bioretention soil, subsurface soil, geology, and ground water conditions was made. The sediments were described by visual and textural examination using the soil classification in general accordance with ASTM D2488, “Standard Recommended Practice for Description of Soils.” The depths indicated on the logs where conditions changed may represent gradational variations between sediment types in the field. The exploration logs in Appendix B are based on the field observations, inspection of the samples, and where applicable, laboratory grain-size analysis. Our explorations were approximately located in the field relative to known site features, and are shown on Figure SLP F3, "Site and Exploration Plan." GPS coordinates for the explorations were taken using a handheld GPS, and are summarized in Appendix B.

The results presented in this document are based on the explorations completed for this study and review of background data. The number, locations, and depths of the explorations were completed within site and budgetary constraints. Because of the nature of exploratory work below ground, interpolation of subsurface conditions between field explorations is necessary. It should be noted that differing subsurface conditions may sometimes be present due to the random nature of deposition and the alteration of topography by past grading and/or filling.

6.1 Hand-Auger Borings in Cell SLP "I"

Hand-auger borings in cell SLP "I" were completed on August 19, 2016. No rain was observed during this time, and no flow was observed from the inlet pipes.

Hand-auger boring number 1 (SLP "I"-HA-1) was completed near the inflow to the cell, and encountered approximately 0.3 feet of leaf litter and bark fragments overlying 2 feet of bioretention soil, overlying material interpreted as Vashon recessional outwash. The native material encountered was dark brown in color. The exploration encountered refusal on cobbles at 2.4 feet. No seepage or caving was observed.

Hand-auger boring number 2 (SLP "I"-HA-2) was completed on the side of the cell opposite the inflow, and encountered approximately 0.1 feet of leaf litter and bark fragments overlying 2.1 feet of bioretention soil, overlying material interpreted as Vashon recessional outwash. The native material encountered was light brown in color. The borehole encountered refusal on a cobble at 2.4 feet. No seepage was observed.

Hand-auger boring number 3 (SLP "I"-HA-3) was completed outside of the cell on the northern edge, and encountered 0.1 feet of topsoil overlying 0.8 feet of material interpreted as Vashon recessional outwash, which was dark brown in color in this location. This exploration encountered refusal on cobbles at 0.9 feet, with no seepage and no caving observed.

6.2 Hand-Auger Borings in Cell SLP "J"

Hand-auger borings in cell SLP "J" were completed on July 28, 2016. No rain was observed during this time, and no flow was observed from the inlet pipes.

Hand-auger boring number 1 (SLP "J"-HA-1) was completed near the inflow to the cell, and encountered approximately 0.3 feet of leaf litter overlying 1.8 feet of bioretention soil, overlying material interpreted as Vashon recessional outwash. The exploration encountered refusal on cobbles at 2.1 feet. No seepage or caving was observed.

Hand-auger boring number 2 (SLP "J"-HA-2) was completed outside of the cell on the southern edge, and encountered 0.2 feet of topsoil overlying 1.2 feet of material interpreted as Vashon recessional outwash, which was dark brown in color in this location. This exploration encountered refusal on cobbles at 1.4 feet, with no seepage and no caving observed.

Hand-auger boring number 3 (SLP "J"-HA-3) was completed near the facility overflow, and encountered 0.2 feet of leaf litter overlying 2 feet of bioretention soil, overlying material interpreted as Vashon recessional outwash. This exploration encountered refusal on cobbles at 2.2 feet. No seepage and no caving were observed.

6.3 Well Points

Well points were installed in HA-2 in cell SLP “I”, and HA-1 in cell SLP “J”. Key dimensions of these well points are provided in Table 3, below.

Table 3
Summary of Cell SLP “I” and SLP “J”
Well Point Dimensions

Well Point	Exploration in which WP was installed	Total Length of Casing (feet)	Interior Diameter	Stickup Height (feet)	Total Depth Inside Casing Below Ground Surface
SLP “I”-WP	SLP “I”-HA-2	5.1	1.25 inch nominal	2.7	2.4
SLP “J”-WP	SLP “J”-HA-1	3.2	1.25 inch nominal	0.6	2.6

7.0 LABORATORY ANALYSIS

Laboratory testing included mechanical grain-size distribution and percent organic matter by weight in accordance with the ASTM D422 and D2974, respectively. Two samples of bioretention soil for each cell were first tested for organic matter content and then the burned material was tested for grain-size distribution for comparison with the aggregate fraction of the bioretention soil mix guidance in the Washington State Department of Ecology (Ecology) 2014 *Stormwater Management Manual for Western Washington* (2014 Ecology Manual). One sample of the subgrade was tested for grain-size distribution. The data is summarized in Table 4.

Table 4
Summary of Cell SLP “I” and SLP “J”
Organic Content and Grain Size Data

Exploration Number	Depth (feet)	Soil Type	Organic Content (% by weight)	USCS Soil Description	Fines Content (% passing #200)	Cu	Cc	USDA Soil Texture*
SLP “I”-HA-1	0.6-1	Bioretention Soil	2.8	SAND (SP)	0.1	2.4	1.1	SAND
SLP “I”-HA-2	0.6-0.9	Bioretention Soil	2.3	SAND (SP)	1.8	3	1	SAND
SLP “I”-HA-2	2.2-2.4	Native	Not tested	Very sandy GRAVEL (GP)	0.4	62.7	1.3	SAND
SLP “J”-HA-1	0.5-1	Bioretention Soil	2.0	SAND (SP)	0.1	3.2	1.7	SAND
SLP “J”-HA-3	0.2-0.5	Bioretention Soil	3.3	SAND (SP)	0.3	2.7	1.3	SAND

USCS: Unified Soil Classification System; Cu: coefficient of uniformity; Cc: coefficient of curvature; USDA: U.S. Dept. of Agriculture; *No hydrometers were performed. USDA soil texture range assumes fines consist entirely of silt to entirely of clay.

7.1 Bioretention Soil Mix

We compared the average organic content and burned fraction gradation against the general guidelines for the bioretention soil mix; see Table 5 below.

The organic content of the tested bioretention soils ranged between 2 to 3.3 percent by weight. The recommended range of organic content by weight is 5 to 8 percent in the 2014 Ecology Manual.

The grain-size analysis test results on the burned soil fraction indicate that the bioretention soils tested generally correlate to a "SAND" based on ASTM D2487 USCS. The respective fines content as measured on the No. 200 sieve ranged from approximately 0.1 to 1.8 percent. The recommended range of fines is 2 to 5 percent in the 2014 Ecology Manual. The coefficient of uniformity ranged from 2.4 to 3.2, consistently less than the recommended value of equal to or greater than 4. The coefficient of curvature ranged from 1.0 to 1.7, consistent with the recommended range of greater than or equal to 1 and less than or equal to 3.

Table 5
General Guidelines for Bioretention Soil Mix (2014 Ecology Manual)
Compared to Averaged Cell SLP "I" and SLP "J" Site Data

Parameter	Recommended Range	SLP "I"	SLP "J"
Organic Content (by weight)	5 to 8 percent	2.6 percent by weight	2.7 percent by weight
Cu coefficient of uniformity	4 or greater	2.7	3
Cc coefficient of curvature	1 to 3	1.1	1.5
Sieve Size	**Percent Passing**		
3/8" (9.51 mm)	100	100	100
#4 (4.76 mm)	95 to 100	99.8	99.8
#10 (2.0 mm)	75 to 90	99.0	99.1
#40 (0.42 mm)	25 to 40	60.3	9.1
#100 (0.15 mm)	4 to 10	3.5	0.8
#200 (0.074 mm)	2 to 5	1.0	0.2

Note: The general guidelines for mineral aggregate gradation are from Table 7.4.1 of the 2014 Ecology Manual.
mm: millimeter

7.2 Subgrade

In SLP "I", a sample of native recessional outwash was sieved. The tested material correlates to a very sandy GRAVEL, trace silt with 0.4 percent by weight of the material passing the No. 200 sieve.

The grain-size distribution data were also transformed to describe the United States Department of Agriculture soil texture. The grain-size distributions were normalized to the No. 10 sieve—i.e., the coarse sand and gravel fraction of the sample is discounted and the remainder is taken as

100 percent of the sample. The fines were assessed relative to the No. 270 sieve. The respective United States Department of Agriculture fines content as measured on the No. 270 sieve after adjusting to remove the weight retained on the #10 sieve was 1 percent for the native recessional outwash material.

8.0 INFILTRATION TESTING

8.1 General Infiltration Test Method

The infiltration tests were conducted in general accordance with the 2014 Ecology Manual. Each test was conducted by discharging water into the facility for a "soaking period," to allow the receptor soils to become saturated. After completion of the soaking period, water was discharged into the cell at a rate sufficient to maintain a relatively constant head. This constitutes the "constant head" phase of infiltration testing. Immediately following the constant head phase of infiltration testing, flow into the facilities was discontinued, and the water level was monitored as it dropped. This constitutes the "falling head" portion of the infiltration testing.

The water for testing was obtained from an on-site fire hydrant and an irrigation pond on the adjacent Lake Spanaway Golf Course. For cell "J", located nearest to the fire hydrant, water was conveyed to the test area with fire hoses (cell SLP "J"). For cell "I", the fire hydrant was too distant from the test cell. The fire hydrant was used to fill an approximately 4,000-gallon capacity water truck, which then intermittently delivered water to an approximately 5,600-gallon tank which was parked next to the facility. Additional water for testing cell SLP "I" was obtained from the nearby irrigation system for the Lake Spanaway Golf Course, and conveyed into the bioretention cell using garden hoses provided by Pierce County Parks personnel.

During infiltration testing of cell SLP "I", the water was conveyed into the bioretention cell via a digital flow meter with gallons per minute (gpm) and total gallon readouts, and discharged through a flow diffuser onto the base of the facilities. For testing cell SLP "J", to maximize possible flow rate, the digital flow meter was removed from the hose and flow rate was monitored using the hydrant meter at the hydrant. Water levels were monitored using a temporary metal staff gauge marked in 0.02-foot increments which was installed for the duration of the test, with a digital water level tape, and with digital pressure transducers. Data from the digital pressure transducers was compensated for barometric response using a separate digital barometer. The area of the pool was measured periodically during testing.

Infiltration tests in each bioretention cell are discussed below, and results are presented in Table 6. Infiltration test data is included in Appendix D to this document.

8.2 Infiltration Test in Cell SLP "I"

AESI performed infiltration testing of cell SLP "I" on September 14, 2016. No rainfall was noted during testing, and no flow from the facility inflow was present. A staff gauge (SG-1) was installed at the well point prior to testing and a second staff gauge (SG-2) was installed near the inflow to the facility during testing. Water levels were measured by hand and by data logger in the well point and the wetted pool. No water was present in the well point or pooled in the cell prior to the start of testing.

During this test, during the initial soak period of 4 hours, water was added to the facility at the maximum rate possible with the on-site water source (up to a combined total of approximately 160 gpm from the storage tank and irrigation water from golf course), which resulted in brief interruptions in flow from the water-truck-supplied tank, when the tank ran dry. The discharge for water into the facility during the infiltration test was located on the northern side of the facility. This location was selected for the inflow during testing because it was the low area and due to anticipated difficulty delineating a wetted pool in the thick leaf litter on the facility base near the curb cut inflow. After the initial soak period, flow was maintained at the maximum rate which could be sustained without interruption (approximately 106 gpm) for approximately 4 hours, during which the water level in the facility fell slowly from approximately 0.3 to 0.26 feet, as measured on the temporary staff gauge near the infiltration test inflow, and was then stable at 0.24 to 0.26 feet. Only trace water (0.06 feet) was observed on the facility surface in the location of the well point, which was present only during a period of maximum possible flow rate prior to the constant head phase of testing, and not present during the constant head phase of testing. The full duration of flow was approximately 7 hours, during which approximately 45,000 gallons of water were used.

After about 7 hours, AESI shut off the flow and monitored water level as it fell. AESI observed a drop in water levels of approximately 0.22 feet during 4 minutes of hand readings on the staff gauge. Water level in the well point was monitored, but no appreciable change was observed beyond trapped water in the end cap.

Table 6
Cell SLP "I" and SLP "J"
Infiltration Test Results

Test No. and Depth	Surface Area (square feet)	Discharge Time (minutes)	Total Volume Discharged (gallons)	Approximate Constant Head Level (feet)	Field Infiltration Rates	
					Constant Head Test (in/hr)	Falling Head Test (in/hr)
SLP "I" bioretention soil	200	444	45,139	0.26	48	41
SLP "I" subgrade	Interpreted to be similar to wetted area				Assumed to be similar to bioretention soil, no overflow.	
SLP "J"	550	503	105,361	0.20	41	59
SLP "J" subgrade	Interpreted to be similar to wetted area				Assumed to be similar to bioretention soil, no overflow.	

in/hr: inches per hour

8.3 Infiltration Test in Cell SLP "J"

AESI performed infiltration testing of cell SLP "J" on September 13, 2016. No rainfall was noted during testing, and no flow from the facility inflows was present. A staff gauge (SG-1) was installed at the well point prior to testing and a second staff gauge (SG-2) was installed near the inflow to the facility during testing. Water levels were measured by hand and by data logger in the well point and the wetted pool. No water was pooled in the cell prior to the start of testing. Prior to testing, water was observed at 3.16 feet below the top of the well point; the water was within the end cap and is 'trapped.'

During this test water was added to the facility at the maximum rate possible using the direct connection to the on-site fire hydrant through the initial soak period and the constant head period. Flow was maintained at approximately 233 gpm for about 8.5 hours, during which approximately 105,000 gallons of water was used. Inflow to the facility was directed onto the rock splash pad surrounding the northern facility inflow. During the final 2 hours of testing, the water level in the facility was stable at approximately 0.2 feet, as measured on the temporary staff gauge near the infiltration test inflow, and water was observed on the surface of the facility in the location of the well point to a depth of 0.18 to 0.2 feet, increasing slowly over time. Water was observed in the well point during the constant head phase of testing, and rose to as high as approximately 1.63 feet below ground surface.

After about 8.5 hours, AESI shut off the flow and monitored water level as it fell. AESI observed a drop in water levels of approximately 0.22 feet during 3.5 minutes of hand readings. During testing, the water level in the well point was present at approximately 2.2 feet below the top of the casing (about 1.6 feet below top of casing) and was stable at this level throughout the final four hours of testing. After inflow was shut off, within about 3 minutes, the water level in the well point dropped to 2.67 feet (the approximate base of screen/top of end cap).

9.0 CONCLUSIONS AND RECOMMENDATIONS

Cells SLP "I" and SLP "J" varied somewhat from the design shown on the civil plan sheets. Variations included the following:

- Bioretention Soil
    - Thickness: Both cells contained areas where the bioretention soil was greater than the planned 2 feet in thickness. Accumulated leaf/pine needle debris was notable in both cells near the inlets, added about 0.2 to 0.3 to the loose soil thickness.
    - Composition: The soil tested in cells SLP "I" and SLP "J" did not meet (contained less than) the recommended guidelines for organic content or silt content. Neither the soil from cells SLP "I" or SLP "J" met the recommended guidelines for fine sand; SLP "I" had slightly too much material passing the #40 sieve, and SLP "J" had too little

material passing the #40 sieve. We interpret that a different load of bioretention soil was placed in SLP "I" than in SLP "J" illustrating variations from the bioretention soil supplier.

- The southern inflow to cell SLP "J" was not constructed in the location indicated on the plan sheet (Sheet 11, Pierce County Surface Water Management, 2015).
- In SLP "J", during infiltration testing, water rose in the well point to a stable level of approximately 1.6 feet below level of bioretention soil. AESI interprets the water level during testing as representative of pooled water within the pore spaces in the bioretention soil.
- Field infiltration rates were higher than 40 in/hr, and were generally similar in both facilities. Water readily soaked through the bioretention soil mix. Minor pooling in the subsurface in cell "J" was observed in the well point, supporting vertical infiltration. AESI interprets that the native soil rate is similar to that of the bioretention soil. These high infiltration rates are consistent with the geological and soils mapping in the area.

10.0 CLOSURE

We appreciate the opportunity to be of continued service to you on this project. Should you have any questions regarding this document or other geotechnical/hydrogeologic aspects of the project, please call us at your earliest convenience.

State of Washington
Licensed Geologist
Hydrogeologist
2335
Jennifer H. Saltonstall

Jennifer Saltonstall
10/25/16

Anton Ypma,
Staff Geologist

Curtis Koger

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Senior Associate Geologist/Hydrogeologist

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Attachments:	Figure SLP F1:	Vicinity Map
	Figure SLP F2:	LiDAR-Based Topography
	Figure SLPF3:	Facility and Exploration Plan SLP "I"
	Figure SLPF4:	Facility and Exploration Plan SLP "J"
	Appendix A:	Project Civil Plans
	Appendix B:	Current Study Exploration Logs and Laboratory Testing Data
	Appendix C:	Background Soil, Geology, and Ground Water Data (Regional Maps, Previous Studies Exploration Logs and Laboratory Testing Data)
	Appendix D:	Soil Probe, Level Survey, and Field Infiltration Testing Data
	Appendix E:	Site Photos

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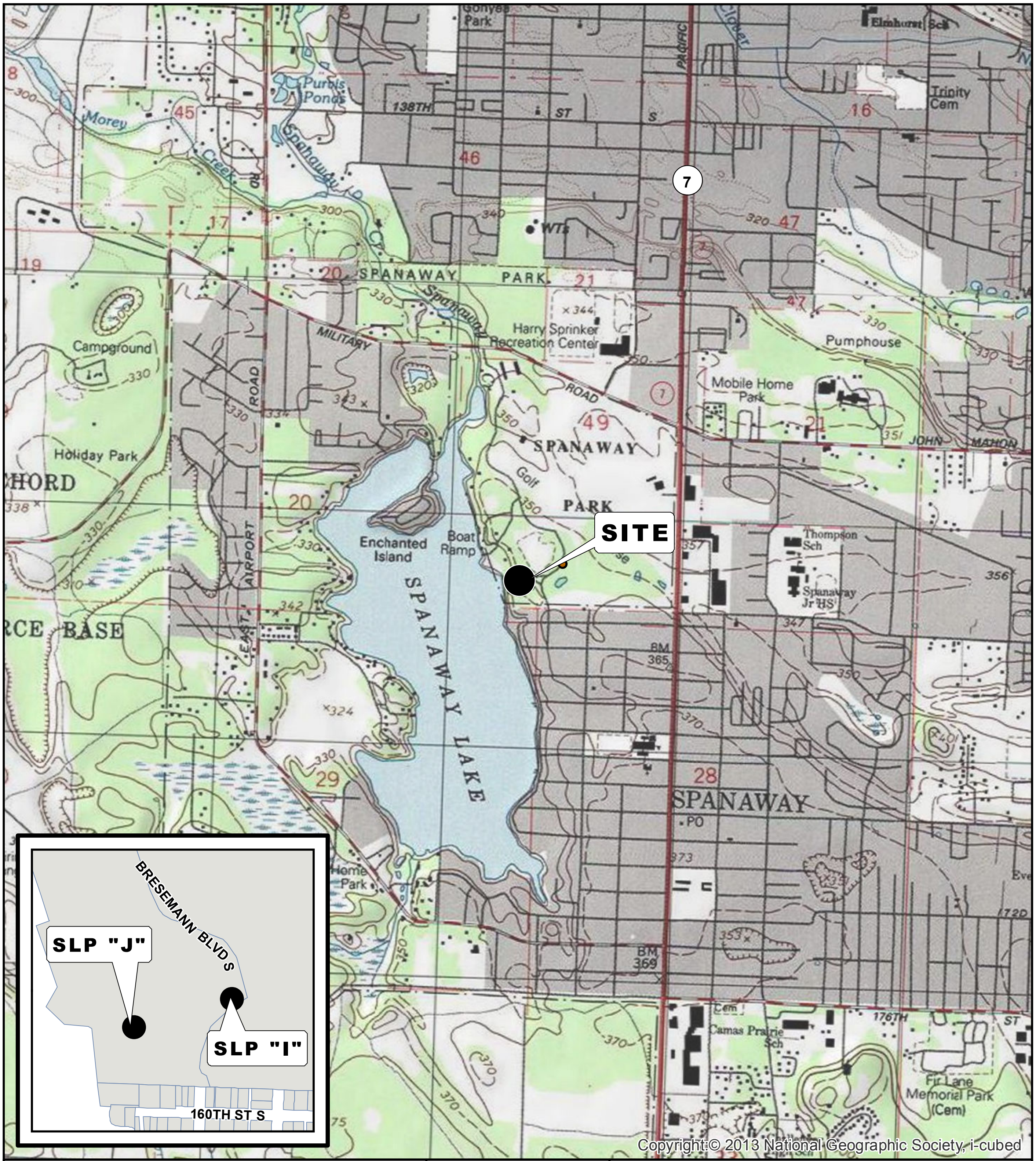

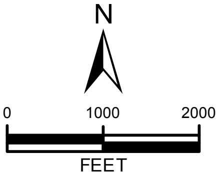

DATA SOURCES / REFERENCES:
USGS: 24K SERIES TOPOGRAPHIC MAPS
PIERCE CO: STREETS, PARCELS 2015

LOCATIONS AND DISTANCES SHOWN ARE APPROXIMATE

NOTE: BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION

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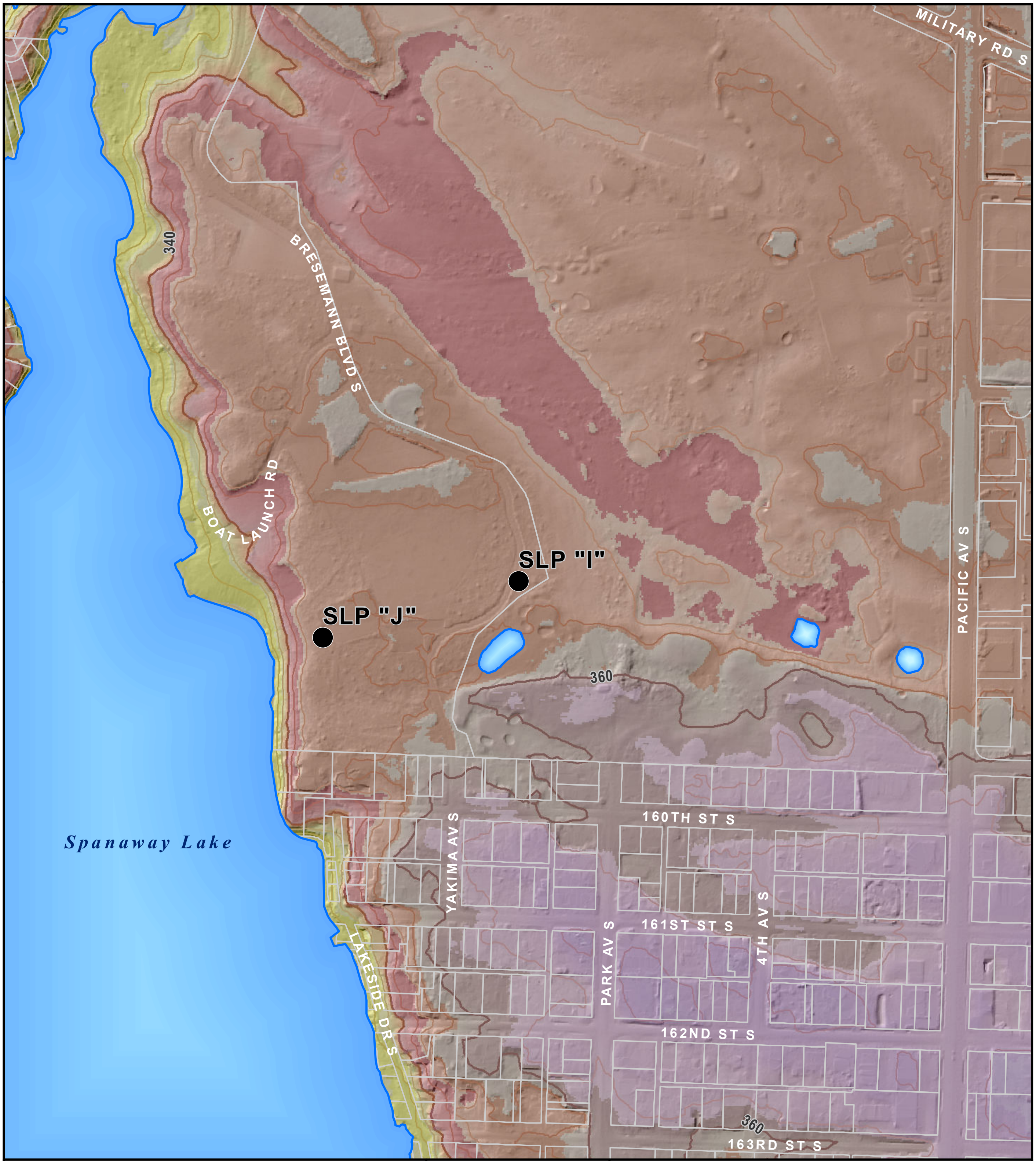
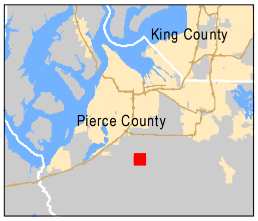
VICINITY MAP

BIORETENTION HYDROLOGIC PERFORMANCE STUDY, SLP SITE
PIERCE COUNTY, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	SLP F1

Document Path: G:\GIS_Projects\aYear2015\postJuly2016\150387 Bioretention Hydro Performance Monitoring\mxd\Fig1s\150387 SLP Fig1 ProjectVicinity.mxd





DATA SOURCES / REFERENCES:
PSLC: LIDAR 2000-2005 SUPERMOSAIC, 6' CELL, PIERCE CO 2010 3' CELL
PIERCE CO: STREETS, PARCELS 2016

LOCATIONS AND DISTANCES SHOWN ARE APPROXIMATE

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NOTE: BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION

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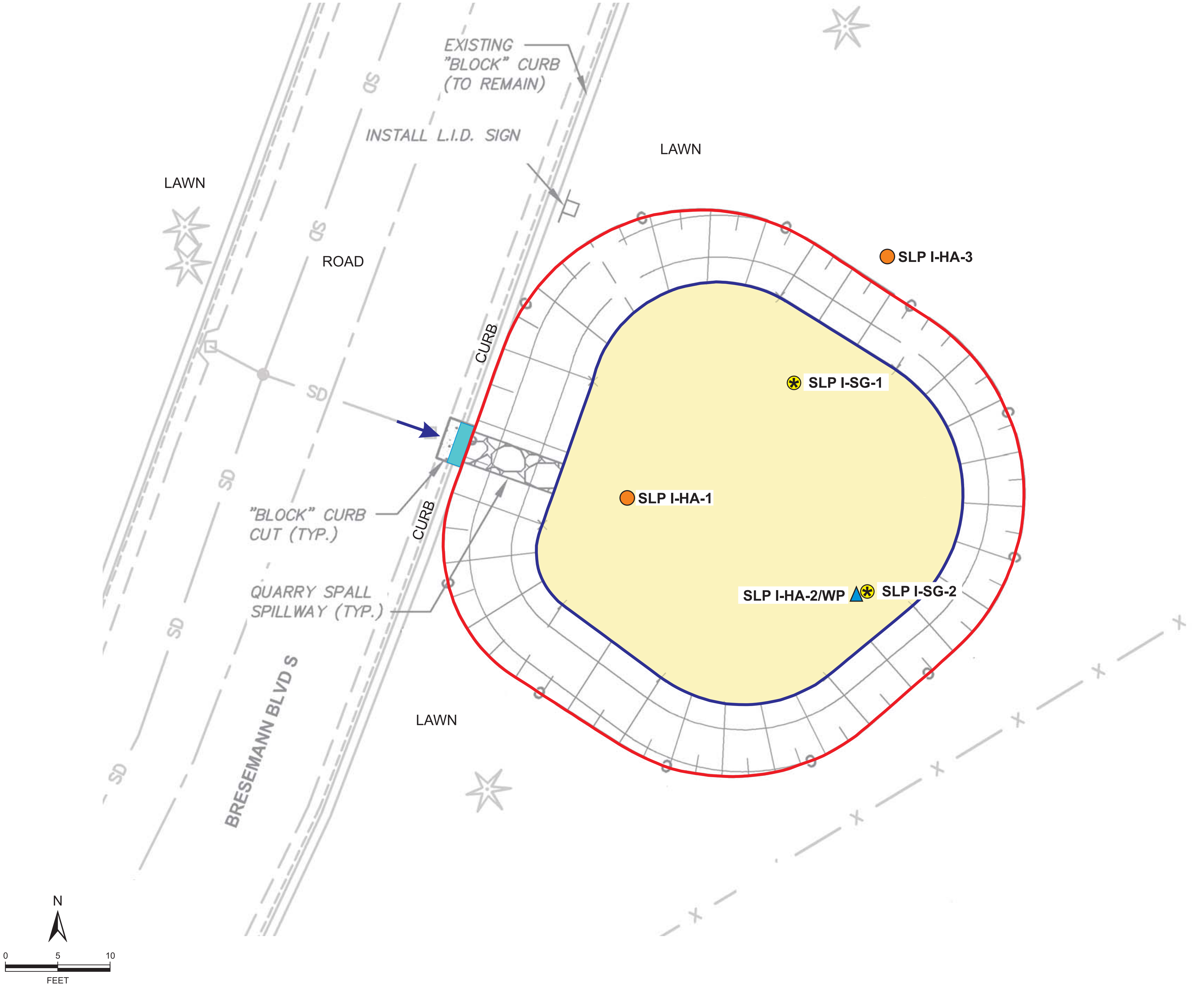
LIDAR BASED TOPOGRAPHY

BIORETENTION HYDROLOGIC
PERFORMANCE STUDY, SLP SITE
SPANAWAY, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	SLP F2

Document Path: G:\GIS_Projects\aYear2015postJuly2016\150387 Bioretention Hydro Performance Monitoring\mxd\Fig2s\150387 SLP Fig2B LIDAR.mxd



LEGEND:

● HA	HAND AUGER
▲ WP	WELL POINT
⊛	TEMPORARY STAFF GAUGE
⬭	BASE OF FACILITY
⬭	TOP OF FACILITY SLOPE
→	INFLOW / OVERFLOW DIRECTION
▬	CURB CUT

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:
1. BASE MAP REFERENCE: PIERCE COUNTY DEPARTMENT OF PUBLIC WORKS, SPANAWAY LAKE PARK LID RETROFIT - PHASE 1, BIORETENTION AREAS H AND I, SHEET 10 OF 16, UNDATED

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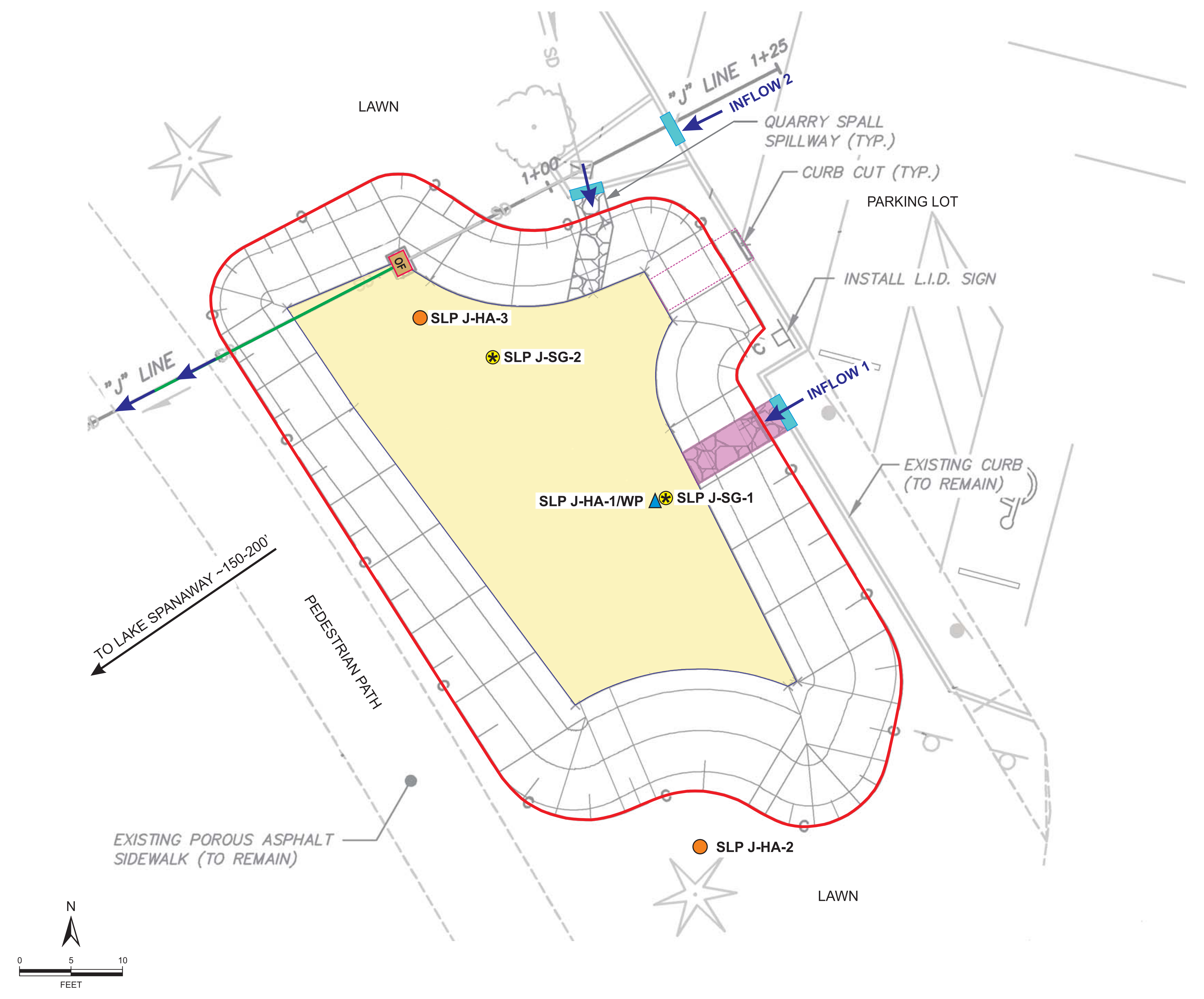
FACILITY AND EXPLORATION PLAN
SLP"I" SITE

BIORETENTION HYDROLOGIC PERFORMANCE
PIERCE COUNTY, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	SLP F3



LEGEND:

● HA	HAND AUGER
▲ WP	WELL POINT
⊛	TEMPORARY STAFF GAUGE
▭	BASE OF FACILITY
▭	TOP OF FACILITY SLOPE
→	INFLOW / OVERFLOW DIRECTION
OF	OVERFLOW GRATE
—	STORM DRAIN
▭	ORIGINAL LOCATION OF SPILLWAY
▬	RELOCATED SPILLWAY
▬	CURB CUT

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:

1. BASE MAP REFERENCE: PIERCE COUNTY DEPARTMENT OF PUBLIC WORKS, SPANAWAY LAKE PARK LID RETROFIT - PHASE 1, BIORETENTION AREA J, SHEET 11 OF 16, UNDATED

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FACILITY AND EXPLORATION PLAN
SLP"J" SITE
BIORETENTION HYDROLOGIC PERFORMANCE
PIERCE COUNTY, WASHINGTON

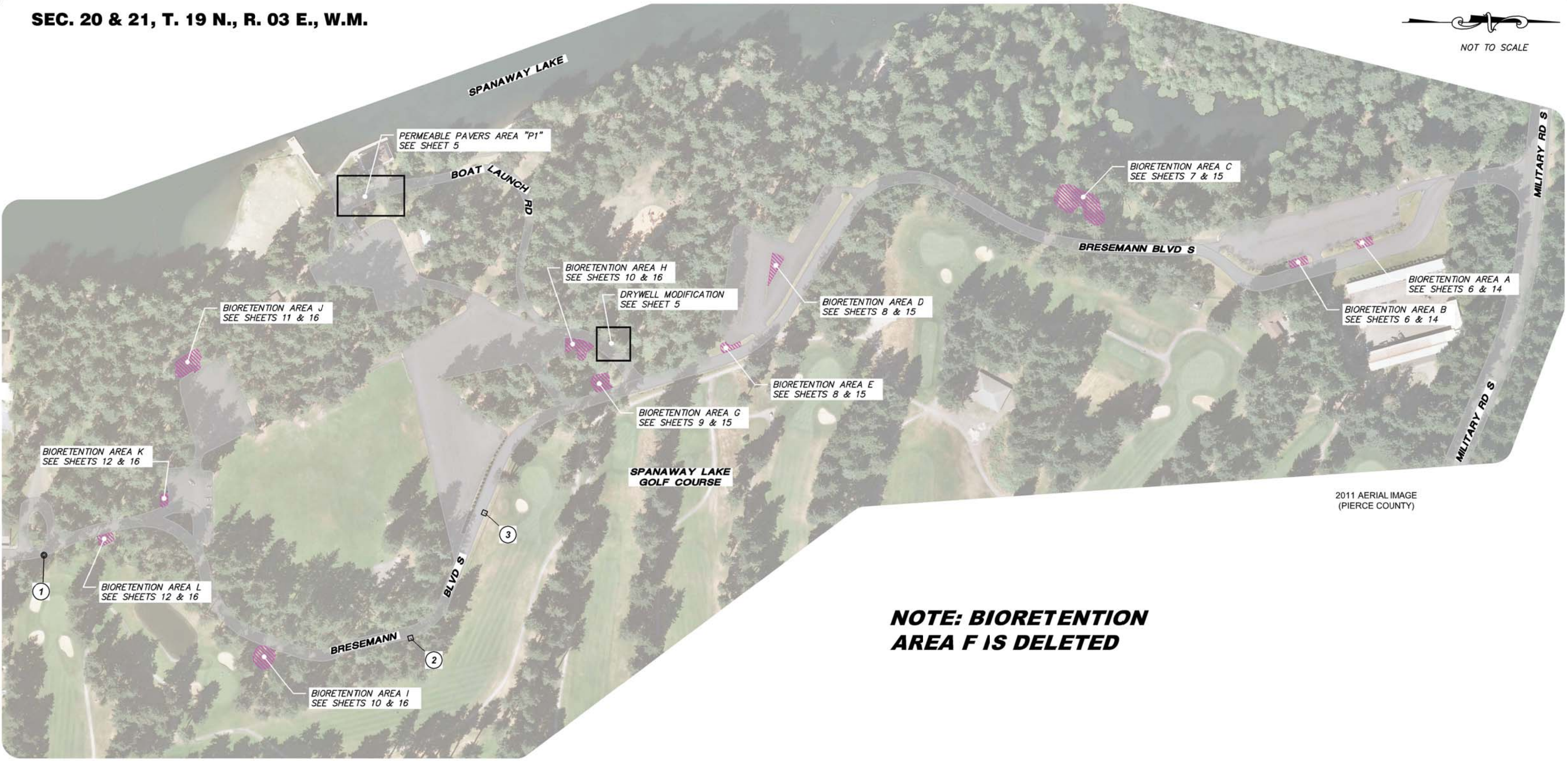
PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	SLP F4

150387 BHPS MCCA \ 150387 Site-Explr.cdr PAGE 9: SLP "J"

APPENDIX A

Project Civil Plans

SEC. 20 & 21, T. 19 N., R. 03 E., W.M.



NOT TO SCALE

2011 AERIAL IMAGE
(PIERCE COUNTY)

NOTE: BIORETENTION AREA F IS DELETED

"PROTECTION OF THE ENVIRONMENT: NO CONSTRUCTION RELATED ACTIVITY SHALL CONTRIBUTE TO THE DEGRADATION OF THE ENVIRONMENT, ALLOW MATERIAL TO ENTER SURFACE OR GROUND WATERS, OR ALLOW PARTICULATE EMISSIONS TO THE ATMOSPHERE, WHICH EXCEED STATE OR FEDERAL STANDARDS. ANY ACTIONS THAT POTENTIALLY ALLOW A DISCHARGE TO STATE WATERS MUST HAVE PRIOR APPROVAL OF THE WASHINGTON STATE DEPARTMENT OF ECOLOGY."

CALL 2 WORKING DAYS BEFORE YOU DIG
1-800-424-5555
UTILITIES UNDERGROUND LOCATION CENTER

DRAWING NO. See Side Stamp	SURVEYED BY: PIERCE COUNTY
DRAWN BY: R. RUTKOSKY	DATE SURVEYED: MAR APR 2012
DESIGNED BY: R. RUTKOSKY	BOOK NO.
CHECKED BY: D.A., I.K.	DATE PLOTTED: See Side Stamp

NO.	DATE	REVISION	BY	APPROVED

Pierce County
DEPARTMENT OF PUBLIC WORKS AND UTILITIES
SURFACE WATER MANAGEMENT
2702 SOUTH 42ND STREET, SUITE 201
TACOMA, WA 98409-7322

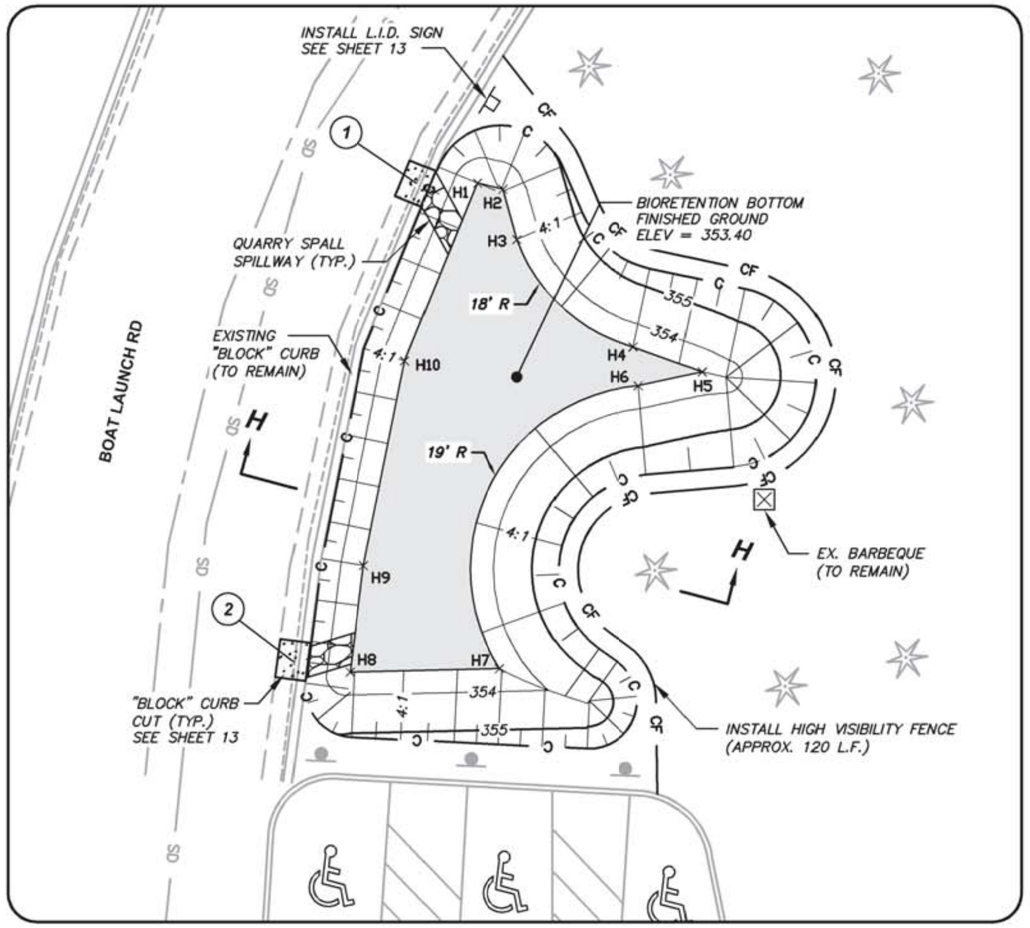
APPROVED BY:
HAROLD SMELT, P.E. SURFACE WATER MANAGEMENT MANAGER

HANS P. HUNGER
33750

SPANAWAY LAKE PARK L.I.D. RETROFIT - PHASE 1
SPANAWAY LAKE PARK SPANAWAY, WA

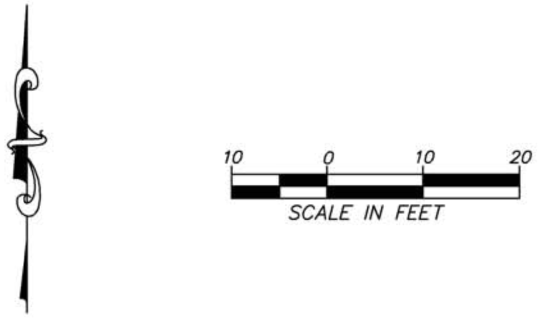
PROJECT OVERVIEW

C.I.P. #D415-006



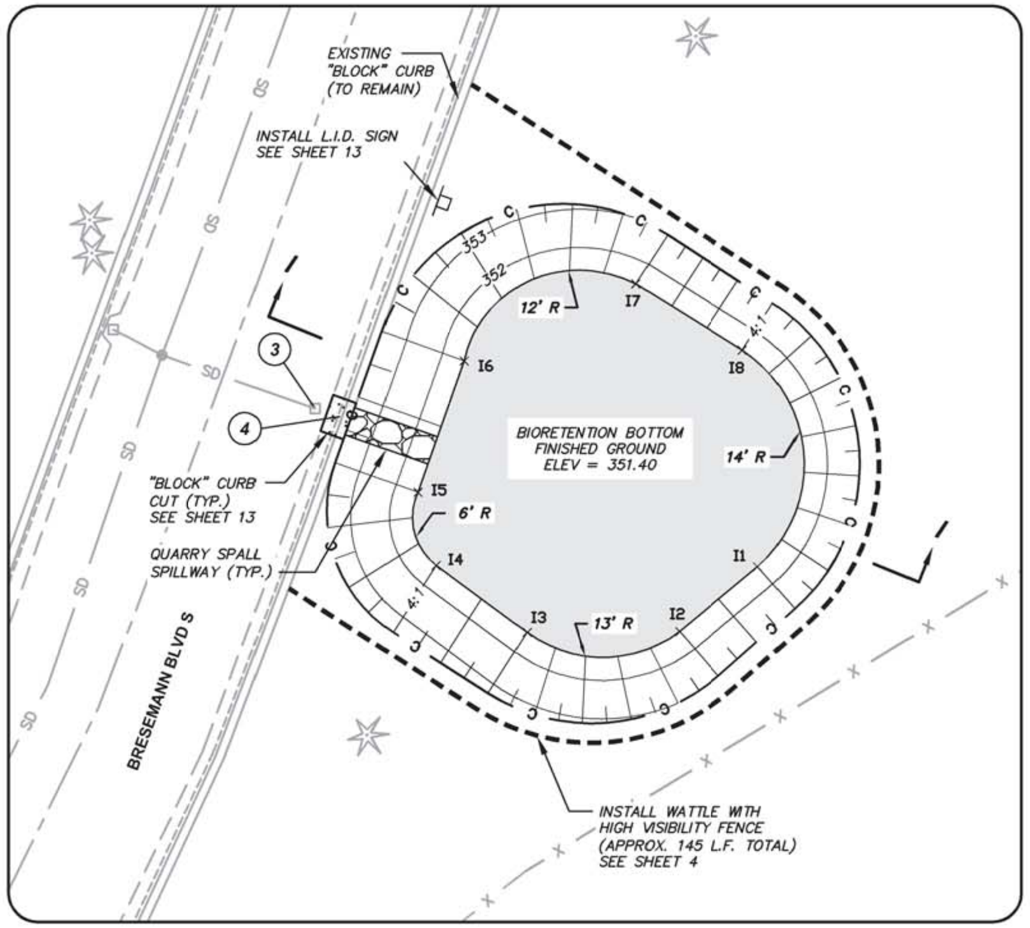
BIORETENTION AREA H (PLAN)

250 C.Y. BIORETENTION EXCAVATION INCL. HAUL
155 C.Y. BIORETENTION SOIL MIX
20 C.Y. BARK OR WOOD CHIP MULCH



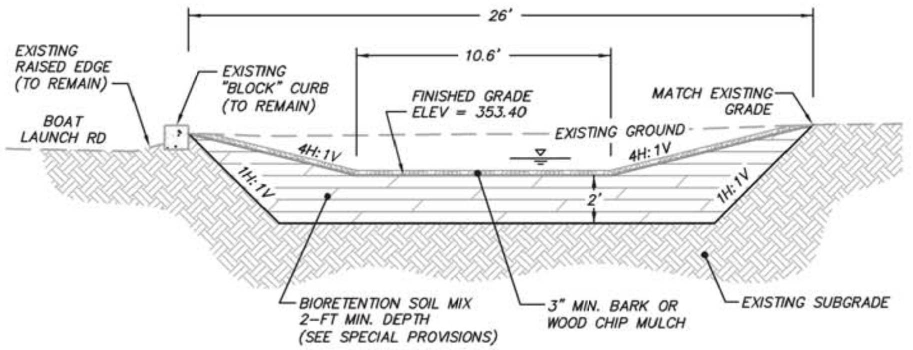
BIORETENTION POINT COORDINATES

POINT NO.	NORTHING	EASTING	ELEVATION	DESCRIPTION
H1	N: 656108.50	E: 1156425.56	353.40	BOTTOM
H2	N: 656107.87	E: 1156428.26	353.40	BOTTOM
H3	N: 656102.64	E: 1156429.72	353.40	BOTTOM
H4	N: 656091.47	E: 1156441.82	353.40	BOTTOM
H5	N: 656088.86	E: 1156448.96	353.40	BOTTOM
H6	N: 656087.41	E: 1156442.35	353.40	BOTTOM
H7	N: 656057.97	E: 1156427.89	353.40	BOTTOM
H8	N: 656057.62	E: 1156412.31	353.40	BOTTOM
H9	N: 656068.69	E: 1156413.73	353.40	BOTTOM
H10	N: 656090.01	E: 1156418.02	353.40	BOTTOM
I1	N: 655316.80	E: 1157189.03	351.40	BOTTOM
I2	N: 655310.04	E: 1157180.88	351.40	BOTTOM
I3	N: 655309.96	E: 1157164.99	351.40	BOTTOM
I4	N: 655316.92	E: 1157155.55	351.40	BOTTOM
I5	N: 655324.54	E: 1157153.66	351.40	BOTTOM
I6	N: 655338.22	E: 1157158.50	351.40	BOTTOM
I7	N: 655346.25	E: 1157176.35	351.40	BOTTOM
I8	N: 655339.33	E: 1157187.41	351.40	BOTTOM



BIORETENTION AREA I (PLAN)

275 C.Y. BIORETENTION EXCAVATION INCL. HAUL
175 C.Y. BIORETENTION SOIL MIX
23 C.Y. BARK OR WOOD CHIP MULCH

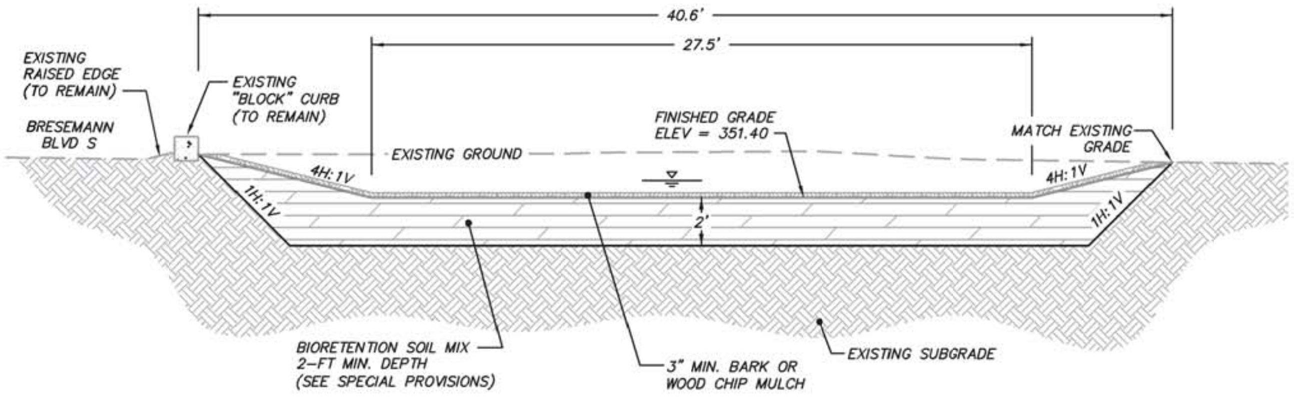


BIORETENTION AREA H (SECTION)

NOT TO SCALE

GENERAL BIORETENTION NOTES:

1. THE UTILITIES SHOWN ARE BASED ON VISIBLE FEATURES AND SHALL BE FIELD VERIFIED PRIOR TO EXCAVATION.
2. ALL COORDINATES GIVEN ARE FOR THE CENTER OF THE EXISTING/PROPOSED STRUCTURE(S), UNLESS OTHERWISE NOTED.
3. UPON REQUEST, AN AUTOCAD FILE (DWG) CAN BE PROVIDED TO CONTRACTOR. THIS FILE WILL CONTAIN CUT/FILL LINES, FEATURE LINES, BREAKLINES, ETC.
4. SEE SHEET 13 FOR "BLOCK" CURB CUT DETAIL.
5. SEE SHEETS 14-16 FOR BIORETENTION AREA PLANTING PLANS.
6. THE CONTRACTOR SHALL AVOID DAMAGE TO ANY EXISTING FEATURES (INCLUDING BUT NOT LIMITED TO: FENCES, CURBS, PAVEMENT, SIDEWALKS, BUILDINGS, CATCH BASINS, TREES, ETC.). ANY REPAIRS SHALL BE AT THE CONTRACTOR'S EXPENSE.
7. THE ELEVATIONS SHOWN IN THE PLAN VIEW(S) AND COORDINATE POINT TABLE(S) ARE FOR FINISHED GROUND. SEE BIORETENTION CROSS SECTIONS FOR SUBGRADE DEPTH, SOIL DEPTH, WOOD CHIP MULCH DEPTH, ETC.
8. HIGH VISIBILITY FENCE AND/OR STRAW WATTLE SHALL BE INSTALLED APPROX. 2 FEET OUTSIDE OF THE DAYLIGHT (CUT) LINE, UNLESS OTHERWISE SHOWN IN THE PLAN(S) OR AS DIRECTED BY THE ENGINEER. SEE SHEET 4 FOR DETAILS/NOTES.
9. EXISTING SUB-GRADE SHALL NOT BE COMPACTED DURING ANY CONSTRUCTION ACTIVITES. BEFORE PLACEMENT OF BIORETENTION SOIL MIX, THE SUB-GRADE SHALL BE SCARIFIED A MINIMUM OF 6".
10. GEOTEXTILE FOR PERMANENT EROSION CONTROL (HIGH SURVIVABILITY/WOVEN) SHALL BE INSTALLED UNDERNEATH ALL QUARRY SPALLS (SPILLWAYS, OVERFLOWS, ETC.) THIS SHALL BE INCIDENTAL TO "QUARRY SPALLS," PER C.Y.



BIORETENTION AREA I (SECTION)

NOT TO SCALE

Date: Aug 20, 2015 8:27:44 AM ()
Drawing: P:\D415-006 SPANAWAY LAKE PARK LID\ACAD\CONSTRUCTION PHASES\D415 PHASE 1.DWG
Xrefs: [D\BLOCK\VICINITY MAP\VICINITY-WHOLE.DWG]

DRAWING NO. See Side Stamp
SURVEYED BY: PIERCE COUNTY
DRAWN BY: R. RUTKOSKY
DATE SURVEYED: MAR APR 2012
DESIGNED BY: R. RUTKOSKY
BOOK NO.
CHECKED BY: D.A., I.K.
DATE PLOTTED: See Side Stamp

NO.	DATE	REVISION	BY	APPROVED

Pierce County
DEPARTMENT OF PUBLIC WORKS AND UTILITIES
SURFACE WATER MANAGEMENT
2702 SOUTH 42ND STREET, SUITE 201
TACOMA, WA 98409-7322

APPROVED BY:
HAROLD SMELT, P.E. SURFACE WATER MANAGEMENT MANAGER

HANS P. HUNGER

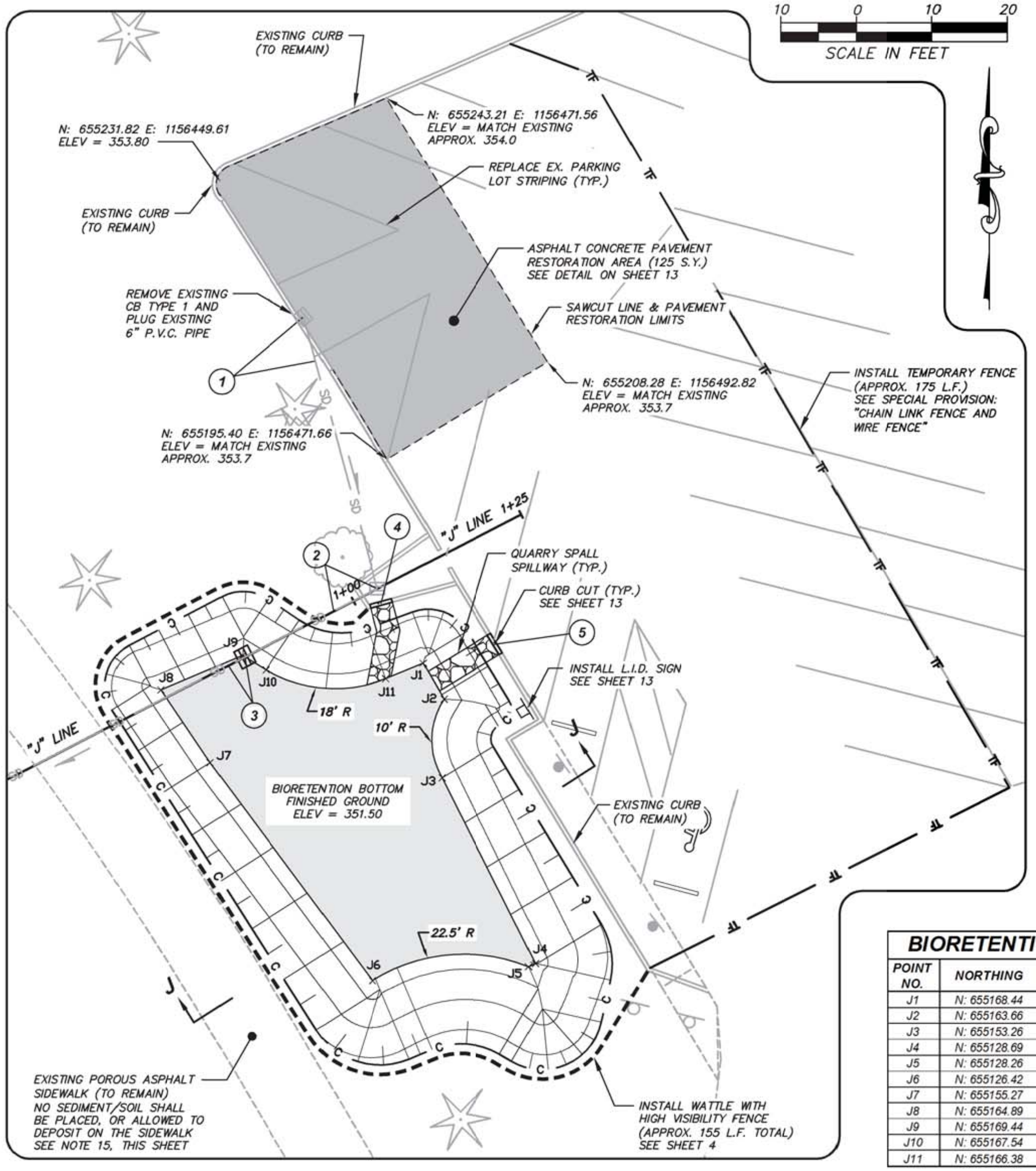
SPANAWAY LAKE PARK L.I.D. RETROFIT - PHASE 1
SPANAWAY LAKE PARK SPANAWAY, WA

BIORETENTION AREAS H & I

C.I.P. #D415-006

SHEET **10** OF **16**

SEC. 20, T. 19 N., R. 03 E., W.M.

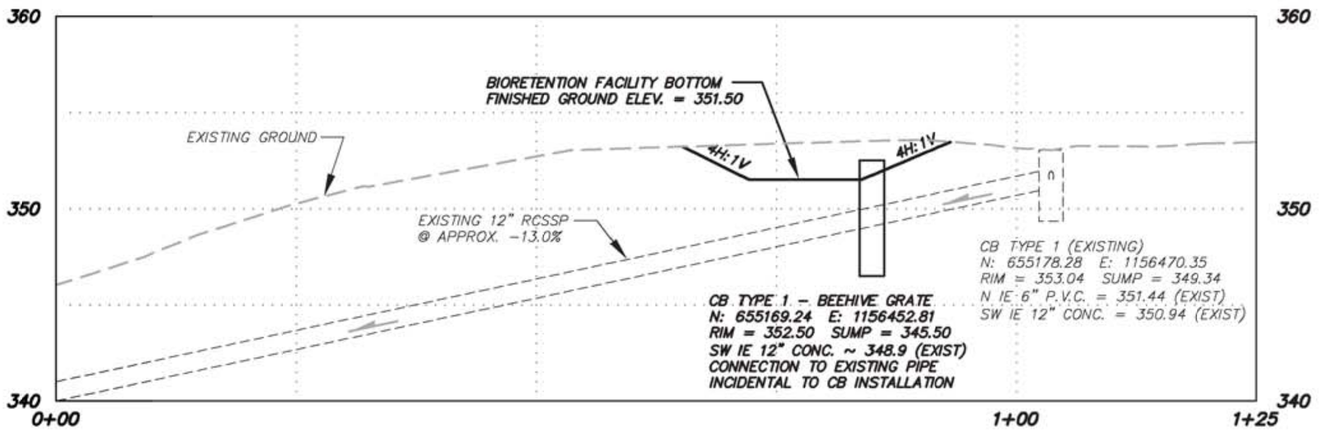


BIORETENTION AREA J (PLAN)

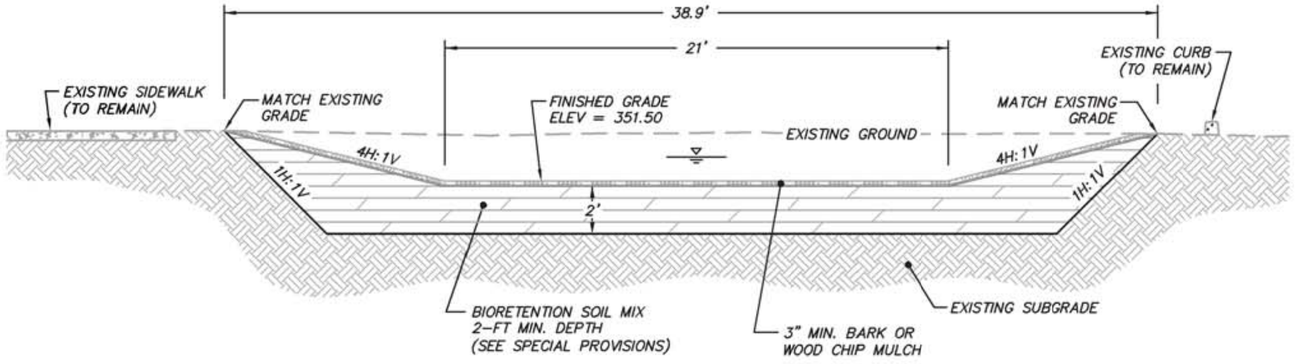
355 C.Y. BIORETENTION EXCAVATION INCL. HAUL
210 C.Y. BIORETENTION SOIL MIX
28 C.Y. BARK OR WOOD CHIP MULCH

BIORETENTION POINT COORDINATES

POINT NO.	NORTHING	EASTING	ELEVATION	DESCRIPTION
J1	N: 655168.44	E: 1156476.42	351.50	BOTTOM
J2	N: 655163.66	E: 1156479.16	351.50	BOTTOM
J3	N: 655153.26	E: 1156478.89	351.50	BOTTOM
J4	N: 655128.69	E: 1156491.25	351.50	BOTTOM
J5	N: 655128.26	E: 1156490.35	351.50	BOTTOM
J6	N: 655126.42	E: 1156469.71	351.50	BOTTOM
J7	N: 655155.27	E: 1156448.23	351.50	BOTTOM
J8	N: 655164.89	E: 1156441.74	351.50	BOTTOM
J9	N: 655169.44	E: 1156452.50	351.50	BOTTOM
J10	N: 655167.54	E: 1156455.61	351.50	BOTTOM
J11	N: 655166.38	E: 1156471.47	351.50	BOTTOM



"J" LINE PROFILE



BIORETENTION AREA J (SECTION)

NOT TO SCALE

GENERAL BIORETENTION NOTES:

1. THE UTILITIES SHOWN ARE BASED ON VISIBLE FEATURES AND SHALL BE FIELD VERIFIED PRIOR TO EXCAVATION.
2. ALL COORDINATES GIVEN ARE FOR THE CENTER OF THE EXISTING/PROPOSED STRUCTURE(S), UNLESS OTHERWISE NOTED.
3. UPON REQUEST, AN AUTOCAD FILE (DWG) CAN BE PROVIDED TO CONTRACTOR. THIS FILE WILL CONTAIN CUT/FILL LINES, FEATURE LINES, BREAKLINES, ETC.
4. SEE SHEET 13 FOR CURB CUT DETAIL.
5. SEE SHEETS 14-16 FOR BIORETENTION PLANTING PLANS.
6. THE CONTRACTOR SHALL AVOID DAMAGE TO ANY EXISTING FEATURES (INCLUDING BUT NOT LIMITED TO: FENCES, CURBS, PAVEMENT, SIDEWALKS, BUILDINGS, CATCH BASINS, TREES, ETC.). ANY REPAIRS SHALL BE AT THE CONTRACTOR'S EXPENSE.
7. THE ELEVATIONS SHOWN IN THE PLAN VIEW(S) AND COORDINATE POINT TABLE(S) ARE FOR FINISHED GROUND. SEE BIORETENTION CROSS SECTIONS FOR SUBGRADE DEPTH, SOIL DEPTH, WOOD CHIP MULCH DEPTH, ETC.
8. HIGH VISIBILITY FENCE AND/OR STRAW WATTLE SHALL BE INSTALLED APPROX. 2 FEET OUTSIDE OF THE DAYLIGHT (CUT) LINE, UNLESS OTHERWISE SHOWN IN THE THE PLAN(S) OR AS DIRECTED BY THE ENGINEER. SEE SHEET 4 FOR DETAILS/NOTES.
9. SEE SHEET 13 FOR PAVEMENT RESTORATION DETAIL/NOTES. SAW-CUTTING THE EXISTING PAVEMENT SHALL BE INCIDENTAL TO "ROADWAY EXCAVATION INCL. HAUL."
10. PAVEMENT FINISHED GRADE SHALL MATCH EXISTING GRADE, UNLESS OTHERWISE SHOWN IN PLAN OR AS DIRECTED BY ENGINEER.
11. UPON COMPLETION OF PAVEMENT RESTORATION AND BIORETENTION CONSTRUCTION, THE EXISTING PAVEMENT LINES SHALL BE RE-ESTABLISHED. SEE SPECIAL PROVISION, "PAVEMENT MARKING". PAID UNDER "PAVEMENT MARKING," LUMP SUM.
12. SAWCUTTING OF EXISTING ASPHALT PARKING LOT, SHALL BE INCIDENTAL TO "ROADWAY EXCAVATION INCL. HAUL."
13. EXISTING SUB-GRADE SHALL NOT BE COMPACTED DURING ANY CONSTRUCTION ACTIVITES. BEFORE PLACEMENT OF BIORETENTION SOIL MIX, THE SUB-GRADE SHALL BE SCARIFIED A MINIMUM OF 6".
14. GEOTEXTILE FOR PERMANENT EROSION CONTROL (HIGH SURVIVABILITY/WOVEN) SHALL BE INSTALLED UNDERNEATH ALL QUARRY SPALLS (SPILLWAYS, OVERFLOWS, ETC.) THIS SHALL BE INCIDENTAL TO "QUARRY SPALLS," PER C.Y.
15. THE EXISTING POROUS ASPHALT SIDEWALK SHALL BE PROTECTED. THE SIDEWALK SHALL BE COVERED BY PLASTIC OR GEOTEXTILE FABRIC TO PREVENT ANY SEDIMENT FROM CLOGGING THE POROUS PAVEMENT. UPON COMPLETION OF BIORETENTION AREA CONSTRUCTION, ANY PROTECTIVE MEASURES MUST BE REMOVED AND DISPOSED OF OFFSITE, AT THE CONTRACTOR'S EXPENSE. ALL WORK ASSOCIATED WITH THIS ACTIVITY SHALL BE INCIDENTAL TO ALL OTHER BID ITEMS.

Date: Aug 20, 2015 8:28:00 AM ◇
Drawing: P:\D415-006 SPANAWAY LAKE PARK LID\ACAD\CONSTRUCTION PHASES\D415 PHASE 1.DWG
Xrefs: [D\BLOCK\VICINITY MAP\VICINITY-WHOLE.DWG]

DRAWING NO. See Side Stamp	SURVEYED BY: PIERCE COUNTY
DRAWN BY: R. RUTKOSKY	DATE SURVEYED: MAR APR 2012
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CHECKED BY: D.A., I.K.	DATE PLOTTED: See Side Stamp

NO.	DATE	REVISION	BY	APPROVED

Pierce County
DEPARTMENT OF PUBLIC WORKS AND UTILITIES
SURFACE WATER MANAGEMENT
2702 SOUTH 42ND STREET, SUITE 201
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APPROVED BY:
HAROLD SMELT, P.E. SURFACE WATER MANAGEMENT MANAGER

HANS P. HUNGER

SPANAWAY LAKE PARK L.I.D. RETROFIT - PHASE 1
SPANAWAY LAKE PARK SPANAWAY, WA

BIORETENTION AREA J

C.I.P. #D415-006

SHEET 11 OF 16

APPENDIX B

Current Study Exploration Logs and Laboratory Testing Data

Cell SLP”I” and SLP”J”
Exploration Latitude and Longitude

Exploration	**Latitude**	**Longitude**
SLP”I”-HA-1	47.11406	-122.44106
SLP”I”-HA-2	47.11403	-122.44102
SLP”I”-HA-3	47.11412	-122.44100
SLP”J”-HA-1	47.11349	-122.44376
SLP”J”-HA-2	47.11342	-122.44375
SLP”J”-HA-3	47.11355	-122.44385

associated earth sciences incorporated

Exploration Log

Project Number	Exploration Number	Sheet
KH150387A	SLP"I"-HA-1	1 of 1

Project Name: Bioretention Hydrologic Performance Study
Location: Pierce County, WA
Driller/Equipment: Hand Auger
Hammer Weight/Drop: N/A

Ground Surface Elevation (ft):
Datum: N/A
Date Start/Finish: 8/19/16,8/19/16
Hole Diameter (in): 4 inches

Depth (ft)	S T	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot 10 20 30 40	Other Tests
				Leaf Litter / Bark Fragments Surface: leaf litter					
				Bioretention Soil Mix Loose, slightly moist, brown, SAND, trace silt; organics present; mostly medium sand (~76 percent) (SP).					
				Vashon Recessional Outwash - Steilacoom Gravel Medium dense, slightly moist, dark brown, very sandy GRAVEL; cobbles present (GP).					
				Bottom of exploration boring at 2.4 feet Refusal on cobbles. No seepage. No caving.					

Sampler Type (ST):

- ▯ 2" OD Split Spoon Sampler (SPT)
- ▯ 3" OD Split Spoon Sampler (D & M)
- ✋ Grab Sample
- ☐ No Recovery
- ◧ Ring Sample
- ▨ Shelby Tube Sample
- M - Moisture
- ▽ Water Level ()
- ▼ Water Level at time of drilling (ATD)

Logged by: ADY
Approved by: JHS

Geologic & Monitoring Well Construction Log

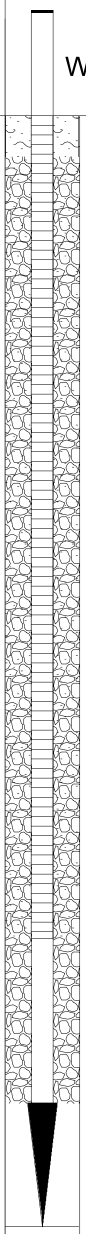
associated earth sciences incorporated

Project Number	Well Number	Sheet
KH150387A	-SLP"I"-HA-2/WP	1 of 1

Project Name Bioretention Hydrologic Performance Study
Elevation (Top of Well Casing) ~2.7 feet (stick up)
Water Level Elevation
Drilling/Equipment Hand Auger
Hammer Weight/Drop N/A

Location Pierce County, WA
Surface Elevation (ft)
Date Start/Finish 8/19/16,8/19/16
Hole Diameter (in) 4 inches

Depth (ft)	Water Level	WELL CONSTRUCTION	ST	Blows/ 6"	Graphic Symbol	DESCRIPTION



Above ground stick up -2.7 feet
Bark fragments 0 to 0.1 foot
Threaded PVC cap

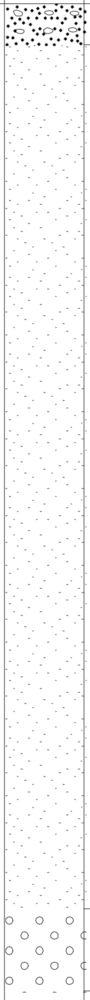
Threaded steel pipe -2.7 to -0.5 feet

Bioretention soil mix 0.1 to 2.4 feet

Stainless steel jacket over stainless steel #60 gauze welded to perforated steel pipe -0.5 to 2.0 feet

Threaded steel pipe, 1 1/4 inch ID and end cap 2.0 to 2.4 feet

Solid drive point 2.4 to 2.7 feet



Leaf Litter / Bark Fragments

Surface: leaf litter, bark fragments

Bioretention Soil Mix

Loose, dry, brown, SAND, trace silt; organics present; mostly fine to medium sand (SP).

Vashon Recessional Outwash - Steilacoom Gravel

Medium dense, slightly moist, light brown, very sandy GRAVEL; cobbles present (GP).

Boring terminated at 2.4 feet.
Well completed at 2.7 feet on 8/19/16.
Refusal on cobbles. No seepage. No caving.

Sampler Type (ST):

▯ 2" OD Split Spoon Sampler (SPT)	☐ No Recovery	M - Moisture	**Logged by:** ADY
▯ 3" OD Split Spoon Sampler (D & M)	▮ Ring Sample	▽ Water Level ()	**Approved by:** JHS
▯ Grab Sample	▱ Shelby Tube Sample	▼ Water Level at time of drilling (ATD)	

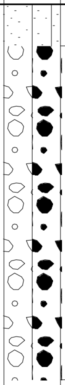
associated earth sciences incorporated

Exploration Log

Project Number	Exploration Number	Sheet
KH150387A	SLP"I"-HA-3	1 of 1

Project Name: Bioretention Hydrologic Performance Study
Location: Pierce County, WA
Driller/Equipment: Hand Auger
Hammer Weight/Drop: N/A

Ground Surface Elevation (ft):
Datum: N/A
Date Start/Finish: 8/19/16,8/19/16
Hole Diameter (in): 4 inches

Depth (ft)	ST	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot 10 20 30 40	Other Tests
				**Topsoil** Surface: grass, moss Loose, slightly moist, dark brown, SAND, trace silt; organics present (SP-SM). **Vashon Recessional Outwash - Steilacoom Gravel** Medium dense, slightly moist, brown, very sandy GRAVEL; cobbles present (GP/GW).					
				Bottom of exploration boring at 0.9 feet Refusal on cobbles. No seepage. No caving. Note: Completed adjacent to cell SLP"I"					

Sampler Type (ST):

▯ 2" OD Split Spoon Sampler (SPT)	☐ No Recovery	M - Moisture
▯ 3" OD Split Spoon Sampler (D & M)	◧ Ring Sample	▽ Water Level ()
✋ Grab Sample	▨ Shelby Tube Sample	▼ Water Level at time of drilling (ATD)

Logged by: ADY
Approved by: JHS

associated earth sciences incorporated

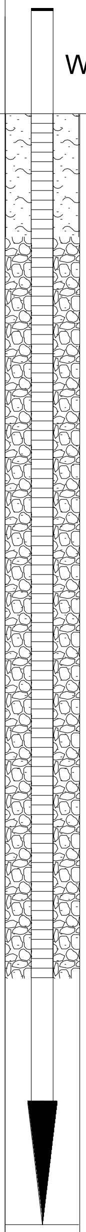
Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KH150387A	-SLP"J"-HA-1/WP	1 of 1

Project Name: Bioretention Hydrologic Performance Study
Elevation (Top of Well Casing): ~0.6 feet (stick up)
Water Level Elevation:
Drilling/Equipment: Hand Auger
Hammer Weight/Drop: N/A

Location: Pierce County, WA
Surface Elevation (ft):
Date Start/Finish: 7/28/16,7/28/16
Hole Diameter (in): 4 inches

Depth (ft)	Water Level	WELL CONSTRUCTION	S T	Blows/ 6"	Graphic Symbol	DESCRIPTION



Above ground stick up -0.6 feet
Leaf litter 0 to 0.3 foot
Threaded PVC cap

Threaded steel pipe -0.6 to -0.3 feet

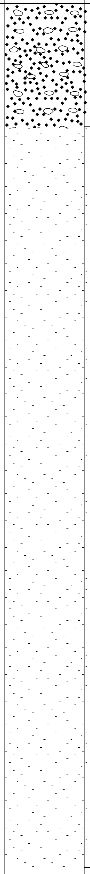
Bioretention soil mix 0.3 to 2.1 feet

Stainless steel jacket over stainless steel #60 gauze welded to perforated steel pipe -0.3 to 2.2 feet

Native soils 2.1 to 2.9 feet

Threaded steel pipe, 1 1/4 inch ID and end cap 2.2 to 2.6 feet

Solid drive point 2.6 to 2.9 feet



Leaf Litter

Surface: leaf litter

Bioretention Soil Mix

Loose, slightly moist, brown, SAND, trace silt; organics present; mostly medium sand (~88 percent) (SP).

Boring terminated at 2.1 feet.
Well completed at 2.9 feet on 7/28/16.
Refusal on cobbles. No seepage. No caving.

Sampler Type (ST):

- ▯ 2" OD Split Spoon Sampler (SPT)
- ▯ 3" OD Split Spoon Sampler (D & M)
- ▯ Grab Sample
- ▯ No Recovery
- ▮ Ring Sample
- ▯ Shelby Tube Sample
- M - Moisture
- ▽ Water Level ()
- ▼ Water Level at time of drilling (ATD)

Logged by: ADY
Approved by: JHS

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Exploration Log

Project Number	Exploration Number	Sheet
KH150387A	SLP"J"-HA-2	1 of 1

Project Name	Bioretention Hydrologic Performance Study	Ground Surface Elevation (ft)	
Location	Pierce County, WA	Datum	N/A
Driller/Equipment	Hand Auger	Date Start/Finish	7/28/16,7/28/16
Hammer Weight/Drop	N/A	Hole Diameter (in)	4 inches

Depth (ft)	S T	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot 10 20 30 40	Other Tests
				Topsoil Surface: grass Loose, slightly moist, dark brown, SAND, trace silt (SP).					
				Vashon Recessional Outwash - Steilacoom Gravel Medium dense, slightly moist, dark brown, very sandy GRAVEL, trace silt; cobbles (4 inches) present (GP/GW).					
				Bottom of exploration boring at 1.4 feet Refusal on cobbles. No seepage. No caving.					

Sampler Type (ST):

- ▯ 2" OD Split Spoon Sampler (SPT)
- ▯ 3" OD Split Spoon Sampler (D & M)
- ▯ Grab Sample
- ☐ No Recovery
- ◧ Ring Sample
- ▱ Shelby Tube Sample
- M - Moisture
- ▽ Water Level ()
- ▼ Water Level at time of drilling (ATD)

Logged by: ADY
Approved by: JHS

associated earth sciences incorporated

Exploration Log

Project Number	Exploration Number	Sheet
KH150387A	SLP"J"-HA-3	1 of 1

Project Name: Bioretention Hydrologic Performance Study
Location: Pierce County, WA
Driller/Equipment: Hand Auger
Hammer Weight/Drop: N/A

Ground Surface Elevation (ft):
Datum: N/A
Date Start/Finish: 7/28/16,7/28/16
Hole Diameter (in): 4 inches

Depth (ft)	S T	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot 10 20 30 40	Other Tests
				Leaf Litter Surface: leaf litter					
				Bioretention Soil Mix Loose, dry, brown, SAND, trace silt; organics present; mostly medium sand (~91 percent) (SP).					
				Bottom of exploration boring at 2.2 feet Refusal on cobbles. No seepage. No caving.					

Sampler Type (ST):

- ▯ 2" OD Split Spoon Sampler (SPT)
- ▯ 3" OD Split Spoon Sampler (D & M)
- ▯ Grab Sample
- ☐ No Recovery
- ◧ Ring Sample
- ▧ Shelby Tube Sample
- M - Moisture
- ▽ Water Level ()
- ▼ Water Level at time of drilling (ATD)

Logged by: ADY
Approved by: JHS

associated earth sciences incorporated

Moisture, Ash, and Organic Matter of Peat and Other Organic Soils - ASTM 2974

Date Sampled 8/19/2016	**Project** BHPS	**Project No.** KH150387A		**Soil Description** Bioretention soil mix
Tested By MS	**Location** SLP "I"	**EB/EP No.** SLP "I"	**Depth**	

Moisture Content	**SLP"I"**	**Moisture Content**	**SLP"I"**
Sample ID	**HA1 0.6-1.0**	Sample ID	**HA2 0.1-0.9**
Wet Weight + Pan	**1124.56**	Wet Weight + Pan	**1211.59**
Dry Weight + Pan	**1063.82**	Dry Weight + Pan	**1173.99**
Weight of Pan	**302.61**	Weight of Pan	**306.51**
Weight of Moisture	**60.74**	Weight of Moisture	**37.60**
Dry Weight of Soil	**761.21**	Dry Weight of Soil	**867.48**
% Moisture	**8.0**	% Moisture	**4.3**

Organic Matter and Ash Content		**Organic Matter and Ash Content**	
Dry Soil Befor Burn + Pan	**1159.55**	Dry Soil Befor Burn + Pan	**1222.79**
Dry Soil After Burn + Pan	**1137.88**	Dry Soil After Burn + Pan	**1203.14**
Weight of Pan	**392.14**	Weight of Pan	**348.66**
Wt. Loss Due to Ignition	**21.67**	Wt. Loss Due to Ignition	**19.65**
Actual Wt. Of Soil After Burr	**745.74**	Actual Wt. Of Soil After Burr	**854.48**
% Organics	**2.8**	% Organics	**2.2**

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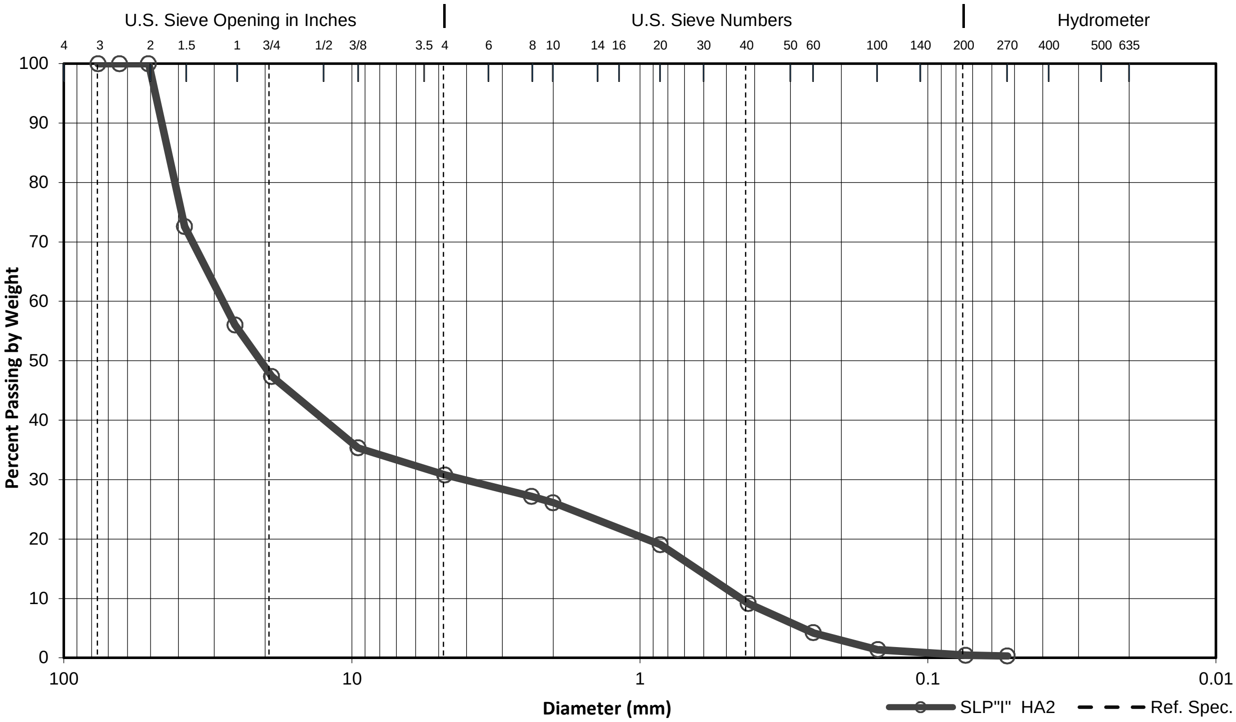
earth sciences
incorporated

GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

Project Name	Project Number	Date Sampled	Date Tested	Tested By
BHPS	**KH150387A**	**8/19/2016**	**9/15/2016**	**GS**
Sample Source	Sample No.	Depth (ft)	Soil Description	
Onsite	**SLP"I" HA2**	**2.2-2.4**	**very sandy GRAVEL, trace silt (GW)**	
Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification	
794.5	**2**	**0.446**	**Not applicable: native material**	



Cobb.	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1	217.5	27.4	72.6		
1	25.4	349.5	44.0	56.0		
3/4	19	418.2	52.6	47.4		
3/8	9.51	513.8	64.7	35.3		
#4	4.76	549.8	69.2	30.8		
#8	2.38	578.6	72.8	27.2		
#10	2	587.1	73.9	26.1		
#20	0.85	643.1	80.9	19.1		
#40	0.42	722.0	90.9	9.1		
#60	0.25	760.8	95.8	4.2		
#100	0.149	783.5	98.6	1.4		
#200	0.074	791.0	99.6	0.4		
#270	0.053	792.0	99.7	0.3		

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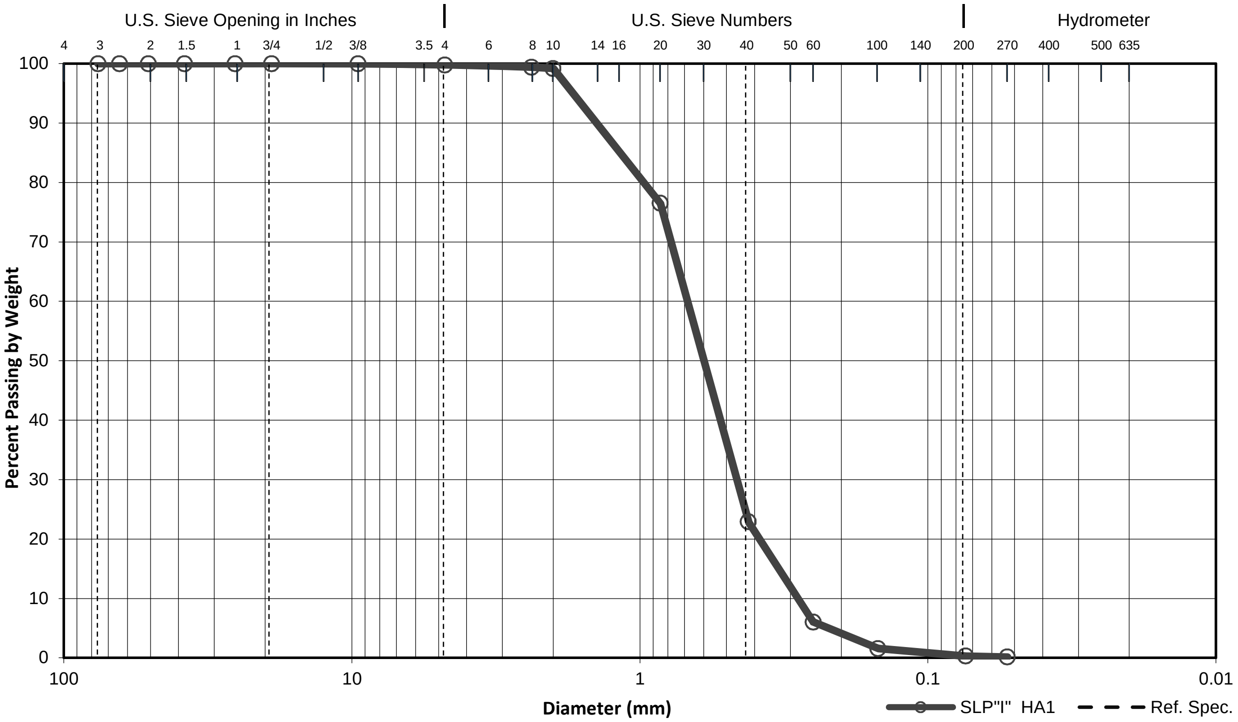
GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

Project Name	Project Number	Date Sampled	Date Tested	Tested By
BHPS	**KH150387A**	**8/19/2016**	**9/15/2016**	**GS**
Sample Source	Sample No.	Depth (ft)	Soil Description	
Onsite	**SLP"I" HA1**	**0.6-1.0**	**SAND, trace silt, trace gravel (SP)**	
Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification	
745.7	**0**	**0.282**	**Bioretention soil mix: burned sample**	



Cobb.	**Gravel**		**Sand**			**Silt or Clay**
	Coarse	Fine	Coarse	Medium	Fine	

Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4		0.0	100.0		
3/4	19		0.0	100.0		
3/8	9.51		0.0	100.0		
#4	4.76	1.6	0.2	99.8		
#8	2.38	4.3	0.6	99.4		
#10	2	6.1	0.8	99.2		
#20	0.85	174.9	23.5	76.5		
#40	0.42	574.8	77.1	22.9		
#60	0.25	700.7	94.0	6.0		
#100	0.149	734.1	98.4	1.6		
#200	0.074	743.4	99.7	0.3		
#270	0.053	744.6	99.9	0.1		

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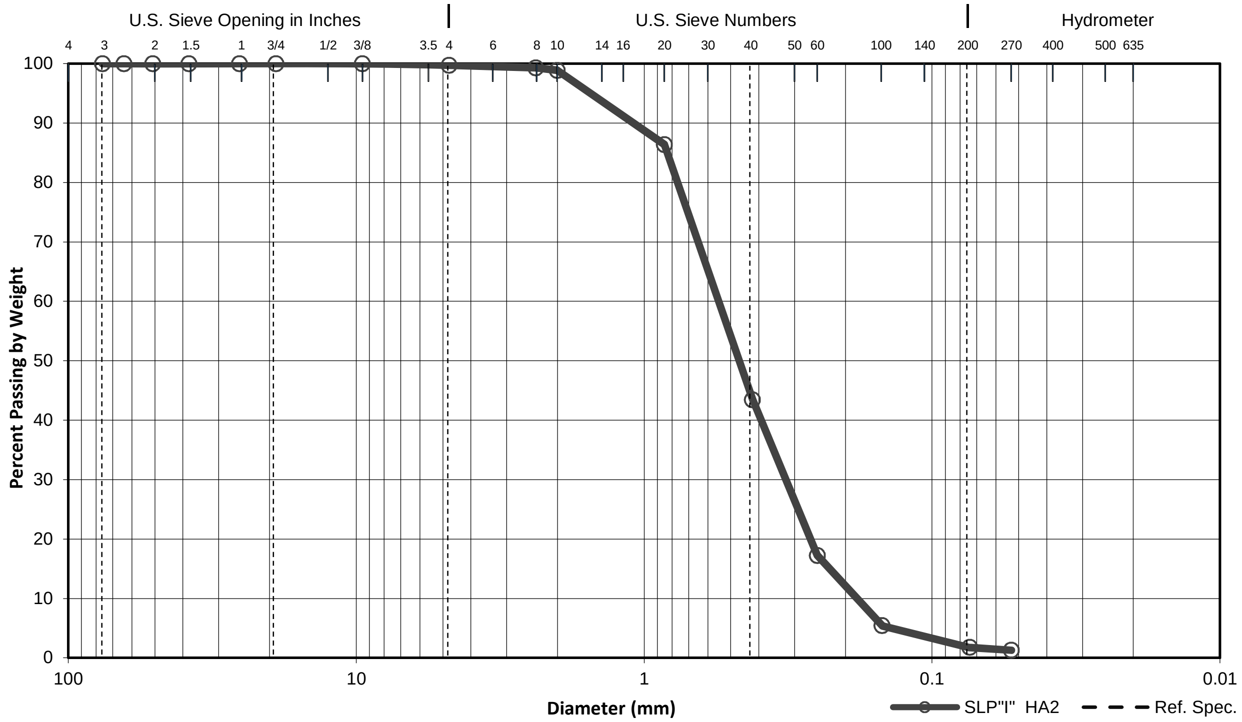
GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

Project Name	Project Number	Date Sampled	Date Tested	Tested By
BHPS	**KH150387A**	**8/19/2016**	**9/15/2016**	**GS**
Sample Source	Sample No.	Depth (ft)	Soil Description	
Onsite	**SLP"I" HA2**	**0.1-0.9**	**SAND, trace silt, trace gravel (SP)**	
Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification	
854.5	**0**	**0.182**	**Bioretention soil mix: burned sample**	



Cobb.	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4		0.0	100.0		
3/4	19		0.0	100.0		
3/8	9.51		0.0	100.0		
#4	4.76	2.4	0.3	99.7		
#8	2.38	6.0	0.7	99.3		
#10	2	9.7	1.1	98.9		
#20	0.85	116.5	13.6	86.4		
#40	0.42	483.4	56.6	43.4		
#60	0.25	707.3	82.8	17.2		
#100	0.149	808.1	94.6	5.4		
#200	0.074	839.5	98.2	1.8		
#270	0.053	843.5	98.7	1.3		

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Moisture, Ash, and Organic Matter of Peat and Other Organic Soils - ASTM 2974

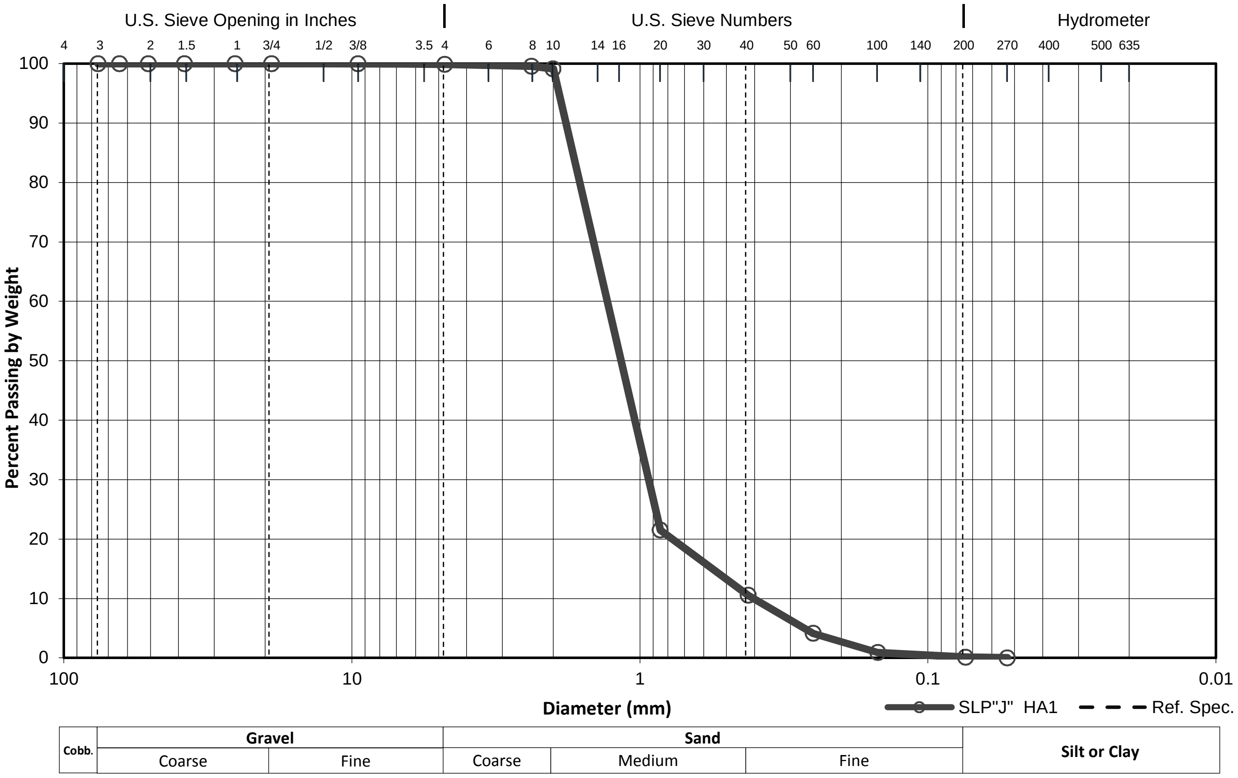
Date Sampled	Project	Project No.		Soil Description
7/28/2016	BHPS	KH150387A		
Tested By	**Location**	**EB/EP No.**	**Depth**	Bioretention soil mix
MS	SLP "J"	SLP "J"		

Moisture Content	**SLP"J"**	**Moisture Content**	**SLP"J"**
Sample ID	**HA1 0.5-1**	Sample ID	**HA3 0.2-0.5**
Wet Weight + Pan	**846.74**	Wet Weight + Pan	**888.05**
Dry Weight + Pan	**794.37**	Dry Weight + Pan	**841.52**
Weight of Pan	**307.39**	Weight of Pan	**303.77**
Weight of Moisture	**52.37**	Weight of Moisture	**46.53**
Dry Weight of Soil	**486.98**	Dry Weight of Soil	**537.75**
% Moisture	**10.8**	% Moisture	**8.7**

Organic Matter and Ash Content		**Organic Matter and Ash Content**	
Dry Soil Befor Burn + Pan	**835.89**	Dry Soil Befor Burn + Pan	**934.27**
Dry Soil After Burn + Pan	**826.11**	Dry Soil After Burn + Pan	**916.66**
Weight of Pan	**348.69**	Weight of Pan	**392.18**
Wt. Loss Due to Ignition	**9.78**	Wt. Loss Due to Ignition	**17.61**
Actual Wt. Of Soil After Burr	**477.42**	Actual Wt. Of Soil After Burr	**524.48**
% Organics	**2.0**	% Organics	**3.2**

GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

Project Name	Project Number	Date Sampled	Date Tested	Tested By
BHPS	**KH150387A**	**7/28/2016**	**9/1/2016**	**MS**
Sample Source	Sample No.	Depth (ft)	Soil Description	
Onsite	**SLP"J" HA1**	**0.5-1**	**SAND, trace silt, trace gravel (SP)**	
Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification	
477.6	**0**	**0.402**	**Bioretention soil mix: burned sample**	



Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4		0.0	100.0		
3/4	19		0.0	100.0		
3/8	9.51		0.0	100.0		
#4	4.76	0.6	0.1	99.9		
#8	2.38	2.2	0.5	99.5		
#10	2	4.2	0.9	99.1		
#20	0.85	374.7	78.5	21.5		
#40	0.42	427.4	89.5	10.5		
#60	0.25	457.9	95.9	4.1		
#100	0.149	473.4	99.1	0.9		
#200	0.074	477.1	99.9	0.1		
#270	0.053	477.5	100.0	0.0		

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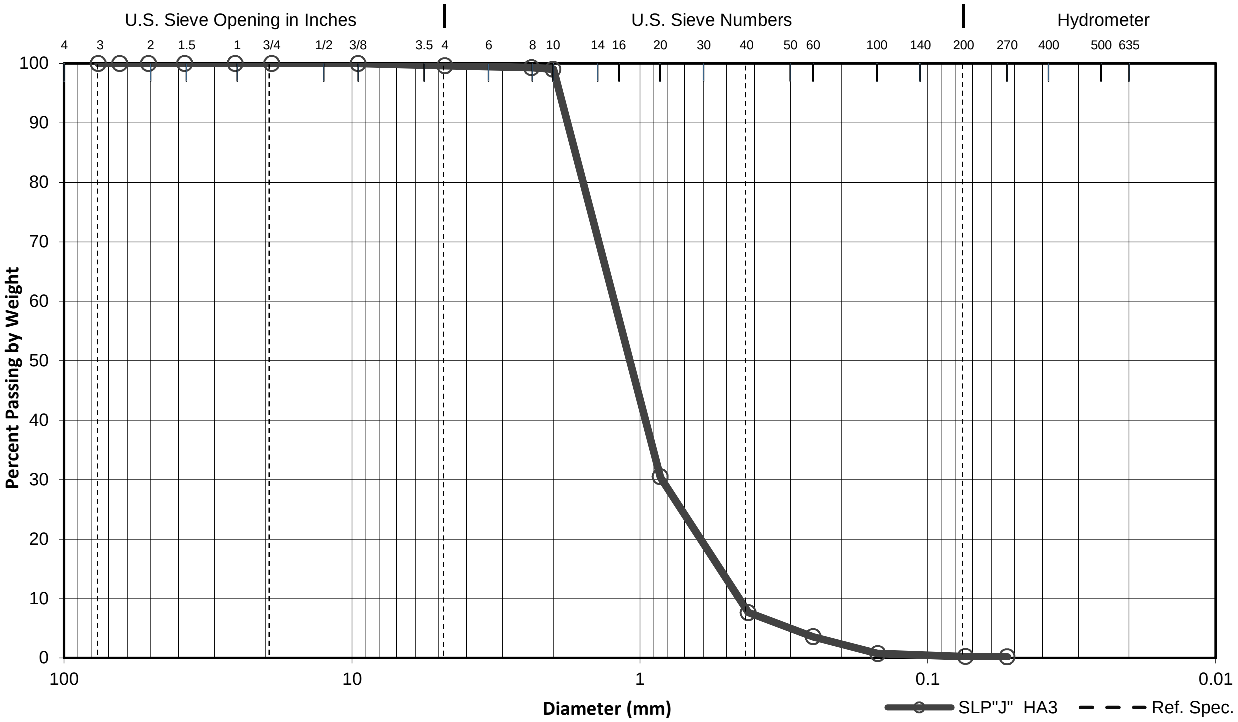
GRAIN SIZE ANALYSIS - MECHANICAL ASTM D422

Project Name	Project Number	Date Sampled	Date Tested	Tested By
BHPS	**KH150387A**	**7/28/2016**	**9/1/2016**	**MS**
Sample Source	Sample No.	Depth (ft)	Soil Description	
Onsite	**SLP"J" HA3**	**0.2-0.5**	**SAND, trace silt, trace gravel (SP)**	
Total Sample Dry Wt. (g)	Moisture Content (%)	D_{10} (mm)	Reference Specification	
524.7	**0**	**0.451**	**Bioretention soil mix: burned sample**	

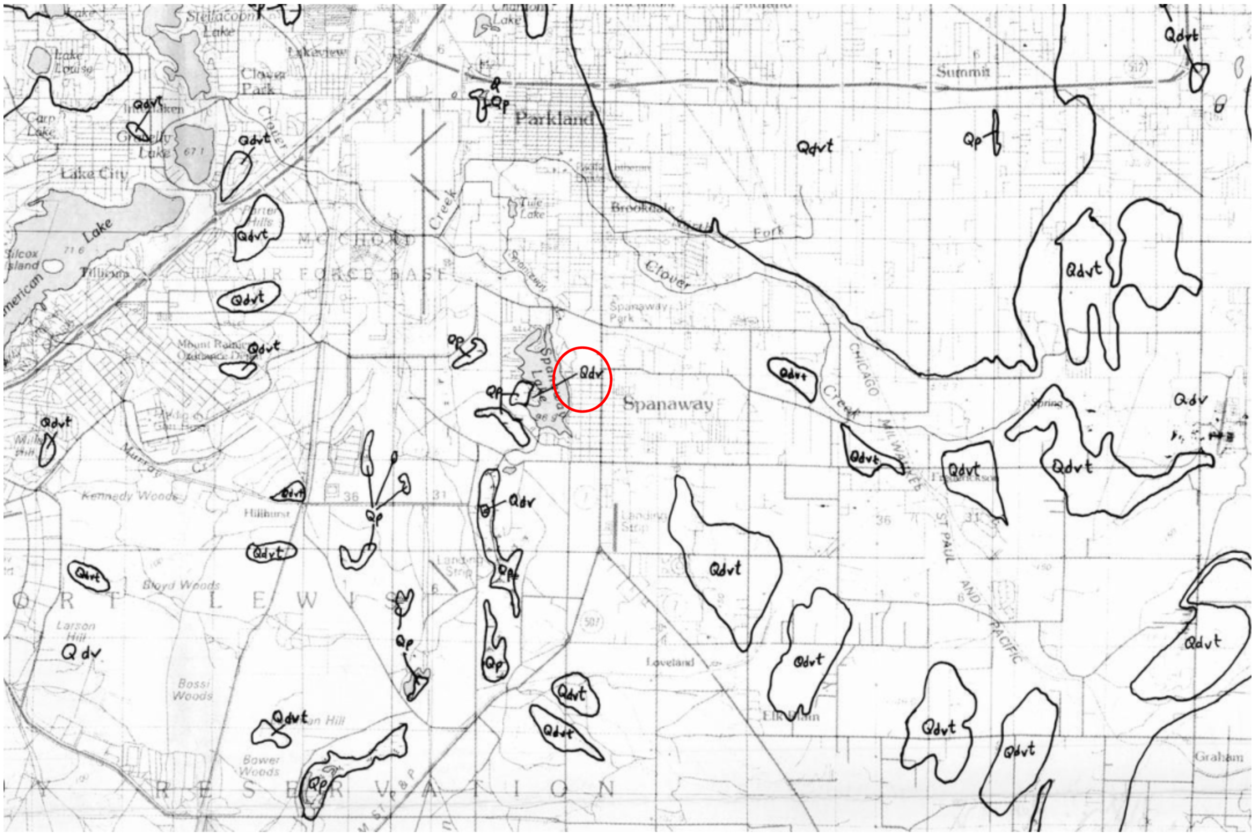


Cobb.	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

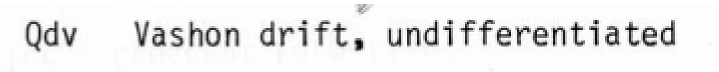
Sieve No.	Diam. (mm)	Cum. Wt. Ret. (g)	% Ret. by Wt.	% Passing by Wt.	% Specs. Pass. by Wt.	
					Min	Max
3	76.1		0.0	100.0		
2.5	64		0.0	100.0		
2	50.8		0.0	100.0		
1.5	38.1		0.0	100.0		
1	25.4		0.0	100.0		
3/4	19		0.0	100.0		
3/8	9.51		0.0	100.0		
#4	4.76	2.0	0.4	99.6		
#8	2.38	3.6	0.7	99.3		
#10	2	5.0	1.0	99.0		
#20	0.85	364.7	69.5	30.5		
#40	0.42	484.5	92.3	7.7		
#60	0.25	505.8	96.4	3.6		
#100	0.149	520.7	99.2	0.8		
#200	0.074	523.4	99.7	0.3		
#270	0.053	523.6	99.8	0.2		

APPENDIX C

Background Soil, Geology, and Ground Water Data (Regional Maps, Previous Studies Exploration Logs and Laboratory Testing Data)

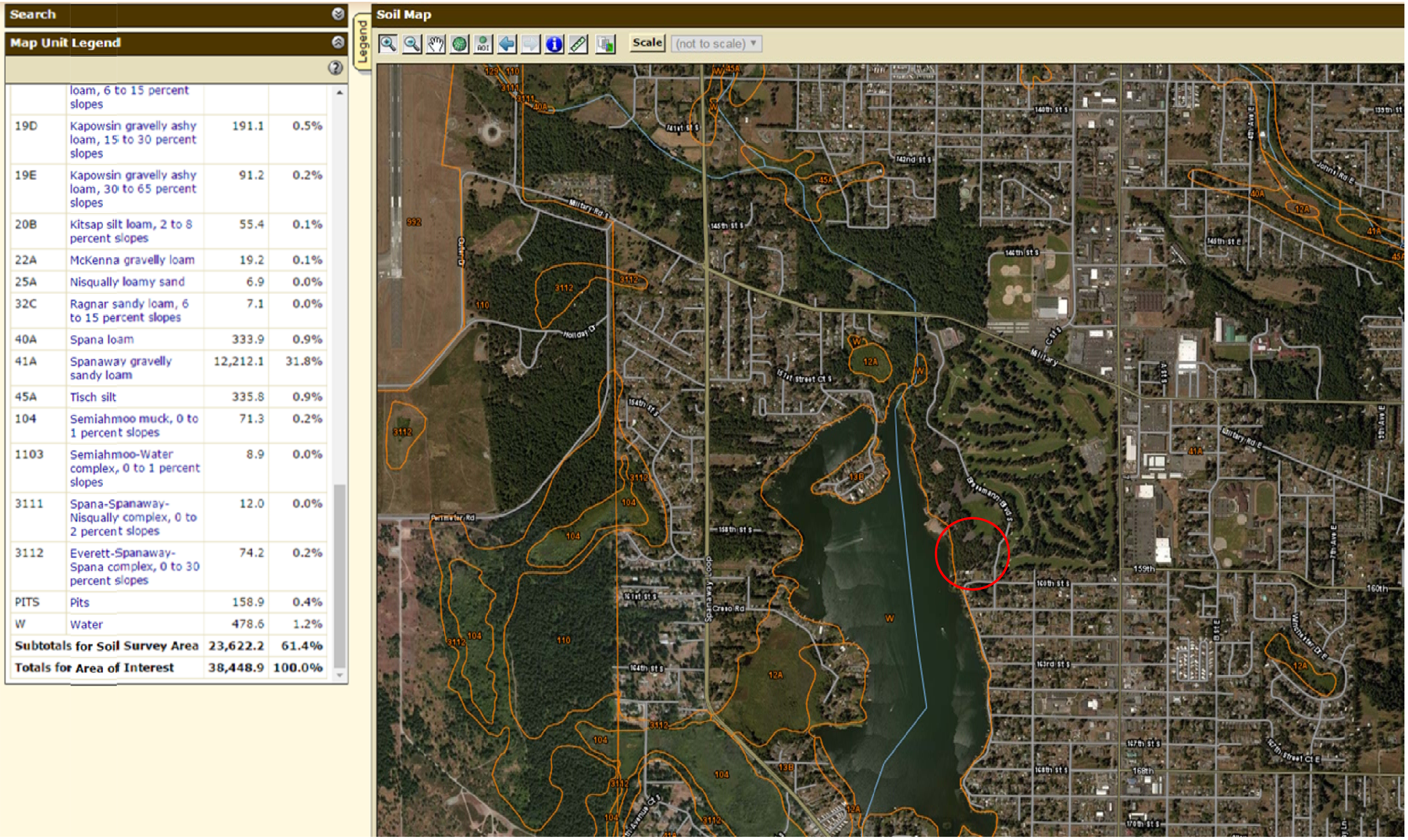


Approximate location of facilities indicated by red outline



Qdv Vashon drift, undifferentiated

Excerpt from Walsh, T.J., 1987, Geologic map of the south half of the Tacoma quadrangle, Washington



	loam, 6 to 15 percent slopes		
19D	Kapowsin gravelly ashy loam, 15 to 30 percent slopes	191.1	0.5%
19E	Kapowsin gravelly ashy loam, 30 to 65 percent slopes	91.2	0.2%
20B	Kitsap silt loam, 2 to 8 percent slopes	55.4	0.1%
22A	McKenna gravelly loam	19.2	0.1%
25A	Nisqually loamy sand	6.9	0.0%
32C	Ragnar sandy loam, 6 to 15 percent slopes	7.1	0.0%
40A	Spana loam	333.9	0.9%
41A	Spanaway gravelly sandy loam	12,212.1	31.8%
45A	Tisch silt	335.8	0.9%
104	Semiahmoo muck, 0 to 1 percent slopes	71.3	0.2%
1103	Semiahmoo-Water complex, 0 to 1 percent slopes	8.9	0.0%
3111	Spana-Spanaway-Nisqually complex, 0 to 2 percent slopes	12.0	0.0%
3112	Everett-Spanaway-Spana complex, 0 to 30 percent slopes	74.2	0.2%
PITS	Pits	158.9	0.4%
W	Water	478.6	1.2%
Subtotals for Soil Survey Area		**23,622.2**	**61.4%**
Totals for Area of Interest		**38,448.9**	**100.0%**

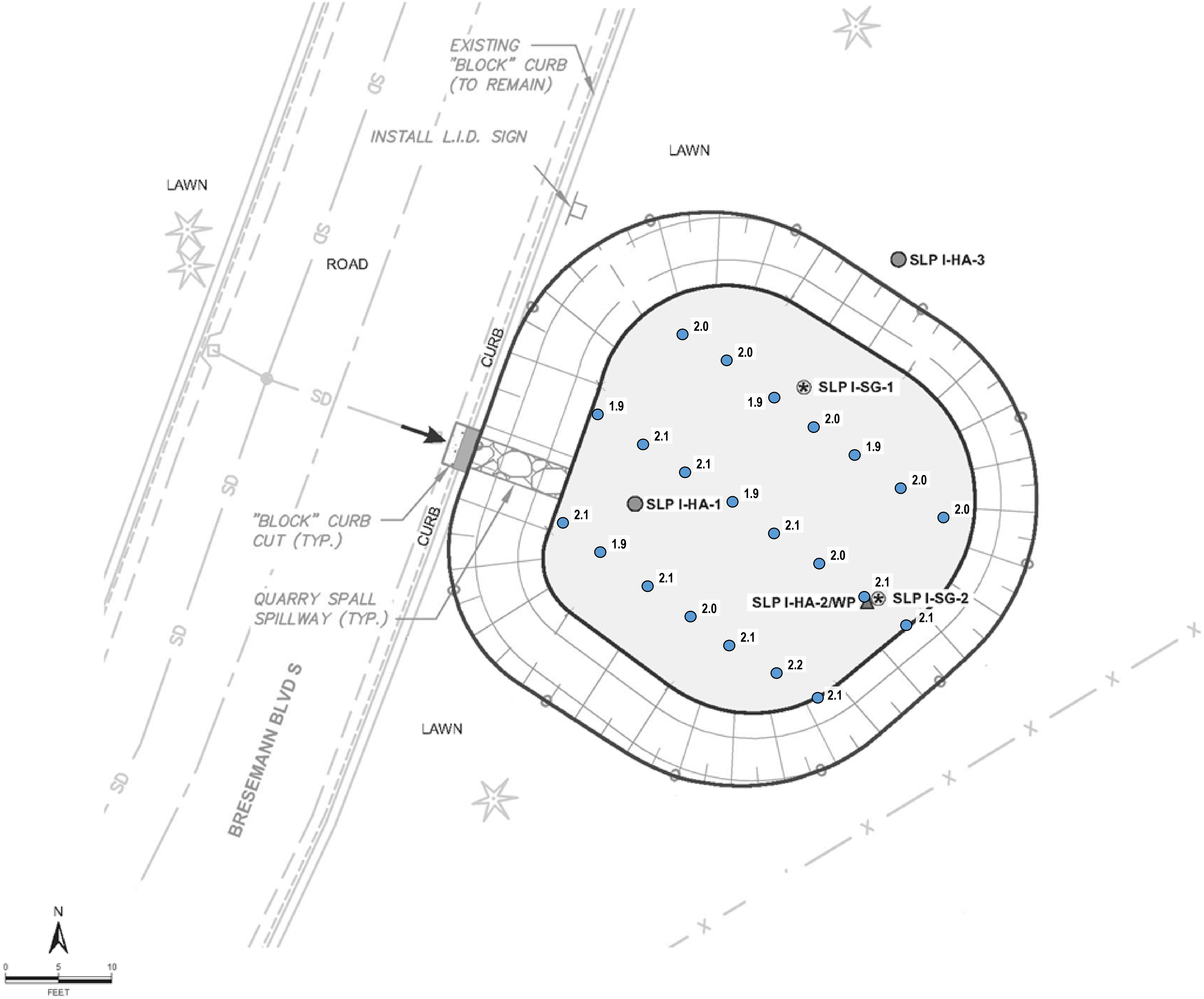
Approximate location of facilities indicated by red outline

Excerpt from Natural Resources Conservation Service, 2016, Web soil survey

APPENDIX D

Soil Probe, Level Survey, and Field Infiltration Testing Data

SLP "I" Soil Probe Data



LEGEND:

● HA	HAND AUGER
▲ WP	WELL POINT
⊛	TEMPORARY STAFF GAUGE
▢	BASE OF FACILITY
▢	TOP OF FACILITY SLOPE
→	INFLOW / OVERFLOW DIRECTION
▬	CURB CUT
● 0.8	Soil Probe and Depth of Loose Soil

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:
1. BASE MAP REFERENCE: PIERCE COUNTY DEPARTMENT OF PUBLIC WORKS, SPANAWAY LAKE PARK LID RETROFIT - PHASE 1, BIORETENTION AREAS H AND I, SHEET 10 OF 16, UNDATED

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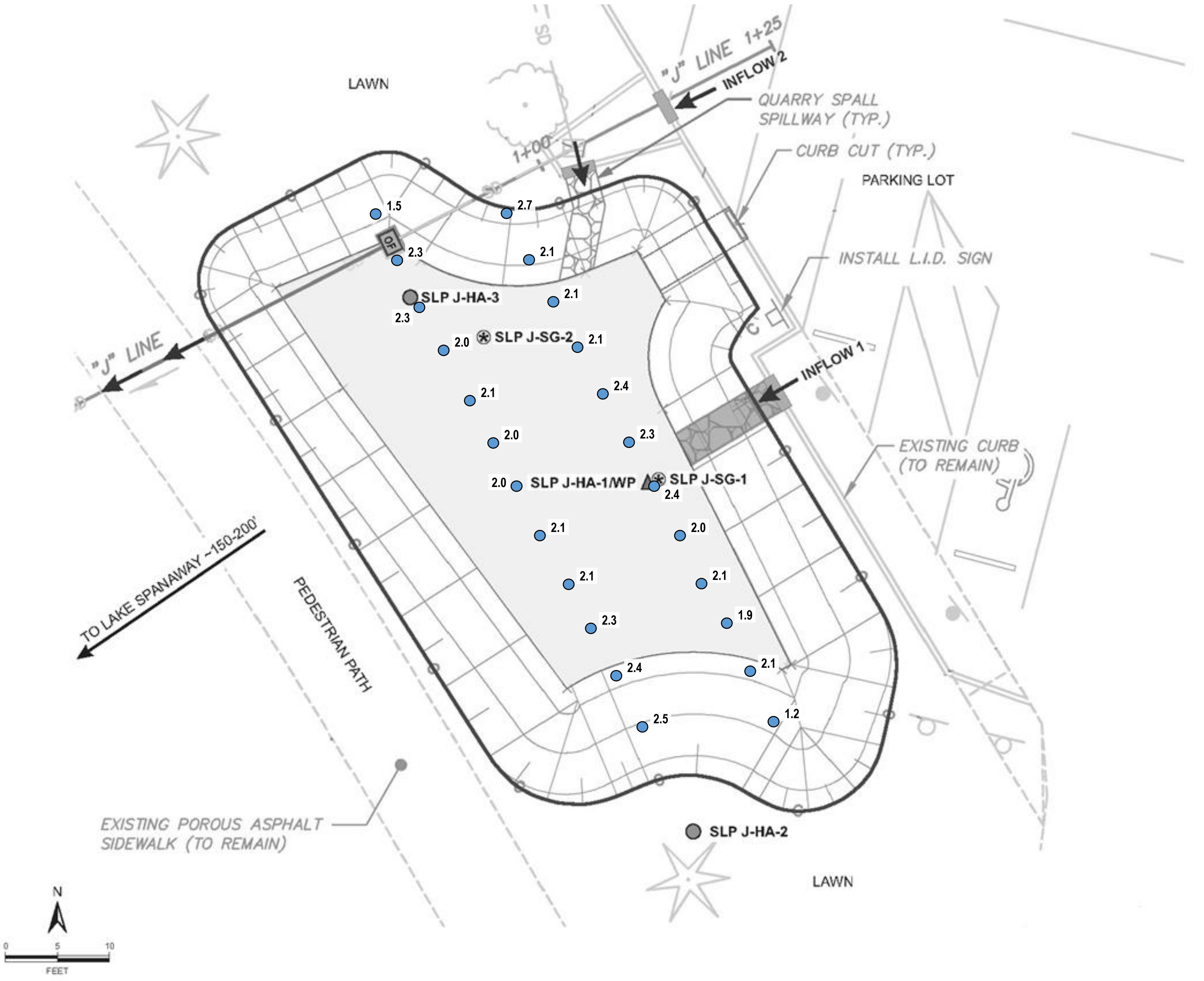
SOIL PROBE DATA
SLP"I" SITE
BIORETENTION HYDROLOGIC PERFORMANCE
PIERCE COUNTY, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	D1

150387 BHPS MCCA\ 150387 Site-Expl.cdr PAGE 9: SLP "I"

SLP “J” Soil Probe Data



LEGEND:

● HA HAND AUGER

▲ WP WELL POINT

⊛ TEMPORARY STAFF GAUGE

▭ BASE OF FACILITY

▭ TOP OF FACILITY SLOPE

→ INFLOW / OVERFLOW DIRECTION

OF OVERFLOW GRATE

— STORM DRAIN

▭ ORIGINAL LOCATION OF SPILLWAY

▬ RELOCATED SPILLWAY

▬ CURB CUT

● 0.8 Soil Probe and Depth of Loose Soil

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:

1. BASE MAP REFERENCE: PIERCE COUNTY DEPARTMENT OF PUBLIC WORKS, SPANAWAY LAKE PARK LID RETROFIT - PHASE 1, BIORETENTION AREA J, SHEET 11 OF 16, UNDATED

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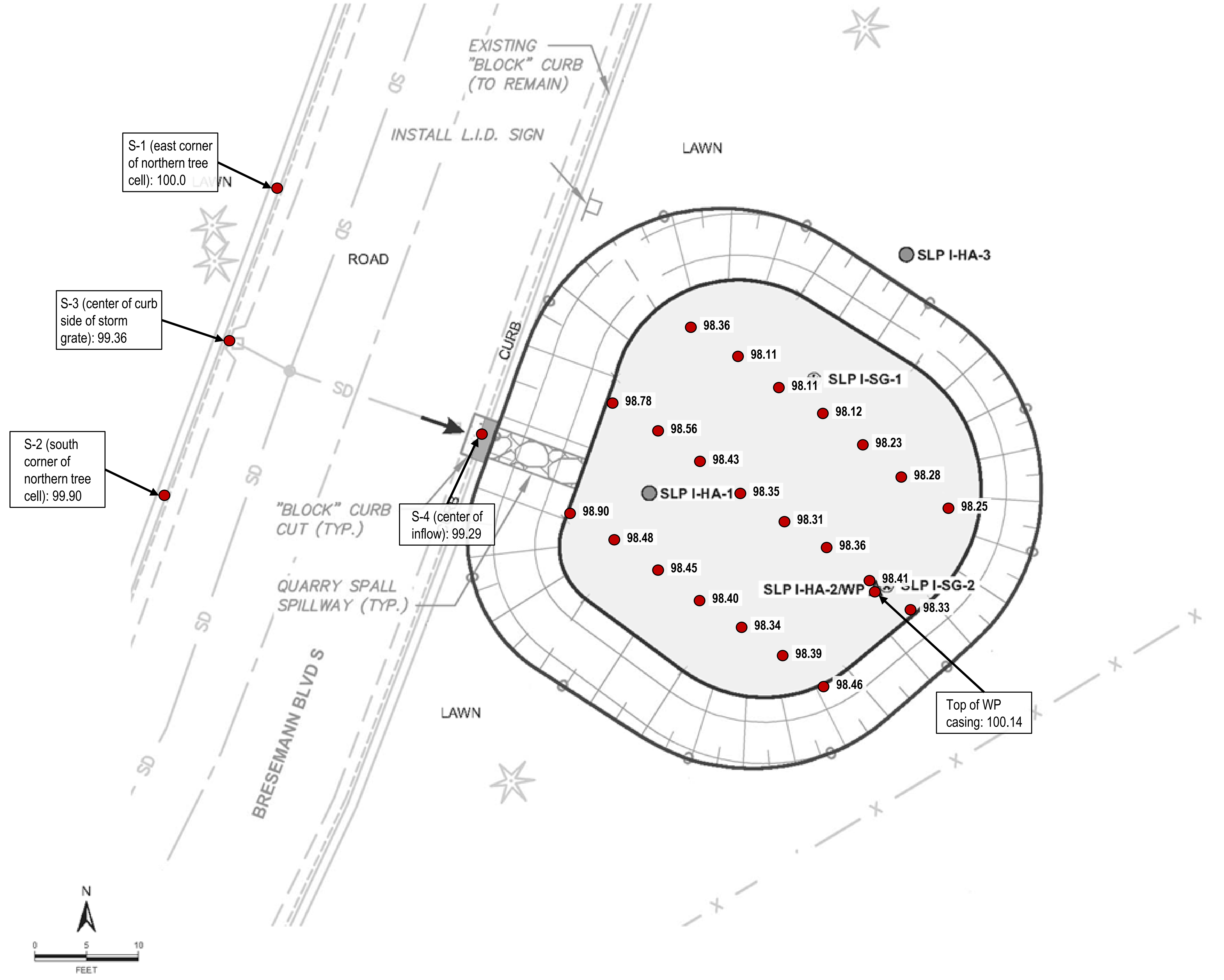
SOIL PROBE DATA
SLP“J” SITE
BIORETENTION HYDROLOGIC PERFORMANCE
PIERCE COUNTY, WASHINGTON

PROJ NO. KH150387A
DATE: 9/16
FIGURE: D1

150387 BHPS MCCA \ 150387 Site-Explr.cdr PAGE 9: SLP "J"

SLP “I” Level Survey Data



LEGEND:

● HA	HAND AUGER
▲ WP	WELL POINT
⊛	TEMPORARY STAFF GAUGE
▭	BASE OF FACILITY
▭	TOP OF FACILITY SLOPE
→	INFLOW / OVERFLOW DIRECTION
▨	CURB CUT
● 98.66	Elevation, Project Datum (see text)

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:
1. BASE MAP REFERENCE: PIERCE COUNTY DEPARTMENT OF PUBLIC WORKS, SPANAWAY LAKE PARK LID RETROFIT - PHASE 1, BIORETENTION AREAS H AND I, SHEET 10 OF 16, UNDATED

BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION.

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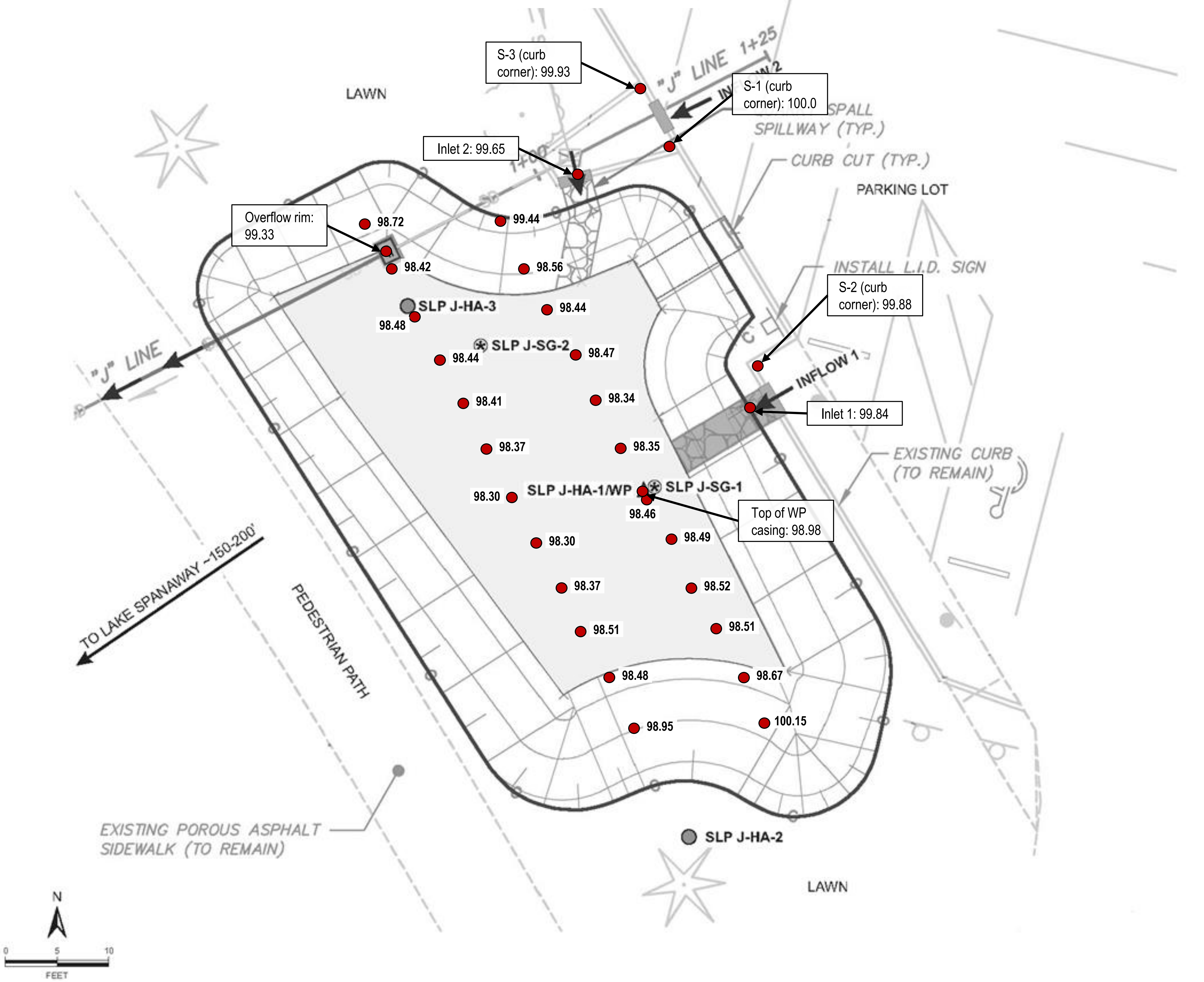
LEVEL SURVEY DATA
SLP“I” SITE
BIORETENTION HYDROLOGIC PERFORMANCE
PIERCE COUNTY, WASHINGTON

PROJ NO. KH150387A	DATE: 9/16	FIGURE: D2

150387 BHPS MCCA\ 150387 Site-Expl.cdr PAGE 9: SLP"I"

SLP "J" Level Survey Data



LEGEND:

- ● HA HAND AUGER
- ▲ WP WELL POINT
- ⊛ TEMPORARY STAFF GAUGE
- ▭ BASE OF FACILITY
- ▭ TOP OF FACILITY SLOPE
- → INFLOW / OVERFLOW DIRECTION
- OF OVERFLOW GRATE
- — STORM DRAIN
- ⬚ ORIGINAL LOCATION OF SPILLWAY
- ▨ RELOCATED SPILLWAY
- ▬ CURB CUT
- ● 98.66 Elevation, Project Datum (see text)

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:
1. BASE MAP REFERENCE: PIERCE COUNTY DEPARTMENT OF PUBLIC WORKS, SPANAWAY LAKE PARK LID RETROFIT - PHASE 1, BIORETENTION AREA J, SHEET 11 OF 16, UNDATED

BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION.

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LEVEL SURVEY DATA
SLP"J" SITE
BIORETENTION HYDROLOGIC PERFORMANCE
PIERCE COUNTY, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	9/16	D2

150387 BHPS MCCA \ 150387 Site-Expl.cdr PAGE 9: SLP "J"

Cell SLP"I"
Level Survey Data

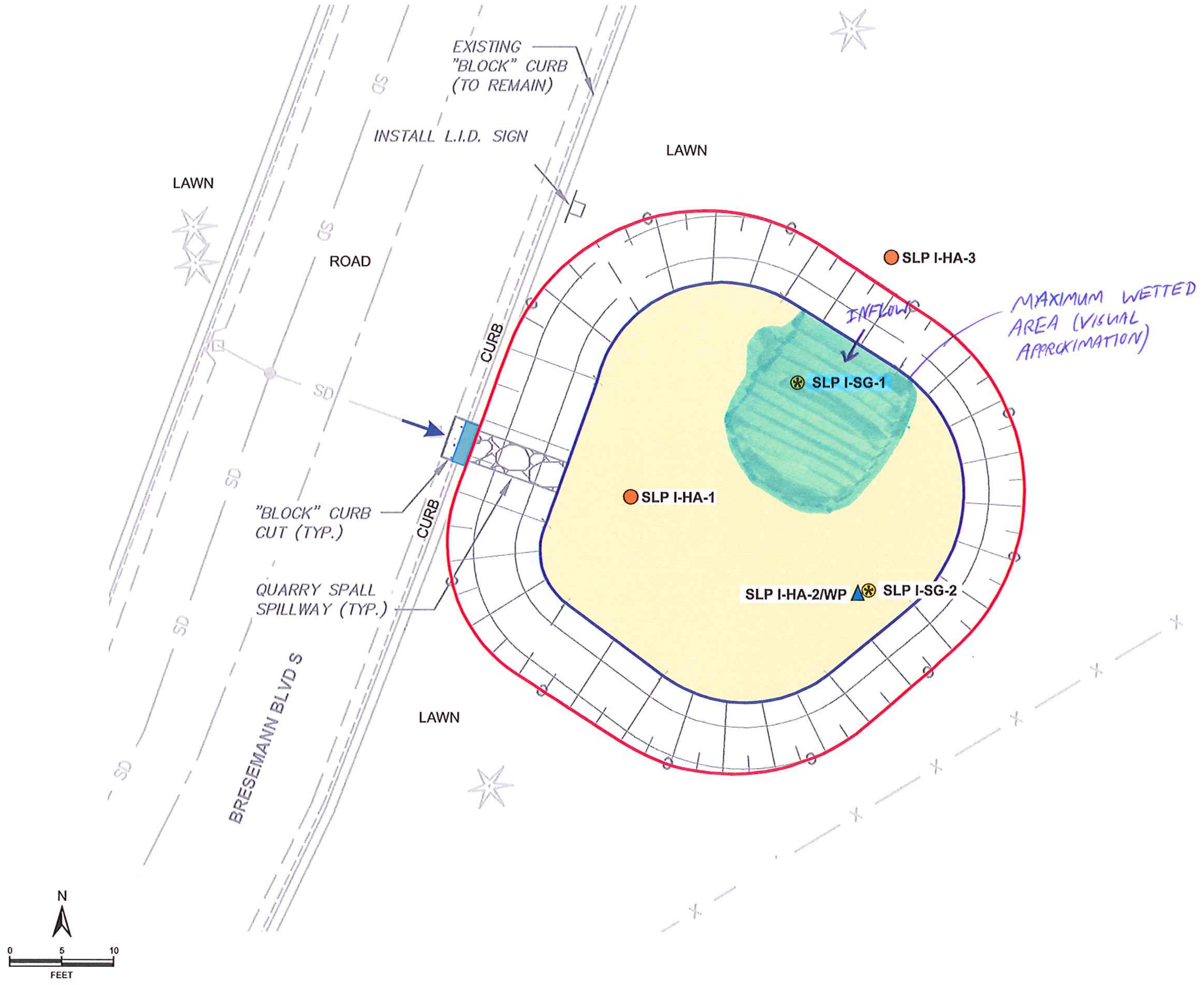
Location	Elevation (feet, project datum)
(S-1) East corner of northern tree cell	100
(S-2) South corner of southern tree cell	99.9
(S-3) Center of curb side of eastern storm grate	99.36
(S-4) Center of inflow	99.29
Well point, top of casing	101
Survey points in base of cell	On site plan

Cell SLP"J"
Level Survey Data

Location	Elevation (feet, project datum)
(S-1) Curb corner (indicated on figure)	100
(S-2) Curb corner (indicated on figure)	99.88
(S-3) Curb corner (indicated on figure)	99.93
Inlet 2	99.65
Inlet 1	99.84
Well point, top of casing	98.98
Overflow rim	99.33
Survey points in base of cell	On site plan

Cell SLP”I” and SLP”J”
Probe Survey Data List (Excludes Outliers)

SLP”I”, Probe Penetration (feet):	SLP”J”, Probe Penetration (feet):
2	2.3
2	2.3
1.9	2
2	2.1
1.9	2
2	2
2	2.1
1.9	2.1
2.1	2.3
2.1	2.4
1.9	2.5
2.1	2.7
2	2.1
2.1	2.1
2.1	2.1
2.1	2.4
1.9	2.3
2.1	2.4
2	2
2.1	2.1
2.2	1.9
2.1	2.1
AVERAGE: 2.0	AVERAGE: 2.2



LEGEND:

● HA	HAND AUGER
▲ WP	WELL POINT
⊛	TEMPORARY STAFF GAUGE
🟨	BASE OF FACILITY
▭	TOP OF FACILITY SLOPE
➔	INFLOW / OVERFLOW DIRECTION
🟦	CURB CUT

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:

1. BASE MAP REFERENCE: PIERCE COUNTY DEPARTMENT OF PUBLIC WORKS, SPANAWAY LAKE PARK LID RETROFIT - PHASE 1, BIORETENTION AREAS H AND I, SHEET 10 OF 16, UNDATED

BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION.

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WETTED AREA

SLP"I" SITE

BIORETENTION HYDROLOGIC PERFORMANCE

PIERCE COUNTY, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KH150387A	10 /16	APPENDIX D

150387 BHPS MCCA \ 150387 Site-Explr.cdr PAGE 9: SLP"I"

LEGEND:

● HA	HAND AUGER
▲ WP	WELL POINT
⊛	TEMPORARY STAFF GAUGE
🟨	BASE OF FACILITY
○	TOP OF FACILITY SLOPE
→	INFLOW / OVERFLOW DIRECTION
OF	OVERFLOW GRATE
—	STORM DRAIN
⬚	ORIGINAL LOCATION OF SPILLWAY
🟪	RELOCATED SPILLWAY
🟦	CURB CUT

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.

NOTES:

1. BASE MAP REFERENCE: PIERCE COUNTY DEPARTMENT OF PUBLIC WORKS, SPANAWAY LAKE PARK LID RETROFIT - PHASE 1, BIORETENTION AREA J, SHEET 11 OF 16, UNDATED

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WETTED AREA
SLP"J" SITE
BIORETENTION HYDROLOGIC PERFORMANCE
PIERCE COUNTY, WASHINGTON

PROJ NO. KH150387A
DATE: 10 /16
FIGURE: APPENDIX D

150387 BHPS MCCA | 150387 Site-Explr.cdr PAGE 9: SLP "J"

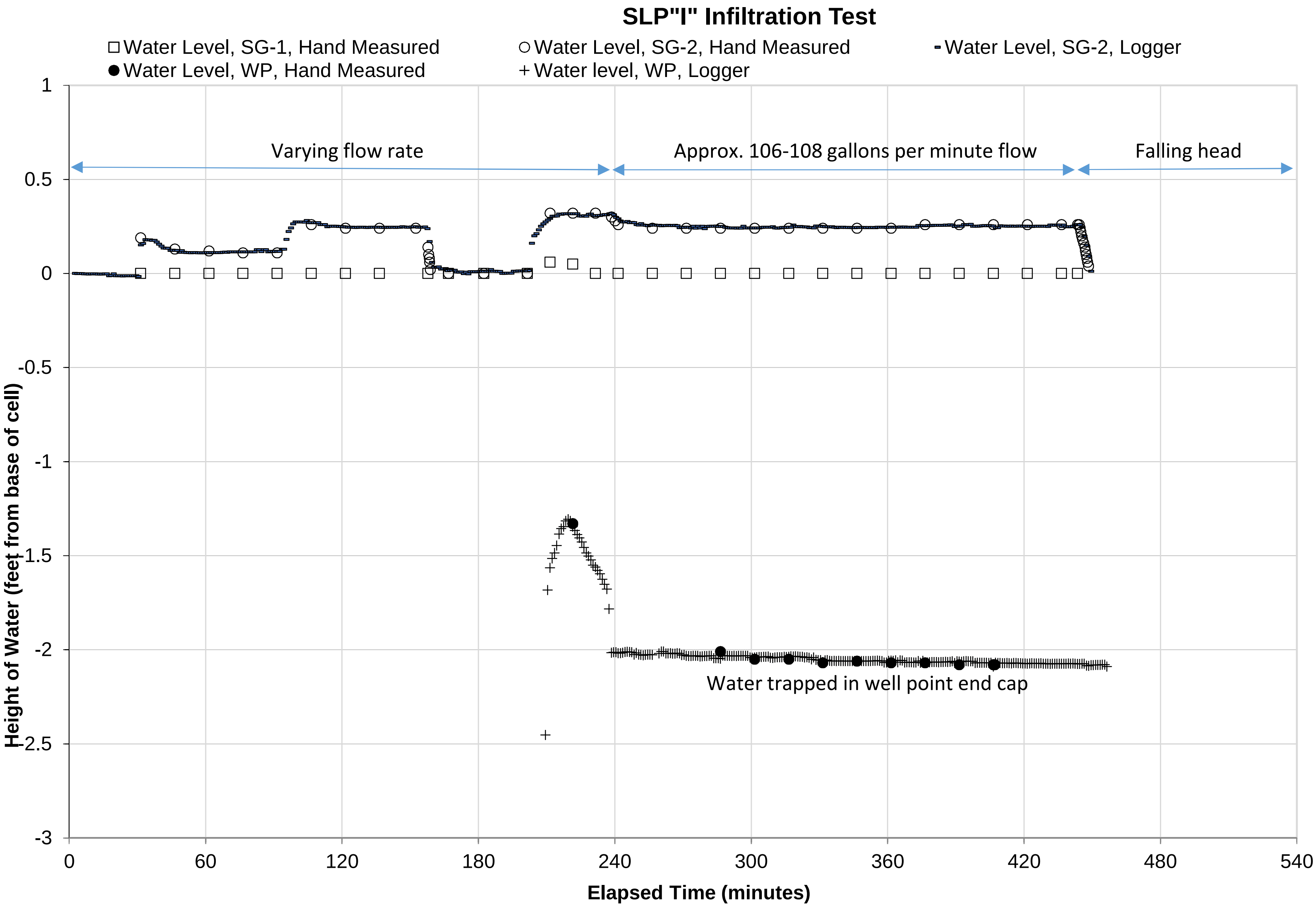
Project Name	Bioretention Hydrologic Performance Assessment
Project Number	KH150387A
Date	9/14/16
Weather	Clear
Test No.	SLP"I" IT-1
Meter	FM7 and FM4
Water Source	Irrigation System, Hydrant + Water Truck and Tank

Receptor Soils	Bioretention Soil over Qvs
Testing Performed By	ADY/LSN

Time (24-hr)	Total (min)	Combined Flow Rate (FM4+FM7) (gpm)	Combined Totalizer (FM4+FM7) (gallons)	SG-1 Stage (ft)	SG-2 Stage (ft)	Depth to water, well point (feet)	Wetted area (ft^2)	Notes
8:28:30	0.0	13.47	0					FM4 water on (from irrigation)
8:53:00	24.5	49.15	338					FM7 water on (from water truck)
8:55:00	26.5	86.75						
9:00:00	31.5	86.85	877	0.00	0.19			
9:15:00	46.5	87.17	2176	0.00	0.13			
9:30:00	61.5	86.70	3466	0.00	0.12			
9:45:00	76.5	85.87		0.00	0.11			
10:00:00	91.5	86.57	6068	0.00	0.11			FM7 increase flow rate to 154.5 gpm
10:15:00	106.5	165.58	8430	0.00	0.26			
10:30:00	121.5	161.15	10873	0.00	0.24	Dry		
10:45:00	136.5	162.27	13318	0.00	0.24			
11:01:00	152.5	13.02			0.24			Tanks dry, FM7 water off
11:06:16	157.8			0.00	0.14			
11:06:39	158.2				0.10			
11:06:54	158.4				0.08			
11:07:04	158.6				0.06			
11:07:19	158.8				0.02	Dry		
11:15:20	166.8	13.39	16668	0.00	0.00			

Time (24-hr)	Total (min)	Combined Flow Rate (FM4+FM7) (gpm)	Combined Totalizer (FM4+FM7) (gallons)	SG-1 Stage (ft)	SG-2 Stage (ft)	Depth to water, well point (feet)	Wetted area (ft^2)	Notes
11:30:55	182.4		16885	0.00	0.00	Dry	24	Trace water on logger in well point
11:50:00	201.5	162.28	17144	0.00	0.00			Tanks refilled, FM7 water on
12:00:00	211.5	161.48	18783	0.06	0.32			
12:10:00	221.5	162.31	20410	0.05	0.32	4		
12:20:00	231.5	162.82	22033	0.00	0.32		480	SG-1 stage fluctuation due to debris
12:26:15	237.8							FM7 decrease flow to 95 gpm; begin constant flow from water tank (topped off by water truck); water truck leaving
12:27:00	238.5				0.30			
12:28:35	240.1				0.28			
12:30:00	241.5	108.91	23528	0.00	0.26			
12:45:00	256.5	106.50	25082	0.00	0.24	5		water truck arriving
13:00:00	271.5	106.77	26685	0.00	0.24		157	water truck leaving
13:15:00	286.5	108.86	28283	0.00	0.24	4.8		
13:30:00	301.5	106.00	29264	0.00	0.24	5		water truck arriving
13:45:00	316.5	105.31	25488	0.00	0.24	4.8		
14:00:00	331.5	107.22	33091	0.00	0.24	4.8	215	water truck leaving
14:15:00	346.5	106.09	34691	0.00	0.24	4.8	215	water truck arriving
14:30:00	361.5	106.37	36263	0.00	0.24	4.8	215	
14:45:00	376.5	106.32	38102	0.00	0.26	4.8	215	water truck leaving
15:00:00	391.5	106.76	39483	0.00	0.26	4.8	215	water truck arriving

Time (24-hr)	Total (min)	Combined Flow Rate (FM4+FM7) (gpm)	Combined Totalizer (FM4+FM7) (gallons)	SG-1 Stage (ft)	SG-2 Stage (ft)	Depth to water, well point (feet)	Wetted area (ft^2)	Notes
15:15:00	406.5	105.26	41061	0.00	0.26	4.8	215	
15:30:00	421.5	107.83	42671	0.00	0.26		215	
15:45:00	436.5	108.94	44285	0.00	0.26	4.8	215	
15:52:00	443.5	106.41	45046	0.00	0.26		215	
15:52:45	444.3	106.00	45139		0.26		215	all water off, begin falling head
15:53:10	444.7				0.24			
15:53:32	445.0				0.22			
15:53:50	445.3				0.20			
15:54:17	445.8				0.18			
15:54:47	446.3				0.16			
15:55:15	446.8				0.14			
15:55:32	447.0				0.12			
15:55:52	447.4				0.10			
15:56:08	447.6				0.08			
15:56:24	447.9				0.06			
15:56:50	448.3				0.04			End of test, retrieve dataloggers

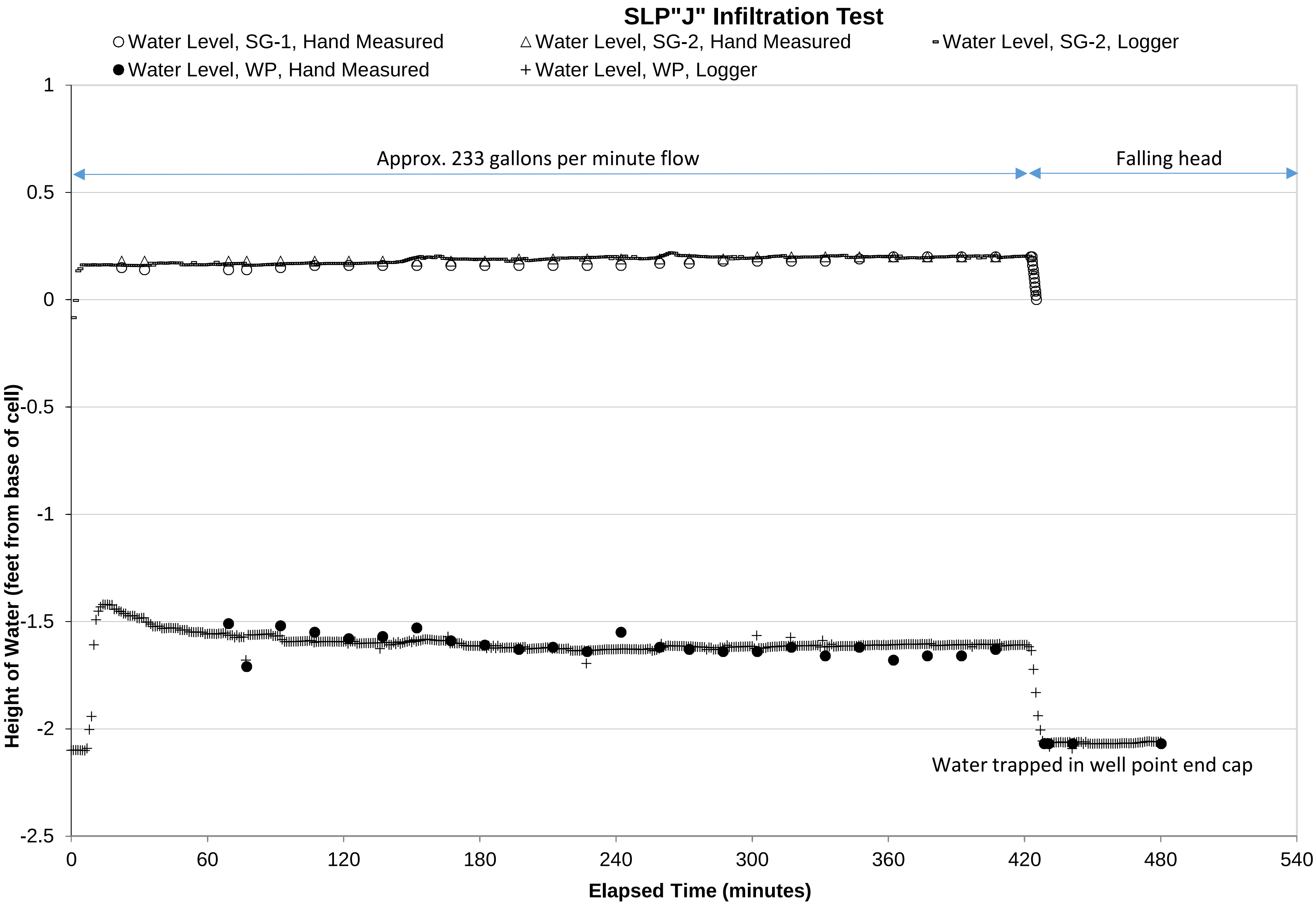

SLP"I" Infiltration Test
□ Water Level, SG-1, Hand Measured
○ Water Level, SG-2, Hand Measured
- Water Level, SG-2, Logger
● Water Level, WP, Hand Measured
+ Water level, WP, Logger
Varying flow rate
Approx. 106-108 gallons per minute flow
Falling head
Water trapped in well point end cap
Height of Water (feet from base of cell)
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
0
60
120
180
240
300
360
420
480
540
Elapsed Time (minutes)

Project Name	Bioretention Hydrologic Performance Assessment	**Receptor Soils**	Bioretention Soil over Qvs
Project Number	KH150387A	**Testing Performed By**	LSN
Date	9/13/16		
Weather	Clear		
Test No.	SLP"J" IT-1		
Meter	FM7, Hydrant Meter		
Water Source	Hydrant		

Time (24-hr)	Total (min)	Flow Rate (gpm)	Totalizer (gallons)	SG-1 Stage (ft)	SG-2 Stage (ft)	Depth to water, well point (feet)	Wetted area (ft^2)	Notes
7:33:00				0.00	0.00	3.16		
7:35:00				0.00	0.00			
7:50:15		25.14	0	0.00	0.00			Water on
7:52:30		24.18	52	0.00	0.00			Increase flow to 51 gpm
7:54:15		54.10	142	0.00	0.00			Increase flow to 100 gpm
8:00:00		100.18	699	0.00	0.00			Increase flow to 153 gpm (max.)
8:17:00		152.17	3248				28	Water off; remove FM7 to increase possible flow rate
8:30:00		230.00	3248					Water on; using city hydrant meter to monitor flow rate
8:35:00			4260					Water off; adding diffuser
8:49:00		187.00	6493					Water on; diffuser installed
8:59:00								Water off; removing non-collapse hoses
9:12:45	0.0	205.00						Water on; non-collapse hoses removed, time zero

Time (24-hr)	Total (min)	Flow Rate (gpm)	Totalizer (gallons)	SG-1 Stage (ft)	SG-2 Stage (ft)	Depth to water, well point (feet)	Wetted area (ft^2)	Notes
9:35:00	22.3			0.15	0.18	1.03		Removed kink in fire hoses, irregular well point water level reading, excluded from graph
9:41:00	28.3	235.60	13528					
9:45:00	32.3			0.14	0.18	1.08	289	Irregular well point water level reading, excluded from graph
10:22:00	69.3	235.60	22259	0.14	0.18	2.11	442	
10:30:00	77.3			0.14	0.18	2.31		
10:45:00	92.3	233.00	27189	0.15	0.18	2.12		
11:00:00	107.3	230.00	30533	0.16	0.18	2.15	418	
11:15:00	122.3	234.00	34363	0.16	0.18	2.18		
11:30:00	137.3	233.00	38986	0.16	0.18	2.17		
11:45:00	152.3	232.00	41171	0.16	0.18	2.13		
12:00:00	167.3	234.00	44642	0.16	0.18	2.19	528	
12:15:00	182.3	233.00	48435	0.16	0.18	2.21		
12:30:00	197.3	236.00	51981	0.16	0.19	2.23		
12:45:00	212.3	233.00	55415	0.16	0.19	2.22		
13:00:00	227.3	233.00	58860	0.16	0.19	2.24		
13:15:00	242.3	235.00	62245	0.16	0.19	2.15		
13:32:00	259.3	235.00	68349	0.17	0.19	2.22		
13:45:00	272.3	233.00	69913	0.17	0.19	2.23		
14:00:00	287.3	235.00	73586	0.18	0.19	2.24		
14:15:00	302.3	235.00	76735	0.18	0.20	2.24		
14:30:00	317.3	233.00	80072	0.18	0.20	2.22		
14:45:00	332.3	234.00	83551	0.18	0.20	2.26		
15:00:00	347.3	233.00	87209	0.19	0.20	2.22	572	
15:15:00	362.3	232.00	90538	0.20	0.20	2.28		
15:30:00	377.3	231.00	94166	0.20	0.20	2.26		
15:45:00	392.3	234.00	97562	0.20	0.20	2.26		

Time (24-hr)	Total (min)	Flow Rate (gpm)	Totalizer (gallons)	SG-1 Stage (ft)	SG-2 Stage (ft)	Depth to water, well point (feet)	Wetted area (ft^2)	Notes
16:00:00	407.3	232.00	101340	0.20	0.20	2.23		
16:15:25	422.7	~232	105361	0.20				Water off, begin falling head
16:16:03	423.3			0.20				
16:16:13	423.5			0.18				
16:16:21	423.6			0.16				
16:16:36	423.9			0.14				
16:16:51	424.1			0.12				
16:17:02	424.3			0.10				
16:17:13	424.5			0.08				
16:17:22	424.6			0.06				
16:17:39	424.9			0.04				
16:17:47	425.0			0.02				
16:18:00	425.3			0.00				
16:21:30	428.8					2.67		
16:23:30	430.8					2.67		
16:34:00	441.3					2.67		
17:13:00	480.3					2.67		End of test, retrieve dataloggers


SLP"J" Infiltration Test
○ Water Level, SG-1, Hand Measured
△ Water Level, SG-2, Hand Measured
▭ Water Level, SG-2, Logger
● Water Level, WP, Hand Measured
+ Water Level, WP, Logger
Approx. 233 gallons per minute flow
Falling head
Water trapped in well point end cap
Height of Water (feet from base of cell)
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
0
60
120
180
240
300
360
420
480
540
Elapsed Time (minutes)

APPENDIX E

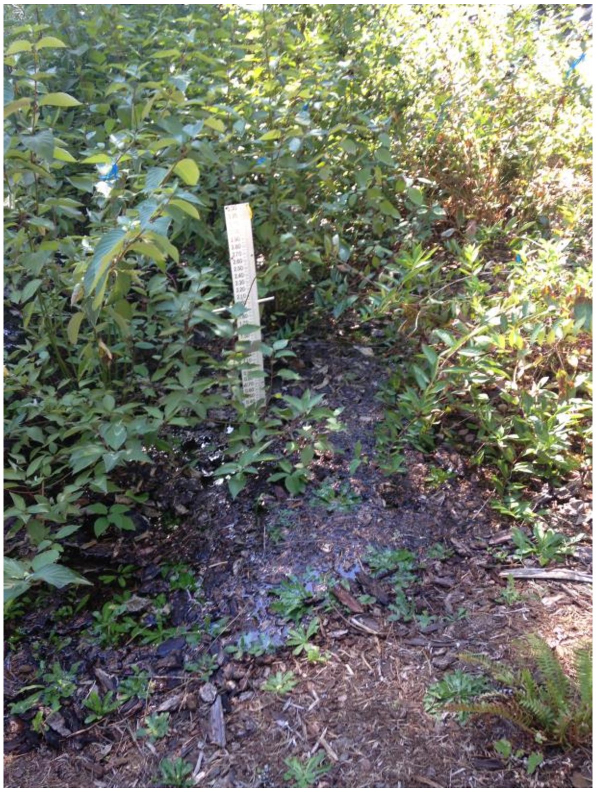
Site Photos

Cell SLP"J"

Cell SLP"I"

Cell SLP"J" northern inlet

Cell SLP"J" overflow structure



Cell SLP”I” during infiltration testing, with SG-2 visible

Cell SLP”J” during infiltration testing, with SG-1 visible

APPENDIX 10

Bellingham Bioretention Study - Vegetation Monitoring Methods and Results. Raedeke Associates, Inc. 10/19/16

Raedeke
Associates, Inc.

Wetland & Aquatic Sciences
Wildlife Ecology
Landscape Architecture

TECHNICAL MEMORANDUM

June 26, 2018

To:	Mr. Eli Mackiewicz, City of Bellingham
From:	Anne Cline, Landscape Architect Chris Wright, Soil Scientist Raedeke Associates, Inc.
RE:	Bellingham Bioretention Hydrologic Performance Study Vegetation Monitoring Methods and Results (R.A.I. No. 2015-037-001)

As part of the Bellingham Bioretention Hydrologic Performance Study, we measured and described the vegetation communities within each of ten bioretention cells with the Puget Sound lowlands. The purpose of describing the vegetation community composition and percent cover is to help assess whether vegetation composition and maintenance may have an influence on the ability of the bioretention cell to perform hydrologic control functions. We also compared the observed present vegetation community with the original planting plan to indicate apparent changes in composition from the original plan.

SUMMARY OF FINDINGS

- Shrub species are surviving well
- Herbaceous species less adaptable – depends on irrigation and the wetland indicator status of the species selected
- Plant survival is affected by the native subgrade
- Complex community site designs tend to reduce to lesser complex composition for herbaceous plants
- Organizational commitment to landscape maintenance tends to be less than needed for the plant composition, resulting in mortality of some plants and establishment of invasive species

METHODS

Bioretention facility plant composition and density was measured for selected monitoring sites in one of three possible approaches, depending on site conditions. Only the bottom of the bioretention cell (the area subject to inundation) was sampled for vegetation.

1. For bioretention units that only had woody vegetation (shrubs and trees), the number of stems were counted within the unit (density). A woody plant is considered and inventoried as a single individual, regardless of the number and size of stems emerging from a common root system. A woody sapling/tree with a single stem is also considered and inventoried as a single individual. However, a woody sapling/tree with multiple stems may be considered and inventoried as multiple individuals if the stems split below 50 centimeters in height (along the stem). In addition to a count of the number of stems within the facility, we estimated estimation the percent cover of the woody vegetation within the study area. We recorded the genus and species of the woody plants, as well as the wetland indicator status (WIS) of the species observed. WIS assignment to plant species is described below.

2. For bioretention units with only herbaceous plant species, a quadrat along pre-determined points along a transect line(s) was used to estimate percent vegetation cover. A 25 cm x 25 cm quadrat was used to record the percentage of herbaceous vegetation versus the percentage of bare ground that covers each quadrat. Plants were identified to genus and species and note made of the wetland indicator status of the observed species. At a minimum, 25% of the unit was sampled.

3. For bioretetion units with woody and herbaceous species, both sampling methods were used. Stem density was counted for the woody species and quadrats were used to estimate coverage of herbaceous vegetation.

WETLAND INDICATOR STATUS (WIS)

Native Plants

Wetland Indicator Status (WIS) is a status used to designate a plant species' preference for occurrence in a wetland or upland based on qualitative descriptions. The WIS for a given species will vary based upon region, with Western Washington being in the Western Mountains, Valleys and Coast region. Using the WIS for the plant species observed provides a basis for evaluation of the soil moisture regime and, by inference, an indication of the plant species best suited for a given site. The WIS of plants within our region was found on the USDA Natural Resource Conservation Service (NRCS 2018a) Plants Database.

Below are the categories and definitions for characterizing a plants preference for growing conditions:

OBL	Obligate Wetland	Hydrophyte	Almost always occur in wetlands
FACW	Facultative Wetland	Hydrophyte	Usually occur in wetlands, but may occur in non-wetlands
FAC	Facultative	Hydrophyte	Occur in wetlands and non-wetlands
FACU	Facultative Upland	Nonhydrophyte	Usually occur in non-wetlands, but may occur in wetlands
UPL	Obligate Upland	Nonhydrophyte	Almost never occur in wetlands

Ornamental Plants

The USDA NRCS (2018a) assigns WIS to native plants and nonnative plants that occur frequently in the natural environment, such as Himalayan blackberry. In the bioretention cells, we found ornamental plant species, as well as native plants, had been installed. Since ornamental plants frequently do not have a WIS, we looked for an equivalent native plant, so we could assign the plant with a WIS where possible. For example, multiple varieties of red twig dogwood (*Cornus sericea*), varieties such as mid-winter fire, or the variegated dogwood, were recorded in bioretention cells. These varieties do not have a WIS, so we assigned the varieties the same WIS as the native red twig dogwood (FACW). As another example, ornamental golden sedge (*Carex aurea*) was installed in one of the bioretention cells. Native golden sedge grows in Washington State and has a WIS of FACW, therefore we assigned the landscape variety the same WIS.

VEGETATION RESULTS AND DATA ANALYSIS

BELLEVUE 145TH PLACE CELL 1 (B145)

Vegetative cover was measured on July 6, 2016 at Bellevue 145th Place Cell 1. According to our field measurements, the bottom of this cell is approximately 465 square feet. The cell contains both woody and herbaceous vegetation; therefore, both sampling methods were used to collect vegetation data. Cell 1 contains nine woody plants and 33 woody stems. Woody cover was estimated at 20%. Herbaceous vegetation was measured in 117 quadrats in the cell.

The planting plan for this cell does not reflect the vegetation that is currently present within the cell. Per the provided plan, this cell was intended to have been vegetated with herbaceous vegetation. Currently shrubs and herbaceous vegetation are growing within the cell. Woody vegetation within the cell was composed of three ornamental ninebarks (*Physocarpus sp.*) (FACW), two Douglas spirea (*Spiraea douglasii*) (FACW), one dwarf artic blue willow (*Salix purpurea 'Nana'*) (FAC), and three variegated red-twig dogwood (*Cornus sericea elegantissima*) (FACW). The ninebark and spirea were not listed on the planting plan for the bioretention cell or listed as plants for installation in the landscape surrounding the bioretention cells. The willow and red-twig dogwood were present on the planting plan to be installed in the surrounding landscape. The stem count for the dogwood was 33, and the other shrubs were single- stemmed.

Per the provided plan, the cell was planted with a mix of taper-tipped rush (*Juncus acuminatus*) (OBL), slender rush (*Juncus tenuis*) (FAC), Japanese forest grass (*Hakonecholoa macra aureola*) (FAC), Joe-Pye weed (*Eupatorium dubium*) (FACW), and slough sedge (*Carex obnupta*) (OBL). We observed slough sedge and dwarf Joe-Pye weed growing within the cell. We did not record any rush species growing within the cell.

For the herbaceous plants, slough sedge was the dominant vegetation and occurred in 59.8% of the quadrats. FACW plants occurred in 12.8% of the quadrats, 3.4% of the quadrats sampled contained plants that are FAC, and 20.5% contained plants that have a WIS rating of FACU. Quadrats that contained no herbaceous plants accounted for 24.7%. Multiple plants with different WIS occurred within a single quadrat during the study; therefore, the total percentage of the WIS for plants often exceeds 100%.

The Bellevue cell is located on a native outwash soil. The U.S.D.A Natural Resource Conservation Service (NRCS 2018b) mapped soils in the area as Alderwood. The native soil is considered well-draining. See the Geotechnical Soils Assessment prepared by AESI for more information on the soils in the bioretention cell.

Maintenance occurs weekly at this cell. The cell is weeded of undesirable plants and the overflow and inlet are checked for garbage and leaf debris. This cell is irrigated.

BLOEDEL DONOVAN PARK WEST CELL, BELLINGHAM (BDP)

Vegetative cover was measured on July 29, 2016 at the West Cell at Bloedel Donovan Park in Bellingham. According to measurements from the North Shore Water Quality Project Parking Lot plan sheet, the cell totaled approximately 615 square feet. The cell contains only woody vegetation; therefore only woody plant and stem data was collected. The west cell contains 144 woody stems, and was too dense to differentiate individual plants. Overall woody cover was estimated at 100%.

This cell was planted with woody shrubs, per plan (constructed pre 2007). The woody shrubs have done extremely well within the cell. Growing in the cell are red-twig dogwood (*Cornus sericeae*) (FACW) and cluster rose (*Rosa pisocarpa*) (FAC). The plan does not indicate how many plants were installed within the cell.

The Bloedel Donvan Park cell is located on well-draining outwash soil. The USDA NRCS (2018b) maps the soils in the area of the cell as Squalicum Urban Land Complex. In our study, we found that the regional water table rises in the winter months to within approximately 0.5 feet of the soil surface at the bottom elevation of the cell. Therefore, the soil within the cell is saturated during the rainy season.

Maintenance did not occur for several years following the installation of the plants. After the plants became established, maintenance occurred twice a year in the cell to remove trash, prune the plants as needed, and mulch. The cell is not normally weeded, unless a noxious (invasive) plant is identified as growing in the cell, then that plant is removed. The cell is not currently irrigated, but most likely it was watered the first two years following installation.

ISSAQUAH HIGH SCHOOL CELL #24, ISSAQUAH (IHS)

Vegetative cover was measured on July 6, 2016 at the Issaquah High School Cell #24. According to measurements from the construction record drawings plan sheet, the cell totaled approximately 1,020 square feet. The cell contains only woody vegetation; therefore only woody plant and stem data was collected. The west cell contains 22 woody plants and 89 woody stems. Overall woody cover was estimated at 100%.

The planting plan for the cell at Issaquah High School (constructed in 2009) is reflective of the plants that were present at the time of our survey. We recorded red-twig dogwood (FACW), dwarf artic willow (FAC), Pacific ninebark (*Physocarpus capitatus*) (FACW), and Douglas spirea (FACW), which were all installed per the approved plan. We counted 78 stems for red-twig dogwood and eleven plants. The other shrubs were single-stemmed.

The only herbaceous vegetation to be installed per plan was hard-stem bulrush (*Schoenoplecutus acutus*) (OBL). We did not record hard-stem bulrush within the cell. Either the cell was not wet enough to maintain the bulrush, which typically grows in permanent standing water, it was shaded out by the shrubs over time, or never installed.

The Issaquah high school cell is located on very well-draining outwash soils. The USDA NRCS (2018b) mapped soils in the area as Everett very gravelly sandy loam.

This cell at Issaquah High School has never been maintained.

MILL CREEK COMMUNITY ASSOCIATION CELL 1, MILL CREEK (MCCA 1)

Vegetative cover was measured on July 8, 2016 at Mill Creek Community Association Cell 1. According to our field measurements, the bottom of this cell totals approximately 300 square feet. The cell contains both woody and herbaceous vegetation; therefore both sampling methods were used to collect vegetation data. Cell 1 contains seven woody plants and 45 woody stems. Woody cover was estimated at 60%. Herbaceous vegetation in the cell was recorded within 80 quadrats.

The planting plan for this bioretention cell (constructed in 2013) is vague. The planting plan specifies three variegated red-twig dogwood and seven clumps of moisture loving grasses. We counted four red-twig dogwoods (FACW) and three Douglas spirea (FACW) in this cell.

The prominent herbaceous plants in the cell were yellow flag iris (*Iris pseudoacorus*) and slough sedge, both species have a WIS of OBL. Other recorded herbaceous plants within the cell included fringed willow herb (*Epilobium ciliatum*) (FACW), creeping buttercup (*Ranunculus repens*) (FAC) and wild ginger (*Asarum caudatum*) (FACU).

Slough sedge or yellow flag iris was counted in 74 of the 80 quadrats; therefore, 92.5% of the sampled area contained OBL plants. FACW plants accounted for 2.5% of the areas sampled, 11.3% were FAC, 5.0% were FACU, 1.3% was unidentified, and 10% contained no herbaceous plants

Maintenance occurs seasonally at this cell. The cell is weeded bimonthly or once a month if needed, during the summer, and once during the fall and winter months. This cell is irrigated daily in the summer drought months and was irrigated every other day or every day from May/ June until mid-October for the first two years following construction in May 2014.

MILL CREEK COMMUNITY ASSOCIATION CELL 2, MILL CREEK (MCCA 2)

Vegetative cover was measured on July 8, 2016 at Mill Creek Community Association Cell 2. According to our field measurements, the bottom of cell 2 totaled approximately 285 square feet. The cell contains both woody and herbaceous vegetation; therefore both sampling methods were used to collect vegetation data. Cell 2 contains three woody plants and four woody stems. Woody cover was estimated at 5%. Herbaceous vegetation in the cell was recorded within 57 quadrats.

The planting plan for Cell #2 (also constructed in 2013) specifies installing three variegated red-twig dogwood and eight clumps of moisture loving grasses. Two red-twig dogwoods (FACW) are growing in the cell along with a single Douglas spirea (FACW).

Herbaceous vegetation in Cell 2 was comprised of yellow flag iris, cattail (*Typha latifolia*), and lady’s mantle (*Alchemilla mollis*). The iris and cattail have a WIS of OBL, and the WIS rating for Lady’s mantle is unknown. We were unable to find a native similar enough to lady’s mantle to assign it a WIS rating. Since the herbaceous vegetation is not identified by name on the planting plan, it is possible the cattails were installed. However, most likely the cattails became established naturally in this cell. This was the only cell in the study in which we observed cattails growing, and this was the only cell of the ten that was ponded for substantial periods of time during the wet season and early spring.

Within this bioretention cell, 45.6% of the sampled area contained OBL plants, 5.2% contained FACW plants, 1.8% contained FAC plants, 6.3% contained FACU plants, 7.0% of the quadrats had no plants, 15.5% were unlisted due to the lady's mantle, and 24.2% were unknown (primarily mosses, which were not identified to species). Five of the cells contained no vegetation comprising 8.7%.

Both Mill Creek bioretention cells are located on native till soil, which is a poorly draining or slowly draining soil. The USDA NRCS (2018b) mapped the soils as Alderwood series. The cells have a small contributing area in comparison to many of the other cells we observed, and are adequately sized.

Maintenance occurs seasonally at this cell. The cell is weeded bimonthly or once a month if needed, during the summer, and once during the fall and winter months. This cell is irrigated daily in the summer months and was irrigated every other day or every day from May/ June until mid-October for the first two years following the construction in May 2014.

NOLL ROAD ROUNDABOUT, POULSBO (NOLL)

Vegetative cover was measured on August 4, 2016 at the Noll Road Roundabout bioretention cell. According to our field measurements, the bottom of this cell totaled approximately 370 square feet. The cell contains both woody and herbaceous vegetation; therefore both sampling methods were used to collect vegetation data. The Noll Road Roundabout cell contains 34 woody plants and 203 woody stems. Overall woody cover was estimated at 70%. Herbaceous vegetation in the cell was recorded within 100 quadrats.

Herbaceous vegetation was not specified on the planting plan for installation in the cell. Only woody shrubs are indicated on the planting plan. Per plan, red-twig dogwood, yellow-twig dogwood, and Pacific ninebark were to be installed in the bottom of the cell. We counted 16 red-twig dogwood and 11 ninebark shrubs. Both dogwood and ninebark have a wetland indicator status of FACW. Other woody species observed in small numbers were red alder saplings (*Alnus rubra*) (FAC), salmonberry (*Rubus spectabilis*) (FAC), red elderberry (*Sambucus racemosa*) (FACU), snowberry (*Symphoricarpos albus*) (FACU), and blackcap raspberry (*Rubus leucodermis*) (FACU). This cell was constructed in 2010.

All herbaceous species sampled within this cell have self-sowed. The most dominant herbaceous plant was hairy cat's ear (*Hypochaeris radicata*)(FACU). Other herbaceous species growing within the cell included fringed willowherb (*Epilobium cilatum*) (FAC), fireweed (*Charmerion angustifolium*) (FACU), and red fescue (*Festuca rubra*) (FAC).

Within this bioretention cell 25.0% of the sampled area contained FACW plants, 25.0% contained FAC plants, greater than 100% of the quadrats contained FACU plants, 2.0% were unknown, and 9.0% contained no plants.

Noll Road bioretention cell is located on a native till soil which is a poorly draining soil. Soils in the area are mapped as Poulsbo gravelly sandy loam (USDA NRCS 2018b). This is the only bioretention cell with an underdrain in this study. The underdrain is located six feet under the bottom of the cell and between the cell and underdrain is rock for water storage. The other design feature of the cell that aids in drainage is the proximity of the inlet to the outlet.

Maintenance occurs at the Noll Road Roundabout two to four times per year. The cell is currently irrigated as needed. We noted an irrigation box on site, but the wiring was removed from the box. It appears the cell was irrigated while the plants were establishing after it was constructed in September 2012, and the irrigation was then decommissioned.

OLYMPIA REGIONAL LEARNING ACADEMY CELL 1-B, OLYMPIA (ORLA 1)

Vegetative cover was measured on July 26, 2016 at Olympia Regional Learning Academy Cell 1-B. According to our field measurements, the bottom of this cell totaled approximately 1,800 square feet. The cell contains both woody and herbaceous vegetation; therefore both sampling methods were used to collect vegetation data. Cell 1-B contains 9 woody plants and 33 woody stems. Overall woody vegetative cover was estimated at 80% areal cover. Herbaceous vegetation was measured in 365 quadrats.

This cell is long and narrow, and the herbaceous vegetation on the plan is a mix of native and landscape plants. The planting plan we obtained does not have the grades called out within the cell, so the designed bottom grade of the cell is unclear. When constructed in 2013, no shrubs were specified to be installed in the bottom of the cell. We counted nine shrubs within the bioretention cell, which were listed in the plant schedule of the planting plan for the side walls of the cell. The shrubs included red-twig dogwood (*Cornus stolonifera ‘Baileyi’*) (FACW), Douglas spirea (FACW), blue arctic willow (*Salix purpurea ‘Canyon blue’*) (FAC), and three landscape variety ninebarks (FACW). It appears plant locations varied slightly from the plan to installation. This may be due to the lack of grades on the planting plan.

Per the planting plan, golden sedge (*Carex aurea*) (FACW) was planted at the lowest elevation of the cell for its entire length. Other herbaceous plants that were apparently installed at the bottom elevation of the cell include hardstem bulrush (*Schoenoplectus acutus*) (OBL) (listed as *Scirpus acutus* on the plan), frosty curls sedge (*Carex Albula*) (FACW), swordleaf rush (*Juncus ensifolius*) (FACW), corkscrew rush (*Juncus effusus Spiralis*) (FACW), and Northern Lights hair grass (*Deschampsia cespitosa ‘Northern Lights’*).

Overall, the planting plan was installed per plan with a few minor changes. Hardstem bulrush was not recorded in any of the quadrats. However, we did record slough sedge (OBL) in multiple quadrats. The slough sedge may have been a replacement plant for the hardstem bulrush or may have become established naturally.

Fringed willowherb (FACW) was the most commonly recorded herbaceous plant in this cell. Fringed willowherb was not planted in the cell, but likely established naturally. The other possibility is that the volunteer species were transported in with the bioretention soil or other soil that may have been used to build the bioretention cell. Slough sedge was the second most recorded herbaceous plant in the quadrats. The golden sedge was recorded in 47 of the quadrats or 12.8%, which may indicate the sedge was not as prevalent in the cell as planned. Overall, 29.0% of the quadrats contained OBL plants, FACW plants were recorded in 78.3% of the quadrats, FAC plants accounted for 21.9%, and FACU plants were recorded in 27.9% of the quadrats. Upland plants were negligible as they were only recorded in 2 quadrats. Also noteworthy is reed canarygrass (*Phalaris arundinacea*) (FACW) appeared in 50 quadrats. Reed canarygrass is an invasive species which can quickly displace the installed herbaceous vegetation if not controlled.

Maintenance is not regularly scheduled for this cell, but it occurs on an “as needed” basis. This cell was hand-weeded shortly after we collected the vegetation data. This cell is irrigated in the summer months.

OLYMPIA REGIONAL LEARNING ACADEMY CELL 2-B, OLYMPIA (ORLA 2)

Vegetative cover was measured on August 25, 2016 at Olympia Regional Learning Academy Cell 2-B. According to our field measurements, the bottom of this cell totaled approximately 2,775 square feet. The cell contains both woody and herbaceous vegetation; therefore both sampling methods were used to collect vegetation data. Cell 2-B contains 179 woody plants and 252 woody stems. Overall woody cover was estimated at 30%. Herbaceous vegetation was recorded in 396 quadrats.

The west bioretention cell was planted similarly to the east rain garden (Cell 1-B). As with Cell 1-B, the planting plan did not have any woody plants shown in the bottom of the cell. Nevertheless, we recorded 179 woody plants growing at the bottom of the cell. The dominant woody vegetation was native willow species (*Salix sp*.). No native willows are listed on the planting plan; therefore we are assuming the willows established naturally in the cell, or came in with the soil. The non-native blue artic willow is specified on the landscape plans. Different willows species have different wetland indicator status, but the predominant willow species in this cell is Pacific willow (*Salix lasiandra*) which has a wetland indicator status of FACW. Other woody volunteers included black cottonwood (*Populus balsamifera*), red alder, and Himalayan blackberry (*Rubus armeniacus),* all having a WIS of FAC. A few scotch broom (*Cytisus scoparius*) plants were recorded, an invasive species that is classified as an upland plant (UPL).

The herbaceous results in this cell were very similar to Cell 1-B, except the installed curly wurly sedge was the most recorded herbaceous plant within 76 cells. Some of the other more commonly recorded herbaceous plants were white clover (*Trifolium repens*) (FAC) in 49 cells, maidenhair switchgrass (*Miscanthus sinensis*) (FAC) in 45 cells, and slough sedge in 41 cells.

Within the bioretention cell, 10.8% of the sampled area contained OBL plants (primarily slough sedge), 38.3% of the sampled area contained plants that have a WIS rating of FACW, FAC plants comprised 42.6% of the sampled area, and 8.0% of the cells contained herbaceous plants that are FACU. Only one upland species was recorded, and 16.6% had no vegetation. In addition, a few herbaceous plants were unidentified.

Both ORLA cells are located on moderately well-draining native soil. The ORLA cells drained at approximately 4 inches per hour. The USDA NRCS (2018b) mapped the soils in the area as Cagey loamy sand with a small area of Yelm fine sandy loam.

Maintenance is not regularly scheduled for this cell, it occurs on an “as needed” basis. This cell was in the process of being hand weeded during data collection. This cell is irrigated in the summer months.

SPANAWAY LAKE PARK CELL I, PIERCE COUNTY (SLP I)

Vegetative cover was measured on August 19, 2016 at Spanaway Lake Park Cell I. According to our field measurements, the bottom of this cell totaled approximately 900 square feet. The cell contains both woody and herbaceous vegetation; therefore both sampling methods were used to collect vegetation data. Cell I contains 52 woody plants and 213 woody stems. Overall woody cover was estimated at 70%. Herbaceous vegetation was recorded in 213 quadrats.

In general, this cell reflects the planting plan. The shrub species and quantities are per plan, with only minor plant quantity differences. This cell was planted with primarily native plants, except the blue arctic willow. The Spanaway cells were the only cells where we recorded twinberry honeysuckle (*Lonicera involucrata*) (FAC). In addition to the installed plants we counted five cottonwood saplings. Although this cell was primarily planted with woody species, per plan 25 slough sedge were planted in the cell. The slough sedge was not dominant in the cell appearing in only 5 quadrats; however, it has survived without irrigation.

Dandelion (*Taraxcum officinales*) was the most recorded herbaceous plant within this cell, and hairy cat’s ear was the second most abundant. Dandelions and hairy cat’s ear have a WIS of FACU.

Within this cell, 2.3% of the quadrats had slough sedge (OBL), 2.8% of the quadrats have FACW and FAC plants occurred in the same quantity. FACU plants occurred in 44.6% of the sampled area, and the rest of the cells contained no herbaceous plants.

The Spanaway park cells are located on very well-draining outwash soil. The USDA NRCS (2018b) mapped the soils in this area as Spanaway gravelly sandy loam.

Maintenance occurs yearly in the cells at Spanaway Lake Park through volunteers, and the cells are not irrigated and have never been irrigated.

SPANAWAY LAKE PARK CELL J, PIERCE COUNTY (SLP J)

Vegetative cover was measured on July 28, 2016 at Spanaway Lake Park Cell J. According Spanaway Lake L.I.D. retrofit plan sheet, the bottom of Cell J totaled 350 square feet. The cell contains only woody vegetation, as no herbaceous plans were specified on the plans; therefore only woody plant and stem data were collected. Cell J contains 28 woody plants and 168 woody stems. Overall woody cover was estimated at 75%.

The planting plan calls for predominantly woody shrubs. California gale (*Myrica gale*) was specified on the planting plan, and we did not record any gale within the cell. Red-twig dogwood (FACW) and twinberry (FAC) were installed per plan. We also recorded cluster rose (*Rosa pisocarpa*) in the cell; however, the planting plan specified nootka rose (*Rosa nuktana*) on the side slopes of the cell. Both roses have a WIS of FAC.

This cell contained a minimal amount of herbaceous vegetation, all of it volunteer plants. Per plan, 37 slough sedge, and 21 deer fern (*Blechnum spicant*) (FAC) were installed in the bottom of the cell. This cell is not irrigated, so most likely the herbaceous vegetation died, or was weeded out by volunteers that maintain the cells.

Maintenance occurs yearly in the cells at Spanaway Lake Park by park volunteers, and the cells are not irrigated and have never been irrigated.

CONCLUSIONS

The herbaceous plants appear to be more difficult to establish than the woody plants and tend to be more sensitive to the hydrologic regime in the cells. However, the results indicate that the species observed trend towards plants with a WIS rating of FAC or FACW, when irrigation is present and the bioretention cell is located on an outwash soil. Slough sedge seems to be the exception, as it is an obligate plant and was common in many of the irrigated bioretention cells. The cells located on till soils without underdrains supported more OBL plants, such as the cattail and iris growing in the Mill Creek cells.

The two Spanaway cells that lacked irrigation were mostly comprised of weedy herbaceous vegetation. Without irrigation and on very well-draining soil, it is difficult to support a community of plants that have a WIS of FAC or FACW. In these instances, it might be best to install plants more adapted to dry conditions (i.e., those with an indicator of FACU or UPL) that are also adapted to survive brief inundation in the winter months.

Although herbaceous vegetation is more difficult to establish in bioretention cells, herbaceous vegetation plays an important role in maintaining the tilth of the soil with the roots and adding organic matter through the senescing of the plants. The herbaceous plants also add visual interest to bioretention cells.

Maintenance in the cells varies greatly. Several cells receive monthly maintenance, while some are only maintained yearly. Many cells are considered landscape features and are weeded regularly. We also viewed cells where the plants were sheared and plant suckers removed. No studies have been done determining if a more constant maintenance regime may result in the compaction of the soils due to frequent walking within the cell. The most important maintenance item is the removal of trash and garbage from cells which may clog the outlet or inlet.

Many of the cells are part of a landscape, and therefore maintained like a landscape through weeding and pruning. However, weedy plants aren’t always detrimental, because the roots of all plants aid in maintaining the infiltration of water. It is a fine line between a plant considered “weedy” and a plant that is invasive and outcompete all installed plants within a cell, such as reed canarygrass. A standard will need to be established for each cell for acceptable limits of weeds depending on the surrounding landscape of the cell, and the desired appearance of the cell.

We talked to multiple ground maintenance professionals during the course of finding suitable cells. In general, maintenance professional would prefer a lower to no-maintenance cell. The most preferable cell would be one that could be mowed. Multiple groundskeepers mentioned recurring problems, such as die-off of plants, having to replant the cells with expensive herbaceous plants, shrubs growing too large and obstructing views, and constant weeding. Cells should be designed to minimize maintenance.

The native woody shrubs tend to be very reliable in the bioretention cells; however, native shrubs, in general, are large plants. If visibility is desired through the cell (such as in a high school parking lot), smaller shrubs may be more appropriate within bioretention cells. The other option would be to install shrubs that can be completely cut back every few years, such as red twig dogwood. This method could be used to keep the shrubs smaller. If cutting back of shrubs is desirable, maintenance personal will need to be informed on how to do this and when. In such cases, it may be beneficial for bioretention cells to have contingency plans in case of failure and instructions on maintenance of the cells.

Finally, the degree to which shrubs maintain infiltration capacity over time, versus the reduction of infiltration by siltation, needs further study (cf. Le Coustumer et al. 2012, Virahsawmy et al. 2014, Livingston 2015).

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APPENDIX 11

Bioretention Hydrologic Performance Phase II Deliverable 5.2 Hydrologic Modeling Results. Clear Creek Solutions, Inc. 6/26/18

CLEAR CREEK SOLUTIONS

CLEAR CREEK SOLUTIONS, INC.

15800 Village Green Drive #3
Mill Creek, WA 98012
425-225-5997
www.clearcreeksolutions.com

MEMORANDUM

DATE: 26 June 2018

TO: Eli Mackiewicz, Engineering Technician, City of Bellingham

CC: Bill Taylor, Principal Investigator

FROM: Doug Beyerlein, P.E., Hydrology Lead and Project Manager

SUBJECT: Bioretention Hydrologic Performance Phase II Deliverable 5.2 Hydrologic Modeling Results

For Task 5 of the Bioretention Hydrologic Performance Phase II we have completed Deliverable 5.2 – Hydrologic Modeling Results.

Modeling Procedures

The field monitoring provided information that was used as part of the WWHM2012 model input for each of the ten bioretention sites.

The hydrologic monitoring data collection (previously discussed) provided time series data for rainfall, inflow, overflow, groundwater, and ponding at 5-minute intervals for use in the individual site models. Each data time series was copied into (imported into) the individual site model's data base for later use in either the model's calculations (rainfall data) or comparison with the model's results (inflow, overflow, groundwater, and ponding data).

The geotechnical data collection provided information about the bioretention soil mix found at each of the ten bioretention sites and the native soil infiltration rate, as measured on-site. Because these bioretention sites were designed and constructed before a standard bioretention soil mix was specified by Ecology it was not expected that any of the soil mixes would meet a specific standard. However, their general soil characteristics, as they related to water movement, provided guidance in the selection of appropriate engineered soil mixes for each of the ten bioretention sites. The native soil infiltration rate was also used in the same way to determine the appropriate infiltration value to include in each model. As will later be discussed, there were sites were groundwater mounding influenced the native soil infiltration rate during the winter months and the input infiltration value was adjusted accordingly to represent these high groundwater periods.

The vegetation data collection was not used directly in the input to the individual site models. However, its potential impact on the hydrologic performance of each site was considered in terms of leaf litter impact on ponding and water infiltrating into the top bioretention soil layer. Also, vegetation influences evapotranspiration from the soil layer. WWHM2012 assumes a standard evapotranspiration rate from the soil that may be dependent based on the type and amount of vegetation.

The other field monitoring data collected for use in the individual bioretention site models were the dimensions of the bioretention facility (length, width, maximum depth of ponding) and the outlet control structure(s), if any. The size of each facility was field measured and compared with design drawings, if available. The elevation of the inlets, outlet riser or weir, and the top of the facility were surveyed. The underdrain elevation and outlet diameter was also measured for the one site (Noll Road) that had an active underdrain.

All of the above field data were used in one way or another in either the WWHM2012 model input for each of the ten bioretention sites or evaluating the model output.

Data Analysis and Results

Modeling Comparison of Observed versus Design Results

Summary

The hydrologic performance of the ten early-design (pre-2012 Ecology manual) bioretention facilities was well represented by WWHM2012. The range in performance in terms of ponding depths and well point elevations met or exceeded the expected WWHM2012 model graphical results comparison with the monitored data more often than not.

In general, the WWHM2012 models of the ten bioretention sites reproduced the monitored bioretention hydrologic performance data with good results when viewing the long-term graphical trends. Good results are defined as periods where the simulated results match closely with the recorded (monitored) data and other periods where the simulated results are sometimes high and sometimes low. There is no obvious bias high or low.

Based on all of the above modeling results it appears that there are two major model inputs that may be influencing the results. The vegetative litter cover noted in the two Spanaway sites may be reducing the infiltration of the ponded water into the bioretention soil mix. Except for SLPI and SLPJ this vegetative litter cover was not explicitly modeled.

The other major model input that may be influencing the results is the evapotranspiration (ET) from the bioretention soil mix. It is set in WWHM2012 to equal 0.5*PET (Potential ET). There is evidence from the well point data that the 0.5 multiplier factor should be higher. That will help to remove water faster from the bioretention soil mix layer.

At this time, based on the bioretention modeling completed for this study, we do not recommended any changes in the Ecology bioretention sizing criteria.

Site Characteristics

The field collected data, described in the previous section, was used to provide input data in the construction of the individual WWHM2012 models of each bioretention site. These data are summarized in Table 1 below.

Table 1. Site General Information

Site	Drainage Area (ac)	Top Area (ft2)	Bottom Area (ft2)	Bottom to Drainage Percentage	Overflow Height (ft)	Modeled Depth (ft)	Native Soil Infiltration (in/hr)	Underdrain
B145	0.494	1600	470	2%	0.4	4.5	9	Yes(1)
BDP	0.8	550	550	2%	0.9	3.6	0.2	No
IHS	2.01	3207	1080	1%	2.5	10.7	60	Yes(2)
MCCA1	0.01	804	299	69%	0.3	1.5	0.04	No
MCCA2	0.142(3)	747	286	5%	0.4	3.4	2	No
ORLA1	0.4	3180	2100	12%	0.67	3.4	23	Yes(3)
ORLA2	0.338	3664	1924	13%	0.52	1.3	4	Yes(3)
NOLL	0.679	4567	520	2%	1.13	2.6	0.01	Yes
SLPI	0.429	1810	792	4%	1.0	2.4(4)	40	No
SLPJ	0.618	2066	1008	4%	0.6	2.6(4)	60	No

Notes:

(1) The underdrain is capped and currently not used.
(2) The underdrain leads to an infiltration gallery and does not discharge to a surface outlet.
(3) The drainage area includes 5400 square feet of drainage from the adjacent permeable pavement parking lot that was not monitored.
(4) The underdrain leads to a gravel trench and does not discharge to a surface outlet.
(5) The modeled depth includes 0.3 feet of surface leaf litter.

The drainage area is the area that contributes runoff to the bioretention site. For each bioretention facility this information was taken from design reports and drawings, if available. Where there was a question about the drainage area it was field checked. For three of the sites (BDP, IHS, and MCCA2) the drainage area in the model was modified to more accurately reflect either measured inflows or ponding depths.

The bottom area is the bottom footprint of each of the bioretention cells. The bottom area is calculated from the field survey information. Most of the bioretention sites had a flat bottom area and sloping sides. The side slopes were calculated based on the difference in bottom and top lengths and widths and bioretention cell heights.

The bottom to drainage percentage is the relative size of the bioretention bottom area to the contributing drainage area. The larger the percentage the larger the bioretention area is to the surrounding area that drains to it. MCCA1, which drains just a portion of the adjacent MCCA Building roof, has the largest percentage at 69%. The proportionally large size of the MCCA1 bottom area relative to the roof area compensates for the very slow native soil infiltration rate. Most of the sites have percentages in the 1-5% rate. This is more typical for a bioretention site and reflects the designer's desire to minimize the size of the bioretention cell.

The overflow height is the height (depth) from the bioretention soil surface to an overflow. The overflow may be a riser inlet, weir, or lowest spot on the side of the bioretention facility. When the ponding depth reaches this height then water can flow out of the bioretention cell via surface discharge (the other ways that water can flow out are by infiltrating into the native soil or discharging through an underground underdrain).

The modeled depth is the total soil depth modeled in the individual WWHM2012 models. This modeled depth typically includes two modeled soil layers. The top modeled soil layer (Layer 1) is the bioretention soil mix (BSM). The second modeled soil layer (Layer 2) is the soil layer below the BSM soil mix (Layer 1) and above the bottom of the monitored well point. Layer 2 was included in each model to provide a subsurface water depth/height that can be compared with the monitored well point data. For the two Spanaway sites (SLPI and SLPJ) a third modeled soil layer was added. For these two sites only a top layer (Layer 1) was added above the BSM layer to represent the effect of leaf litter in reducing the water movement into the BSM layer (which in these models is Layer 2). Details of the composition of the modeled depth in each bioretention site are presented in Table 2 below.

Native soil infiltration (inches per hour) for each site was initially based on the infiltration tests conducted as part of the geotechnical field measurements. Through the modeling process some of the native soil infiltration rates were adjusted to compensate for the effects of seasonal high groundwater or groundwater mounding that reduced the ability of water to move vertically through the modeled soil layers and into the underlying native soils.

An underdrain is a set of pipes in the bottom of the bioretention facility that collect water and discharge it through an outlet control structure. Typically underdrains are connected to a storm sewer system. Underdrains are used where it appears that the native soil infiltration rate is insufficient to remove all of the water from the bioretention cell and there is a potential for surface ponding to overtop the facility and flood surrounding properties. Underdrains can prevent this from happening. Most of the ten sites do not have underdrains and most or all of the water infiltrates into the native soil. Three sites (B145, IHS, and NOLL) have underdrains, but only NOLL has an underdrain that provides surface discharge. This surface discharge (outflow) was both monitored and modeled.

Table 2 provides information on the modeled soil layers in each bioretention model.

Table 2. Modeled Soil Layer Information

Site	Layer 1 Soil	Layer 1 Depth (ft)	Layer 2 Soil	Layer 2 Depth (ft)	Layer 3 Soil	Layer 3 Depth (ft)	Native Soil Infiltration (in/hr)
B145	ASTM15	1.6	ASTM4	2.9	None	0	9
BDP	ASTM15	1.7	Gravel	1.9	None	0	0.2
IHS	ASTM9	1.6	ASTM35	9.1	None	0	60
MCCA1	ASTM4	0.8	ASTM4	0.7	None	0	0.04
MCCA2	ASTM1	1.0	ASTM12	2.4	None	0	2
ORLA1	ASTM2	1.3	ASTM24	2.1	None	0	23
ORLA2	ASTM2	1.3	ASTM24	5.0	None	0	4
NOLL	ASTM60	1.5	Gravel	1.1	None	0	0.01
SLPI	ASTM2	0.3	ASTM50	1.7	Gravel	0.4	40
SLPJ	ASTM2	0.3	ASTM60	1.9	Gravel	0.4	60

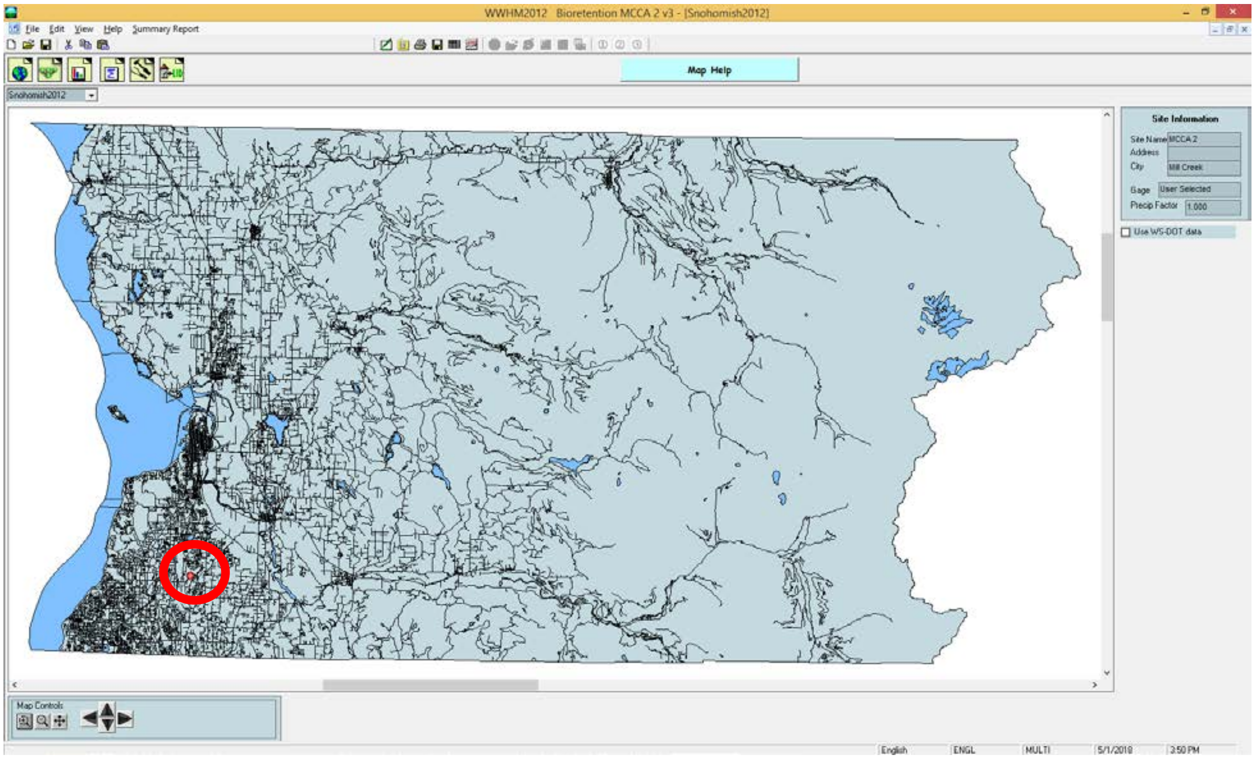
As described above, the modeled depth is the total soil depth modeled in the individual WWHM2012 models. The modeled soil depth is composed two or more individual soil layers.

For each model (except the two Spanaway models) Layer 1 represents the bioretention soil mix (BSM) type and depth. The Layer 1 depth is the depth or thickness of the BSM, as measured in the geotechnical field work. The actual Layer 1 soil mix was initially unknown, but could be determined by comparing the monitored and modeled surface pond depths and soil water depths. WWHM2012 provides the soil input parameter values for the Ecology-standard bioretention soil mix, but all of these sites were designed and constructed before that standard mix was required. WWHM2012 also provides soil input parameter values for a range of ASTM (American Society for Testing and Materials) soils. For the purposes of hydrologic modeling the ASTM number specification (for example, ASTM15) refers to the saturated conductivity value (15 inches per hour for ASTM15).

Layer 2 is not necessarily an engineered bioretention soil mix soil. Layer 2 is the soil layer below the BSM soil mix (Layer 1) and above the bottom of the monitored well point. Layer 2 was included in each model to provide a subsurface water depth/height that can be compared with the monitored well point data. For the two Spanaway sites (SLPI and SLPJ) a third modeled soil layer was added. For these two sites only a top layer (Layer 1) was added above the BSM layer to represent the effect of leaf litter in reducing the water movement into the BSM layer (which in these models is Layer 2). Layer 2 soils were typically found to have different saturated conductivity values than the Layer 1 BSM soils.

WWHM2012 Model Construction

A separate WWHM2012 model was constructed for each of the ten bioretention sites. The bioretention site was located on the appropriate WWHM2012 project site map (see Figure 1 for an example).

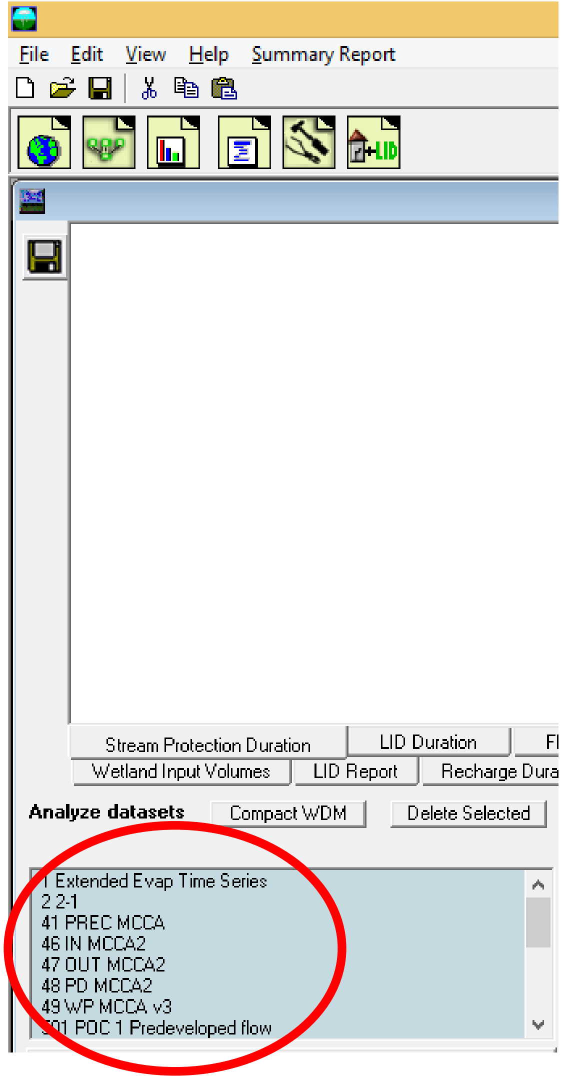


Site Name MCCA 2
Address
City Mill Creek
Gage User Selected
Precip Factor 1.000
☐ Use WS-DOT data

Figure 1. WWHM2012 Project Site (MCCA2) in Snohomish County

The MCCA2 bioretention site is located at the red dot in the center of the red circle in Snohomish County.

For each model the corresponding monitored 5-minute data were imported into the specific model's data base file (HSPF WDM file), as shown in Figure 2.



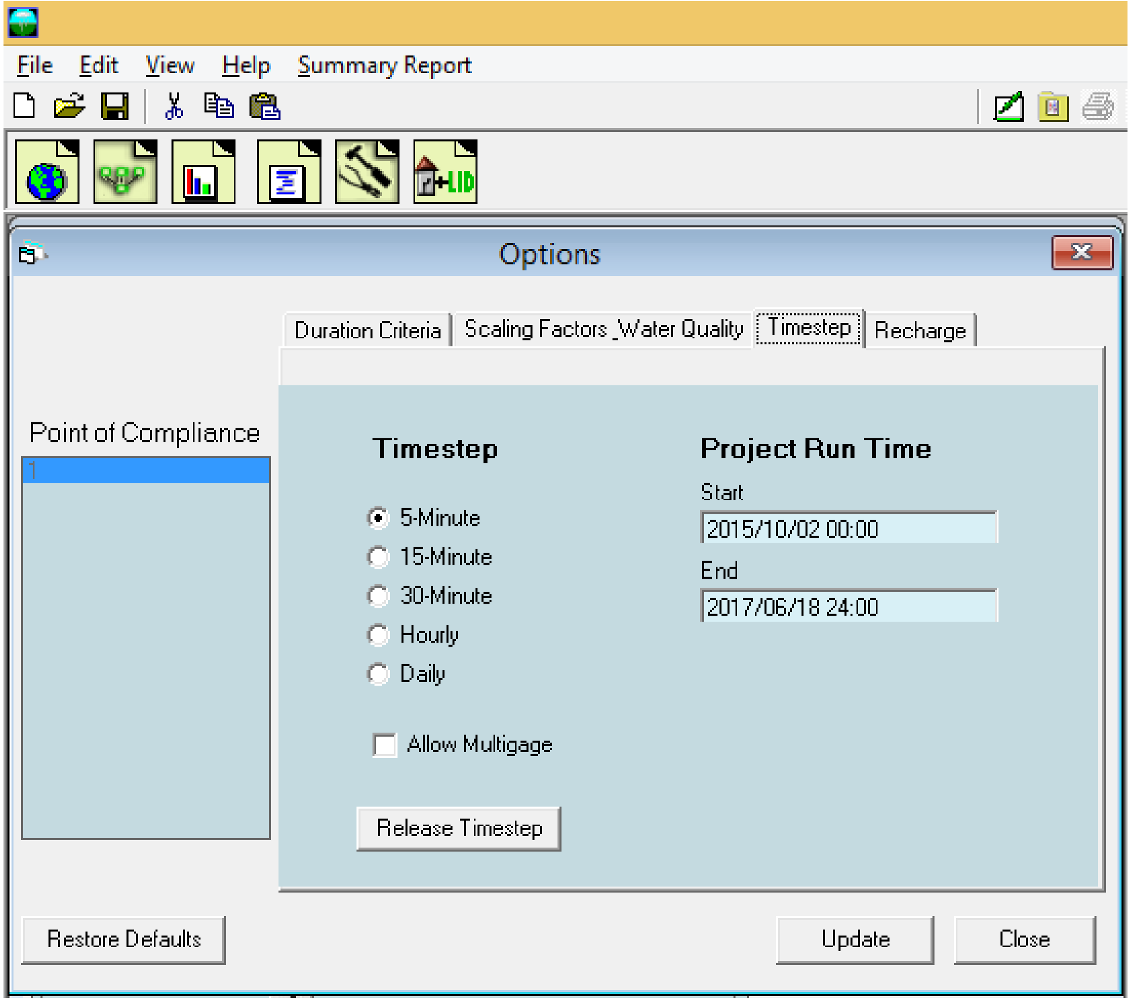
1 Extended Evap Time Series
2 2-1
41 PREC MCCA
46 IN MCCA2
47 OUT MCCA2
48 PD MCCA2
49 WP MCCA v3
501 POC 1 Predeveloped flow

Figure 2. WWHM2012 Time Series Data

Each monitored data set is given a unique data set number (DSN), as shown in Figure 2.

For MCCA2 the monitored 5-minute precipitation time series is data set number 41; the monitored inflow is DSN 46; the monitored outflow is DSN 47; the pond depth is DSN 48; and the well point depth is DSN 49. These monitored time series will be used to compare and evaluate the model results.

The model simulation period time step and start and end dates were changed from the default WWHM2012 simulation values. These changes were made by going to View, Options, Timestep (see Figure 3). The WWHM2012 default time step was changed from 15 minutes to 5 minutes because all of the monitored data were collected in 5-minute intervals. The WWHM2012 simulation start and end dates were changed to run from 1 October 2015 through the end of the data collection period (typically June or July 2017). The monitored data did not actually start until October 2016, but the model simulation period was started a year earlier to provide a start-up period for the simulation. The model results were compared with the monitored data only for the period of October 2016 through June/July 2017.



Timestep

● 5-Minute
○ 15-Minute
○ 30-Minute
○ Hourly
○ Daily

☐ Allow Multigage

Project Run Time

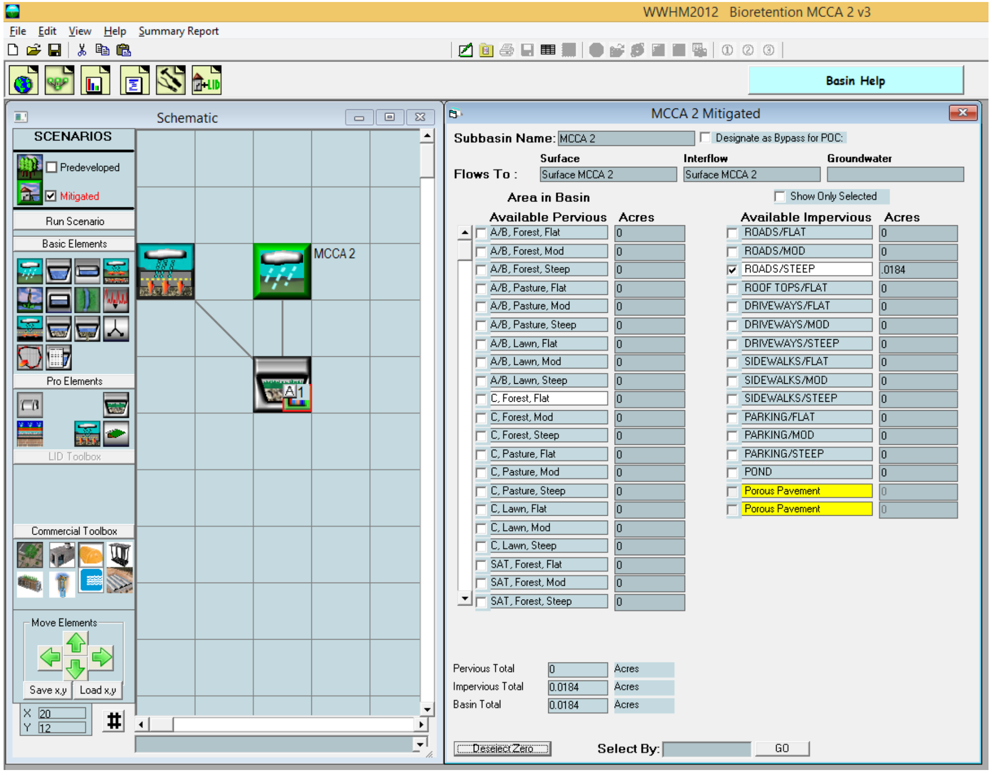
Start: 2015/10/02 00:00

End: 2017/06/18 24:00

Figure 3. WWHM2012 Simulation Time Step and Start and End Dates (for MCCA2)

The contributing drainage area for each bioretention facility was determined from design reports and drawings, if available. Where there was a question about the drainage area it was field checked, as described above. The specific acreages were input to each WWHM2012 model using the WWHM2012 Land-use element (see Figure 4). For the MCCA sites (both MCCA1 and MCCA2) the MCCA Building roof area was designated as “Roads/Steep” instead of “Roof Tops/Flat” because this roof has a slope greater than 15 percent and the only roof option is for a flat (<5%) roof. The “Roads/Steep” designation better represents the roof’s actual hydrologic behavior than “Roof Tops/Flat”.

For the MCCA2 site the WWHM2012 Permeable Pavement element was also added to the model to represent runoff from the adjacent permeable pavement parking lot (Figure 5).



☐ Predeveloped
☑ Mitigated

X 20
Y 12

Subbasin Name: MCCA 2 ☐ Designate as Bypass for POC:

	Surface	Interflow	Groundwater
Flows To :	Surface MCCA 2	Surface MCCA 2	

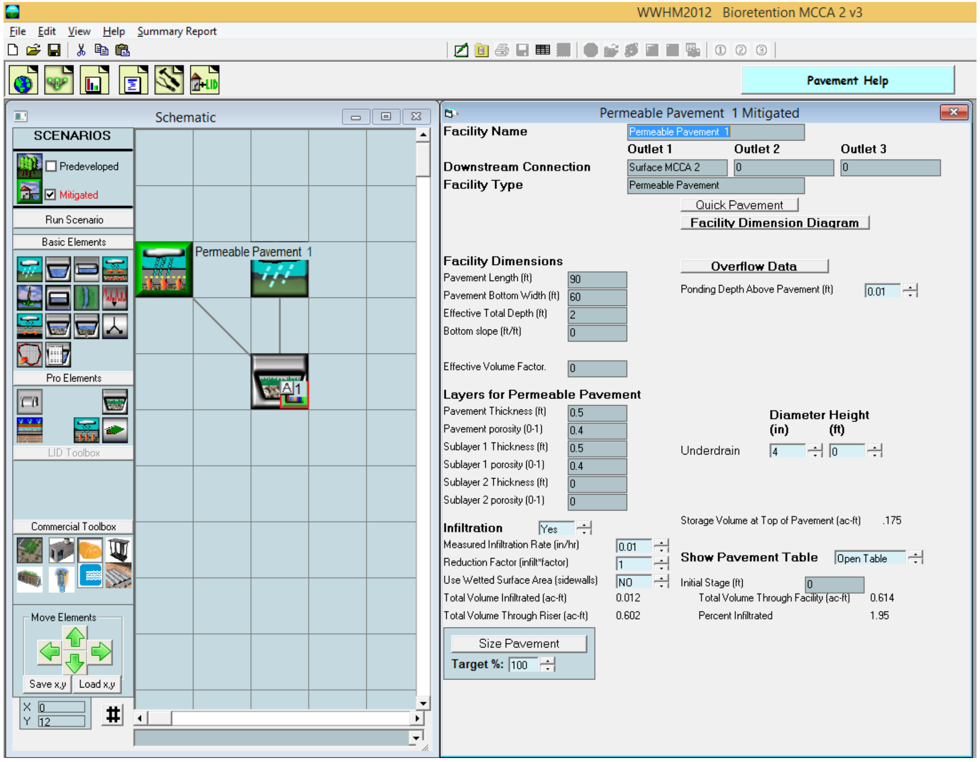
Area in Basin ☐ Show Only Selected

Available Pervious	Acres	Available Impervious	Acres
☐ A/B, Forest, Flat	0	☐ ROADS/FLAT	0
☐ A/B, Forest, Mod	0	☐ ROADS/MOD	0
☐ A/B, Forest, Steep	0	☑ ROADS/STEEP	.0184
☐ A/B, Pasture, Flat	0	☐ ROOF TOPS/FLAT	0
☐ A/B, Pasture, Mod	0	☐ DRIVEWAYS/FLAT	0
☐ A/B, Pasture, Steep	0	☐ DRIVEWAYS/MOD	0
☐ A/B, Lawn, Flat	0	☐ DRIVEWAYS/STEEP	0
☐ A/B, Lawn, Mod	0	☐ SIDEWALKS/FLAT	0
☐ A/B, Lawn, Steep	0	☐ SIDEWALKS/MOD	0
☐ C, Forest, Flat	0	☐ SIDEWALKS/STEEP	0
☐ C, Forest, Mod	0	☐ PARKING/FLAT	0
☐ C, Forest, Steep	0	☐ PARKING/MOD	0
☐ C, Pasture, Flat	0	☐ PARKING/STEEP	0
☐ C, Pasture, Mod	0	☐ POND	0
☐ C, Pasture, Steep	0	☐ Porous Pavement	0
☐ C, Lawn, Flat	0	☐ Porous Pavement	0
☐ C, Lawn, Mod	0		
☐ C, Lawn, Steep	0		
☐ SAT, Forest, Flat	0		
☐ SAT, Forest, Mod	0		
☐ SAT, Forest, Steep	0		

Pervious Total	0	Acres
Impervious Total	0.0184	Acres
Basin Total	0.0184	Acres

Select By:

Figure 4. WWHm2012 Land-use Element



☐ Predeveloped
☑ Mitigated

X 0
Y 12

Facility Name Permeable Pavement 1

	Outlet 1	Outlet 2	Outlet 3
Downstream Connection	Surface MCCA 2	0	0
Facility Type	Permeable Pavement		

Facility Dimensions

Pavement Length (ft)	90
Pavement Bottom Width (ft)	60
Effective Total Depth (ft)	2
Bottom slope (ft/ft)	0
Effective Volume Factor.	0

Ponding Depth Above Pavement (ft) 0.01

Layers for Permeable Pavement

Pavement Thickness (ft)	0.5
Pavement porosity (0-1)	0.4
Sublayer 1 Thickness (ft)	0.5
Sublayer 1 porosity (0-1)	0.4
Sublayer 2 Thickness (ft)	0
Sublayer 2 porosity (0-1)	0

	Diameter (in)	Height (ft)
Underdrain	4	0

Storage Volume at Top of Pavement (ac-ft) .175

Infiltration Yes

Measured Infiltration Rate (in/hr)	0.01
Reduction Factor (infilt*factor)	1
Use Wetted Surface Area (sidewalls)	NO
Total Volume Infiltrated (ac-ft)	0.012
Total Volume Through Riser (ac-ft)	0.602

Show Pavement Table Open Table

Initial Stage (ft) 0

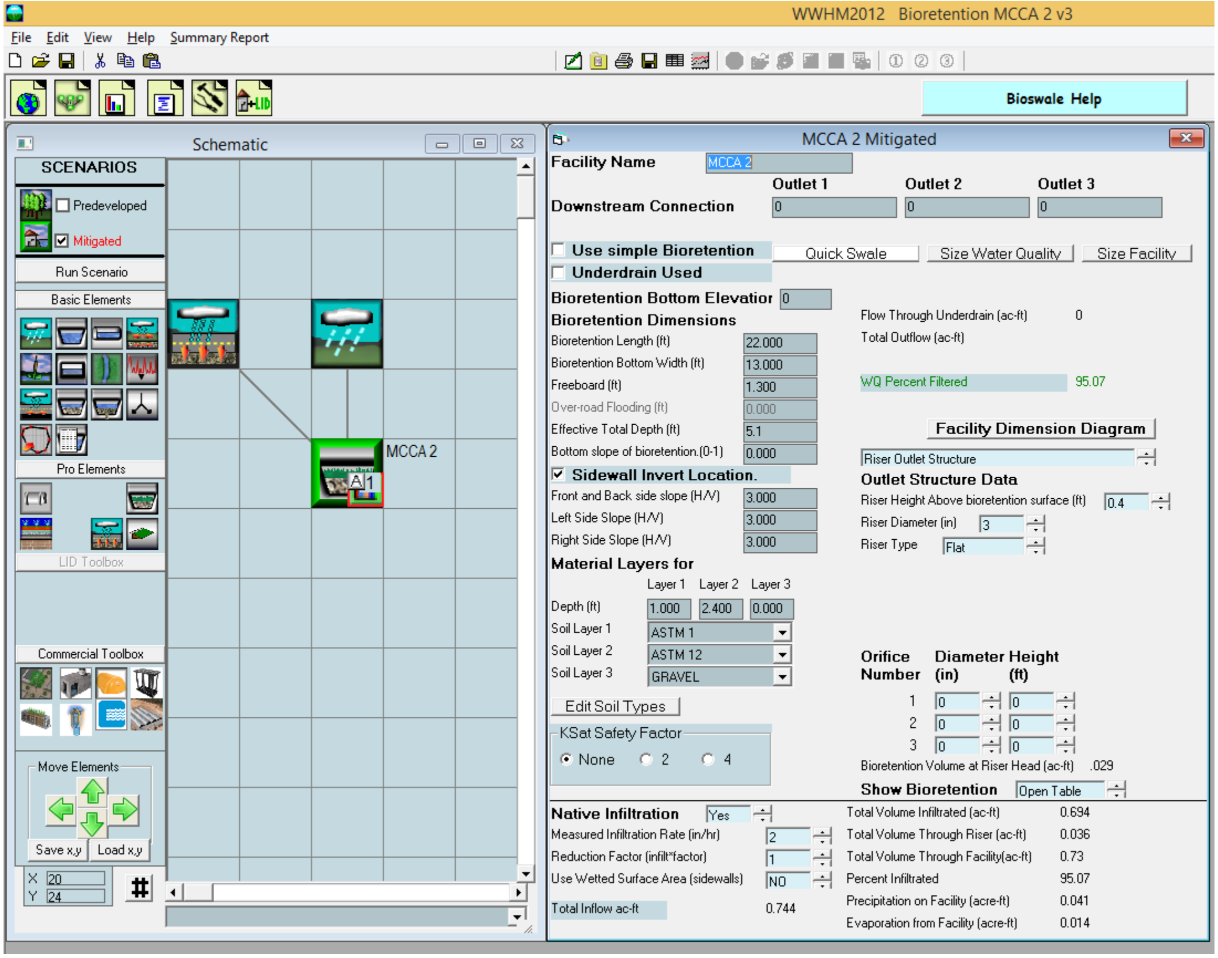
Total Volume Through Facility (ac-ft) 0.614

Percent Infiltrated 1.95

Target %: 100

Figure 5. WWHM2012 Permeable Pavement Element

The specific bioretention facility is represented in WWHM2012 by the Bioretention element and contains all of the user input for defining the dimensions and characteristics of the bioretention site. The reader is referred to the *WWHM2012 User Manual* for more details about the Bioretention element input and model calculations. The MCCA2 Bioretention element is shown in Figure 6.



Facility Name: MCCA 2

	Outlet 1	Outlet 2	Outlet 3
Downstream Connection	0	0	0

☐ Use simple Bioretention
☐ Underdrain Used

Bioretention Bottom Elevatior: 0

Bioretention Dimensions

Bioretention Length (ft): 22.000
Bioretention Bottom Width (ft): 13.000
Freeboard (ft): 1.300
Over-road Flooding (ft): 0.000
Effective Total Depth (ft): 5.1
Bottom slope of bioretention.(0-1): 0.000

☑ Sidewall Invert Location.

Front and Back side slope (H/V): 3.000
Left Side Slope (H/V): 3.000
Right Side Slope (H/V): 3.000

Material Layers for

	Layer 1	Layer 2	Layer 3
Depth (ft)	1.000	2.400	0.000

Soil Layer 1: ASTM 1
Soil Layer 2: ASTM 12
Soil Layer 3: GRAVEL

KSat Safety Factor: ● None ○ 2 ○ 4

Flow Through Underdrain (ac-ft): 0
Total Outflow (ac-ft):
WQ Percent Filtered: 95.07

Riser Outlet Structure

Outlet Structure Data

Riser Height Above bioretention surface (ft): 0.4
Riser Diameter (in): 3
Riser Type: Flat

Orifice Number	Diameter (in)	Height (ft)
1	0	0
2	0	0
3	0	0

Bioretention Volume at Riser Head (ac-ft): .029

Show Bioretention: Open Table

Native Infiltration: Yes
Measured Infiltration Rate (in/hr): 2
Reduction Factor (infilt*factor): 1
Use Wetted Surface Area (sidewalls): NO

Total Inflow ac-ft: 0.744

Total Volume Infiltrated (ac-ft): 0.694
Total Volume Through Riser (ac-ft): 0.036
Total Volume Through Facility(ac-ft): 0.73
Percent Infiltrated: 95.07
Precipitation on Facility (acre-ft): 0.041
Evaporation from Facility (acre-ft): 0.014

Figure 6. WWHM2012 Bioretention Element (for MCCA2)

<u>WWHM2012 Model Results</u>

Two sets of WWHM2012 model results were generated and evaluated. For each site WWHM2012 was first set up to compare the model results with the monitored data. For the comparison of the model simulation results with the monitored/recorded data the primary focus was trying to match the simulated and recorded ponding depths and the simulated and recorded well point data. The ponding depths showed how the water ponded on the surface of the bioretention facility. The well point data showed how the water filled up the bioretention soil column. The ponding and well point data are linked. If the well point data shows that the bioretention soil column is completely saturated then water cannot drain from the surface into the bioretention soil and this causes water to pond on the surface. Water can also pond on the surface even if the soil column is not completely saturated if the inflow of water into the bioretention facility is greater than the infiltration into the top layer (Layer 1) of the bioretention soil mix.

At each site the specific bioretention soil mix was not known (this problem is discussed above). The infiltration rate into the native soil was known from the geotechnical field work, but could be different based on seasonal factors.

Each model was set up with a specific bioretention soil mix for each soil layer and an infiltration rate. These model inputs were then adjusted to produce the best match of the simulated ponding and well point results with the recorded data. Those final model inputs are shown in Table 3. The ponding depth plots and the well point plots are shown for each site in the Individual Bioretention Site Results discussion below.

The model inflow and outflow simulation results were also compared with the monitored inflow and outflow data, where available. A number of issues were found with the monitored inflow data. Specifically, there were numerous periods in December 2016 and January and February 2017 where because of freezing conditions and/or snow the monitored inflow data matched poorly with the monitored rainfall data. For this reason the inflow to the bioretention site was simulated from monitored rainfall data rather than using the monitored inflow data. This decision eliminated the possibility of any error in the monitored/recorded inflow data affecting the bioretention results. The simulated inflow volumes were plotted together with the recorded inflow data to identify inconsistencies. The comparison plot for each site is shown in in the Individual Bioretention Site Results discussion below.

For the majority of the bioretention sites there was no outflow. This was because all of the inflow to the bioretention site infiltrated into the native soil. Also, outflow, when it did occur, could be difficult to measure due to the outlet configuration.

Model results are presented in both statistical and graphical formats. The statistical format compares the model simulated versus recorded/monitored inflow data, pond depths, soil layer water content depths, and underdrain discharge volumes for the ten sites in terms of maximum values, minimum, mean, and standard deviation of the 5-minute data for the data collection period. For the statistical comparison periods where there were identified data collection problems (primarily due to freezing conditions and/or snow in December 2016, January 2017, and February 2017) were deleted from the statistical calculations.

The statistical results are shown in tables 3, 4, 5, and 6, below. Table 3 shows the maximum, minimum, mean, and standard deviation of the 5-minute data for monitored/recorded (R) and model simulated (S) bioretention site inflow results.

Table 3. Bioretention Site Inflow (cfs)

Site	MAX-R	MAX-S	MIN-R	MIN-S	MEAN-R	MEAN-S	STD DEV-R	STD DEV-S
B145	0.522	0.211	0.000	0.000	0.003	0.003	0.016	0.008
BDP	0.372	0.627	0.000	0.000	0.006	0.005	0.020	0.018
IHS	0.688	0.986	0.000	0.000	0.023	0.018	0.055	0.042
MCCA1	0.071	0.009	0.000	0.000	0.0003	0.0001	0.0014	0.0003
MCCA2	0.069	0.061	0.000	0.000	0.001	0.001	0.002	0.003
ORLA1	0.072	0.817	0.000	0.000	0.003	0.004	0.006	0.012
ORLA2	0.067	0.690	0.000	0.000	0.001	0.004	0.004	0.010
NOLL	0.139	0.287	0.000	0.000	0.001	0.004	0.005	0.011
SLPI	0.191	0.232	0.000	0.000	0.003	0.002	0.011	0.008
SLPJ	0.298	0.322	0.000	0.000	0.006	0.003	0.018	0.011

Table 4. Bioretention Site Pond Depth (feet)

Site	MAX-R	MAX-S	MIN-R	MIN-S	MEAN-R	MEAN-S	STD DEV-R	STD DEV-S
B145	0.52	0.45	-0.13	0.00	0.02	0.01	0.07	0.03
BDP	1.15	2.04	0.24	0.00	0.38	0.34	0.16	0.42
IHS	1.38	1.57	-0.15	0.00	0.04	0.01	0.12	0.06
MCCA1	0.08	0.08	-0.08	0.00	-0.010	0.0004	0.015	0.003
MCCA2	0.58	0.48	-0.15	0.00	0.15	0.02	0.14	0.07
ORLA1	0.08	0.38	-0.05	0.00	0.01	0.003	0.01	0.01
ORLA2	0.57	0.37	-0.17	0.00	0.01	0.004	0.02	0.01
NOLL	0.48	0.63	-0.07	0.00	0.04	0.01	0.08	0.03
SLPI	0.54	0.44	-0.08	0.00	0.02	0.003	0.04	0.02
SLPJ	0.63	0.52	-0.38	0.00	0.01	0.004	0.05	0.02

Table 5. Bioretention Site Well Point Depth (feet)

Site	MAX-R	MAX-S	MIN-R	MIN-S	MEAN-R	MEAN-S	STD DEV-R	STD DEV-S
B145	3.94	3.77	0.09	0.07	0.59	1.14	0.27	0.68
BDP	3.57	3.49	0.89	0.00	2.20	2.10	0.74	1.44
IHS	10.17	10.01	0.58	0.21	3.77	2.07	1.48	1.28
MCCA1	1.46	1.41	-0.22	0.00	0.48	0.34	0.14	0.29
MCCA2	2.78	2.97	-0.30	0.00	0.99	0.71	0.71	0.54
ORLA1	1.07	2.03	0.00	0.00	0.72	0.53	0.18	0.34
ORLA2	0.67	0.60	0.18	0.11	0.55	0.52	0.09	0.08
NOLL	1.98	1.55	1.29	0.00	1.45	0.21	0.08	0.19
SLPI	0.10	2.17	0.00	0.00	0.05	0.25	0.01	0.20
SLPJ	1.19	2.40	-0.07	0.00	-0.02	0.26	0.05	0.22

Table 6. Bioretention Underdrain Discharge (cfs) – NOLL Only

Site	MAX-R	MAX-S	MIN-R	MIN-S	MEAN-R	MEAN-S	STD DEV-R	STD DEV-S
NOLL	0.024	0.237	0.000	0.000	0.0001	0.004	0.001	0.011

The statistical comparisons do not necessarily match well. This can be for a number of reasons, as discussed in the individual site results below. As such, the statistical comparison of results can be misleading. What is more important is the ability to match trends rather than statistics. By looking at graphical trends we can visually see if the model provides the same trends in terms of inflow, ponding, and well point data as the monitored info. The statistics cannot show trends and therefore are less useful in evaluating the modeling results than the graphical comparisons.

A summary of the model graphical comparisons is presented in Table 7. The table presents a comparison of the model simulated versus recorded/monitored inflow data, pond depths, soil layer water content depths, and underdrain discharge volumes for the ten sites.

Table 7. Comparison of Model (S) versus Monitored (R) Results

Site	S vs R Inflow	S vs R Pond	S vs R Soil Layer	S vs R Underdrain
B145	Good*	Mixed	Good	N/A
BDP	Mixed	Good	Good	N/A
IHS	Mixed	Mixed	Good	N/A
MCCA1	Mixed	Good	Mixed	N/A
MCCA2	High**	Good	Mixed	N/A
ORLA1	High	Mixed	High	N/A
ORLA2	High	Low	Good	N/A
NOLL	High	Mixed	High	High
SLPI	Mixed	Mixed	High	N/A
SLPJ	Low	Mixed	High	N/A

* Good, expect for frozen conditions; ** High due to parking lot runoff

S vs R Inflow is the comparison of the simulated (S) inflow volume to the bioretention site compared to the monitored or recorded (R) inflow volume. The simulated inflow volume is calculated from the rainfall on the contributing drainage area to the bioretention site. The monitored inflow volume is calculated from the inflow measurements collected at specific input locations entering the bioretention site.

S vs R Pond is the comparison of the simulated (S) bioretention site surface ponding depths compared to the monitored or recorded (R) ponding depths.

S vs R Soil Layer is the comparison of the simulated (S) bioretention site subsurface soil layer water elevations compared to the monitored or recorded (R) well point data.

S vs R Underdrain is the comparison of the simulated (S) bioretention site underdrain outflow compared to the monitored or recorded (R) underdrain outflow.

The comparison categories of “Good”, “Mixed”, “High”, and “Low” are somewhat subjective, but are based on a total view of the comparison plot for each type of data. There is no statistical measure or test that can adequately represent the ability of the model results to reproduce the monitored data, due to missing data periods, weather problems related to freezing conditions, and timing issues. An evaluation of the results by a modeling professional takes these issues into account and allows for an unbiased opinion.

For this purposes of this comparison, “Good” is defined as a good overall match of the simulated and recorded data. Even if there is not an exact match, both sets of data follow the same trends and magnitudes.

“Mixed” is similar to “Good” but shows more variability. With “Mixed” some periods match well while other periods match poorly, but the simulated results are neither consistently high or low.

“High” means that the simulated results are consistently high. There may be a valid reason for this different between the simulated and recorded results, but regardless the difference is noticeable. “Low” is similar, but in the opposite direction (the simulated results are consistently low).

Further discussion of these graphical results and the comparison plots from which they were determined is presented below in the individual site modeling section of this report.

The second set of model results was based on the long-term county precipitation data. For each site the long-term (50 years or longer) precipitation record was used to generate long-term simulated ponding and outflow data. These simulated data were not compared against the monitored data, but were used to evaluate the individual bioretention’s site to meet Ecology minimum requirements #5 and #6.

Minimum Requirement #5 (MR#5) is the LID flow duration performance standard. MR#5 requires that flow durations between 8 percent of the 2-year flow (0.08Q2) and 50 percent of the 2-year flow (0.50Q2) do not increase above the predevelopment land use conditions. For each of these models the predevelopment land use was defined as forested. WWHM2012 provides the appropriate calculations to demonstrate compliance with MR#5.

Minimum Requirement #6 (MR#6) is the water quality performance standard. MR#6 requires that at least 91 percent of the total runoff volume be treated. Treatment in a bioretention facility consists of water movement through the bioretention soil mix. This treated water can then either infiltrated into the native soil or exit via an underdrain or both. Water that discharges through the surface outlet (riser or weir) is not treated. WWHM2012 provides the appropriate calculations to demonstrate compliance with MR#6.

Compliance with MR#5 and MR#6 is shown in Table 8.

Table 8. Minimum Requirement Compliance

Site	MR#5	MR#6
B145	Yes	Yes
BDP	No	No
IHS	Yes	Yes
MCCA1	Yes	Yes
MCCA2	Yes	Yes
ORLA1	Yes	Yes
ORLA2	Yes	Yes
NOLL	No	Yes
SLPI	Yes	Yes
SLPJ	Yes	Yes

All of the sites, except BDP and NOLL, pass the MR#5 LID flow duration criterion. BDP does not pass because of too many outlet overflows (see Individual Bioretention Site Results for details). NOLL does not pass because there is no flow constrictor (orifice) on the NOLL bioretention site underdrain and the underdrain flows exceed MR#5.

All of the sites pass the MR#6 water quality standard, except BDP. As with MR#5, BDP does not pass because too much of the bioretention discharge is surface discharge over the outlet weir. BDP does not have the needed 91% of the flow being treated by filtering through the bioretention soil mix.

Bioretention facilities can also be designed and constructed to meet Minimum Requirement #7 (MR#7). MR#7 is the stream protection flow control standard. MR#7 requires that flow durations between 50 percent of the 2-year flow (0.50Q2) and the 50-year flow (Q50) do not increase above the predevelopment land use conditions. While WWHM2012 provides the appropriate calculations to demonstrate compliance with MR#7, we did not evaluate the bioretention facilities for this compliance. This is because they did not have to be designed to meet this standard and to test them for compliance would be potentially misleading as to the effectiveness of their hydrologic performance. Specific compliance with MR#7 usually requires an orifice on the underdrain outlet and a riser designed specifically to control the release of high flows to meet MR#7. None of the ten bioretention facilities were observed to have these flow control features.

Individual Bioretention Site Results

Individual bioretention model results are discussed below. Each bioretention site has a unique set of characteristics that influenced the model set up and the comparison of model (simulation) results with the monitored (recorded) field data.

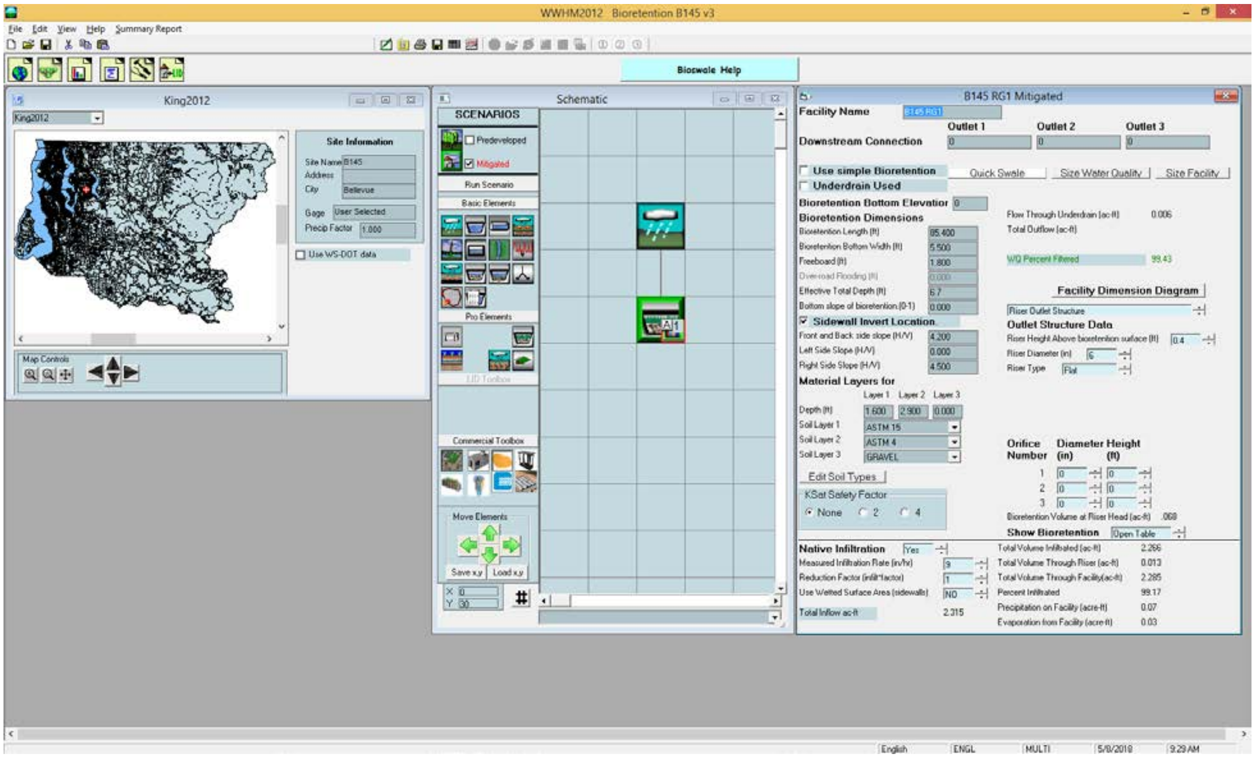
At each site the simulated and recorded daily inflow volumes are plotted and compared. The purpose of this comparison is to identify any potential errors in either the simulated or recorded inflow volumes. The simulated inflow volumes are calculated by WWHM2012 using the monitored rainfall data and the contributing drainage area to the bioretention site. It is possible that either one of those model inputs contains errors. The recorded/monitored inflow volumes are field measured values. These recorded values also may contain errors due to weather conditions (snow and/or freezing temperatures) and/or not recording all of the inflow sources to the bioretention site. By comparing the two sets of daily inflow volumes it is possible to identify problems that can and will affect the ability of WWHM2012 to correctly reproduce the surface ponding and soil layer elevations measured in the field.

At each site the simulated and recorded bioretention surface ponding depths are plotted and compared. The purpose of this comparison is to see how well WWHM2012 can reproduce the recorded/monitored ponding data. Surface ponding is a critical measure of the bioretention site's hydrologic performance. Excessive surface ponding can result in surface discharge via riser or weir that does not provide any water quality treatment or LID flow control.

At each site the simulated and recorded bioretention well point data are also plotted and compared. The well point data shows how the water fills up the bioretention soil column. The ponding and well point data are linked. If the well point data shows that the bioretention soil column is completely saturated then water cannot drain from the surface into the bioretention soil layer and this causes water to pond on the surface. Water can also pond on the surface even if the soil column is not completely saturated if the inflow of water into the bioretention facility is greater than the infiltration into the top layer (Layer 1) of the bioretention soil mix.

It should be noted that the monitored well point data is not a perfect match for the WWHM2012 soil layer moisture calculations. The monitored well point data is a measure of the "free" water in the soil column. This is water that freely drains to the well and fluctuates up and down depending on inflow to the soil from above and infiltration to the native soil below. The WWHM2012 simulated soil layer data is calculated based on the soil's hydraulic conductivity and wilting point (and other factors). Included in these simulated soil moisture calculates is both the "free" water measured in the monitored wells (well point data) and water that cannot freely flow, but remains trapped in the void spaces between soil particles. In WWHM2012 this "trapped" water is removed by evapotranspiration. The "trapped" water is not included in the well point monitored data. This is the reason for the discrepancy between the simulated and recorded soil layer plotted results.

B145: Bellevue, King County



King2012

Site Information

Site Name: B145
Address:
City: Bellevue
Gage: User Selected
Precip Factor: 1.000
☐ Use WS-DOT data

X: 0
Y: 30

B145 RG1 Mitigated

Facility Name: B145 RG1

	Outlet 1	Outlet 2	Outlet 3
Downstream Connection	0	0	0

☐ Use simple Bioretention
☐ Underdrain Used

Bioretention Bottom Elevation: 0

Bioretention Dimensions

Bioretention Length (ft): 85.400
Bioretention Bottom Width (ft): 5.500
Freeboard (ft): 1.800
Over-road Flooding (ft): 0.000
Effective Total Depth (ft): 6.7
Bottom slope of bioretention.(0-1): 0.000

☑ Sidewall Invert Location

Front and Back side slope (H/V): 4.200
Left Side Slope (H/V): 0.000
Right Side Slope (H/V): 4.500

Material Layers for

	Layer 1	Layer 2	Layer 3
Depth (ft)	1.600	2.900	0.000

Soil Layer 1: ASTM 15
Soil Layer 2: ASTM 4
Soil Layer 3: GRAVEL

KSat Safety Factor: ● None ○ 2 ○ 4

Flow Through Underdrain (ac-ft): 0.006
Total Outflow (ac-ft):
WQ Percent Filtered: 99.43

Riser Outlet Structure

Outlet Structure Data

Riser Height Above bioretention surface (ft): 0.4
Riser Diameter (in): 6
Riser Type: Flat

Orifice Number	Diameter (in)	Height (ft)
1	0	0
2	0	0
3	0	0

Bioretention Volume at Riser Head (ac-ft): .068
Show Bioretention: Open Table

Native Infiltration: Yes
Measured Infiltration Rate (in/hr): 9
Reduction Factor (infilt*factor): 1
Use Wetted Surface Area (sidewalls): NO
Total Inflow ac-ft: 2.315

Total Volume Infiltrated (ac-ft): 2.266
Total Volume Through Riser (ac-ft): 0.013
Total Volume Through Facility(ac-ft): 2.285
Percent Infiltrated: 99.17
Precipitation on Facility (acre-ft): 0.07
Evaporation from Facility (acre-ft): 0.03

The B145 bioretention site is located in Bellevue, King County, Washington. The drainage area to B145 consists of 0.19 acres of NRCS Type C soil, lawn vegetation, on a moderate slope (5-15%) and 0.304 acres of roads on a flat slope (0-5%).

The B145 surface bottom footprint is 470 square feet. This equals 2% of the tributary drainage area to B145.

B145 has a surface discharge via riser outlet set at 0.4 feet above the surface bottom. Most of the inflow to B145 is infiltrated into the native soil beneath the bioretention soil layers. An underdrain was included in the construction of the bioretention facility, but is capped and provides no discharge from the site.

A native soil infiltration rate of 9 inches per hour together with a bioretention top soil layer of ASTM15 soil and a second soil layer of ASTM4 soil best reproduced the monitored soil moisture and surface ponding conditions.

Figure B145-1 shows the simulated (red) and recorded (blue) daily inflow volumes and, along the top of the figure, the B145 site monitored daily rainfall data. The simulated and recorded daily inflow volumes match well, except for winter periods (January and February 2017) where snow and freezing conditions affected the recorded values.

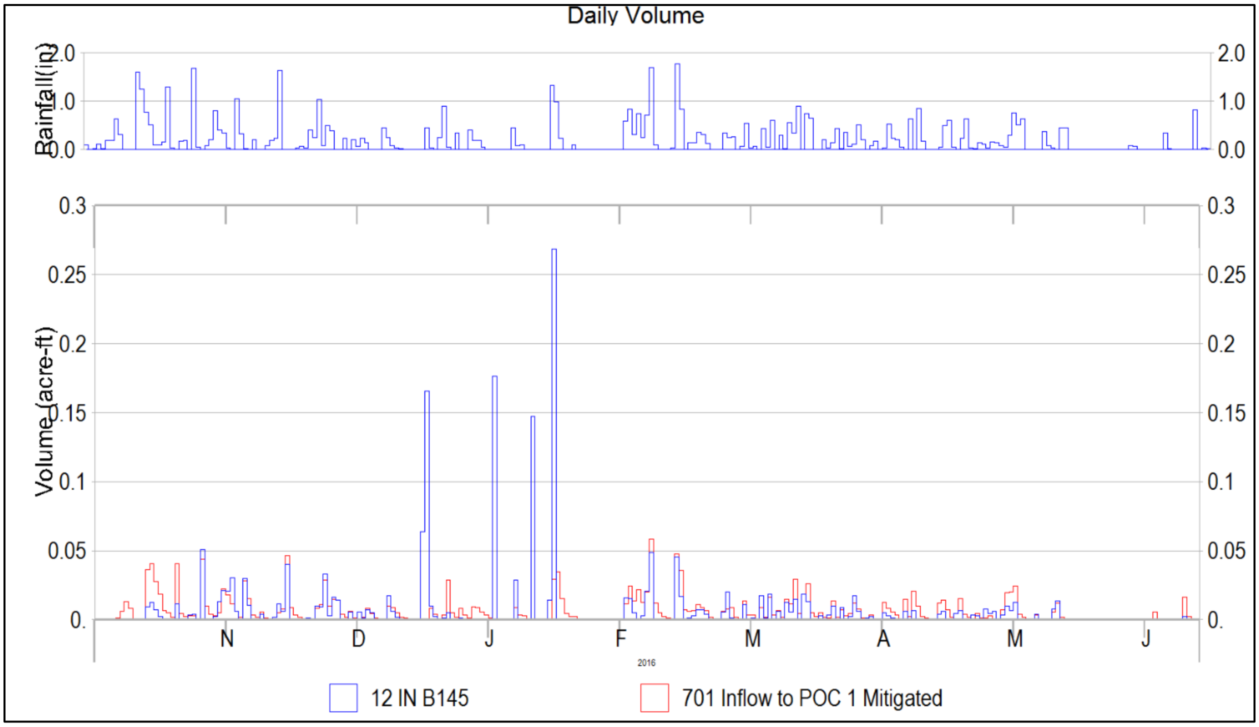


Figure B145-1. B145 Daily Inflow Volumes

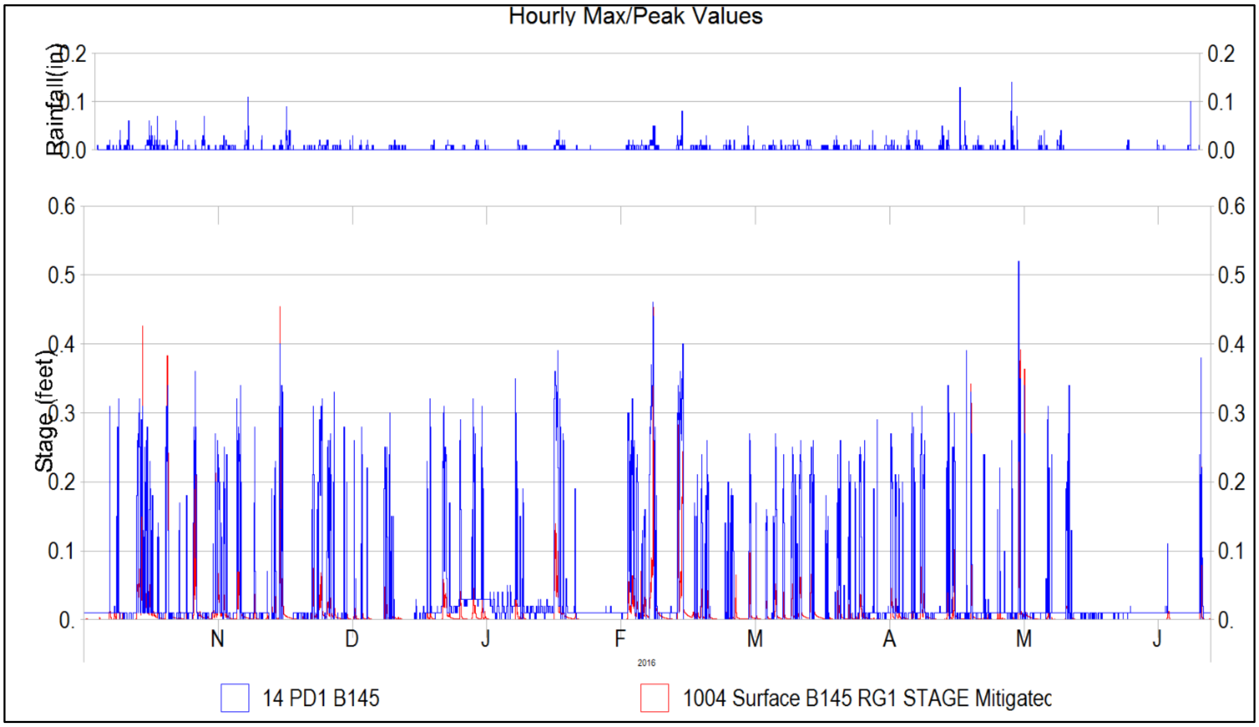


Figure B145-2. B145 Hourly Surface Ponding Depths

Figure B145-2 shows the simulated (red) and recorded (blue) hourly maximum 5-minute surface ponding (stage) values and, along the top of the figure, the B145 site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values are mixed. The higher/larger ponding depths match well, but the simulated depths for the smaller events do not show as much of a response as the monitored data.

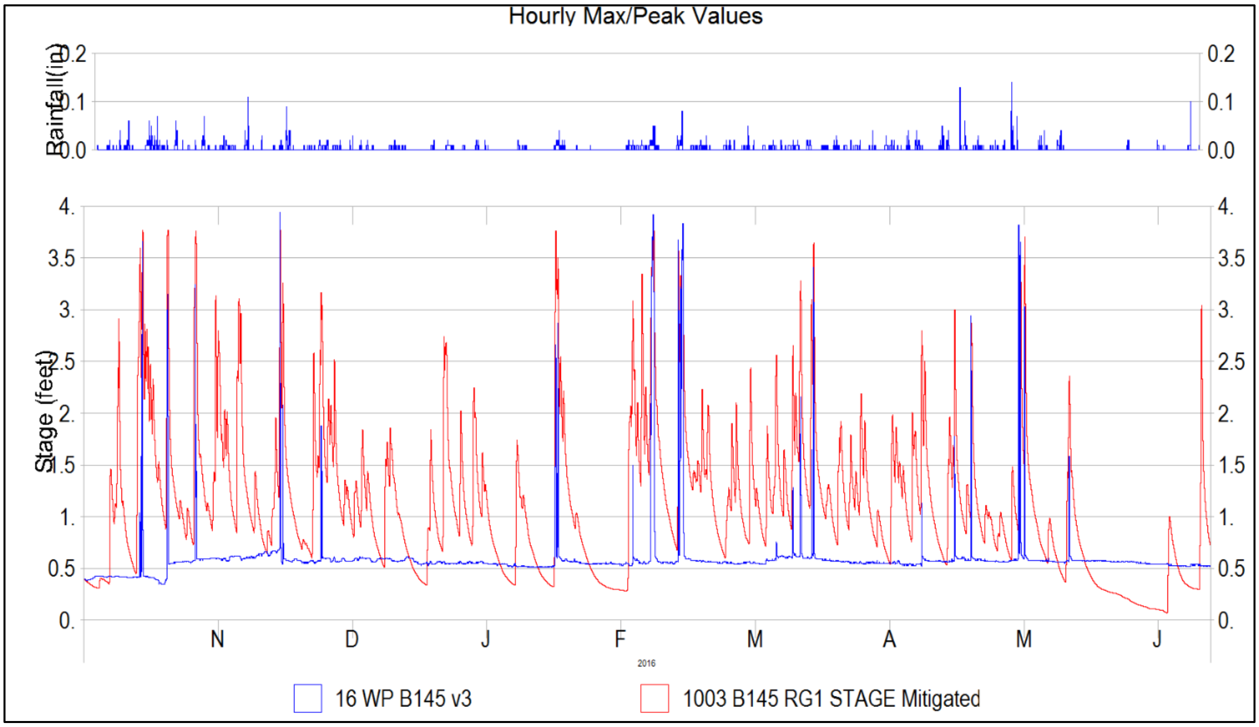
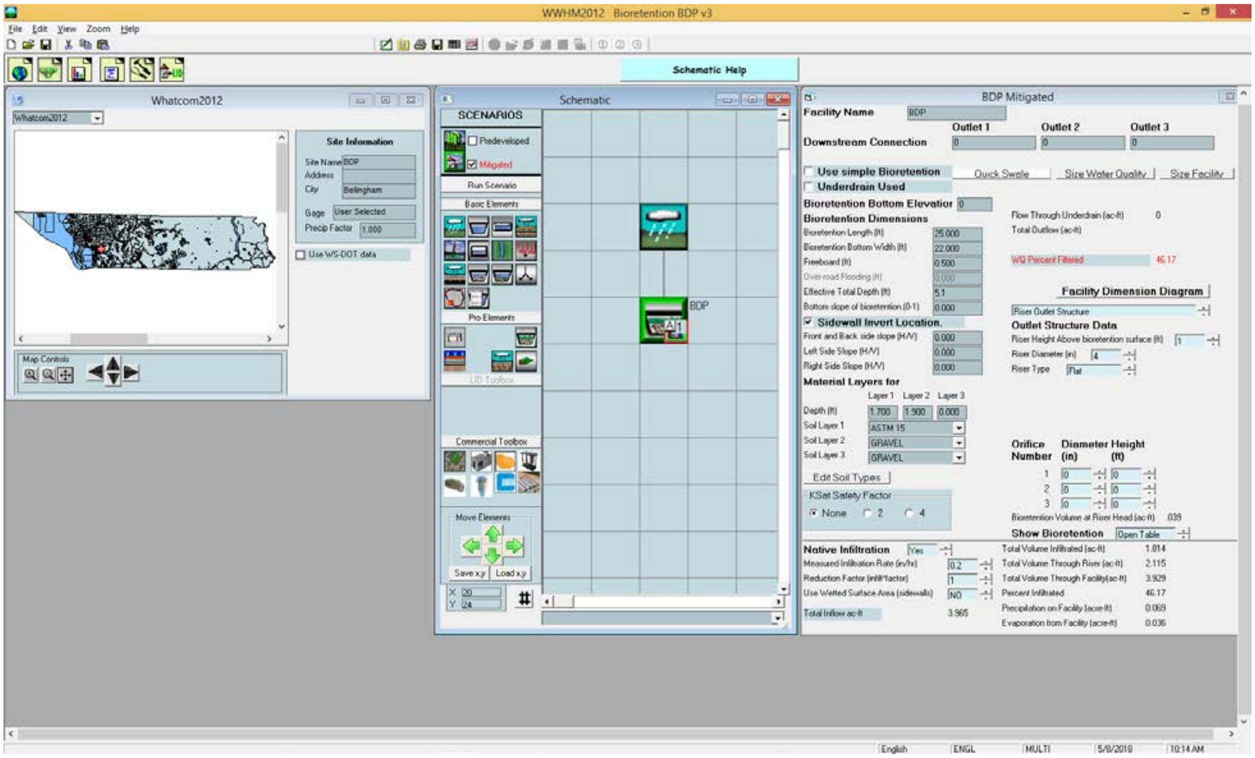


Figure B145-3. B145 Hourly Soil Layer Well Point Elevations

Figure B145-3 shows the simulated (red) and recorded (blue) hourly maximum 5-minute soil layer well point elevations (stage) values and, along the top of the figure, the B145 site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values match well for the major events. The simulated values for the smaller events show more fluctuation than the recorded well point data and longer recession periods. This is probably due to difference in the water that is included in the two sets of data, as described in the introductory remarks to this section.

BDP: Bellingham, Whatcom County



Site Information
Site Name BDP
Address
City Bellingham
Gage User Selected
Precip Factor 1.000
☐ Use WS-DOT data

☐ Predeveloped
☑ Mitigated

X 20
Y 24

Facility Name BDP
Downstream Connection: Outlet 1 0; Outlet 2 0; Outlet 3 0
☐ Use simple Bioretention
☐ Underdrain Used
Bioretention Bottom Elevatior 0
Bioretention Dimensions
Bioretention Length (ft) 25.000
Bioretention Bottom Width (ft) 22.000
Freeboard (ft) 0.500
Over-road Flooding (ft) 0.000
Effective Total Depth (ft) 5.1
Bottom slope of bioretention (0-1) 0.000
☑ Sidewall Invert Location.
Front and Back side slope (H/V) 0.000
Left Side Slope (H/V) 0.000
Right Side Slope (H/V) 0.000
Material Layers for

	Layer 1	Layer 2	Layer 3
Depth (ft)	1.700	1.900	0.000

Soil Layer 1 ASTM 15
Soil Layer 2 GRAVEL
Soil Layer 3 GRAVEL
KSat Safety Factor ● None ○ 2 ○ 4

Flow Through Underdrain (ac-ft) 0
Total Outflow (ac-ft)
WQ Percent Filtered 46.17
Riser Outlet Structure
Outlet Structure Data
Riser Height Above bioretention surface (ft) 1
Riser Diameter (in) 4
Riser Type Flat

Orifice Number	Diameter (in)	Height (ft)
1	0	0
2	0	0
3	0	0

Bioretention Volume at Riser Head (ac-ft) .039
Show Bioretention Open Table

Native Infiltration Yes
Measured Infiltration Rate (in/hr) 0.2
Reduction Factor (infilt*factor) 1
Use Wetted Surface Area (sidewalls) NO
Total Inflow ac-ft 3.965

Total Volume Infiltrated (ac-ft) 1.014
Total Volumn Through Riser (ac-ft) 2.115
Total Volume Through Facility(ac-ft) 3.929
Percent Infiltrated 46.17
Precipitation on Facility (acre-ft) 0.069
Evaporation from Facility (acre-ft) 0.036

The BDP bioretention site is located in Bellingham, Whatcom County, Washington. The drainage area to BDP consists of 0.80 acres of pavement on a flat slope (0-5%). Initially, it was believed that 1.60 acres of pavement drains to BDP, but modeling inflow results when compared to the monitored data showed this to be unlikely and that half that amount (0.80 acres) is a more probable contributing drainage area.

The BDP surface bottom footprint is 550 square feet. This equals 2% of the 0.8-acre tributary drainage area to BDP.

BDP has a surface discharge via weir outlet set at 0.9 feet above the surface bottom. Approximately one-half of the inflow to BDP is infiltrated into the native soil beneath the bioretention soil layers. BDP contains no underdrain.

A native soil infiltration rate of 0.2 inches per hour together with a bioretention top soil layer of ASTM15 soil and a second soil layer of gravel best reproduced the monitored soil moisture and surface ponding conditions. A high groundwater table from Lake Whatcom appears to greatly reduce the native soil infiltration rate.

Figure BDP-1 shows the simulated (red) and recorded (blue) daily inflow volumes and, along the top of the figure, the BDP site monitored daily rainfall data. The simulated and recorded daily inflow volumes are mixed. Winter periods (November 2016 through February 2017) show major differences where snow and freezing conditions affected the recorded values.

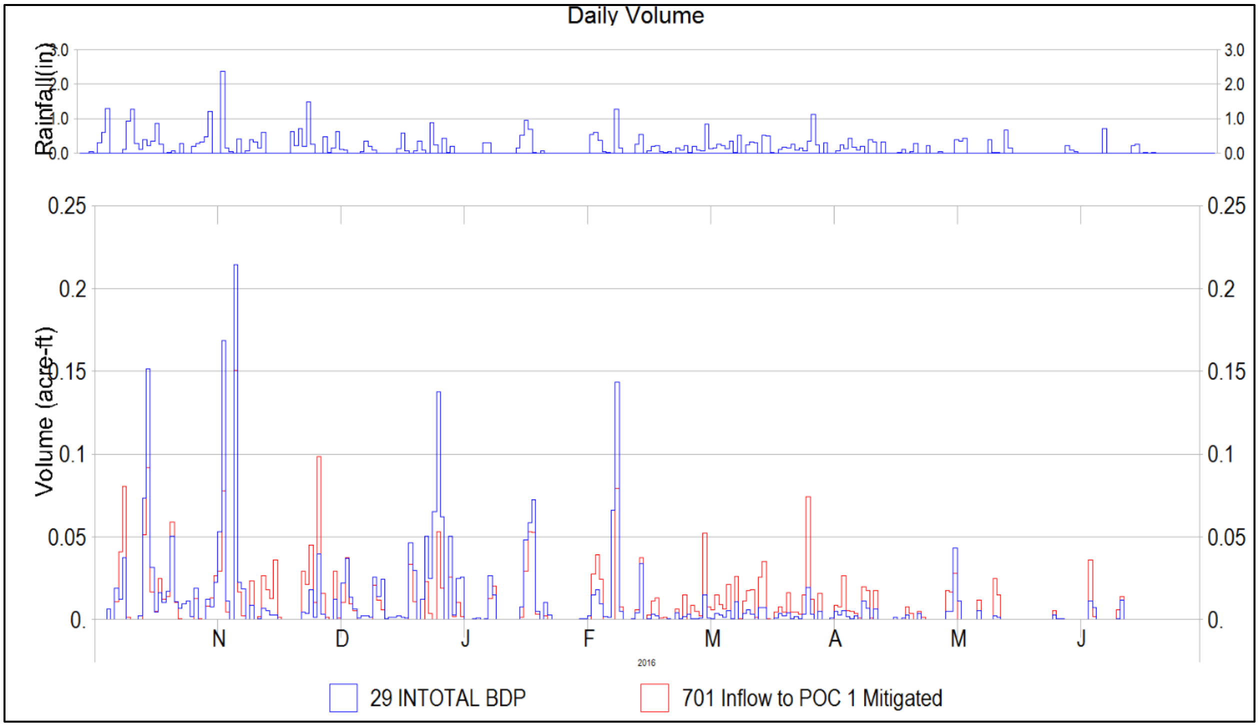


Figure BDP-1. BDP Daily Inflow Volumes

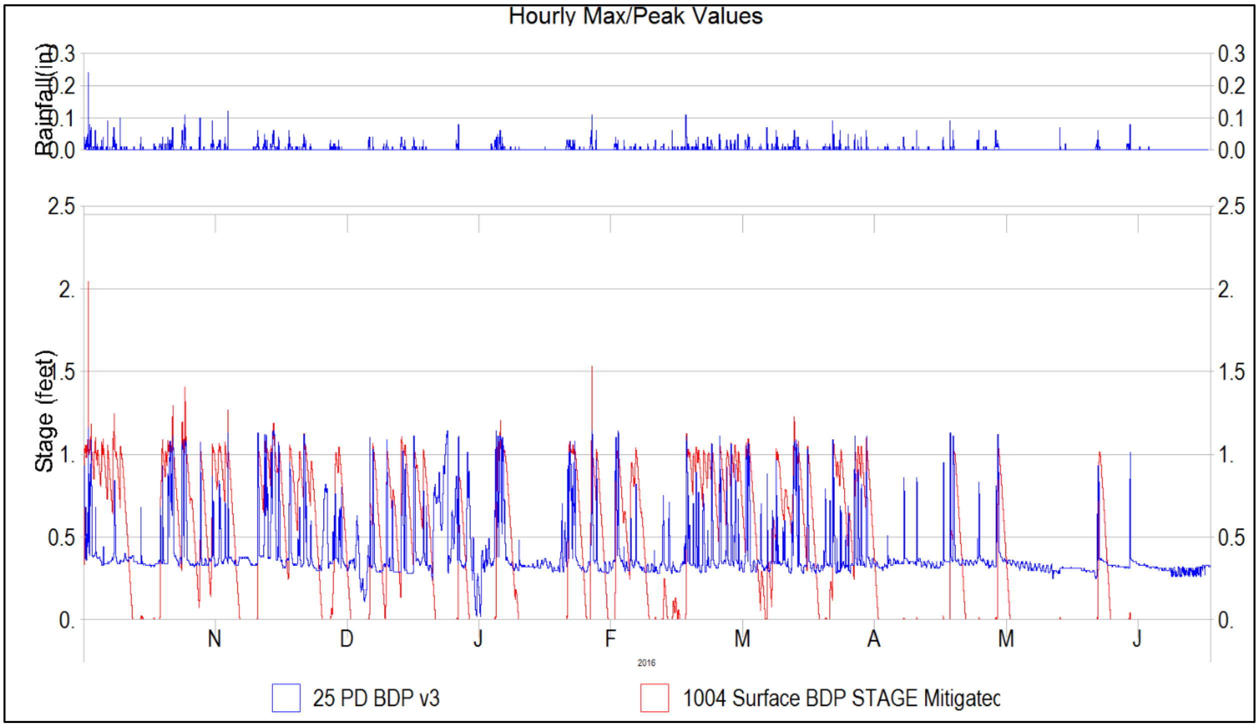


Figure BDP-2. BDP Hourly Surface Ponding Depths

Figure BDP-2 shows the simulated (red) and recorded (blue) hourly maximum 5-minute surface ponding (stage) values and, along the top of the figure, the BDP site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values in general show a good match, except for dry periods where the simulated depths drop down to zero and the recorded depths stay elevated. These consistently elevated recorded ponding depths are due to the effect of Lake Whatcom's groundwater influence.

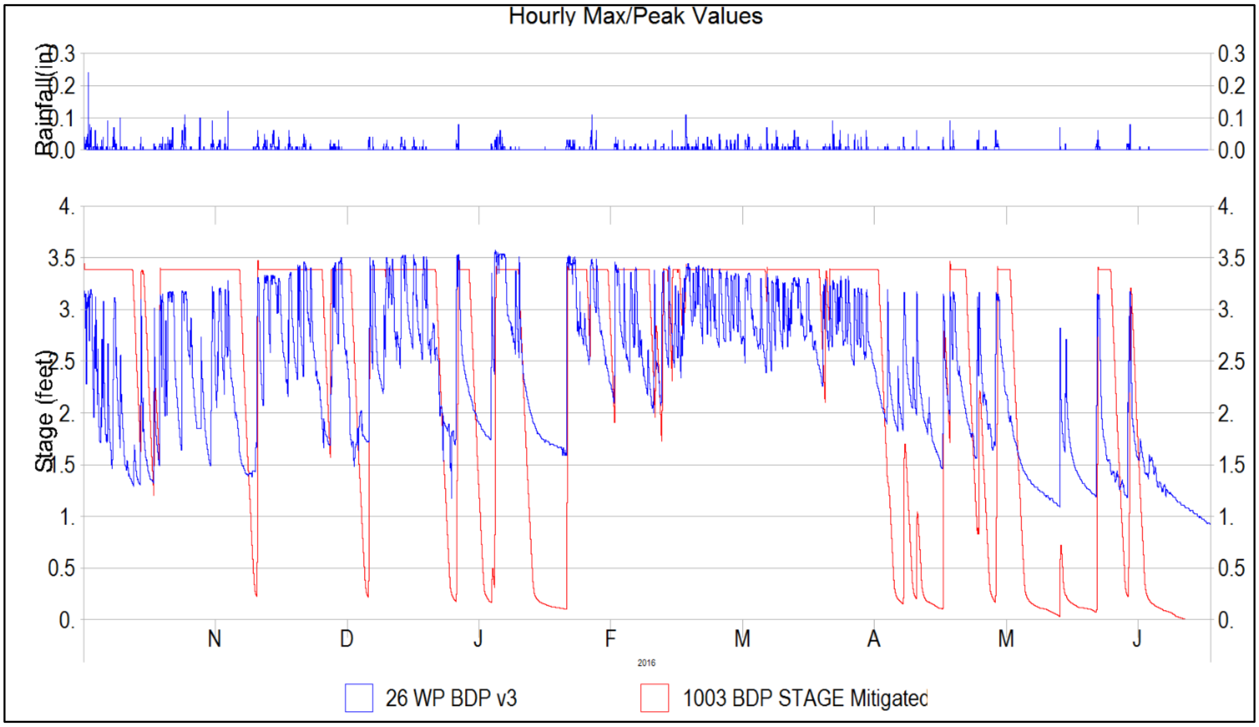
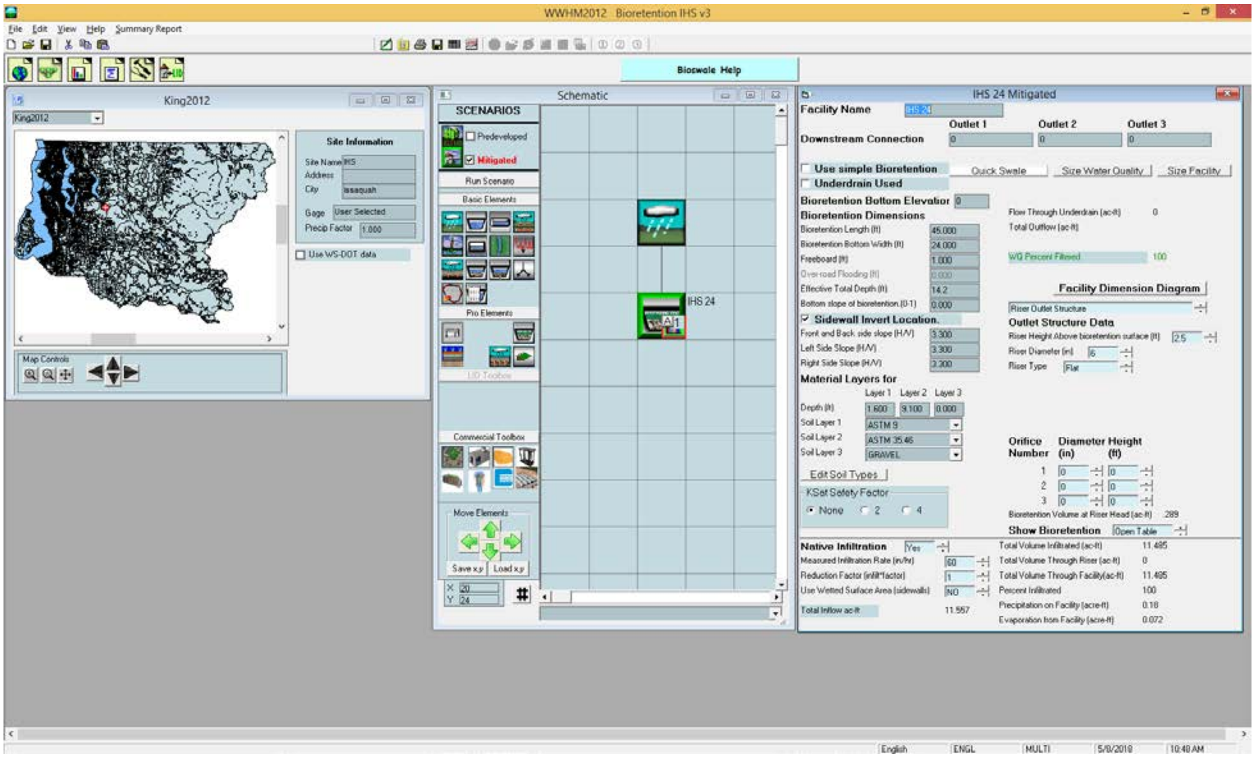


Figure BDP-3. BDP Hourly Soil Layer Well Point Elevations

Figure BDP-3 shows the simulated (red) and recorded (blue) hourly maximum 5-minute soil layer well point elevations (stage) values and, along the top of the figure, the BDP site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values match well. As with the ponding results above, the simulated values show more fluctuation than the recorded well point data. These consistently elevated recorded well point depths are due to the effect of Lake Whatcom's groundwater influence.

IHS: Issaquah, King County



Site Information

Site Name IHS
Address
City Issaquah
Gage User Selected
Precip Factor 1.000
☐ Use WS-DOT data

X 20
Y 24

IHS 24 Mitigated

Facility Name IHS 24

	Outlet 1	Outlet 2	Outlet 3
Downstream Connection	0	0	0

☐ Use simple Bioretention
☐ Underdrain Used

Bioretention Bottom Elevation 0

Bioretention Dimensions

Bioretention Length (ft) 45.000
Bioretention Bottom Width (ft) 24.000
Freeboard (ft) 1.000
Over-road Flooding (ft) 0.000
Effective Total Depth (ft) 14.2
Bottom slope of bioretention (0-1) 0.000

☑ Sidewall Invert Location.

Front and Back side slope (H/V) 3.300
Left Side Slope (H/V) 3.300
Right Side Slope (H/V) 3.300

Material Layers for

	Layer 1	Layer 2	Layer 3
Depth (ft)	1.600	9.100	0.000

Soil Layer 1 ASTM 9
Soil Layer 2 ASTM 35.46
Soil Layer 3 GRAVEL

KSat Safety Factor
● None ○ 2 ○ 4

Flow Through Underdrain (ac-ft) 0
Total Outflow (ac-ft)
WQ Percent Filtered 100

Riser Outlet Structure

Outlet Structure Data

Riser Height Above bioretention surface (ft) 2.5
Riser Diameter (in) 6
Riser Type Flat

Orifice Number	Diameter (in)	Height (ft)
1	0	0
2	0	0
3	0	0

Bioretention Volume at Riser Head (ac-ft) .289

Show Bioretention Open Table

Native Infiltration Yes
Measured Infiltration Rate (in/hr) 60
Reduction Factor (infilt*factor) 1
Use Wetted Surface Area (sidewalls) NO
Total Inflow ac-ft 11.557

Total Volume Infiltrated (ac-ft) 11.495
Total Volume Through Riser (ac-ft) 0
Total Volume Through Facility(ac-ft) 11.495
Percent Infiltrated 100
Precipitation on Facility (acre-ft) 0.18
Evaporation from Facility (acre-ft) 0.072

The IHS bioretention site is located in Issaquah, King County, Washington. The drainage area to IHS consists of 0.41 acres of NRCS Type C soil, lawn vegetation, on a moderate slope (5-15%) and 1.60 acres of pavement on a flat slope (0-5%). Initially, it was believed that 0.80 acres of pavement drains to IHS, but modeling inflow results when compared to the monitored data showed this to be too small and that twice that amount (1.60 acres) is a more probable contributing drainage area.

The IHS surface bottom footprint is 1080 square feet. This equals 2% of the 2.01-acre tributary drainage area to IHS.

IHS has a surface discharge via riser outlet set at 2.5 feet above the surface bottom. Most of the inflow to IHS is infiltrated into the native soil beneath the bioretention soil layers. The riser outlet is connected to an infiltration gallery so all of the inflow infiltrates into the native soil either through the bottom of the bioretention facility or through the overflow infiltration gallery.

A native soil infiltration rate of 60 inches per hour together with a bioretention top soil layer of ASTM9 soil and a second soil layer of ASTM35 soil best reproduced the monitored soil moisture and surface ponding conditions.

Figure IHS-1 shows the simulated (red) and recorded (blue) daily inflow volumes and, along the top of the figure, the IHS site monitored daily rainfall data. The simulated and recorded daily inflow volumes match well, except for winter periods (January and February 2017) where snow and freezing conditions affected the recorded values.

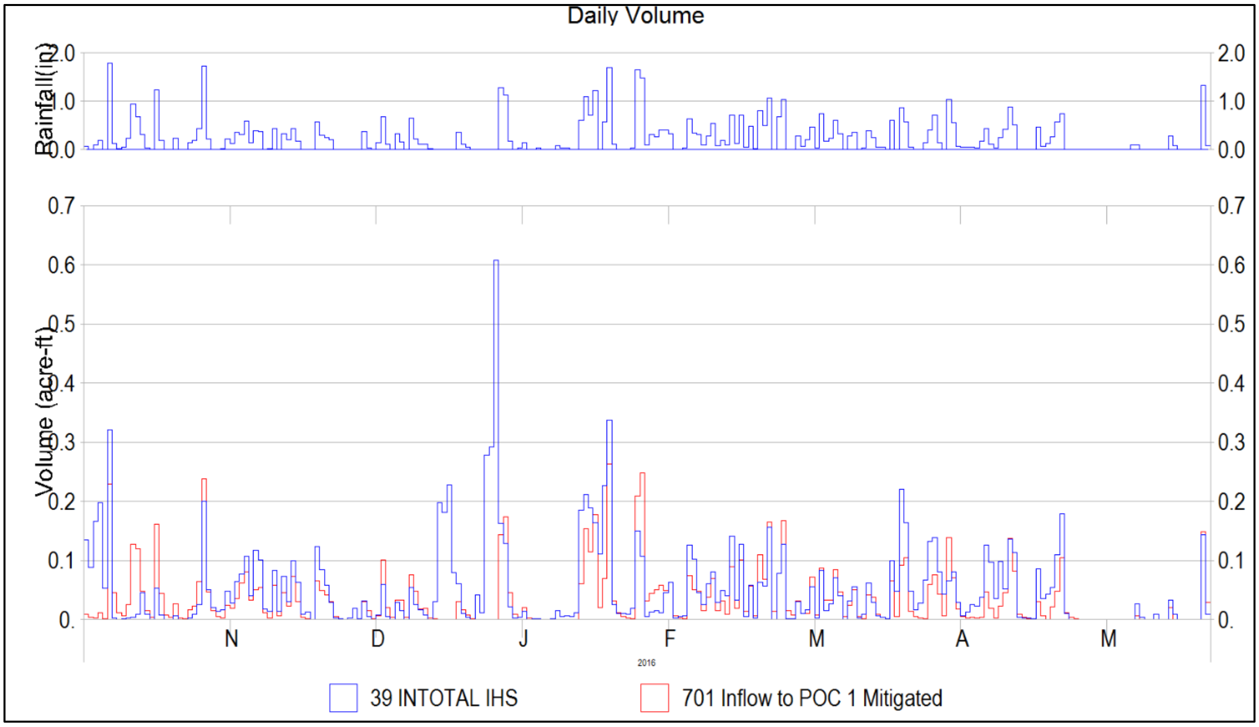


Figure IHS-1. IHS Daily Inflow Volumes

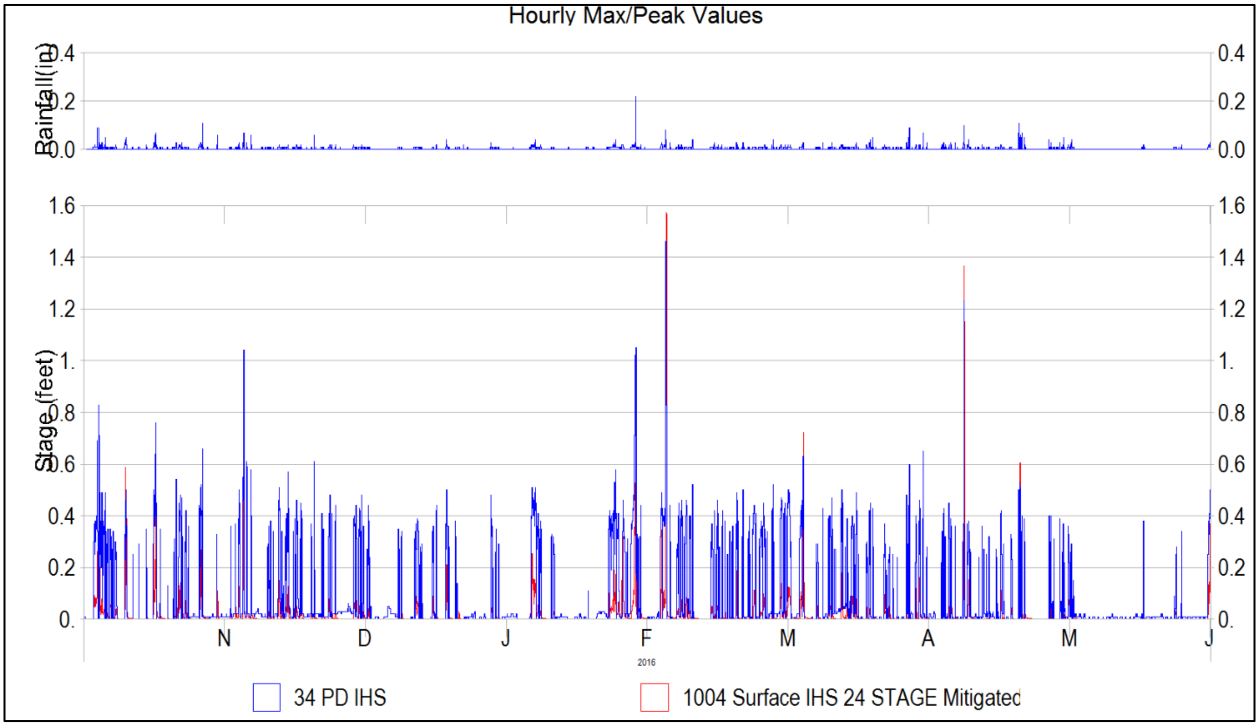


Figure IHS-2. IHS Hourly Surface Ponding Depths

Figure IHS-2 shows the simulated (red) and recorded (blue) hourly maximum 5-minute surface ponding (stage) values and, along the top of the figure, the IHS site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values are mixed. The higher/larger ponding depths match well, but the simulated depths for the smaller events do not show as much of a response as the monitored data.

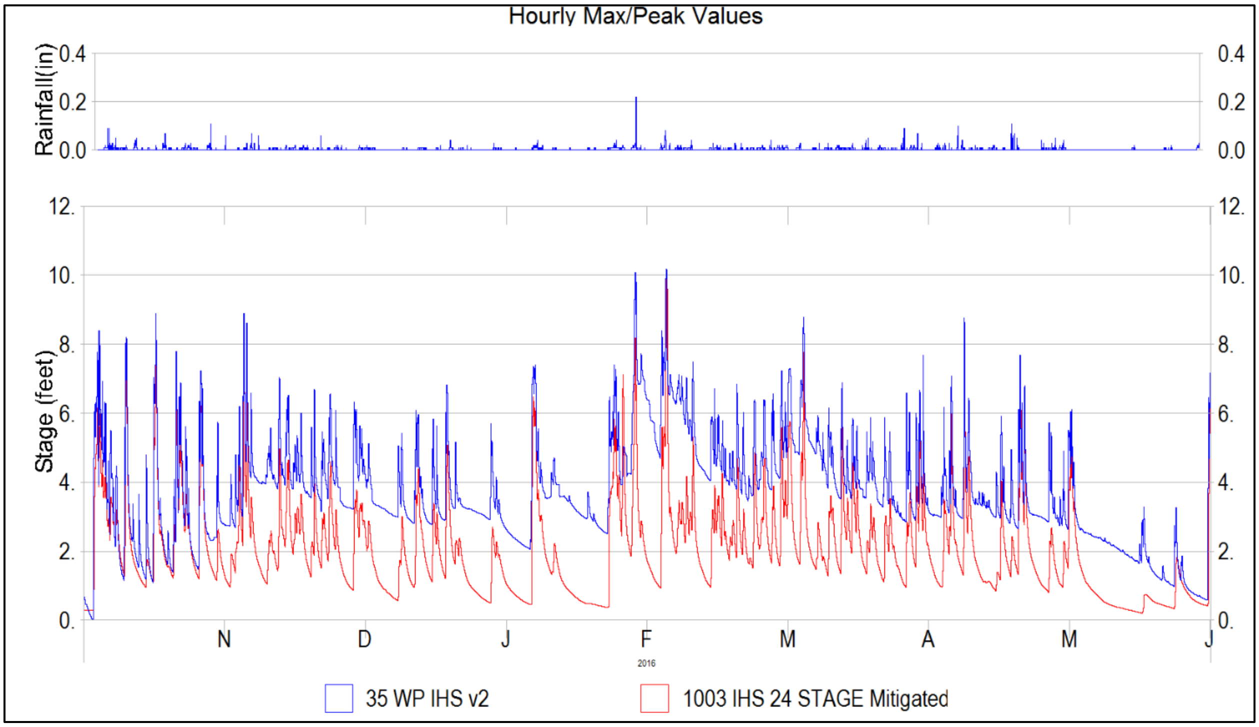
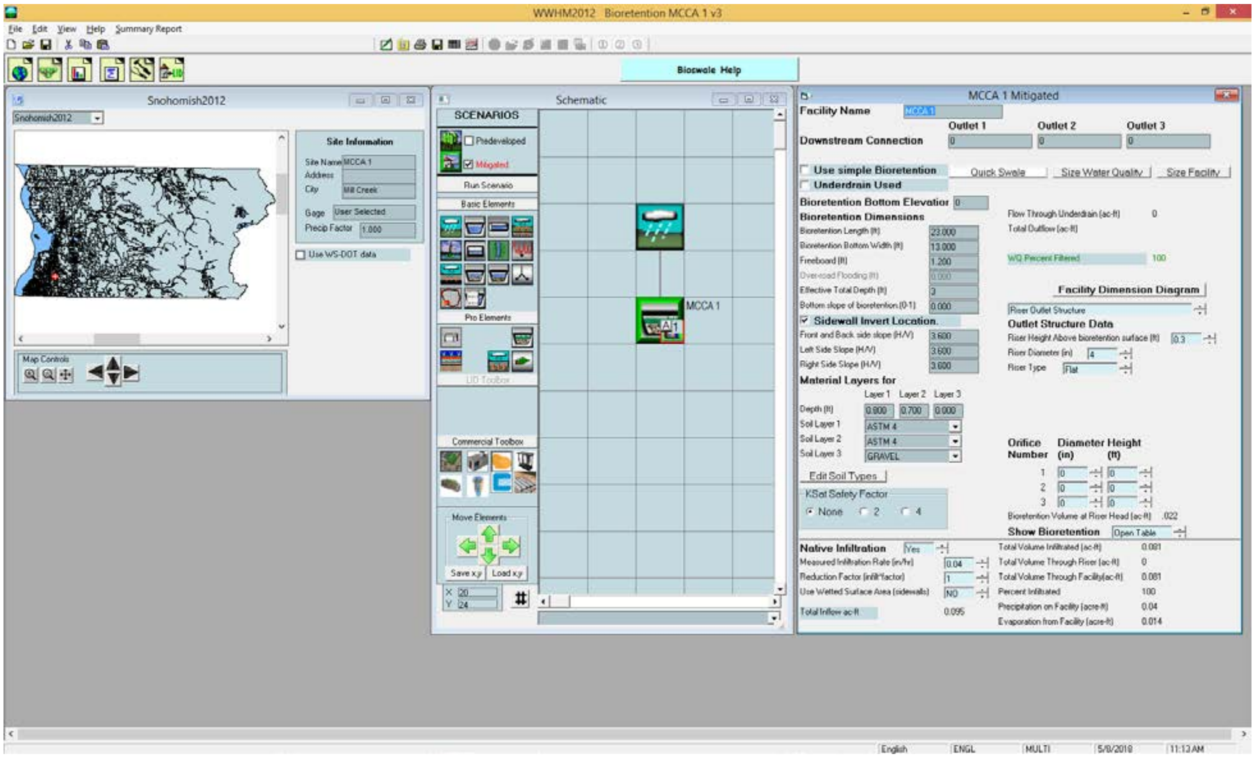


Figure IHS 3. IHS Hourly Soil Layer Well Point Elevations

Figure IHS 3 shows the simulated (red) and recorded (blue) hourly maximum 5-minute soil layer well point elevations (stage) values and, along the top of the figure, the IHS site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values match well for the major events. The simulated values for the smaller events show more fluctuation than the recorded well point data and longer recession periods. This may be due to raised groundwater levels in winter and spring months (groundwater mounding) affecting the recorded data.

MCCA1: Mill Creek, Snohomish County



MCCA 1 Mitigated

Facility Name: MCCA 1

Downstream Connection: Outlet 1: 0; Outlet 2: 0; Outlet 3: 0

☐ Use simple Bioretention

☐ Underdrain Used

Bioretention Bottom Elevation: 0

Bioretention Dimensions
- Bioretention Length (ft): 23.000
- Bioretention Bottom Width (ft): 13.000
- Freeboard (ft): 1.200
- Over-road Flooding (ft): 0.000
- Effective Total Depth (ft): 3
- Bottom slope of bioretention (0-1): 0.000

☑ Sidewall Invert Location.
- Front and Back side slope (H/V): 3.600
- Left Side Slope (H/V): 3.600
- Right Side Slope (H/V): 3.600

Material Layers for

	Layer 1	Layer 2	Layer 3
Depth (ft)	0.800	0.700	0.000

- Soil Layer 1: ASTM 4
- Soil Layer 2: ASTM 4
- Soil Layer 3: GRAVEL

KSat Safety Factor: ● None ○ 2 ○ 4

Flow Through Underdrain (ac-ft): 0

Total Outflow (ac-ft):

WQ Percent Filtered: 100

Riser Outlet Structure

Outlet Structure Data
- Riser Height Above bioretention surface (ft): 0.3
- Riser Diameter (in): 4
- Riser Type: Flat

Orifice Number	Diameter (in)	Height (ft)
1	0	0
2	0	0
3	0	0

Bioretention Volume at Riser Head (ac-ft): .022

Show Bioretention: Open Table

Native Infiltration: Yes
- Measured Infiltration Rate (in/hr): 0.04
- Reduction Factor (infilt*factor): 1
- Use Wetted Surface Area (sidewalls): NO

Total Inflow ac-ft: 0.095

- Total Volume Infiltrated (ac-ft): 0.081
- Total Volume Through Riser (ac-ft): 0
- Total Volume Through Facility(ac-ft): 0.081
- Percent Infiltrated: 100
- Precipitation on Facility (acre-ft): 0.04
- Evaporation from Facility (acre-ft): 0.014

The MCCA1 bioretention site is located in Mill Creek, Snohomish County, Washington. The drainage area to MCCA1 consists of 0.01 acres of roof on a steep slope (>15%).

The MCCA1 surface bottom footprint is 299 square feet. This equals 69% of the tributary drainage area to MCCA1.

MCCA1 has no surface outlet but overtops the site at 0.3 feet above the surface bottom. All of the inflow to MCCA1 is infiltrated into the native soil beneath the bioretention soil layers.

A native soil infiltration rate of 0.04 inches per hour together with a bioretention top soil layer of ASTM4 soil and a second soil layer of ASTM4 soil best reproduced the monitored soil moisture and surface ponding conditions.

Figure MCCA1-1 shows the simulated (red) and recorded (blue) daily inflow volumes and, along the top of the figure, the MCCA1 site monitored daily rainfall data. The simulated and recorded daily inflow volumes match well, except for winter periods (January and February 2017) where snow and freezing conditions affected the recorded values.

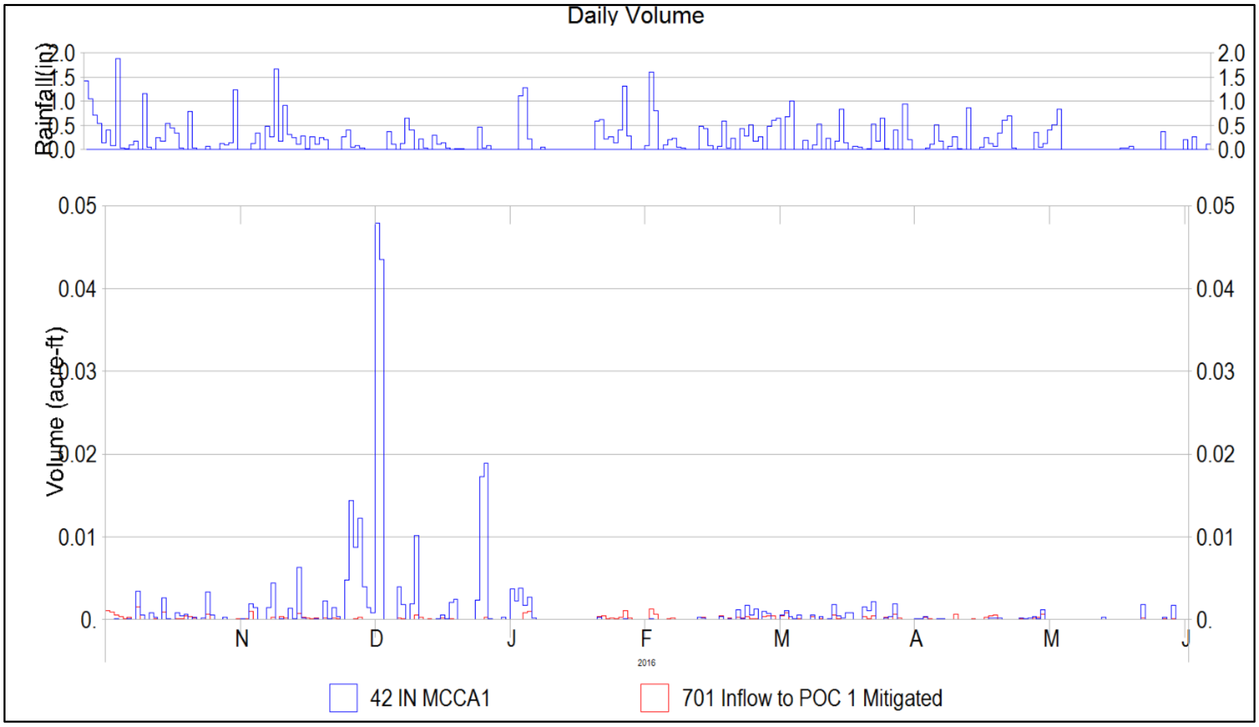


Figure MCCA1-1. MCCA1 Daily Inflow Volumes

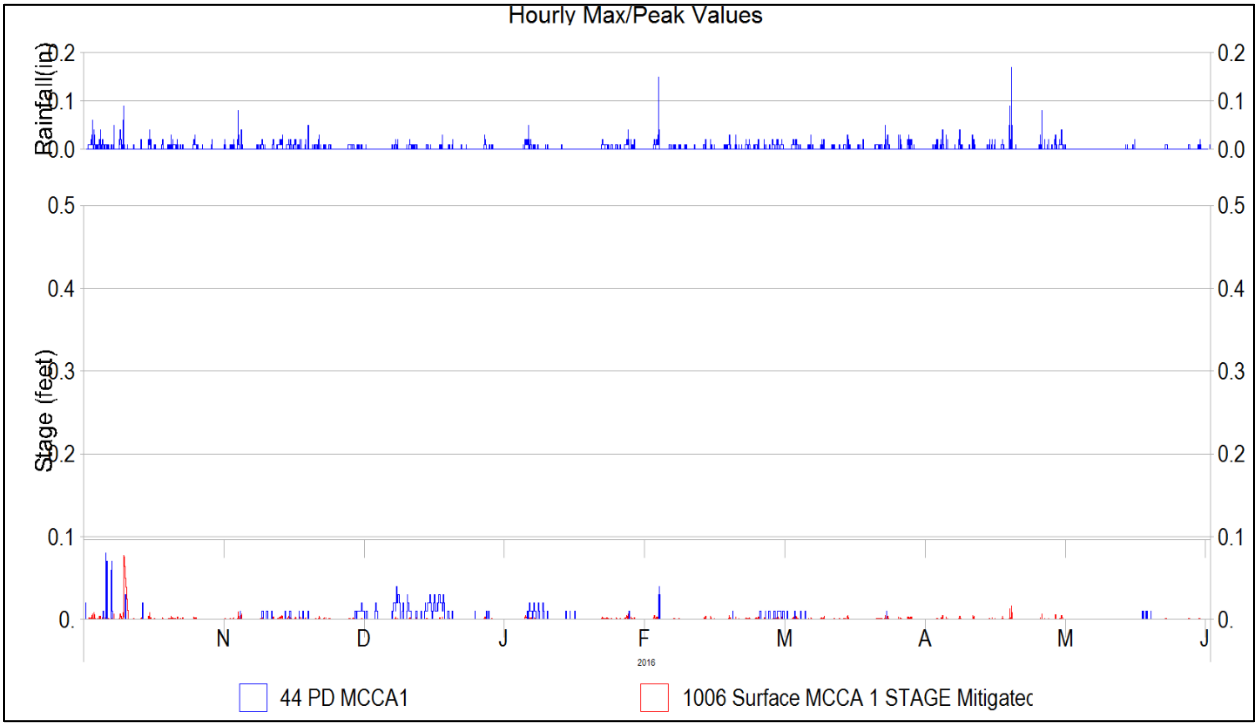


Figure MCCA1-2. MCCA1 Hourly Surface Ponding Depths

Figure MCCA1-2 shows the simulated (red) and recorded (blue) hourly maximum 5-minute surface ponding (stage) values and, along the top of the figure, the MCCA1 site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values match well. Due to the relatively large bioretention surface bottom area compared to the contributing roof drainage area there is very little surface ponding, even during major storm events.

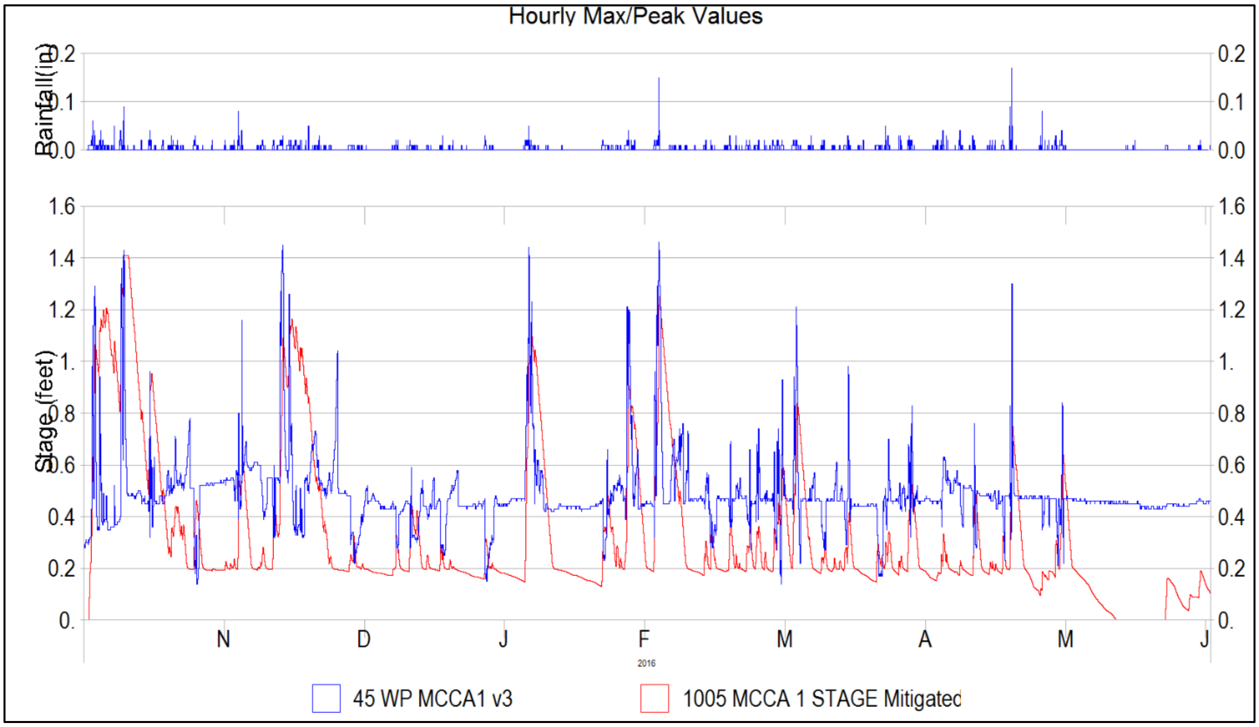
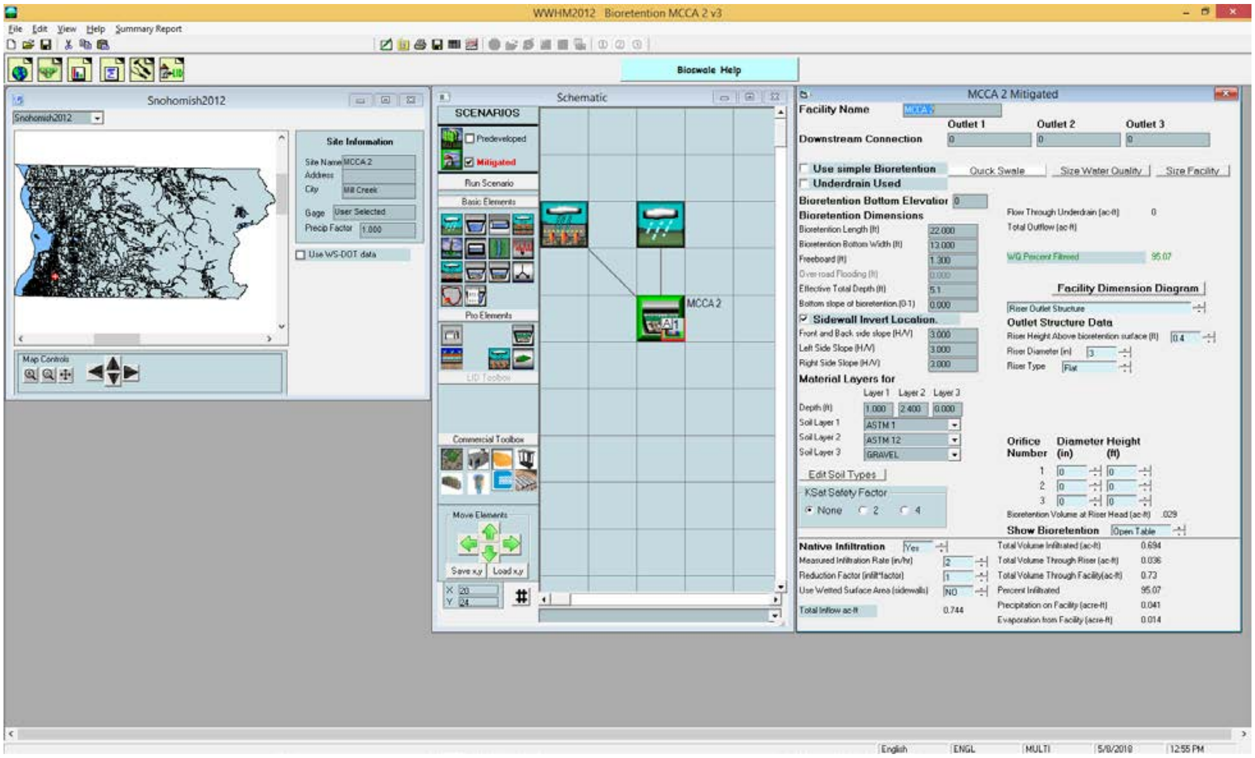


Figure MCCA1-3. MCCA1 Hourly Soil Layer Well Point Elevations

Figure MCCA1-3 shows the simulated (red) and recorded (blue) hourly maximum 5-minute soil layer well point elevations (stage) values and, along the top of the figure, the MCCA1 site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values match well for the major events. The simulated values for the smaller events show more fluctuation than the recorded well point data and longer recession periods. This may be due to raised groundwater levels in winter and spring months (groundwater mounding) affecting the recorded data.

MCCA2: Mill Creek, Snohomish County



Site Name MCCA 2
City Mill Creek
Gage User Selected
Precip Factor 1.000
X 20
Y 24

MCCA 2 Mitigated

Facility Name MCCA 2

	Outlet 1	Outlet 2	Outlet 3
Downstream Connection	0	0	0

☐ Use simple Bioretention
☐ Underdrain Used

Bioretention Bottom Elevation 0

Bioretention Dimensions

Bioretention Length (ft) 22.000
Bioretention Bottom Width (ft) 13.000
Freeboard (ft) 1.300
Over-road Flooding (ft) 0.000
Effective Total Depth (ft) 5.1
Bottom slope of bioretention (0-1) 0.000

☑ Sidewall Invert Location.

Front and Back side slope (H/V) 3.000
Left Side Slope (H/V) 3.000
Right Side Slope (H/V) 2.000

Material Layers for

	Layer 1	Layer 2	Layer 3
Depth (ft)	1.000	2.400	0.000

Soil Layer 1 ASTM 1
Soil Layer 2 ASTM 12
Soil Layer 3 GRAVEL

KSat Safety Factor
● None ○ 2 ○ 4

Flow Through Underdrain (ac-ft) 0
Total Outflow (ac-ft)
WQ Percent Filtered 95.07

Riser Outlet Structure

Outlet Structure Data

Riser Height Above bioretention surface (ft) 0.4
Riser Diameter (in) 3
Riser Type Flat

Orifice Number	Diameter (in)	Height (ft)
1	0	0
2	0	0
3	0	0

Bioretention Volume at Riser Head (ac-ft) .029

Show Bioretention Open Table

Native Infiltration Yes
Measured Infiltration Rate (in/hr) 2
Reduction Factor (infilt*factor) 1
Use Wetted Surface Area (sidewalls) NO
Total Inflow ac-ft 0.744

Total Volume Infiltrated (ac-ft) 0.694
Total Volume Through Riser (ac-ft) 0.036
Total Volume Through Facility(ac-ft) 0.73
Percent Infiltrated 95.07
Precipitation on Facility (acre-ft) 0.041
Evaporation from Facility (acre-ft) 0.014

The MCCA2 bioretention site is located in Mill Creek, Snohomish County, Washington. The drainage area to MCCA2 consists of 0.0184 acres of roof on a steep slope (>15%) plus 5400 square feet (0.124 acres) of adjacent permeable pavement (see below for explanation).

The MCCA2 surface bottom footprint is 286 square feet. This equals 5% of the tributary drainage area to MCCA2.

MCCA2 was designed to have a surface outlet at 0.4 feet above the surface bottom. This designed (and constructed) outlet was via a pipe to the gravel under layer of the adjacent permeable pavement parking lot. However, monitored ponding data indicates that this outlet to the parking lot actually acts as an inlet from the gravel layer of the permeable pavement to MCCA2.

A native soil infiltration rate of 2 inches per hour together with a bioretention top soil layer of ASTM1 soil and a second soil layer of ASTM12 soil best reproduced the monitored soil moisture and surface ponding conditions.

Figure MCCA2-1 shows the simulated (red) and recorded (blue) daily inflow volumes and, along the top of the figure, the MCCA2 site monitored daily rainfall data. The simulated and recorded daily inflow volumes do not match because the recorded inflow volumes do not include the inflow from the permeable pavement.

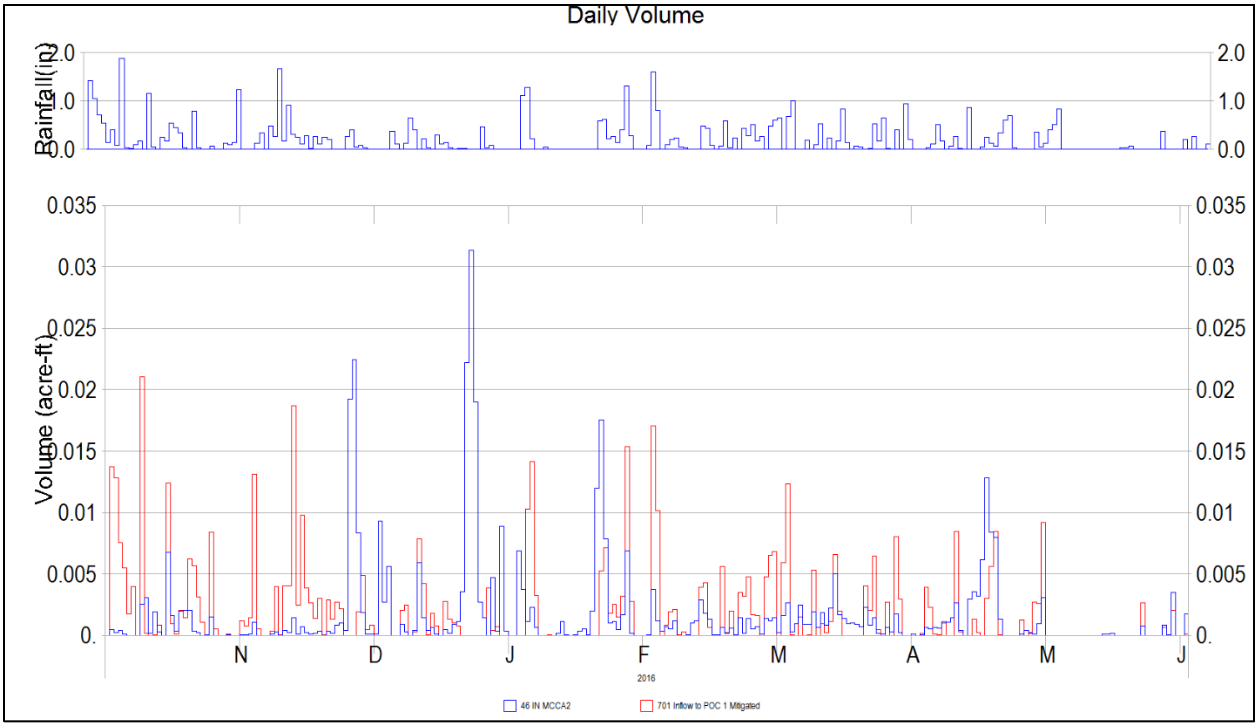


Figure MCCA2-1. MCCA2 Daily Inflow Volumes

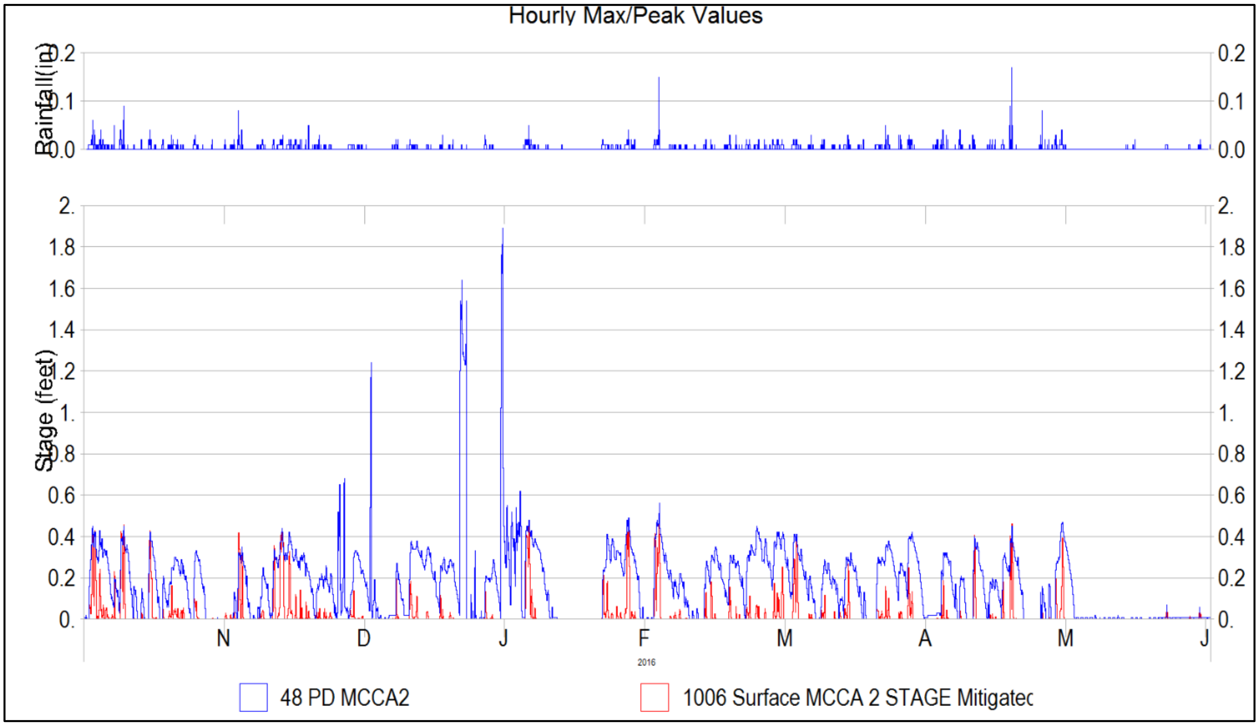


Figure MCCA2-2. MCCA2 Hourly Surface Ponding Depths

Figure MCCA2-2 shows the simulated (red) and recorded (blue) hourly maximum 5-minute surface ponding (stage) values and, along the top of the figure, the MCCA2 site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values match well with the inclusion of the inflow from the permeable pavement. Without the permeable pavement inflow MCCA2 would have similar minimal ponding depths to what was monitored in MCCA1.

To confirm that the monitored roof runoff inflow to MCCA2 is insufficient to provide enough water to produce ponding a hand calculation outside of WWHM2012 was made to compare the inflow volume with the ponding volume for the first major storm event in October 2016. The total rainfall volume on the portion of the roof that drains to MCCA2 plus the rainfall volume falling directly on the bioretention surface area was calculated and found to be smaller than the monitored pond volume in MCCA2. The extra water must come from somewhere and a thorough site investigation concluded that the only realistic source of this additional water must be from the gravel layer under the permeable pavement in the parking lot. When the permeable pavement was added to the WWHM MCCA2 bioretention model the simulated and recorded pond depths matched well, except for winter periods (January and February 2017) where snow and freezing conditions affected the recorded values.

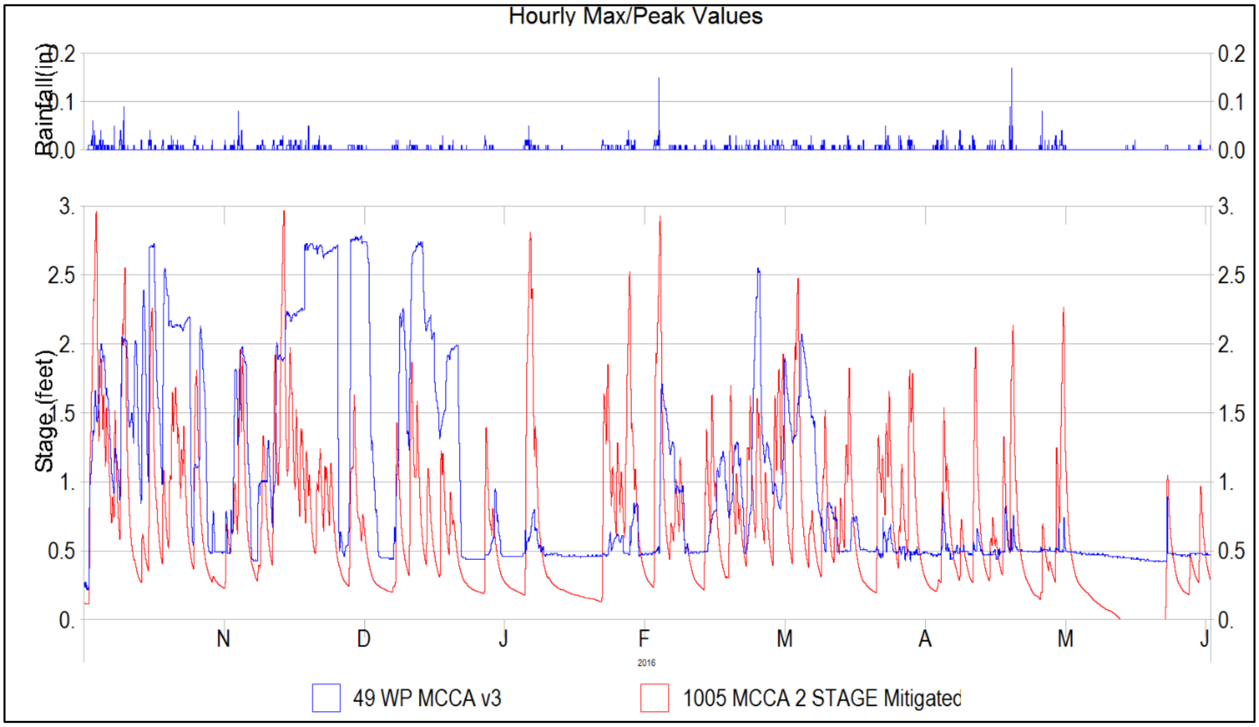
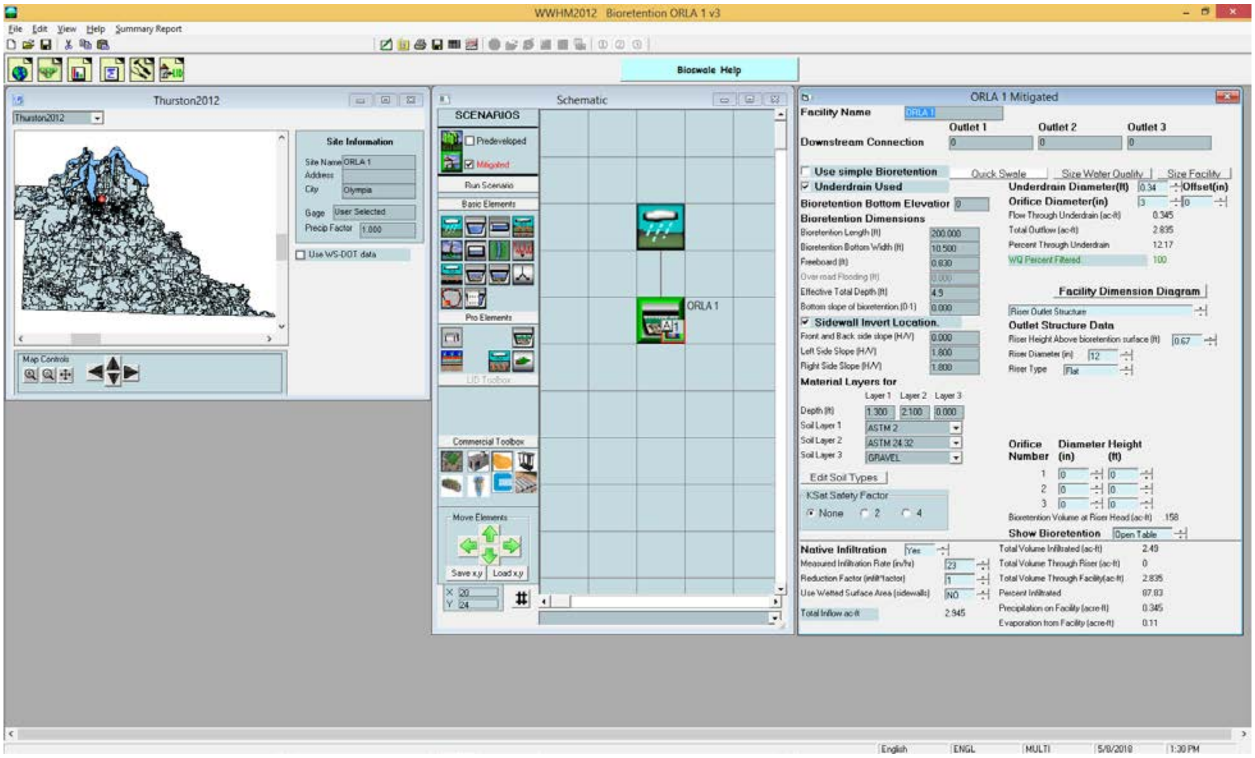


Figure MCCA2-3. MCCA2 Hourly Soil Layer Well Point Elevations

Figure MCCA2-3 shows the simulated (red) and recorded (blue) hourly maximum 5-minute soil layer well point elevations (stage) values and, along the top of the figure, the MCCA2 site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values match well for the major events. The simulated values for the smaller events show more fluctuation than the recorded well point data. This may be due to raised groundwater levels in winter and spring months (groundwater mounding) affecting the recorded data.

ORLA1: Olympia, Thurston County



WWHM2012 Bioretention ORLA 1 v3

Thurston2012

Site Information
Site Name ORLA 1
City Olympia
Gage User Selected
Precip Factor 1.000
☐ Use WS-DOT data

SCENARIOS
☐ Predeveloped
☑ Mitigated

ORLA 1 Mitigated

Facility Name ORLA 1

	Outlet 1	Outlet 2	Outlet 3
Downstream Connection	0	0	0

☐ Use simple Bioretention
☑ Underdrain Used
Bioretention Bottom Elevation 0

Bioretention Dimensions
Bioretention Length (ft) 200.000
Bioretention Bottom Width (ft) 10.500
Freeboard (ft) 0.830
Over road Flooding (ft) 0.000
Effective Total Depth (ft) 4.9
Bottom slope of bioretention (0-1) 0.000

☑ Sidewall Invert Location.
Front and Back side slope (H/V) 0.000
Left Side Slope (H/V) 1.800
Right Side Slope (H/V) 1.800

Material Layers for

	Layer 1	Layer 2	Layer 3
Depth (ft)	1.300	2.100	0.000

Soil Layer 1 ASTM 2
Soil Layer 2 ASTM 24.32
Soil Layer 3 GRAVEL

KSat Safety Factor ● None ○ 2 ○ 4

Underdrain Diameter(ft) 0.34
Orifice Diameter(in) 3
Offset(in) 0
Flow Through Underdrain (ac-ft) 0.345
Total Outflow (ac-ft) 2.835
Percent Through Underdrain 12.17
WQ Percent Filtered 100

Riser Outlet Structure

Outlet Structure Data
Riser Height Above bioretention surface (ft) 0.67
Riser Diameter (in) 12
Riser Type Flat

Orifice Number	Diameter (in)	Height (ft)
1	0	0
2	0	0
3	0	0

Bioretention Volume at Riser Head (ac-ft) .158
Show Bioretention Open Table

Native Infiltration Yes
Measured Infiltration Rate (in/hr) 23
Reduction Factor (infilt*factor) 1
Use Wetted Surface Area (sidewalls) NO
Total Inflow ac-ft 2.945

Total Volume Infiltrated (ac-ft) 2.49
Total Volume Through Riser (ac-ft) 0
Total Volume Through Facility(ac-ft) 2.835
Percent Infiltrated 87.83
Precipitation on Facility (acre-ft) 0.345
Evaporation from Facility (acre-ft) 0.11

The ORLA1 bioretention site is located in Olympia, Thurston County, Washington. The drainage area to ORLA1 consists of 0.40 acres of roof on a flat slope (0-5%).

The ORLA1 surface bottom footprint is 2100 square feet. This equals 12% of the tributary drainage area to ORLA1.

ORLA1 has a surface outlet at 0.67 feet above the surface bottom. ORLA1 also has an underdrain. The underdrain is set at the bottom of the bioretention soil layer. Most of the inflow to ORLA1 is infiltrated into the native soil beneath the bioretention soil layers. The underdrain is connected to a gravel trench so all of the inflow infiltrates into the native soil either through the bottom of the bioretention facility or through the underdrain gravel trench.

A native soil infiltration rate of 23 inches per hour together with a bioretention top soil layer of ASTM2 soil and a second soil layer of ASTM24 soil best reproduced the monitored soil moisture and surface ponding conditions.

Figure ORLA1-1 shows the simulated (red) and recorded (blue) daily inflow volumes and, along the top of the figure, the ORLA1 site monitored daily rainfall data. The simulated daily inflow volumes are consistently higher than the recorded data in the early months of October and November 2017, but then tend to match well for the later months starting in January. There is no obvious reason for the seasonal difference in inflow volumes.

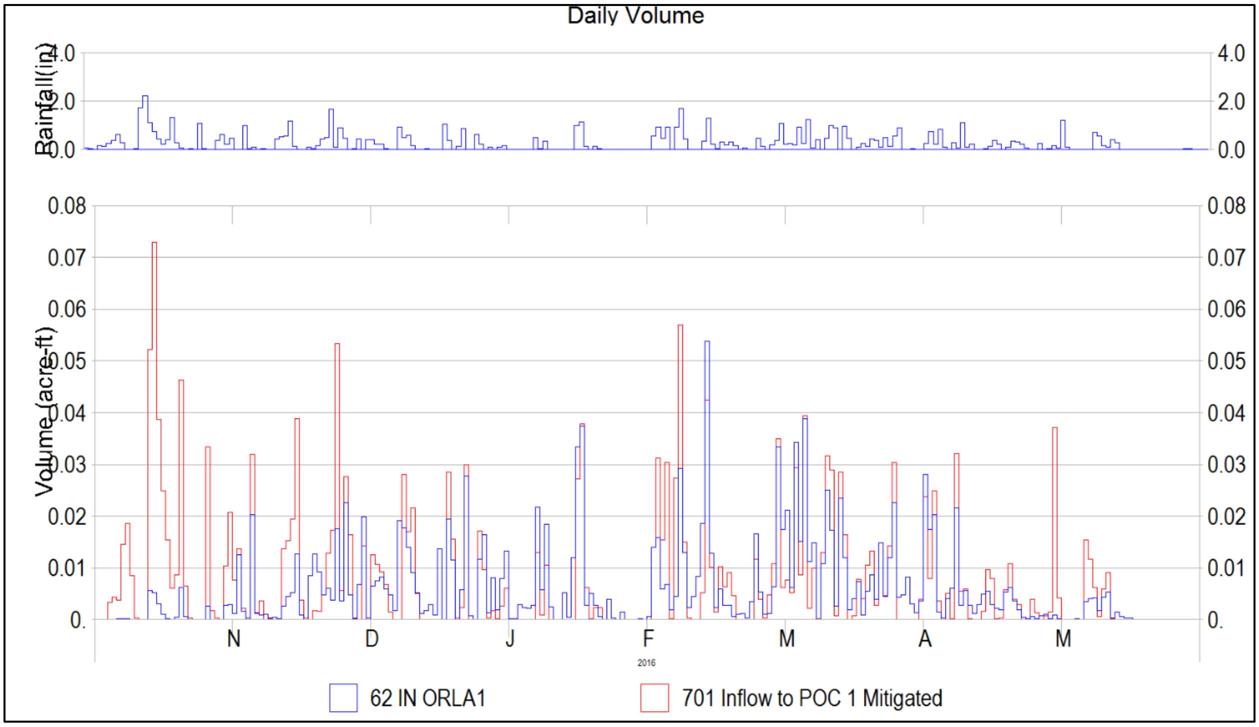


Figure ORLA1-1. ORLA1 Daily Inflow Volumes

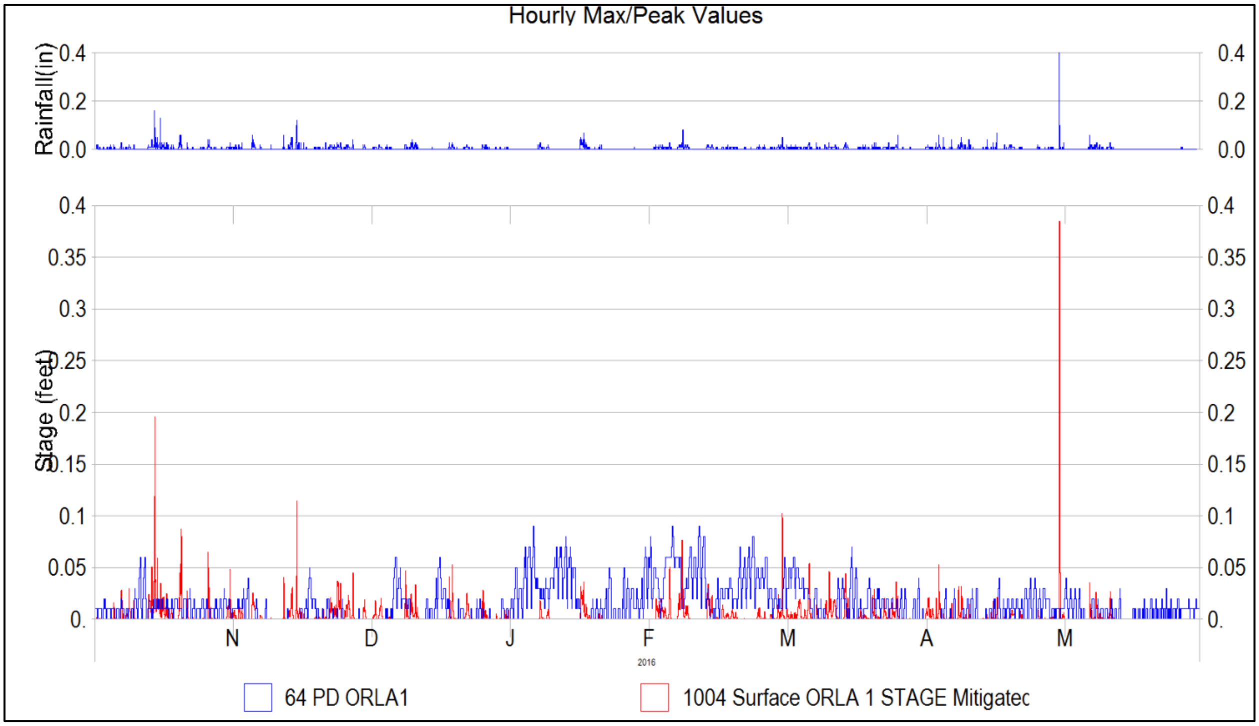


Figure ORLA1-2. ORLA1 Hourly Surface Ponding Depths

Figure ORLA1-2 shows the simulated (red) and recorded (blue) hourly maximum 5-minute surface ponding (stage) values and, along the top of the figure, the ORLA1 site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values show mixed results. Most of the time there is very little surface ponding. This is due to the relatively large bioretention surface bottom area compared to the contributing roof drainage area. However, there are some large storm events in October 2016 and May 2017 that produce high simulated runoff and corresponding high ponding depths, but neither are seen in the recorded data. The monitored rainfall data were compared with surrounding county rain gages and appear to be correct, but there is no obvious reason for the discrepancy between the monitored rainfall data and the inflow (and ponding) data.

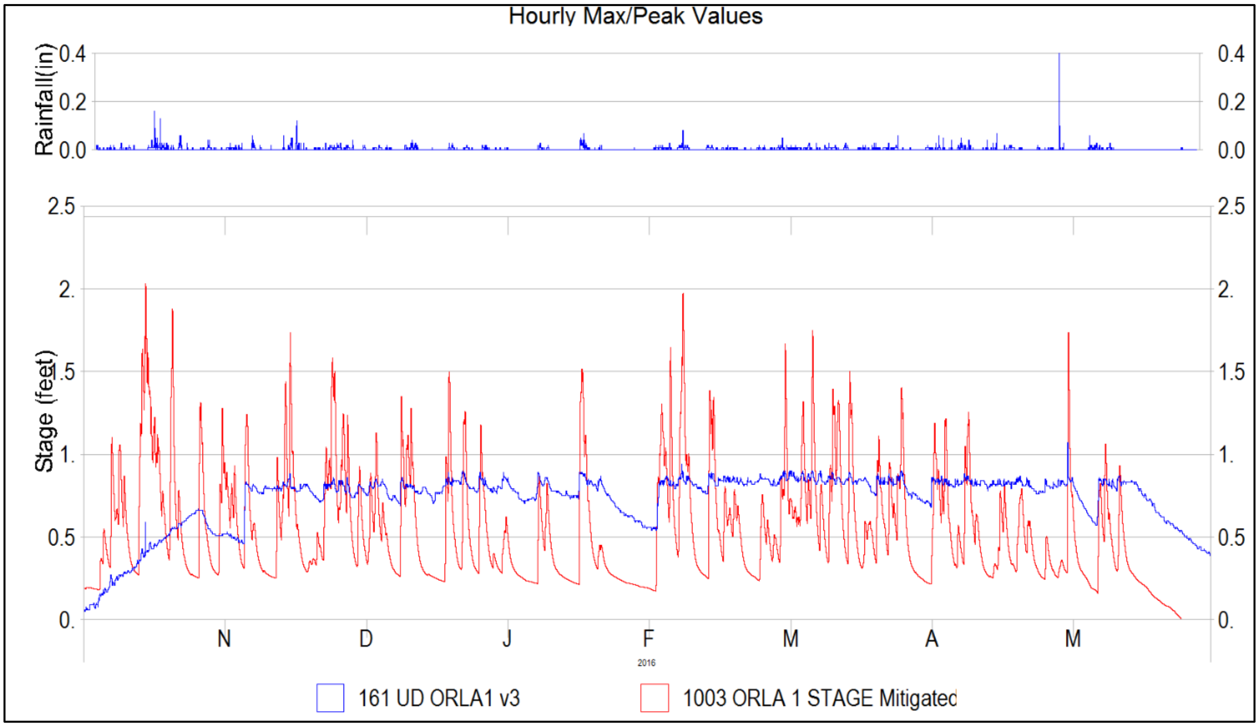
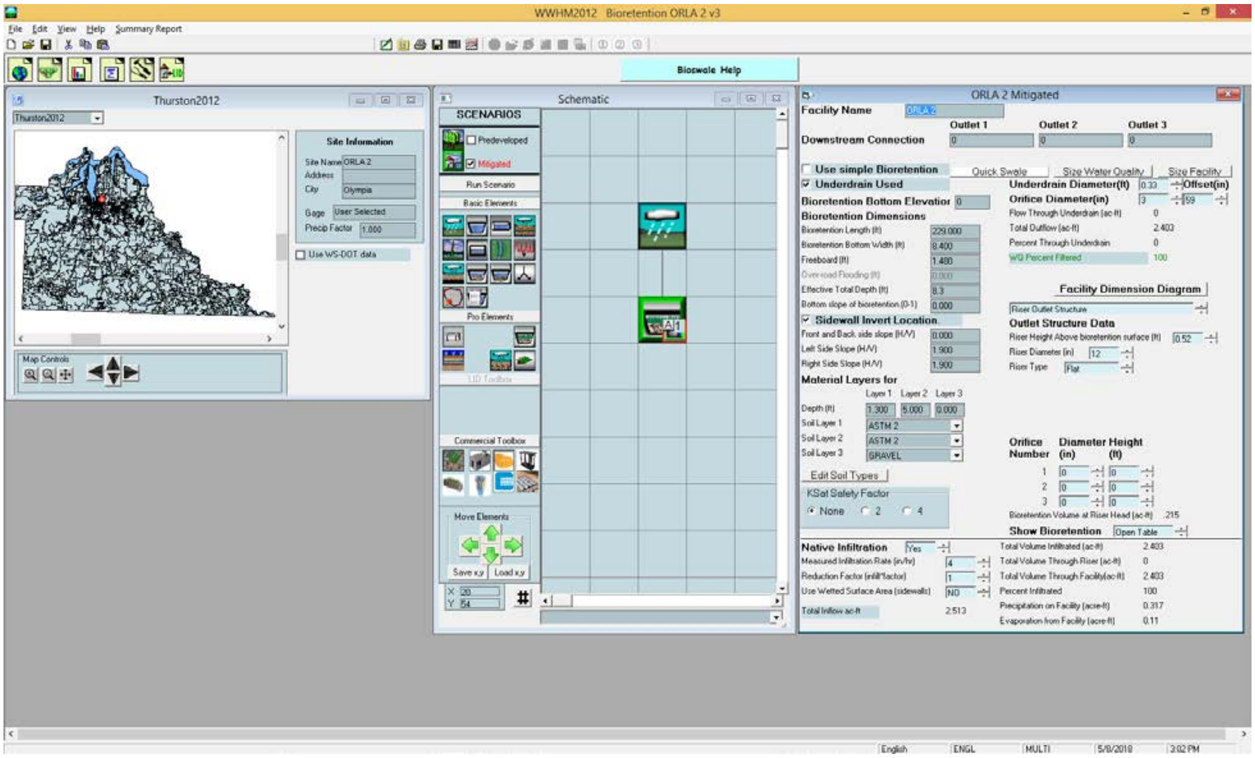


Figure ORLA1-3. ORLA1 Hourly Soil Layer Well Point Elevations

Figure ORLA1-3 shows the simulated (red) and recorded (blue) hourly maximum 5-minute soil layer well point elevations (stage) values and, along the top of the figure, the ORLA1 site monitored hourly maximum 5-minute rainfall data. The simulated values show more fluctuation than the recorded well point data. This may be due to raised groundwater levels in winter and spring months (groundwater mounding) affecting the recorded data.

ORLA2: Olympia, Thurston County



Thurston2012

Site Information

Site Name ORLA 2

Address

City Olympia

Gage User Selected

Precip Factor 1.000

☐ Use WS-DOT data

☐ Predeveloped

☑ Mitigated

X 20

Y 54

ORLA 2 Mitigated

Facility Name ORLA 2

	Outlet 1	Outlet 2	Outlet 3
Downstream Connection	0	0	0

☐ Use simple Bioretention

☑ Underdrain Used

Bioretention Bottom Elevation 0

Bioretention Dimensions

Bioretention Length (ft) 229.000

Bioretention Bottom Width (ft) 8.400

Freeboard (ft) 1.480

Overroad Flooding (ft) 0.000

Effective Total Depth (ft) 8.3

Bottom slope of bioretention (0-1) 0.000

☑ Sidewall Invert Location

Front and Back side slope (H/V) 0.000

Left Side Slope (H/V) 1.900

Right Side Slope (H/V) 1.900

Material Layers for

	Layer 1	Layer 2	Layer 3
Depth (ft)	1.300	5.000	0.000

Soil Layer 1 ASTM 2

Soil Layer 2 ASTM 2

Soil Layer 3 GRAVEL

KSat Safety Factor ● None ○ 2 ○ 4

Underdrain Diameter(ft) 0.33 Offset(in)

Orifice Diameter(in) 3 59

Flow Through Underdrain (ac-ft) 0

Total Outflow (ac-ft) 2.403

Percent Through Underdrain 0

WQ Percent Filtered 100

Riser Outlet Structure

Outlet Structure Data

Riser Height Above bioretention surface (ft) 0.52

Riser Diameter (in) 12

Riser Type Flat

Orifice Number	Diameter (in)	Height (ft)
1	0	0
2	0	0
3	0	0

Bioretention Volume at Riser Head (ac-ft) .215

Show Bioretention Open Table

Native Infiltration Yes

Measured Infiltration Rate (in/hr) 4

Reduction Factor (infilt*factor) 1

Use Wetted Surface Area (sidewalls) NO

Total Inflow ac-ft 2.513

Total Volume Infiltrated (ac-ft) 2.403

Total Volume Through Riser (ac-ft) 0

Total Volume Through Facility(ac-ft) 2.403

Percent Infiltrated 100

Precipitation on Facility (acre-ft) 0.317

Evaporation from Facility (acre-ft) 0.11

The ORLA2 bioretention site is located in Olympia, Thurston County, Washington. The drainage area to ORLA2 consists of 0.338 acres of roof on a flat slope (0-5%).

The ORLA2 surface bottom footprint is 1924 square feet. This equals 13% of the tributary drainage area to ORLA2.

ORLA2 has a surface outlet at 0.52 feet above the surface bottom. ORLA2 also has an underdrain. The underdrain is set at 59 inches above the bottom of the bioretention soil layer. Most of the inflow to ORLA2 is infiltrated into the native soil beneath the bioretention soil layers. The underdrain is connected to a gravel trench so all of the inflow infiltrates into the native soil either through the bottom of the bioretention facility or through the underdrain gravel trench.

A native soil infiltration rate of 4 inches per hour together with a bioretention top soil layer of ASTM2 soil and a second soil layer of ASTM24 soil best reproduced the monitored soil moisture and surface ponding conditions.

Figure ORLA2-1 shows the simulated (red) and recorded (blue) daily inflow volumes and, along the top of the figure, the ORLA2 site monitored daily rainfall data. The simulated daily inflow volumes are consistently higher than the recorded data for most of the monitored period. The recorded data is from monitored roof runoff via downspouts to ORLA2. There is no obvious reason for the difference in inflow volumes.

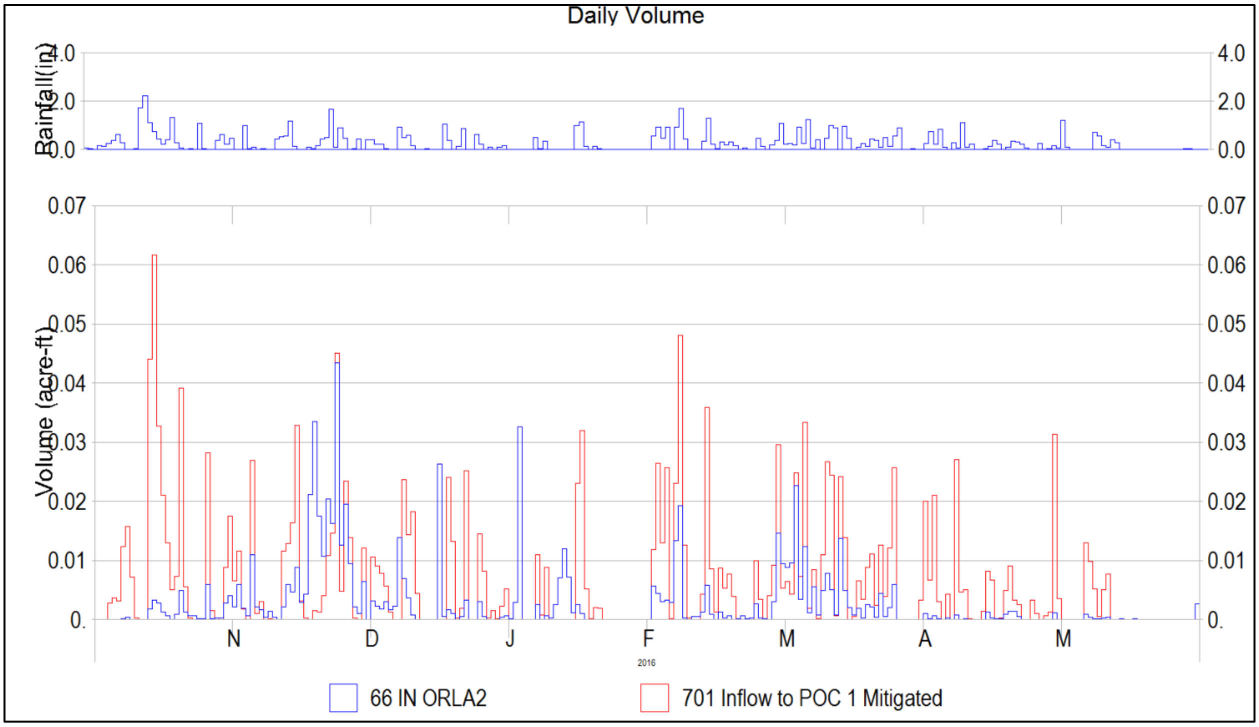


Figure ORLA2-1. ORLA2 Daily Inflow Volumes

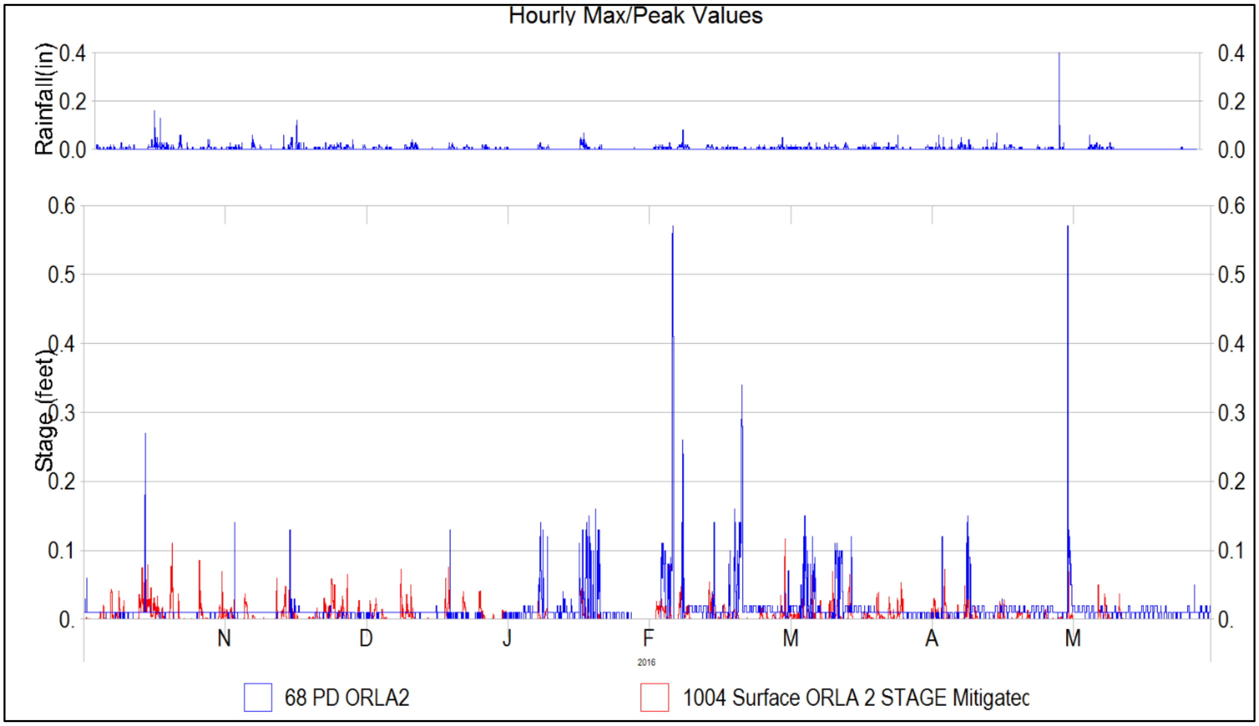


Figure ORLA2-2. ORLA1 Hourly Surface Ponding Depths

Figure ORLA2-2 shows the simulated (red) and recorded (blue) hourly maximum 5-minute surface ponding (stage) values and, along the top of the figure, the ORLA2 site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values show low simulated ponding depths compared to the recorded depths. That said, most of the time there is very little surface ponding. This is due to the relatively large bioretention surface bottom area compared to the contributing roof drainage area. However, there are some large storm events in October 2016 and May 2017 that produce high recorded ponding depths not reproduced by the simulated results (this is the opposite of what was seen in ORLA1).

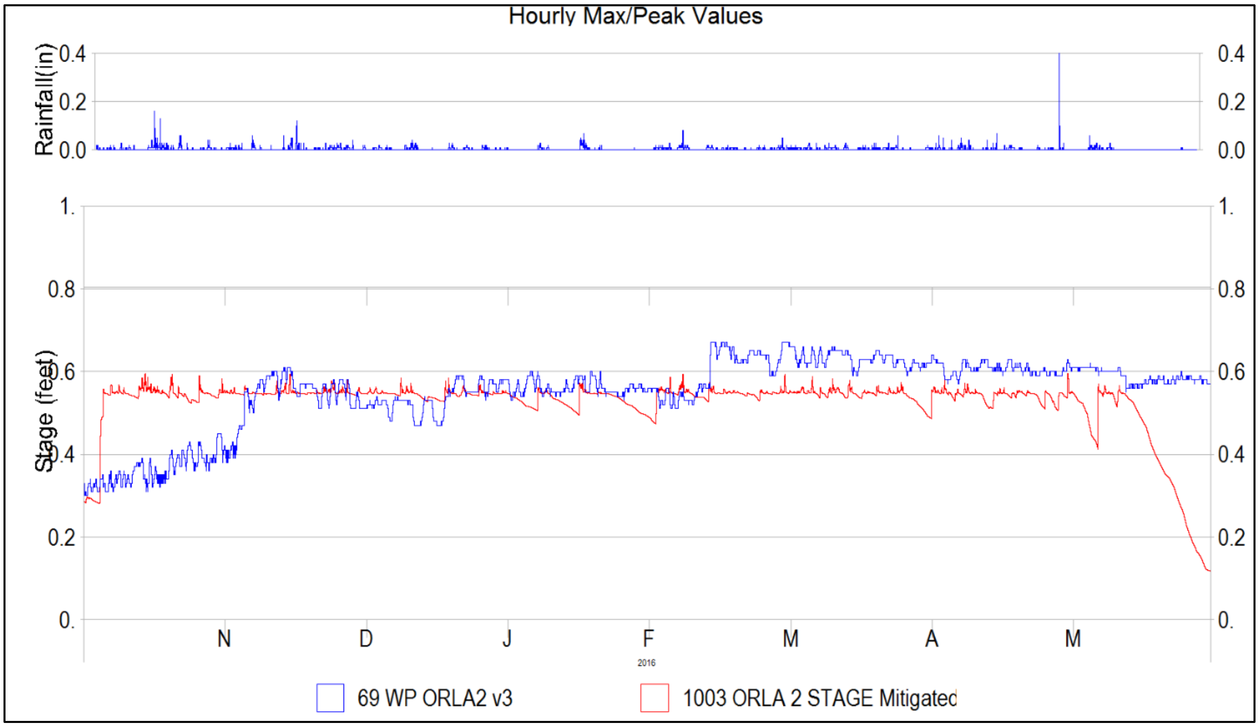
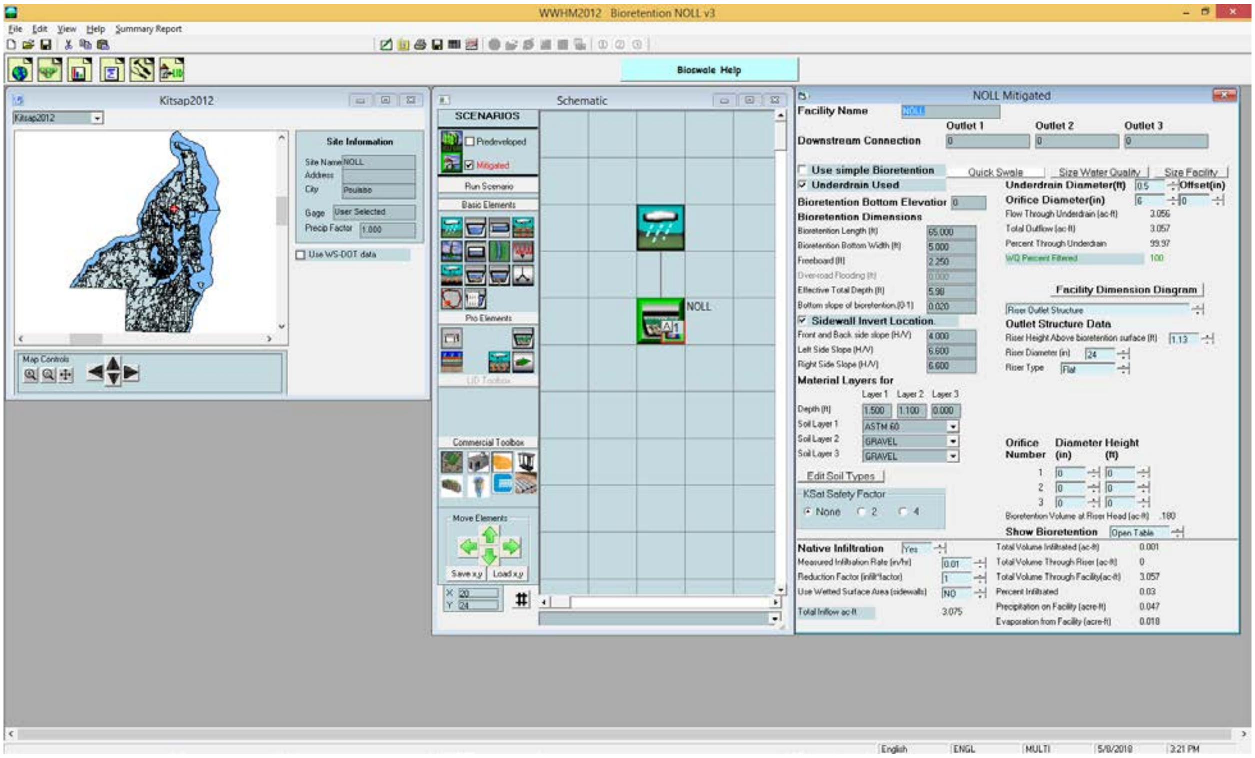


Figure ORLA2-3. ORLA2 Hourly Soil Layer Well Point Elevations

Figure ORLA2-3 shows the simulated (red) and recorded (blue) hourly maximum 5-minute soil layer well point elevations (stage) values and, along the top of the figure, the ORLA2 site monitored hourly maximum 5-minute rainfall data. The simulated values match well with the recorded well point data, even though the ponding depths do not show a good match.

NOLL: Poulsbo, Kitsap County



Kitsap2012

Site Information
Site Name NOLL
Address
City Poulsbo
Gage User Selected
Precip Factor 1.000
☐ Use WS-DOT data

☐ Predeveloped
☑ Mitigated

X 20
Y 24

Facility Name NOLL
Downstream Connection: Outlet 1 0; Outlet 2 0; Outlet 3 0
☐ Use simple Bioretention
☑ Underdrain Used
Bioretention Bottom Elevation 0
Bioretention Dimensions
Bioretention Length (ft) 65.000
Bioretention Bottom Width (ft) 5.000
Freeboard (ft) 2.250
Overroad Flooding (ft) 0.000
Effective Total Depth (ft) 5.90
Bottom slope of bioretention.(0-1) 0.020
☑ Sidewall Invert Location.
Front and Back side slope (H/V) 4.000
Left Side Slope (H/V) 6.600
Right Side Slope (H/V) 6.600
Material Layers for

	Layer 1	Layer 2	Layer 3
Depth (ft)	1.500	1.100	0.000

Soil Layer 1 ASTM 60
Soil Layer 2 GRAVEL
Soil Layer 3 GRAVEL
KSat Safety Factor ● None ○ 2 ○ 4

Native Infiltration Yes
Measured Infiltration Rate (in/hr) 0.01
Reduction Factor (infilt*factor) 1
Use Wetted Surface Area (sidewalls) NO
Total Inflow ac-ft 3.075

Underdrain Diameter(ft) 0.5 Offset(in) 0
Orifice Diameter(in) 6
Flow Through Underdrain (ac-ft) 3.056
Total Outflow (ac-ft) 3.057
Percent Through Underdrain 99.97
WQ Percent Filtered 100

Riser Outlet Structure
Outlet Structure Data
Riser Height Above bioretention surface (ft) 1.13
Riser Diameter (in) 24
Riser Type Flat

Orifice Number	Diameter (in)	Height (ft)
1	0	0
2	0	0
3	0	0

Bioretention Volume at Riser Head (ac-ft) .180
Show Bioretention Open Table

Total Volume Infiltrated (ac-ft) 0.001
Total Volume Through Riser (ac-ft) 0
Total Volume Through Facility(ac-ft) 3.057
Percent Infiltrated 0.03
Precipitation on Facility (acre-ft) 0.047
Evaporation from Facility (acre-ft) 0.018

The NOLL bioretention site is located in Poulsbo, Kitsap County, Washington. The drainage area to NOLL consists of 0.288 acres of NRCS Type C soil, lawn vegetation, on a flat slope (0-5%), 0.36 acres of roads on a flat slope (0-5%), and 0.041 acres of sidewalk on a flat slope (0-5%).

The NOLL surface bottom footprint is 520 square feet. This equals 2% of the tributary drainage area to NOLL.

NOLL has a surface outlet at 1.13 feet above the surface bottom. NOLL also has an underdrain. The underdrain is set at the bottom of the bioretention soil layer. Most of the inflow to NOLL is discharged through the underdrain. The underdrain is connected to a stormwater surface conveyance system.

A native soil infiltration rate of 0.01 inches per hour together with a bioretention top soil layer of ASTM60 soil and a second soil layer of gravel best reproduced the monitored soil moisture and surface ponding conditions.

Figure NOLL-1 shows the simulated (red) and recorded (blue) daily inflow volumes and, along the top of the figure, the NOLL site monitored daily rainfall data. The simulated and recorded daily inflow volumes match well, except for December 2016 where snow and freezing conditions affected the recorded values.

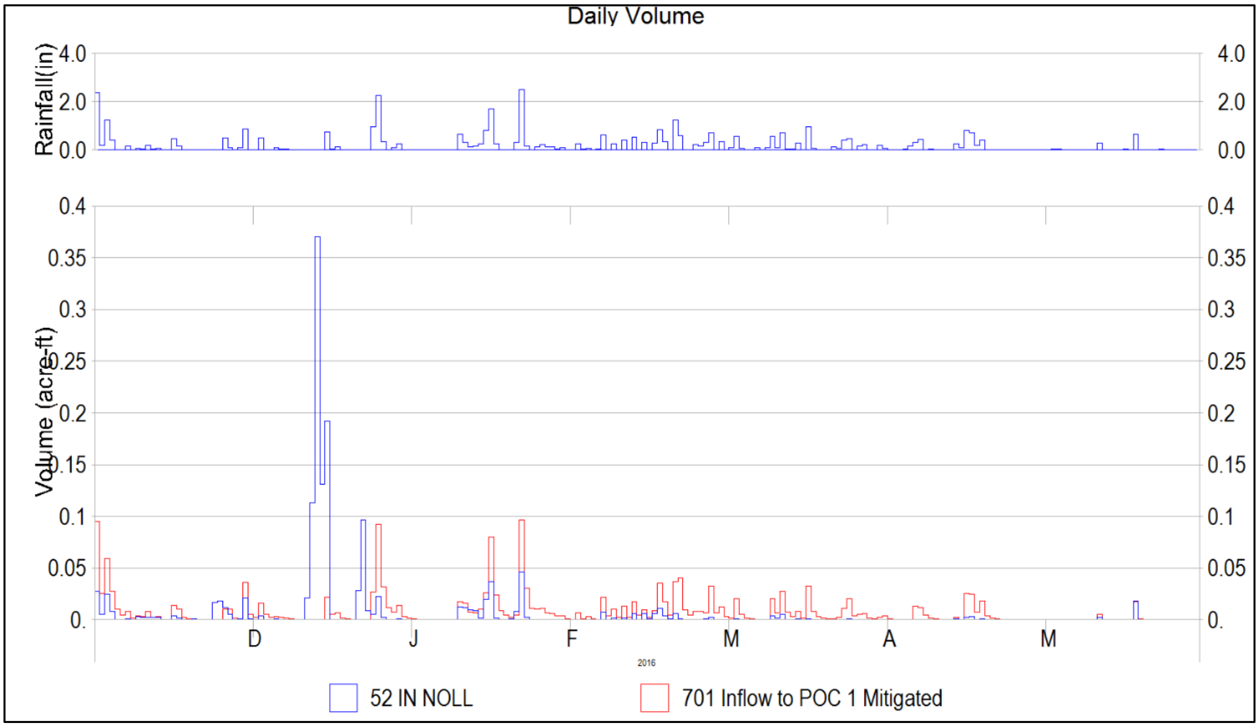


Figure NOLL-1. NOLL Daily Inflow Volumes

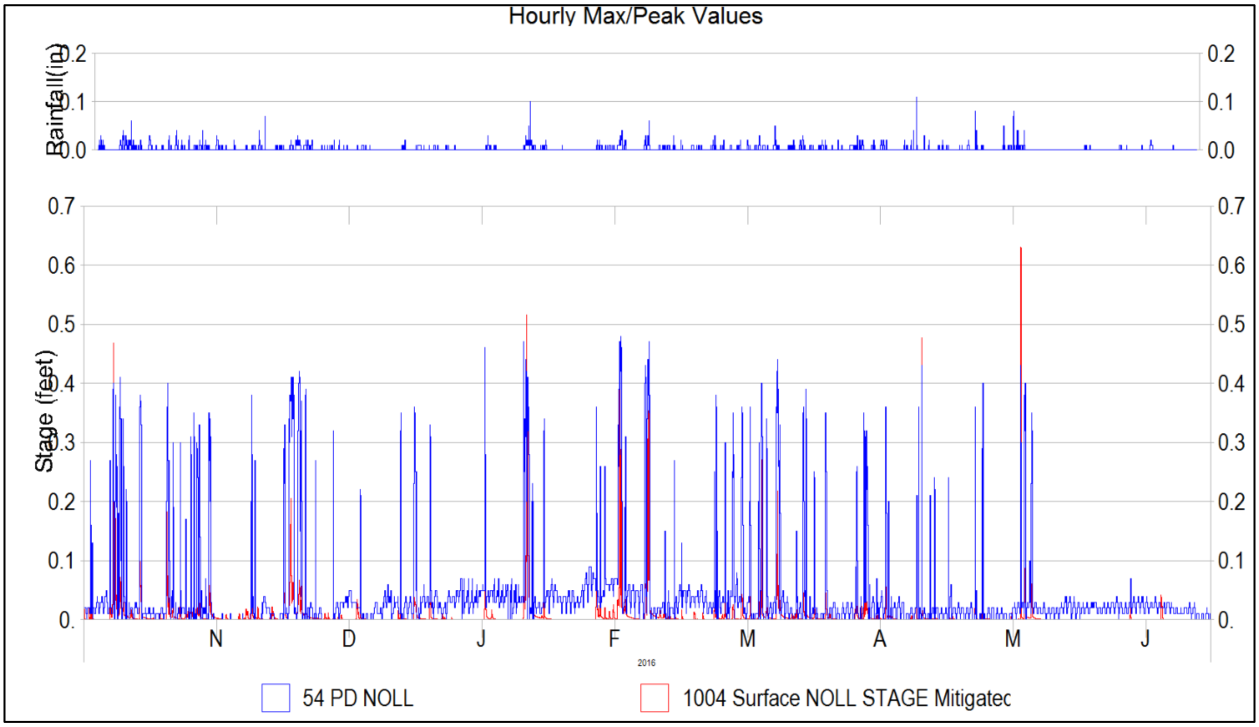


Figure NOLL-2. NOLL Hourly Surface Ponding Depths

Figure NOLL-2 shows the simulated (red) and recorded (blue) hourly maximum 5-minute surface ponding (stage) values and, along the top of the figure, the NOLL site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values are mixed. The higher/larger ponding depths match well, but the simulated depths for the smaller events do not show as much of a response as the monitored data.

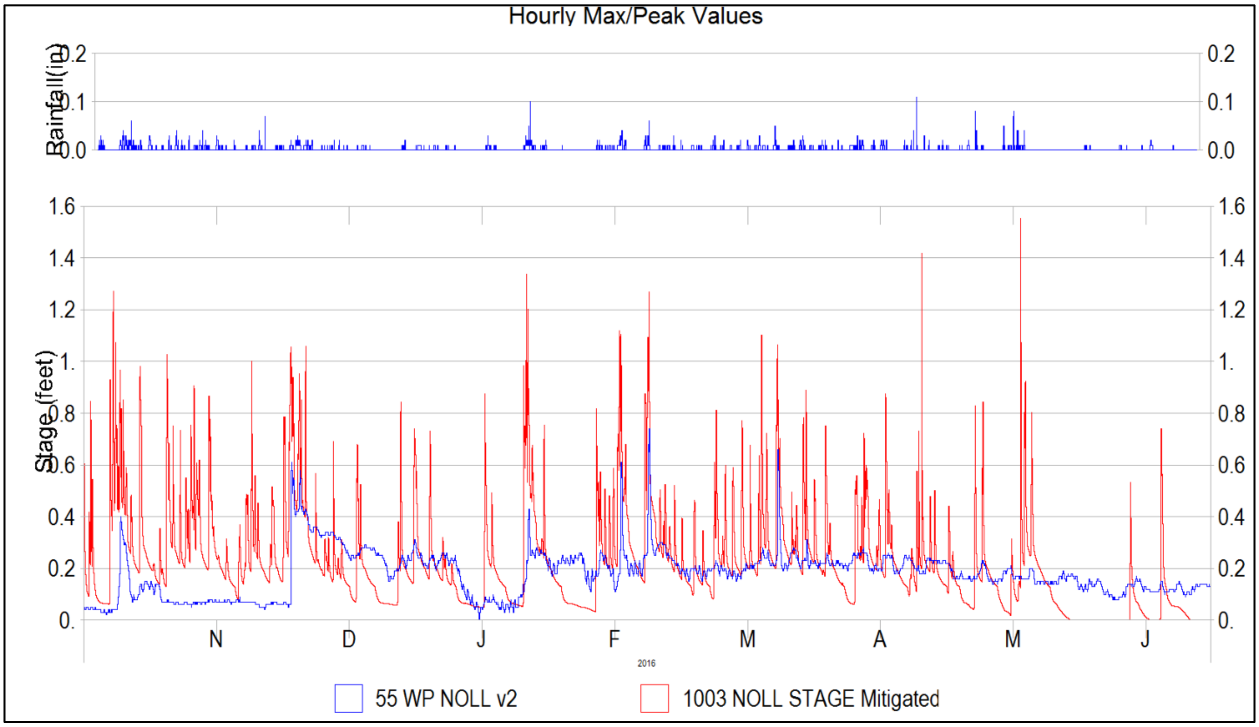


Figure NOLL-3. NOLL Hourly Soil Layer Well Point Elevations

Figure NOLL-3 shows the simulated (red) and recorded (blue) hourly maximum 5-minute soil layer well point elevations (stage) values and, along the top of the figure, the NOLL site monitored hourly maximum 5-minute rainfall data. The simulated values show more fluctuation than the recorded well point data. This may be due to the underdrain's drainage of water from the soil layers.

Figure NOLL-4 shows the simulated (red) and recorded (blue) daily underdrain discharge volumes and, along the top of the figure, the NOLL site monitored daily rainfall data. The simulated daily underdrain discharges volumes are consistently higher than the recorded volumes.

Figure NOLL-5 shows that the simulated (blue) daily inflow volumes and the simulated (red) daily underdrain discharge (outflow) volumes are nearly identical (note that the inflow volume does not include rain on NOLL bioretention site). This shows that all or nearly all of the inflow is discharged via the underdrain. These results are consistent and expected.

The recorded (monitored) underdrain outlet flows do not show this consistency with the inflow volumes.

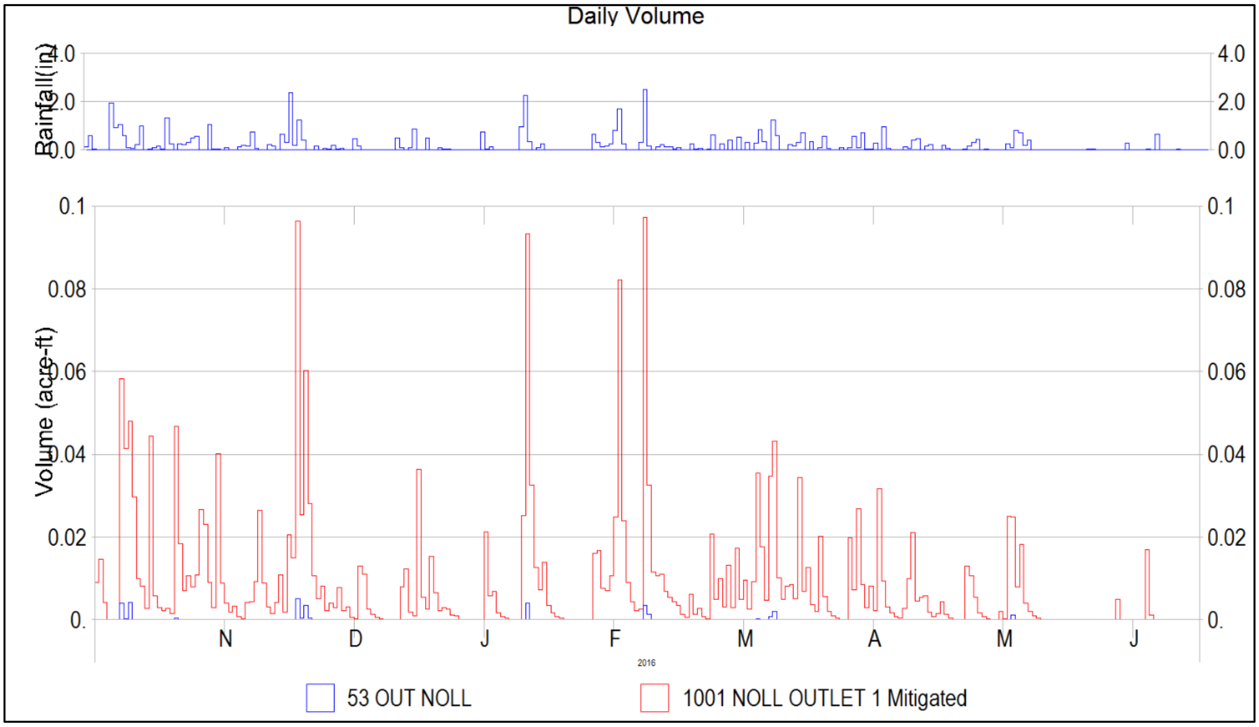


Figure NOLL-4. NOLL Daily Underdrain Discharge Volumes

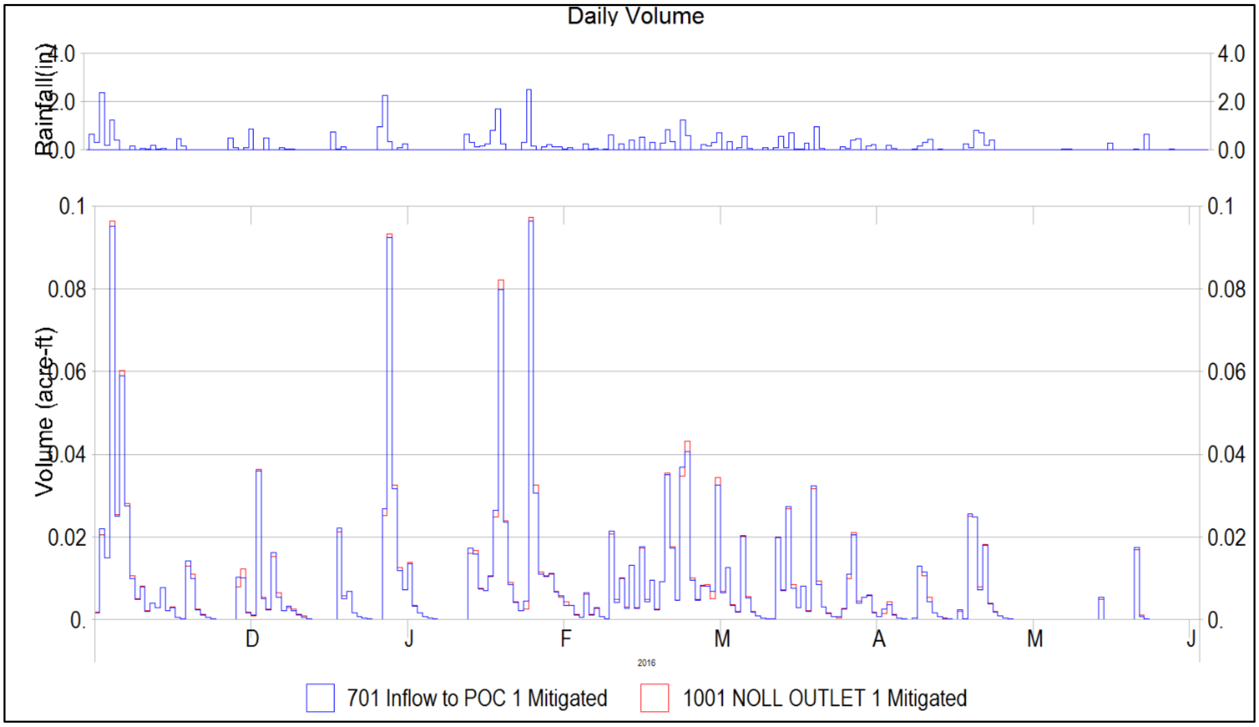
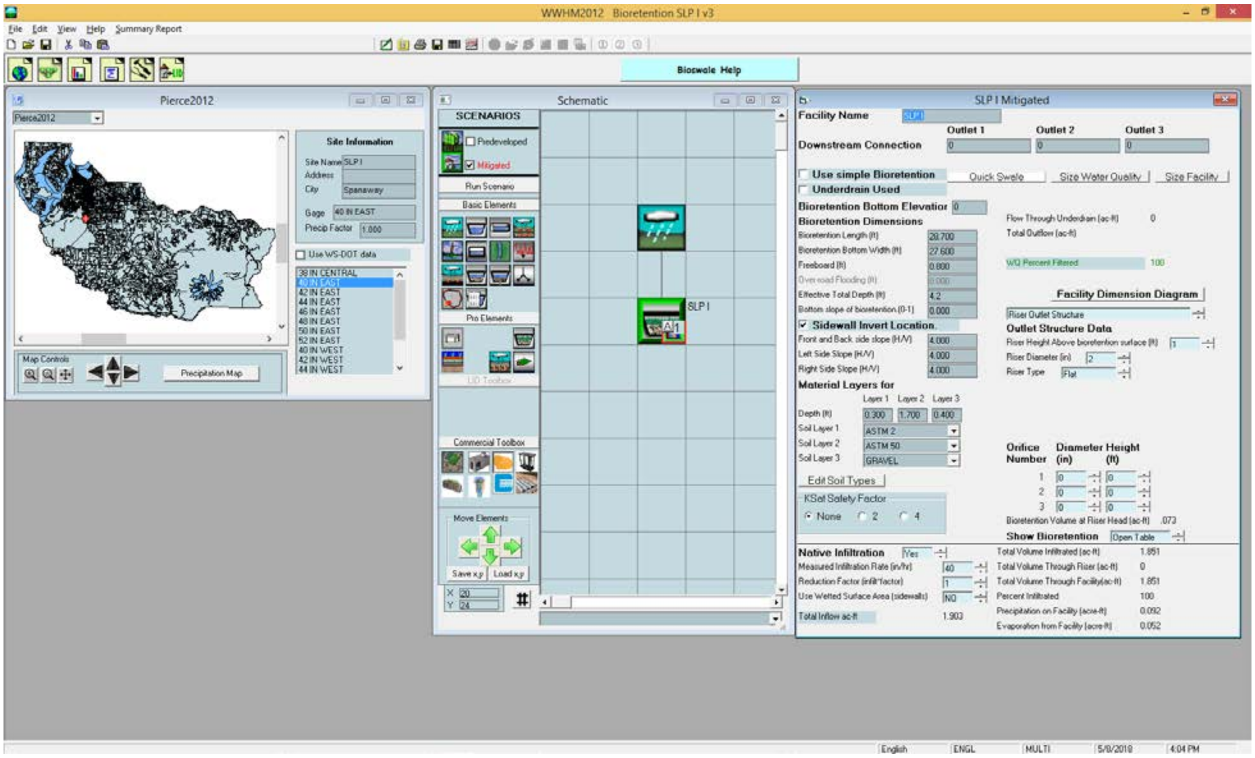


Figure NOLL-5. NOLL Daily Simulated Inflow and Underdrain Discharge Volumes

SLPI: Spanaway, Pierce County



Site Information
Site Name SLP I
Address
City Spanaway
Gage 40 IN EAST
Precip Factor 1.000
☐ Use WS-DOT data
38 IN CENTRAL
40 IN EAST
42 IN EAST
44 IN EAST
46 IN EAST
48 IN EAST
50 IN EAST
52 IN EAST
40 IN WEST
42 IN WEST
44 IN WEST
X 20
Y 24

Facility Name SLP I

	Outlet 1	Outlet 2	Outlet 3
Downstream Connection	0	0	0

☐ Use simple Bioretention
☐ Underdrain Used
Bioretention Bottom Elevatior 0
Bioretention Dimensions
Bioretention Length (ft) 28.700
Bioretention Bottom Width (ft) 27.600
Freeboard (ft) 0.800
Over-road Flooding (ft) 0.000
Effective Total Depth (ft) 4.2
Bottom slope of bioretention (0-1) 0.000
☑ Sidewall Invert Location
Front and Back side slope (H/V) 4.000
Left Side Slope (H/V) 4.000
Right Side Slope (H/V) 4.000

Material Layers for

	Layer 1	Layer 2	Layer 3
Depth (ft)	0.300	1.700	0.400

Soil Layer 1 ASTM 2
Soil Layer 2 ASTM 50
Soil Layer 3 GRAVEL
KSat Safety Factor
● None ○ 2 ○ 4

Flow Through Underdrain (ac-ft) 0
Total Outflow (ac-ft)
WQ Percent Filtered 100
Riser Outlet Structure
Outlet Structure Data
Riser Height Above bioretention surface (ft) 1
Riser Diameter (in) 2
Riser Type Flat

Orifice Number	Diameter (in)	Height (ft)
1	0	0
2	0	0
3	0	0

Bioretention Volume at Riser Head (ac-ft) .073
Show Bioretention Open Table

Native Infiltration Yes
Measured Infiltration Rate (in/hr) 40
Reduction Factor (infilt*factor) 1
Use Wetted Surface Area (sidewalls) NO
Total Inflow ac-ft 1.903

Total Volume Infiltrated (ac-ft) 1.851
Total Volume Through Riser (ac-ft) 0
Total Volume Through Facility(ac-ft) 1.851
Percent Infiltrated 100
Precipitation on Facility (acre-ft) 0.092
Evaporation from Facility (acre-ft) 0.052

The SLPI bioretention site is located in Spanaway, Pierce County, Washington. The drainage area to SLPI consists of 0.429 acres of road on a flat slope (0-5%).

The SLPI surface bottom footprint is 792 square feet. This equals 4% of the tributary drainage area to SLPI.

SLPI has no surface outlet control structure but overtops the site at 1.0 feet above the surface bottom. All of the inflow to SLPI is infiltrated into the native soil beneath the bioretention soil layers.

A native soil infiltration rate of 40 inches per hour together with a bioretention top soil layer of ASTM2 soil, a second soil layer of ASTM50 soil, and a third soil layer of gravel best reproduced the monitored soil moisture and surface ponding conditions. The top ASTM layer of 0.3 feet represents leaf litter. This was added to reproduce monitored surface ponding depths.

Figure SLPI-1 shows the simulated (red) and recorded (blue) daily inflow volumes and, along the top of the figure, the SLPI site monitored daily rainfall data. The simulated and recorded daily inflow volumes are mixed. Winter periods (November 2016 through February 2017) show major differences where snow and freezing conditions affected the recorded values. The simulated daily inflow volumes are also low in the spring, during the drier months.

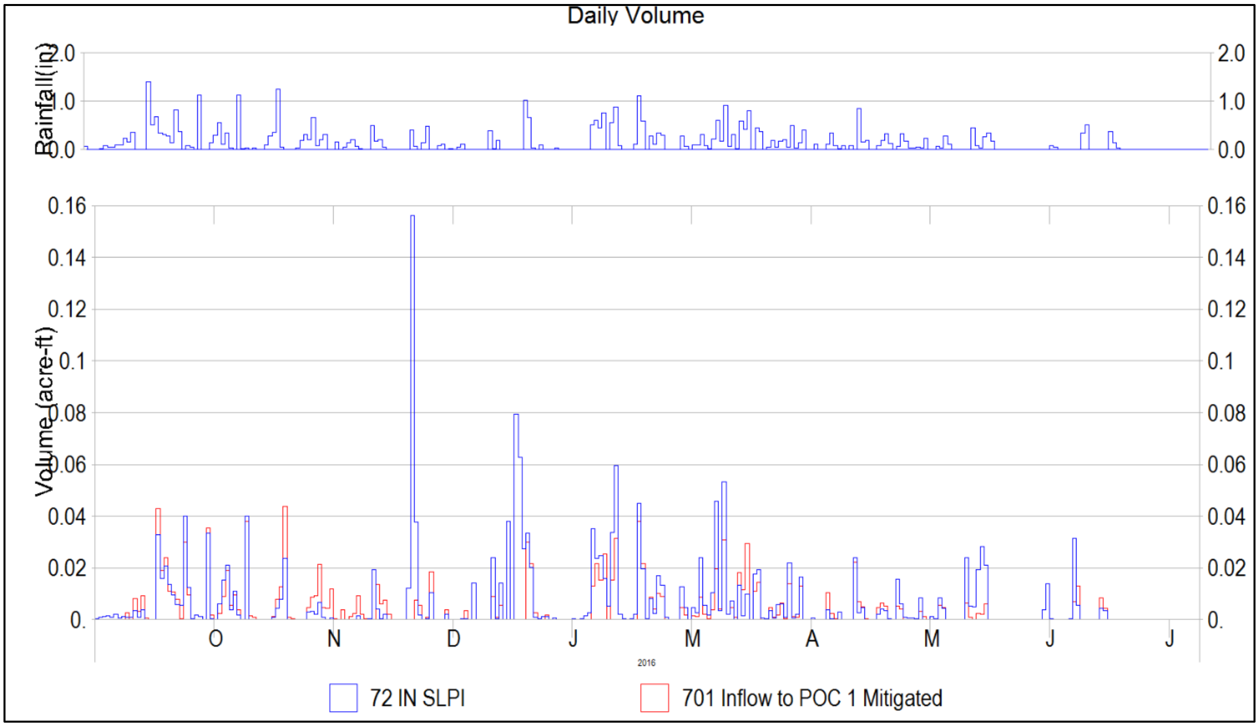


Figure SLPI-1. SLPI Daily Inflow Volumes

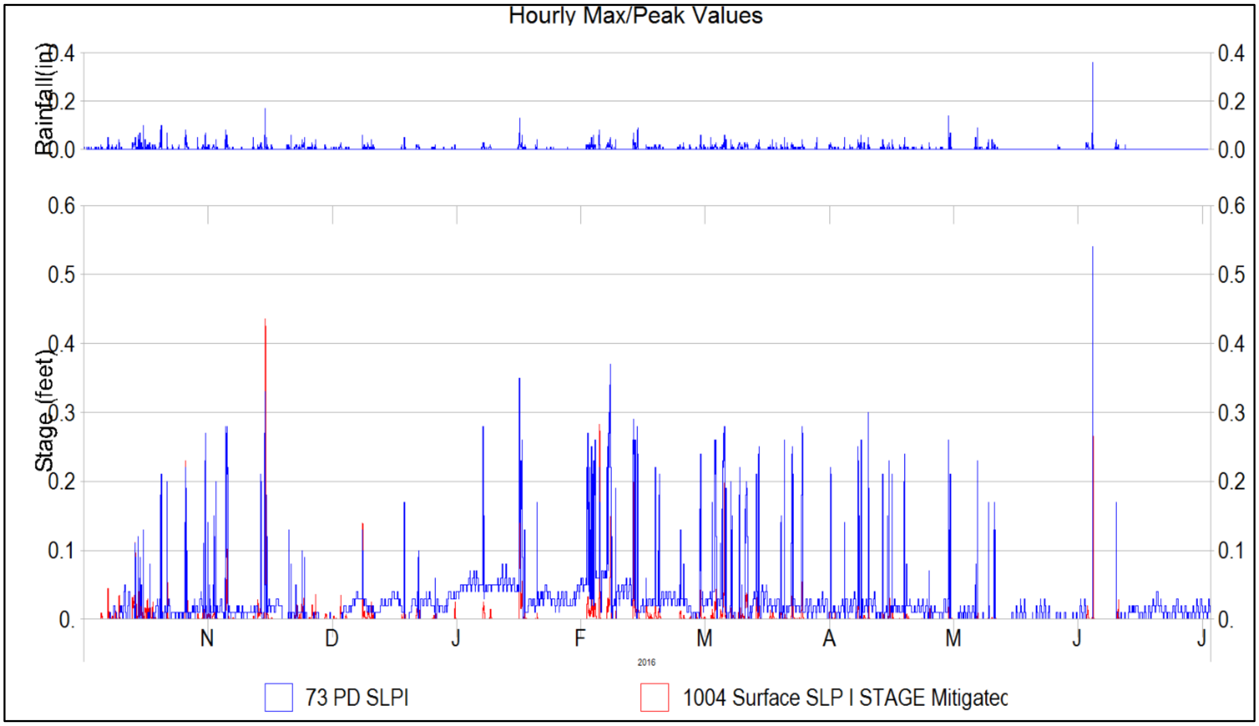


Figure SLPI-2. SLPI Hourly Surface Ponding Depths

Figure SLPI-2 shows the simulated (red) and recorded (blue) hourly maximum 5-minute surface ponding (stage) values and, along the top of the figure, the SLPI site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values are mixed. The higher/larger ponding depths match well, but the simulated depths for the smaller events do not show as much of a response as the monitored data.

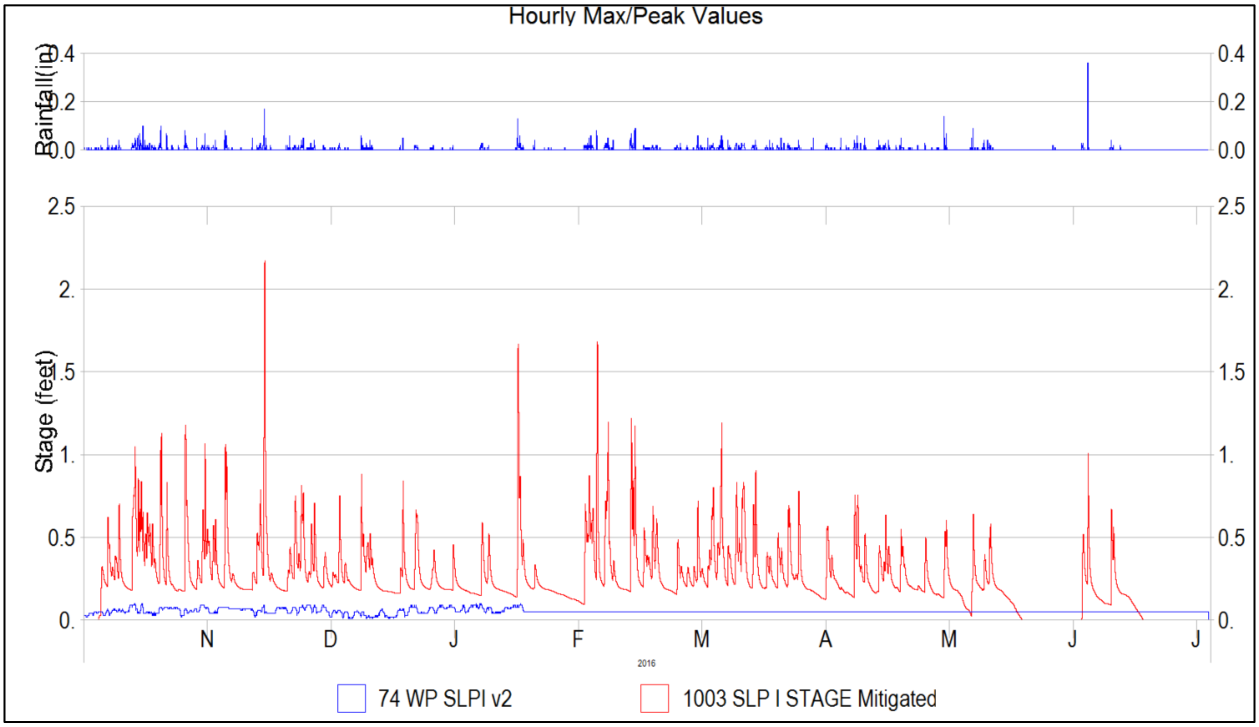
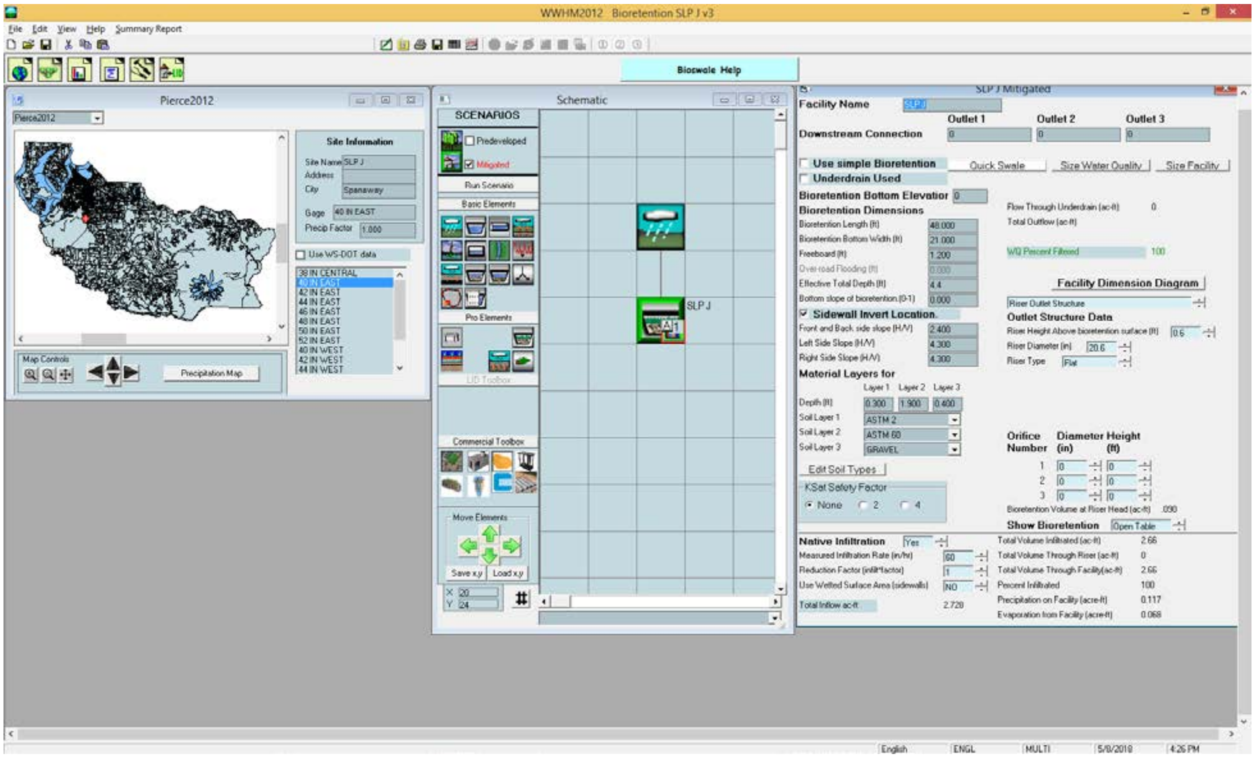


Figure SLPI-3. SLPI Hourly Soil Layer Well Point Elevations

Figure SLPI-3 shows the simulated (red) and recorded (blue) hourly maximum 5-minute soil layer well point elevations (stage) values and, along the top of the figure, the SLPI site monitored hourly maximum 5-minute rainfall data. The simulated values show more fluctuation than the recorded well point data. This may be due to the high native soil infiltration rate and drainage of water from the soil layers.

SLPJ: Spanaway, Pierce County



SLP J Mitigated

Site Information
Site Name: SLP J
Address:
City: Spanaway
Gage: 40 IN EAST
Precip Factor: 1.000
☐ Use WS-DOT data
38 IN CENTRAL
40 IN EAST
42 IN EAST
44 IN EAST
46 IN EAST
48 IN EAST
50 IN EAST
52 IN EAST
40 IN WEST
42 IN WEST
44 IN WEST

Facility Name: SLPJ

	Outlet 1	Outlet 2	Outlet 3
Downstream Connection	0	0	0

☐ Use simple Bioretention
☐ Underdrain Used
Bioretention Bottom Elevation: 0

Bioretention Dimensions
Bioretention Length (ft): 48.000
Bioretention Bottom Width (ft): 21.000
Freeboard (ft): 1.200
Over-road Flooding (ft): 0.000
Effective Total Depth (ft): 4.4
Bottom slope of bioretention.(0-1): 0.000
☑ Sidewall Invert Location.
Front and Back side slope (H/V): 2.400
Left Side Slope (H/V): 4.300
Right Side Slope (H/V): 4.300

Material Layers for

	Layer 1	Layer 2	Layer 3
Depth (ft)	0.300	1.900	0.400

Soil Layer 1: ASTM 2
Soil Layer 2: ASTM 60
Soil Layer 3: GRAVEL
KSat Safety Factor: ● None ○ 2 ○ 4

Native Infiltration: Yes
Measured Infiltration Rate (in/hr): 60
Reduction Factor (infilt*factor): 1
Use Wetted Surface Area (sidewalls): NO
Total Inflow ac-ft: 2.720

Flow Through Underdrain (ac-ft): 0
Total Outflow (ac-ft):
WQ Percent Filtered: 100

Riser Outlet Structure
Outlet Structure Data
Riser Height Above bioretention surface (ft): 0.6
Riser Diameter (in): 20.6
Riser Type: Flat

Orifice Number	Diameter (in)	Height (ft)
1	0	0
2	0	0
3	0	0

Bioretention Volume at Riser Head (ac-ft): .090
Show Bioretention: Open Table

Total Volume Infiltrated (ac-ft): 2.66
Total Volume Through Riser (ac-ft): 0
Total Volume Through Facility(ac-ft): 2.66
Percent Infiltrated: 100
Precipitation on Facility (acre-ft): 0.117
Evaporation from Facility (acre-ft): 0.068

The SLPJ bioretention site is located in Spanaway, Pierce County, Washington. The drainage area to SLPI consists of 0.618 acres of road on a flat slope (0-5%).

The SLPJ surface bottom footprint is 1008 square feet. This equals 4% of the tributary drainage area to SLPJ.

SLPJ has a surface outlet control structure that overtops at 0.6 feet above the surface bottom. All of the inflow to SLPJ is infiltrated into the native soil beneath the bioretention soil layers.

A native soil infiltration rate of 60 inches per hour together with a bioretention top soil layer of ASTM2 soil, a second soil layer of ASTM60 soil, and a third soil layer of gravel best reproduced the monitored soil moisture and surface ponding conditions. The top ASTM layer of 0.3 feet represents leaf litter. This was added to reproduce monitored surface ponding depths.

Figure SLPJ-1 shows the simulated (red) and recorded (blue) daily inflow volumes and, along the top of the figure, the SLPJ site monitored daily rainfall data. The simulated daily inflow volumes are consistently lower than the recorded volumes although there are good matches in both the early fall (October 2017) and late spring (May-June 2017).

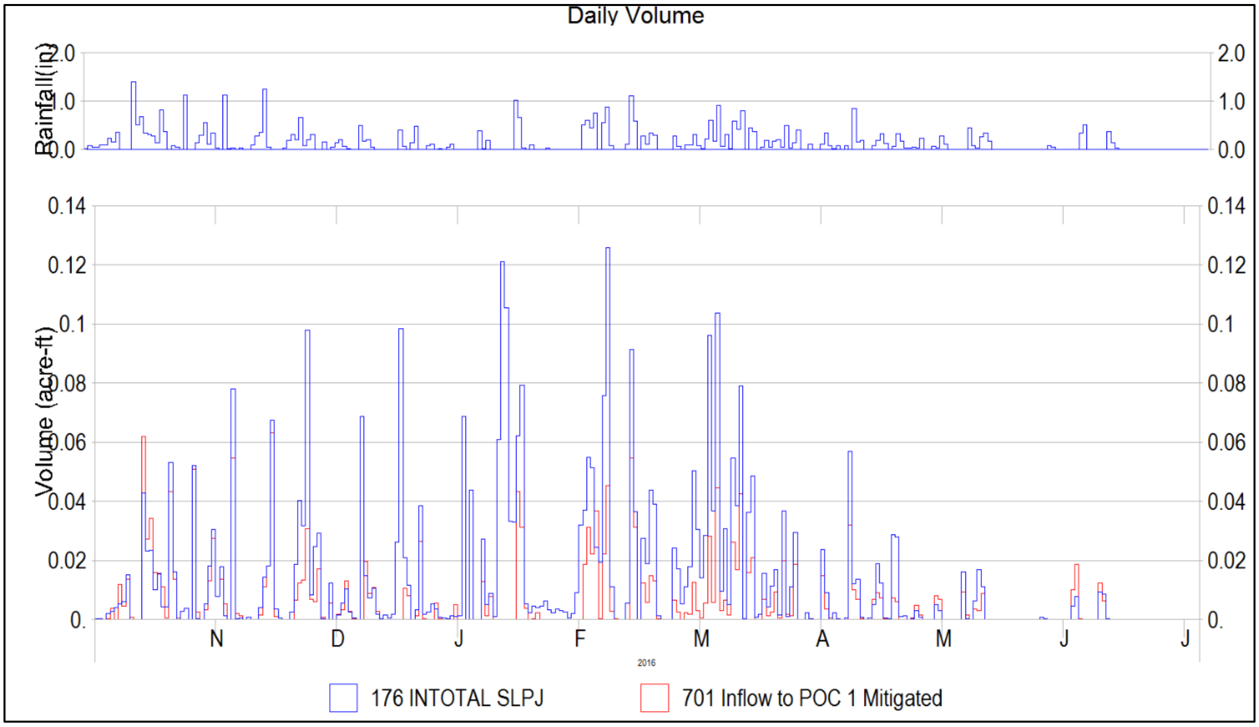


Figure SLPJ-1. SLPI Daily Inflow Volumes

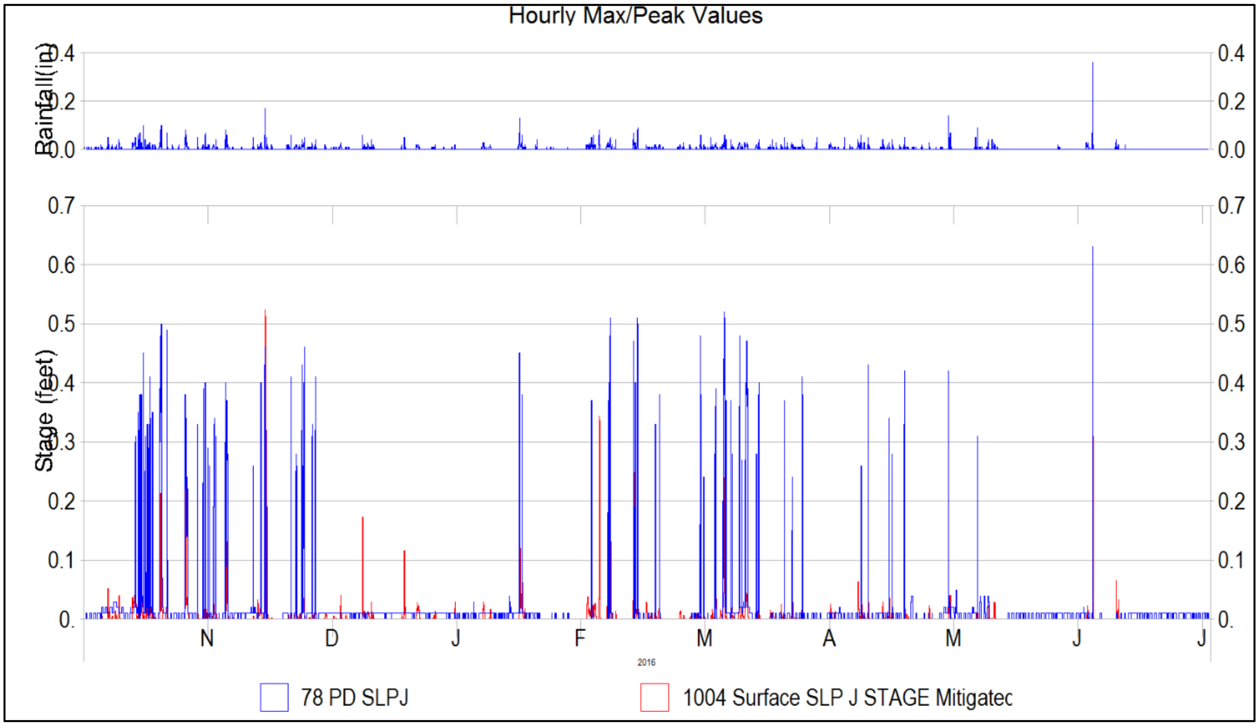


Figure SLPJ-2. SLPJ Hourly Surface Ponding Depths

Figure SLPJ-2 shows the simulated (red) and recorded (blue) hourly maximum 5-minute surface ponding (stage) values and, along the top of the figure, the SLPJ site monitored hourly maximum 5-minute rainfall data. The simulated and recorded ponding values are mixed. The higher/larger ponding depths match well, but the simulated depths for the smaller events do not show as much of a response as the monitored data.

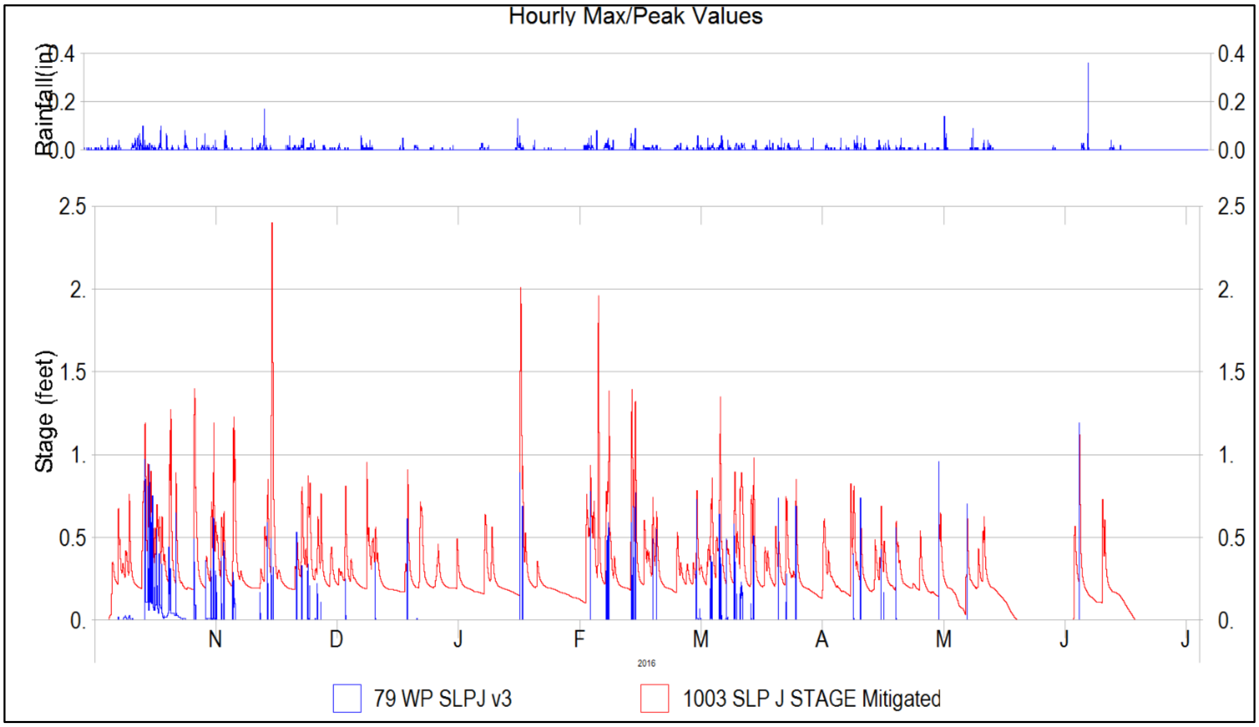


Figure SLPJ-3. SLPJ Hourly Soil Layer Well Point Elevations

Figure SLPJ-3 shows the simulated (red) and recorded (blue) hourly maximum 5-minute soil layer well point elevations (stage) values and, along the top of the figure, the SLPJ site monitored hourly maximum 5-minute rainfall data. The simulated values show more fluctuation than the recorded well point data. This may be due to the high native soil infiltration rate and drainage of water from the soil layers.

Summary

In general, the WWHM2012 models of the ten bioretention sites reproduced the monitored bioretention hydrologic performance data with good results when viewing the graphical trends. Good results are defined as periods where the simulated results match closely with the recorded (monitored) data and other periods where the simulated results are sometimes high and sometimes low. There is no obvious bias high or low.

Based on all of the above modeling results it appears that there are two major model inputs that may be influencing the results. The vegetative litter cover noted in the two Spanaway sites may be reducing the infiltration of the ponded water into the bioretention soil mix. Except for SLPI and SLPJ this vegetative litter cover was not explicitly modeled.

The other major model input that may be influencing the results is the evapotranspiration (ET) from the bioretention soil mix. It is set in WWHM2012 to equal 0.5*PET (Potential ET). There is evidence from the well point data that the 0.5 multiplier factor should be higher. That will help to remove water faster from the bioretention soil mix layer.

The complete set of WWHM2012 models for the ten sites has been provided to the Department of Ecology.