FINAL DRAINAGE REPORT

Submitted to City of Mukilteo

December 2018

# Harbour Reach Drive Extension

Submitted by:

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# Final Drainage Report

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| Project: | Harbour Reach Drive Extension<br>City of Mukilteo<br>Snohomish County, Washington |
| Date: | **December 2018** |
| Civil Engineer: | Perteet Inc.<br>2707 Colby Avenue, Suite 900<br>Everett, Washington 98201<br>Phone #: 425.252.7700 |

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# 1.0 PROJECT OVERVIEW

The proposed project is located in the City of Mukilteo and Snohomish County, Washington, within Sections 27 and 28, Township 28 N Range 4 E of the Willamette Meridian. It lies within the Puget Sound Watershed, and the Picnic Point Creek drainage basin. Based on the threshold analysis, it has been determined that two (2) Threshold Discharge Areas (TDAs) out of four (4) total TDAs, will be required to satisfy both water quality treatment and flow control requirements (TDA 3 and TDA 4). The remaining TDAs are under the thresholds and therefore are exempt from any water quality treatment and flow control requirements. Refer to Appendix A of this report for figures that delineate the TDA boundaries.

There is a considerable amount of upstream off-site area that contributes runoff through the Harbour Reach Drive right-of-way. This runoff enters the site primarily in the form of point discharges through storm pipes and stream crossings, but also through gutter flow from upstream roadways. All off-site areas that are tributary to the Harbour Reach Drive site have been delineated and can be found in Figure A.17 in Appendix A of this report. All off-site flows which enter the Harbour Reach Drive right-of-way will be routed around the on-site stormwater BMPs either within new storm drain systems or existing storm drain systems. All existing downstream conditions will be maintained post-project.

The project limits are confined to Harbour Reach Drive between Beverly Park Road and a point roughly 250' north of Pointes Drive. Between Beverly Park Road and South Road, for a stretch of approximately 1,430 feet, no roadway exists. Pre-construction conditions in this section are undeveloped and forested. Between South Road and Blue Heron Boulevard, a stretch of 1,710 feet, Harbour Reach Drive is comprised of a single driving lane in each direction, a center turn lane, and sidewalks. The road is crowned, and stormwater sheet flows to both sides of the road where it is collected in catch basins and curb inlets and conveyed via storm pipe to various outfalls near seasonal streams. This section of road terminates roughly 100 feet north of Blue Heron Boulevard, at which point conditions are again undeveloped and forested until Harbour Pointe Boulevard SW, located roughly 565 feet north of Blue Heron Boulevard. After Harbour Pointe Boulevard SW, Harbour Reach Drive extends north with a single lane in each direction separated alternately by a turn lane and median, for a stretch of approximately 440 feet, at which point the project limits end north of Pointes Drive.

Topographic relief across the project site is approximately 118 feet. The southern end of the project is highest in elevation, with a maximum elevation of 587 feet. It slopes steeply down to elevation 469 feet at the seasonal stream outfall near the junction of Harbour Reach Drive and South Road, before climbing back up to a plateau at an elevation of roughly 502 feet. Just after Blue Heron Boulevard, the existing conditions slope steeply down into another valley at an elevation of 473 feet, and climbs steeply back out of that valley to an elevation of 520 feet near the northern extents of the project.

The proposed roadway improvements include constructing new roadway and widening existing roadway between Beverly Park Road and Harbour Pointe Boulevard N. The new roadway shall be two 11' travel lanes, 5' bike lanes with a 2' buffer, curb, gutter, 4' planter strips, and sidewalk of varying width on both sides. Retaining walls will be necessary throughout the project. Intersection improvements include turn lanes, ADA ramps, and a roundabout. Drainage and utility improvements will include new stream crossings, new storm drain conveyance systems, two stormwater detention vaults, and modular wetlands for water quality treatment. Proposed improvements also include the addition of street lighting and utility relocations.

Between Beverly Park Road and Pointes Drive, the project site encompasses a total of approximately 9.52 acres.

The following permits will be required for this project:

- Section 404 Permit – US Army Corps of Engineers
- Section 401 Water Quality Certification – Washington Department of Ecology
- Section 402 NPDES Construction Stormwater General Permit – Washington Department of Ecology
- Hydraulic Project Approval – Washington Department of Fish and Wildlife
- SEPA and Critical Areas Review – City of Mukilteo
- Public Agency Utility Exception – City of Mukilteo

Refer to Figures A.1 –A.16 in Appendix A for existing conditions and existing impervious areas.


Figure 1. Vicinity Map (Not to Scale).

# 2.0 DISCUSSION OF MINIMUM REQUIREMENTS

## 2.1 Minimum Requirements Summary

The project's drainage design will follow the Mukilteo Municipal Code (MMC), City of Mukilteo Development Standards (MDS) and the 2012 Stormwater Management Manual for Western Washington as amended in December of 2014 (SWMMWW). The intent of this section is to demonstrate how each of the minimum requirements, as outlined in Volume 1, Section 2.4 of the SWMMWW, are being addressed for this project. The project currently has more than 35% existing impervious coverage, results in more than 2,000 SF of new plus replaced hard surface, and adds more than 5,000 SF of new hard surfaces, meaning that all minimum requirements apply to the new hard surfaces and the converted vegetation areas. There are no other known requirements for this project, such as conditional use permits, basin plans, developer agreements, etc. No deviations are being applied for as part of this project. Refer to the Table below for the Project level Minimum Requirements Applicability Procedure. Flowcharts are provided in Appendix I for reference.

Table 3.5. Minimum Requirements (MR) Applicability Procedure – Project Level.

| Questions | Response | Action Required |
|---|---|---|
| *Step 1:* Does the site have 35% or more of existing impervious coverage | Yes | Minimum Requirements for redevelopment apply |
| *Step 2:* Does the project result in or add 2,000 square feet or more of new, replaced or new plus replaced hard surface, or include 7,000 square feet or more of land disturbing activity? | Yes, the project adds 133,375 square feet of new hard surface. | Minimum Requirements #1 through #5 apply to the new and replaced hard surfaces and the land disturbed. |
| *Step 3:* Does the project result in or add 5,000 square feet or more of new hard surfaces, or convert ¾ acres or more of native vegetation to lawn or landscaped areas, or convert 2.5 acres or more of native vegetation to pasture? | Yes. | All Minimum Requirements apply to the new hard surfaces and the converted vegetation areas. |
| *Step 4:* Is this a road related project? | Yes. | No action required. Continue to Step 5. |
| *Step 5:* Does the project add 5000 SF or more of new hard surfaces? | Yes. | No action required. Continue to Step 6. |
| *Step 6:* Do the new hard surfaces add 50% or more to the existing hard surfaces within the project limits? | No. The area of Existing Hard surfaces within project limits is 269,517 SF. The new hard surfaces have an area of 133,375 SF, or 49% of the existing hard surfaces. | No additional requirements. |

The minimum requirements are listed below, and a brief description follows each requirement.

## 2.2 Minimum Requirement #1: Preparation of Stormwater Site Plans

This full drainage report and accompanying construction drawings provide a comprehensive Stormwater Site Plan for the proposed improvements.

A Construction Stormwater Pollution Prevention Plan that meets the standards set forth in the Ecology Manual will be prepared by the contractor who successfully wins the construction contract for this project. The Temporary Erosion and Sediment Control (TESC) plans can be used as a starting point for controlling runoff that occurs during construction. However, since conditions can change often during construction, the contractor must be prepared to adjust erosion and sediment control measures in order to prevent erosion sedimentation, and flooding situations.

Permanent Stormwater Control Planning involves the preservation of the new storm drainage system after construction is complete. This drainage report, which includes a maintenance plan section, can be utilized to maintain and preserve the effective operation of the proposed drainage system well beyond the completion of the project.

## 2.3 Minimum Requirement #2: Construction Stormwater Pollution Prevention (SWPP)

The Stormwater Pollution Prevention Plan (SWPPP) will not be prepared as part of this design package. The contractor will be responsible for preparing a SWPPP for approval by the City and ensuring that all construction activity is in compliance with the SWPPP document and standards set forth therein.

## 2.4 Minimum Requirement #3: Source Control of Pollution

Source control is not anticipated to be needed after the project has been completed. However, during the construction phase of the project, source control BMPs shall be on-site at all times in the event of a spill or other hazardous situations. Control of source pollutants should be discussed in the SWPPP.

## 2.5 Minimum Requirement #4: Preservation of Natural Drainage Systems and Outfalls

The proposed drainage system was designed to match, as close as practical, the existing drainage system within the project limits. After construction, runoff from the project site will continue to discharge off-site at the same locations where it currently discharges.

## 2.6 Minimum Requirement #5: On-Site Stormwater Management

The project is located within a narrow corridor with no opportunity to disperse or infiltrate runoff because of soil conditions and the project site's proximity to adjacent developments, retaining walls, steep slopes, streams, wetlands, and buffer zones.

Implementation of Low Impact Development (LID) design concepts on a roadway corridor project such as this is bound to inherent design constraints. The linear nature of the project lends itself to solutions that will fit within that context. Right-of-way considerations are also a key factor in selection of LID strategies. Many of the common LID design solutions are better suited to site development applications, such as minimizing site disturbance or retaining native vegetation. Harbour Reach Drive is bounded by developed land, steep slopes, and wetlands, there exists little opportunity to set aside areas for preserving native vegetation. However, the project site is still subject to Minimum Requirement #5, which requires the use of on-site stormwater BMPs (LID BMPs) to the greatest extent feasible. This project has elected to utilize List #2 in lieu of the LID performance standard. The following analysis describes which LID BMPs are feasible and which are infeasible.

### List #2

Lawn and Landscaped Areas:

- Post-Construction Soil Quality and Depth: Considered to be feasible and will therefore be used in all landscaped areas.

Roofs: Not applicable since this is a roadway project.

Other Hard Surfaces:

- Full Dispersion: Not feasible because the project's proximity to steep slopes, retaining walls, and confined ROW, which limit space for the full dispersion of site runoff.
- Permeable Pavement: Not feasible for the roadway surface since this is a highly traveled arterial, and it is in close proximity to retaining walls and steep slopes. Pervious asphalt is not recommended industry wide for this type of application. Pervious concrete sidewalks will not be used either, as much of the site is adjacent to retaining walls and steep slopes.
- Bioretention: Not feasible because of the proximity to steep slopes and retaining walls.
- Sheet Flow Dispersion: Not feasible because the project's proximity to steep slopes, retaining walls, and confined ROW, which limit space for the dispersion of site runoff.
- Concentrated Flow Dispersion: Not feasible because the project's proximity to steep slopes, retaining walls, and confined ROW, which limit space for the dispersion of site runoff.

## 2.7 Minimum Requirement #6: Runoff Treatment

Runoff treatment will be performed by Modular Wetland Systems. Modular Wetland units will be used to treat runoff from equivalent areas in TDAs 3 and 4. Each of these units will be located downstream of the detention vaults discussed below. All other TDAs are under the thresholds for water quality treatment and are therefore not required to provide water quality treatment BMPs. Refer to Section 5.5 of this report for more details about these facilities.

## 2.8 Minimum Requirement #7: Flow Control

Flow control for this project is provided by two detention vaults, one in TDA 3 and one in TDA 4. All other TDAs are under the thresholds for flow control and are therefore not required to provide flow control BMPs. Refer to Section 5.4 of this report for more details about these facilities.

## 2.9 Minimum Requirement #8: Wetlands Protection

Proposed project improvements will have no adverse hydrologic impact on the adjacent downstream wetlands. The project limits do cross existing wetlands. However, through water quality treatment, flow control, and mitigation efforts, developed conditions will maintain existing hydrology to the greatest extent feasible.

## 2.10 Minimum Requirement #9: Operation and Maintenance

A maintenance plan has been prepared for the proposed storm system and can be found in Appendix F of this report.

# 3.0 SITE AND BASIN EXISTING CONDITION SUMMARY

## 3.1 Existing Utilities

Utilities along the Harbour Reach Drive corridor include the following: sanitary sewer, water, gas, overhead power lines, buried power lines, buried fiber optic lines, buried telecommunication lines, and storm sewer lines.

A 6" PVC sanitary sewer line runs NE to SW along the east side of Beverly Park Road, and is met by a line that runs east down 132nd Street SW. A 12" concrete sanitary sewer line crosses the proposed Harbour Reach Drive extension roughly 50 feet north of the seasonal stream located to the north of Blue Heron Boulevard. An 8" sanitary sewer line crosses Harbour Reach Drive 100 feet north of its intersection with Harbour Pointe Boulevard.

A water main runs NE to SW along the west side of Beverly Park Road, and is met by a line that runs to the SE down 132nd Street SW. A 12" water main runs along the north side of Blue Heron Boulevard, crossing Harbour Reach Drive. Two water lines cross the proposed Harbour Reach Drive extension roughly 100 feet south of Harbour Pointe Boulevard. A separate water line runs along the north side of Harbour Pointe Boulevard, crossing Harbour Reach Drive, before joining via a tee joint with a 12" main that runs south, across Harbour Pointe Boulevard, and north, along the east side of Harbour Reach Drive. The 12" main that runs north tapers to the south bound lane of Harbour Pointe Drive roughly 230 feet north of Harbour Pointe Boulevard, where it continues beneath the drive path until Chennault Beach Road. In addition to service lines, multiple 12" water lines extend from this main down intersecting streets, including along the north side of Pointes Drive.

A 4" gas line runs NE to SW along the east side of Beverly Park Road, and is met by a line that runs SE down 132nd Street SW. A 4" gas line runs along the south side of Harbour Pointe Boulevard and is met by a 2" line that runs north along the west side of Harbour Reach Drive. This 2" line continues past Pointes Drive, where the line exits the project limits.

Overhead power lines run along both sides of Beverly Park Road. A buried power line crosses the future Harbour Reach Drive alignment just north of Blue Heron Boulevard.

## 3.2 Existing Drainage Conditions Summary

Surface runoff from the existing sections of Harbour Reach Drive currently sheet flows to the sides of the roadway where it is collected by the existing drainage system. This system consists of closed conveyance systems, which discharge to detention ponds, streams, wetlands, and swales. The project site is not located within a flood zone, as evidenced in the FEMA map included in Appendix G of this report. Figures A.1 –A.16 in Appendix A show the existing drainage patterns, existing drainage system components, upstream tributary areas, and outfall locations. Refer to these drawings for locations of discharge points and sources of off-site flow. Based on GIS map investigations, basin map investigations, downstream analyses, and site investigations by the project engineer, it was determined that the entire project area is divided into four (4) distinct Threshold Discharge Areas (TDAs). Project TDA limits and their associated sub-basin limits and discharge locations are delineated in Figures A.1 through A.8, located in Appendix A of this report. A delineation of existing land cover conditions (Figures A.9 through A.16) can also be found in Appendix A of this report. Upstream Basin Delineations (Figure A.17) can be found in Appendix A as well.

TDA 1 is limited to a small section of 132nd Street and Beverly Park Road. The intersection of 132nd Street and Beverly Park Road sets the beginning or ending areas of TDA 1, 2, and 3. The two roadways are crowned. Runoff from TDA 1 is collected and conveyed to the east in an existing storm drain conveyance system that runs along Beverly Park Road, which exits the projects eastern limits.

TDA 2 includes part of 132nd Street and Beverly Park Road. Runoff sheet flows to both sides of the Beverly Park Road into gutters and is collected by catch basins along the gutter. Runoff is then directed into the conveyance system that runs to the west along the south side of the roadway, and out of project limits.

TDA 3 is divided into three sub-basins. Sub-basins 3A and 3B are located between Beverly Park Road and South Road, and divided by a crest near station 21+25. Stormwater in these sub-basins sheet flows to separate channels over undeveloped, forested terrain. An upstream area of approximately 6.1 acres contributes runoff to sub-basin 3A, and an upstream area of approximately 96.4 acres contributes to sub-basin 3B. Sub-basin 3C is the largest sub-basin of TDA 3, beginning at the intersection of South Road and Harbour Reach Drive and continuing to the north until reaching a high point near Blue Heron Boulevard. There is an existing conveyance system that collects runoff from the roadway within sub-basin 3C and discharges into an existing detention pond. In addition to the on-site area, there is a tributary off-site area of approximately 37.8 acres that contributes to the existing conveyance system. This runoff is generated by Travis Industries, a developed property to the east of Harbour Reach. Runoff generated by the Travis Industries parking lots is conveyed into biofiltration swales located to the west of Harbour Reach. Overflow from these biofiltration swales is diverted into the Harbour Reach conveyance system. Runoff generated from the non-pollution generating rooftops of Travis Industries is conveyed directly into the on-site Harbour Reach conveyance system. Refer to Exhibits A.20-A.22 for Travis Industries' drainage plans in the vicinity of the Harbour Reach Improvements. A separate off-site area of approximately 12.3 acres bypasses the on-site conveyance systems by passing underneath the roadway in a 30" concrete culvert into an existing wetland.

TDA 4 is separated into two sub-basins; 4A and 4B. Sub-basin 4A begins approximately 120 feet north of the intersection of Blue Heron Boulevard, where Harbour Reach Drive terminates, and ends 100 feet south of the Harbour Pointe Boulevard intersection. The existing conditions, between Harbour Reach Drive and Harbour Pointe Boulevard, are heavily wooded. The discharge point is located between the two intersections and is comprised of a stream. There is an upstream area of approximately 153.1 acres that contributes to the runoff in this sub-basin. Sub-basin 4B begins approximately 100 feet south of the Harbour Pointe Boulevard intersection, which is super elevated to the north. A conveyance system collects this runoff, as well as runoff from the high point, approximately 700 feet to the north, to the intersection and discharges into Picnic Point Creek at the northeast corner of the intersection.

# 4.0 OFF-SITE ANALYSIS

## 4.1 Downstream Analysis

Four (4) TDAs have been identified within the project limits in accordance with the definitions of the 2014 Stormwater Management Manual for Western Washington, Volume I, Sections 2.4 and 2.5.

The sub-basins on the site correlate to individual outfalls. Each outfall and sub-basin are summarized below:

| TDA | Sub-Basin | Start Station | End Station | Discharge Description | Outlet Location | Discharge to Downstream Via |
|---|---|---|---|---|---|---|
| 1 | N/A | 8+00 RT | 10+75 RT | 12" pipe | 9+75 RT | Conveyance System |
| 2 | N/A | 9+00 LT | 11+25 LT | 12" pipe | 10+50 LT | Conveyance System |
| 3 | 3A | 10+40 LT | 21+35 | Wetland | 20+45 LT | Wetland |
| | 3B | 21+15 LT | 24+45 RT | Seasonal Stream | 22+65 LT | Seasonal Stream |
| | 3C | 23+75 RT | 42+05 LT | 36" Pipe | 30+05 LT | Detention Pond |
| 4 | 4A | 41+35 LT | 46+80 LT | Picnic Point Creek | 44+50 | Picnic Point Creek |
| | 4B | 46+25 RT | 207+15 | 18" Pipe | 200+60 RT | Picnic Point Creek |

A Level 1 downstream analysis was performed for TDAs 1 through 4 on October 19, 2016. A Level 1 downstream analysis includes a review of resources, a visual inspection of storm conveyance systems for evident erosion, sedimentation, or other drainage issues and a discussion of possible effects due to proposed project improvements. Photos taken at various locations along the downstream route are included in the narrative below. The downstream routes and photo locations have been delineated on Figure A.17.

Prior to performing any field reconnaissance, it is important to gather as much information about the project site and its surrounding area as possible. Becoming familiar with site topography, likely Threshold Discharge Areas (TDAs), receiving waters, and various other site related information will aid with the field reconnaissance and in making a complete assessment of site conditions.

Table 4.1 below provides the applicable information sources that were consulted as part of these downstream analyses. These sources helped to provide an overall view of the project site, its downstream areas, and any existing and potential impacts on downstream waters and properties.

Table 4.1. Information Sources Consulted.

| Item # | Source Reviewed | Findings |
|---|---|---|
| 1 | GIS Data | Project vicinity map, aerial photograph, road features, vegetation, topography, land use, etc. |
| 2 | Topography (USGS quadrangle maps and other survey maps) | On-site topography and utilities provided by GIS. |
| 3 | FEMA Map | The project does not lie within a floodplain. |
| 4 | Sensitive Area Map | Sensitive area mapping and information provided by GIS |
| 5 | Clean Water Act Section 303(d) List of Impaired Waters | Ecology website. Impairments listed on the 303(d) list for Picnic Point Creek include temperature, dissolved oxygen, and pH. Picnic Point Creek does have one bioassessment listing. |
| 6 | Total Maximum Daily Loads (TMDLs) | Ecology website. No TMDLs listed for Picnic Point Creek. |
| 7 | Natural Resources Conservation Service Soil Survey (NRCS) | NRCS soil maps were reviewed for the project site, downstream, and upstream off-site areas. |
| 8 | Geotechnical Evaluation | This includes soil characteristics, groundwater data, soil infiltration rates, etc. Refer to the geotechnical report. |

A downstream analysis was completed for each of the downstream flow paths from each TDA outfall location to ¼ mile downstream of the project site.

The flow paths from each discharge point are shown on Figure A.17. Sub-basins that converge within ¼ mile, as measured from the uppermost sub-basin, are part of the same TDA.

### 4.1.1 Picnic Point Drainage Basin Summary

#### Picnic Point Creek Basin

The Picnic Point Creek drainage basin has an area of about 1,300 acres (approximately two square miles). The basin has a length of 2.5 miles and maximum width of 1.2 miles. Picnic Point Creek flows into Puget Sound at Picnic Point County Park. The maximum elevation within the basin is 580 feet in the vicinity of Highway 99.

Existing hydrology from the project area feeds wetlands and shallow flow. Picnic Point Creek is a shallow meandering creek that flows through and is adjacent to multiple wetlands and small ponds. The soils consist of Alderwood gravelly sandy loam, Alderwood-Everett gravelly sandy loams, Alderwood-Urban land complex, and Everett gravelly sandy loam. The land surrounding the creek ranges from single-family residential to commercial, with a large portion being undeveloped.

The creek begins around Cyrus Way and South Road and runs west until it reaches the Puget Sound. It flows under multiple roadways and railroads in concrete culverts along the way. TDAs 1, 2, 3, and 4 drain to this basin.

#### TDA 1 Downstream Analysis

This downstream analysis begins at the intersection of 132nd Street SW and Beverly Park Road. A walkthrough of the downstream routes of each TDA was performed on Wednesday, October 19, 2016. The weather was overcast with a temperature near 60 degrees Fahrenheit. Precipitation had been recorded in the week leading up to the visit. Refer to Figure A.17 for a delineation of the downstream drainage route.

TDA 1 is limited to a small section of 132nd Street and Beverly Park Road. The intersection of 132nd Street and Beverly Park Road sets the beginning or ending areas of TDA 1, 2, and 3. TDA 1 includes part of 132nd Street and Beverly Park Road. Runoff sheet flows to both sides of the Beverly Park Road into gutters and is collected by catch basins along the gutter. Runoff is then directed into the conveyance system that runs to the northeast along the east side of the roadway. It appears the runoff is discharged into a forested channel approximately 1,200 feet downstream and discharges into a wetland associated with Picnic Point Creek, to the south of South Road. This wetland appears to be the commencement of Picnic Point Creek. The creek crosses under South Road twice before it meets up with the discharge point for TDA 3, sub-basin 3B.

All the catch basins, storm pipe, and drainage channels observed during this TDA's downstream walkthrough appeared to be in good condition with no visible clogging or obstructions to prevent flow within the conveyance system. Adverse impacts are not anticipated as a result of the proposed improvements within TDA 1 of the project site.


Photo 101. TDA 1 conveyance system along Beverly Park Road.

### TDA 2 Downstream Analysis

The downstream analysis for this TDA begins at the intersection of 132nd Street SW and Beverly Park Road as well. The two roadways are crowned. Runoff from TDA 2 is collected and conveyed to the southwest in an existing storm drain conveyance system that runs along Beverly Park Road. Runoff flows southwesterly for approximately 1/2 mile prior to tuning west and eventually is discharged into an unnamed stream. The unnamed stream ultimately discharges into the Puget Sound. There is one wetland adjacent to Beverly Park Road to the west.

Almost all the catch basins, storm pipe, and drainage channels observed during this TDA's downstream walkthrough appeared to be in good condition with no visible clogging or obstructions to prevent flow within the conveyance system. The exception to this was the conveyance system along the west side of Beverly Park Road, where the catch basins were full of water. There was no indication of flow within the catch basins, nor was clogging observed in any catch basin. Adverse impacts are not anticipated as a result of the proposed improvements within TDA 2 of the project site.


Photo 201. TDA 2 conveyance system along Beverly Park Road.

### TDA 3 Downstream Analysis

TDA 3 is split into three sub-basins; 3A, 3B, and 3C. The analysis for this TDA begins at each sub-basins discharge point.

Sub-basin 3A is located between Beverly Park Road and the high point to the south of South Road. The discharge point is at the low point, approximately 360 feet to the south of South Road, and it discharges to the southwest. The flow enters into a channel and a wetland and ultimately discharges into Picnic Point Creek (refer to sub-basin 3B). The area surrounding this location is heavily forested. In addition to the on-site area, an upstream area of approximately 6.1 acres also contributes runoff to this sub-basin. The quarter-mile mark for this downstream system is shown on Figure A.17.

Sub-basin 3B is located to the south of South Road. Sub-basin 3B ends at South Road, where it intersects with Harbour Reach Drive, which is an existing paved roadway. The discharge point is located approximately 150 feet to the north of the high point, just to the south of South Road, where it discharges into a seasonal stream. The stream continues to flow to the west through a heavily forested ravine and eventually discharges into Picnic Point Creek approximately 650 feet downstream. In addition to the on-site area, an upstream area of approximately 96.4 acres also contributes runoff to this sub-basin.

Sub-basin 3C is the largest sub-basin of TDA 3, beginning at the intersection of South Road and Harbour Reach Drive and continuing to the north until reaching a high point near Blue Heron Boulevard. There is an existing conveyance system that collects runoff from the roadway within sub-basin 3C and discharges into an existing detention pond. In addition to the on-site area, there is a tributary off-site area of approximately 37.8 acres that contributes to the existing conveyance system. This runoff is generated by Travis Industries, a developed property to the east of Harbour Reach. Runoff generated by the Travis Industries parking lots is conveyed into biofiltration swales located to the west of Harbour Reach. Overflow from these biofiltration swales is diverted into the Harbour Reach conveyance system. Runoff generated from the non-pollution generating rooftops of Travis Industries is conveyed directly into the on-site Harbour Reach conveyance system. Refer to Exhibits A.20-A.22 for Travis Industries' drainage plans in the vicinity of the Harbour Reach Improvements. A separate off-site area of approximately 12.3 acres bypasses the on-site conveyance systems by passing underneath the roadway in a 30" concrete culvert into an existing wetland. This wetland routes flows to the west, discharging into Picnic Point Creek.

All the catch basins, storm pipe, and drainage channels and flow paths observed during this TDA's downstream walkthrough appeared to be in good condition with no visible clogging or obstructions to prevent flow within the conveyance system. Adverse impacts are not anticipated as a result of the proposed improvements within TDA 3 of the project site.


Photo 301. TDA 3 downstream path of Picnic Point Creek.

Photo 302. TDA 2 3 downstream path of Picnic Point Creek.

Photo 303. TDA 3 downstream path of Picnic Point Creek.


Photo 304. Outlet pipe into swale near South Road.


Photo 305. Swale near South Road.

### TDA 4 Downstream Analysis

TDA 4 is separated into two sub-basins; 4A and 4B. Sub-basin 4A begins approximately 120 feet north of the intersection of Blue Heron Boulevard, where Harbour Reach Drive terminates, and ends 100 feet south of the Harbour Pointe Boulevard intersection. The existing conditions, between Harbour Reach Drive and Harbour Pointe Boulevard, are heavily wooded. There is a discharge point between the two intersections that outfalls directly into Picnic Point Creek. The creek bed is heavily forested. It continues to the south for approximately three-quarters of a mile, where it then combines with flows from TDA 3. There is an upstream area of approximately 153.1 acres that contributes to the runoff in this sub-basin.

Sub-basin 4B begins approximately 100 feet south of the Harbour Pointe Boulevard intersection, which is super elevated to the north. A conveyance system collects this runoff, as well as runoff from the high point, approximately 700 feet to the north, to the intersection and discharges into Picnic Pointe Creek at the northeast corner of the intersection. The flow continues south, flowing underneath Harbour Pointe Boulevard, for approximately 600 feet where it combines with the flow from sub-basin 4A.

All the catch basins, storm pipe, and drainage channels observed during this TDA's downstream walkthrough appeared to be in good condition with no visible clogging or obstructions to prevent flow within the conveyance system. Adverse impacts are not anticipated as a result of the proposed improvements within TDA 4 of the project site.

Photo 401. Discharge area of Harbour Reach Drive on NE corner of Harbour Pointe Boulevard SW.

Photo 402. Picnic Point Creek to the south of Harbour Pointe Boulevard SW.

## 4.2 Upstream Analysis

Stormwater runoff from areas upstream (east) of the project has been identified and can be viewed in Figure A.17. The proposed drainage system for the roadway will be designed to maintain separation between on-site and upstream stormwater flow. The outfalls from the existing systems will be maintained.

There is a considerable amount of upstream off-site area that contributes runoff onto the Harbour Reach extension project area. This runoff enters the site either in the form of sheet flow or as point discharge through storm pipes, drainage ditches, and stream crossings. All off-site areas that are tributary to the project site have been delineated and can be found on Figure A.17.

The vast majority of the tributary upstream areas consist of land cover associated with private commercial developments. Impervious areas consist of roofs, sidewalks and roads where pervious areas consist of landscaped areas and wooded areas surrounding stream corridors.

There are no adverse impacts anticipated within these upstream areas as a result of the improvements associated with the project. All existing stream crossings and storm drain crossings will be maintained to the maximum extent feasible.

# 5.0 PERMANENT STORMWATER CONTROL PLAN

## 5.1 Pre-Developed Site Hydrology

Pre developed conditions were assumed to be forested, regardless of current existing conditions. As previously discussed, four distinct sub-basins have been identified within project limits. Pre-developed site hydrology is summarized in the table below. Refer to Section 3.2 for more detail on existing conditions.

| TDA | Sub-Basin | Sub-Basin Area (Acres) | Current Land Use | Hydrologic Soil Group | Pre-Developed Land Use |
|---|---|---|---|---|---|
| 1 | N/A | 0.32 | Impervious | Urban Land Complex | Forested |
| 2 | N/A | 0.24 | Impervious | Urban Land Complex | Forested |
| 3 | 3A | 2.19 | Forested | Urban Land Complex | Forested |
|  | 3B | 0.55 | Forested | Gravelly Sandy Loam | Forested |
|  | 3C | 3.14 | Impervious | Gravelly Sandy loam | Forested |
| 4 | 4A | 0.88 | Forested | Gravelly Sandy loam | Forested |
|  | 4B | 0.60 | Impervious | Gravelly Sandy Loam | Forested |

## 5.2 Developed Site Hydrology

Refer to Section 5.6 for detailed descriptions of proposed improvements within each TDA.

Developed Site Hydrology is summarized in the table below. Refer to Sections 5.3 through 5.6 for more detail on developed conditions.

| TDA | Sub-Basin | Sub-Basin Area (Acres) | Current Land Use | Hydrologic Soil Group | Developed Land Use |
|---|---|---|---|---|---|
| 1 | N/A | 0.32 | Impervious | Urban Land Complex | Grass and Impervious |
| 2 | N/A | 0.24 | Impervious | Urban Land Complex | Grass and Impervious |
| 3 | 3A | 2.19 | Forested | Urban Land Complex | Grass and Impervious |
|  | 3B | 0.55 | Forested | Gravelly Sandy Loam | Grass and Impervious |
|  | 3C | 3.14 | Impervious | Gravelly Sandy loam | Grass and Impervious |
| 4 | 4A | 0.88 | Forested | Gravelly Sandy loam | Grass and Impervious |
|  | 4B | 0.60 | Impervious | Gravelly Sandy Loam | Grass and Impervious |

## 5.3 Performance Goals and Standards

Per Minimum Requirement #7 of the Stormwater Management Manual for Western Washington (SWMMWW), any one of the following circumstances requires achievement of the standard flow control requirement for Western Washington:

- Projects in which the total of effective impervious surfaces is 10,000 SF or more in a threshold discharge area (TDA)
- Projects that convert ¾ acres or more of vegetation to lawn or landscape, or convert 2.5 acres or more of native vegetation to pasture in a TDA, and from which there is a surface discharge in a natural or man-made conveyance system from the site

- Projects that through a combination of effective hard surfaces and converted vegetation areas cause a 0.10 cubic feet per second increase in the 100-year flow frequency from a threshold discharge area as estimated using the Western Washington Hydrology Model or other approved model and one-hour time steps (or a 0.15 cfs increase using 15-minute time steps).

For this project, only the first and third circumstances apply. See below for each TDA's flow control threshold analysis.

| TDA | New Impervious Surface (SF) | New Imp. Surface Greater than 10,000 SF? | Change in Pre-Developed to Untreated Post-Developed Runoff (CFS) | Flow Control Required? |
|---|---|---|---|---|
| 1 | 833 | No | <0.1 | No |
| 2 | 48 | No | <0.1 | No |
| 3 | 100,883 | Yes | >0.1 CFS | Yes |
| 4 | 31,611 | Yes | >0.1 CFS | Yes |

The following flow control standards are to be applied to this project:

- Provide storage volume required to match the duration of pre-developed peak flows from 50% of the 2 year up to the 50-year storm flow, using a flow restrictor (such as an orifice or weir), and check the 100 year peak flow for property damage.
- Pre-developed land-use is to assume forested conditions, regardless of actual existing site conditions.
- Modeling for the sizing of detention facility is to be the continuous simulation model MGSFlood or equivalent.

Per Minimum Requirements #6 of the Stormwater Management Manual for Western Washington (SWMMWW), either of the following circumstances requires achievement of the standard water quality treatment requirement for Western Washington:

- Projects in which the total of pollution-generating hard surface (PGHS) is 5,000 square feet or more in a threshold discharge area of the project.
- Projects in which the total of pollution-generating pervious surfaces (PGPS) – not including permeable pavements – is three quarters (3/4) of an acre or more in a threshold discharge area, and from which there will be a surface discharge in a natural or man-made conveyance system from the site.

For this project, only the first circumstance applies. See below for each TDA's water quality treatment threshold analysis.

| TDA | New Pollution Generating Hard Surface (SF) | New NPGHS Greater than 5000 SF? | Water Quality Treatment Required? |
|---|---|---|---|
| 1 | 630 | No | No |
| 2 | 0 | No | No |
| 3 | 74,492 | Yes | Yes |
| 4 | 25,070 | Yes | Yes |

The following water quality treatment standards are applied to this project:

- Modular Wetlands, which are located downstream of detention facilities, were sized to treat the full 2-year release rate from the detention facilities.
- For this project, the runoff treatment target is for Enhanced Treatment since the ADT is greater than 7,500 for the horizon year 2040.

Calculations for the sizing of the flow control and stormwater treatment BMPs can be found in appendix C of this report. Equivalent Area Maps can be found in Appendix B of this report.

## 5.4 Flow Control

Concrete detention vaults were chosen as the preferred flow control BMP for TDAs 3 and 4. The detention vaults were sized using MGSFlood, a continuous simulation software. Storage volumes for the detention vaults are required to match the duration of pre-developed peak flows from 50% of the 2-year up to the 50-year storm flow, using a flow restrictor or an orifice weir. Pre-developed land was assumed to be forested, regardless of actual existing site conditions. Refer to the table below for required capture areas, and actual capture areas:

| TDA | Required Impervious Capture Area (SF) | Actual Impervious Capture Area (SF) | Additional Impervious Capture Area Beyond Required (SF) |
|---|---|---|---|
| 3 | 100,883 | 102,300 | 1,417 |
| 4 | 31,611 | 34,737 | 3,126 |

### 5.4.1 TDA 3

Because of steep slopes throughout the TDA and lack of right-of-way space, open detention ponds or similar flow control BMPs were not feasible. Therefore, a single detention vault will serve as the flow control BMP for TDA 3.

The proposed detention vault will be located within the Harbour Reach Drive right-of-way, just north of the roundabout at the intersection of Harbour Reach Drive and South Road. It will have an interior area of 4,480 SF, and a live storage depth of 11', translating to a storage volume of 49,280. Refer to project plans for details and drawings. Refer to Appendix C for sizing calculations.

A Type 2 54-inch control structure will be located adjacent to the detention vault. This structure will control the release of stormwater runoff into the downstream system.

Where TDA 3 ends and TDA 4 begins, just north of Harbour Point Boulevard, proposed drainage conditions result in the transfer of roughly 1,775 SF from TDA 4 into TDA 3. In order to offset this imbalance, an equivalent area of TDA 3 is captured from TDA 3 and transferred into TDA 4. Refer to Figure B9 in Appendix B of this report for a depiction of this area swap.

### 5.4.2 TDA 4

Because of steep slopes throughout the TDA, open detention ponds or similar flow control BMPs were not feasible. Therefore, a single detention vault will serve as the flow control BMP for TDA 4.

The proposed detention vault will be located within the Harbour Reach Drive right-of-way, just north of Blue Heron Boulevard. It will have an interior area of 3,562 SF and a live storage depth of 6', translating to a storage volume of 21,120 CF. Refer to project plans for details and drawings. Refer to Appendix C for sizing calculations.

A Type 2 54-inch control structure will be located adjacent to the detention vault. This structure will control the release of stormwater runoff into the downstream system.

## 5.5 Water Quality

Flow rates were provided to the manufacturer for Modular Wetland sizing purposes. For the Modular Wetlands, both of which were placed after detention facilities, the units were sized to treat the full 2 year release rate from the detention vaults obtained via MGSFlood. For this project, the runoff treatment target is for Enhanced Treatment since the ADT is greater than 7,500 for the horizon year 2040. Refer to the table below for required capture areas, and actual capture areas:

| TDA | Required PGIS Capture Area (SF) | Actual PGIS Capture Area (SF) | Additional PGIS Capture Area Beyond Required (SF) |
|---|---|---|---|
| 3 | 74,492 | 74,731 | 239 |
| 4 | 25,070 | 26,081 | 1,011 |

### 5.5.1 TDA 3

The Modular Wetland was chosen because of its ability to treat a large area with a single unit and to receive runoff from pipe flow, instead of just surface flow. Placing it immediately downstream of the TDA 3 Detention Vault results in a smaller sized unit than if it were to be placed upstream of the detention vault. Based on the manufacturer's sizing, a 4' x 6' Modular Wetland will satisfy water quality treatment requirements. Refer to project plans for drawings and details for this Modular Wetland, and refer to appendix C of this report for sizing calculations.

### 5.5.2 TDA 4

The Modular Wetland was chosen because of its ability to treat a large area with a single unit and to receive runoff from pipe flow, instead of just surface flow. Placing it immediately downstream of the TDA 4 Detention Vault results in a smaller sized unit than if it were to be placed upstream of the detention vault. Based on the manufacturer's sizing, a 4' x 6' Modular Wetland will satisfy water quality treatment requirements. Refer to project plans for drawings and details for this Modular Wetland, and refer to Appendix C of this report for sizing calculations.

## 5.6 Conveyance System and Design

The Harbour Reach Drive Extension project is separated into four TDAs conveying roadway drainage to the appropriate stormwater facility and outfall locations. Per the Mukilteo Development Standards, the conveyance system has been analyzed using the rational method, and will accommodate the 100-year storm without overtopping for all systems discharging to major creeks, and the 25-year storm for all others. The software program StormShed3G was used to check conveyance capacities. Refer to Appendix D for the conveyance calculations. These calculations demonstrate that all proposed on-site systems have adequate capacity to convey the 100-year storm.

Gutter flow analysis has been performed to review possible flooding encroachment into the traveled way. A 10-year design storm (WSDOT HM) and an acceptable spread width of the shoulder width (bike lane) plus two feet (WSDOT HM) was used to check inlet spacing at worst case locations. Spot check calculations for inlet spacing and spread width compliance have been included in Appendix D. Catch basins were placed no more than 150 feet apart, per City of Mukilteo standards.

After project completion, surface runoff from the newly constructed/widened roadway will be directed to the new gutter line (and existing gutter line where conditions were not changed) on either side of Harbour Reach Drive. Catch basins will collect this runoff and the new storm pipe system will convey it to an existing storm drain system or directly to each TDA's respective natural discharge points. Off-site upstream areas will also be collected and conveyed by both the new and existing on-site conveyance systems. Runoff from these off-site areas will be conveyed in separate conveyance systems, bypassing the flow control and water treatment facilities. The following sections describe the proposed drainage system for each of the project's four TDAs.

Roadway improvements within TDA 1 consist of intersection improvements and widening at the north and east corners of Beverly Park Road and 132nd Street SW, and the addition of new curb ramps. After project completion, on-site surface runoff from TDA 1 will sheet flow to existing and new gutter lines at the north and northeast corner of Beverly Park Road, where it will be collected in existing and proposed catch basins and conveyed off-site to the existing discharge point. TDA 1 is below the threshold for both water quality treatment and flow control requirements

Roadway improvements within TDA 2 consist of very minor intersection improvements at the south corner of Beverly Park Road and 132nd Street SW, including the addition of new curb ramps. After project completion, on-site surface runoff from TDA 2 will be unchanged. Existing curb lines will be replaced, but not relocated, and the existing conveyance system will remain in-place. TDA 2 is below the threshold for both water quality treatment and flow control requirements.

Roadway improvements within TDA 3 include the extension of Harbour Reach Drive into undeveloped land. This section of roadway will include drive lanes, bike lanes, curb and gutter, planters, and sidewalks, and a roundabout. TDA 3 improvements also include the widening of the existing portion of Harbour Reach Drive north of South Road, and South of Blue Heron Boulevard. These improvements will result in a wider roadway, and new planter strips and sidewalk. After project completion, on-site surface runoff from TDA 3 will be conveyed along the newly constructed gutter lines to catch basins and a closed storm drain system. To detain and treat runoff from the new impervious and pollution generating surfaces added to this TDA, runoff from a designated equivalent area (refer to Figure B.10 in Appendix B of this report) will be directed into a detention vault just north of the intersection of Harbour Reach Drive and South Road, and then into a Modular Wetland located within the proposed roundabout. Once treated, runoff from the equivalent area will be discharged into the existing seasonal stream in sub-basin 3B, which discharges to Picnic Point Creek. The outfall system will consist of a flexible HDPE pipe that runs down a steep slope and into a bubble up energy dissipator. The HDPE pipe will be below grade for the vast majority of the steep slope, but anchoring will be provided where the pipe is at grade. The energy dissipator consists of a Type 2 48" catch basin with a debris cage, surrounded by quarry spalls. Runoff will enter the catch basin below its rim elevation, and spill out through the debris cage before entering Picnic Point Creek. Culverts will collect and direct off-site upstream runoff beneath the proposed roadway to maintain exiting drainage conditions.

Roadway improvements within TDA 4 include the extention of Harbour Reach Drive North of Blue Heron Boulevard up to Harbour Pointe Boulevard. This section of Harbour reach will include drive lanes, bike lanes, curb and gutter, planters, and sidewalk. After project completion, on-site surface runoff from TDA 4 will be conveyed along the newly constructed gutter lines to catch basins and a closed storm drain system. To detain and treat runoff generated by the new impervious and pollution generating surfaces, runoff from a designated equivalent area (Refer to Figure B.11 in Appendix B of this report) will be directed into a detention vault just north of Blue Heron Boulevard, and then into a Modular Wetland located within the planter strip and sidewalk west of the vault. Once treated, the runoff from the equivalent area will be discharged into the existing seasonal stream near station 44+50. The outfall system will consist of a flexible HDPE pipe that runs down a steep slope and into a bubble up energy dissipator. The pipe will be at grade in some locations on the steep slope, and will require anchoring. The energy dissipator consists of a Type 2 48" catch basin with a debris cage, surrounded by quarry spalls. Runoff will enter the catch basin below its rim elevation, and spill out through the debris cage before entering the seasonal stream. The HDPE pipe in this section will be at grade for much of the steep slope, and anchoring will be provided. Refer to Appendix D for Outfall Stability Calculations. Runoff from sub-basin 4B will be conveyed along the newly constructed gutter lines on either side of Harbour Reach Drive, collected in catch basins, and directed to the existing discharge point, which will be maintained. Off-site upstream runoff will be able to pass beneath the proposed roadway to maintain exiting drainage conditions.

# 6.0 OPERATION AND MAINTENANCE MANUAL

The City of Mukilteo shall be responsible for the maintenance and operation of on-site drainage facilities.

1. Drainage facilities shall be maintained at appropriate times so that their water quantity and water quality control functions, and access are not impaired; and shall include keeping all drainage facilities and access areas free of accumulated debris or trash and all impervious surfaces free from sediment.
2. Maintenance of all drainage facilities shall be conducted by the responsible party in compliance with an operation and maintenance plan for drainage facilities developed in accordance with the requirements of this title.
3. Any modification to detention facilities for maintenance which is not part of an approved maintenance schedule will require prior approval by the Engineer. A revision to the approved plans, drainage computations, or maintenance schedule shall require re-submittal to the City for approval prior to modification.

The attached specific maintenance requirements, found in Appendix F of this report, indicate each maintenance component and the conditions when maintenance is required. The drainage facilities shall be inspected twice a year during the first two years of operation, and once a year thereafter. The drainage facilities shall be inspected to determine whether conditions exist which would require maintenance. If it is determined that conditions exist that require maintenance, this maintenance is to be performed in a timely manner.

Any standing water removed during the maintenance operation must be disposed of in a sanitary sewer (as approved by the governing jurisdiction) or to another City approved discharge location. Residuals must be disposed of in accordance with current health department requirements of the local government.

The facility-specific maintenance standards contained in Appendix F of this report are intended to be conditions for determining if maintenance actions are required as identified through inspection. They are not intended to be measures of the facilities' required condition at all times between inspections. In other words, exceedance of these conditions at any time between inspections and/or maintenance does not automatically constitute a violation of these standards. However, based upon inspection observations, the inspection and maintenance schedules shall be adjusted to minimize the length of time that a facility is in a condition that requires a maintenance action.

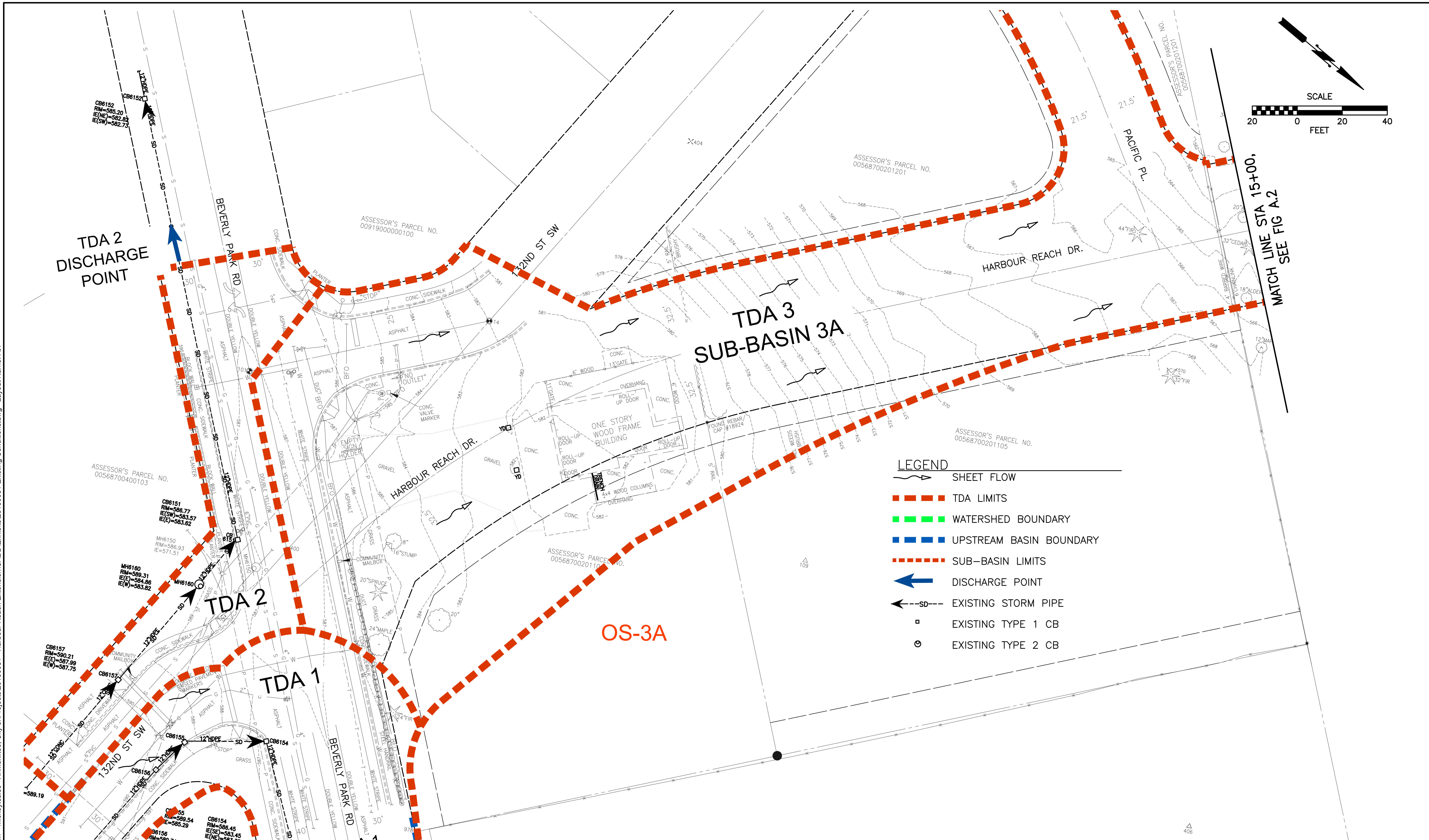
Refer to the sheets in Appendix F as a guide for maintaining the drainage components associated with this project.

The proposed drainage system consists of the following elements:

- Detention Vault
- Modular Wetland
- Catch Basins
- Storm Drain Pipe
- Flow Control Structure
- Bubble-up Energy Dissipator

# APPENDIX A

## Existing Condition Figures

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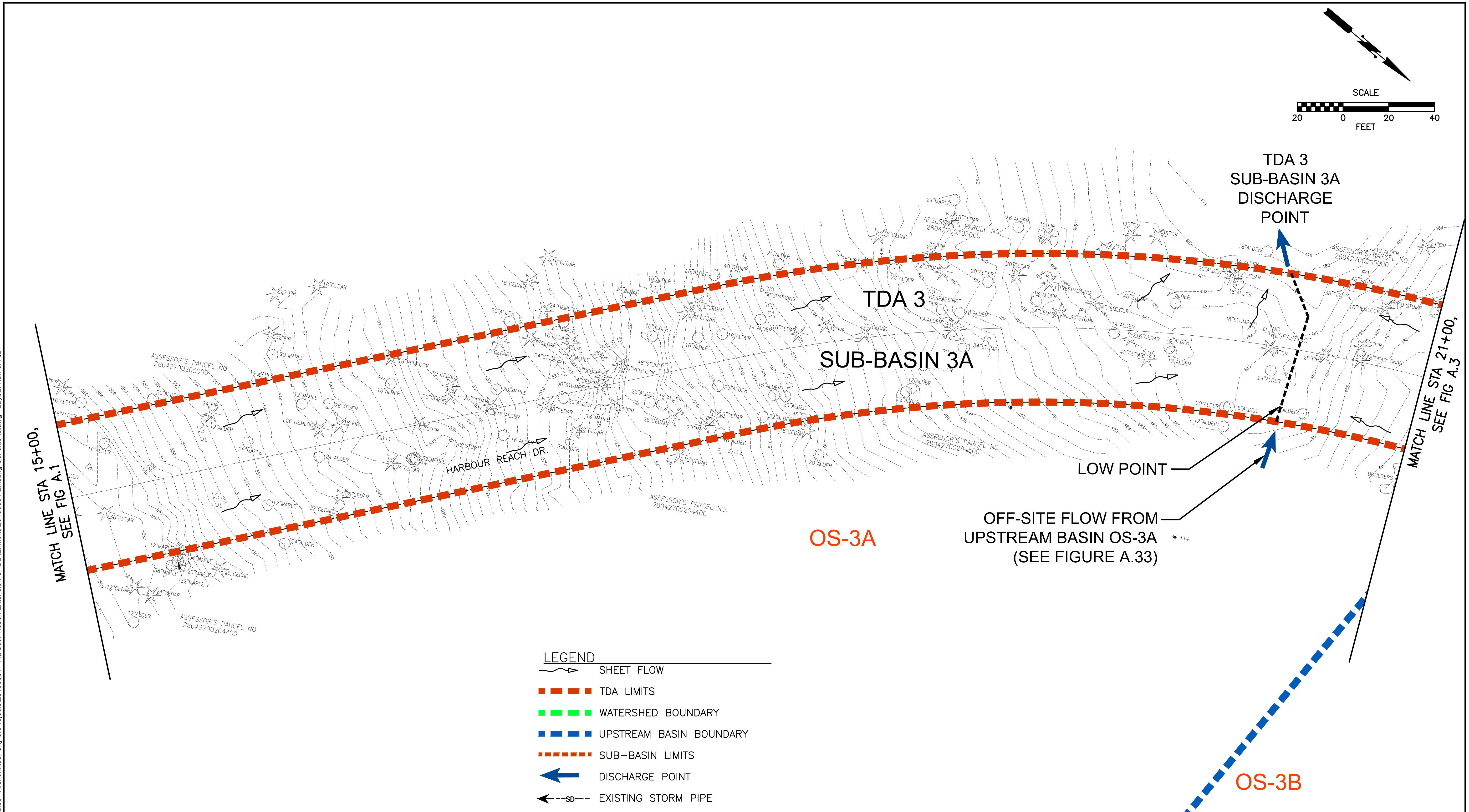
HARBOUR REACH EXTENSION

EXISTING CONDITIONS

FIGURE A.1




LEGEND

- SHEET FLOW
- TDA LIMITS
- WATERSHED BOUNDARY
- UPSTREAM BASIN BOUNDARY
- SUB–BASIN LIMITS
- DISCHARGE POINT
- EXISTING STORM PIPE
- EXISTING TYPE 1 CB
- EXISTING TYPE 2 CB

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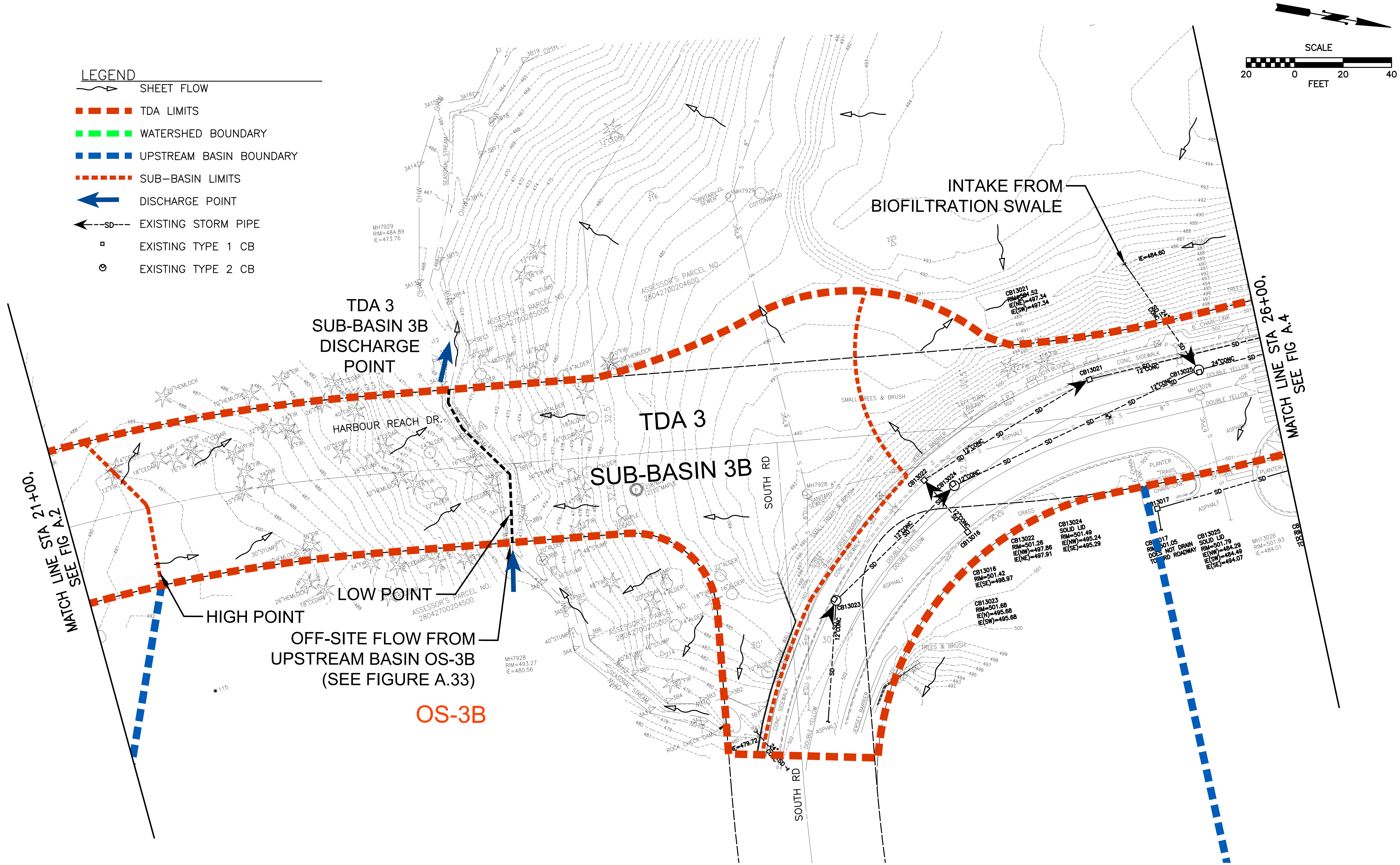
HARBOUR REACH EXTENSION

EXISTING CONDITIONS

FIGURE A.2

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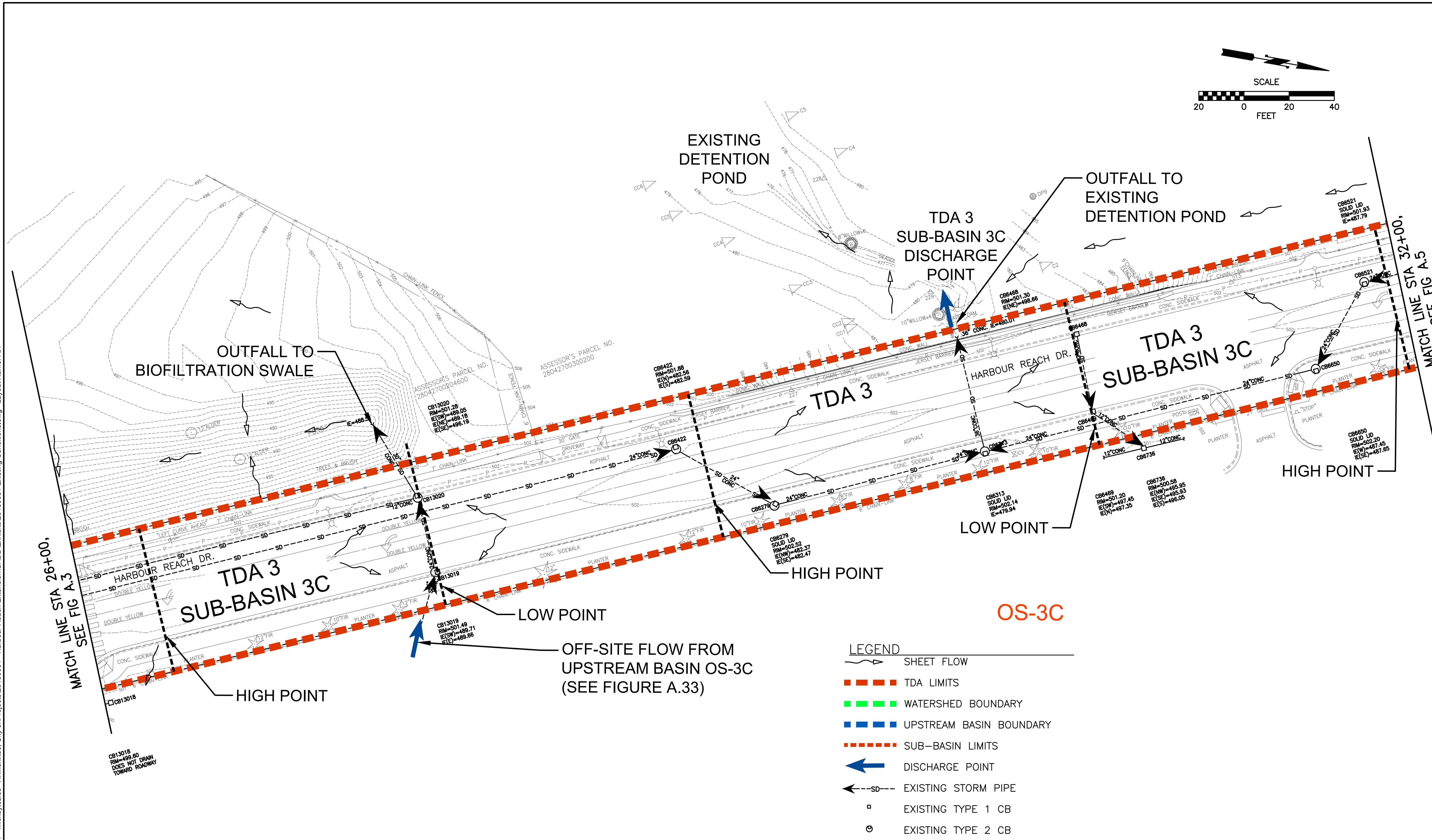
HARBOUR REACH EXTENSION

EXISTING CONDITIONS

FIGURE
A.3




LEGEND

- SHEET FLOW
- TDA LIMITS
- WATERSHED BOUNDARY
- UPSTREAM BASIN BOUNDARY
- SUB–BASIN LIMITS
- DISCHARGE POINT
- EXISTING STORM PIPE
- EXISTING TYPE 1 CB
- EXISTING TYPE 2 CB

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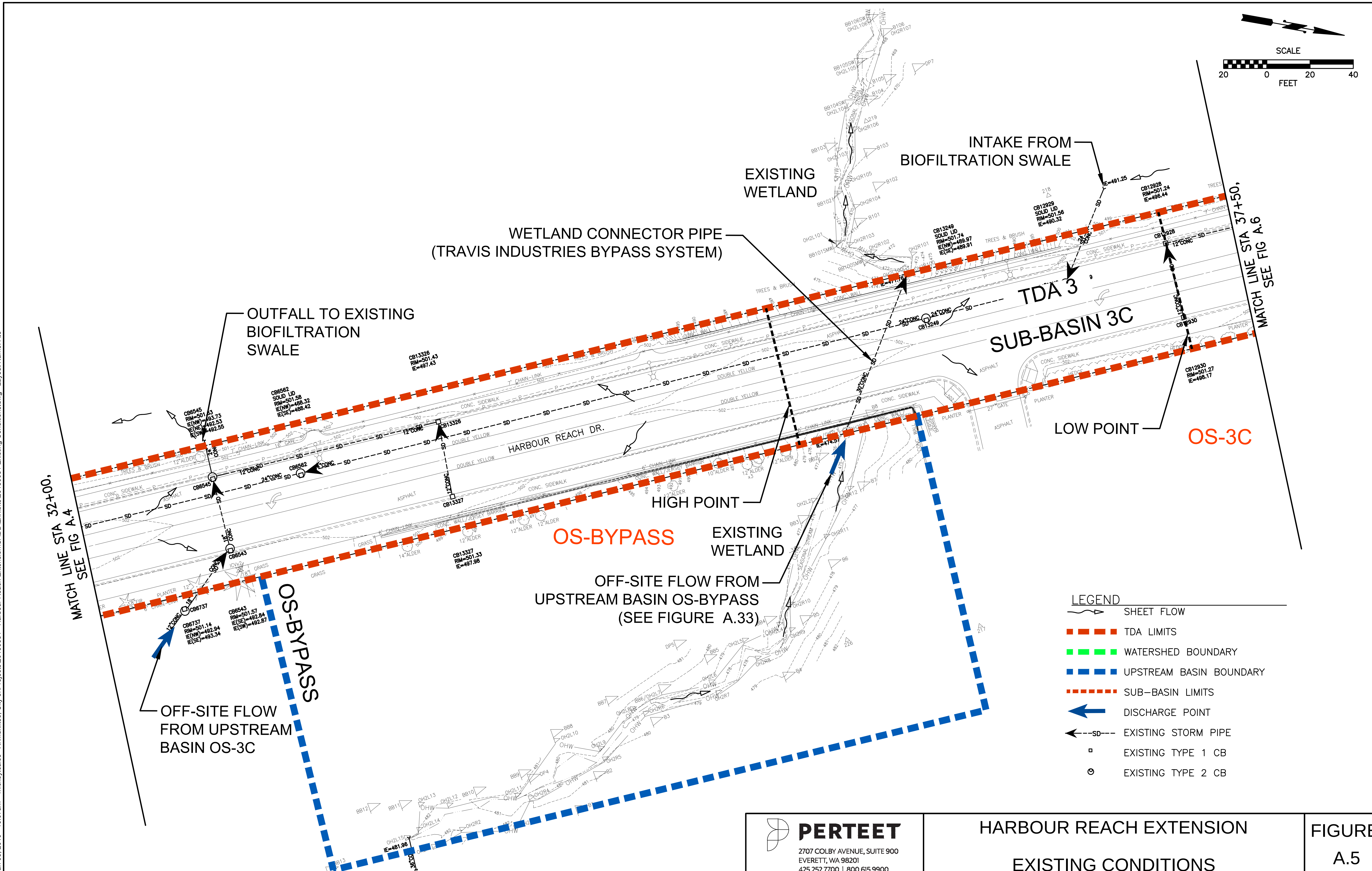
HARBOUR REACH EXTENSION

EXISTING CONDITIONS

FIGURE A.4

Jan 03, 2019 - 10:07am mickey.cales X:\Mukilteo, City of\Projects\20150051 - Harbour Reach Extension\CADD\Exhibits\20150051 Existing Conditions.dwg Layout Name: A.4

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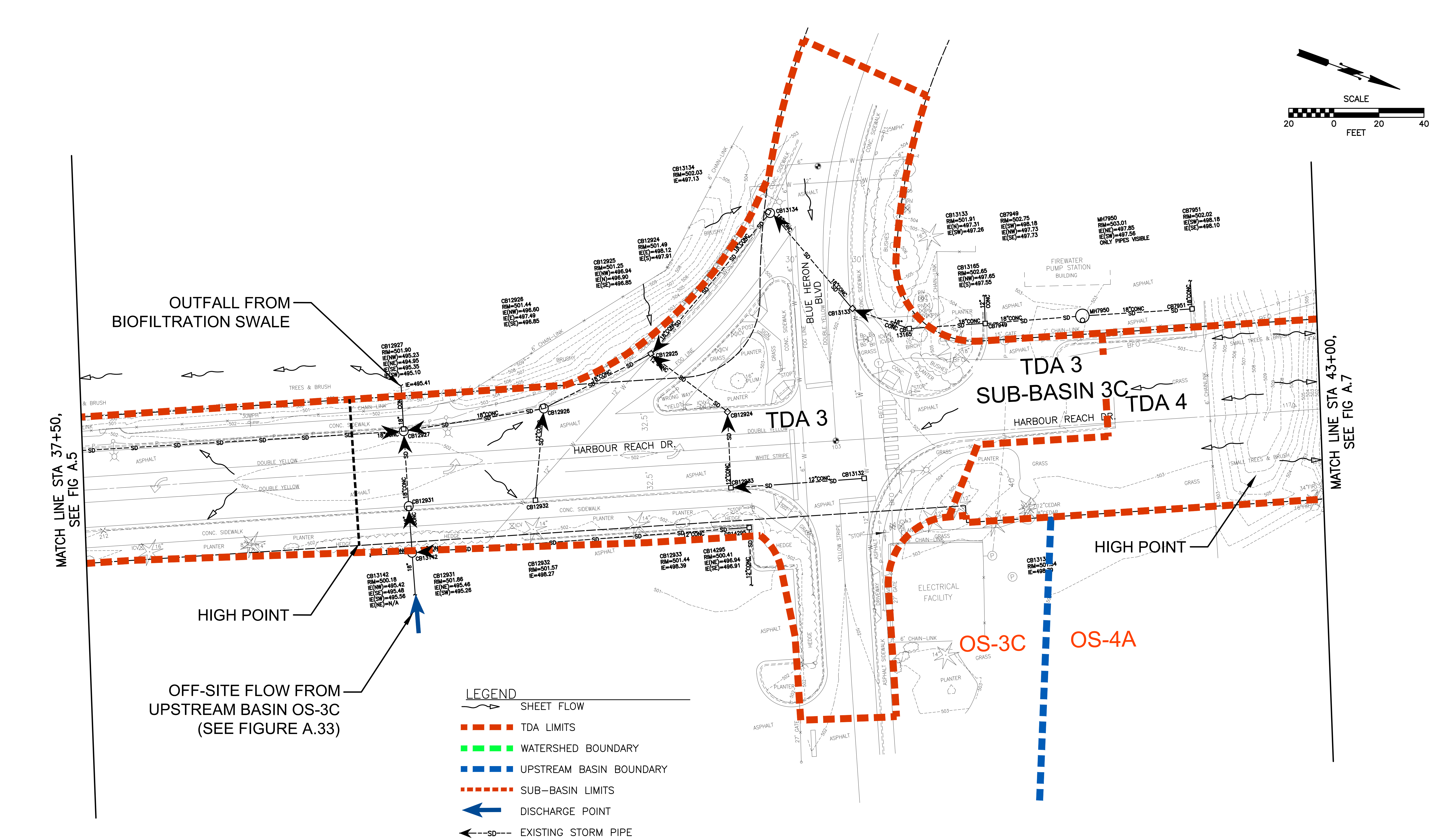
HARBOUR REACH EXTENSION

EXISTING CONDITIONS

FIGURE A.5

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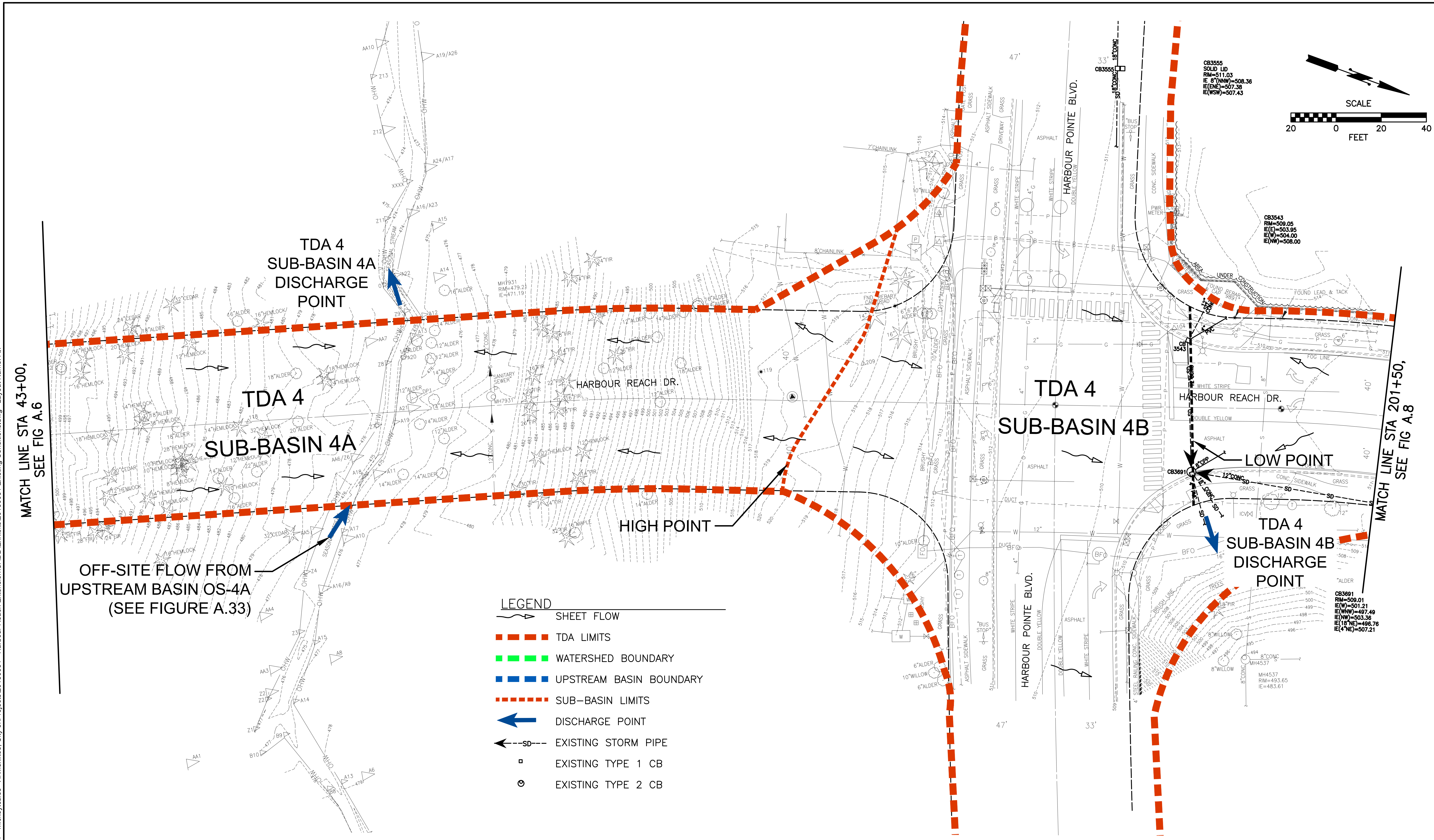
HARBOUR REACH EXTENSION

EXISTING CONDITIONS

FIGURE A.6





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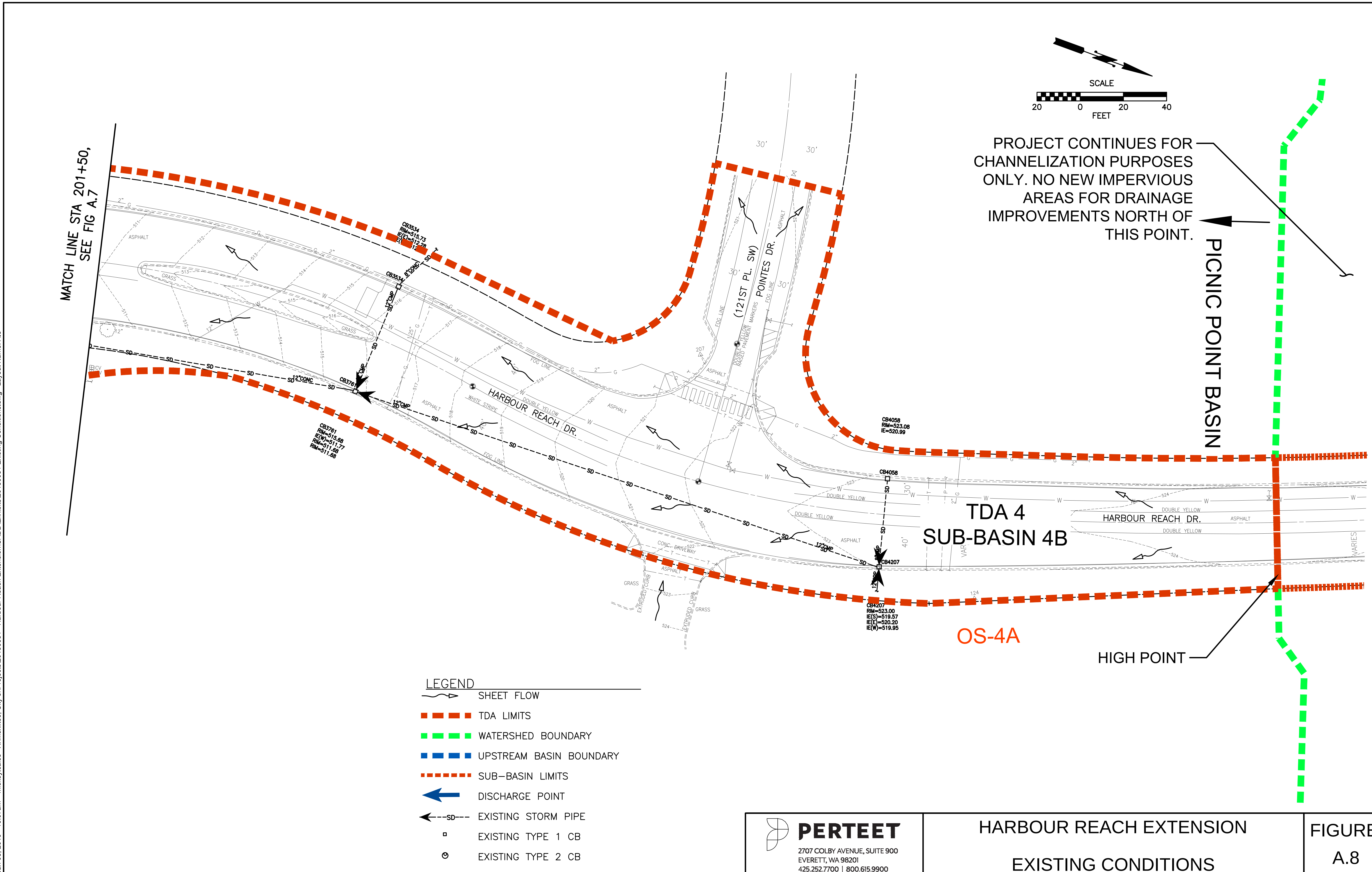
HARBOUR REACH EXTENSION

EXISTING CONDITIONS

FIGURE A.7


MATCH LINE STA 201+50, SEE FIG A.7
SCALE
20 0 20 40
FEET
PROJECT CONTINUES FOR CHANNELIZATION PURPOSES ONLY. NO NEW IMPERVIOUS AREAS FOR DRAINAGE IMPROVEMENTS NORTH OF THIS POINT.
PICNIC POINT BASIN
(121ST PL. SW) POINTES DR.
HARBOUR REACH DR.
TDA 4
SUB-BASIN 4B
OS-4A
HIGH POINT
CB3761
RIM=515.68
IE(W)=511.77
RIM=511.68
CB4058
RIM=523.08
IE=520.99
CB4207
RIM=523.00
IE(S)=519.57
IE(E)=520.20
IE(W)=519.95
LEGEND
SHEET FLOW
TDA LIMITS
WATERSHED BOUNDARY
UPSTREAM BASIN BOUNDARY
SUB–BASIN LIMITS
DISCHARGE POINT
EXISTING STORM PIPE
EXISTING TYPE 1 CB
EXISTING TYPE 2 CB
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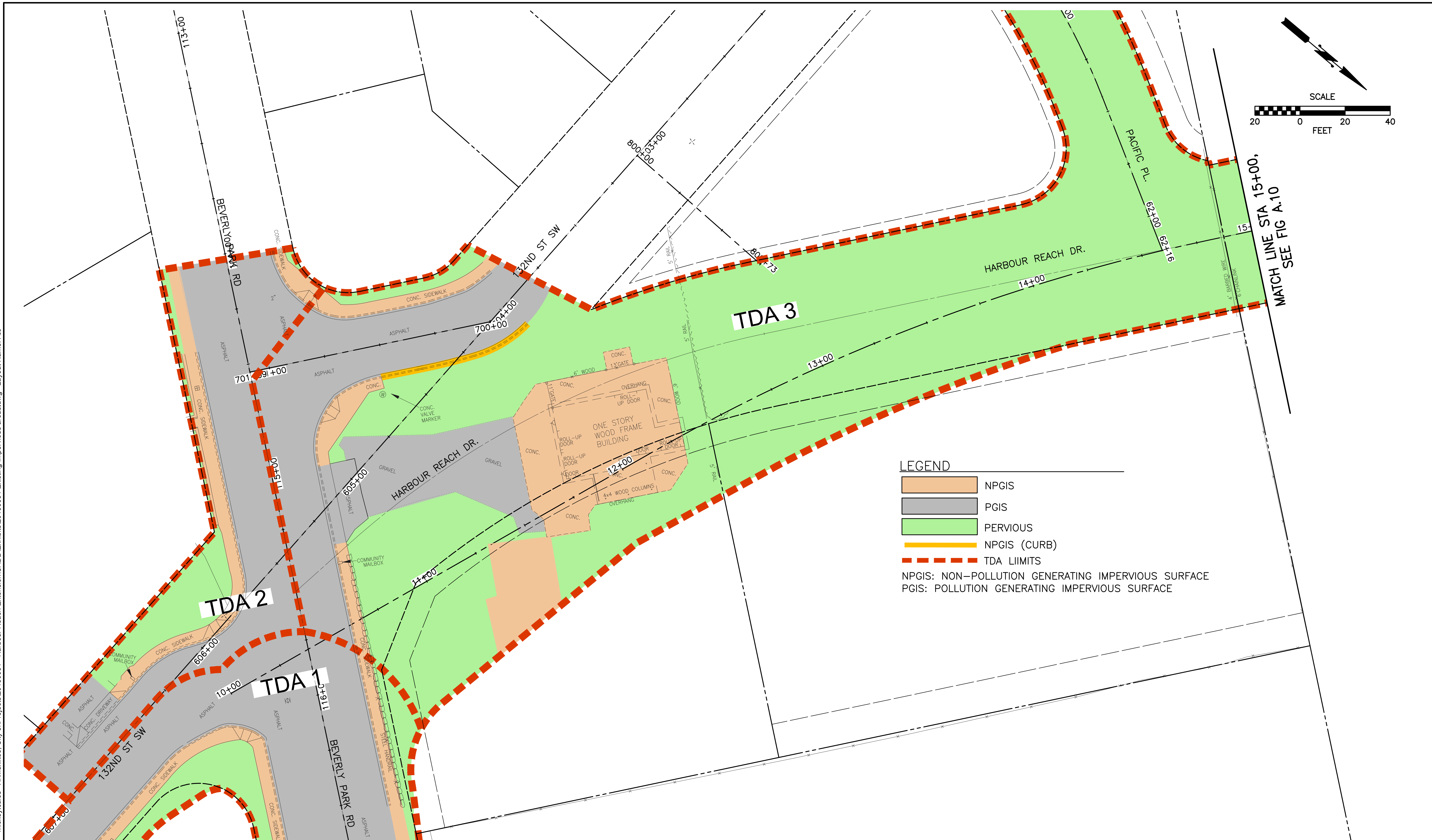
HARBOUR REACH EXTENSION
EXISTING CONDITIONS
FIGURE
A.8

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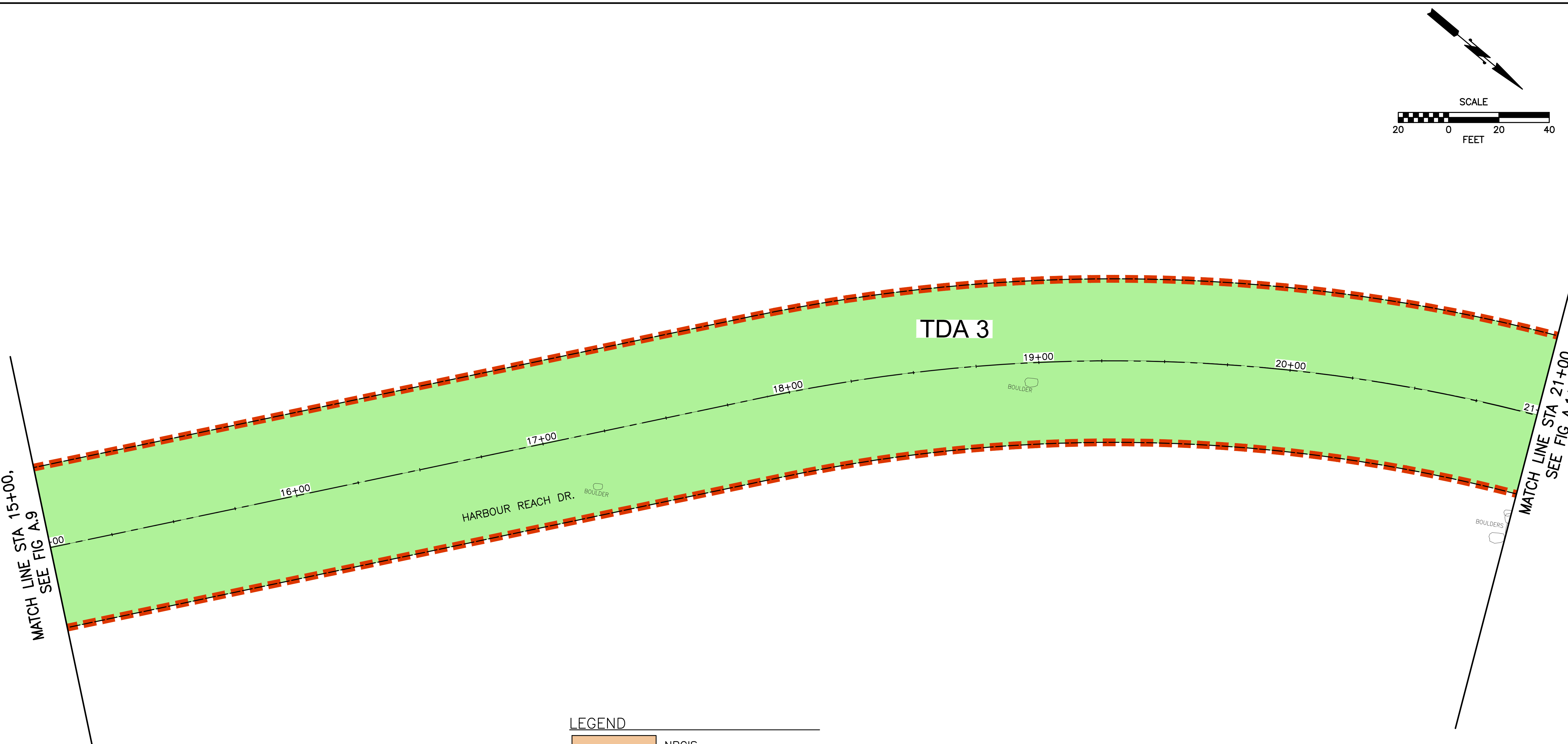
HARBOUR REACH EXTENSION

EXISTING IMPERVIOUS AREAS

FIGURE A.9




LEGEND

NPGIS
PGIS
PERVIOUS
NPGIS (CURB)
TDA LIIMITS

NPGIS: NON-POLLUTION GENERATING IMPERVIOUS SURFACE
PGIS: POLLUTION GENERATING IMPERVIOUS SURFACE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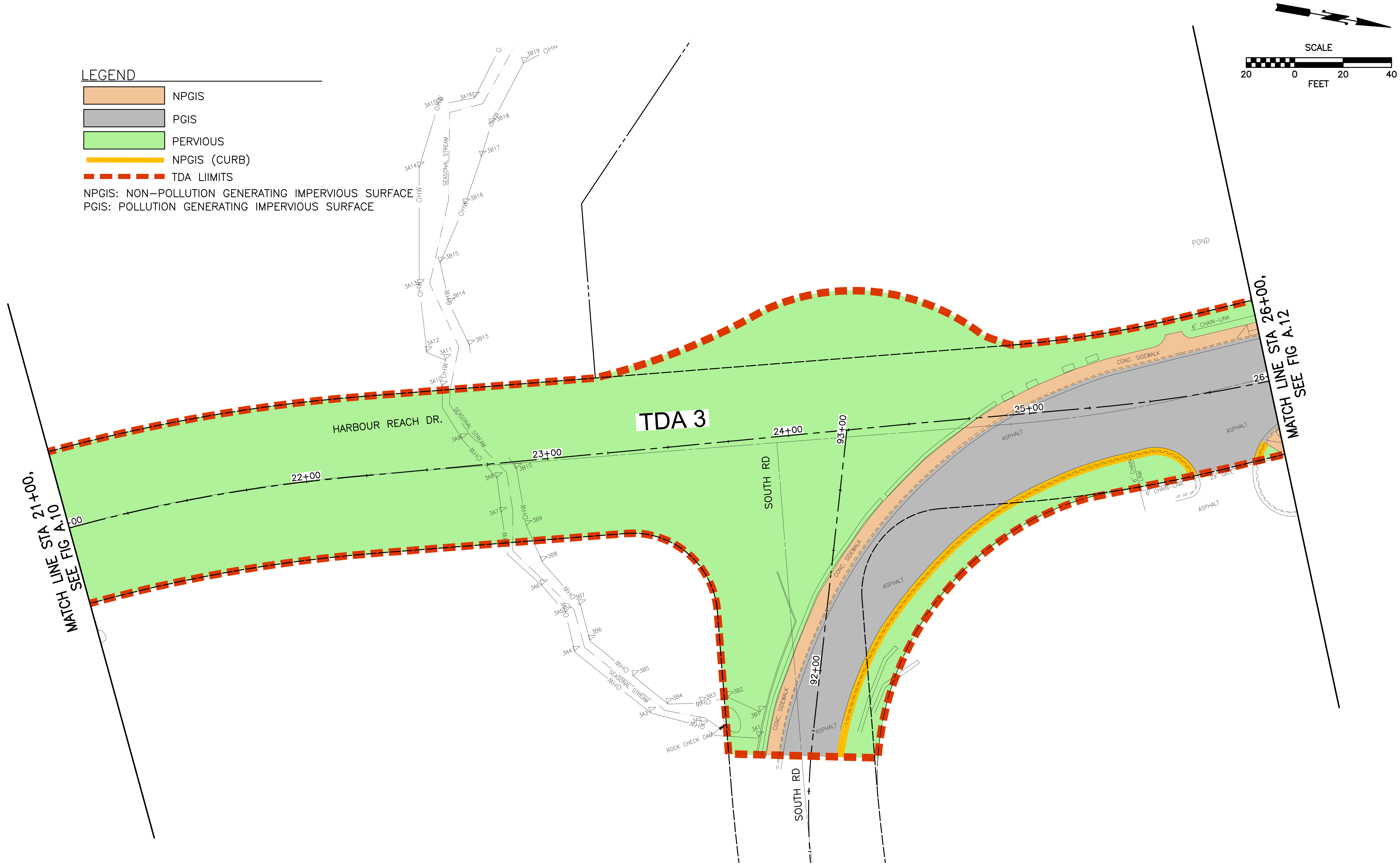
HARBOUR REACH EXTENSION

EXISTING IMPERVIOUS AREAS

FIGURE A.10




Jan 03, 2019 - 9:58am mickey.cales X:\Mukilteo, City of\Projects\20150051 - Harbour Reach Extension\CADD\Exhibits\20150051 Existing Impervious areas.dwg Layout Name: A.11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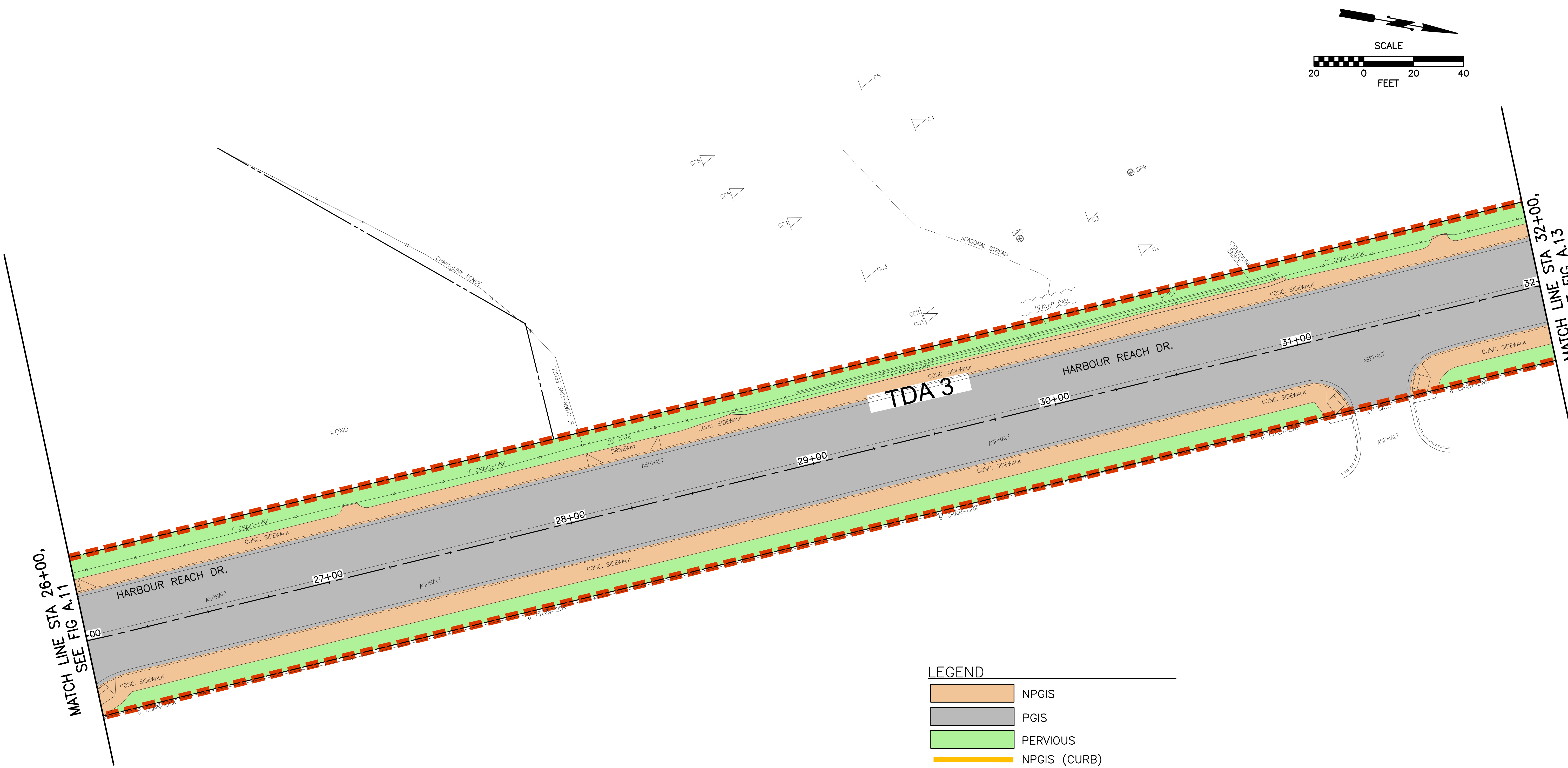
HARBOUR REACH EXTENSION

EXISTING IMPERVIOUS AREAS

FIGURE A.11




LEGEND

| | |
|---|---|
| (orange fill) | NPGIS |
| (gray fill) | PGIS |
| (green fill) | PERVIOUS |
| (yellow line) | NPGIS (CURB) |
| (red dashed line) | TDA LIIMITS |

NPGIS: NON–POLLUTION GENERATING IMPERVIOUS SURFACE
PGIS: POLLUTION GENERATING IMPERVIOUS SURFACE

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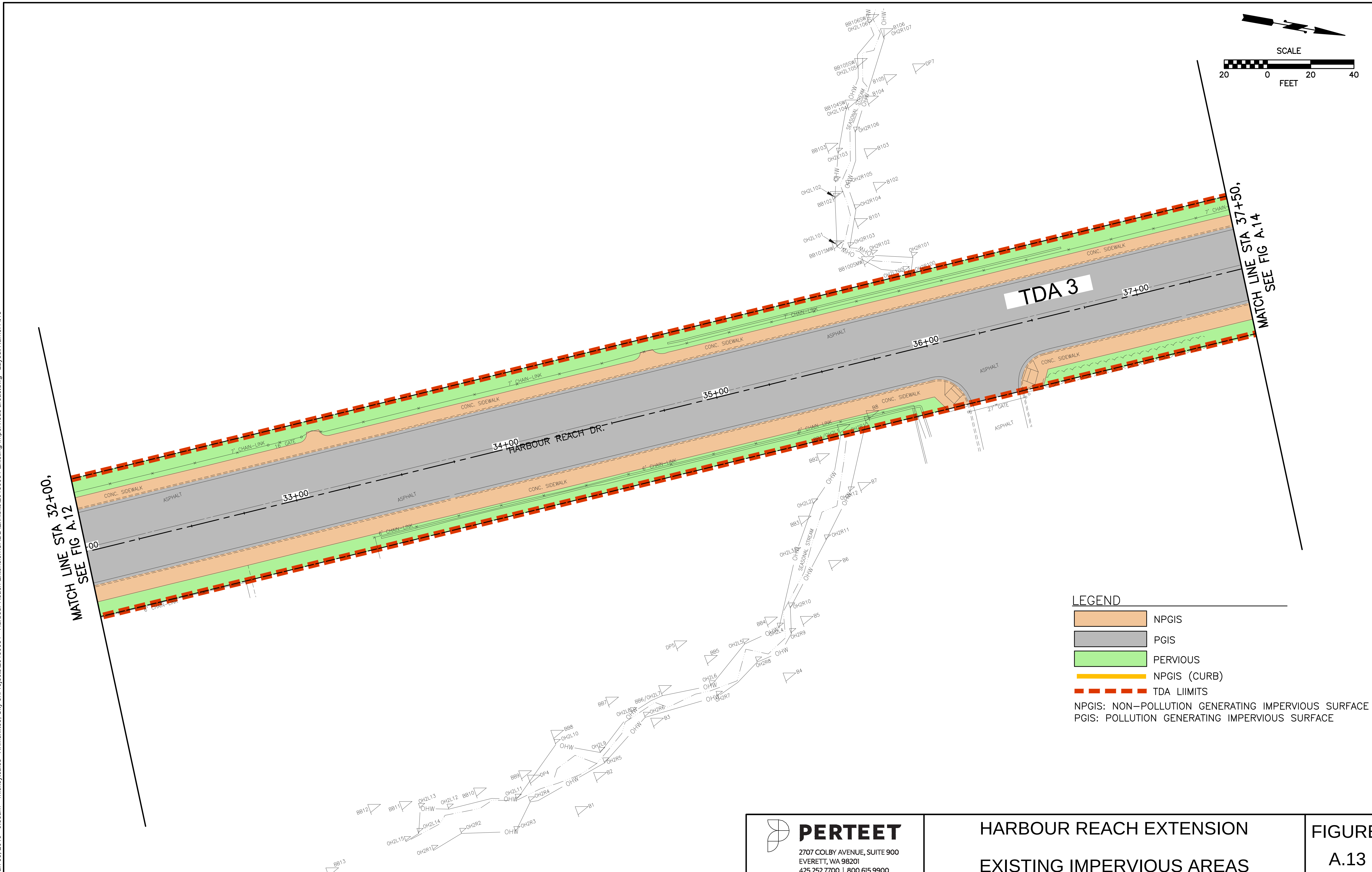
HARBOUR REACH EXTENSION

EXISTING IMPERVIOUS AREAS

FIGURE A.12




HARBOUR REACH EXTENSION

EXISTING IMPERVIOUS AREAS

FIGURE A.13


LEGEND

- NPGIS
- PGIS
- PERVIOUS
- NPGIS (CURB)
- TDA LIIMITS

NPGIS: NON–POLLUTION GENERATING IMPERVIOUS SURFACE
PGIS: POLLUTION GENERATING IMPERVIOUS SURFACE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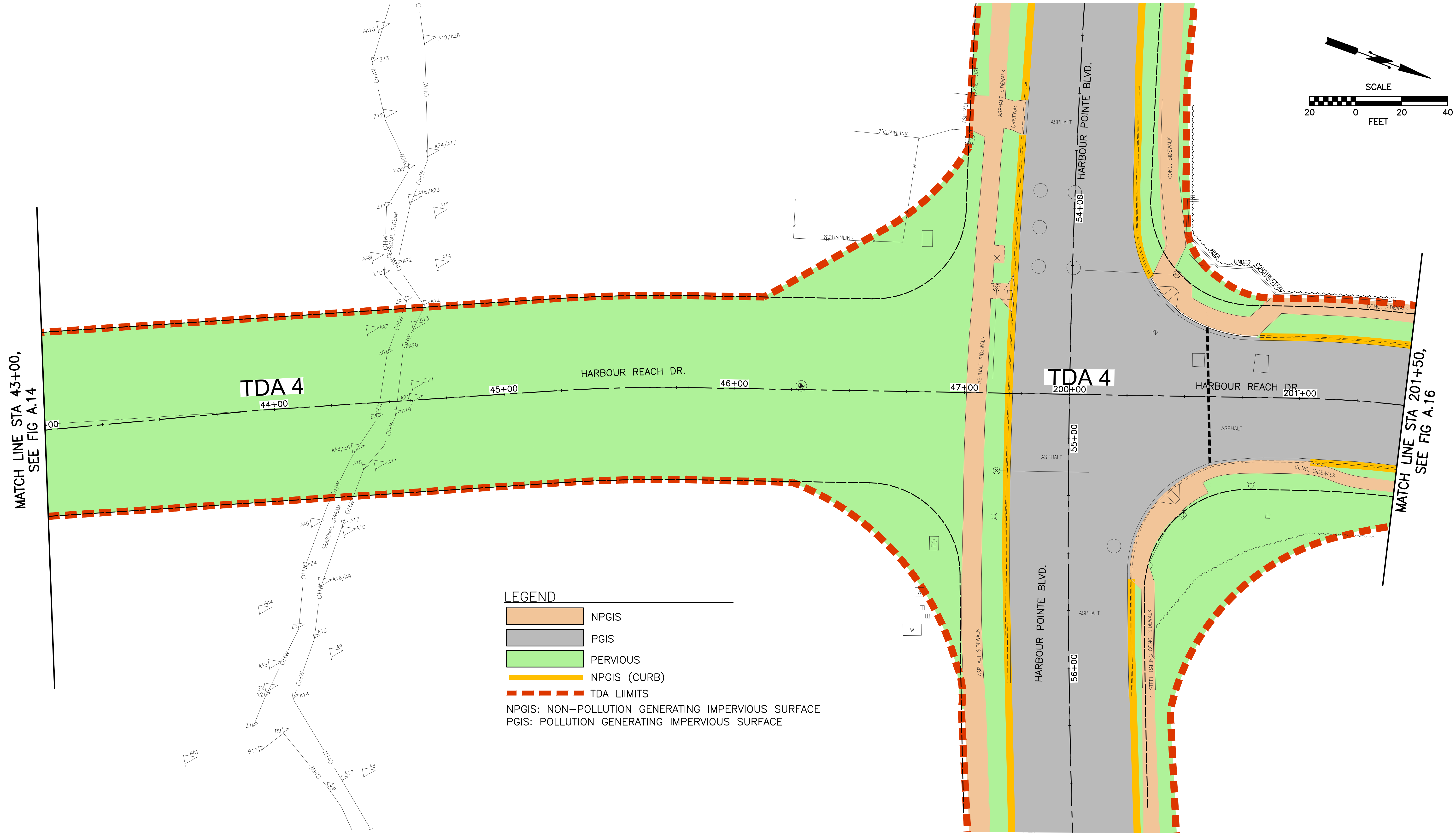
HARBOUR REACH EXTENSION

EXISTING IMPERVIOUS AREAS

FIGURE A.14




LEGEND

- NPGIS
- PGIS
- PERVIOUS
- NPGIS (CURB)
- TDA LIIMITS

NPGIS: NON–POLLUTION GENERATING IMPERVIOUS SURFACE
PGIS: POLLUTION GENERATING IMPERVIOUS SURFACE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HARBOUR REACH EXTENSION

EXISTING IMPERVIOUS AREAS

FIGURE A.15


LEGEND

- NPGIS
- PGIS
- PERVIOUS
- NPGIS (CURB)
- TDA LIIMITS

NPGIS: NON-POLLUTION GENERATING IMPERVIOUS SURFACE
PGIS: POLLUTION GENERATING IMPERVIOUS SURFACE

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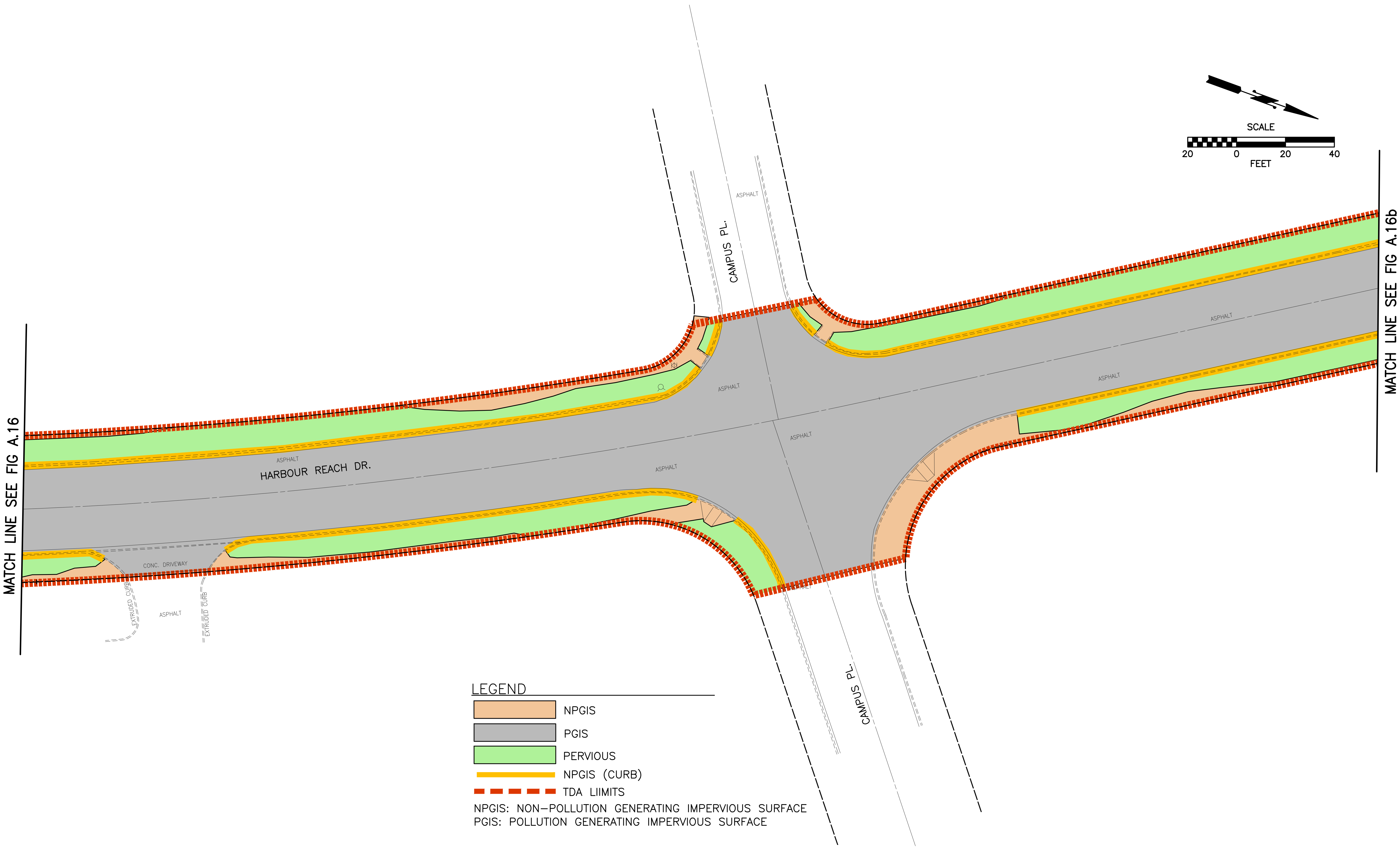
HARBOUR REACH EXTENSION

EXISTING IMPERVIOUS AREAS

FIGURE A.16




LEGEND

- NPGIS
- PGIS
- PERVIOUS
- NPGIS (CURB)
- TDA LIIMITS

NPGIS: NON-POLLUTION GENERATING IMPERVIOUS SURFACE
PGIS: POLLUTION GENERATING IMPERVIOUS SURFACE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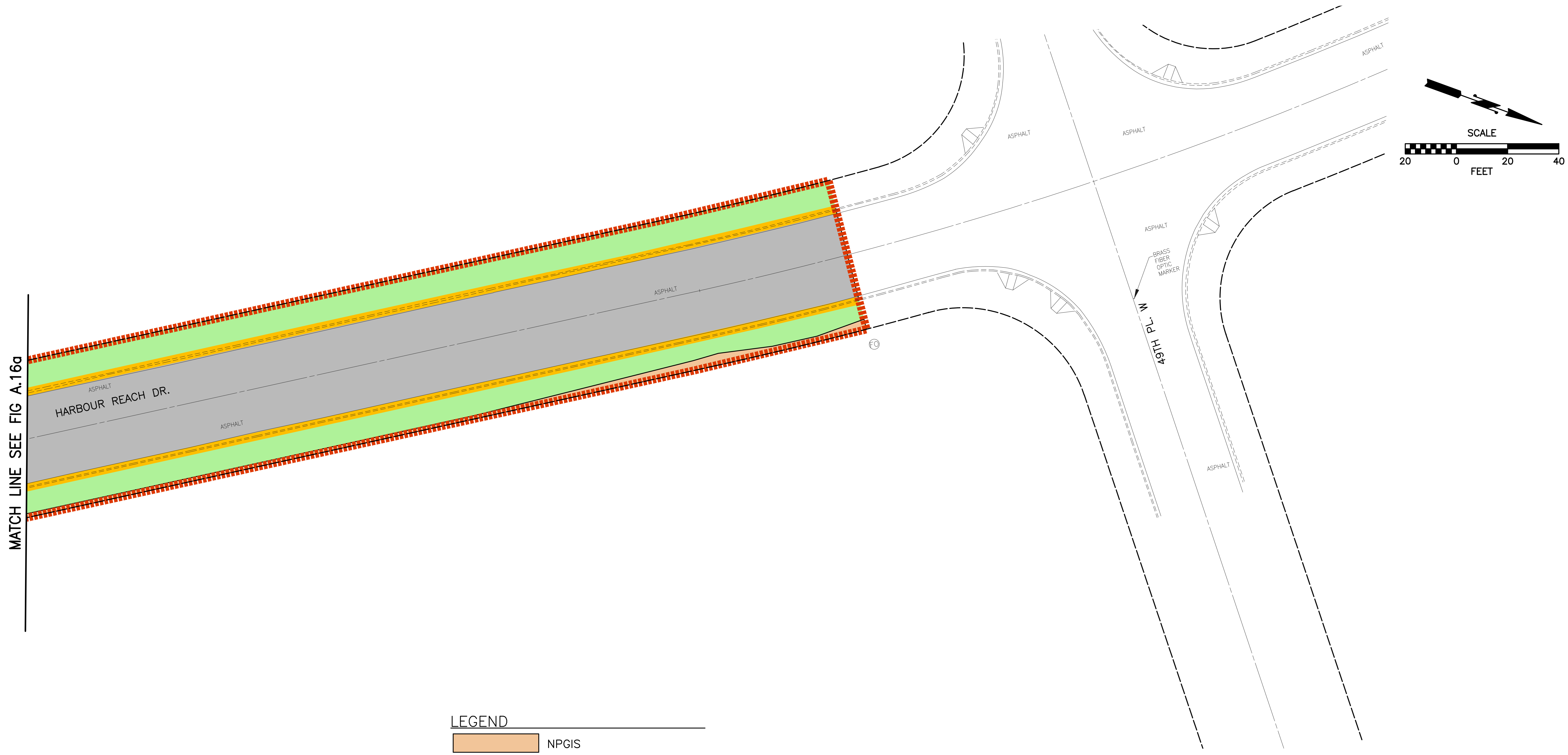
HARBOUR REACH EXTENSION

EXISTING IMPERVIOUS AREAS

FIGURE A.16a




LEGEND

- NPGIS
- PGIS
- PERVIOUS
- NPGIS (CURB)
- TDA LIIMITS

NPGIS: NON–POLLUTION GENERATING IMPERVIOUS SURFACE
PGIS: POLLUTION GENERATING IMPERVIOUS SURFACE

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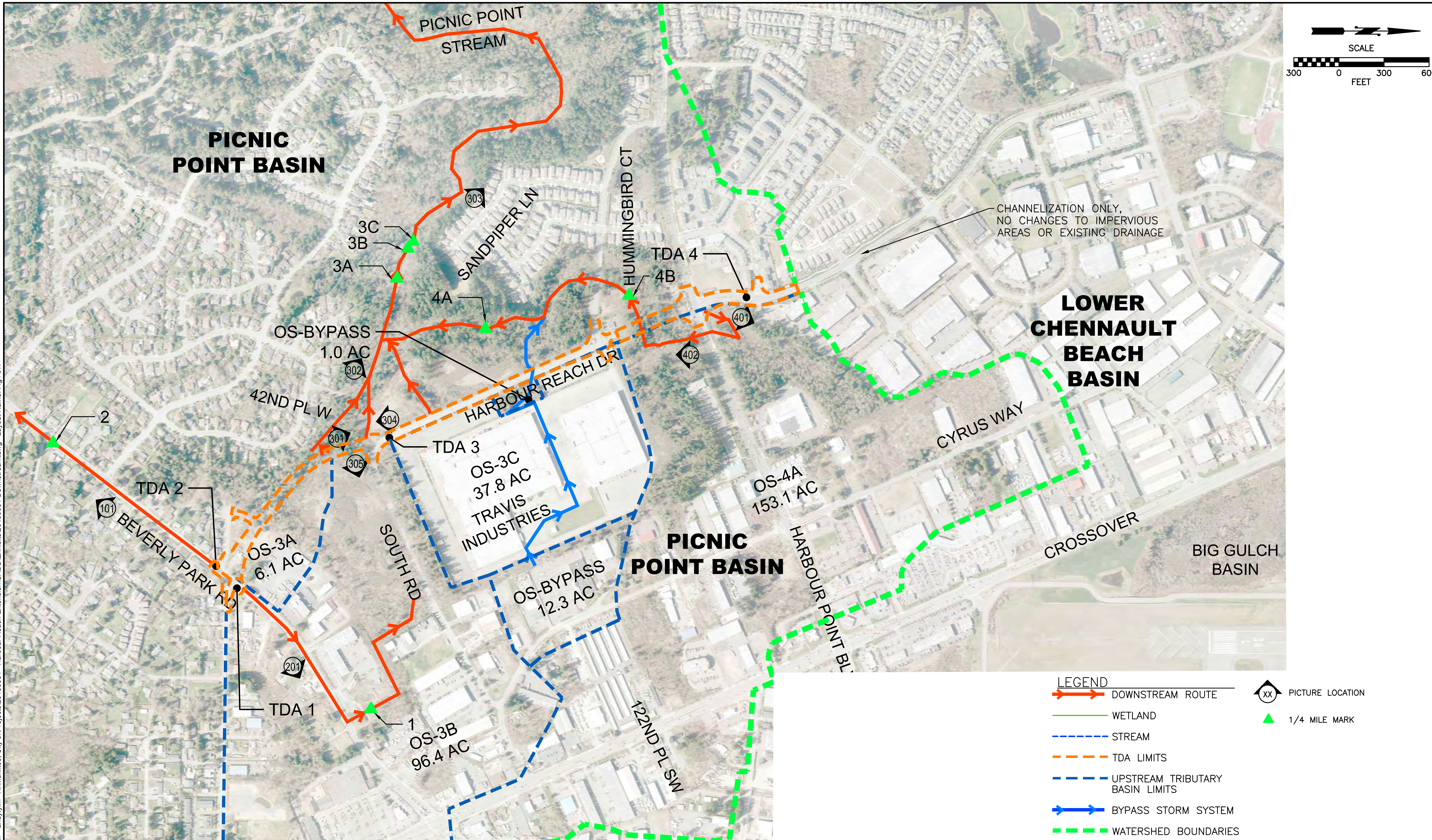
HARBOUR REACH EXTENSION

EXISTING IMPERVIOUS AREAS

FIGURE A.16b

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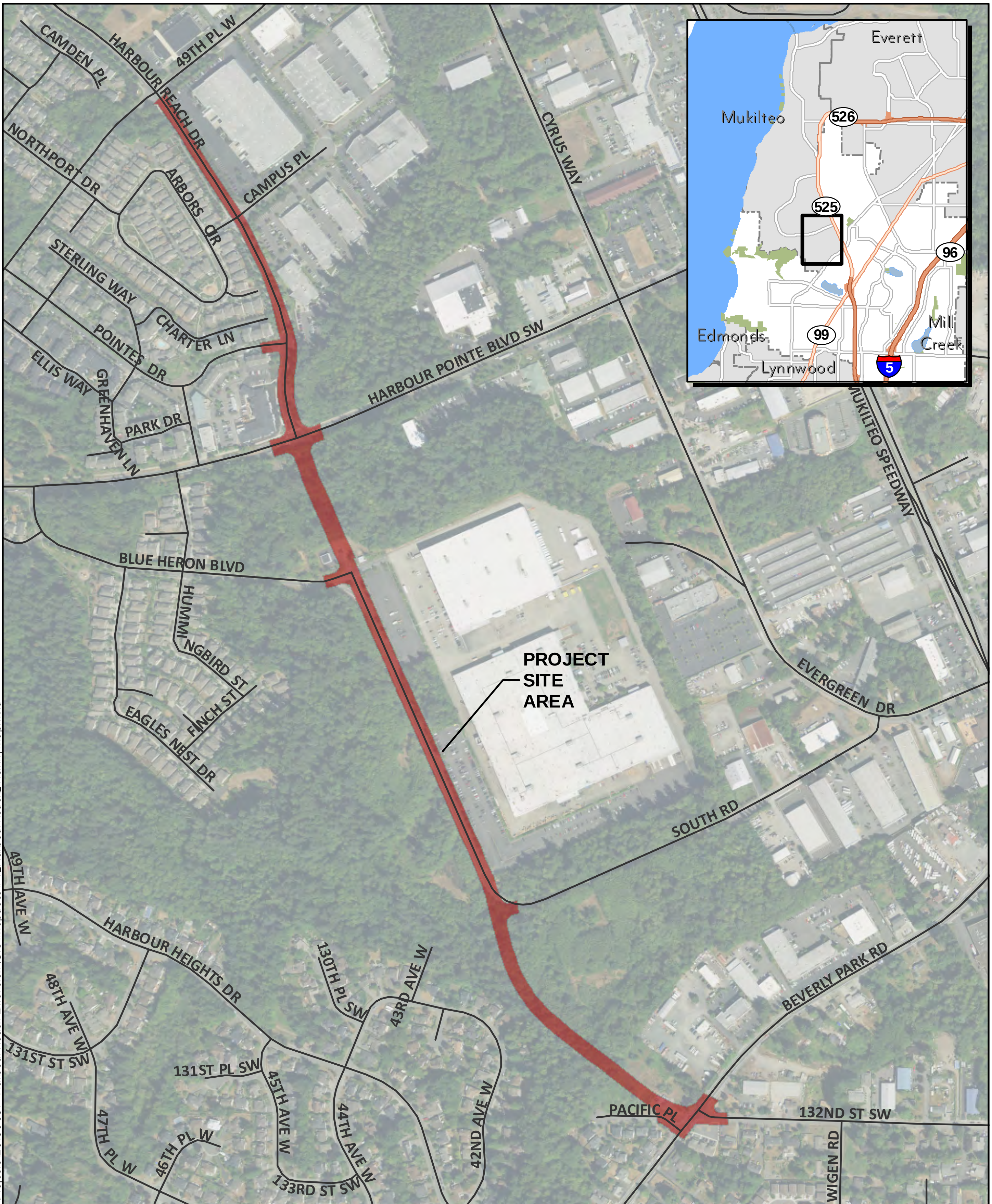
HARBOUR REACH EXTENSION

DOWNSTREAM ROUTES & UPSTREAM BASINS

FIGURE A.17




PERTEET

0 300 600
Feet

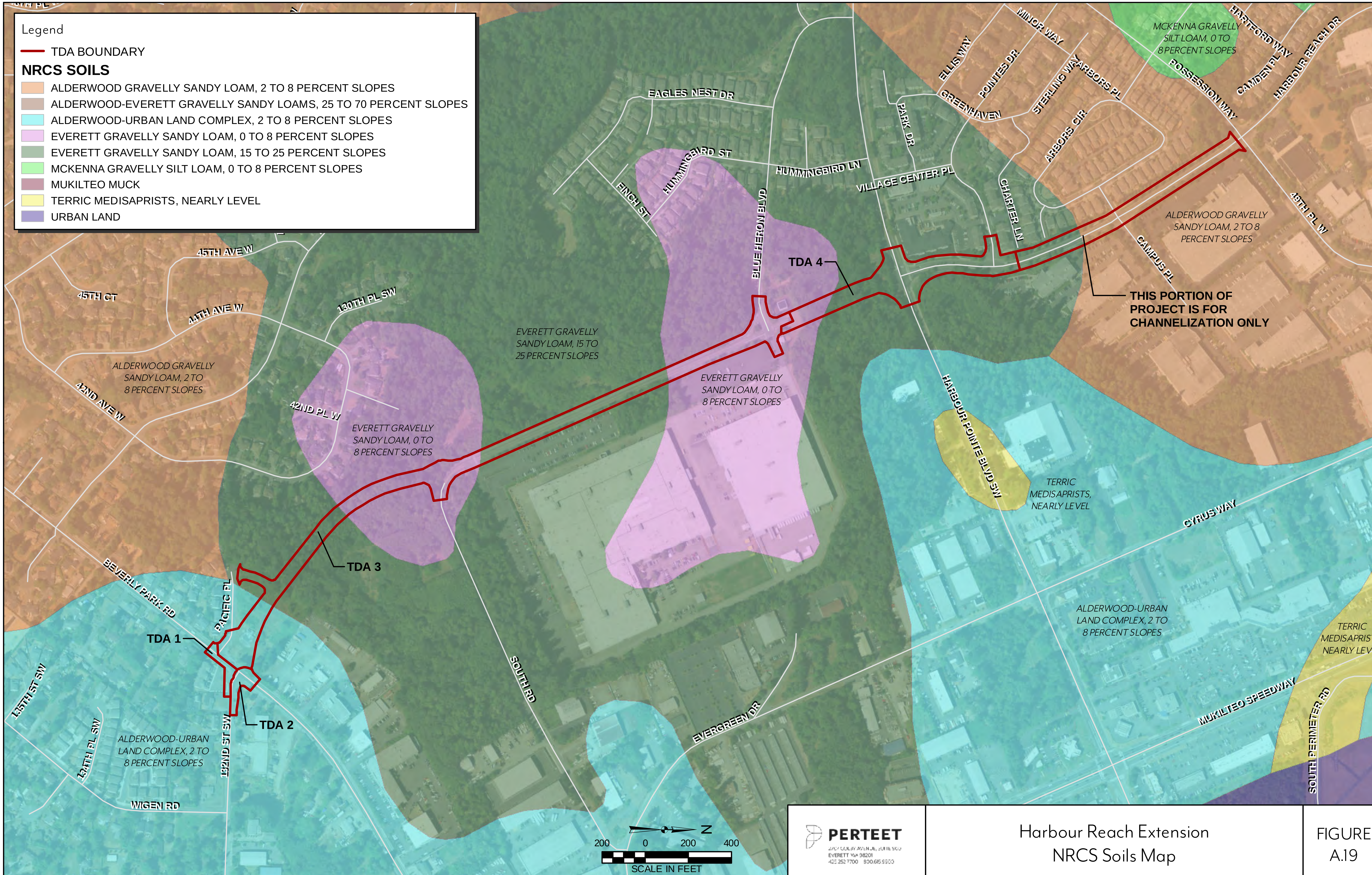
Legend
Project Site Area

Harbour Reach Extension
Vicinity Map

Figure A.18

Path: X:\Mukilteo, City of\Projects\20150051 - Harbour Reach Extension\GIS\Mapdocs\PT_HarbourReach_VicinityMap.mxd

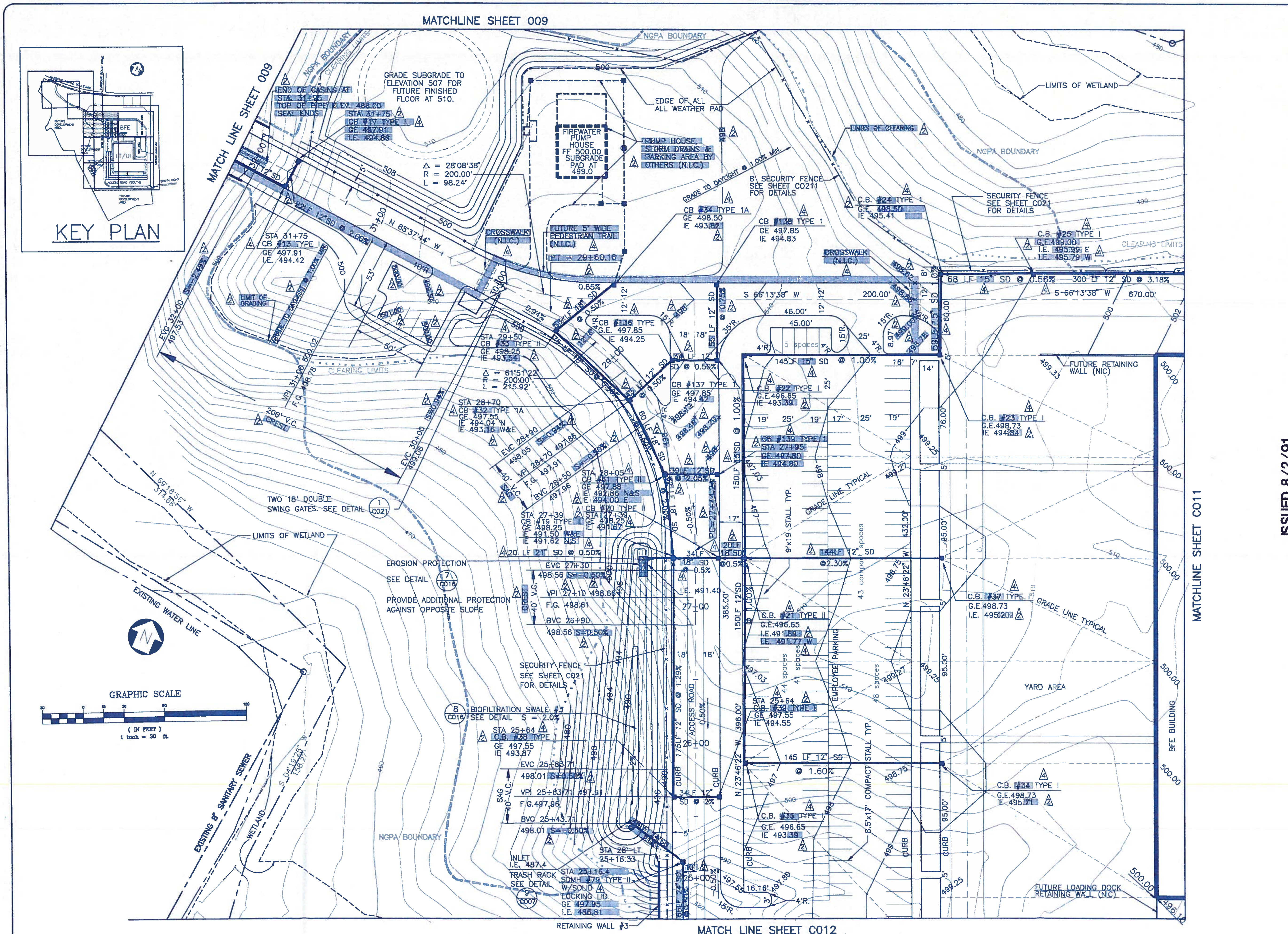
Source: Snohomish County




Harbour Reach Extension
NRCS Soils Map

FIGURE A.19

Sec. 27 & 28, T. 28 N., R. 4 E., W.M.




ISSUED 8/2/91

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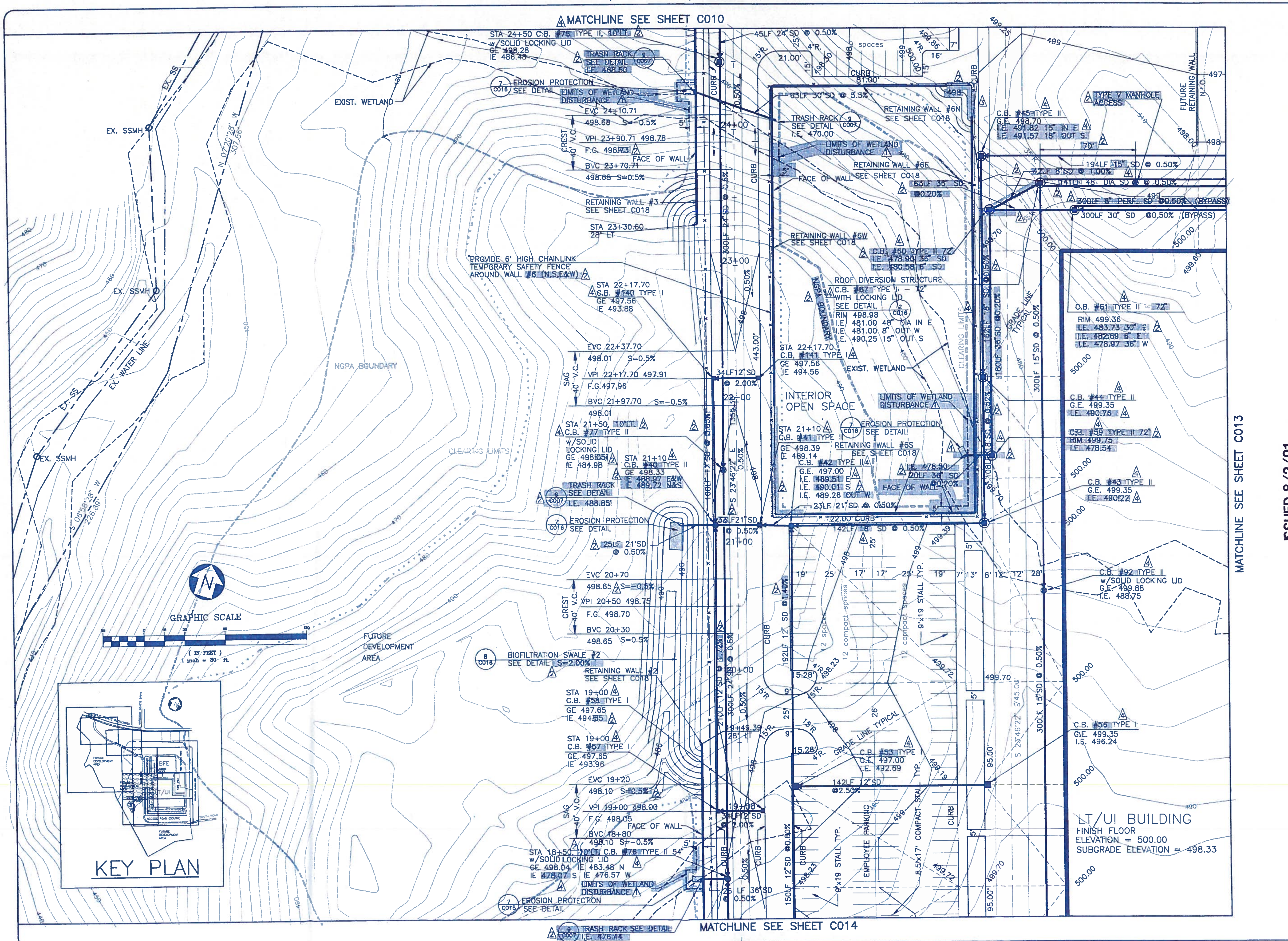
P.O. Box C-97304
Bellevue, WA 98009-9304
PLANNING • ENGINEERING • SURVEYING • LANDSCAPE ARCHITECTURE

HARBOUR POINTE LIMITED PARTNERSHIP
HARBOUR POINTE INDUSTRIAL PARK PHA
GRADING & DRAINAGE PLAN
INITIAL GRADING CONTRACT
MUKILTEO WASHINGTON

Date 5/3/91
Scale 1"=30'
Designed
Drawn CEC
Checked EWW
Approved
Dwg. Number 3-0423-0203-1.56
Filename 0423C10
SHEET C010 of 25

Sec. 27 & 28, T. 28 N., R. 4 E., W.M.

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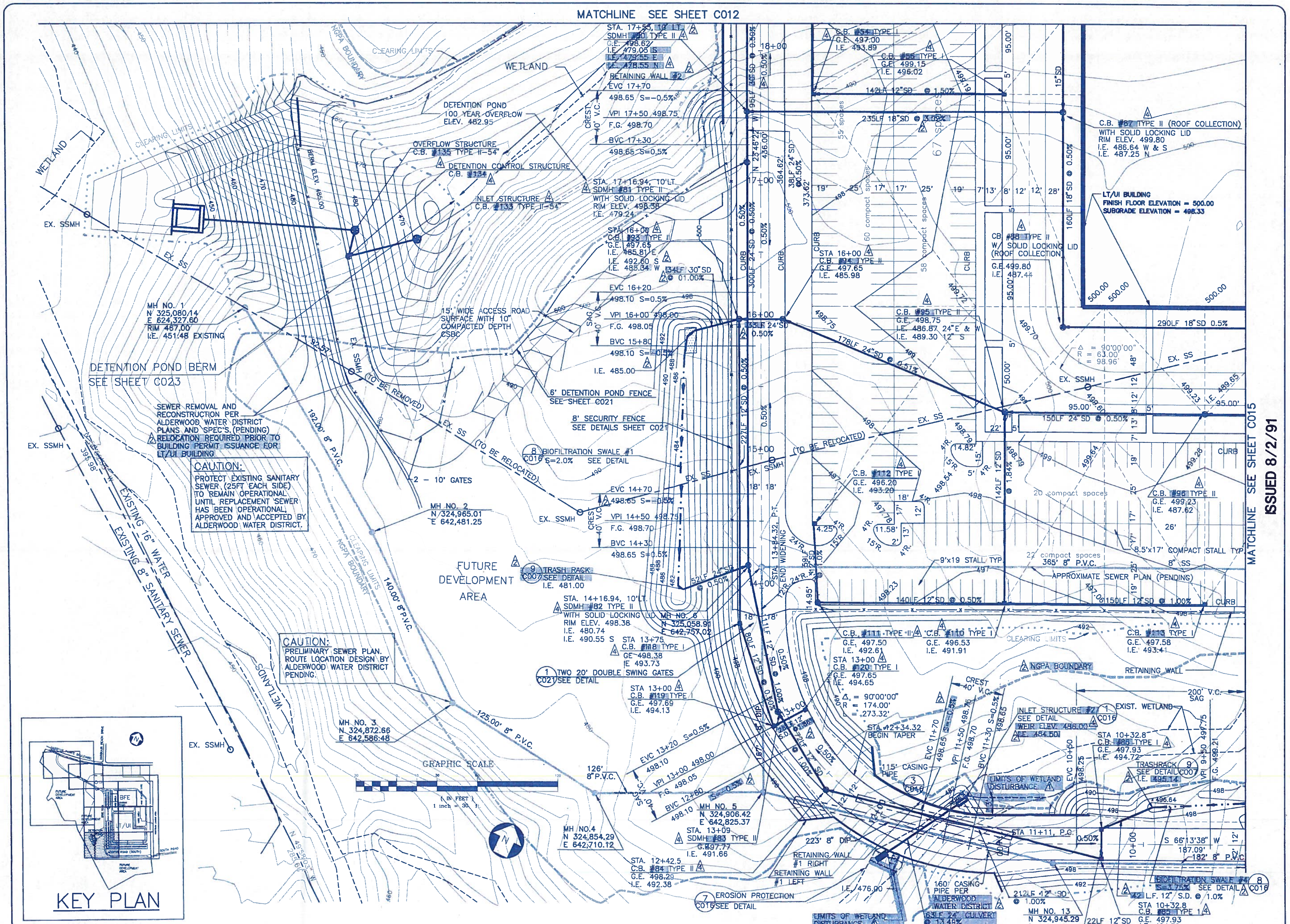
HARBOUR POINTE LIMITED PARTNERSHIP
HARBOUR POINTE INDUSTRIAL PARK PHASE 1
GRADING & DRAINAGE PLAN
INITIAL GRADING CONTRACT
MUKILTEO WASHINGTON

| Revisions | By | Date |
|---|---|---|
| REVISED PER SNO CO COMMENTS | | 8/1/91 |
| REVISED PER SNO CO COMMENTS | | 7/31/91 |
| ADDED ADDITIONAL SITE INFORMATION AND REVISED CALLOUTS | | 6/26/91 |
| ADDED LIMITS OF WETLAND DISTURBANCE | | 6/10/91 |
| REVISED & ISSUED FOR CONSTRUCTION | | 5/24/91 |

Date MAY 3, 1991
Scale 1" = 30'
Designed MDC/JPM
Drawn JPM/MH
Checked EWW
Approved X
Dwg. Number 3-0423-0203-1.54
Filename 0423C12
SHEET C012 of 25




ISSUED 8/2/91

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W&H
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P.O. Box C-97304
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EUGENE W. WRIGHT — REGISTERED PROFESSIONAL ENGINEER

HARBOUR POINTE LIMITED PARTNERSHIP
HARBOUR POINTE INDUSTRIAL PARK PHASE 1
GRADING & DRAINAGE PLAN
INITIAL GRADING CONTRACT
MUKILTEO — WASHINGTON

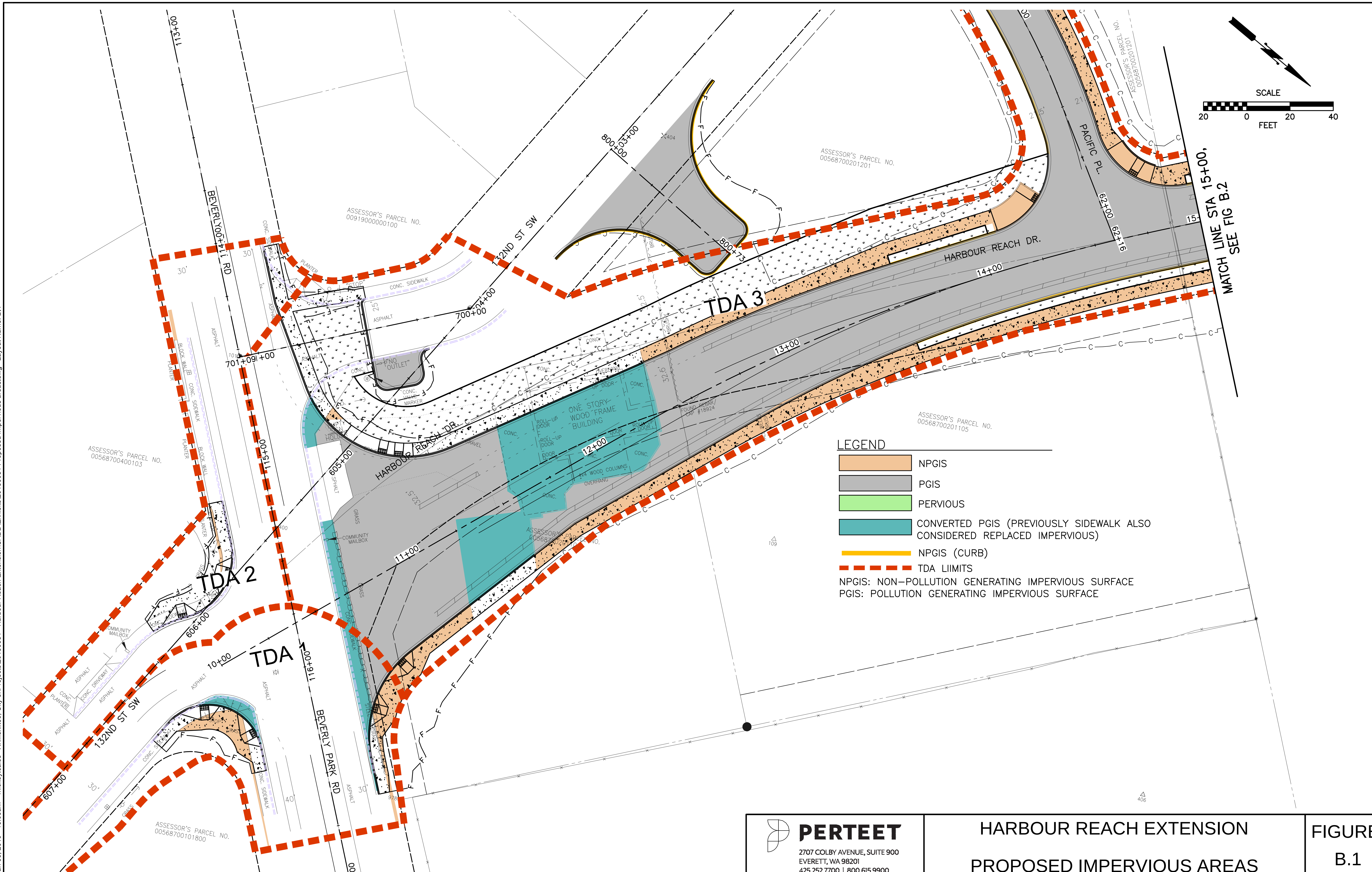
| Revisions | By | Date |
|---|---|---|
| REVISED & ISSUED FOR CONSTRUCTION | | 5/24/91 |
| ADDED LIMITS OF WETLAND DISTURBANCE | | 6/10 |
| ADDED ADDITIONAL SITE DETAILS & REVISED CALLOUTS | | 7/12/91 |
| REVISED PER SHO CO | | 7/26/91 |
| Revised per Sno Co Comments | | 8/1/91 |

Date 5-24-91
Scale 1"=30'
Designed MDC JPM
Drawn JPM
Checked EWW
Approved
Dwg Number 3-0423-0203-1.54
Filename 0423C014
SHEET C014 of 25

# APPENDIX B

## Developed Condition Figures

Figures B.1 – B.8 Proposed Impervious Area Maps
Figure B.9 TDA Area Swap Exhibit
Figures B.10 – B.11 Equivalent Area Maps

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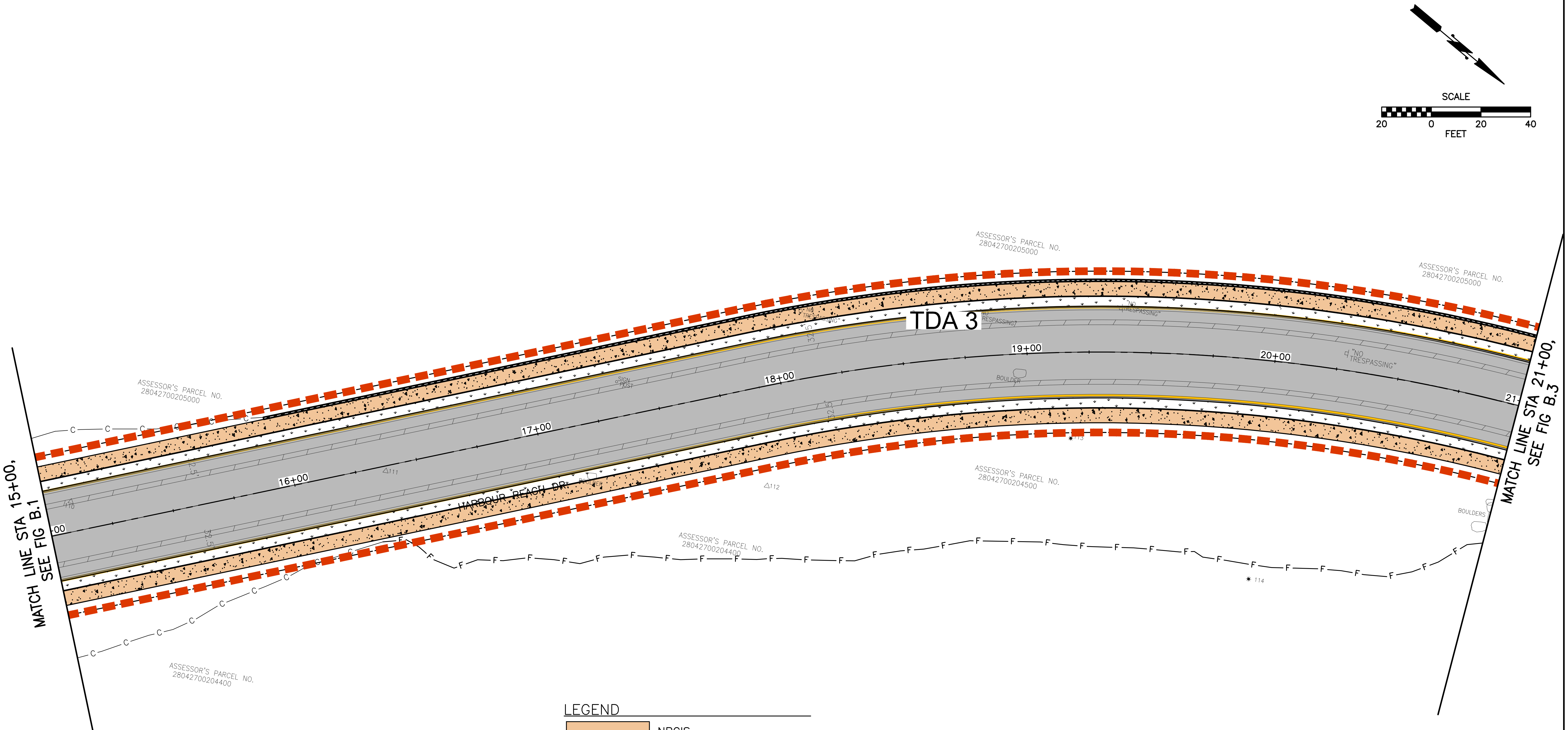
HARBOUR REACH EXTENSION

PROPOSED IMPERVIOUS AREAS

FIGURE B.1




LEGEND

- NPGIS
- PGIS
- PERVIOUS
- CONVERTED PGIS (PREVIOUSLY SIDEWALK ALSO CONSIDERED REPLACED IMPERVIOUS)
- NPGIS (CURB)
- TDA LIIMITS

NPGIS: NON-POLLUTION GENERATING IMPERVIOUS SURFACE
PGIS: POLLUTION GENERATING IMPERVIOUS SURFACE

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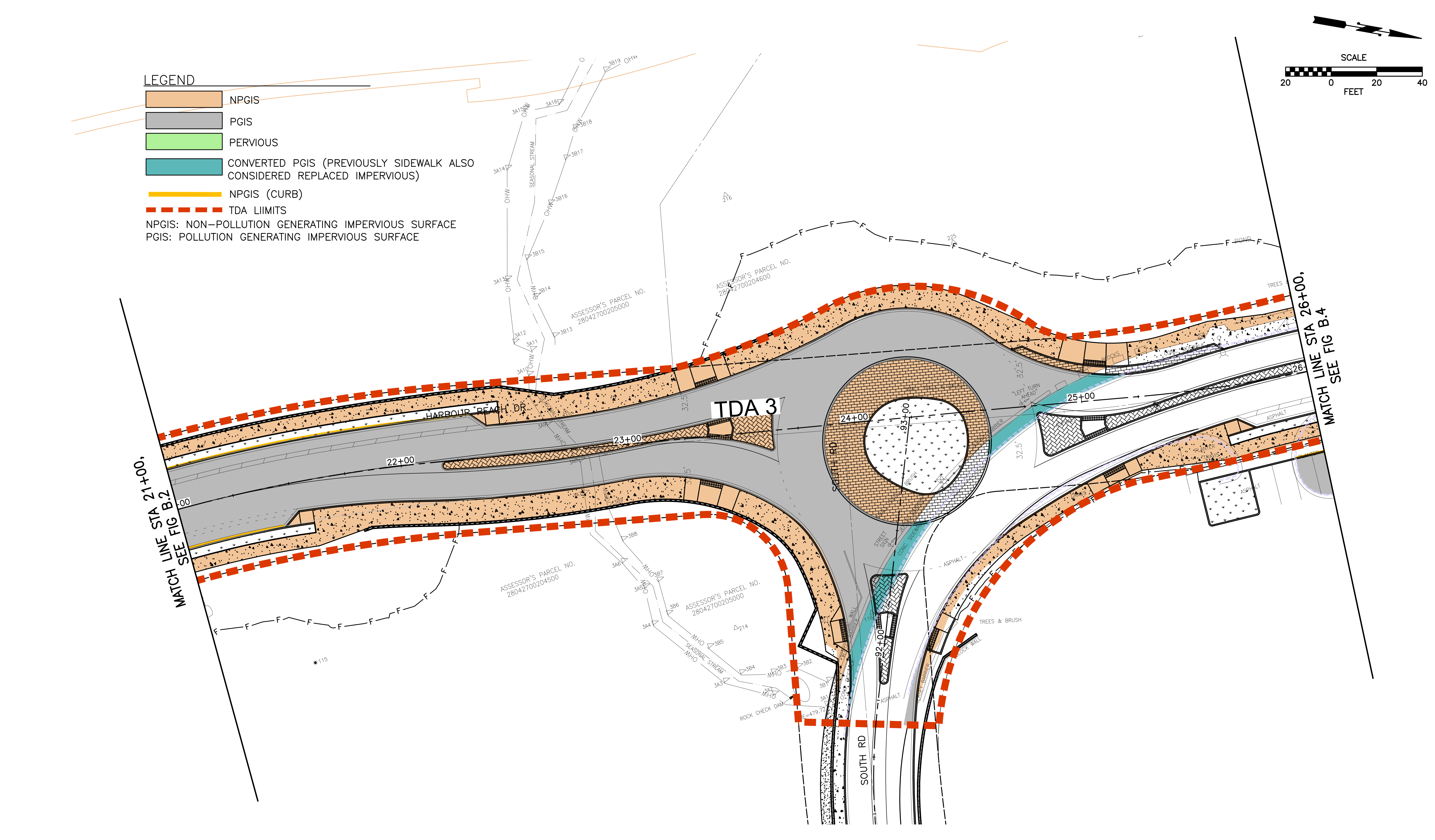
HARBOUR REACH EXTENSION

PROPOSED IMPERVIOUS AREAS

FIGURE B.2

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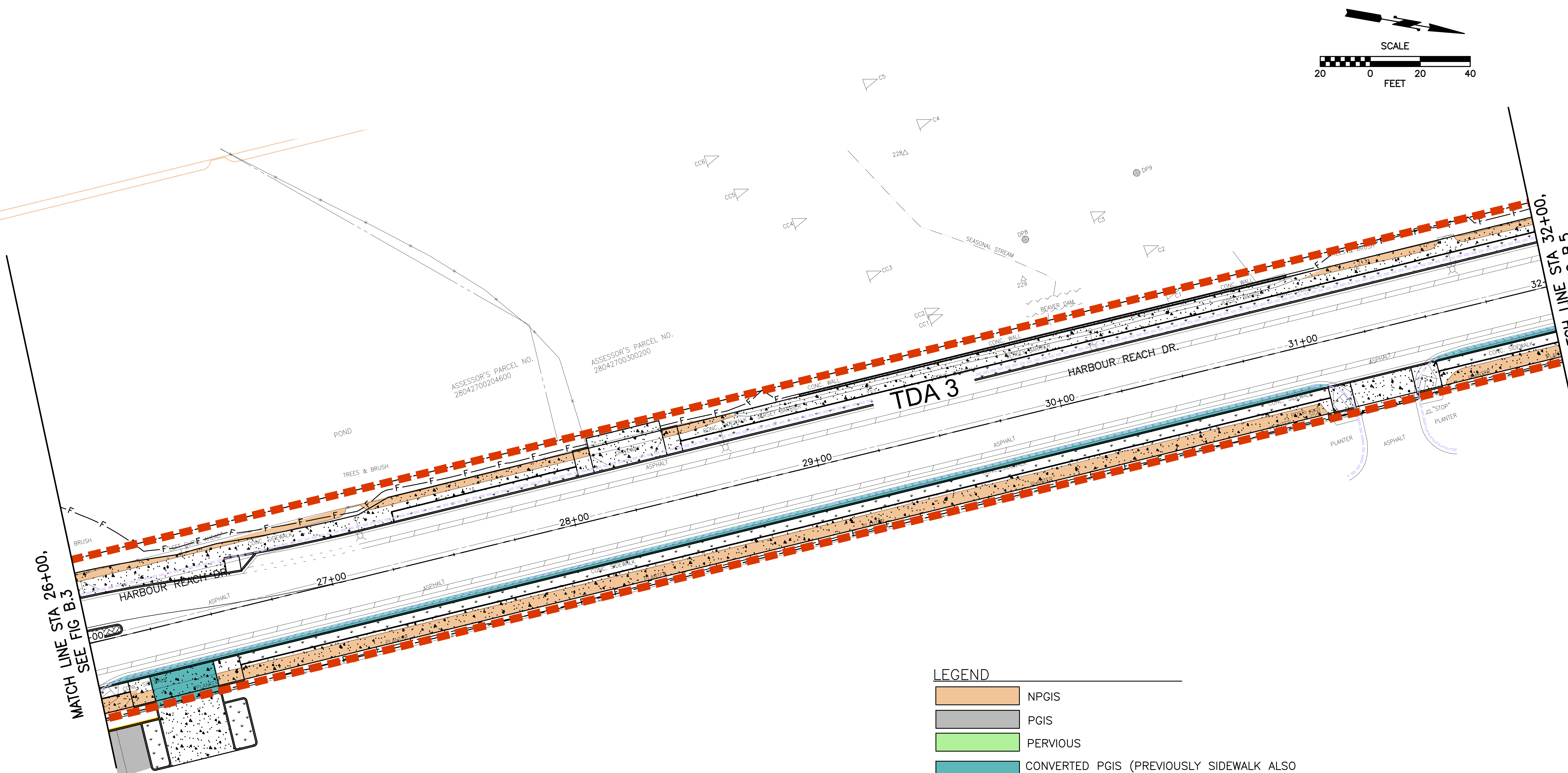
HARBOUR REACH EXTENSION

PROPOSED IMPERVIOUS AREAS

FIGURE B.3




LEGEND

- NPGIS
- PGIS
- PERVIOUS
- CONVERTED PGIS (PREVIOUSLY SIDEWALK ALSO CONSIDERED REPLACED IMPERVIOUS)
- NPGIS (CURB)
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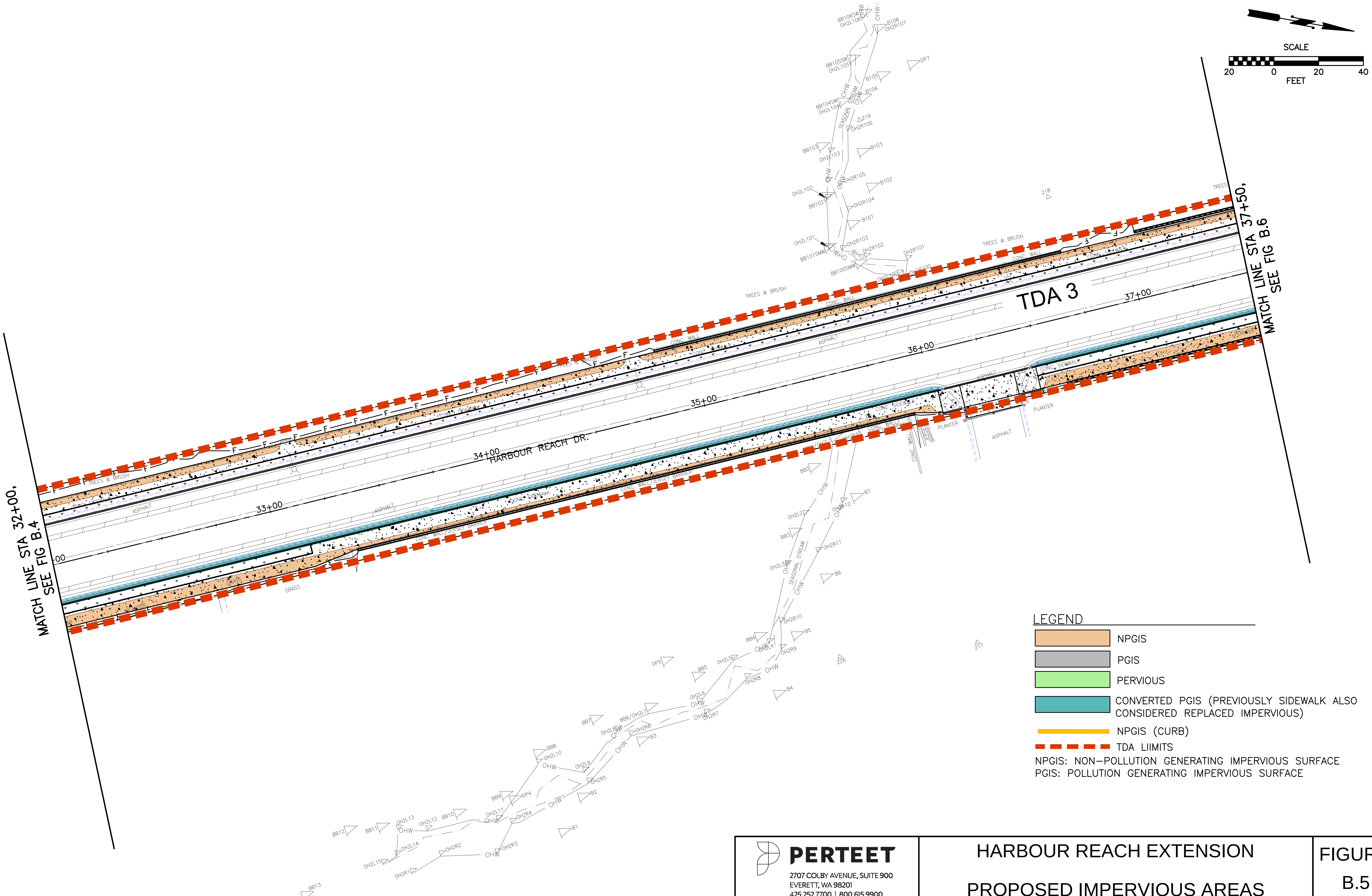
HARBOUR REACH EXTENSION

PROPOSED IMPERVIOUS AREAS

FIGURE B.4




## LEGEND

- NPGIS
- PGIS
- PERVIOUS
- CONVERTED PGIS (PREVIOUSLY SIDEWALK ALSO CONSIDERED REPLACED IMPERVIOUS)
- NPGIS (CURB)
- TDA LIIMITS

NPGIS: NON–POLLUTION GENERATING IMPERVIOUS SURFACE
PGIS: POLLUTION GENERATING IMPERVIOUS SURFACE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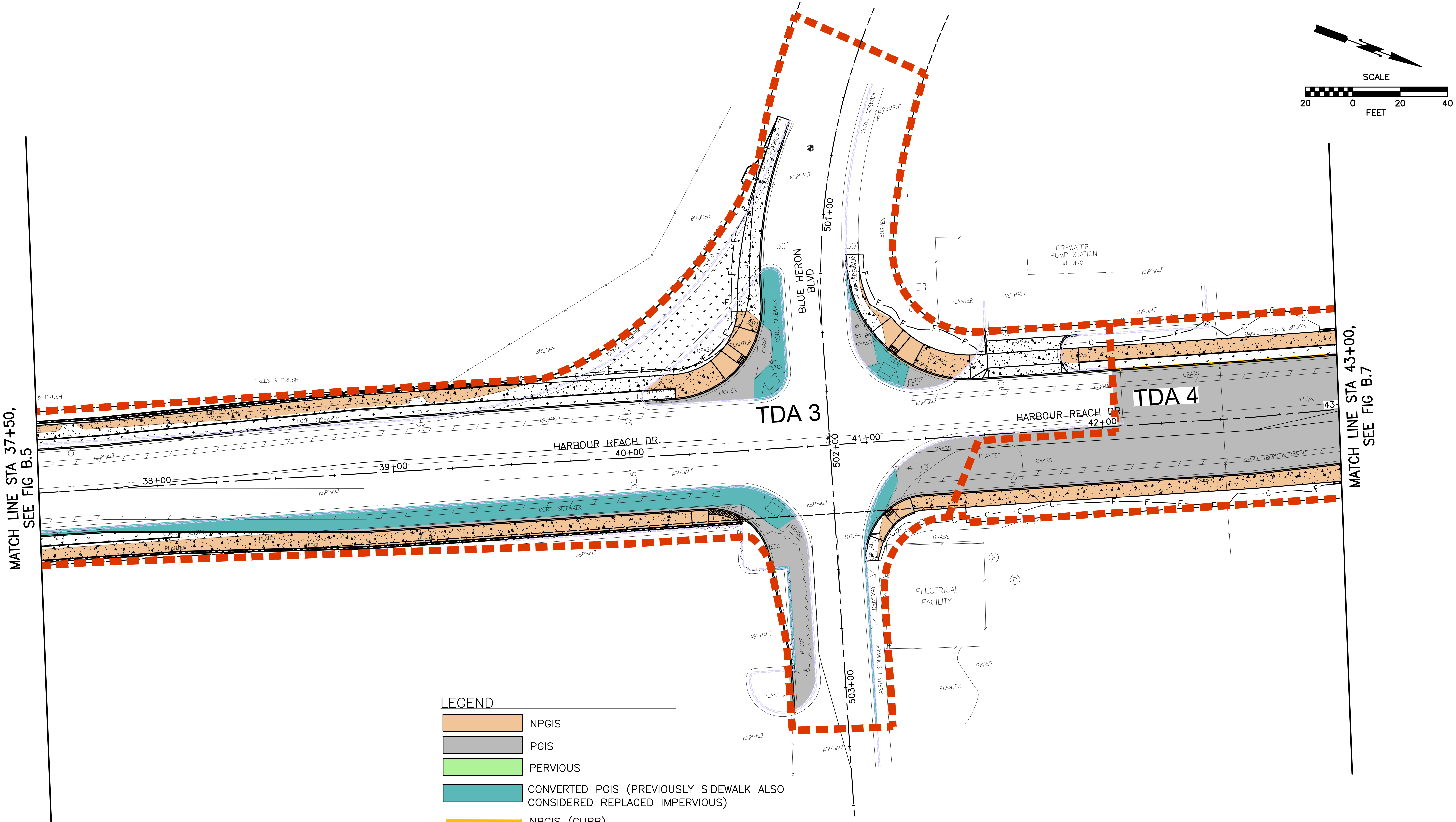
HARBOUR REACH EXTENSION

PROPOSED IMPERVIOUS AREAS

FIGURE B.5




LEGEND

- NPGIS
- PGIS
- PERVIOUS
- CONVERTED PGIS (PREVIOUSLY SIDEWALK ALSO CONSIDERED REPLACED IMPERVIOUS)
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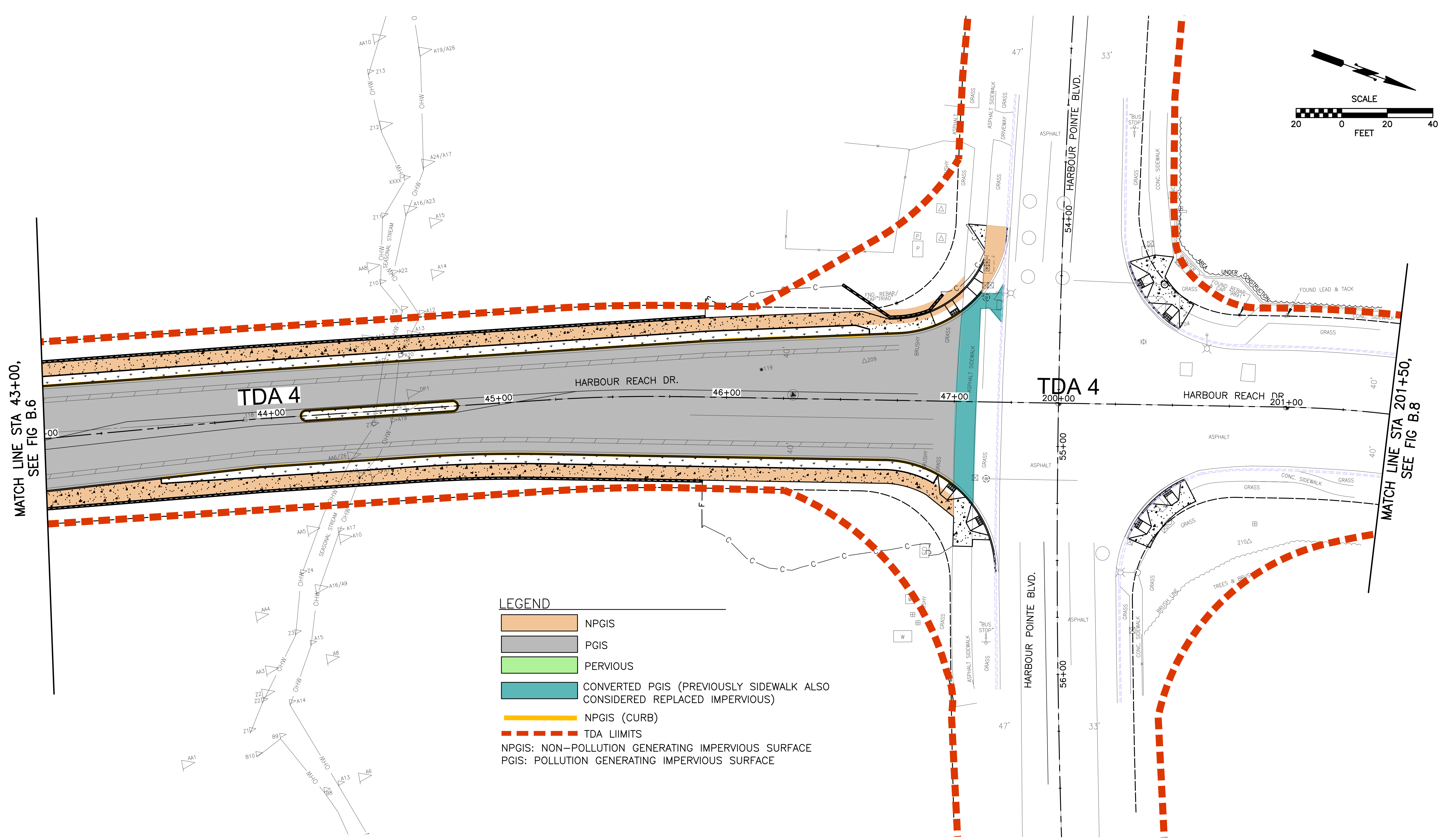
HARBOUR REACH EXTENSION

PROPOSED IMPERVIOUS AREAS

FIGURE B.6





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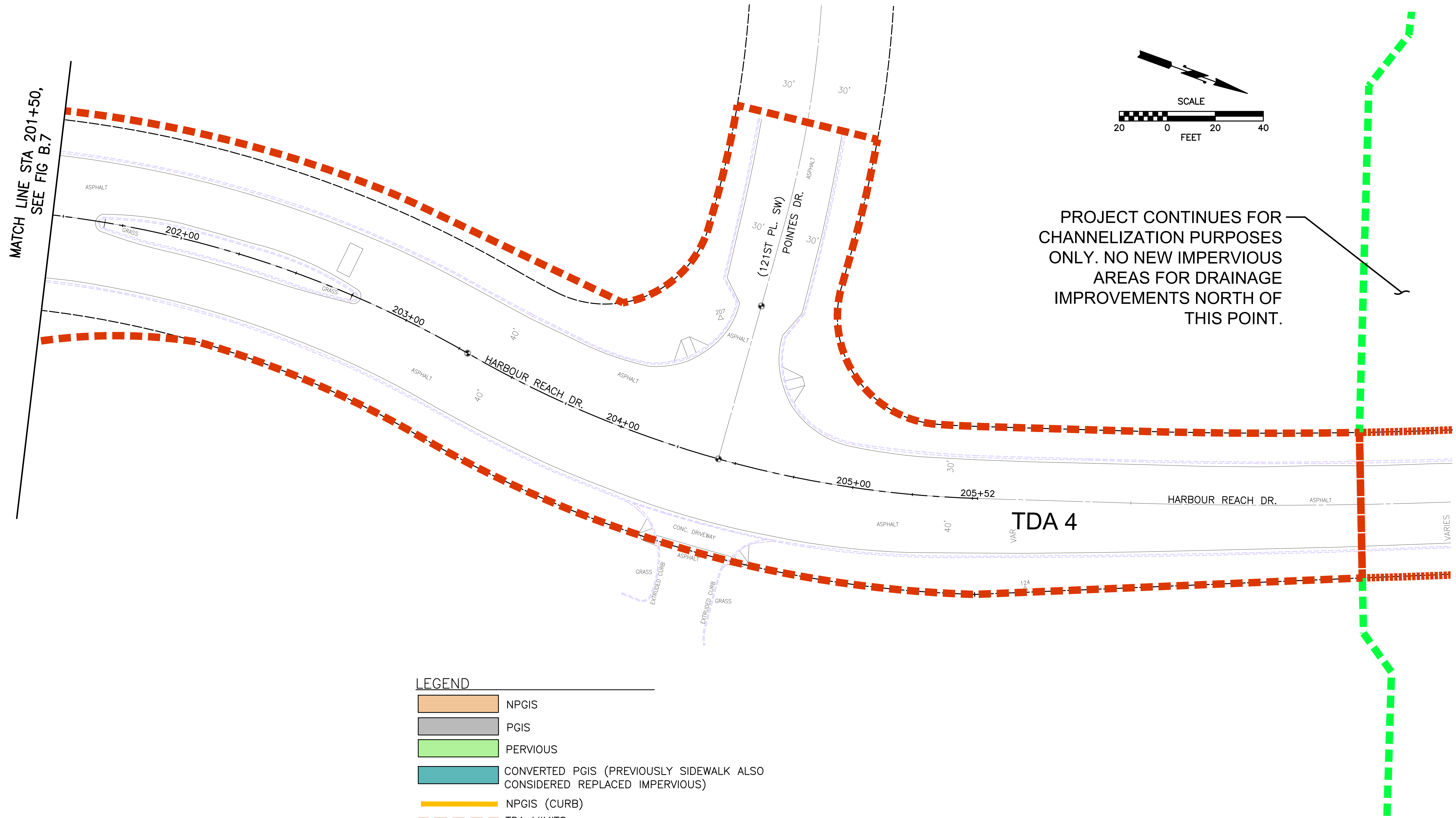
HARBOUR REACH EXTENSION

PROPOSED IMPERVIOUS AREAS

FIGURE B.7




LEGEND

- NPGIS
- PGIS
- PERVIOUS
- CONVERTED PGIS (PREVIOUSLY SIDEWALK ALSO CONSIDERED REPLACED IMPERVIOUS)
- NPGIS (CURB)
- TDA LIIMITS

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PGIS: POLLUTION GENERATING IMPERVIOUS SURFACE


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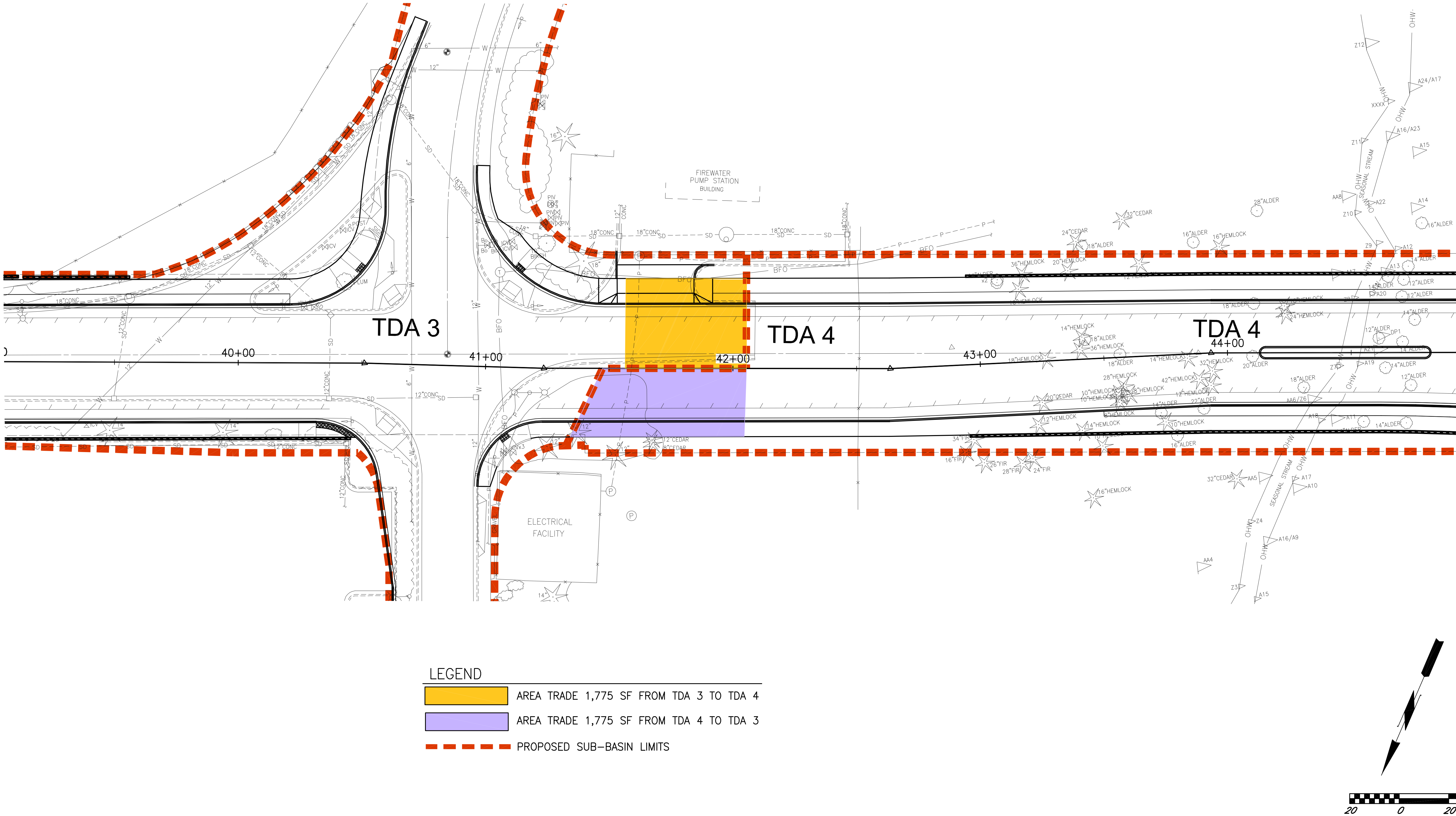
HARBOUR REACH EXTENSION

PROPOSED IMPERVIOUS AREAS

FIGURE B.8




LEGEND

AREA TRADE 1,775 SF FROM TDA 3 TO TDA 4

AREA TRADE 1,775 SF FROM TDA 4 TO TDA 3

PROPOSED SUB-BASIN LIMITS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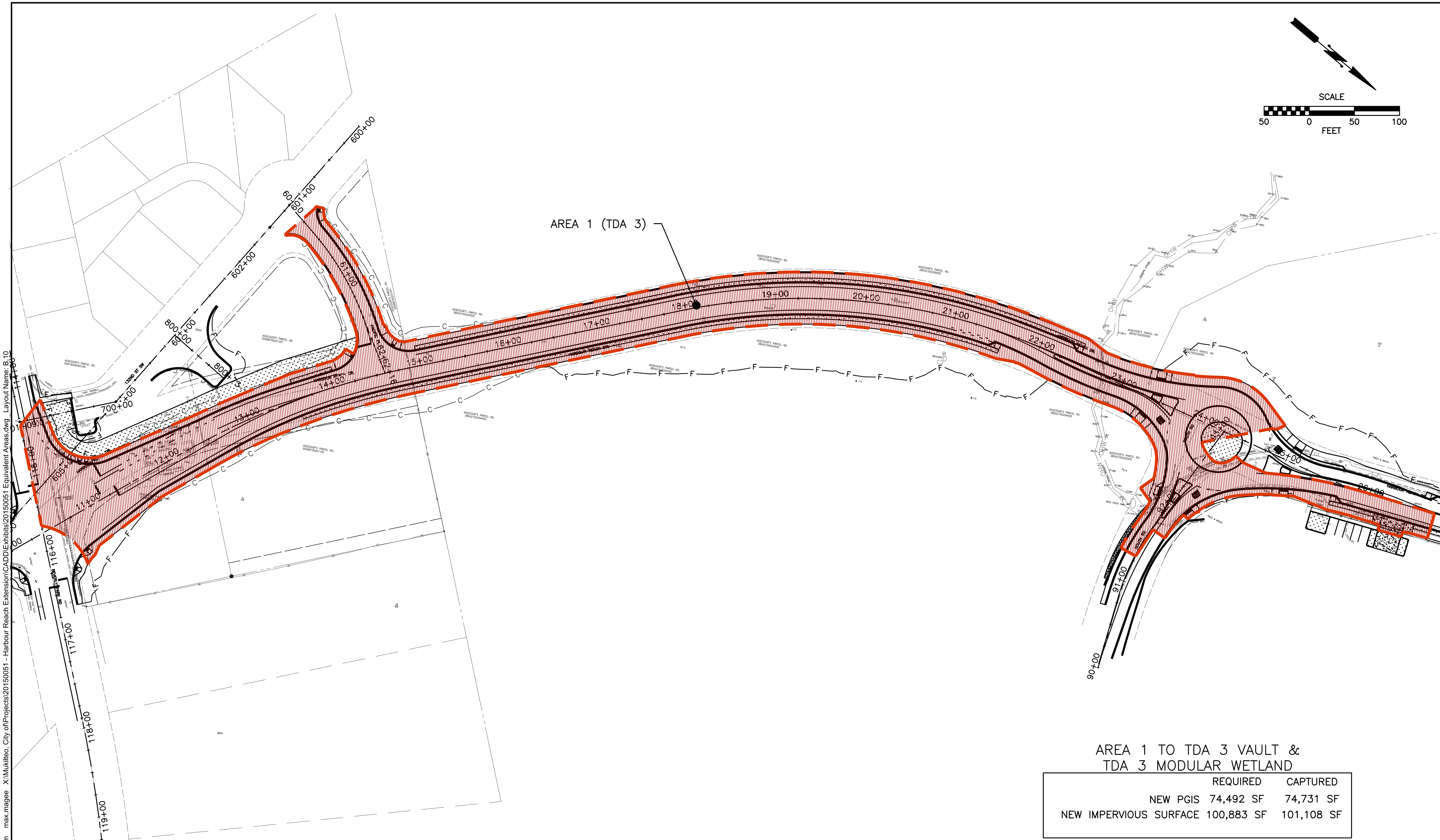
HARBOUR REACH EXTENSION

AREA SWAP EXHIBIT

FIGURE B.9


Dec 06, 2018 - 11:03am max.magee X:\Mukilteo, City of\Projects\20150051 - Harbour Reach Extension\CADD\Exhibits\20150051 Area Swap.dwg Layout Name: B.9




AREA 1 TO TDA 3 VAULT &
TDA 3 MODULAR WETLAND

| | REQUIRED | CAPTURED |
|---|---|---|
| NEW PGIS | 74,492 SF | 74,731 SF |
| NEW IMPERVIOUS SURFACE | 100,883 SF | 101,108 SF |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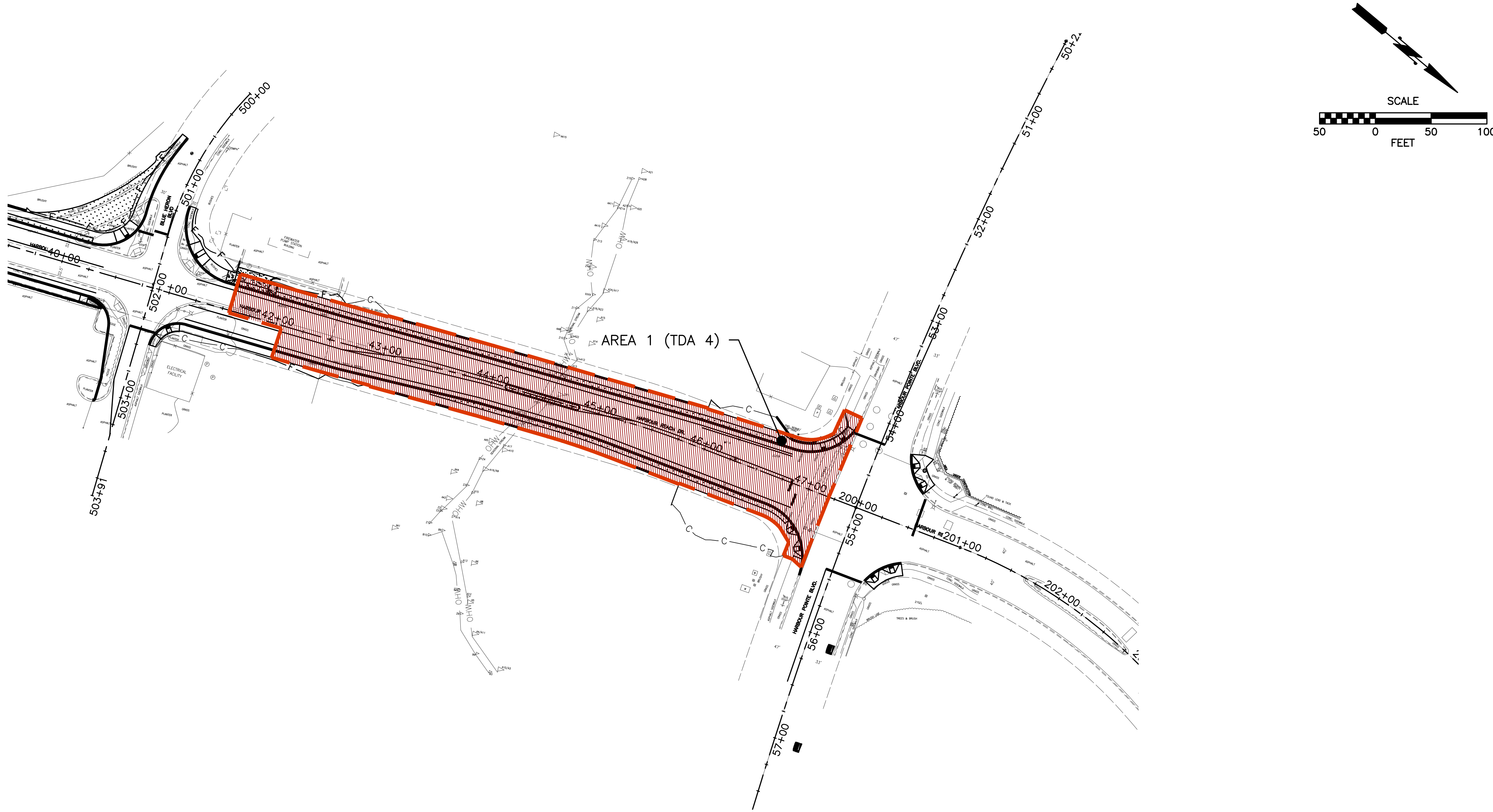
# HARBOUR REACH EXTENSION

## EQUIVALENT AREAS

FIGURE
B.10




AREA 1 TO TDA 4 VAULT &
TDA 4 MODULAR WETLAND

| | REQUIRED | CAPTURED |
|---|---|---|
| NEW PGIS | 25,070 SF | 26,081 SF |
| NEW IMPERVIOUS SURFACE | 32,109 SF | 34,736 SF |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HARBOUR REACH EXTENSION

EQUIVALENT AREAS

FIGURE
B.11

# APPENDIX C

## Flow Control and Water Quality Treatment Calculations

**20150051 – Harbour Reach Extension**

| **CALCULATION REPORT** |
|---|
| Calculated by: Max Magee, PE      Date: 11/8/18 |
| Checked By:  Date:  Brian Caferro, PE     Date:  11/10/18 |

**Flow Control and Water Quality Treatment Calculations**

**Objective:** The purpose of this analysis is to:

- Size two detention vaults for the purpose of satisfying flow control requirements for the on-site portion of the Harbour Reach Drive Extension project.
- Size two modular wetland units for the purpose of satisfying enhanced water quality treatment requirements for the Harbour Reach Drive Extension project.

**Key Design Factors and Assumptions:**

- Hydrologic analysis for sizing the detention vaults was performed using MGSFlood software, a continuous simulation model.
- Rainfall data for MGSFlood was obtained from the Extended Timeseries Region Map within the MGSFlood model. Region "Puget East 40" was used for the MGSFlood model.
- Equivalent and/or capture areas were identified and then used as the tributary areas to each flow control and water quality treatment facility. A delineation of these areas can be found in Appendix B of this report.
- Pre-developed land-use for the on-site flow control facilities was assumed to be forested conditions, regardless of actual site conditions.
- The modular wetland units for TDAs 3 and 4 was sized using the 2 year release rates leaving the detention vault. Flow rate information generated from the MGSFlood model was provided to the manufacturer who then sized the units accordingly.

**Summary of Results:**

**Flow Control**

Flow control is required for TDAs 3 and 4 per the threshold analysis. The following table is a summary of the required versus provided volumes.

| Facility | Required Volume | Provided Volume |
|---|---|---|
| TDA 3 | 48,972 | 49,280 |
| TDA 4 | 20,280 | 20,400 |

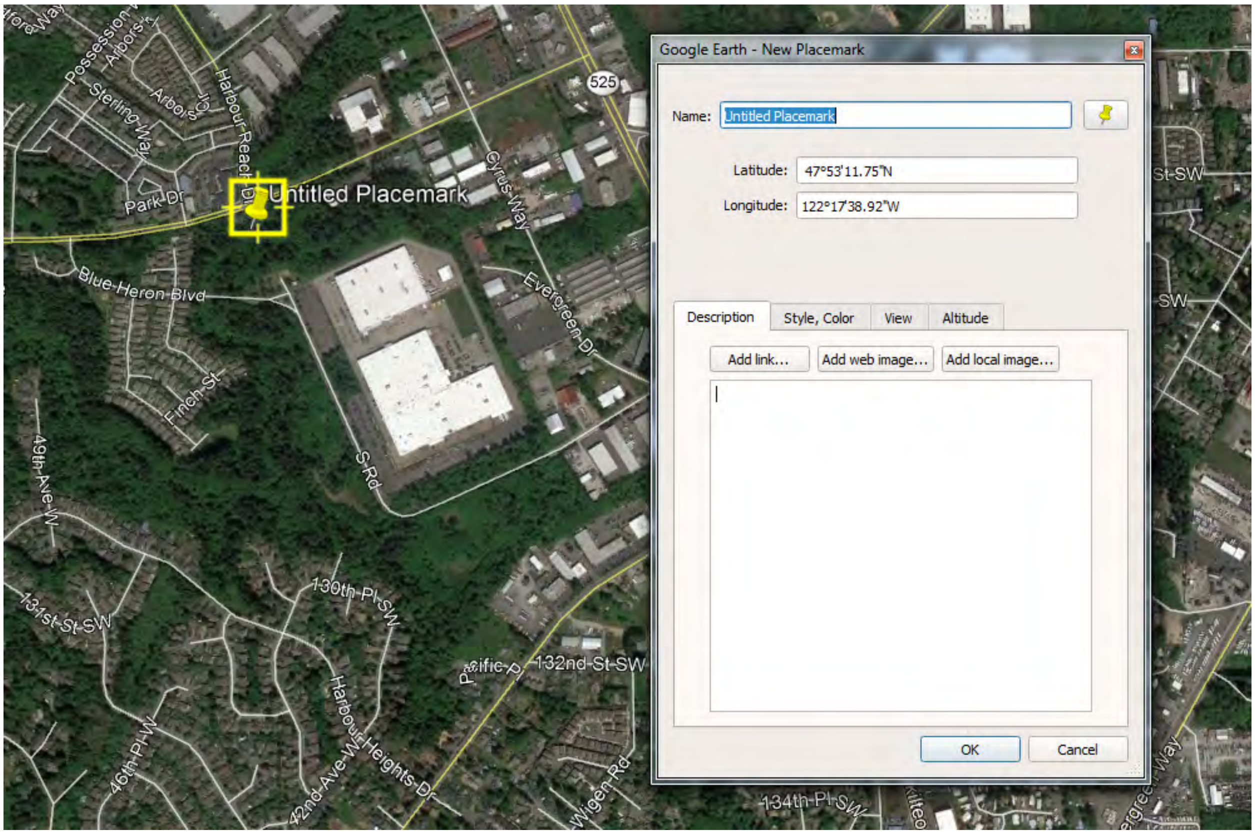
**Water Quality Treatment**

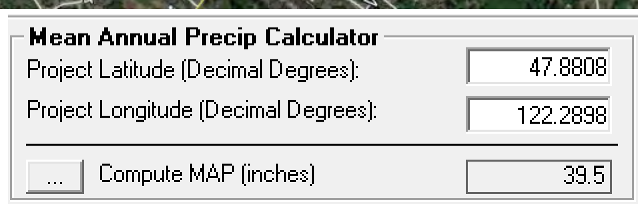
Water quality treatment is required for TDAs 3 and 4 per the threshold analysis.

The required Modular Wetland sizes were determined by the manufacturer based on the flow rate information that they were provided.

**Precipitation Data**:

- Mean Annual precipitation (MAP) = Puget East 40 inches per MAP.
- Note: MAP was also checked using Latitude/Longitude Coordinates, inputting the coordinates into MGSFlood software, and verifying precipitation.



# TDA 3

# MGS FLOOD
# PROJECT REPORT

**Program Version: MGSFlood 4.38**
**Program License Number: 200310001**
**Project Simulation Performed on: 09/16/2018 2:52 PM**
**Report Generation Date: 10/10/2018 8:28 AM**

| | |
|---|---|
| Input File Name: | TDA 3 Detention Vault.fld |
| Project Name: | Harbour Reach Drive Extension Project |
| Analysis Title: | TDA 3 Detention Vault |
| Comments: | |

**PRECIPITATION INPUT**

Computational Time Step (Minutes): 15

Extended Precipitation Time Series Selected
Climatic Region Number: 13

Full Period of Record Available used for Routing
Precipitation Station : 96004005 Puget East 40 in_5min 10/01/1939-10/01/2097
Evaporation Station : 961040 Puget East 40 in MAP
Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1
HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) ***************

*********************** WATERSHED DEFINITION ***********************

**Predevelopment/Post Development Tributary Area Summary**

| | Predeveloped | Post Developed |
|---|---|---|
| Total Subbasin Area (acres) | 2.500 | 2.500 |
| Area of Links that Include Precip/Evap (acres) | 0.000 | 0.000 |
| Total (acres) | 2.500 | 2.500 |

**----------------------SCENARIO: PREDEVELOPED**
Number of Subbasins: 1

---------- Subbasin : Subbasin 1 ----------

| -------Area(Acres) -------- | |
|---|---|
| Till Forest | 2.443 |
| Till Pasture | 0.000 |
| Till Grass | 0.000 |
| Outwash Forest | 0.000 |
| Outwash Pasture | 0.000 |
| Outwash Grass | 0.000 |

| | |
|---|---|
| Wetland | 0.000 |
| Green Roof | 0.000 |
| User 2 | 0.000 |
| Impervious | 0.057 |

----------------------------------------------

| | |
|---|---|
| Subbasin Total | 2.500 |

**---------------------SCENARIO: POSTDEVELOPED**
Number of Subbasins: 1

---------- Subbasin : Subbasin 1 ----------
-------Area(Acres) --------

| | |
|---|---|
| Till Forest | 0.000 |
| Till Pasture | 0.000 |
| Till Grass | 0.179 |
| Outwash Forest | 0.000 |
| Outwash Pasture | 0.000 |
| Outwash Grass | 0.000 |
| Wetland | 0.000 |
| Green Roof | 0.000 |
| User 2 | 0.000 |
| Impervious | 2.321 |

----------------------------------------------

| | |
|---|---|
| Subbasin Total | 2.500 |

************************* **LINK DATA** *******************************

---------------------SCENARIO: PREDEVELOPED
Number of Links: 0

************************* **LINK DATA** *******************************

---------------------SCENARIO: POSTDEVELOPED
Number of Links: 1

**------------------------------------------**
**Link Name: Detention Vault**
Link Type: Structure
Downstream Link: None

Prismatic Pond Option Used
Pond Floor Elevation (ft) : 100.00
Riser Crest Elevation (ft) : 111.00
Max Pond Elevation (ft) : 111.50
Storage Depth (ft) : 11.00
Pond Bottom Length (ft) : 159.0
Pond Bottom Width (ft) : 28.0
Pond Side Slopes (ft/ft) : L1= 0.00 L2= 0.00 W1= 0.00 W2= 0.00
Bottom Area (sq-ft) : 4452.
Area at Riser Crest El (sq-ft) : 4,452.
(acres) : 0.102

Volume at Riser Crest (cu-ft) : 48,972.
(ac-ft) : 1.124
Area at Max Elevation (sq-ft) : 4452.
(acres) : 0.102
Vol at Max Elevation (cu-ft) : 52,088.
(ac-ft) : 1.196

Massmann Infiltration Option Used
Hydraulic Conductivity (in/hr) : 0.00
Depth to Water Table (ft) : 100.00
Bio-Fouling Potential : Low
Maintenance : Average or Better

Riser Geometry
Riser Structure Type : Circular
Riser Diameter (in) : 12.00
Common Length (ft) : 0.010
Riser Crest Elevation : 111.00 ft

Hydraulic Structure Geometry

Number of Devices: 4

---Device Number 1 ---
Device Type : Circular Orifice
Control Elevation (ft) : 100.00
Diameter (in) : 0.70
Orientation : Horizontal
Elbow : No

---Device Number 2 ---
Device Type : Circular Orifice
Control Elevation (ft) : 105.90
Diameter (in) : 0.70
Orientation : Horizontal
Elbow : Yes

---Device Number 3 ---
Device Type : Circular Orifice
Control Elevation (ft) : 107.00
Diameter (in) : 0.80
Orientation : Horizontal
Elbow : Yes

---Device Number 4 ---
Device Type : Circular Orifice
Control Elevation (ft) : 108.00
Diameter (in) : 0.85
Orientation : Horizontal
Elbow : Yes

************************FLOOD FREQUENCY AND DURATION STATISTICS**********************

**---------------------SCENARIO: PREDEVELOPED**
Number of Subbasins: 1

Number of Links: 0

**----------------------SCENARIO: POSTDEVELOPED**
Number of Subbasins: 1
Number of Links: 1

********** **Subbasin: Subbasin 1** **********

Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

| Tr (yrs) | Flood Peak (cfs) |
|---|---|
| 2-Year | 0.880 |
| 5-Year | 1.137 |
| 10-Year | 1.314 |
| 25-Year | 1.668 |
| 50-Year | 2.069 |
| 100-Year | 2.445 |
| 200-Year | 2.521 |

********** Link: Detention Vault ********** Link Inflow Frequency Stats
Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

| Tr (yrs) | Flood Peak (cfs) |
|---|---|
| 2-Year | 0.880 |
| 5-Year | 1.137 |
| 10-Year | 1.314 |
| 25-Year | 1.668 |
| 50-Year | 2.069 |
| 100-Year | 2.445 |
| 200-Year | 2.521 |

********** Link: Detention Vault ********** Link WSEL Stats
WSEL Frequency Data(ft)
(Recurrence Interval Computed Using Gringorten Plotting Position)

| Tr (yrs) | WSEL Peak (ft) |
|---|---|
| 1.05-Year | 103.419 |
| 1.11-Year | 103.768 |
| 1.25-Year | 104.207 |
| 2.00-Year | 105.503 |
| 3.33-Year | 106.465 |
| 5-Year | 107.306 |
| 10-Year | 108.549 |
| 25-Year | 109.193 |
| 50-Year | 109.655 |
| 100-Year | 109.785 |

*************Groundwater Recharge Summary ***************
Recharge is computed as input to Perlnd Groundwater Plus Infiltration in Structures

Total Predeveloped Recharge During Simulation

| Model Element | Recharge Amount (ac-ft) |
|---|---|
| Subbasin: Subbasin 1 | 421.244 |
| Total: | 421.244 |

Total Post Developed Recharge During Simulation

| Model Element | Recharge Amount (ac-ft) |
|---|---|
| Subbasin: Subbasin 1 | 21.876 |
| Link: Detention Vault | 0.000 |
| Total: | 21.876 |

**Total Predevelopment Recharge is Greater than Post Developed**
**Average Recharge Per Year, (Number of Years= 158)**
**Predeveloped: 2.666 ac-ft/year, Post Developed: 0.138 ac-ft/year**

*************Water Quality Facility Data ***************

**---------------------SCENARIO: PREDEVELOPED**

Number of Links: 0

**---------------------SCENARIO: POSTDEVELOPED**

Number of Links: 1

********** Link: Detention Vault **********

Basic Wet Pond Volume (91% Exceedance): 10442. cu-ft
Computed Large Wet Pond Volume, 1.5*Basic Volume: 15663. cu-ft

Infiltration/Filtration Statistics--------------------
Inflow Volume (ac-ft): 1076.62
Inflow Volume Including PPT-Evap (ac-ft): 1076.62
Total Runoff Infiltrated (ac-ft): 0.00, 0.00%
Total Runoff Filtered (ac-ft): 0.00, 0.00%
Primary Outflow To Downstream System (ac-ft): 1076.40
Secondary Outflow To Downstream System (ac-ft): 0.00
Percent Treated (Infiltrated+Filtered)/Total Volume: 0.00%

*************Compliance Point Results ***************

Scenario Predeveloped Compliance Subbasin: Subbasin 1

Scenario Postdeveloped Compliance Link: Detention Vault

***** Point of Compliance Flow Frequency Data *****
Recurrence Interval Computed Using Gringorten Plotting Position

| Predevelopment Runoff | | Postdevelopment Runoff | |
|---|---|---|---|
| Tr (Years) | Discharge (cfs) | Tr (Years) | Discharge (cfs) |
| 2-Year | 6.179E-02 | 2-Year | 3.068E-02 |
| 5-Year | 0.100 | 5-Year | 5.902E-02 |
| 10-Year | 0.136 | 10-Year | 9.217E-02 |
| 25-Year | 0.171 | 25-Year | 0.106 |
| 50-Year | 0.213 | 50-Year | 0.115 |
| 100-Year | 0.237 | 100-Year | 0.117 |
| 200-Year | 0.351 | 200-Year | 0.128 |

** Record too Short to Compute Peak Discharge for These Recurrence Intervals

****** Flow Duration Performance ******

| | | |
|---|---|---|
| Excursion at Predeveloped 50%Q2 (Must be Less Than 0%): | -0.1% | PASS |
| Maximum Excursion from 50%Q2 to Q2 (Must be Less Than 0%): | -0.1% | PASS |
| Maximum Excursion from Q2 to Q50 (Must be less than 10%): | 8.2% | PASS |
| Percent Excursion from Q2 to Q50 (Must be less than 50%): | 12.0% | PASS |

---

MEETS ALL FLOW DURATION DESIGN CRITERIA: PASS

---

# TDA 4

# MGS FLOOD
# PROJECT REPORT

**Program Version: MGSFlood 4.38**
**Program License Number: 200310001**
**Project Simulation Performed on: 12/06/2018 3:19 PM**
**Report Generation Date: 12/06/2018 3:28 PM**

| | |
|---|---|
| Input File Name: | TDA 4 Detention Vault.fld |
| Project Name: | Harbour Reach Drive Extension Project |
| Analysis Title: | TDA 4 Detention Vault |
| Comments: | |

## PRECIPITATION INPUT

Computational Time Step (Minutes): 15

Extended Precipitation Time Series Selected
Climatic Region Number: 13

Full Period of Record Available used for Routing
Precipitation Station : 96004005 Puget East 40 in_5min 10/01/1939-10/01/2097
Evaporation Station : 961040 Puget East 40 in MAP
Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1
HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) ***************

**********************  WATERSHED DEFINITION  ***********************

**Predevelopment/Post Development Tributary Area Summary**

| | Predeveloped | Post Developed |
|---|---|---|
| Total Subbasin Area (acres) | 0.877 | 0.877 |
| Area of Links that Include Precip/Evap (acres) | 0.000 | 0.000 |
| Total (acres) | 0.877 | 0.877 |

**---------------------SCENARIO: PREDEVELOPED**
Number of Subbasins: 1

---------- Subbasin : Subbasin 1 ----------

| -------Area(Acres) -------- | |
|---|---|
| Till Forest | 0.817 |
| Till Pasture | 0.000 |
| Till Grass | 0.000 |
| Outwash Forest | 0.000 |
| Outwash Pasture | 0.000 |
| Outwash Grass | 0.000 |

| | |
|---|---|
| Wetland | 0.000 |
| Green Roof | 0.000 |
| User 2 | 0.000 |
| Impervious | 0.060 |

----------------------------------------------

| | |
|---|---|
| Subbasin Total | 0.877 |

**----------------------SCENARIO: POSTDEVELOPED**

Number of Subbasins: 1

---------- Subbasin : Subbasin 1 ----------

-------Area(Acres) --------

| | |
|---|---|
| Till Forest | 0.000 |
| Till Pasture | 0.000 |
| Till Grass | 0.080 |
| Outwash Forest | 0.000 |
| Outwash Pasture | 0.000 |
| Outwash Grass | 0.000 |
| Wetland | 0.000 |
| Green Roof | 0.000 |
| User 2 | 0.000 |
| Impervious | 0.797 |

----------------------------------------------

| | |
|---|---|
| Subbasin Total | 0.877 |

************************* **LINK DATA** *******************************

----------------------SCENARIO: PREDEVELOPED

Number of Links: 0

************************* **LINK DATA** *******************************

----------------------SCENARIO: POSTDEVELOPED

Number of Links: 1

**------------------------------------------**

**Link Name: Detention Vault**

Link Type: Structure

Downstream Link: None

Prismatic Pond Option Used

| | |
|---|---|
| Pond Floor Elevation (ft) | : 492.00 |
| Riser Crest Elevation (ft) | : 498.00 |
| Max Pond Elevation (ft) | : 499.00 |
| Storage Depth (ft) | : 6.00 |
| Pond Bottom Length (ft) | : 87.0 |
| Pond Bottom Width (ft) | : 40.0 |
| Pond Side Slopes (ft/ft) | : L1= 0.00 L2= 0.00 W1= 0.00 W2= 0.00 |
| Bottom Area (sq-ft) | : 3480. |
| Area at Riser Crest El (sq-ft) | : 3,480. |
| (acres) | : 0.080 |

Volume at Riser Crest (cu-ft) : 20,880.
(ac-ft) : 0.479
Area at Max Elevation (sq-ft) : 3480.
(acres) : 0.080
Vol at Max Elevation (cu-ft) : 24,708.
(ac-ft) : 0.567

Massmann Infiltration Option Used
Hydraulic Conductivity (in/hr) : 0.00
Depth to Water Table (ft) : 100.00
Bio-Fouling Potential : Low
Maintenance : Average or Better

Riser Geometry
Riser Structure Type : Circular
Riser Diameter (in) : 12.00
Common Length (ft) : 0.000
Riser Crest Elevation : 498.00 ft

Hydraulic Structure Geometry

Number of Devices: 3

---Device Number 1 ---
Device Type : Circular Orifice
Control Elevation (ft) : 492.00
Diameter (in) : 0.35
Orientation : Horizontal
Elbow : No

---Device Number 2 ---
Device Type : Circular Orifice
Control Elevation (ft) : 494.00
Diameter (in) : 0.35
Orientation : Horizontal
Elbow : Yes

---Device Number 3 ---
Device Type : Circular Orifice
Control Elevation (ft) : 495.00
Diameter (in) : 0.35
Orientation : Horizontal
Elbow : Yes

**********************FLOOD FREQUENCY AND DURATION STATISTICS*******************

**---------------------SCENARIO: PREDEVELOPED**
Number of Subbasins: 1
Number of Links: 0

**---------------------SCENARIO: POSTDEVELOPED**
Number of Subbasins: 1
Number of Links: 1

************ Subbasin: Subbasin 1 ************

Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

| Tr (yrs) | Flood Peak (cfs) |
|---|---|
| 2-Year | 0.304 |
| 5-Year | 0.391 |
| 10-Year | 0.456 |
| 25-Year | 0.581 |
| 50-Year | 0.715 |
| 100-Year | 0.850 |
| 200-Year | 0.875 |

********** Link: Detention Vault ********** Link Inflow Frequency Stats
Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

| Tr (yrs) | Flood Peak (cfs) |
|---|---|
| 2-Year | 0.304 |
| 5-Year | 0.391 |
| 10-Year | 0.456 |
| 25-Year | 0.581 |
| 50-Year | 0.715 |
| 100-Year | 0.850 |
| 200-Year | 0.875 |

********** Link: Detention Vault ********** Link WSEL Stats
WSEL Frequency Data(ft)
(Recurrence Interval Computed Using Gringorten Plotting Position)

| Tr (yrs) | WSEL Peak (ft) |
|---|---|
| 1.05-Year | 494.320 |
| 1.11-Year | 494.680 |
| 1.25-Year | 494.923 |
| 2.00-Year | 495.543 |
| 3.33-Year | 496.040 |
| 5-Year | 496.333 |
| 10-Year | 497.185 |
| 25-Year | 497.573 |
| 50-Year | 497.966 |
| 100-Year | 498.012 |

*************Groundwater Recharge Summary ***************
Recharge is computed as input to Perlnd Groundwater Plus Infiltration in Structures

Total Predeveloped Recharge During Simulation

| Model Element | Recharge Amount (ac-ft) |
|---|---|
| Subbasin: Subbasin 1 | 140.875 |

| | |
|---|---|
| Total: | 140.875 |

Total Post Developed Recharge During Simulation

| Model Element | Recharge Amount (ac-ft) |
|---|---|
| Subbasin: Subbasin 1 | 9.777 |
| Link: Detention Vault | 0.000 |
| Total: | 9.777 |

**Total Predevelopment Recharge is Greater than Post Developed**
**Average Recharge Per Year, (Number of Years= 158)**
**Predeveloped: 0.892 ac-ft/year, Post Developed: 0.062 ac-ft/year**

***********Water Quality Facility Data *************

**---------------------SCENARIO: PREDEVELOPED**

Number of Links: 0

**---------------------SCENARIO: POSTDEVELOPED**

Number of Links: 1

********** Link: Detention Vault **********

Basic Wet Pond Volume (91% Exceedance): 3597. cu-ft
Computed Large Wet Pond Volume, 1.5*Basic Volume: 5396. cu-ft

Infiltration/Filtration Statistics--------------------
Inflow Volume (ac-ft): 373.42
Inflow Volume Including PPT-Evap (ac-ft): 373.42
Total Runoff Infiltrated (ac-ft): 0.00, 0.00%
Total Runoff Filtered (ac-ft): 0.00, 0.00%
Primary Outflow To Downstream System (ac-ft): 373.31
Secondary Outflow To Downstream System (ac-ft): 0.00
Percent Treated (Infiltrated+Filtered)/Total Volume: 0.00%

***********Compliance Point Results *************

Scenario Predeveloped Compliance Subbasin: Subbasin 1

Scenario Postdeveloped Compliance Link: Detention Vault

***** Point of Compliance Flow Frequency Data *****
Recurrence Interval Computed Using Gringorten Plotting Position

| Predevelopment Runoff | | Postdevelopment Runoff | |
|---|---|---|---|
| Tr (Years) | Discharge (cfs) | Tr (Years) | Discharge (cfs) |
| 2-Year | 3.191E-02 | 2-Year | 1.230E-02 |

| | | | |
|---|---|---|---|
| 5-Year | 4.841E-02 | 5-Year | 1.514E-02 |
| 10-Year | 6.229E-02 | 10-Year | 1.756E-02 |
| 25-Year | 7.540E-02 | 25-Year | 1.859E-02 |
| 50-Year | 9.379E-02 | 50-Year | 2.338E-02 |
| 100-Year | 0.106 | 100-Year | 3.900E-02 |
| 200-Year | 0.146 | 200-Year | 9.930E-02 |

** Record too Short to Compute Peak Discharge for These Recurrence Intervals

**** **Flow Duration Performance** ****

| | | |
|---|---|---|
| Excursion at Predeveloped 50%Q2 (Must be Less Than 0%): | -55.6% | PASS |
| Maximum Excursion from 50%Q2 to Q2 (Must be Less Than 0%): | -55.6% | PASS |
| Maximum Excursion from Q2 to Q50 (Must be less than 10%): | 0.4% | PASS |
| Percent Excursion from Q2 to Q50 (Must be less than 50%): | 1.3% | PASS |

-------------------------------------------------------------------------------------------------
MEETS ALL FLOW DURATION DESIGN CRITERIA: PASS
-------------------------------------------------------------------------------------------------

Bio Clean
A Forterra Company

Date: 11/30/18

Subject: 7985 – Harbour Reach Extension, Mukilteo, Wa

To Whom It May Concern,

The MWS Linear will be sized in accordance with the TAPE GULD approval for the Modular Wetland System. The system is sized at a loading rate of (less than or equal to) 1.0 gpm/ sq ft, where the pre-filter cartridges are sized at a loading rate of less than 2.1 gpm/ sq ft. Design, sizing, and loading have been reviewed and approved by a Modular Wetland Representative and is ready for final approval. Shown below are the calculations for this Project:

<u>MWS-L-4-6.33-V-UG - North</u>

- Required Treatment Flow Rate = 0.01 cfs
- MWS-Linear-4-6 Treatment Capacity Provided = 0.01 cfs or 4.48 gpm at 2.1' HGL
- Pre-filter Cartridge = 1 half size cartridge
- Surface Area per Cartridge = 12.8 sq ft
- Loading rate (Pre-Filter Cartridge) = 0.4 gpm / sq ft
- MWS Wetland Surface Area = 19.53 sf
- Loading Rate (Wetland Media) = 0.2 gpm/sf

<u>MWS-L-4-6.33-V-UG - South</u>

- Required Treatment Flow Rate = 0.031 cfs
- MWS-Linear-4-6 Treatment Capacity Provided = 0.031 cfs or 13.91 gpm at 2.1' HGL
- Pre-filter Cartridge = 1 half size cartridge
- Surface Area per Cartridge = 12.8 sq ft
- Loading rate (Pre-Filter Cartridge) = 1.1 gpm / sq ft
- MWS Wetland Surface Area = 19.53 sf
- Loading Rate (Wetland Media) = 0.7 gpm/sf

If you have any questions please feel free to contact us at your convenience.

Sincerely,

Anthony J. Spolar

Anthony J. Spolar, E.I.T.

398 Via El Centro, Oceanside, CA 92058
(469) 458-7973 • Fax (760) 433-3176
www.biocleanenvironmental.com

# APPENDIX D

## Conveyance Calculations

Conveyance Calculations
Conveyance Catchment Area Maps
Gutter Flow Calculations
Outfall Calculations

**20150051 – Harbour Reach Extension**

| |
|---|
| **CALCULATION REPORT** |
| Calculated by: Kern McGee, EIT  Date: 11/8/18 |
| Checked by: Max Magee, PE  Date: 12/4/2018 |

**Conveyance and Gutter Flow Calculations**

**Objective:**

To analyze the capacity of proposed storm pipe systems, and to determine catch basin spacing

**Designer Notes**

- Minimum Tc = 5.00 min
- Smooth wall pipe with manning's coefficients of 0.012 for all pipe is used in this analysis
- "Max El" corresponds to rim elevation at the structure
- "Start El" corresponds to the lowest pipe invert in a particular structure
- System is analyzed for a 100-year storm event using the Rational method, to be conservative
- StormShed 3G model is used for analyzing the storm
- Rainfall IDF Family Everett was used
- Event storm precipitation values used:
  - 2-year – 1.50 in
  - 10-year – 2.00 in
  - 25-year – 2.50 in
  - 100-year – 3.00 in
- Tailwater elevation is set to equal the top of the outlet pipe at each outfall. For detention vaults, tailwater elevation is set at the 50 year flood elevation
- Rational Method was used in the gutter flow calculations.
- Gutter flow calculations were only performed in areas determined to have significant runoff and the potential for larger spread widths along the gutter line.
- Vane grate dimensions used to determine interception on continuous grade:
  - Grate Width: 1.67'
  - Grate Length: 2.00'
  - Typical Tc along roadway = 5.00 minutes
  - C = 0.90 (paved area)
  - Slope L = Longitudinal slope of roadway
  - Super T = Cross slope of roadway
  - Width of shoulder = shoulder width per plans
  - Zd allowable = width of bike lane plus 2' into the adjacent lane (but adjacent lane needs 10' of lane width free of water)

**Appended on: Thursday, November 08, 2018 1:03:11 PM**

# Layout Report: CB2 to TDA 3 Vault

| Event | Precip (in) |
|---|---|
| 2 yr 24 hr | 1.50 |
| 10 year | 2.00 |
| 25 year | 2.50 |
| 100 year | 3.00 |

## Reach Records

### Record Id: SD10

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB11 | **UpNode** | CB10 |
| **Material** | unspecified | **Size** | 12 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 132.00 ft | **Slope** | 0.64% |
| **Up Invert** | 554.01 ft | **Dn Invert** | 553.16 ft |

| Conduit Constraints | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

### Record Id: SD11

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB12 | **UpNode** | CB11 |

| | | | |
|---|---|---|---|
| **Material** | unspecified | **Size** | 12 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 50.00 ft | **Slope** | 4.00% |
| **Up Invert** | 553.16 ft | **Dn Invert** | 551.16 ft |

| **Conduit Constraints** | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

## Record Id: SD12

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB14 | **UpNode** | CB12 |
| **Material** | unspecified | **Size** | 12 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 150.00 ft | **Slope** | 8.00% |
| **Up Invert** | 551.16 ft | **Dn Invert** | 539.16 ft |

| **Conduit Constraints** | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

## Record Id: SD13

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB12 | **UpNode** | CB13 |
| **Material** | unspecified | **Size** | 12 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 36.00 ft | **Slope** | 0.61% |

| | | | |
|---|---|---|---|
| **Up Invert** | 551.38 ft | **Dn Invert** | 551.16 ft |

| Conduit Constraints | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

## Record Id: SD14

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB16 | **UpNode** | CB14 |
| **Material** | unspecified | **Size** | 12 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 100.00 ft | **Slope** | 6.94% |
| **Up Invert** | 539.16 ft | **Dn Invert** | 532.22 ft |

| Conduit Constraints | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

## Record Id: SD15

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB14 | **UpNode** | CB15 |
| **Material** | unspecified | **Size** | 12 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 36.00 ft | **Slope** | 0.61% |
| **Up Invert** | 539.38 ft | **Dn Invert** | 539.16 ft |

| Conduit Constraints | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |

| | | | | |
|---|---|---|---|---|
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

## Record Id: SD16

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB17 | **UpNode** | CB16 |
| **Material** | unspecified | **Size** | 12 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 34.00 ft | **Slope** | 0.85% |
| **Up Invert** | 532.22 ft | **Dn Invert** | 531.93 ft |

| **Conduit Constraints** | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

## Record Id: SD17

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB19 | **UpNode** | CB17 |
| **Material** | unspecified | **Size** | 12 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 147.00 ft | **Slope** | 8.18% |
| **Up Invert** | 531.93 ft | **Dn Invert** | 519.90 ft |

| **Conduit Constraints** | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

## Record Id: SD18

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB20 | **UpNode** | CB18 |
| **Material** | unspecified | **Size** | 12 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 98.00 ft | **Slope** | 4.15% |
| **Up Invert** | 507.47 ft | **Dn Invert** | 503.40 ft |

| **Conduit Constraints** | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

## Record Id: SD19

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB18 | **UpNode** | CB19 |
| **Material** | unspecified | **Size** | 12 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 139.00 ft | **Slope** | 8.94% |
| **Up Invert** | 519.90 ft | **Dn Invert** | 507.47 ft |

| **Conduit Constraints** | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

## Record Id: SD2

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |

| | | | |
|---|---|---|---|
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB3 | **UpNode** | CB2 |
| **Material** | unspecified | **Size** | 12 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 154.00 ft | **Slope** | 0.90% |
| **Up Invert** | 582.69 ft | **Dn Invert** | 581.30 ft |

| Conduit Constraints | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

## Record Id: SD20

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB21 | **UpNode** | CB20 |
| **Material** | unspecified | **Size** | 12 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 84.00 ft | **Slope** | 2.38% |
| **Up Invert** | 503.40 ft | **Dn Invert** | 501.40 ft |

| Conduit Constraints | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

## Record Id: SD21

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB24 | **UpNode** | CB21 |
| **Material** | unspecified | **Size** | 18 in Diam |

| | | | |
|---|---|---|---|
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 68.00 ft | **Slope** | 4.16% |
| **Up Invert** | 501.40 ft | **Dn Invert** | 498.57 ft |

| **Conduit Constraints** | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

## Record Id: SD22

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB21 | **UpNode** | CB22 |
| **Material** | unspecified | **Size** | 12 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 35.00 ft | **Slope** | 0.51% |
| **Up Invert** | 501.58 ft | **Dn Invert** | 501.40 ft |

| **Conduit Constraints** | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

## Record Id: SD23

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB25 | **UpNode** | CB23 |
| **Material** | unspecified | **Size** | 18 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 110.00 ft | **Slope** | 0.55% |
| **Up Invert** | 498.25 ft | **Dn Invert** | 497.65 ft |

| Conduit Constraints | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

### Record Id: SD24

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB23 | **UpNode** | CB24 |
| **Material** | unspecified | **Size** | 18 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 61.00 ft | **Slope** | 0.52% |
| **Up Invert** | 498.57 ft | **Dn Invert** | 498.25 ft |

| Conduit Constraints | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

### Record Id: SD25

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB30 | **UpNode** | CB25 |
| **Material** | unspecified | **Size** | 18 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 73.00 ft | **Slope** | 1.10% |
| **Up Invert** | 497.65 ft | **Dn Invert** | 496.85 ft |

| Conduit Constraints | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

## Record Id: SD26

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB30 | **UpNode** | CB26 |
| **Material** | unspecified | **Size** | 12 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 52.00 ft | **Slope** | 0.65% |
| **Up Invert** | 497.19 ft | **Dn Invert** | 496.85 ft |

| **Conduit Constraints** | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

## Record Id: SD27

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB63 | **UpNode** | CB27 |
| **Material** | unspecified | **Size** | 12 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 46.00 ft | **Slope** | 1.63% |
| **Up Invert** | 498.60 ft | **Dn Invert** | 497.85 ft |

| **Conduit Constraints** | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

## Record Id: SD28

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB27 | **UpNode** | CB28 |
| **Material** | unspecified | **Size** | 12 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 27.00 ft | **Slope** | 1.26% |
| **Up Invert** | 498.94 ft | **Dn Invert** | 498.60 ft |

| Conduit Constraints | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

## Record Id: SD29

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | TDA 3 Vault | **UpNode** | CB29 |
| **Material** | unspecified | **Size** | 18 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 8.00 ft | **Slope** | 0.50% |
| **Up Invert** | 496.54 ft | **Dn Invert** | 496.50 ft |

| Conduit Constraints | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

## Record Id: SD3

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |

| | | | |
|---|---|---|---|
| **DnNode** | CB4 | **UpNode** | CB3 |
| **Material** | unspecified | **Size** | 12 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 129.00 ft | **Slope** | 6.36% |
| **Up Invert** | 581.30 ft | **Dn Invert** | 573.10 ft |

| **Conduit Constraints** | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

## Record Id: SD30

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB29 | **UpNode** | CB30 |
| **Material** | unspecified | **Size** | 18 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 53.00 ft | **Slope** | 0.58% |
| **Up Invert** | 496.85 ft | **Dn Invert** | 496.54 ft |

| **Conduit Constraints** | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

## Record Id: SD4

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB6 | **UpNode** | CB4 |
| **Material** | unspecified | **Size** | 12 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |

| | | | |
|---|---|---|---|
| **Length** | 154.00 ft | **Slope** | 7.74% |
| **Up Invert** | 573.10 ft | **Dn Invert** | 561.18 ft |

| **Conduit Constraints** | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

## Record Id: SD5

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB4 | **UpNode** | CB5 |
| **Material** | unspecified | **Size** | 12 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 50.00 ft | **Slope** | 0.60% |
| **Up Invert** | 573.40 ft | **Dn Invert** | 573.10 ft |

| **Conduit Constraints** | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

## Record Id: SD6

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB8 | **UpNode** | CB6 |
| **Material** | unspecified | **Size** | 12 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 75.00 ft | **Slope** | 7.48% |
| **Up Invert** | 561.18 ft | **Dn Invert** | 555.57 ft |

| **Conduit Constraints** |
|---|

| Min Vel | Max Vel | Min Slope | Max Slope | Min Cover |
|---|---|---|---|---|
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

### Record Id: SD63

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB26 | **UpNode** | CB63 |
| **Material** | unspecified | **Size** | 12 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 68.00 ft | **Slope** | 0.97% |
| **Up Invert** | 497.85 ft | **Dn Invert** | 497.19 ft |

| **Conduit Constraints** | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

### Record Id: SD7

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB6 | **UpNode** | CB7 |
| **Material** | unspecified | **Size** | 12 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 36.00 ft | **Slope** | 0.61% |
| **Up Invert** | 561.40 ft | **Dn Invert** | 561.18 ft |

| **Conduit Constraints** | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

**Record Id: SD8**

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB11 | **UpNode** | CB8 |
| **Material** | unspecified | **Size** | 12 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 23.00 ft | **Slope** | 10.48% |
| **Up Invert** | 555.57 ft | **Dn Invert** | 553.16 ft |

| Conduit Constraints | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

**Record Id: SD9**

| | | | |
|---|---|---|---|
| **Section Shape:** | Circular | | |
| **Uniform Flow Method:** | Manning's | **Coefficient:** | 0.012 |
| **Routing Method:** | Travel Time Shift | **Contributing Hyd** | |
| **DnNode** | CB10 | **UpNode** | CB9 |
| **Material** | unspecified | **Size** | 12 in Diam |
| **Ent Losses** | Groove End w/Headwall | | |
| **Length** | 24.00 ft | **Slope** | 0.71% |
| **Up Invert** | 554.18 ft | **Dn Invert** | 554.01 ft |

| Conduit Constraints | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | 0.00 ft | **Ex/Infil Rate** | 0.00 in/hr |

# Node Records

### Record Id: CB10

| | | | |
|---|---|---|---|
| Descrip: | STA 1433, 176.70 LT | Increment | 0.10 ft |
| Start El. | 554.01 ft | Max El. | 558.10 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

### Record Id: CB11

| | | | |
|---|---|---|---|
| Descrip: | STA 1462, 49.33 LT | Increment | 0.10 ft |
| Start El. | 553.16 ft | Max El. | 557.83 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

### Record Id: CB12

| | | | |
|---|---|---|---|
| Descrip: | STA 1500, 18.00 LT | Increment | 0.10 ft |
| Start El. | 551.16 ft | Max El. | 555.43 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

### Record Id: CB13

| | | | |
|---|---|---|---|
| Descrip: | STA 1500, 18.00 RT | Increment | 0.10 ft |
| Start El. | 551.38 ft | Max El. | 555.43 ft |

| | | | |
|---|---|---|---|
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

### Record Id: CB14

| | | | |
|---|---|---|---|
| Descrip: | STA 1650, 18.00 LT | Increment | 0.10 ft |
| Start El. | 539.16 ft | Max El. | 543.66 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

### Record Id: CB15

| | | | |
|---|---|---|---|
| Descrip: | STA 1650, 18.00 RT | Increment | 0.10 ft |
| Start El. | 539.38 ft | Max El. | 543.66 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

### Record Id: CB16

| | | | |
|---|---|---|---|
| Descrip: | STA 1800, 18.00 LT | Increment | 0.10 ft |
| Start El. | 532.22 ft | Max El. | 535.72 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |

| |
|---|
| MH/CB Type Node |

**Record Id: CB17**

| | | | |
|---|---|---|---|
| Descrip: | STA 1800, 18.00 RT | Increment | 0.10 ft |
| Start El. | 531.93 ft | Max El. | 535.43 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

**Record Id: CB18**

| | | | |
|---|---|---|---|
| Descrip: | STA 1950, 18.00 LT | Increment | 0.10 ft |
| Start El. | 507.47 ft | Max El. | 512.47 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

**Record Id: CB19**

| | | | |
|---|---|---|---|
| Descrip: | STA 1950, 18.00 RT | Increment | 0.10 ft |
| Start El. | 519.90 ft | Max El. | 523.43 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

**Record Id: CB2**

| | | | |
|---|---|---|---|
| Descrip: | STA 1056, 81.04 RT | Increment | 0.10 ft |
| Start El. | 582.69 ft | Max El. | 586.22 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

### Record Id: CB20

| | | | |
|---|---|---|---|
| Descrip: | STA 2100, 18.00 LT | Increment | 0.10 ft |
| Start El. | 503.40 ft | Max El. | 506.83 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

### Record Id: CB21

| | | | |
|---|---|---|---|
| Descrip: | STA 2100, 18.00 RT | Increment | 0.10 ft |
| Start El. | 501.40 ft | Max El. | 503.99 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

### Record Id: CB22

| | | | |
|---|---|---|---|
| Descrip: | STA 2199, 18.00 LT | Increment | 0.10 ft |
| Start El. | 500.92 ft | Max El. | 504.42 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |

| | | | |
|---|---|---|---|
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

### Record Id: CB23

| | | | |
|---|---|---|---|
| Descrip: | STA 2200, 18.00 RT | Increment | 0.10 ft |
| Start El. | 498.25 ft | Max El. | 502.72 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

### Record Id: CB24

| | | | |
|---|---|---|---|
| Descrip: | STA 2283, 18.41 LT | Increment | 0.10 ft |
| Start El. | 498.57 ft | Max El. | 502.75 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

### Record Id: CB25

| | | | |
|---|---|---|---|
| Descrip: | STA 2283, 18.41 RT | Increment | 0.10 ft |
| Start El. | 497.65 ft | Max El. | 501.73 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

## Record Id: CB26

| | | | |
|---|---|---|---|
| Descrip: | STA 2488, 16.98 LT | Increment | 0.10 ft |
| Start El. | 497.19 ft | Max El. | 502.20 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

## Record Id: CB27

| | | | |
|---|---|---|---|
| Descrip: | STA 2445, 66.94 RT | Increment | 0.10 ft |
| Start El. | 498.60 ft | Max El. | 502.16 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

## Record Id: CB28

| | | | |
|---|---|---|---|
| Descrip: | Prototype Record | Increment | 0.10 ft |
| Start El. | 498.94 ft | Max El. | 502.44 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

## Record Id: CB29

| | | | |
|---|---|---|---|
| Descrip: | Prototype Record | Increment | 0.10 ft |
| Start El. | 496.54 ft | Max El. | 501.25 ft |

| | | | |
|---|---|---|---|
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

### Record Id: CB3

| | | | |
|---|---|---|---|
| Descrip: | STA 1101, 62.35 LT | Increment | 0.10 ft |
| Start El. | 581.30 ft | Max El. | 585.32 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

### Record Id: CB30

| | | | |
|---|---|---|---|
| Descrip: | STA 2401, 55.19 RT | Increment | 0.10 ft |
| Start El. | 496.85 ft | Max El. | 501.62 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

### Record Id: CB4

| | | | |
|---|---|---|---|
| Descrip: | STA 1225, 25.78 LT | Increment | 0.10 ft |
| Start El. | 573.10 ft | Max El. | 577.17 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |

| |
|---|
| MH/CB Type Node |

### Record Id: CB5

| | | | |
|---|---|---|---|
| Descrip: | STA 1225, 24.00 RT | Increment | 0.10 ft |
| Start El. | 573.40 ft | Max El. | 577.21 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

### Record Id: CB6

| | | | |
|---|---|---|---|
| Descrip: | STA 1375, 18.43 LT | Increment | 0.10 ft |
| Start El. | 561.18 ft | Max El. | 565.42 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

### Record Id: CB63

| | | | |
|---|---|---|---|
| Descrip: | STA 2425 91.05RT | Increment | 0.10 ft |
| Start El. | 497.85 ft | Max El. | 502.38 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

### Record Id: CB7

| | | | |
|---|---|---|---|
| Descrip: | STA 1375, 18.18 RT | Increment | 0.10 ft |
| Start El. | 561.40 ft | Max El. | 565.42 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

### Record Id: CB8

| | | | |
|---|---|---|---|
| Descrip: | STA 1440, 48.06 LT | Increment | 0.10 ft |
| Start El. | 555.57 ft | Max El. | 559.34 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

### Record Id: CB9

| | | | |
|---|---|---|---|
| Descrip: | STA 1415, 166.91 LT | Increment | 0.10 ft |
| Start El. | 554.18 ft | Max El. | 559.00 ft |
| Void Ratio | 100.00 | | |
| Condition | Existing | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

### Record Id: TDA 3 Vault

| | | | |
|---|---|---|---|
| Descrip: | STA 2415, 10.00 RT | Increment | 0.10 ft |
| Start El. | 497.00 ft | Max El. | 498.00 ft |
| Void Ratio | 100.00 | | |

| Dummy Type Node |
| --- |

**Appended on: Thursday, November 08, 2018 12:57:50 PM**

## ROUTEHYD [] THRU [CB2] USING [100 yr] AND [Everett] NOTZERO RELATIVE RATIONAL

**Rational Method analysis**

| Reach ID | Area (ac) | TC (min) | i (in/hr) | Flow (cfs) | Full Q (cfs) | Full ratio | nDepth (ft) | Size | nVel (ft/s) | fVel (ft/s) | CArea |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| SD9 | 0.006 | 5.00 | 3.9213 | 0.0212 | 3.261 | 0.0065 | 0.0575 | 12 in Diam | 1.1727 | 4.152 | B9 |
| SD10 | 0.0191 | 5.3411 | 3.7726 | 0.0649 | 3.1055 | 0.0209 | 0.1001 | 12 in Diam | 1.5851 | 3.954 | B10 |
| SD7 | 0.098 | 5.00 | 3.9213 | 0.3459 | 3.0226 | 0.1144 | 0.2291 | 12 in Diam | 2.5487 | 3.8485 | B7 |
| SD5 | 0.145 | 5.00 | 3.9213 | 0.5117 | 2.9978 | 0.1707 | 0.279 | 12 in Diam | 2.857 | 3.8169 | B5 |
| SD2 | 0.049 | 5.00 | 3.9213 | 0.1729 | 3.6715 | 0.0471 | 0.1475 | 12 in Diam | 2.398 | 4.6747 | B2 |
| SD3 | 0.17 | 6.0703 | 3.50 | 0.4991 | 9.7574 | 0.0512 | 0.1535 | 12 in Diam | 6.5316 | 12.4235 | B3 |
| SD4 | 0.55 | 6.3995 | 3.3933 | 1.5474 | 10.7671 | 0.1437 | 0.2557 | 12 in Diam | 9.7648 | 13.7091 | B4 |
| SD6 | 0.874 | 6.6624 | 3.3142 | 2.3463 | 10.5845 | 0.2217 | 0.3202 | 12 in Diam | 10.8198 | 13.4767 | B6 |
| SD8 | 0.969 | 6.7779 | 3.281 | 2.5543 | 12.5276 | 0.2039 | 0.3064 | 12 in Diam | 12.5192 | 15.9506 | B8 |
| SD11 | 1.0617 | 6.8085 | 3.2724 | 2.8205 | 7.7402 | 0.3644 | 0.4176 | 12 in Diam | 9.0784 | 9.8551 | B11 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SD13 | 0.0921 | 5.00 | 3.9213 | 0.2967 | 3.0226 | 0.0982 | 0.2116 | 12 in Diam | 2.449 | 3.8485 | B13 |
| SD12 | 1.2098 | 6.9003 | 3.2468 | 3.2078 | 10.9463 | 0.2931 | 0.371 | 12 in Diam | 12.1003 | 13.9372 | B12 |
| SD15 | 0.112 | 5.00 | 3.9213 | 0.3596 | 3.0226 | 0.119 | 0.2334 | 12 in Diam | 2.5812 | 3.8485 | B15 |
| SD14 | 1.4348 | 7.1069 | 3.1911 | 3.7451 | 10.1953 | 0.3673 | 0.4196 | 12 in Diam | 11.9802 | 12.9811 | B14 |
| SD16 | 1.5108 | 7.246 | 3.1551 | 3.9002 | 3.5741 | 1.0912 | 1.00 | 12 in Diam | 4.9659 | 4.5507 | B16 |
| SD17 | 1.5848 | 7.3601 | 3.1263 | 4.0545 | 11.0712 | 0.3662 | 0.4188 | 12 in Diam | 13.0004 | 14.0963 | B17 |
| SD19 | 1.8148 | 7.5486 | 3.0803 | 4.5765 | 11.5731 | 0.3954 | 0.4375 | 12 in Diam | 13.8547 | 14.7353 | B19 |
| SD18 | 2.0308 | 7.7158 | 3.0411 | 5.0579 | 7.884 | 0.6415 | 0.5823 | 12 in Diam | 10.6559 | 10.0382 | B18 |
| SD20 | 2.1818 | 7.8691 | 3.0062 | 5.3733 | 5.9705 | 0.90 | 0.7424 | 12 in Diam | 8.5939 | 7.6019 | B20 |
| SD22 | 0.002 | 5.00 | 3.9213 | 0.0045 | 2.7754 | 0.0016 | 0.0302 | 12 in Diam | 0.6516 | 3.5338 | B22 |
| SD21 | 2.2968 | 8.032 | 2.9703 | 5.5992 | 23.2726 | 0.2406 | 0.5002 | 18 in Diam | 10.8526 | 13.1696 | B21 |
| SD24 | 2.3968 | 8.1364 | 2.9479 | 5.8223 | 8.2281 | 0.7076 | 0.9318 | 18 in Diam | 5.0469 | 4.6562 | B24 |
| SD23 | 2.4908 | 8.3379 | 2.906 | 5.9853 | 8.4621 | 0.7073 | 0.9316 | 18 in Diam | 5.1899 | 4.7886 | B23 |
| SD25 | 2.6378 | 8.6911 | 2.8362 | 6.2167 | 11.9673 | 0.5195 | 0.7675 | 18 in Diam | 6.8325 | 6.7721 | B25 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SD28 | 0.105 | 5.00 | 3.9213 | 0.3706 | 4.343 | 0.0853 | 0.1973 | 12 in Diam | 3.3792 | 5.5296 | B28 |
| SD27 | 0.125 | 5.1332 | 3.8614 | 0.4344 | 4.9416 | 0.0879 | 0.2004 | 12 in Diam | 3.8749 | 6.2919 | B27 |
| SD63 | 0.169 | 5.331 | 3.7768 | 0.5744 | 3.8128 | 0.1507 | 0.2617 | 12 in Diam | 3.508 | 4.8546 | B63 |
| SD26 | 0.216 | 5.6541 | 3.6488 | 0.7093 | 3.1202 | 0.2273 | 0.324 | 12 in Diam | 3.2178 | 3.9727 | B26 |
| SD30 | 2.8888 | 8.8692 | 2.8027 | 6.7764 | 8.6898 | 0.7798 | 0.9967 | 18 in Diam | 5.4351 | 4.9174 | B30 |
| SD29 | 2.9948 | 9.0317 | 2.773 | 6.9602 | 8.0683 | 0.8627 | 1.076 | 18 in Diam | 5.1305 | 4.5657 | B29 |

**HGL Analysis**

| From Node | To Node | HG El (ft) | App (ft) | Bend (ft) | Junct Loss (ft) | Adjusted HG El (ft) | Max El (ft) |
|---|---|---|---|---|---|---|---|
| | | | | | | | 497.576 |
| CB29 | TDA 3 Vault | 498.1064 | 0.2283 | 0.0074 | ------ | 497.8855 | 501.2500 |
| CB30 | CB29 | 498.5320 | 0.1922 | 0.1045 | 0.0175 | 498.4619 | 501.6200 |
| CB25 | CB30 | 499.1189 | ------ | 0.1594 | ------ | 499.2784 | 501.7300 |
| CB23 | CB25 | 499.7897 | 0.1686 | 0.0954 | ------ | 499.7165 | 502.7200 |
| CB24 | CB23 | 500.2933 | 0.1559 | 0.0591 | ------ | 500.1965 | 502.7500 |
| CB21 | CB24 | 502.7440 | ------ | 0.0764 | 0.0005 | 502.8209 | 503.9900 |
| CB20 | CB21 | 505.5234 | ------ | 0.0052 | ------ | 505.5286 | 506.8300 |
| CB18 | CB20 | 509.4500 | ------ | 0.0067 | ------ | 509.4567 | 512.4700 |
| CB19 | CB18 | 521.6940 | ------ | 0.0025 | ------ | 521.6966 | 523.4300 |
| CB17 | CB19 | 533.5055 | ------ | 0.5282 | ------ | 534.0337 | 535.4300 |
| CB16 | CB17 | 534.8384 | 0.3531 | 0.5377 | ------ | 535.0230 | 535.7200 |
| CB14 | CB16 | 540.6125 | ------ | 0.0042 | 0.0232 | 540.6400 | 543.6600 |
| CB12 | CB14 | 552.4431 | ------ | 0.0570 | 0.0169 | 552.5170 | 555.4300 |
| CB11 | CB12 | 554.3011 | ------ | 0.0291 | 0.0035 | 554.3337 | 557.8300 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| CB10 | CB11 | 554.3343 | 0.0214 | 0.0365 | ------ | 554.3494 | 558.1000 |
| CB9 | CB10 | 554.3744 | ------ | ------ | ------ | 554.3744 | 559.0000 |
| CB8 | CB11 | 556.5933 | ------ | 0.0433 | ------ | 556.6366 | 559.3400 |
| CB6 | CB8 | 562.1548 | ------ | 0.3129 | 0.2506 | 562.7183 | 565.4200 |
| CB7 | CB6 | 562.7252 | ------ | ------ | ------ | 562.7252 | 565.4200 |
| CB4 | CB6 | 573.8297 | ------ | 0.1831 | 0.0689 | 574.0816 | 577.1700 |
| CB5 | CB4 | 574.2371 | ------ | ------ | ------ | 574.2371 | 577.2100 |
| CB3 | CB4 | 581.6695 | ------ | 0.0817 | ------ | 581.7512 | 585.3200 |
| CB2 | CB3 | 582.9151 | ------ | ------ | ------ | 582.9151 | 586.2200 |
| CB13 | CB12 | 552.5222 | ------ | ------ | ------ | 552.5222 | 555.4300 |
| CB15 | CB14 | 540.6474 | ------ | ------ | ------ | 540.6474 | 543.6600 |
| CB22 | CB21 | 502.8209 | ------ | ------ | ------ | 502.8209 | 504.4200 |
| CB26 | CB30 | 498.4966 | 0.0083 | 0.0016 | ------ | 498.4899 | 502.2000 |
| CB63 | CB26 | 498.5148 | 0.2331 | 0.0032 | ------ | 498.2849 | 502.3800 |
| CB27 | CB63 | 498.9643 | ------ | 0.0390 | ------ | 499.0032 | 502.1600 |
| CB28 | CB27 | 499.2759 | ------ | ------ | ------ | 499.2759 | 502.4400 |

**Conduit Notes**

| Reach | HW Depth (ft) | HW/D ratio | Q (cfs) | TW Depth (ft) | Dc (ft) | Dn (ft) | Comment |
|---|---|---|---|---|---|---|---|
| SD29 | 1.5664 | 1.0443 | 6.96 | 1.0760 | 1.0216 | 1.0760 | Outlet Control M1 Backwater |
| SD30 | 1.6820 | 1.1214 | 6.78 | 1.3455 | 1.0079 | 0.9967 | Outlet Control M1 Backwater |
| SD25 | 1.4689 | 0.9793 | 6.22 | 1.6119 | 0.9638 | 0.7675 | SuperCrit flow, Inlet end controls |
| SD23 | 2.1447 | 1.4298 | 5.99 | 1.6284 | 0.9447 | 0.9316 | Outlet Control |
| SD24 | 1.7233 | 1.1489 | 5.82 | 1.4665 | 0.9317 | 0.9318 | Outlet Control M1 Backwater |
| SD21 | 1.3440 | 0.8960 | 5.60 | 1.6265 | 0.9171 | 0.5002 | SuperCrit flow, Inlet end controls |
| SD20 | 2.1234 | 2.1234 | 5.37 | 1.4209 | 0.9341 | 0.7424 | SuperCrit flow, Inlet end controls |
| SD18 | 1.9800 | 1.9800 | 5.06 | 2.1286 | 0.9199 | 0.5823 | SuperCrit flow, Inlet end controls |
| SD19 | 1.7940 | 1.7940 | 4.58 | 1.9867 | 0.8918 | 0.4375 | SuperCrit flow, Inlet end controls |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| SD17 | 1.5755 | 1.5755 | 4.05 | 1.7966 | 0.8523 | 0.4188 | SuperCrit flow, Inlet end controls |
| SD16 | 2.9084 | 2.9084 | 3.90 | 2.1037 | 0.8387 | >D | Outlet Control |
| SD14 | 1.4525 | 1.4525 | 3.75 | 2.8030 | 0.8241 | 0.4196 | SuperCrit flow, Inlet end controls |
| SD12 | 1.2831 | 1.2831 | 3.21 | 1.4800 | 0.7673 | 0.3710 | SuperCrit flow, Inlet end controls |
| SD11 | 1.1411 | 1.1411 | 2.82 | 1.3570 | 0.7205 | 0.4176 | SuperCrit flow, Inlet end controls |
| SD10 | 1.1742 | 1.1742 | 0.06 | 1.1737 | 0.1033 | 0.1001 | Outlet Control |
| SD9 | 0.1944 | 0.1944 | 0.02 | 0.3394 | 0.0586 | 0.0575 | Outlet Control M1 Backwater |
| SD8 | 1.0233 | 1.0233 | 2.55 | 1.1737 | 0.6850 | 0.3064 | SuperCrit flow, Inlet end controls |
| SD6 | 0.9748 | 0.9748 | 2.35 | 1.0666 | 0.6556 | 0.3202 | SuperCrit flow, Inlet end controls |
| SD7 | 1.5448 | 1.5448 | 0.35 | 1.5383 | 0.2426 | 0.2291 | Outlet Control |
| SD4 | 0.7297 | 0.7297 | 1.55 | 1.5383 | 0.5278 | 0.2557 | SuperCrit flow, Inlet end controls |
| SD5 | 0.8371 | 0.8371 | 0.51 | 0.9816 | 0.2967 | 0.2790 | Outlet Control M1 Backwater |
| SD3 | 0.3695 | 0.3695 | 0.50 | 0.9816 | 0.2930 | 0.1535 | SuperCrit flow, Inlet end controls |
| SD2 | 0.2251 | 0.2251 | 0.17 | 0.4512 | 0.1702 | 0.1475 | SuperCrit flow, Inlet end controls |
| SD13 | 1.3618 | 1.3618 | 0.30 | 1.3570 | 0.2243 | 0.2116 | Outlet Control |
| SD15 | 1.4870 | 1.4870 | 0.36 | 1.4800 | 0.2475 | 0.2334 | Outlet Control |
| SD22 | 1.4209 | 1.4209 | 0.00 | 1.4209 | 0.0266 | 0.0302 | Outlet Control |
| SD26 | 1.6446 | 1.6446 | 0.71 | 1.6119 | 0.3513 | 0.3240 | Outlet Control |
| SD63 | 1.3248 | 1.3248 | 0.57 | 1.2999 | 0.3150 | 0.2617 | Outlet Control |
| SD27 | 0.3643 | 0.3643 | 0.43 | 0.4349 | 0.2727 | 0.2004 | SuperCrit flow, Inlet end controls |
| SD28 | 0.3359 | 0.3359 | 0.37 | 0.4032 | 0.2514 | 0.1973 | SuperCrit flow, Inlet end controls |

**Appended on: Thursday, November 08, 2018 2:23:26 PM**

# Layout Report: CB61 to TDA 4 Vault

| Event | Precip (in) |
|---|---|
| 2 yr 24 hr | 1.50 |
| 10 year | 2.00 |
| 25 year | 2.50 |
| 100 year | 3.00 |

**Reach Records**

**Record Id: SD55**

| | | | |
|---|---|---|---|
| Section Shape: | Circular | | |
| Uniform Flow Method: | Manning's | Coefficient: | 0.012 |
| Routing Method: | Travel Time Shift | Contributing Hyd | |
| DnNode | CB56 | UpNode | CB55 |
| Material | unspecified | Size | 12 in Diam |
| Ent Losses | Groove End w/Headwall | | |
| Length | 44.00 ft | Slope | 4.45% |
| Up Invert | 501.96 ft | Dn Invert | 500.00 ft |

| Conduit Constraints | | | | |
|---|---|---|---|---|
| Min Vel | Max Vel | Min Slope | Max Slope | Min Cover |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| Drop across MH | 0.00 ft | Ex/Infil Rate | 0.00 in/hr |

**Record Id: SD56**

| | | | |
|---|---|---|---|
| Section Shape: | Circular | | |
| Uniform Flow Method: | Manning's | Coefficient: | 0.012 |
| Routing Method: | Travel Time Shift | Contributing Hyd | |
| DnNode | TDA 4 Vault | UpNode | CB56 |
| Material | unspecified | Size | 12 in Diam |
| Ent Losses | Groove End w/Headwall | | |
| Length | 56.00 ft | Slope | 4.46% |
| Up Invert | 500.00 ft | Dn Invert | 497.50 ft |

| Conduit Constraints | | | | |
|---|---|---|---|---|
| Min Vel | Max Vel | Min Slope | Max Slope | Min Cover |
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| **Drop across MH** | **0.00 ft** | **Ex/Infil Rate** | **0.00 in/hr** |

**Record Id: SD57**

| | | | |
|---|---|---|---|
| **Section Shape:** | **Circular** | | |
| **Uniform Flow Method:** | **Manning's** | **Coefficient:** | **0.012** |
| **Routing Method:** | **Travel Time Shift** | **Contributing Hyd** | |
| **DnNode** | **CB56** | **UpNode** | **CB57** |
| **Material** | **unspecified** | **Size** | **12 in Diam** |
| **Ent Losses** | **Groove End w/Headwall** | | |
| **Length** | **149.00 ft** | **Slope** | **4.11%** |
| **Up Invert** | **506.12 ft** | **Dn Invert** | **500.00 ft** |

| **Conduit Constraints** | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| **2.00 ft/s** | **15.00 ft/s** | **0.50%** | **2.00%** | **3.00 ft** |

| | | | |
|---|---|---|---|
| **Drop across MH** | **0.00 ft** | **Ex/Infil Rate** | **0.00 in/hr** |

**Record Id: SD58**

| | | | |
|---|---|---|---|
| **Section Shape:** | **Circular** | | |
| **Uniform Flow Method:** | **Manning's** | **Coefficient:** | **0.012** |
| **Routing Method:** | **Travel Time Shift** | **Contributing Hyd** | |
| **DnNode** | **CB57** | **UpNode** | **CB58** |
| **Material** | **unspecified** | **Size** | **12 in Diam** |
| **Ent Losses** | **Groove End w/Headwall** | | |
| **Length** | **42.00 ft** | **Slope** | **0.95%** |
| **Up Invert** | **506.52 ft** | **Dn Invert** | **506.12 ft** |

| **Conduit Constraints** | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| **2.00 ft/s** | **15.00 ft/s** | **0.50%** | **2.00%** | **3.00 ft** |

| | | | |
|---|---|---|---|
| **Drop across MH** | **0.00 ft** | **Ex/Infil Rate** | **0.00 in/hr** |

**Record Id: SD59**

| | | | |
|---|---|---|---|
| **Section Shape:** | **Circular** | | |
| **Uniform Flow Method:** | **Manning's** | **Coefficient:** | **0.012** |
| **Routing Method:** | **Travel Time Shift** | **Contributing Hyd** | |
| **DnNode** | **CB57** | **UpNode** | **CB59** |

| | | | |
|---|---|---|---|
| **Material** | **unspecified** | **Size** | **12 in Diam** |
| **Ent Losses** | **Groove End w/Headwall** | | |
| **Length** | **148.00 ft** | **Slope** | **0.53%** |
| **Up Invert** | **506.91 ft** | **Dn Invert** | **506.12 ft** |

| **Conduit Constraints** | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| **2.00 ft/s** | **15.00 ft/s** | **0.50%** | **2.00%** | **3.00 ft** |

| | | | |
|---|---|---|---|
| **Drop across MH** | **0.00 ft** | **Ex/Infil Rate** | **0.00 in/hr** |

**Record Id: SD60**

| | | | |
|---|---|---|---|
| **Section Shape:** | **Circular** | | |
| **Uniform Flow Method:** | **Manning's** | **Coefficient:** | **0.012** |
| **Routing Method:** | **Travel Time Shift** | **Contributing Hyd** | |
| **DnNode** | **CB59** | **UpNode** | **CB60** |
| **Material** | **unspecified** | **Size** | **12 in Diam** |
| **Ent Losses** | **Groove End w/Headwall** | | |
| **Length** | **69.00 ft** | **Slope** | **0.55%** |
| **Up Invert** | **507.69 ft** | **Dn Invert** | **507.31 ft** |

| **Conduit Constraints** | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |
| **2.00 ft/s** | **15.00 ft/s** | **0.50%** | **2.00%** | **3.00 ft** |

| | | | |
|---|---|---|---|
| **Drop across MH** | **0.00 ft** | **Ex/Infil Rate** | **0.00 in/hr** |

**Record Id: SD61**

| | | | |
|---|---|---|---|
| **Section Shape:** | **Circular** | | |
| **Uniform Flow Method:** | **Manning's** | **Coefficient:** | **0.012** |
| **Routing Method:** | **Travel Time Shift** | **Contributing Hyd** | |
| **DnNode** | **CB59** | **UpNode** | **CB61** |
| **Material** | **unspecified** | **Size** | **12 in Diam** |
| **Ent Losses** | **Groove End w/Headwall** | | |
| **Length** | **77.00 ft** | **Slope** | **0.55%** |
| **Up Invert** | **507.33 ft** | **Dn Invert** | **506.91 ft** |

| **Conduit Constraints** | | | | |
|---|---|---|---|---|
| **Min Vel** | **Max Vel** | **Min Slope** | **Max Slope** | **Min Cover** |

| | | | | |
|---|---|---|---|---|
| 2.00 ft/s | 15.00 ft/s | 0.50% | 2.00% | 3.00 ft |

| | | | |
|---|---|---|---|
| Drop across MH | 0.00 ft | Ex/Infil Rate | 0.00 in/hr |

**Node Records**
**Record Id: CB55**

| | | | |
|---|---|---|---|
| Descrip: | Prototype Record | Increment | 0.10 ft |
| Start El. | 501.96 ft | Max El. | 506.04 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

**Record Id: CB56**

| | | | |
|---|---|---|---|
| Descrip: | Prototype Record | Increment | 0.10 ft |
| Start El. | 500.00 ft | Max El. | 506.04 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

**Record Id: CB57**

| | | | |
|---|---|---|---|
| Descrip: | Prototype Record | Increment | 0.10 ft |
| Start El. | 506.12 ft | Max El. | 509.99 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

**Record Id: CB58**

| | | | |
|---|---|---|---|
| Descrip: | Prototype Record | Increment | 0.10 ft |
| Start El. | 506.52 ft | Max El. | 510.03 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |

| | | | |
|---|---|---|---|
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

**Record Id: CB59**

| | | | |
|---|---|---|---|
| Descrip: | Prototype Record | Increment | 0.10 ft |
| Start El. | 506.91 ft | Max El. | 511.56 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

**Record Id: CB60**

| | | | |
|---|---|---|---|
| Descrip: | Prototype Record | Increment | 0.10 ft |
| Start El. | 507.69 ft | Max El. | 511.19 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

**Record Id: CB61**

| | | | |
|---|---|---|---|
| Descrip: | Prototype Record | Increment | 0.10 ft |
| Start El. | 507.33 ft | Max El. | 510.83 ft |
| Void Ratio | 100.00 | | |
| Condition | Proposed | Structure Type | CB-TYPE 1 |
| | | Channelization | No Special Shape |
| Catch | 0.00 ft | Bottom Area | 3.97 sf |
| MH/CB Type Node | | | |

**Record Id: TDA 4 Vault**

| | | | |
|---|---|---|---|
| Descrip: | | Increment | 0.00 ft |
| Start El. | 497.00 ft | Max El. | 498.00 ft |
| Void Ratio | 100.00 | | |

| Dummy Type Node |
|---|

**Appended on: Thursday, November 08, 2018 2:22:35 PM**

## ROUTEHYD [] THRU [CB62-2] USING [100 yr] AND [Everett] NOTZERO RELATIVE RATIONAL

### Rational Method analysis

| Reach ID | Area (ac) | TC (min) | i (in/hr) | Flow (cfs) | Full Q (cfs) | Full ratio | nDepth (ft) | Size | nVel (ft/s) | fVel (ft/s) | CArea |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SD58 | 0.142 | 5.00 | 3.9213 | 0.4629 | 3.7769 | 0.1226 | 0.2366 | 12 in Diam | 3.2593 | 4.8088 | B58 |
| SD61 | 0.104 | 5.00 | 3.9213 | 0.3619 | 2.8584 | 0.1266 | 0.2402 | 12 in Diam | 2.4941 | 3.6394 | B61 |
| SD60 | 0.107 | 5.00 | 3.9213 | 0.3725 | 2.872 | 0.1297 | 0.2431 | 12 in Diam | 2.5236 | 3.6567 | B60 |
| SD59 | 0.243 | 5.5145 | 3.7026 | 0.7929 | 2.8276 | 0.2804 | 0.3622 | 12 in Diam | 3.0889 | 3.6002 | B59 |
| SD57 | 0.497 | 6.3131 | 3.4205 | 1.4566 | 7.8434 | 0.1857 | 0.292 | 12 in Diam | 7.6313 | 9.9865 | B57 |
| SD55 | 0.126 | 5.00 | 3.9213 | 0.4013 | 8.164 | 0.0492 | 0.1506 | 12 in Diam | 5.4023 | 10.3947 | B55 |
| SD56 | 0.748 | 6.6385 | 3.3212 | 2.0934 | 8.1771 | 0.256 | 0.345 | 12 in Diam | 8.715 | 10.4114 | B56 |

### HGL Analysis

| From Node | To Node | HG El (ft) | App (ft) | Bend (ft) | Junct Loss (ft) | Adjusted HG El (ft) | Max El (ft) |
|---|---|---|---|---|---|---|---|
| | | | | | | | 498.1186 |
| CB56 | TDA 4 Vault | 500.9131 | ------ | 0.0298 | 0.1841 | 501.1270 | 506.0400 |
| CB57 | CB56 | 506.8394 | ------ | 0.0009 | 0.0559 | 506.8963 | 509.9900 |
| CB58 | CB57 | 507.0703 | ------ | ------ | ------ | 507.0703 | 510.0300 |
| No approach losses at node CB60 because inverts and/or crowns are offset. | | | | | | | |
| CB59 | CB57 | 507.4251 | ------ | 0.0216 | 0.0536 | 507.5003 | 511.5600 |
| CB61 | CB59 | 507.6652 | ------ | ------ | ------ | 507.6652 | 510.8300 |
| CB60 | CB59 | 508.0304 | ------ | ------ | ------ | 508.0304 | 511.1900 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| CB55 | CB56 | 502.2948 | ------ | ------ | ------ | 502.2948 | 506.0400 |

**Conduit Notes**

| Reach | HW Depth (ft) | HW/D ratio | Q (cfs) | TW Depth (ft) | Dc (ft) | Dn (ft) | Comment |
|---|---|---|---|---|---|---|---|
| SD56 | 0.9131 | 0.9131 | 2.09 | 0.6186 | 0.6186 | 0.3450 | SuperCrit flow, Inlet end controls |
| SD57 | 0.7194 | 0.7194 | 1.46 | 1.1270 | 0.5114 | 0.2920 | SuperCrit flow, Inlet end controls |
| SD58 | 0.5503 | 0.5503 | 0.46 | 0.7763 | 0.2819 | 0.2366 | Outlet Control M1 Backwater |
| SD59 | 0.5151 | 0.5151 | 0.79 | 0.7763 | 0.3723 | 0.3622 | SuperCrit flow, Inlet end controls |
| SD61 | 0.3352 | 0.3352 | 0.36 | 0.5903 | 0.2483 | 0.2402 | SuperCrit flow, Inlet end controls |
| SD60 | 0.3404 | 0.3404 | 0.37 | 0.2521 | 0.2521 | 0.2431 | SuperCrit flow, Inlet end controls |
| SD55 | 0.3348 | 0.3348 | 0.40 | 1.1270 | 0.2619 | 0.1506 | SuperCrit flow, Inlet end controls |

## INLET SPACING - CURB AND GUTTER SPREADSHEET (ENGLISH UNITS)

| | |
|---|---|
| Tc = | 5.00 |
| C = | 0.90 |
| I = | 2.50 |
| m= | 6.31 |
| n= | 0.58 |

Existing cb
Important
Proposed cb
High Point
Another Sheet

Project Name: Harbour Reach Extension - Beverly Park Rd to South Rd
Project #: 20150051
S.R.: N/A
Calculated By James Lee    Checked by Max Magee
Date: 10/31/2018    Date 12/6/2018
**Instructions:** Red Text is automatically calculated. Black Text should be input by designer. Move mouse over column titles for a detailed description of each entry.

WSDOT Classification Map
Proposed Urban Major Collector
Zd = Shoulder + 1/2 Driving Lane (5' bike lane+3' buffer+5.5' lane=13.5')

*Depth not to exceed 0.12' at shoulder
13.5' spread at T=2%
11.5' spread at T=3.2%

| Station | Distance | Width | Δ Q | Σ Q | Slope L | Super T | G.W. | G.L. | d | $Z_d$ | $Q_{bp}$** | Vcontinuous** | Vside** | $E_o$ | $R_s$ | E | $Q_i$ | $Q_{bp}$** | Allowable Spread | $Z_d$ Check | Velocity Check | $Q_{bp}$ Check | Comments (L/R) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flowing North (RT) | | | | | | | | | | | | | | | | | | | | | | | |
| **10+50.00** | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | **-------------** | **High Point** |
| 10+75.00 | 25 | 45.00 | 0.06 | 0.06 | 0.040 | 0.020 | | | 0.04 | 1.88 | 0.06 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 11+00.00 | 25 | 41.00 | 0.05 | 0.11 | 0.047 | 0.020 | | | 0.05 | 2.32 | 0.11 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 11+25.00 | 25 | 37.00 | 0.05 | 0.16 | 0.051 | 0.020 | | | 0.05 | 2.61 | 0.16 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 11+50.00 | 25 | 33.50 | 0.04 | 0.20 | 0.057 | 0.020 | | | 0.06 | 2.80 | 0.20 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 11+75.00 | 25 | 30.50 | 0.04 | 0.24 | 0.062 | 0.020 | | | 0.06 | 2.94 | 0.24 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 12+00.00 | 25 | 30.50 | 0.04 | 0.28 | 0.071 | 0.020 | | | 0.06 | 3.04 | 0.28 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 12+25.00 | 25 | 30.50 | 0.04 | 0.32 | 0.074 | 0.020 | 1.67 | 2.00 | 0.06 | 3.17 | 0.04 | 3.55 | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | OK, VELOCITY < 5 FT/SEC | | |
| 12+50.00 | 25 | 30.00 | 0.04 | 0.08 | 0.079 | 0.020 | | | 0.04 | 1.88 | 0.08 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 12+75.00 | 25 | 29.00 | 0.04 | 0.12 | 0.080 | 0.020 | | | 0.04 | 2.16 | 0.12 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 13+00.00 | 25 | 28.60 | 0.04 | 0.16 | 0.080 | 0.020 | | | 0.05 | 2.39 | 0.16 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 13+25.00 | 25 | 28.50 | 0.04 | 0.19 | 0.080 | 0.020 | | | 0.05 | 2.58 | 0.19 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 13+50.00 | 25 | 28.50 | 0.04 | 0.23 | 0.080 | 0.020 | | | 0.06 | 2.76 | 0.23 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 13+75.00 | 25 | 24.50 | 0.03 | 0.26 | 0.080 | 0.020 | 1.67 | 2.00 | 0.06 | 2.89 | 0.03 | 3.43 | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | OK, VELOCITY < 5 FT/SEC | | |
| 14+00.00 | 25 | 24.50 | 0.03 | 0.06 | 0.080 | 0.020 | | | 0.03 | 1.64 | 0.06 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 14+25.00 | 25 | 24.50 | 0.03 | 0.09 | 0.080 | 0.020 | | | 0.04 | 1.94 | 0.09 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 14+50.00 | 25 | 24.50 | 0.03 | 0.12 | 0.080 | 0.020 | | | 0.04 | 2.17 | 0.12 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 14+75.00 | 25 | 24.50 | 0.03 | 0.15 | 0.080 | 0.020 | | | 0.05 | 2.36 | 0.15 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 15+00.00 | 25 | 24.50 | 0.03 | 0.18 | 0.080 | 0.020 | 1.67 | 2.00 | 0.05 | 2.54 | 0.01 | 3.06 | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | OK, VELOCITY < 5 FT/SEC | | |
| 15+25.00 | 25 | 24.50 | 0.03 | 0.04 | 0.080 | 0.020 | | | 0.03 | 1.46 | 0.04 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 15+50.00 | 25 | 24.50 | 0.03 | 0.07 | 0.080 | 0.020 | | | 0.04 | 1.80 | 0.07 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 15+75.00 | 25 | 24.50 | 0.03 | 0.11 | 0.080 | 0.020 | | | 0.04 | 2.06 | 0.11 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 16+00.00 | 25 | 24.50 | 0.03 | 0.14 | 0.080 | 0.020 | | | 0.05 | 2.27 | 0.14 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 16+25.00 | 25 | 24.50 | 0.03 | 0.17 | 0.080 | 0.020 | | | 0.05 | 2.45 | 0.17 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 16+50.00 | 25 | 24.50 | 0.03 | 0.20 | 0.080 | 0.020 | 1.67 | 2.00 | 0.05 | 2.62 | 0.01 | 3.15 | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | OK, VELOCITY < 5 FT/SEC | | |
| 16+75.00 | 25 | 24.50 | 0.03 | 0.04 | 0.080 | 0.020 | | | 0.03 | 1.49 | 0.04 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 17+00.00 | 25 | 24.50 | 0.03 | 0.08 | 0.080 | 0.020 | | | 0.04 | 1.82 | 0.08 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 17+25.00 | 25 | 24.50 | 0.03 | 0.11 | 0.080 | 0.020 | | | 0.04 | 2.08 | 0.11 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 17+50.00 | 25 | 24.50 | 0.03 | 0.14 | 0.080 | 0.020 | | | 0.05 | 2.29 | 0.14 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | Normal Crown |
| 17+75.00 | 25 | 49.00 | 0.06 | 0.20 | 0.080 | 0.020 | | | 0.05 | 2.63 | 0.20 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | LT Level Crown |
| 18+00.00 | 25 | 49.00 | 0.06 | 0.27 | 0.080 | 0.026 | 1.67 | 2.00 | 0.06 | 2.47 | 0.01 | 3.57 | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | OK, VELOCITY < 5 FT/SEC | | |
| 18+25.00 | 25 | 49.00 | 0.06 | 0.08 | 0.080 | 0.032 | | | 0.04 | 1.36 | 0.08 | | | | | | | | 11.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | Full Super |
| 18+50.00 | 25 | 49.00 | 0.06 | 0.14 | 0.080 | 0.032 | | | 0.05 | 1.70 | 0.14 | | | | | | | | 11.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 18+75.00 | 25 | 49.00 | 0.06 | 0.20 | 0.080 | 0.032 | | | 0.06 | 1.96 | 0.20 | | | | | | | | 11.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 19+00.00 | 25 | 49.00 | 0.06 | 0.27 | 0.080 | 0.032 | | | 0.07 | 2.17 | 0.27 | | | | | | | | 11.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 19+25.00 | 25 | 49.00 | 0.06 | 0.33 | 0.080 | 0.032 | | | 0.08 | 2.35 | 0.33 | | | | | | | | 11.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 19+50.00 | 25 | 49.00 | 0.06 | 0.39 | 0.080 | 0.032 | 1.67 | 2.00 | 0.08 | 2.51 | 0.02 | 4.15 | | | | | | | 11.50 | OK, Zd ALLOWABLE > Zd DESIGN | OK, VELOCITY < 5 FT/SEC | | |
| 19+75.00 | 25 | 49.00 | 0.06 | 0.08 | 0.080 | 0.032 | | | 0.05 | 1.41 | 0.08 | | | | | | | | 11.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 20+00.00 | 25 | 49.00 | 0.06 | 0.15 | 0.075 | 0.032 | | | 0.06 | 1.76 | 0.15 | | | | | | | | 11.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 20+25.00 | 25 | 49.00 | 0.06 | 0.21 | 0.070 | 0.032 | | | 0.07 | 2.04 | 0.21 | | | | | | | | 11.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 20+50.00 | 25 | 49.00 | 0.06 | 0.27 | 0.065 | 0.032 | | | 0.07 | 2.28 | 0.27 | | | | | | | | 11.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 20+75.00 | 25 | 49.00 | 0.06 | 0.34 | 0.060 | 0.032 | | | 0.08 | 2.51 | 0.34 | | | | | | | | 11.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 21+00.00 | 25 | 49.00 | 0.06 | 0.40 | 0.055 | 0.032 | 1.67 | 2.00 | 0.09 | 2.72 | 0.03 | 3.67 | | | | | | | 11.50 | OK, Zd ALLOWABLE > Zd DESIGN | OK, VELOCITY < 5 FT/SEC | | |
| 21+25.00 | 25 | 49.00 | 0.06 | 0.09 | 0.050 | 0.032 | | | 0.05 | 1.61 | 0.09 | | | | | | | | 11.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 21+50.00 | 25 | 49.00 | 0.06 | 0.16 | 0.039 | 0.032 | | | 0.07 | 2.04 | 0.16 | | | | | | | | 11.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 21+75.00 | 25 | 50.00 | 0.06 | 0.22 | 0.034 | 0.032 | | | 0.08 | 2.39 | 0.22 | | | | | | | | 11.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | Full Super |
| 22+00.00 | 25 | 51.00 | 0.07 | 0.29 | 0.030 | 0.030 | 1.67 | 2.00 | 0.08 | 2.80 | 0.03 | 2.68 | | | | | | | 11.50 | OK, Zd ALLOWABLE > Zd DESIGN | OK, VELOCITY < 5 FT/SEC | | |
| 22+25.00 | 25 | 53.00 | 0.07 | 0.09 | 0.023 | 0.020 | | | 0.05 | 2.49 | 0.09 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | LT Level Crown |
| 22+50.00 | 25 | 57.00 | 0.07 | 0.17 | 0.020 | 0.020 | | | 0.06 | 3.19 | 0.17 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | Normal Crown |
| 22+75.00 | 25 | 27.00 | 0.03 | 0.20 | 0.016 | 0.020 | | | 0.07 | 3.54 | 0.20 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 22+83.00 | 8 | 27.00 | 0.01 | 0.21 | 0.014 | 0.020 | 1.67 | 2.00 | 0.07 | 3.71 | 0.04 | 1.78 | 1.54 | 0.80 | 0.23 | 0.84 | 0.18 | 0.03 | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | OK, VELOCITY < 5 FT/SEC | | |
| 23+00.00 | 17 | 25.00 | 0.02 | 0.06 | 0.013 | 0.020 | | | 0.05 | 2.27 | 0.06 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 23+25.00 | 25 | 27.00 | 0.03 | 0.09 | 0.014 | 0.020 | | | 0.05 | 2.70 | 0.09 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 23+50.00 | 25 | 34.00 | 0.04 | 0.13 | 0.001 | 0.020 | | | 0.10 | 5.12 | 0.13 | | | | | | | | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 23+75.00 | 25 | 45.00 | 0.06 | 0.19 | 0.012 | 0.020 | 1.67 | 2.00 | 0.07 | 3.65 | 0.04 | 1.64 | 1.43 | 0.80 | 0.26 | 0.85 | 0.16 | 0.03 | 13.50 | OK, Zd ALLOWABLE > Zd DESIGN | OK, VELOCITY < 5 FT/SEC | | |
| 23+90.00 | 15 | 60.00 | 0.05 | 0.07 | | | | | | | 0.07 | | | | | | | | 13.50 | | | OK, Qbp < 0.1 CFS | Flow into RB |

**INLET SPACING - CURB AND GUTTER SPREADSHEET (ENGLISH UNITS)**

| | |
|---|---|
| Tc = | 5.00 |
| C = | 0.90 |
| I = | 2.50 |
| m= | 6.31 |
| n= | 0.58 |

Existing cb
Important
Proposed cb
High Point
Another Sheet

Project Name: Harbour Reach Extension - Beverly Park Rd to South Rd
Project #: 20150051
S.R.: N/A
Calculated By James Lee Checked by Max Magee
Date: 10/31/2018 Date 12/6/2018
**Instructions:** Red Text is automatically calculated. Black Text should be input by designer. Move mouse over column titles for a detailed description of each entry.

WSDOT Classification Map
Proposed Urban Major Collector
Zd = Shoulder + 1/2 Driving Lane (5' bike lane+3' buffer+5.5' lane=13.5')

*Depth not to exceed 0.12' at shoulder
13.5' spread at T=2%
11.5' spread at T=3.2%

| Station | Distance | Width | Δ Q | Σ Q | Slope L | Super T | G.W. | G.L. | d | $Z_d$ | $Q_{bp**}$ | Vcontinuous** | Vside** | $E_o$ | $R_s$ | E | $Q_i$ | $Q_{bp**}$ | Allowable Spread | $Z_d$ Check | Velocity Check | $Q_{bp}$ Check | Comments (L/R) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flowing North (LT) | | | | | | | | | | | | | | | | | | | | | | | |
| **10+75.00** | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | **-------------** | **High Point** |
| 11+00.00 | 25 | 53.00 | 0.07 | 0.07 | 0.047 | *0.020* | | | 0.04 | 1.93 | 0.07 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 11+25.00 | 25 | 44.00 | 0.06 | 0.13 | 0.051 | *0.020* | | | 0.05 | 2.39 | 0.13 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 11+50.00 | 25 | 40.00 | 0.05 | 0.18 | 0.057 | *0.020* | | | 0.05 | 2.66 | 0.18 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 11+75.00 | 25 | 37.00 | 0.05 | 0.22 | 0.062 | *0.020* | | | 0.06 | 2.86 | 0.22 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 12+00.00 | 25 | 35.00 | 0.05 | 0.27 | 0.071 | *0.020* | | | 0.06 | 2.99 | 0.27 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 12+25.00 | 25 | 32.00 | 0.04 | 0.31 | 0.074 | *0.020* | 1.67 | 2.00 | 0.06 | 3.14 | 0.04 | 3.52 | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | OK, VELOCITY < 5 FT/SEC | | |
| 12+50.00 | 25 | 30.00 | 0.04 | 0.08 | 0.079 | *0.020* | | | 0.04 | 1.86 | 0.08 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 12+75.00 | 25 | 30.00 | 0.04 | 0.12 | 0.080 | *0.020* | | | 0.04 | 2.15 | 0.12 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 13+00.00 | 25 | 29.00 | 0.04 | 0.16 | 0.080 | *0.020* | | | 0.05 | 2.38 | 0.16 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 13+25.00 | 25 | 29.00 | 0.04 | 0.19 | 0.080 | *0.020* | | | 0.05 | 2.58 | 0.19 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 13+50.00 | 25 | 29.00 | 0.04 | 0.23 | 0.080 | *0.020* | | | 0.06 | 2.76 | 0.23 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 13+75.00 | 25 | 25.00 | 0.03 | 0.26 | 0.080 | *0.020* | 1.67 | 2.00 | 0.06 | 2.90 | 0.03 | 3.43 | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | OK, VELOCITY < 5 FT/SEC | | |
| 14+00.00 | 25 | 25.00 | 0.03 | 0.06 | 0.080 | *0.020* | | | 0.03 | 1.65 | 0.06 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 14+25.00 | 25 | 25.00 | 0.03 | 0.09 | 0.080 | *0.020* | | | 0.04 | 1.95 | 0.09 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 14+50.00 | 25 | 25.00 | 0.03 | 0.12 | 0.080 | *0.020* | | | 0.04 | 2.18 | 0.12 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 14+75.00 | 25 | 25.00 | 0.03 | 0.16 | 0.080 | *0.020* | | | 0.05 | 2.38 | 0.16 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 15+00.00 | 25 | 25.00 | 0.03 | 0.19 | 0.080 | *0.020* | 1.67 | 2.00 | 0.05 | 2.55 | 0.01 | 3.08 | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | OK, VELOCITY < 5 FT/SEC | | |
| 15+25.00 | 25 | 25.00 | 0.03 | 0.04 | 0.080 | *0.020* | | | 0.03 | 1.47 | 0.04 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 15+50.00 | 25 | 25.00 | 0.03 | 0.08 | 0.080 | *0.020* | | | 0.04 | 1.82 | 0.08 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 15+75.00 | 25 | 25.00 | 0.03 | 0.11 | 0.080 | *0.020* | | | 0.04 | 2.07 | 0.11 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 16+00.00 | 25 | 25.00 | 0.03 | 0.14 | 0.080 | *0.020* | | | 0.05 | 2.29 | 0.14 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 16+25.00 | 25 | 25.00 | 0.03 | 0.17 | 0.080 | *0.020* | | | 0.05 | 2.47 | 0.17 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 16+50.00 | 25 | 25.00 | 0.03 | 0.20 | 0.080 | *0.020* | 1.67 | 2.00 | 0.05 | 2.64 | 0.01 | 3.17 | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | OK, VELOCITY < 5 FT/SEC | | |
| 16+75.00 | 25 | 25.00 | 0.03 | 0.05 | 0.080 | *0.020* | | | 0.03 | 1.51 | 0.05 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 17+00.00 | 25 | 25.00 | 0.03 | 0.08 | 0.080 | *0.020* | | | 0.04 | 1.84 | 0.08 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 17+25.00 | 25 | 25.00 | 0.03 | 0.11 | 0.080 | *0.015* | | | 0.04 | 2.51 | 0.11 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 17+50.00 | 25 | 25.00 | 0.03 | 0.14 | 0.080 | *0.002* | 1.67 | 2.00 | 0.02 | 9.73 | 0.09 | 1.90 | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | OK, VELOCITY < 5 FT/SEC | **OK, Qbp < 0.1 CFS** | Normal Crown |
| Flowing North (LT) | | | | | | | | | | | | | | | | | | | | | | | |
| 22+25.00 | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | ------------- | **-------------** | LT Level Crown |
| 22+50.00 | 28 | 19.00 | 0.03 | 0.03 | 0.020 | *0.001* | | | 0.01 | 10.53 | 0.03 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | Normal Crown |
| 22+75.00 | 25 | 19.00 | 0.02 | 0.05 | 0.016 | *0.011* | | | 0.03 | 3.09 | 0.05 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 22+83.00 | 26 | 19.00 | 0.03 | 0.08 | 0.014 | *0.020* | | | 0.05 | 2.53 | 0.08 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 23+00.00 | 27 | 19.00 | 0.03 | 0.10 | 0.013 | *0.020* | | | 0.06 | 2.88 | 0.10 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 23+25.00 | 30 | 19.00 | 0.03 | 0.13 | 0.014 | *0.020* | | | 0.06 | 3.13 | 0.13 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 23+50.00 | 35 | 19.00 | 0.03 | 0.17 | 0.001 | *0.020* | | | 0.11 | 5.57 | 0.17 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 23+75.00 | 25 | 19.00 | 0.02 | 0.19 | 0.012 | *0.020* | 1.67 | 2.00 | 0.07 | 3.65 | 0.04 | 1.64 | 1.43 | 0.80 | 0.26 | 0.85 | 0.16 | 0.03 | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | OK, VELOCITY < 5 FT/SEC | **OK, Qbp < 0.1 CFS** | |

****FOR LAST GRATE ON RUN OF GUTTER, IF SPREADSHEET SHOWS A VALUE FOR Vside, CHECK Vside AND Qbp (COLUMN S) FOR COMPLIANCE. OTHERWISE, CHECK Vcontinuous AND Qbp (COLUMN L) FOR COMPLIANCE.**

**INLET SPACING - CURB AND GUTTER SPREADSHEET (ENGLISH UNITS)**

| | |
|---|---|
| Tc = | 5.00 |
| C = | 0.90 |
| I = | 2.50 |
| m= | 6.31 |
| n= | 0.58 |

Existing cb
Important
Proposed cb
High Point
Another Sheet

Project Name: Harbour Reach Extension - Harbour Pointe Blvd to Blue Heron Blvd
Project #: 20150051
S.R.: N/A
Calculated By James Lee    Checked By Max Magee
Date: 10/31/2018    Date; 12/6/2018
**Instructions:** Red Text is automatically calculated. Black Text should be input by designer. Move mouse over column titles for a detailed description of each entry.

WSDOT Classification Map
Proposed Urban Major Collector
Zd = Shoulder + 1/2 Driving Lane (5' bike lane+3' buffer+5.5' lane=13.5')

*Depth not to exceed 0.12' at shoulder
13.5' spread at T=2%

| Station | Distance | Width | Δ Q | Σ Q | Slope L | Super T | G.W. | G.L. | d | $Z_d$ | $Q_{bp}$** | Vcontinuous** | Vside** | $E_o$ | $R_s$ | E | $Q_i$ | $Q_{bp}$** | Allowable Spread | $Z_d$ Check | Velocity Check | $Q_{bp}$ Check | Comments (L/R) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flowing South (RT) | | | | | | | | | | | | | | | | | | | | | | | |
| **47+00.00** | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | **------------** | **High Point** |
| 46+75.00 | 25 | 37.00 | 0.05 | 0.05 | 0.025 | *0.020* | 1.67 | 2.00 | 0.04 | 1.91 | 0.00 | 1.33 | | | | | | | *7.00* | OK, Zd ALLOWABLE > Zd DESIGN | OK, VELOCITY < 5 FT/SEC | | |
| 46+00.00 | 75 | 32.50 | 0.13 | 0.13 | 0.027 | *0.020* | | | 0.05 | 2.71 | 0.13 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 45+50.00 | 50 | 32.50 | 0.08 | 0.21 | 0.027 | *0.020* | | | 0.07 | 3.28 | 0.21 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 45+25.00 | 25 | 30.00 | 0.04 | 0.25 | 0.027 | *0.020* | | | 0.07 | 3.49 | 0.25 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 45+00.00 | 25 | 28.00 | 0.04 | 0.29 | 0.027 | *0.020* | 1.67 | 2.00 | 0.07 | 3.67 | 0.06 | 2.41 | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | OK, VELOCITY < 5 FT/SEC | | |
| 44+75.00 | 25 | 28.00 | 0.04 | 0.09 | 0.027 | *0.020* | | | 0.05 | 2.41 | 0.09 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 44+50.00 | 25 | 27.50 | 0.04 | 0.13 | 0.027 | *0.020* | | | 0.05 | 2.72 | 0.13 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 44+25.00 | 25 | 27.50 | 0.04 | 0.16 | 0.027 | *0.020* | | | 0.06 | 2.98 | 0.16 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 44+00.00 | 25 | 27.50 | 0.04 | 0.20 | 0.027 | *0.020* | | | 0.06 | 3.21 | 0.20 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 43+75.00 | 25 | 27.25 | 0.04 | 0.23 | 0.027 | *0.020* | 1.67 | 2.00 | 0.07 | 3.41 | 0.04 | 2.27 | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | OK, VELOCITY < 5 FT/SEC | | |
| 43+50.00 | 25 | 27.00 | 0.03 | 0.07 | 0.027 | *0.020* | | | 0.04 | 2.21 | 0.07 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 43+25.00 | 25 | 26.50 | 0.03 | 0.11 | 0.027 | *0.020* | | | 0.05 | 2.55 | 0.11 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 43+00.00 | 25 | 26.00 | 0.03 | 0.14 | 0.024 | *0.020* | | | 0.06 | 2.88 | 0.14 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 42+75.00 | 25 | 26.00 | 0.03 | 0.18 | 0.018 | *0.020* | | | 0.07 | 3.29 | 0.18 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 42+50.00 | 25 | 26.00 | 0.03 | 0.21 | 0.017 | *0.020* | | | 0.07 | 3.57 | 0.21 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 42+25.00 | 25 | 26.00 | 0.03 | 0.24 | 0.013 | *0.020* | 1.67 | 2.00 | 0.08 | 3.95 | 0.06 | 1.80 | 1.55 | 0.77 | 0.23 | 0.82 | 0.20 | 0.04 | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | OK, VELOCITY < 5 FT/SEC | | |
| 42+00.00 | 25 | 26.00 | 0.03 | 0.08 | 0.013 | *0.020* | | | 0.05 | 2.57 | 0.08 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 41+75.00 | 25 | 26.00 | 0.03 | 0.11 | 0.009 | *0.020* | | | 0.06 | 3.15 | 0.11 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 41+50.00 | 25 | 26.00 | 0.03 | 0.14 | 0.008 | *0.020* | | | 0.07 | 3.56 | 0.14 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 41+25.00 | 25 | 26.00 | 0.03 | 0.18 | 0.008 | *0.020* | | | 0.08 | 3.85 | 0.18 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 41+21.00 | 4 | 26.00 | 0.01 | 0.18 | 0.008 | *0.020* | 1.67 | 2.00 | 0.08 | 3.89 | 0.04 | 1.39 | 1.20 | 0.78 | 0.32 | 0.85 | 0.15 | 0.03 | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | OK, VELOCITY < 5 FT/SEC | **OK, Qbp < 0.1 CFS** | |
| Flowing South (LT) | | | | | | | | | | | | | | | | | | | | | | | |
| **47+00.00** | ------------ | ------------ | ------------ | ------------ | | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | ------------ | **------------** | **High Point** |
| 46+75.00 | 25 | 36.00 | 0.05 | 0.05 | 0.025 | *0.020* | 1.67 | 2.00 | 0.04 | 1.89 | 0.00 | 1.32 | | | | | | | *7.00* | OK, Zd ALLOWABLE > Zd DESIGN | OK, VELOCITY < 5 FT/SEC | | |
| 46+50.00 | 25 | 34.00 | 0.04 | 0.04 | 0.027 | *0.020* | | | 0.04 | 1.82 | 0.04 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 46+25.00 | 25 | 33.00 | 0.04 | 0.09 | 0.027 | *0.020* | | | 0.05 | 2.35 | 0.09 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 46+00.00 | 25 | 31.00 | 0.04 | 0.13 | 0.027 | *0.020* | | | 0.05 | 2.71 | 0.13 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 45+75.00 | 25 | 30.00 | 0.04 | 0.17 | 0.027 | *0.020* | | | 0.06 | 3.00 | 0.17 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 45+50.00 | 25 | 28.00 | 0.04 | 0.20 | 0.027 | *0.020* | | | 0.06 | 3.23 | 0.20 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 45+25.00 | 25 | 27.50 | 0.04 | 0.24 | 0.027 | *0.020* | | | 0.07 | 3.43 | 0.24 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 45+00.00 | 25 | 27.50 | 0.04 | 0.27 | 0.027 | *0.020* | 1.67 | 2.00 | 0.07 | 3.61 | 0.05 | 2.38 | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | OK, VELOCITY < 5 FT/SEC | | |
| 44+00.00 | 100 | 27.50 | 0.14 | 0.19 | 0.027 | *0.020* | | | 0.06 | 3.18 | 0.19 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 43+50.00 | 50 | 28.00 | 0.07 | 0.27 | 0.027 | *0.020* | 1.67 | 2.00 | 0.07 | 3.58 | 0.05 | 2.36 | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | OK, VELOCITY < 5 FT/SEC | | |
| 43+25.00 | 25 | 29.00 | 0.04 | 0.09 | 0.027 | *0.020* | | | 0.05 | 2.36 | 0.09 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 43+00.00 | 25 | 29.00 | 0.04 | 0.12 | 0.027 | *0.020* | | | 0.05 | 2.70 | 0.12 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 42+75.00 | 25 | 29.00 | 0.04 | 0.16 | 0.024 | *0.020* | | | 0.06 | 3.03 | 0.16 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 42+50.00 | 25 | 30.00 | 0.04 | 0.20 | 0.018 | *0.020* | | | 0.07 | 3.46 | 0.20 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 42+25.00 | 25 | 30.00 | 0.04 | 0.24 | 0.017 | *0.020* | | | 0.08 | 3.76 | 0.24 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 42+00.00 | 25 | 30.00 | 0.04 | 0.28 | 0.013 | *0.020* | | | 0.08 | 4.16 | 0.28 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 41+75.00 | 25 | 30.00 | 0.04 | 0.32 | 0.013 | *0.020* | | | 0.09 | 4.39 | 0.32 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 41+52.00 | 23 | 30.00 | 0.04 | 0.35 | 0.009 | *0.020* | 1.67 | 2.00 | 0.10 | 4.88 | 0.12 | 1.76 | 1.47 | 0.67 | 0.25 | 0.75 | 0.27 | 0.09 | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | OK, VELOCITY < 5 FT/SEC | | |
| 41+50.00 | 2 | 30.00 | 0.00 | 0.09 | 0.008 | *0.020* | | | 0.06 | 2.98 | 0.09 | | | | | | | | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | | | |
| 41+25.00 | 25 | 30.00 | 0.04 | 0.13 | 0.008 | *0.020* | 1.67 | 2.00 | 0.07 | 3.41 | 0.02 | 1.25 | 1.10 | 0.83 | 0.36 | 0.89 | 0.12 | 0.01 | *13.50* | OK, Zd ALLOWABLE > Zd DESIGN | OK, VELOCITY < 5 FT/SEC | **OK, Qbp < 0.1 CFS** | |

****FOR LAST GRATE ON RUN OF GUTTER, IF SPREADSHEET SHOWS A VALUE FOR Vside, CHECK Vside AND Qbp (COLUMN S) FOR COMPLIANCE. OTHERWISE, CHECK Vcontinuous AND Qbp (COLUMN L) FOR COMPLIANCE.**

PERTEET

Project No. 20150051 Sheet ____ of ____

Project: Harbour Reach Extension

Subject: TDA 3 Outfall Stability Check

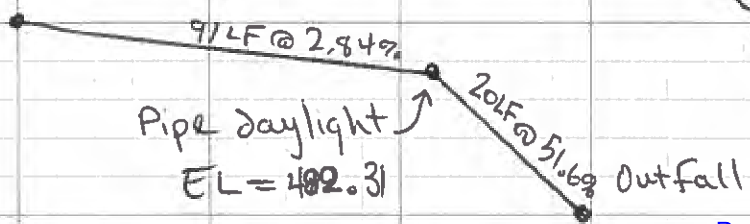
Calculated by: KCM Date: 11/19/18

Checked by: BJC Date: 11/20/18

Modular Wetland Outfall IE = 484.97

$W_p$ (18" DIPS HDPE SDR 17) = 29.04 lbs/ft

Source: www.jmeagle.com




Post 100% design, the pipe material and weight were changed to 18" DIPS HDPE SDR 32.5, which weighs 15.69 lb/ft. This results in even less force of pipe downhill, so the calcs were not rerun.

Force of pipe downhill:

$F = [(W_p L_1)\sin\theta_1] + [(W_p L_2)\sin\theta_2]$  $W_p = 29.04$  $L_1 = 91$  $\theta_1 =$

$L_2 = 20$  $\theta_2 =$

$\sin\theta_1 = \frac{2.66}{91} = .0293$

$\sin\theta_2 = \frac{10.31}{20} = .5155$

$F = 29.04[(91 * .0293) + (20 * .5155)] = \boxed{376.83 \text{ lb}}$

Resistance greater than Pipe force.

Force of Resistance (Buried)

$F_R = f W_p L_1$  $f = .35$ SG

$F_R = .35(29.04)(91) = \boxed{924.924 \text{ lb}}$

$\cos\theta_2 = \frac{17.14}{20}$

Force of Resistance (surface)

$F_R = f W_p L_2 \cos\theta_2 (1/2)$ ← halved for partial burial

$F_R = .35(29.04)(20)(\frac{17.14}{20})(1/2) = \boxed{87.1 \text{ lbs}}$

project pad grid_2017.indd

**PERTEET**

Project No. 20150051 Sheet ____ of ____

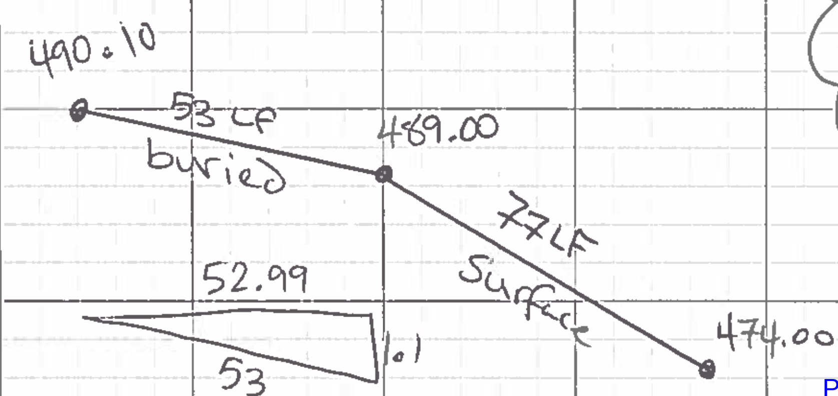
Project: Harbour Reach Extension

Subject: TDA 4 Outfall Stability Check

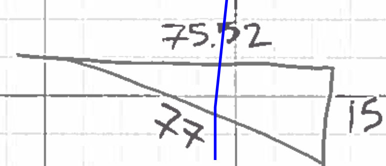
Calculated by: KCM Date: 11/20/18

Checked by: BJC Date: 11/20/18

CB#53 Outfall




$w_p$ (12" DIPS HDPE SDR 17)
$= 13.30$ lbs/ft
Source: www.jmeagle.com




Post 100% design, the pipe material and weight were changed to 12" DIPS HDPE SDR 32.5, which weighs 7.19 lb/ft. This results in even less force of pipe downhill, so the calcs were not rerun.

Force of pipe downhill

$$F = [w_p L_1 \sin\theta_1] + [w_p L_2 \sin\theta_2] = [13.3 * 53 * \tfrac{1.1}{53}] + [13.3 * 77 * \tfrac{15}{77}]$$

$$\boxed{F = 214.13 \text{ lbs}}$$

Force of Resistance (Buried)

$F_{RB} = f w_p L_1$ $f = .35$ SG

$$= .35(13.3)(53) = \boxed{246.72 = F_{RB}}$$

Force of Resistance (Surface)

$$F_{RS} = f w_p L_2 \cos\theta_2 = .35(13.3)(77)\left(\frac{75.52}{77}\right) = 351.55$$

Divide in half to reflect partial burial

$\rightarrow 351.55 \times .5 = \boxed{175.77 \text{ lbs}}$

$\boxed{\text{Force of pipe exceeded by buried + surface resistance.}}$

# APPENDIX E

## Geotechnical Report Excerpt

**Draft Geotechnical Engineering Report**
**Harbour Reach Drive Extension**
**Mukilteo, Washington**

May 26, 2017

SHANNON & WILSON, INC.

GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Excellence. Innovation. Service. Value.

*Since 1954.*

Submitted To:
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21-1-12561-102

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# DRAFT GEOTECHNICAL ENGINEERING REPORT
# HARBOUR REACH DRIVE EXTENSION
# MUKILTEO, WASHINGTON

## 1.0 INTRODUCTION

This report presents the results of our subsurface explorations and geotechnical engineering analyses and recommendations for the proposed Harbour Reach Drive Extension Project (Project) in Mukilteo, Washington. The Project is an effort by the City of Mukilteo (City) to construct a new urban arterial connecting Beverly Park Road and Harbour Point Boulevard North. The general location of the Project is shown in the Vicinity Map, Figure 1.

## 2.0 PROJECT UNDERSTANDING AND SITE DESCRIPTION

### 2.1 Proposed Project Understanding

The proposed Project includes approximately 1.7 miles of new and improved roadway. The Project will provide a parallel north-south alternative to State Route 525, increasing the City's traffic capacity and emergency response time. The Project will include a two-lane arterial, bicycle and pedestrian facilities, streetscapes, and traffic calming alternatives.

The south end of the Project begins at the intersections of Beverly Park Road and 132$^{nd}$ Street SW. From this intersection, the alignment travels northwest and crosses over a ravine through which an un-named, seasonal stream flows (Figure 2, Sheet 1). The roadway will cross the ravine on fill soil supported by back-to-back structural earth walls (SEWs) approximately 910 feet long and up to 40 feet tall. The stream crossing will consist of a 13-foot-wide metal arch culvert through the SEWs and embankment soil. A stormwater vault will be constructed and buried in the earth embankment under the roadway.

At the north end of the south ravine crossing, the arterial will connect into the existing Harbour Reach Drive (South Road) and continue north to Blue Heron Boulevard (Figure 2, Sheets 1 through 3). Along this segment, the proposed arterial will expand east at grade to the City right-of-way line.

After reaching the intersection of Harbour Reach Drive (South Road) and Blue Heron Boulevard, the alignment continues north over a second ravine, through which Picnic Point Creek flows, to the intersection of Harbour Point Boulevard SW (Figure 2, Sheet 3). The roadway will cross the ravine on fill soil supported by back-to-back SEWs approximately 380 feet long and up to 40 feet-tall. The stream crossing will consist of a 26-foot-wide metal arch culvert through the

SEWs and embankment soil. A stormwater vault will be constructed and buried in the earth embankment and native soil under the roadway.

At the intersection of Harbour Point Boulevard SW and Harbour Reach Drive, the Project will follow the existing Harbour Reach Drive alignment to Harbour Point Boulevard N. Roundabouts will be installed at the intersections with Harbour Point Boulevard SW (Figure 2, Sheet 3), Possession Way (Figure 2, Sheet 4), Chennault Beach Road (Figure 2, Sheet 5), and Harbour Point Boulevard N (Figure 2, Sheet 6). Pervious concrete for stormwater management is being considered at the roundabouts at Harbour Point Boulevard SW and Harbour Point Boulevard N.

## 2.2 Existing Site Description

The south end of the alignment, Station 10+00, at Beverly Park Road, to about Station 12+50 is relatively flat. Northwest of about Station 12+50, the existing grade drops about 10 feet in elevation over a distance of about 65 feet and then continues at a downward slope of 3 to 4 degrees to the southern slope crest of a ravine, near Station 15+00. The ravine is wooded with deciduous and coniferous trees, vegetation, and wetlands. From the top of the slope crest of the ravine, the topography drops about 95 feet to an un-named seasonal stream, near Station 22+75, and then rises about 30 feet to the existing Harbour Reach Drive (South Road) near Station 25+00.

From Station 25+00 to about Station 40+50, the existing Harbour Reach Drive (South Road) is relatively flat. It was constructed as fill in 1991 using SEWs and cantilever reinforced concrete walls. Shannon & Wilson, Inc. (Shannon & Wilson) and H.W. Lochner (Lochner) performed a site reconnaissance of the existing walls on September 29, 2016, and submitted a report of our findings to the City of Mukilteo on November 23, 2016 (Lochner, 2016). We understand the existing SEWs and cantilever retaining walls will not to be modified as part of the Project. No geotechnical recommendations related to the existing retaining walls are provided herein.

North of the intersection at Blue Heron Boulevard, near Station 42+50, the alignment drops about 35 to 40 feet in elevation into another ravine, crosses Picnic Point Creek near Station 44+50, and rises back up to Harbour Point Boulevard SW near Station 47+00. The existing ground surface slopes at approximately 24 and 36 degrees on the south and north slopes of the ravine, respectively. The ravine is wooded with deciduous and coniferous trees, vegetation, and wetlands.

After the alignment crosses Harbour Point Boulevard SW, the terrain is relatively flat and passes through a developed residential area along the existing Harbour Reach Drive to the north end of the Project alignment at Harbour Point Boulevard N. The existing Harbour Reach Drive consists of one northbound and one southbound lane and a center turn lane with sidewalks running adjacent on both sides of the roadway.

### 2.3 Scope of Services

Shannon & Wilson is the geotechnical engineering consultant for the Project. In this capacity, we provided geotechnical engineering services for the following tasks:

- Planning
- Field reconnaissance and subsurface explorations
- Geotechnical laboratory testing
- Field and laboratory data compilation
- Engineering evaluation, including:
  - Resilient moduli and frost susceptibility considerations for pavement design
  - Earthwork recommendations for fill and embankment slopes
  - Shallow foundation bearing resistance for the stream crossing structures
  - SEW design recommendations for roadway embankment fill
  - Settlement estimates for the retaining walls and fill slopes
  - Embankment fill placement and compaction recommendations
  - Infiltration rates for soil under the permeable pavement
  - Foundation recommendations for new luminaries and traffic signals
- Geotechnical report preparation

These tasks were authorized by Lochner in a Consultant Agreement for Project Number 000010924 dated June 27, 2016.

## 3.0 SUBSURFACE EXPLORATIONS

We explored the subsurface conditions along the proposed Project alignment by completing 2 drill borings and 18 hand-auger borings between February 13 and 27, 2017. The borings extended approximately 3 to 17 feet below the ground surface (bgs). Groundwater observation wells were installed in the two drill borings with 5-foot screens located approximately 3 to 10 feet bgs.

The approximate exploration locations are shown in Figure 2. Appendix B describes the field methods and procedures used to advance the borings and install the wells. Logs of the borings are included in Appendix A. Select historical exploration logs retrieved for this report are included in Appendix A and shown in Figure 2.

## 4.0 GEOTECHNICAL LABORATORY TESTING

Geotechnical laboratory testing was performed on select soil samples retrieved from the explorations to evaluate index and engineering properties. We prepared a laboratory test program based on the subsurface conditions encountered and our understanding of the Project. Laboratory testing included visual soil classification, water content determinations, and grain size analyses.

The geotechnical laboratory testing was performed in Shannon & Wilson's laboratory in Seattle, Washington, and in general accordance with ASTM International (ASTM) standard procedures. A description of the laboratory test procedures and the laboratory test results are presented in Appendix B.

## 5.0 GEOLOGY AND SUBSURFACE CONDITIONS

Our understanding of the geology and subsurface conditions along the Project alignment is based on our literature review, geotechnical explorations, and our general understanding of the geologic history and stratigraphy of the region. Our interpretation of the geology and subsurface conditions are shown in our soil descriptions on the boring logs included in Appendix A and the geologic profiles shown in Figures 3 through 5.

### 5.1 Regional Geologic Setting

The glacial history of the area is complex, with multiple advances of the Cordilleran ice sheet into the Puget Lowlands during the early to late Pleistocene. The last continental glaciation of the Puget Lowland (Vashon Stade of the Frasier Glaciation) occurred between 15,000 and 13,500 years ago. The weight of the ice resulted in compaction of the glacial soils beneath the ice. As the glacier receded, the meltwater deposited material suspended within the ice sheet throughout the area. This material was more recently reworked by flowing streams and rivers (alluvium) and erosion and soil creep (colluvium). The till and weathered till deposits are glacially overridden. Fill, colluvium, and alluvium deposits are not glacially overridden.

### 5.2 Geologic Units

The following paragraphs describe the geologic units observed during our site reconnaissance, historical document review, and Project explorations.

#### 5.2.1 Fill

Fill was encountered in borings SW-1-17 and SW-2-17 and consists of very loose to medium-dense, silty sand with fine gravel. The fill was placed to construct the existing Harbour Reach Drive. At approximately 14.5 feet bgs in SW-1-17, the fill becomes lensed with oxidation-stained silty sand, appearing to be previously native material disturbed during construction of the SEW.

### 5.2.2 Colluvium

Colluvium is soil that is deposited on slopes by mass wasting processes, including rockfall, soil creep, and non-concentrated erosion caused by sheet wash and rain splash. In general, colluvium was encountered in the explorations above the creek elevations in the ravines. It consists of silty sand with gravel with trace to little organics.

Colluvium may contain cobbles and boulders, though no cobbles and boulders were encountered in the explorations. On steep slopes, colluvium is subject to creep; however, on gentler slopes, colluvium typically is relatively stable.

### 5.2.3 Alluvium

Alluvium is soil that is deposited by low- to high-energy flowing water and deposited as the water loses energy. In general, alluvium was encountered in the explorations along the lower portions of the ravines. It consists of loose to medium-dense gravels and sands with varying amounts of fines. The presence of large gravels in the explorations may return artificially high penetration test blow counts.

Alluvium typically contains cobbles and boulders and can contain logs; though no cobbles, boulders, or logs were encountered in the explorations. Boulders were observed at the surface along the alignment from approximate Stations 17+00 to 22+00. Excavated and natural slopes in the alluvium can ravel, especially during periods of rainfall.

### 5.2.4 Till/Weathered Till

Till is that which was deposited at the base of an advancing glacial ice sheet and subsequently overridden by the ice. Till and weathered till were encountered along the Project alignment. In general, the till consists of medium-dense to very dense, silty sand with gravel. The till is described as diamict and cemented.

Till commonly contains layers and lenses of saturated cohesionless silt, sand and gravel, and cohesive clay and silt. Cobbles and boulders are commonly present, though none were encountered in the explorations. Weathered till has the same material matrix as till and is identified by layers of oxidation and color change.

## 5.3 Groundwater

Shallow, unconfined groundwater is present along the alignment in the alluvial and colluvial deposits that overlie the till and weathered till. Groundwater levels across the site range between 1 to 6 feet bgs. During drilling, we observed groundwater at boring SW-1-17 just under the asphalt parking lot.

We estimate that the groundwater table is likely perched above the less permeable till and weathered till material and flows downslope toward the streams located along the Project alignment.

# 6.0 ENGINEERING ANALYSES AND RECOMMENDATIONS

## 6.1 Seismic Design Considerations

We developed design ground motion recommendations for the Project in accordance with the American Association of State Highway and Transportation Officials (AASHTO) Load and Resistance Factor Design (LRFD) Bridge Design Specifications (BDS) (AASHTO, 2014). The seismological inputs required to develop ground motions for design are the peak ground acceleration (PGA), short-period spectral acceleration ($S_s$) and spectral acceleration at the 1-second period ($S_1$). These parameters were developed using the AASHTO LRFD BDS ground motion level corresponding to a 7-percent probability of exceedance in 75 years (about a 1,000-year return period).

The magnitude and soft rock PGA for the design ground motion level were determined based on results of the 2002 U.S. Geological Survey (USGS) probabilistic seismic hazard analyses. Using the USGS interactive de-aggregation and Project location, we estimate a design magnitude and soft rock PGA of 6.9 and 0.40g, respectively.

The soft rock PGA is modified for subsurface conditions within 100 feet of the ground surface. The Washington Division of Geology and Earth Resources Site Class Map of Snohomish County, Washington (Palmer and others, 2004) shows that the site could be classified as Site Class C. Based on the descriptions of the subsurface conditions encountered, we recommend that the site be classified as Site Class C. For this determination, we did not consider the existing fill soil along the Harbour Reach Drive segment between the two ravines as part of the subsurface stratum. This was considered engineered fill and wall structures above the subsurface stratum. Seismic design parameters, including the recommended site design PGA ($A_s$), are shown in Table 1.

## 6.2 Ravine Crossing Structures

### 6.2.1 Structural Earth Walls

#### 6.2.1.1 General

SEWs are constructed using compacted soil with intervening layers of man-made reinforcing material (strips, bars, or mats of steel or polymeric reinforcement) that extend behind the wall face to reinforce the soil and create a soil gravity block. Detailed wall design, including internal and compound stability and the required reinforcement properties, are typically performed by the vendor of the proprietary wall system. The wall designer should perform external stability, bearing resistance, and sliding resistance analyses.

The embedment depth of the SEW depends on whether the ground is horizontal or sloping in front of the wall. Where the ground surface in front of the wall face is near-horizontal, the base of the reinforced soil mass (top of leveling pad) should be a minimum of 24 inches, or 5 percent of the wall height, whichever is greater, below the ground surface. If the ground surface in front of the wall is sloped, the bottom of the reinforced zone should be a minimum of 24 inches below the elevation at which there is a 4-foot horizontal distance from the wall face to the slope face in front of the wall.

The face-to-face dimension for back-to-back SEWs should be a minimum of 1.1 times the average wall height of the two walls at any specific station. The minimum SEW reinforcing lengths are typically 0.7 times the wall height (H) or 8 feet, whichever is greater. The actual design length may be controlled by stability considerations and may be greater than the 0.7H or 8 feet.

#### 6.2.1.2 Preliminary Analysis

We performed a static global stability analysis along a section of the proposed SEWs using the commercially available software, SLOPE/W (Geo-Slope International Ltd, 2016), to determine a minimum recommended SEW reinforcement length. The results of our analysis indicate that a minimum reinforcement length equal to 70 percent of the wall height (0.7H) will provide a static global factor of safety greater than 1.3 for the proposed wall configuration.

We did not perform internal, external, or compound stability analyses of the proposed walls. We recommend the wall designer be required to perform these analyses to determine the required reinforcing lengths and spacing for when they design the walls. The wall designer should perform these analyses, including external stability analyses for bearing resistance, overturning, and sliding resistance, for both static and seismic conditions.

Recommended soil parameters to be used for SEW design are provided in Table 2. SEW design should be performed using AASHTO (2014) criteria.

#### 6.2.2 Cast-in-Place Concrete (CIPC) Cantilever Walls

CIPC cantilever walls are currently planned to be constructed adjacent to and integrated with the underground stormwater vault within the south ravine fill. CIPC cantilever walls consist of a steel reinforced concrete stem and base slab, either in the shape of an "L" or "T." Overturning and sliding due to lateral earth pressures are resisted by the wall's self-weight and the weight of the soil above the base slab.

##### 6.2.2.1 Lateral Pressures

Lateral earth pressures against SEWs, CIPC cantilever walls, and buried vaults depend on many factors, including method of backfill placement and degree of compaction, backfill slope, surcharges, the type of backfill and/or adjacent native soil, drainage provisions, water pressure, and whether the wall or structure can yield or deflect laterally or rotate at the top after or during backfill placement or during and after excavation. For walls that are allowed to move at least 0.001 times the wall height, we recommend that a static, active, lateral earth pressure be used. For walls or structures that are not allowed to move 0.001 times the wall height, static, at-rest, lateral earth pressures should be used. For our analyses, we assume the SEWs can be designed to resist active earth pressures and the buried stormwater vault designed to resist at-rest earth pressures. The CIPC cantilever walls will depend on the adjacent stormwater vault integration, and we provide both active and at-rest lateral earth pressures for design consideration.

For the seismic condition, we assume that the walls along the Project alignment will be allowed to move at least 0.001 times the height of the wall during and after seismic shaking; therefore, we recommend that seismic, active, lateral earth pressures be used. Our recommendations for the seismic lateral earth pressures include static and seismic lateral earth pressure components. The seismic lateral earth pressure provided is consistent with a pseudo-static analysis using the Mononobe-Okabe equation for lateral earth pressures, a horizontal seismic coefficient of 0.20g, and the assumed retained soil. In accordance with typical practice, we used a horizontal seismic coefficient equal to one-half of the site design PGA of 0.40g.

Figures 6 through 8 present our recommended static and seismic lateral earth pressure equivalent fluid weights and distributions. The lateral earth pressure recommendations assume the ground surface behind the wall is level. Seismic forces associated with sloshing water in the stormwater vaults are not included in Figures 6 through 8 and should be considered in the CIPC cantilever wall design, as appropriate. Based on the depth of groundwater encountered in the Project subsurface explorations, we assume the groundwater will be below the base of the walls.

Lateral earth pressures due to surcharge loads should be added to the recommended lateral earth pressures, where appropriate. Lateral pressures as a result of surcharge loads may be evaluated based on the diagrams presented in Figure 9.

#### 6.2.2.2 Passive Resistance

The nominal passive resistance pressure recommended for design of the CIPC cantilever walls is presented in Figure 7. This value assumes that the footing extends at least 2 feet below the lowest adjacent exterior grade, that the backfill around the structure is properly drained and compacted per the recommendations in this report, and that the soil in front of the wall will remain in place for the life of the structure (i.e., protected from erosion and man-made activities). The graded surface in front of the wall should be horizontal a distance equal to two times the foundation embedment depth plus the width of the footing in front of the wall. If the ground surface in front of the wall is sloped, the passive resistance should be reduced accordingly.

Resistance factors should be applied to the passive resistance. For static conditions, we recommend a resistance factor of 0.50 be applied to the nominal passive earth pressure. For seismic conditions, we recommend a resistance factor of 1.0 be applied to the nominal passive earth pressure.

Passive resistance should not be relied on for SEW design. The SEWs will likely have shallow embedment depths with potential for soil to be disturbed or removed in front of the wall during the life of the structure.

#### 6.2.2.3 Sliding Resistance

Lateral loads may be resisted through the base friction of the CIPC cantilever wall base slab. We recommend CIPC cantilever wall base slabs be designed using a coefficient of sliding, tanδ, of 0.47. This value assumes the concrete for the base slab will be cast against medium-dense alluvium/weathered till. A resistance factor of 1.0 should be applied to the sliding resistance in accordance with AASHTO Table 11.5.7-1 (AASHTO, 2014).

For the SEWs, the wall designer should perform sliding resistance analyses.

### 6.2.3 Foundation Bearing Resistance

Foundations for the SEWs and CIPC cantilever walls should bear in the underlying medium-dense alluvium or the medium-dense to very-dense weathered till/till. The forest duff, topsoil, and colluvium should be removed, and soft or loose alluvium and weathered till should be excavated and removed to the depth necessary to expose competent bearing subgrade.

We estimated the factored bearing resistance for the SEWs and CIPC cantilever walls. The Strength and Extreme Limit cases are based on the guidelines provided in AASHTO LRFD BDS (AASHTO, 2014). Recommended factored bearing resistance versus footing width for the walls are provided in Figures 10 and 11. Analysis input parameters and resistance factors are included in the figures.

### 6.2.4 Wall Drainage

#### 6.2.4.1 Surface Drainage

A surface seal such as pavement or an 8-inch-thick layer of impervious soil should be provided on top of the fill to reduce infiltration and groundwater buildup in and behind the walls. Surface water should be captured in catch basins and drain pipes and drain into a sewer or stormwater collection system. The ground surface in front of the walls should be sloped such that water is diverted away from the wall toe. The ground surface above the walls should be shaped to divert water away from the walls.

#### 6.2.4.2 Subsurface Drainage

Our analyses assume that groundwater would be below the base of the SEW and CIPC cantilever walls. To achieve and maintain this drainage condition, the drainage measures presented in Figures 6 and 7 should be implemented. These recommendations include placement of a drainage blanket below the reinforced zone of the SEW and installation of an underdrain pipe at the foundation level for the SEWs and CIPC cantilever walls. The underdrain pipe should be installed over the full wall length and drain into a sewer, stormwater collection system, or other appropriate discharge location away from the embankment.

### 6.2.5 Settlement

Up to 40 feet of fill will be placed at the ravines to achieve the desired finished grades. Assuming compliance with the recommendations in this report, we estimate that settlement will be 1 inch or less beneath the fill embankments and about 0.5 to 1 percent of the wall height within the compacted embankments. The foundation subsurface material and the recommended embankment fill is granular; therefore, settlement will essentially occur as the embankments are constructed and the loads are applied.

### 6.3 Stream Crossing Structures

Two stream crossing structures, consisting of metal arch culverts founded on cast-in-place concrete stem wall and strip footing foundations are planned as part of the Project. The culvert stream crossing located near Station 22+75 (Figure 2, Sheet 1) has a nominal span length of 13 feet and a crossing width of approximately 69 feet. The culvert stream crossing located near Station 44+45 (Figure 2, Sheet 3) has a nominal span length of 26 feet and a crossing width of approximately 75 feet. We calculated the bearing resistance of the foundation soil following AASHTO LRFD BDS (AASHTO, 2014) for the Service and Strength Limit states.

Foundations for the culvert stream crossings should bear in the underlying medium-dense alluvium and be deep enough to appropriately reduce the potential for undermining from erosion and scour. The forest duff, topsoil, and colluvium should be removed, and loose alluvium excavated to competent bearing subgrade. Figure 12 shows the calculated factored bearing resistance for strip foundations supporting the metal arch culverts. Analysis input parameters and resistance factors are included in Figure 12.

### 6.4 Uplift Resistance

Hydrostatic uplift resistance should be accounted for in the design of the buried stormwater vaults where the groundwater table will be above the base of the vaults and where potential leakage from the vaults could result in elevated groundwater conditions. Underdrain pipes at the CIPC cantilever walls should help maintain naturally occurring groundwater below the base of the stormwater vault. The stormwater vault planned north of Blue Heron Boulevard will be partially constructed in native soil and should be evaluated for uplift pressure. Perched groundwater was observed during exploration of HB-13-17 at the till contact; approximately 1 foot bgs. Test pit SW-26, completed in April 1991, observed seepage about 2.5 feet bgs.

The uplift pressure due to buoyancy acting against the bottom of the vault should be resisted by the weight of the structure and the friction between the structure and adjacent soil. If this resistance is not sufficient, an exterior protruding footing (shear key) should be provided to resist uplift using the buoyant unit weight of the soil above the shear key. Recommendations for design of hydrostatic uplift resistance are provided in Figure 13.

Stormwater vault and retaining wall designs should consider the potential for the vaults to leak. We recommend provisions be included in the design and construction to intercept and remove water that may leak from the vaults to reduce the potential for water pressure and flow associated with leakage from the vaults to impact the structures and roadway.

### 6.5 Pavement Subgrade

The roadway pavement will be constructed on both existing and new fill. New fill will be used to construct the ravine crossings and is recommended to be WSDOT Gravel Borrow for SEW and WSDOT Gravel Backfill for Walls, as specified in Standard Specification Sections 9-03.14(4) and 9-03.12(2), respectively (WSDOT, 2016a). For densely compacted Gravel Borrow for SEW and densely compacted Gravel Backfill for Walls, we recommend using a subgrade resilient modulus of 27 kips per square inch (ksi) for pavement design.

Existing fill was encountered along the existing roadway corridor south of Blue Heron Boulevard and near the intersection with Harbour Point Boulevard N. The existing fill consists of very loose to medium-dense silty sand and silty sand with gravel. Loose, soft, wet, or otherwise yielding subgrade exposed during construction should be removed and replaced with compacted Gravel Borrow meeting WSDOT Standard Specifications 9-03.14(1) (WSDOT, 2016a). For existing medium-dense silty sand and silty sand with gravel, and where less than 4 feet of existing loose material is removed and replaced, we recommend using a subgrade resilient modulus of 14 ksi for pavement design.

Pavements subject to vehicular traffic should be protected from potential damage from frost action. Frost-susceptible soils are generally regarded as those soils having more than 3 percent of their dry weight finer than 0.02 millimeter. Based on the recommended new and existing fill gradations, we recommend that the pavement be designed assuming that the soils are frost-susceptible.

Pavement can be designed for frost protection by providing a pavement section that is equal to or thicker than half of the expected frost depth, in accordance with the WSDOT Pavement Policy Manual (WSDOT, 2015). We evaluated the expected freeze depth using the WSDOT Pavement Policy Manual frost depth contour maps corresponding to the design freezing index. Based on the WSDOT frost depth contour maps, the expected depth of freeze for coarse-grained soil is 20 to 25 inches. Coarse-grained soil is defined as having less than 50 percent pass the No. 200 sieve. The maximum frost depth in the Mukilteo area during the extremely cold winters of 1949 and 1950 was measured at about 15 to 20 inches. Based on this information, we recommend assuming a frost depth of 24 inches for pavement design.

## 6.6 Luminaires and Signal Poles

### 6.6.1 Luminaire Foundations

The WSDOT standard design for luminaire foundations is shown on WSDOT Standard Plan J-28.30-03 (WSDOT, 2016b). Foundation Type A has a minimum embedment depth of 4.5 feet on level ground or a slope not exceeding 4 horizontal to 1 vertical (4H:1V), and a minimum allowable lateral bearing pressure of 2,000 pounds per square foot (psf). Foundation Type B has a minimum embedment depth of 8.0 feet for slopes steeper than 4H:1V, but not exceeding 2H:1V, and an allowable lateral bearing pressure of 1,500 psf.

Luminaires founded in the newly placed compacted Gravel Borrow for SEW or native till/weathered till soil can be designed using Standard Foundation Types A or B. Luminaires founded in medium-dense existing silty sand fill, as encountered in boring SW-1-17 (Figure 2, Sheet 2), can also be designed using Standard Foundation Types A or B.



Soft or loose soil, as encountered in boring SW-2-17 (Figure 2, Sheet 6), is considered unsuitable material for Standard Foundation Types A or B. Where encountered, we recommend that the soft or loose soil be removed and replaced with controlled density fill or compacted Select Borrow as specified in Sections 9-03.14(2) of the WSDOT Standard Specifications (WSDOT, 2016a). The excavation should extend to the contact depth with the underlying medium-dense to very dense weathered till/till, be at least the diameter of the foundation at the contact depth, and extend back to the ground surface at a slope of 2H:1V or flatter. Luminaires founded in the overexcavated and replaced material as described above and shown on Standard Plan J-28.30-03 can be designed using Standard Foundation Types A or B.

### 6.6.2 Traffic Signal Pole Foundations

The WSDOT standard design for traffic signal pole foundations is shown on WSDOT Standard Plan J-26.10-03 (WSDOT, 2016b). We recommend assuming an allowable lateral bearing pressure of 2,500 psf for signal pole foundations installed in newly placed compacted Gravel Borrow for SEW, existing medium-dense silty sand fill (such as that encountered in boring SW-1-17 [Figure 2, Sheet 2]), and in native medium-dense to very dense weathered till/till.

Soft or loose soil, as encountered in boring SW-2-17 (Figure 2, Sheet 6), is considered unsuitable material for the standard plan foundations. Where encountered, we recommend that the soft or loose soil be removed and replaced with controlled density fill or compacted Select Borrow as specified in Sections 9-03.14(2) of the WSDOT Standard Specifications (WSDOT, 2016a). The excavation should extend to the contact depth with the underlying medium-dense to very dense weathered till/till, be at least the diameter of the foundation at the contact depth, and extend back to the ground surface at a slope of 2H:1V or flatter. Traffic signal poles founded in the overexcavated and replaced material as described above and shown on Standard Plan J-26.10-03 can be designed using an allowable lateral bearing pressure of 2,500 psf.

### 6.7 Infiltration Rates

We understand pervious concrete is being considered at the roundabouts at Harbour Point Boulevard SW (Figure 2, Sheet 3) and Harbour Point Boulevard N (Figure 2, Sheet 6), and at the existing Harbour Reach Drive segment between the two ravines (Figure 2, Sheet 2). Pervious concrete is a porous concrete that allows stormwater to flow through the concrete, into a gravel bed for storage, and then infiltrate into the underlying subgrade soil.

The Stormwater Management Manual for Western Washington (SMMWW) (Washington State Department of Ecology [DOE], 2014) requires the base of all infiltration systems to be 5 feet or greater above the seasonal high-water mark, glacial till, or other low permeability layers. The till contact at the Harbour Point Boulevard N roundabout is about 4.5 feet below existing grade. The till contact at the Harbour Point Boulevard SW roundabout will likely be less than 5 feet below proposed finished cut grade.



Groundwater levels were measured in the wells at Harbour Point Boulevard N and at the existing Harbour Reach Drive segment on April 20, 2017. The measured groundwater levels were approximately 4.5 feet and 5.5 feet, respectively. During the winter months and wet weather conditions, the groundwater table could be higher.

In our opinion, infiltration at the site will not meet the minimum requirements of the DOE SMMWW (DOE, 2014). However, if the design includes pervious concrete, we analyzed design infiltration rates.

Short-term infiltration rates were estimated for the soil at the Harbour Point Boulevard N roundabout and the existing Harbour Reach Drive segment using grain size data and an analytical solution from the SMMWW (DOE, 2014). Recommended correction factors from the SMMWW were applied to the short-term infiltration rates to obtain long-term design infiltration rates. Based on the soil encountered at each location, we recommend using the following long-term design infiltration rates:

- Harbour Point Boulevard SW and Harbour Point Boulevard N Roundabouts = ¼ inch per hour
- Existing Harbour Reach Drive Segment = ½ inch per hour

Our recommend long-term design infiltration rates assume the soil conditions at the Harbour Point Boulevard SW and Harbour Point Boulevard N roundabouts are similar to those encountered in SW-2-17, and the soil conditions along the existing Harbour Reach Drive segment are similar to those encountered in SW-1-17.

If pervious concrete or other infiltration facilities will be implemented at these locations, we recommend an engineer review the existing subgrade soil for stability and load deformation resistance when saturated. For the pervious concrete planned at the existing Harbour Reach Drive segment, the existing walls should be reviewed for drainage and structural integrity for the added water pressures.

Due to the shallow till contact depth and the likely variability of the till material, we recommend a perforated or slotted underdrain pipe be installed in the gravel bed at the Harbour Point Boulevard SW and Harbour Point Boulevard N roundabouts to remove water that has infiltrated and to maintain the groundwater elevation near the top of till contact. The pipe should be installed over the full length of the pervious concrete or other infiltration facility and drain into a sewer or stormwater collection system or other appropriate location. Cleanouts should be provided along the underdrain pipe length.



# 7.0 CONSTRUCTION CONSIDERATIONS

## 7.1 General

The applicability of the design recommendations provided in this report is contingent on good construction practice. Poor construction techniques may alter conditions from those on which our recommendations are based, resulting in poor facility performance (e.g., reduced foundation resistance, increased settlement, excessive retaining wall deflections). The following sections present additional earthwork considerations for this Project.

## 7.2 Site Preparation and Grading

For areas of proposed improvements, we recommend that trees and brush be cleared and that roots, stumps, man-made debris, and existing slabs, pavement, and utility lines be removed from beneath the proposed improvements and areas to be graded. Grass, forest duff, topsoil, and colluvium that cover the site should be removed. In general, our subsurface explorations encountered about 1 to 3½ feet of grass, forest duff, topsoil, and colluvium in the ravine areas.

In areas of fill placement or foundation construction, the newly exposed soil surface should be compacted using a heavy vibratory roller (10-ton or heavier static weight). Native subgrade soils should be proof rolled and, if necessary, compacted to achieve at least 95 percent of the Modified Proctor maximum dry density (ASTM D1557). The proof-rolling operations should consist of several passes of a fully loaded dump truck or vehicle of similar weight to test the surface for pockets or zones of loose or soft native subgrade. Loose or soft subgrade should be compacted to a dense, unyielding condition or removed and replaced with at least 2 feet of compacted structural fill. Subgrade surfaces that will receive fill or foundations should be dense and unyielding and should be evaluated by a qualified geotechnical engineer prior to placing the fill or constructing the foundations.

### 7.3 Reuse of On-Site Soil

Topsoil is not considered suitable for reuse as structural fill and should be removed from the site or stockpiled for reuse in landscape areas.

Colluvium, alluvium, weathered till, and till could be reused as Common Borrow per the WSDOT Standard Specification Section 9-03.14(3) (WSDOT, 2016a). Wood debris and organics may need to be removed from the colluvium and alluvium to meet specifications. Boulders and cobbles larger than 4 inches should be removed prior to or during fill placement. The on-site soil contains sufficient fines to make it moisture sensitive. The soil may be difficult to place or compact during wet weather, in wet conditions, or if it was excavated from below the groundwater table or within a perched groundwater area. The Contractor should be advised that the on-site soil may require moisture conditioning before placement and compaction.

Evaluating the cost-effectiveness and schedule implications for reusing on-site excavated soil should be the Contractor's responsibility.



### 7.4 Obstructions

Based on our explorations and interpretation of the local geologic deposits, the Contractor should expect to encounter cobbles and boulders during excavation at the site. The cobbles and boulders may range from 3 inches to greater than 24 inches. The Contractor should be prepared to advance excavations past such obstructions using suitable means, methods, and equipment.

### 7.5 Wall Backfill

Material within the reinforced zone and in between back-to-back SEWs should consist of Gravel Borrow for Structural Earth Wall, as specified in the WSDOT Standard Specification Section 9-03.14(4) (WSDOT, 2016a).

Backfill behind the CIPC walls should meet the requirements of the WSDOT Standard Specification Section 9-03.12(2), Gravel Backfill for Walls (WSDOT, 2016a).

## 7.6 Structural Fill

Fill placed as roadway embankment beyond the wall locations or as backfill placed in trenches above pipe zone bedding should consist of Select Borrow or Common Borrow as specified in Sections 9-03.14(2) and 9-03.14(3), respectively, of the WSDOT Standard Specifications (WSDOT, 2016a). If Common Borrow is used, we recommend the fill be granular and contain 1 percent or less organic material by weight.

For backfill of utility trenches, the pipe zone bedding should extend from the trench bottom to at least 8 to 12 inches above the pipe. Pipe zone bedding should consist of select granular soil free from organic matter meeting the requirements for Gravel Backfill for Pipe Zone Bedding as specified in Standard Specification Section 9.03.12(3) (WSDOT, 2016a).

If fill is to be placed during periods of wet weather or under wet conditions, no matter what time of the year, the fill material should contain no more than 5 percent fines (material passing the No. 200 sieve based on wet sieving the minus 3/4-inch fraction). The fines should be non-plastic.



## 7.7 Placement and Compaction

Prior to placement of the fill, any ponding water should be drained from the area. Structural fill and pipe zone bedding should be placed in horizontal uniform lifts, compacted to a dense and unyielding condition, and to at least 95 percent of the Modified Proctor maximum dry density (ASTM D1557). In general, the thickness of soil layers before compaction should not exceed 10 inches for heavy equipment compactors or 6 inches for hand-operated compactors. The most appropriate lift thickness should be determined in the field using the Contractor’s selected equipment and fill, and verified with in situ soil density testing. We recommend that fill placement and compaction be observed and tested by a qualified geotechnical engineer or technician.

## 7.8 Wet Weather Conditions

In the Snohomish County area, wet weather generally begins about mid-October and continues through about May, although rainy periods could occur at any time of year. Therefore, it would be advisable to schedule earthwork during the drier weather months of June through September. The soils observed in our subsurface explorations that are likely to be encountered during grading activities are granular but contain sufficient amounts of clay, silt, and fine sand to make them moisture sensitive. The soils would likely provide a suitable working surface under dry conditions; however, after continued repetitions by wheel loads, the materials could degrade, especially in the presence of water.

During the wet weather months, the groundwater elevation could rise, resulting in seepage into the excavation. Performing earthwork during dry weather would reduce the problems and costs associated with rainwater, trafficability, and handling of wet soil. However, should wet weather/wet condition earthwork be unavoidable, the following recommendations are provided:

- The ground surface in and surrounding the construction area should be sloped as much as possible to promote runoff of precipitation away from the work areas and to prevent the ponding of water.
- Work areas, slopes, and stock piles should be covered with plastic and appropriate erosion and sediment control measures applied. The use of sloping, ditching, sumps, dewatering, and other measures should be employed as necessary to permit proper completion of the work.
- Earthwork should be accomplished in small sections to minimize exposure to wet conditions. That is, each section should be small enough so that the removal of unsuitable soils and placement and compaction of clean structural fill could be accomplished on the same day.
- The size or type of construction equipment may need to be limited to mitigate soil disturbance. It could be necessary to excavate soils with a backhoe, or equivalent, and locate them so that the equipment does not pass over the excavated areas. Thus, subgrade disturbance caused by equipment traffic would be minimized.
- No soil should be left un-compacted and exposed to moisture. A smooth-drum vibratory roller, or equivalent, should roll the surface to promote rapid runoff of the surface water.
- In-place soil or fill soil that becomes wet and unstable and/or too wet to suitably compact should be removed and replaced with clean, granular soil, such as WSDOT Gravel Borrow.
- Excavation and placement of structural fill material should be observed on a full-time basis by a representative from our firm experienced in wet weather/wet condition earthwork to determine that all work is being accomplished in accordance with the Project specifications and our recommendations.
- Grading and earthwork should not be performed during periods of heavy, continuous rainfall.

We recommend that the above requirements for wet weather/wet condition earthwork be incorporated into the contract specifications.

## 8.0 LIMITATIONS

This report was prepared for the exclusive use of the City of Mukilteo and Lochner for specific application to the design and construction of the Harbour Reach Drive Extension as it relates to the geotechnical aspects discussed in this report. It should be made available to prospective contractors for information on factual data only, and not as a warranty of subsurface conditions. Construction observation by our firm is necessary to confirm recommendations and interpretations made in this report.

The conclusions and recommendations contained in this report are based on site conditions as they existed at the time this report was prepared, and further assume that the Project and previous field explorations are representative of the subsurface conditions beneath the site; that is, the subsurface conditions everywhere are not significantly different from those disclosed by the field explorations. If conditions different from those described in this report are observed or appear present, we should be advised at once so that we can review these conditions and reconsider our recommendations, where necessary. If conditions have changed because of natural processes or human activity at or near the site, we recommend this report be reviewed to determine the applicability of the conclusions and recommendations considering the changed conditions and lapse of time.

Within the limitations of the scope, schedule, and budget, the conclusions and recommendations presented in this report were prepared in accordance with generally accepted professional geotechnical engineering principles and practices in this area at the time this report was prepared. We make no other warranty, either express or implied. The conclusions and recommendations are based on our understanding of the Project as described in this report and the site conditions as interpreted from our site visits and field explorations.

Unanticipated soil, rock, and groundwater conditions are commonly encountered and cannot be fully determined by merely taking samples from a limited number of explorations. Such unexpected conditions frequently require that additional expenditures be made to attain a properly constructed project. Therefore, a contingency fund is recommended to accommodate such potential extra costs.

Depending on the scope of site improvements, the prospective contractor's design approach, and the prospective contractor's intended means and methods of construction, additional geotechnical data may be necessary. The suitability, adequacy, and sufficiency of the data contained in this report, for purposes of design, bidding, and construction, should be determined solely by the prospective contractor.

Our scope of our services did not include environmental assessment or evaluation regarding the presence or absence of hazardous or toxic materials in the soil, surface water, groundwater, or air on, below, or around the site. We have prepared the document entitled, "Important Information About Your Geotechnical/Environmental Report" as Appendix C in this report to assist you and others in understanding the use and limitations of our report.

**SHANNON & WILSON, INC.**




Brian S. Reznick, PE
Associate

AXT:BSR:WLM:SRB\axt

## 9.0 REFERENCES

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**TABLE 1**
**AASHTO SEISMIC DESIGN PARAMETERS**

| Spectral Response Acceleration (SRA) and Site Coefficients | Zero Period | Short Period | 1-Second Period |
|---|---|---|---|
| Mapped SRA | PGA = 0.40 | $S_S$ = 0.899 | $S_1$ = 0.308 |
| Site Coefficients (Site Class C) | $F_{PGA}$ = 1.00 | $F_a$ = 1.040 | $F_v$ = 1.492 |
| Design SRA (Site Class C) | $A_S$ =0.40 | $S_{DS}$ = 0.935 | $S_{D1}$ = 0.460 |

Notes:
AASHTO = American Association of State Highway and Transportation Officials
$A_s$ = modified zero-period spectral acceleration
$F_a$ = site factor at short-period range (0.2 second)
$F_{PGA}$ = site factor at zero-period
$F_v$ = site factor at long-period (1.0 second) range
PGA = peak ground acceleration
$S_1$ = long-period (1.0 second) spectral acceleration
$S_{D1}$ = modified long-period (1.0 second) spectral response acceleration
$S_{DS}$ = modified short-period spectral response acceleration
$S_s$ = short-period spectral acceleration

**TABLE 2**
**RECOMMENDED SOIL PARAMETERS FOR STRUCTURAL EARTH WALL DESIGN**

| Structural Earth Wall (SEW) Design Parameter | SEW Nos. 1, 2, 3, and 4 |
|---|---|
| **Reinforced Zone Fill** | Gravel Borrow for SEW[1] |
| Moist Unit Weight, $\gamma$ (pcf) | 135 |
| Effective Friction Angle, $\phi'$ (degree) | 38 |
| Cohesion, c' (psf) | 0 |
| **Retained Fill** | Gravel Borrow for SEW[1] |
| Moist Unit Weight, $\gamma$ (pcf) | 135 |
| Effective Friction Angle, $\phi'$ (degree) | 38 |
| Cohesion, c' (psf) | 0 |
| **Foundation Soil** | Alluvium, Weathered Till, or Till |
| Moist Unit Weight, $\gamma$ (pcf) | 130 |
| Effective Friction Angle, $\phi'$ (degree) | 33 |
| Cohesion, c' (psf) | 0 |
| Depth to Groundwater Below Base Reinforcement Layer, $d_w$ (feet) | 0 |
| **Seismic Parameters** | |
| Seismic Site Class | C |
| Seismic Horizontal Acceleration Coefficient, $K_h$, for Internal and External Stability Analysis [2] | 0.20g |
| **Surcharge Load, $q_s$ (psf)** | |
| Traffic | 250 |

Notes:

[1] As specified in Section 9-03.14(4) of the Washington State Department of Transportation (WSDOT) Standard Specification (WSDOT, 2016).

[2] The seismic horizontal acceleration coefficient, $k_h$, is calculated by applying a wall displacement ductility factor (DF) to the peak ground acceleration (PGA). For The American Association of State Highway and Transportation Officials (AASHTO)-based SEWs, kh, is calculated by applying a DF of 0.5 to the design earthquake (As).

pcf = pounds per cubic foot

psf = pounds per square foot


0 2 4

Approximate Scale in Miles

NOTE

Map adapted from aerial imagery provided by Google Earth Pro, reproduced by permission granted by Google Earth ™ Mapping Service.

City of Mukilteo
Harbour Reach Drive Extension
Mukilteo, Washington

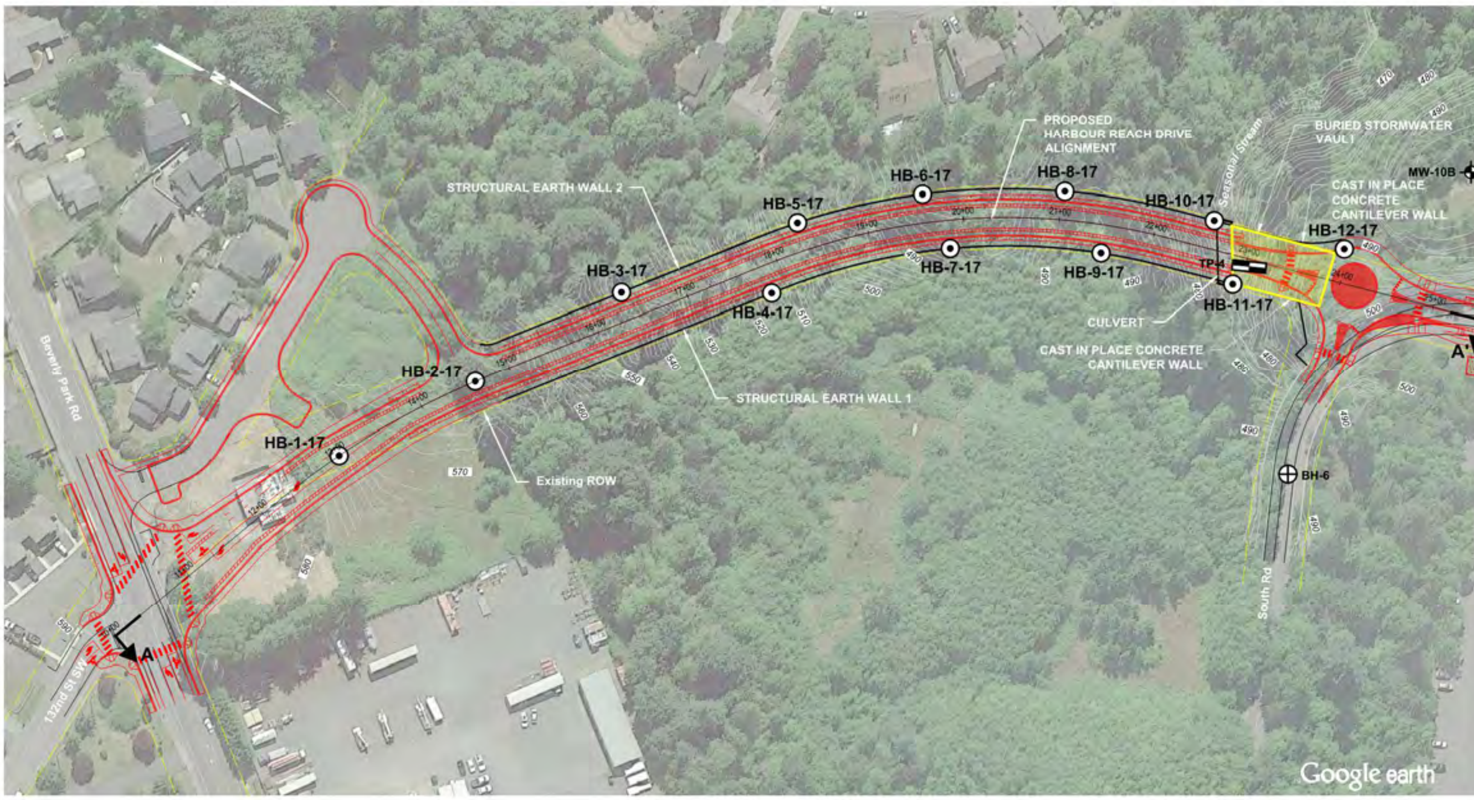
**VICINITY MAP**

May 2017 21-1-12561-102

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

**FIG. 1**

Filename: J:\211\12561\102\21-1-12561-102 Fig 1 - Vicinity Plan.dwg Date: 05-23-2017 Login: jrs




LEGEND

HB-1-17 Hand Boring Designation and Approximate Location

SW-1-17 Boring Designation and Approximate Location

BH-1 1991 Boring Designation and Approximate Location

MW-2 1991 Monitoring Well Designation and Approximate Location

SW-1 1991 Test Pit Designation and Approximate Location

0 100 200

Scale in Feet

Contour Interval = 1 Foot

NAD83 WA State Plane North Zone Datum

NOTE

Figure adapted from Lochner files, *10924-AL.dwg, 10924-PV-MK.dwg,* and *20150051 Topo Grid Coords.dwg,* received 1-27-17. Aerial imagery provided by Google Earth Pro, reproduced by permission granted by Google Earth ™ Mapping Service.

City of Mukilteo
Harbour Reach Drive Extension
Mukilteo, Washington

**SITE AND EXPLORATION PLAN**

May 2017 21-1-12561-102

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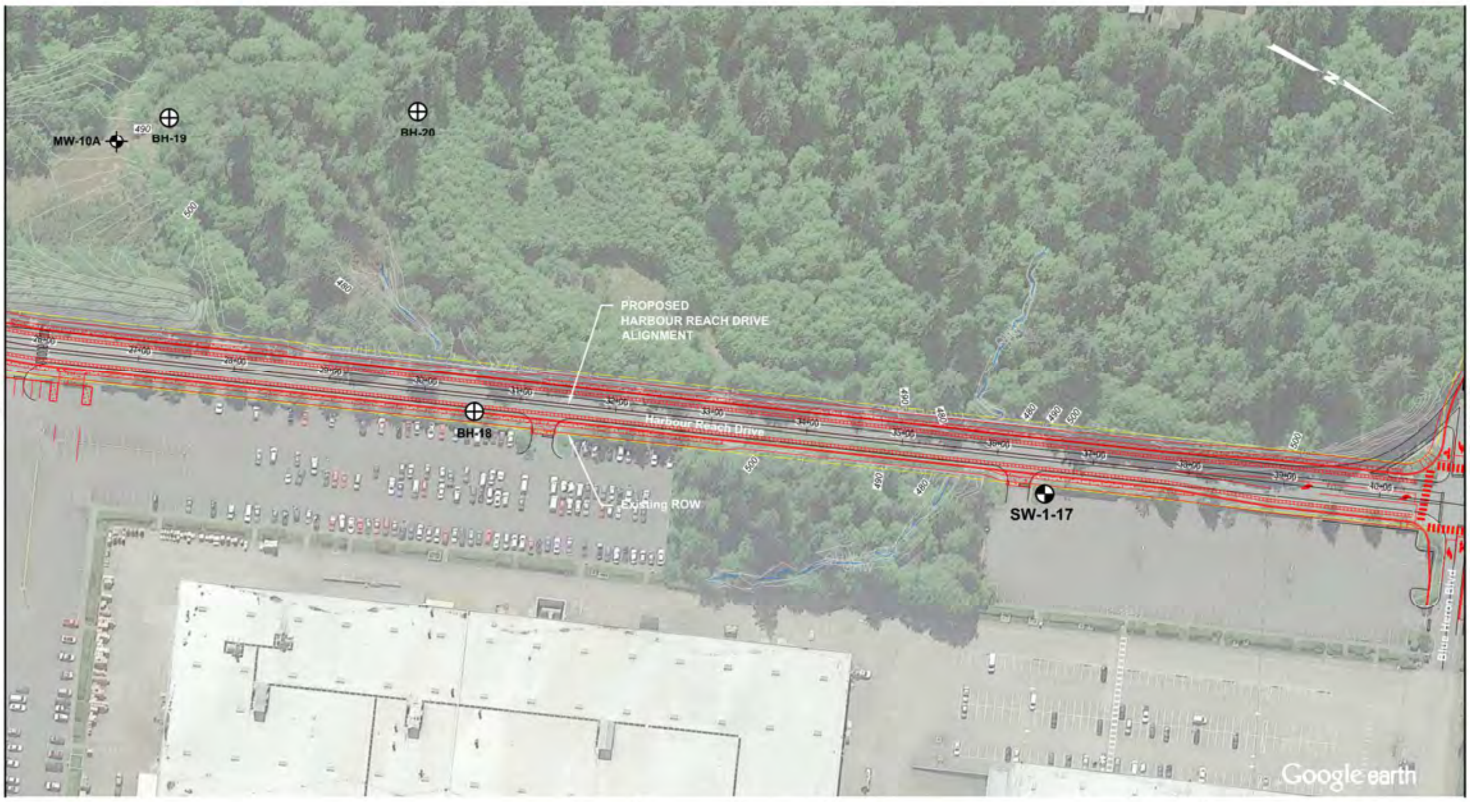
**FIG. 2**
Sheet 1 of 6

Filename: J:\211\12561\102\21-1-12561-102 Fig 2 - Site Plan.dwg Layout: Sheet 1 Date: 05-23-2017 Login: jrs




LEGEND

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0 100 200

Scale in Feet

Contour Interval = 1 Foot

NAD83 WA State Plane North Zone Datum

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City of Mukilteo
Harbour Reach Drive Extension
Mukilteo, Washington

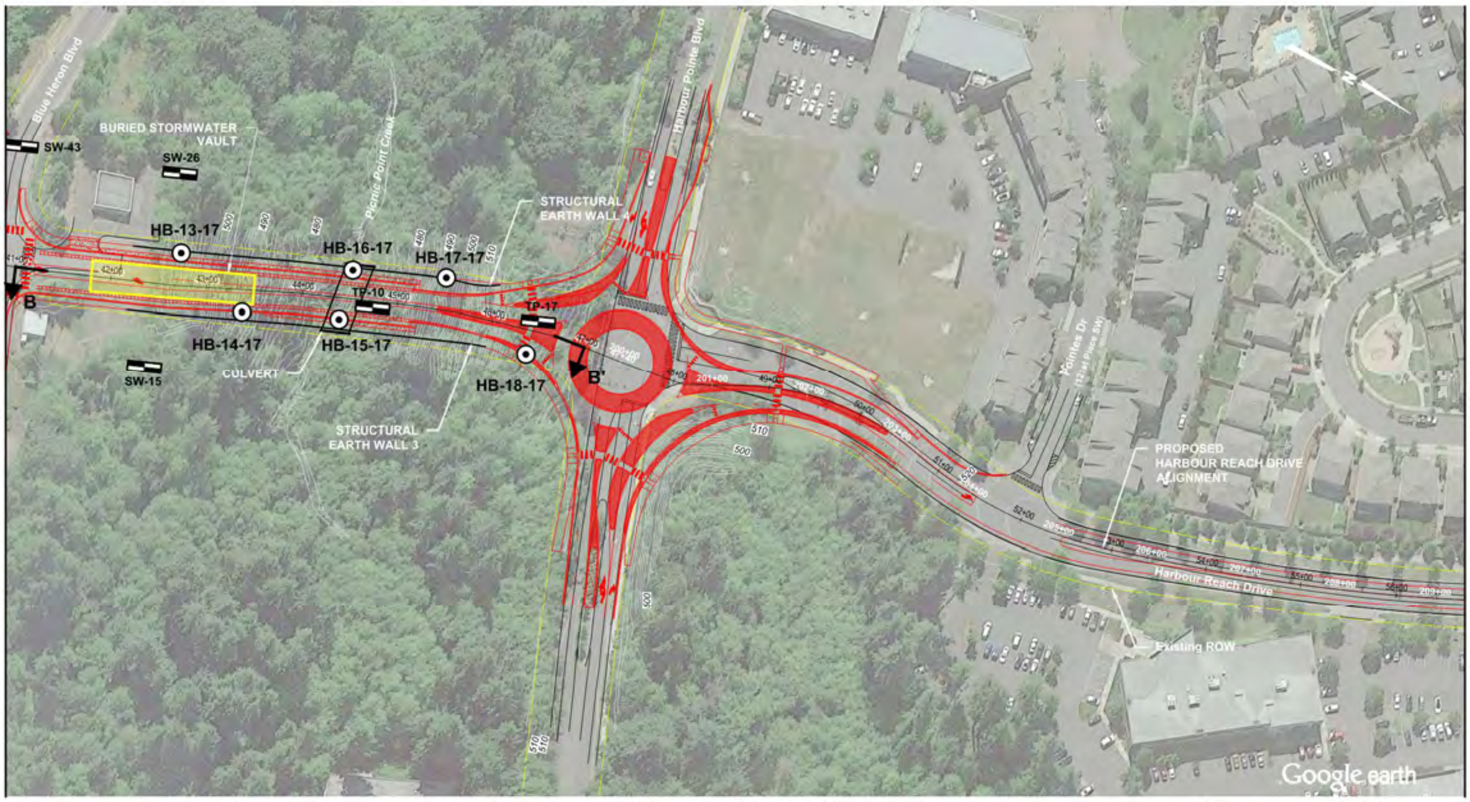
## SITE AND EXPLORATION PLAN

May 2017 21-1-12561-102

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 2
Sheet 2 of 6

Filename: J:\211\12561\102\21-1-12561-102 Fig 2 - Site Plan.dwg Layout: Sheet 2 Date: 05-23-2017 Login: jrs




LEGEND

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City of Mukilteo
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**SITE AND EXPLORATION PLAN**

May 2017 21-1-12561-102

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

**FIG. 2**
Sheet 3 of 6

Filename: J:\211\12561\102\21-1-12561-102 Fig 2 - Site Plan.dwg Layout: Sheet 3 Date: 05-23-2017 Login: jrs


LEGEND

**HB-1-17** Hand Boring Designation and Approximate Location

**SW-1-17** Boring Designation and Approximate Location

**BH-1** 1991 Boring Designation and Approximate Location

**MW-2** 1991 Monitoring Well Designation and Approximate Location

**SW-1** 1991 Test Pit Designation and Approximate Location

0 100 200

Scale in Feet

Contour Interval = 1 Foot

NAD83 WA State Plane North Zone Datum

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City of Mukilteo
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**SITE AND EXPLORATION PLAN**

May 2017 21-1-12561-102

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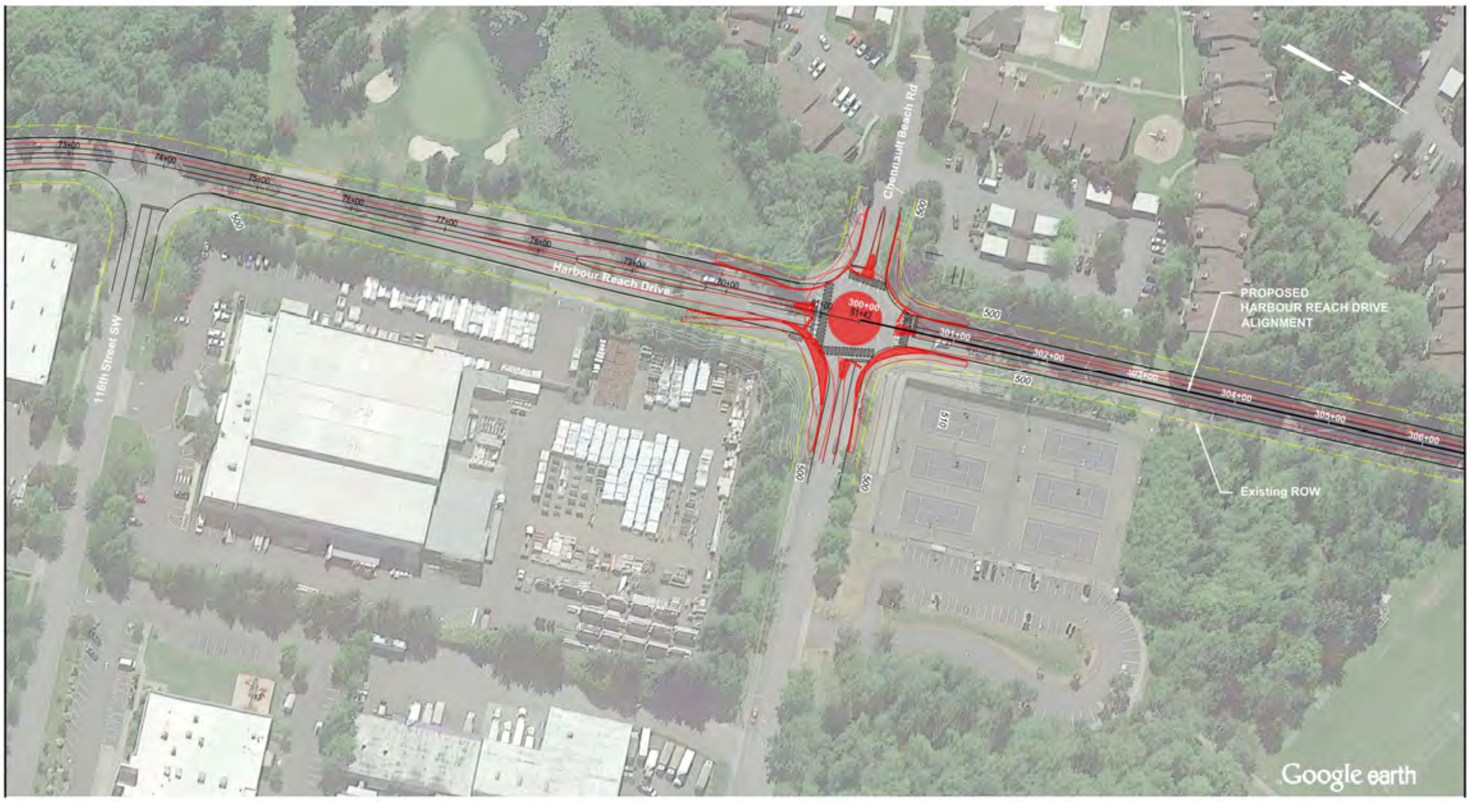
**FIG. 2**
Sheet 4 of 6

Filename: J:\211\12561\102\21-1-12561-102 Fig 2 - Site Plan.dwg Layout: Sheet 4 Date: 05-23-2017 Login: jrs




LEGEND

HB-1-17 Hand Boring Designation and Approximate Location

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0 100 200

Scale in Feet

Contour Interval = 1 Foot

NAD83 WA State Plane North Zone Datum

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City of Mukilteo
Harbour Reach Drive Extension
Mukilteo, Washington

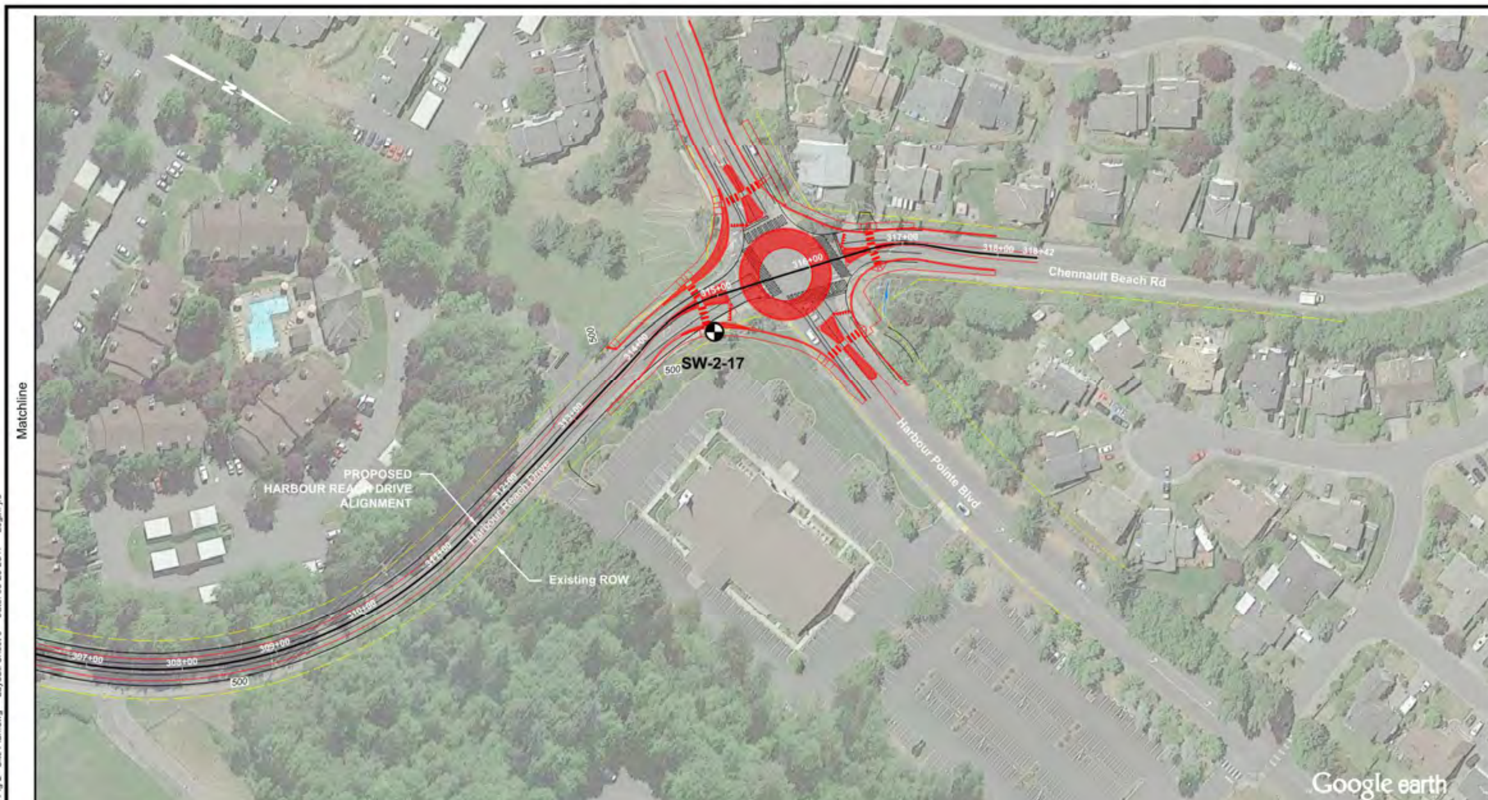
**SITE AND EXPLORATION PLAN**

May 2017 21-1-12561-102

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

**FIG. 2**
Sheet 5 of 6

Filename: J:\211\12561\102\21-1-12561-102 Fig 2 - Site Plan.dwg Layout: Sheet 5 Date: 05-23-2017 Login: jrs




LEGEND

HB-1-17 Hand Boring Designation and Approximate Location

SW-1-17 Boring Designation and Approximate Location

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0 100 200

Scale in Feet

Contour Interval = 1 Foot

NAD83 WA State Plane North Zone Datum

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City of Mukilteo
Harbour Reach Drive Extension
Mukilteo, Washington

SITE AND EXPLORATION PLAN

May 2017 21-1-12561-102

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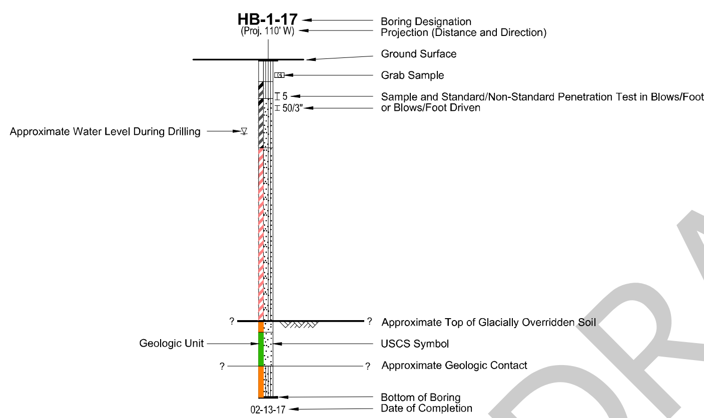
FIG. 2
Sheet 6 of 6

Filename: J:\211\12561\102\21-1-12561-102 Fig 2 - Site Plan.dwg Layout: Sheet 6 Date: 05-23-2017 Login: jrs

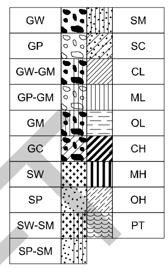
## S&W BORING LOG LEGEND




## SOIL AND SAMPLING LEGEND

### UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)

(From USACE Tech Memo 3-357)




### SAMPLE TYPES

- Grab Sample
- 1.5" O.D. Split Spoon Sample with 40 lb. Hammer (Non-standard penetration test - NSPT) or 2" O.D. split spoon with 140 lb. Hammer (Standard penetration test - SPT)

1. Dual Symbols (symbols separated by a hyphen, i.e., SP-SM, Poorly Graded Sand with Silt) are used for soils with between 5% and 12% fines or when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart.
2. Borderline symbols (symbols separated by a slash, i.e., CL/ML, Lean Clay/Silt; GW/SW, Well-Graded GRAVEL/Well-Graded SAND) indicate that the soil may fall into one of two possible basic groups, based on ASTM D 2488 Visual Manual Classification System. The graphic symbol of only the first group symbol is shown on the profile.

## GEOLOGIC UNITS

### Holocene Deposits

- Hf — Forest Duff/Topsoil/Fill
- Hc — Colluvium
- Ha — Alluvium

### Quaternary Pre-Vashon Deposits

- Qvt — Till
- Qvt(W) — Till (Weathered)

## RELATIVE DENSITY / CONSISTENCY

| COARSE-GRAINED SOILS | | FINE-GRAINED/COHESIVE SOILS | |
|---|---|---|---|
| N, SPT, BLOWS/FT. | RELATIVE DENSITY | N, SPT, BLOWS/FT. | RELATIVE CONSISTENCY |
| 0 - 4 | Very loose | <2 | Very soft |
| 4 - 10 | Loose | 2 - 4 | Soft |
| 10 - 30 | Medium dense | 4 - 8 | Medium stiff |
| 30 - 50 | Dense | 8 - 15 | Stiff |
| Over 50 | Very dense | 15 - 30 | Very stiff |
| | | Over 30 | Hard |

## NOTES

1. This profile is constructed from surface elevations and project alignment, received from H.W. Lochner, on January 12, 2017. The subsurface conditions shown are interpreted from the explorations conducted by Shannon & Wilson. The geology, as encountered in the explorations, has been projected into the plane of the profile or section. Elevations and contacts should be considered approximate. Variations between the profile and actual conditions are likely to exist.
2. Water levels shown were measured during drilling. They may not be representative of the actual groundwater level. Groundwater fluctuations should be expected.
3. The locations and extents of proposed structures should be considered approximate. Project alignments presented in exhibits were developed by H.W. Lochner.

DRAFT

City of Mukilteo
Harbour Reach Drive Extension
Mukilteo, Washington

**GEOLOGIC PROFILE LEGEND AND NOTES**

May 2017 | 21-1-12561-102

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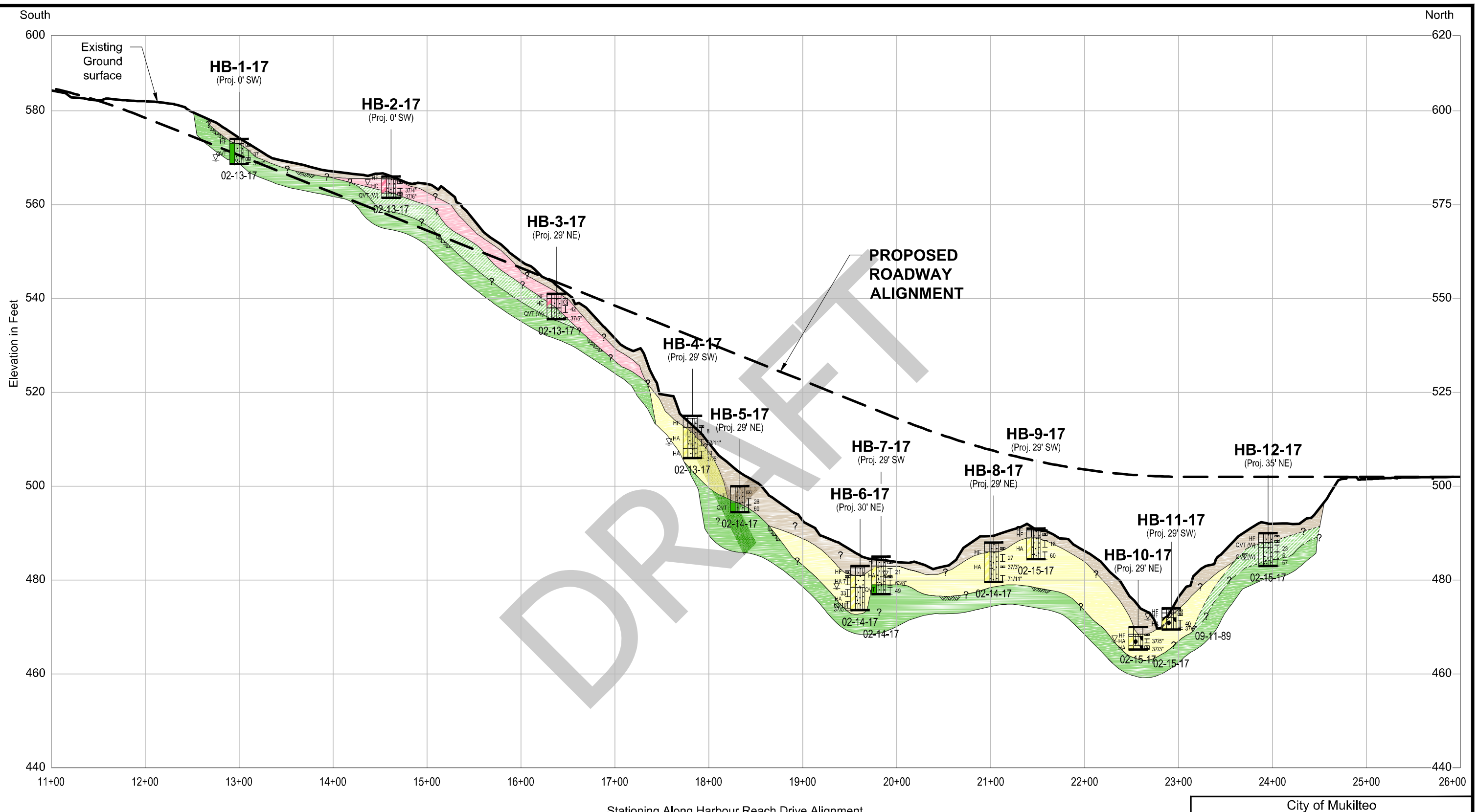
**FIG. 3**




GEOLOGIC UNITS

| Holocene Deposits | | Quaternary Pre-Vashon Deposits | |
|---|---|---|---|
| Hf | Forest Duff/Topsoil/Fill | Qvt | Till |
| Hc | Colluvium | Qvt(W) | Till (Weathered) |
| Ha | Alluvium | | |

0 100 200
Horizontal Scale in Feet

0 20 40
Vertical Scale in Feet

Vertical Exaggeration = 4X

NOTE

Ground surface and proposed roadway alignment adapted from client file, *10924-profiles.dwg*, received 1-27-17.

City of Mukilteo
Harbour Reach Drive Extension
Mukilteo, Washington

**GENERALIZED SUBSURFACE PROFILE A-A'**

May 2017 21-1-12561-102

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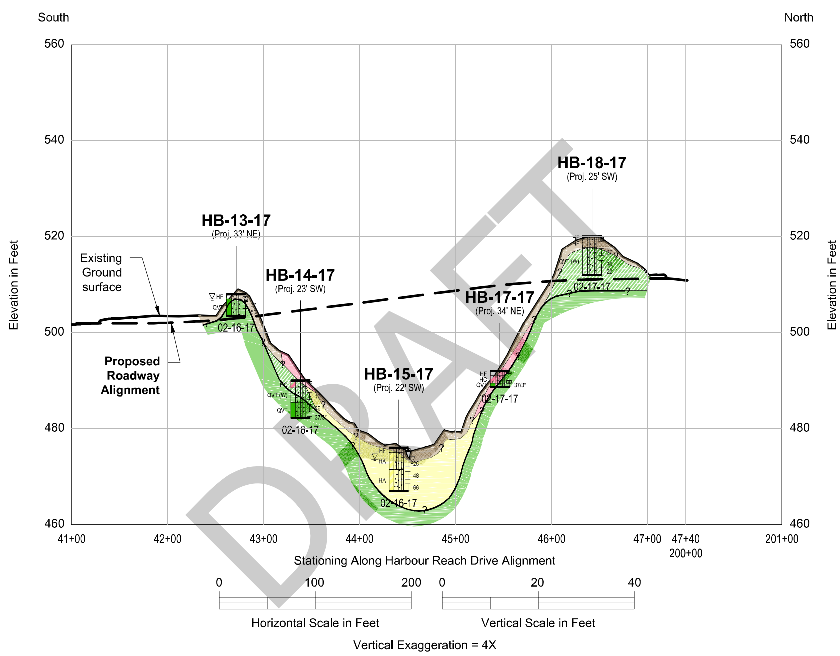
**FIG. 4**

Filename: J:\211\12561\102\21-1-12561-102 Profiles.dwg Layout: FIG 4 Date: 05-22-2017 Login: jrs




GEOLOGIC UNITS

Holocene Deposits

Hf — Forest Duff/Topsoil/Fill
Hc — Colluvium
Ha — Alluvium

Quaternary Pre-Vashon Deposits

Qvt — Till
Qvt(W) — Till (Weathered)

NOTE

Ground surface and proposed roadway alignment adapted from client file, *10924-profiles.dwg*, received 1-27-17.

City of Mukilteo
Harbour Reach Drive Extension
Mukilteo, Washington

**GENERALIZED SUBSURFACE PROFILE B-B'**

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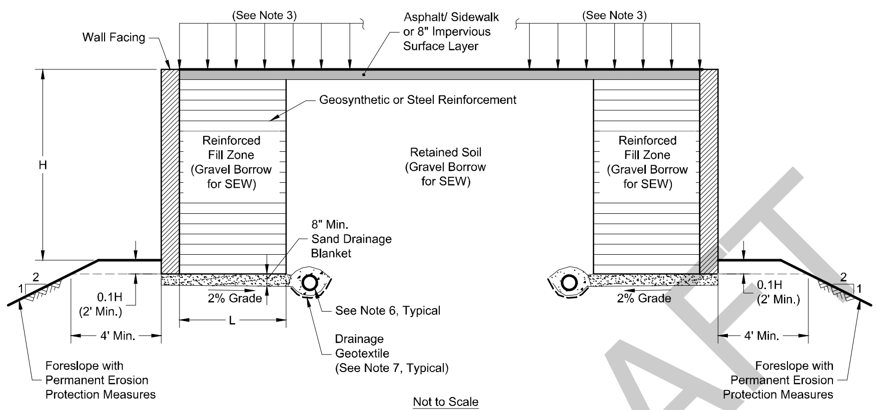
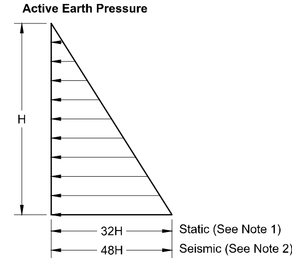
**FIG. 5**

Filename: J:\211\12561\102\21-1-12561-102 Profiles.dwg Layout: FIG 5 Date: 05-22-2017 Login: jrs

**Structural Earth Wall (SEW)**




**Active Earth Pressure**






NOTES

1. Recommended lateral earth pressures assume backfill materials consist of free-draining granular fill and that a subdrain is installed behind the reinforced zone of each wall.

2. Active seismic earth pressure was calculated using the Mononobe-Okabe method using a horizontal seismic coefficient of 1/2 PGA of the design earthquake.

3. Surcharge load should be added to the active pressure where appropriate. See Figure 9.

4. Loose soil at wall foundations should be excavated down to dense soil and replaced with Gravel Borrow for SEW. The excavation shall be kept free of water. The prepared foundation should be evaluated by a geotechnical engineer or their representative prior to placement of backfill, concrete, or blocks.

5. Sand Drainage Blanket shall meet the requirements of WSDOT Standard Specification Section 9-03.13(1). Gravel Borrow for SEW shall meet the requirements of WSDOT Standard Specification Section 9-03.14(4).

6. 6" Diameter (Minimum) Slotted Pipe
   Bed in washed 3/8" to No. 8 sieve size pea gravel (8" minimum cover around pipe), sloped to drain and connect by tightline to storm drain outfall. No fabric around pipe. Maximum slot width is 1/8". Where slotted drain connects to tightline, construct impervious collar (concrete or clay) to force all water into tightline.

7. Place drainage geotextile below drain pipe and drainage backfill only. Drainage geotextile shall meet the requirements of WSDOT Standard Specification Section 9-33.2, for a non-woven, moderate survivability Class B geosynthetic. Geotextile should not be placed below retaining wall, between drainage sand and gravel and retained soil, or wrapped over top of the drain pipe.

8. Drainage blanket, reinforced backfill, and retained soil should be placed and compacted in accordance with WSDOT Standard Specification Sections 2-03.3(14)C and 6-13-3(7).

9. See Table 2 for recommended soil parameters for SEW design.

LEGEND

H = Height of Wall in Feet

L = 0.7H or 8 Feet, whichever is greater. Actual length to be determined by wall designer

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Mukilteo, Washington

**LATERAL EARTH PRESSURES FOR SEW WALL DESIGN**

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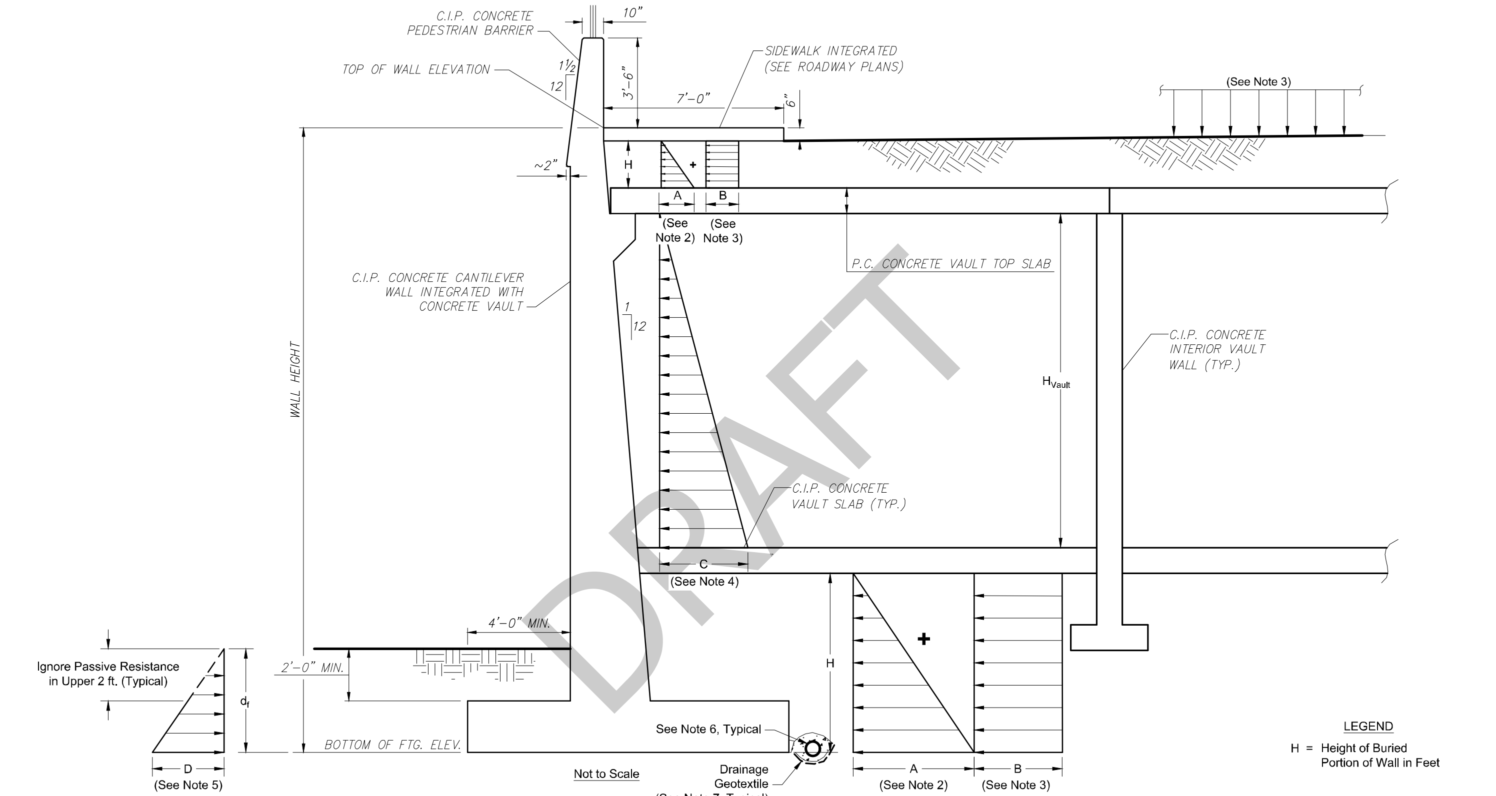
**FIG. 6**

File: J:\211\12561\102\21-1-12561-102 LEPs.dwg Date: 05-25-2017 Author: jrs




NOTES

1. Conceptual adapted from drawing provided by Lochner in *Hrde_Str_Typ-Sections.dwg*.
2. Lateral earth pressure calculation:
   At Rest: A = 52H (pcf) for static conditions, 70H (pcf) for seismic conditions.
   Active: A = 30H (pcf) for static conditions, 48H (pcf) for seismic conditions.
3. See Figure 9 for surcharge loading. Note the surcharge loading should include overburden soil, structural dead loads, and live loads.
4. Static Water Pressure Calculation: C = 62$H_{Vault}$. Seismic water pressures for sloshing should be considered as appropriate for the project design criteria.
5. Nominal Passive Earth Pressure Calculation: D = 700$d_f$ (pcf) for static conditions, 625$d_f$ (pcf) for seismic conditions.
6. 6" Diameter (Minimum) Slotted Pipe
   Bed in washed 3/8" to No. 8 sieve size pea gravel (8" minimum cover around pipe), sloped to drain and connect by tightline to storm drain outfall. No fabric around pipe. Maximum slot width is 1/8". Where slotted drain connects to tightline, construct impervious collar (concrete or clay) to force all water into tightline.
7. Place drainage geotextile below drain pipe and drainage backfill only. Drainage geotextile shall meet the requirements of WSDOT Standard Specification Section 9-33.2, for a non-woven, moderate survivability Class B geosynthetic. Geotextile should not be placed below retaining wall, or wrapped over top of the drain pipe.

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**LATERAL EARTH PRESSURES FOR CIPC WALLS**

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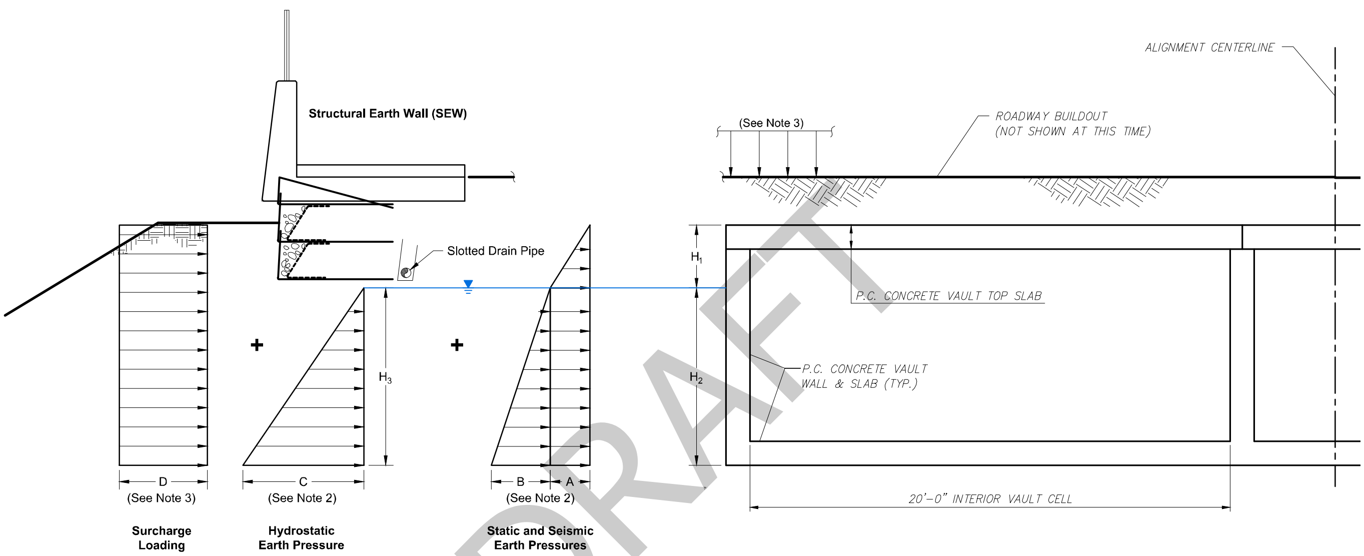
**FIG. 7**

File: J:\211\12561\102\21-1-12561-102 LEPs.dwg Date: 05-25-2017 Author: jrs






Not to Scale

LEGEND

$H_1$ = Height of Wall Above Groundwater in Feet

$H_2$ = Height of Wall Below Groundwater in Feet

$H_3$ = Height of Groundwater in Feet

NOTES

1. Conceptual adapted from drawing provided by Lochner in *Hrde_Str_Typ-Sections.dwg*.

2. Lateral earth pressure calculation:
   A = $60H_1$ (pcf) for static conditions, $75H_1$ (pcf) for seismic conditions.
   B = $30H_2$ (pcf) for static conditions, $38H_2$ (pcf) for seismic conditions.
   C = $62H_3$ (pcf) for hydrostatic conditions. Assume that groundwater exists below the base of the MSE wall.

3. See Figure 9 for surcharge loading. Note the surcharge loading should include overburden soil, structural dead loads, and live loads.

City of Mukilteo
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**LATERAL EARTH PRESSURES FOR BURIED VAULTS**

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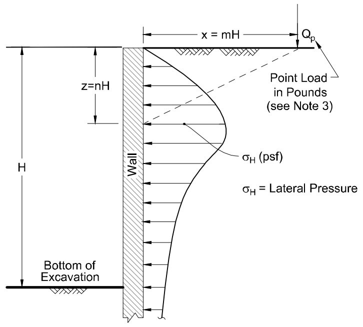
**FIG. 8**

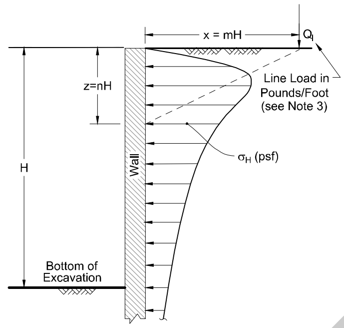
File: J:\211\12561\102\21-1-12561-102 LEPs.dwg Date: 05-25-2017 Author: jrs




ELEVATION VIEW

For m ≤ 0.4: $\sigma_H = 0.28 \dfrac{Q_p}{H^2} \dfrac{n^2}{(0.16 + n^2)^3}$ (psf) (see Note 3)

For m > 0.4: $\sigma_H = 1.77 \dfrac{Q_p}{H^2} \dfrac{m^2 n^2}{(m^2 + n^2)^3}$ (psf)



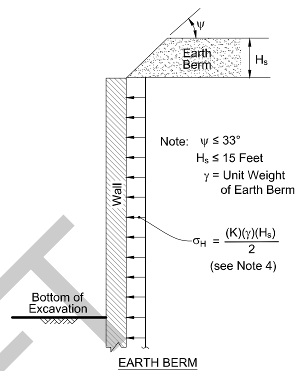

ELEVATION VIEW

For m ≤ 0.4: $\sigma_H = 0.20 \dfrac{Q_l}{H} \dfrac{n}{(0.16 + n^2)^2}$ (psf) (see Note 3)

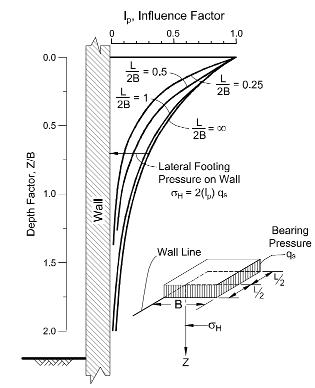
For m > 0.4: $\sigma_H = 1.28 \dfrac{Q_l}{H} \dfrac{m^2 n}{(m^2 + n^2)^2}$ (psf)

**B) LATERAL PRESSURE DUE TO LINE LOAD**
**i.e. NARROW CONTINUOUS FOOTING**
**PARALLEL TO WALL**

(NAVFAC DM 7.02, 1986)

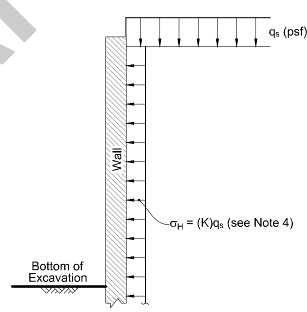



EARTH BERM




**E) LATERAL PRESSURE DUE**
**TO ADJACENT FOOTING**
(see Notes 5 and 6)

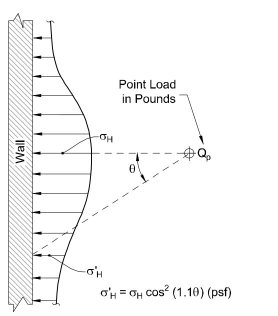
(derived from NAVFAC DM 7.02, 1986; and Sandhu, *Earth Pressure on Walls Due to Surcharge*, 1974)




UNIFORM SURCHARGE

**D) LATERAL PRESSURE DUE TO EARTH BERM**
**OR UNIFORM SURCHARGE**

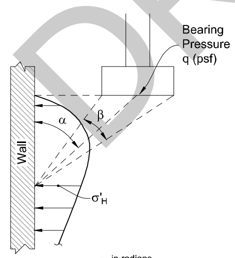
(derived from Poulos and Davis, *Elastic Solutions for Soil and Rock Mechanics*, 1974; and Terzaghi and Peck, *Soil Mechanics in Engineering Practice*, 1967)




PLAN VIEW

**A) LATERAL PRESSURE DUE TO POINT LOAD**
**i.e. SMALL ISOLATED FOOTING OR WHEEL LOAD**

(NAVFAC DM 7.2, 1986)




in radians

$\sigma_H = \dfrac{2q}{\pi} (\beta - \sin\beta \cos 2\alpha)$ (psf)

**C) LATERAL PRESSURE DUE TO STRIP LOAD**

(derived from Fang, *Foundation Engineering Handbook*, 1991)

NOTES

1. Figures are not drawn to scale.
2. Applicable surcharge pressures should be added to appropriate permanent and temporary wall lateral earth and water pressure.
3. If point or line loads are close to the back of the wall such that m ≤ 0.4, it may be more appropriate to model the actual load distribution (i.e., Detail E) or use more rigorous analysis methods.
4. The recommended K values are 0.22 for flexible walls and 0.38 for rigid walls under static conditions, and 0.36 for flexible walls and 0.53 for rigid walls under seismic conditions.

City of Mukilteo
Harbour Reach Drive Extension
Mukilteo, Washington

**RECOMMENDED SURCHARGE LOADING FOR TEMPORARY AND PERMANENT WALLS**

May 2017 | 21-1-12561-102

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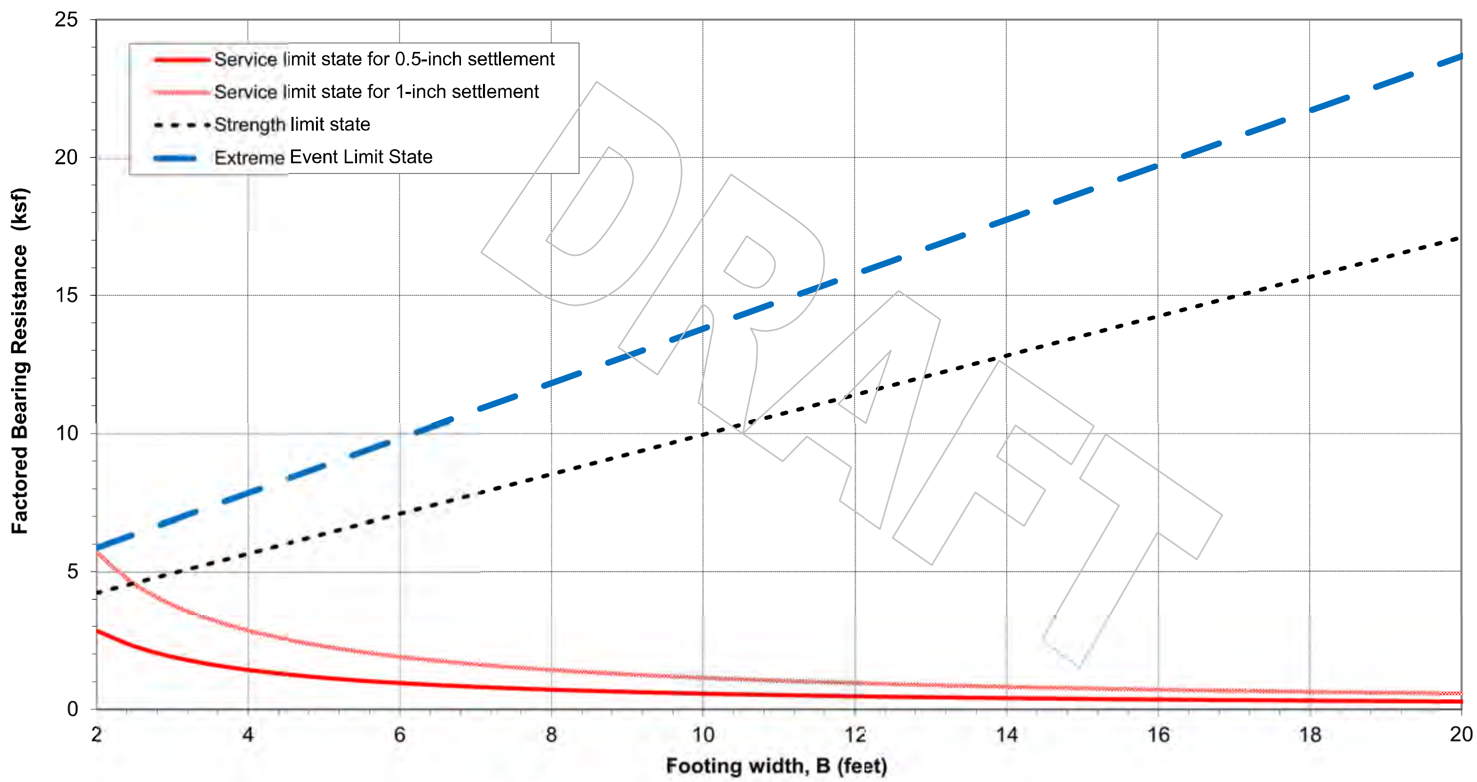
**FIG. 9**



File: J:\211\12561\102\21-1-12561-102 Fig 9 - Surcharge Loading.dwg Date: 05-25-2017 Author: jrs




NOTES

1. We recommend using the following resistance factors for footing LRFD design; the plotted bearing capacities use the bearing capacity resistance factors presented in the following table.

| Limit State | Sliding Shear | Passive Press. | Bearing Capacity |
|---|---|---|---|
| Service | 1.0 | 1.0 | 1.0 |
| Strength | 1.0 | 0.5 | 0.65 |
| Extreme Event | 1.0 | 1.0 | 0.9 |

2. The factored bearing capacities are based on a soil friction angle of 33 degrees, a soil cohesion of 0 psf, a total unit weight of 130 pcf, a Poisson's ratio of 0.3, and a soil elastic modulus of 280 ksf. We assumed that the bottom of the reinforced zone was 2 feet below the ground surface.

3. **psf -** pounds per square foot; **pcf -** pounds per cubic foot; **ksf -** kips per square foot (1 kip = 1000 pounds)

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**FACTORED BEARING RESISTANCE VERSUS REINFORCED ZONE WIDTH SEW**

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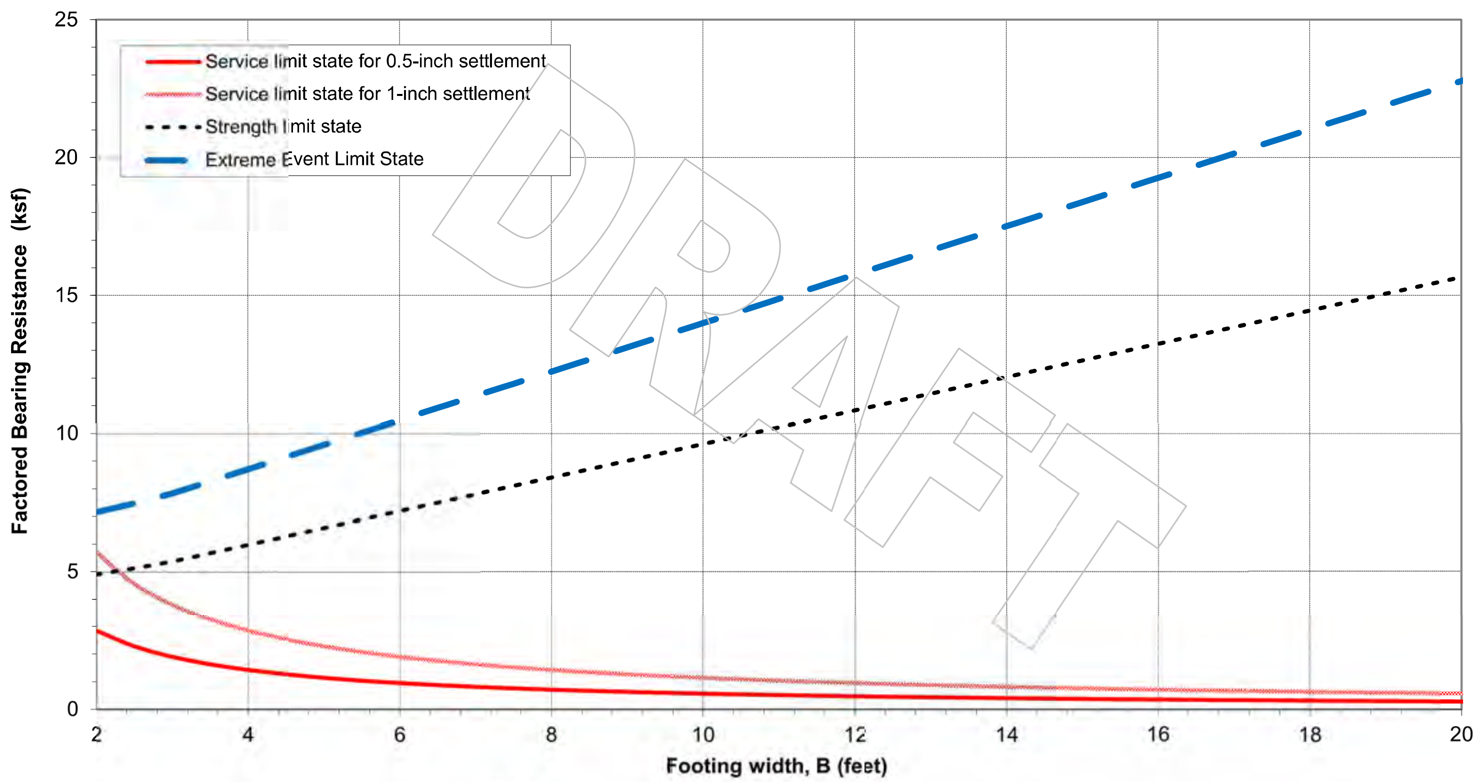
**FIG. 10**

**FIG. 10**




NOTES

1. We recommend using the following resistance factors for footing LRFD design; the plotted bearing capacities use the bearing capacity resistance factors presented in the table below.

| Limit State | Sliding Shear | Passive Press. | Bearing Capacity |
|---|---|---|---|
| Service | 1.0 | 1.0 | 1.0 |
| Strength | 1.0 | 0.5 | 0.55 |
| Extreme Event | 1.0 | 1.0 | 0.8 |

2. The factored bearing capacities are based on a soil friction angle of 33 degrees, a soil cohesion of 0 psf, a total unit weight of 130 pcf, a Poisson's ratio of 0.3, and a soil elastic modulus of 280 ksf. We assumed that the bottom of the footing was 3 feet below the ground surface.

3. **psf -** pounds per square foot; **pcf -** pounds per cubic foot; **ksf -** kips per square foot (1 kip = 1000 pounds)

City of Mukilteo
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**FACTORED BEARING RESISTANCE VERSUS FOOTING WIDTH CIPC WALL**

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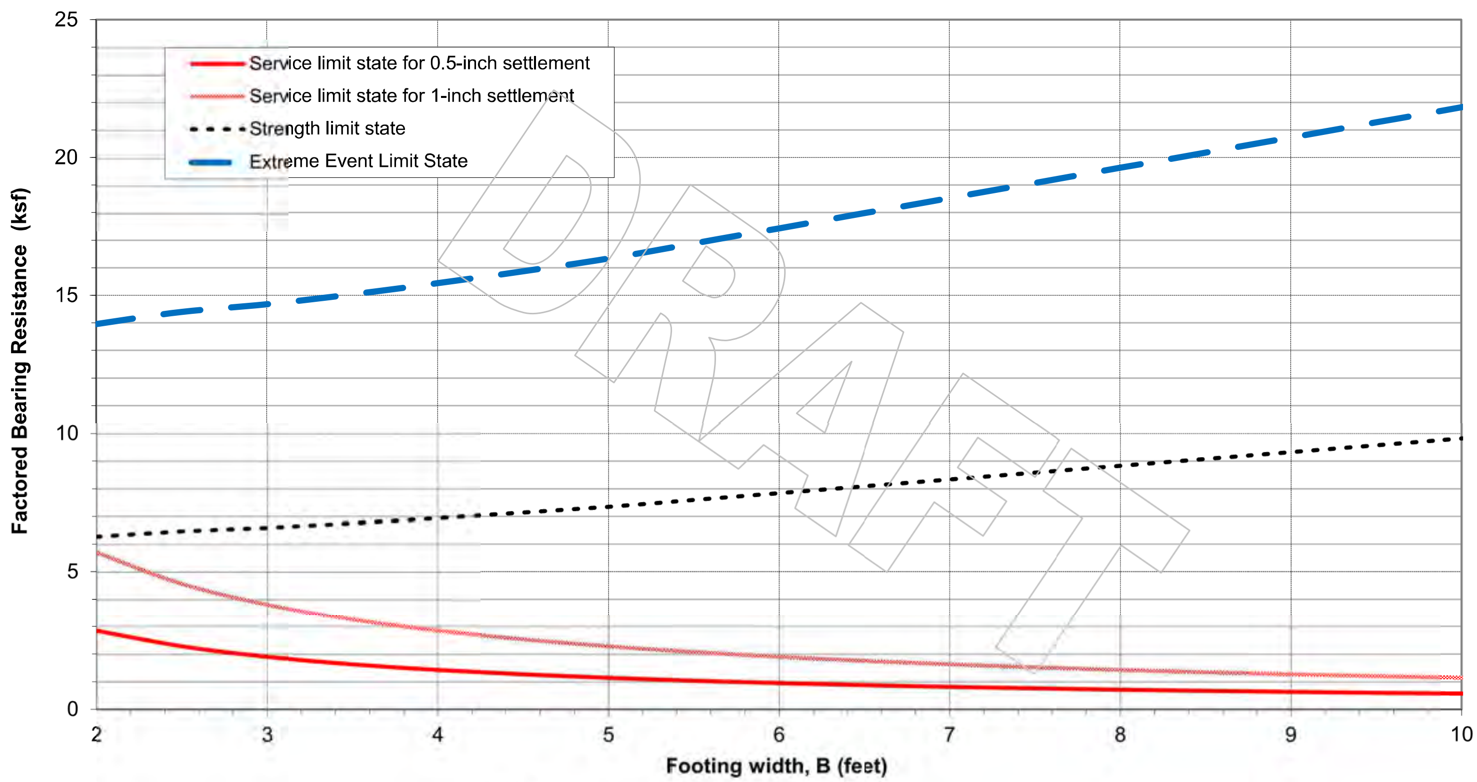
**FIG. 11**

FIG. 11

AASHTO_Spread_Footing_v1.5 - Stream 5/25/2017




NOTES

1. We recommend using the following resistance factors for footing LRFD design; the plotted bearing capacities use the bearing capacity resistance factors presented in the following table.

| Limit State | Sliding Shear | Passive Press. | Bearing Capacity |
|---|---|---|---|
| Service | 1.0 | 1.0 | 1.0 |
| Strength | 0.8 | 0.5 | 0.45 |
| Extreme Event | 1.0 | 1.0 | 1.0 |

2. The factored bearing capacities are based on a soil friction angle of 33 degrees, a soil cohesion of 0 psf, a total unit weight of 130 pcf, a Poisson's ratio of 0.3, and a soil elastic modulus of 280 ksf. We assumed that the bottom of the footing was 5 feet below the ground surface.

3. **psf -** pounds per square foot; **pcf -** pounds per cubic foot; **ksf -** kips per square foot (1 kip = 1000 pounds)

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**FACTORED BEARING RESISTANCE VERSUS FOOTING WIDTH STREAM CULVERT**

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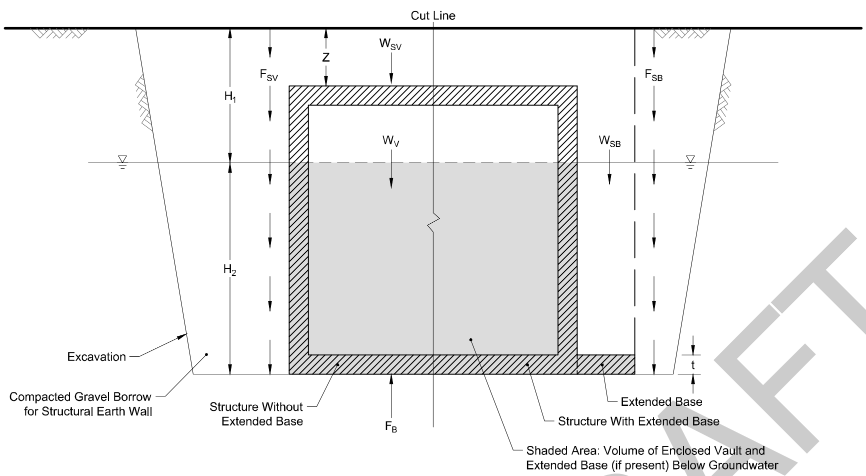
**FIG. 12**

**FIG. 12**




Not to Scale

## NOTATION

$\gamma_T$ = Total Unit Weight of Soil Above Groundwater Level, $\gamma_T$ = 135 pcf

$\gamma_B$ = Buoyant Unit Weight of Soil Below Groundwater Level, $\gamma_B$ = 72.6 pcf

$\gamma_W$ = Unit Weight of Water, $\gamma_W$ = 62.4 pcf (Fresh Water)

$\phi$ = Soil Internal Friction Angle, $\phi$ = 38°

$\delta$ = Soil - Structure Interface Friction Angle, $\delta = \frac{2}{3}\phi$ (Precast Concrete)

K = $K_o$ for Unshored Excavations, K = $K_a$ otherwise

$K_o$ = At-Rest Earth Pressure Coefficient, $K_o = 1 - \sin\phi$

$K_a$ = Active Earth Pressure Coefficient, $K_a = \dfrac{1-\sin\phi}{1+\sin\phi}$

$A_{Top}$ = Area of Top of Vault, Ft$^2$

$A_{EB}$ = Area of Extended Base, Ft$^2$

P = Perimeter Distance Around Base of Vault and Extended Base (if present), Ft. May Not Be Same Shape as Shown

t = Thickness of Extended Base, Ft.

V = Volume of Enclosed Vault and Extended Base (if present) Below Groundwater, Ft$^3$. May Not Be Same Shape as Shown

Z = Depth to Top of Vault

$H_1$ = Depth to Groundwater

$H_2$ = Depth from Groundwater to Base of Vault



## EQUATIONS

Factor of Safety without Extended Base = $\dfrac{W_V + W_{SV} + F_{SV}\,(P)}{F_B}$

Factor of Safety with Extended Base = $\dfrac{W_V + W_{SV} + W_{SB} + F_{SB}\,(P)}{F_B}$

$W_V$ = Weight of Vault and Extended Base (if present), lb

$W_{SV}$ = Weight of Soil Above Vault (if present), lb

Buried Vault with Groundwater Below Top of Vault: $W_{SV} = \gamma_T\, Z\, A_{Top}$ (lb)

Buried Vault with Groundwater Above Top of Vault: $W_{SV} = [\gamma_T\, H_1 + \gamma_B\,(Z - H_1)]\, A_{Top}$ (lb)

$W_{SB}$ = Weight of Soil Above Extended Base (if present), lb

$= [\gamma_T\, H_1 + \gamma_B\,(H_2 - t)]\, A_{EB}$

$F_{SV}$ = Shearing Resistance of Soil to Vault Wall, lb/Ft

$= (\frac{1}{2})\,(\tan\delta)\,(K)\,(2\,\gamma_T\, H_1\, H_2 + \gamma_T\, H_1^2 + \gamma_B\, H_2^2)$

$F_{SB}$ = Shearing Resistance of Soil, lb/Ft

$= (\frac{1}{2})\,(\tan\phi)\,(K)\,(2\,\gamma_T\, H_1\, H_2 + \gamma_T\, H_1^2 + \gamma_B\, H_2^2)$

$F_B$ = Buoyant Force, lb

$= V\,\gamma_W$

## NOTES

1. Uplift could result in high moments in bottom slab.
2. If temporary or permanent shoring is left in place adjacent to vault, $F_{SV}$ and $F_{SB}$ should be ignored.

City of Mukilteo
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**UPLIFT RESISTANCE FOR BURIED STORMWATER VAULT**

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**FIG. 13**

Filename: J:\211\12561\102\21-1-12561-102 Fig 13.dwg Layout: Stormwater Vault Date: 05-25-2017 Login: jrs

# APPENDIX F

## Inspection and Maintenance Documentation

Table V-4.5.2(5). Maintenance Standards – Catch Basins.

| Maintenance Component | Defect | Conditions When Maintenance is Needed | Results Expected When Maintenance is Performed |
|---|---|---|---|
| General | Trash and Debris | Trash or debris which is located immediately in front of the catch basin opening or is blocking inletting capacity of the basin by more than 10%. | No trash or debris located immediately in front of catch basin or on grate opening. |
| | | Trash or debris (in the basin) that exceeds 60 percent of the sump depth as measured from the bottom of basin to invert of the lowest pipe into or out of the basin, but in no case less than a minimum of six inches clearance from the debris surface to the invert of the lowest pipe. | No trash or debris in the catch basin. |
| | | Trash or debris in any inlet or outlet pipe blocking more than 1/3 of its height. | Inlet and outlet pipes free of trash or debris. |
| | | Dead animals or vegetation that could generate odors that could cause complaints or dangerous gases (e.g., methane). | No dead animals or vegetation present within the catch basin. |
| | Sediment | Sediment (in the basin) that exceeds 60 percent of the sump depth as measured from the bottom of basin to invert of the lowest pipe into or out of the basin, but in no case less than a minimum of 6 inches clearance from the sediment surface to the invert of the lowest pipe. | No sediment in the catch basin |
| | Structure Damage to Frame and/or Top Slab | Top slab has holes larger than 2 square inches or cracks wider than 1/4 inch. (Intent is to make sure no material is running into basin). | Top slab is free of holes and cracks. |
| | | Frame not sitting flush on top slab, i.e., separation of more than 3/4 inch of the frame from the top slab. Frame not securely attached. | Frame is sitting flush on the riser rings or top slab and firmly attached. |
| | Fractures or Cracks in Basin Walls/Bottom | Maintenance person judges that structure is unsound. | Basin replaced or repaired to design standards. |
| | | Grout fillet has separated or cracked wider than 1/2 inch and longer than 1 foot at the joint of any inlet/outlet pipe or any evidence of soil particles entering catch basin through cracks. | Pipe is regrouted and secure at basin wall. |

| | | | |
|---|---|---|---|
| | Settlement/ Misalignment | If failure of basin has created a safety, function, or design problem. | Basin replaced or repaired to design standards. |
| | Vegetation | Vegetation growing across and blocking more than 10% of the basin opening.<br><br>Vegetation growing in inlet/outlet pipe joints that is more than six inches tall and less than six inches apart. | No vegetation blocking opening to basin.<br><br>No vegetation or root growth present. |
| | Contamination and Pollution | See "Detention Ponds" (No. 1). | No pollution present. |
| Catch Basin Cover | Cover Not in Place | Cover is missing or only partially in place. Any open catch basin requires maintenance. | Catch basin cover is closed |
| | Locking Mechanism Not Working | Mechanism cannot be opened by one maintenance person with proper tools. Bolts into frame have less than 1/2 inch of thread. | Mechanism opens with proper tools. |
| | Cover Difficult to Remove | One maintenance person cannot remove lid after applying normal lifting pressure.<br><br>(Intent is keep cover from sealing off access to maintenance.) | Cover can be removed by one maintenance person. |
| Ladder | Ladder Rungs Unsafe | Ladder is unsafe due to missing rungs, not securely attached to basin wall, misalignment, rust, cracks, or sharp edges. | Ladder meets design standards and allows maintenance person safe access. |
| Metal Grates (If Applicable) | Grate Opening Unsafe | Grate with opening wider than 7/8 inch. | Grate opening meets design standards. |
| | Trash and Debris | Trash and debris that is blocking more than 20% of grate surface inletting capacity. | Grate free of trash and debris. |
| | Damaged or Missing. | Grate missing or broken member(s) of the grate. | Grate is in place and meets design standards. |

Table V-4.5.2(4). Maintenance Standards – Control Structure/Flow Restrictor.

| Maintenance Component | Defect | Condition When Maintenance is Needed | Results Expected When Maintenance is Performed |
|---|---|---|---|
| General | Trash and Debris (Includes Sediment) | Material exceeds 25% of sump depth or 1 foot below orifice plate. | Control structure orifice is not blocked. All trash and debris removed. |
| | Structural Damage | Structure is not securely attached to manhole wall. | Structure securely attached to wall and outlet pipe. |
| | | Structure is not in upright position (allow up to 10% from plumb). | Structure in correct position. |
| | | Connections to outlet pipe are not watertight and show signs of rust. | Connections to outlet pipe are water tight; structure repaired or replaced and works as designed. |
| | | Any holes – other than designed holes – in the structure. | Structure has no holes other than designed holes. |
| Cleanout Gate | Damaged or Missing | Cleanout gate is not water tight or is missing. | Gate is watertight and works as designed. |
| | | Gate cannot be moved up and down by one maintenance person. | Gate moves up and down easily and is watertight. |
| | | Chain/rod leading to gate is missing or damaged. Gate is rusted over 50% of its surface area. | Chain is in place and works as designed. Gate is repaired or replaced to meet design standards. |
| Orifice Plate | Damaged or Missing | Control device is not working properly due to missing, out of place, or bent orifice plate. | Plate is in place and works as designed. |
| | Obstructions | Any trash, debris, sediment, or vegetation blocking the plate. | Plate is free of all obstructions and works as designed. |
| Overflow Pipe | Obstructions | Any trash or debris blocking (or having the potential of blocking) the overflow pipe. | Pipe is free of all obstructions and works as designed. |
| Manhole | See "Closed Detention Systems" (No. 3). | See "Closed Detention Systems" (No. 3). | See "Closed Detention Systems" (No. 3). |
| Catch Basin | See "Catch Basins" (No. 5). | See "Catch Basins" (No. 5). | See "Catch Basins" (No. 5). |

Table V-4.5.2(3). Maintenance Standards – Closed Detention Systems (Tanks/Vaults).

| Maintenance Component | Defect | Conditions When Maintenance is Needed | Results Expected When Maintenance is Performed |
|---|---|---|---|
| Storage Area | Plugged Air Vents | One-half of the cross section of a vent is blocked at any point or the vent is damaged. | Vents open and functioning. |
| | Debris and Sediment | Accumulated sediment depth exceeds 10% of the diameter of the storage area for 1/2 length of storage vault or any point depth exceeds 15% of diameter.<br><br>(Example: 72-inch storage tank would require cleaning when sediment reaches depth of 7 inches for more than 1/2 length of tank.) | All sediment and debris removed from storage area. |
| | Joints Between Tank/Pipe Section | Any openings or voids allowing material to be transported into facility.<br><br>(Will require engineering analysis to determine structural stability). | All joint between tank/pipe sections are sealed. |
| | Tank Pipe Bent Out of Shape | Any part of tank/pipe is bent out of shape more than 10% of its design shape. (Review required by engineer to determine structural stability.) | Tank/pipe repaired or replaced to design. |
| | Vault Structure Includes Cracks in Wall, Bottom, Damage to Frame and/or Top Slab | Cracks wider than 1/2-inch and any evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determines that the vault is not structurally sound. | Vault replaced or repaired to design specifications and is structurally sound. |
| | | Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or any evidence of soil particles entering the vault through the walls. | No cracks more than 1/4-inch wide at the joint of the inlet/outlet pipe. |
| Manhole | Cover Not in Place | Cover is missing or only partially in place. Any open manhole requires maintenance. | Manhole is closed. |
| | Locking Mechanism Not Working | Mechanism cannot be opened by one maintenance person with proper tools. Bolts into frame have less than 1/2 inch of thread (may not apply to self-locking lids). | Mechanism opens with proper tools. |
| | Cover Difficult to Remove | One maintenance person cannot remove lid after applying normal lifting pressure. Intent is to keep cover from sealing off access to maintenance. | Cover can be removed and reinstalled by one maintenance person. |
| | Ladder Rungs Unsafe | Ladder is unsafe due to missing rungs, misalignment, not securely attached to structure wall, rust, or cracks. | Ladder meets design standards. Allows maintenance person safe access. |
| Catch Basins | See "Catch Basins" (No. 5) | See "Catch Basins" (No. 5). | See "Catch Basins" (No. 5). |

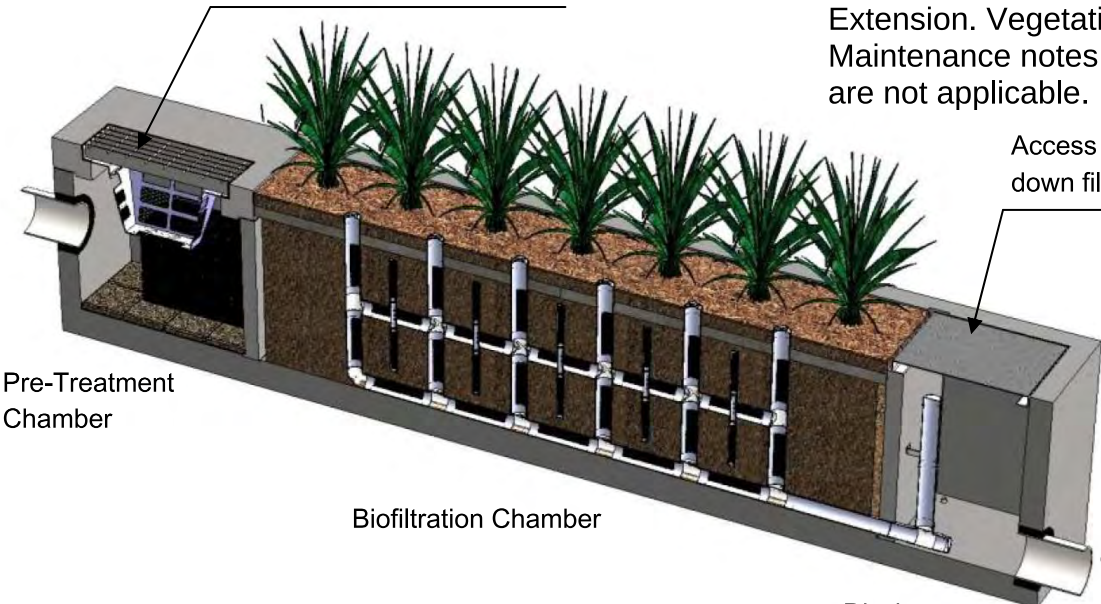
# Maintenance Guidelines for
# Modular Wetland System - Linear

## Maintenance Summary

- <u>Remove Trash from Screening Device</u> – average maintenance interval is 6 to 12 months.
    - (*5 minute average service time*).
- <u>Remove Sediment from Separation Chamber</u> – average maintenance interval is 12 to 24 months.
    - (*10 minute average service time*).
- <u>Replace Cartridge Filter Media</u> – average maintenance interval 12 to 24 months.
    - (*10-15 minute per cartridge average service time*).
- <u>Replace Drain Down Filter Media</u> – average maintenance interval is 12 to 24 months.
    - (*5 minute average service time*).
- <u>Trim Vegetation</u> – average maintenance interval is 6 to 12 months.
    - (*Service time varies*).

NOTE: There is no vegetation in the modular wetlands proposed for the Harbour Reach Drive Extension. Vegetation Maintenance notes are not applicable.

## System Diagram



# Maintenance Procedures

## Screening Device

1. Remove grate or manhole cover to gain access to the screening device in the Pre-Treatment Chamber. Vault type units do not have screening device. Maintenance can be performed without entry.
2. Remove all pollutants collected by the screening device. Removal can be done manually or with the use of a vacuum truck. The hose of the vacuum truck will not damage the screening device.
3. Screening device can easily be removed from the Pre-Treatment Chamber to gain access to separation chamber and media filters below. Replace grate or manhole cover when completed.

## Separation Chamber

1. Perform maintenance procedures of screening device listed above before maintaining the separation chamber.
2. With a pressure washer spray down pollutants accumulated on walls and cartridge filters.
3. Vacuum out Separation Chamber and remove all accumulated pollutants. Replace screening device, grate or manhole cover when completed.

## Cartridge Filters

1. Perform maintenance procedures on screening device and separation chamber before maintaining cartridge filters.
2. Enter separation chamber.
3. Unscrew the two bolts holding the lid on each cartridge filter and remove lid.
4. Remove each of 4 to 8 media cages holding the media in place.
5. Spray down the cartridge filter to remove any accumulated pollutants.
6. Vacuum out old media and accumulated pollutants.
7. Reinstall media cages and fill with new media from manufacturer or outside supplier. Manufacturer will provide specification of media and sources to purchase.
8. Replace the lid and tighten down bolts. Replace screening device, grate or manhole cover when completed.

## Drain Down Filter

1. Remove hatch or manhole cover over discharge chamber and enter chamber.
2. Unlock and lift drain down filter housing and remove old media block. Replace with new media block. Lower drain down filter housing and lock into place.
3. Exit chamber and replace hatch or manhole cover.

MODULAR WETLANDS

# Maintenance Notes

1. Following maintenance and/or inspection, it is recommended the maintenance operator prepare a maintenance/inspection record. The record should include any maintenance activities performed, amount and description of debris collected, and condition of the system and its various filter mechanisms.

2. The owner should keep maintenance/inspection record(s) for a minimum of five years from the date of maintenance. These records should be made available to the governing municipality for inspection upon request at any time.

3. Transport all debris, trash, organics and sediments to approved facility for disposal in accordance with local and state requirements.

4. Entry into chambers may require confined space training based on state and local regulations.

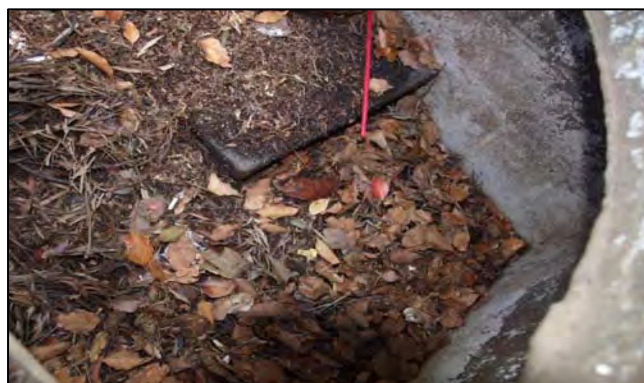
5. No fertilizer shall be used in the Biofiltration Chamber.

6. Irrigation should be provided as recommended by manufacturer and/or landscape architect. Amount of irrigation required is dependent on plant species. Some plants may require irrigation.

# Maintenance Procedure Illustration

**Screening Device**

The screening device is located directly under the manhole or grate over the Pre-Treatment Chamber. It's mounted directly underneath for easy access and cleaning. Device can be cleaned by hand or with a vacuum truck.

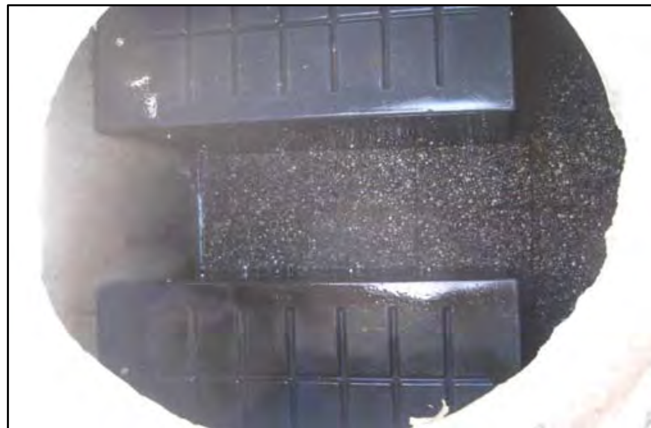


**Separation Chamber**

The separation chamber is located directly beneath the screening device. It can be quickly cleaned using a vacuum truck or by hand. A pressure washer is useful to assist in the cleaning process.

## Cartridge Filters

The cartridge filters are located in the Pre-Treatment chamber connected to the wall adjacent to the biofiltration chamber. The cartridges have removable tops to access the individual media filters. Once the cartridge is open media can be easily removed and replaced by hand or a vacuum truck.




## Drain Down Filter

The drain down filter is located in the Discharge Chamber. The drain filter unlocks from the wall mount and hinges up. Remove filter block and replace with new block.

## Trim Vegetation

Vegetation should be maintained in the same manner as surrounding vegetation and trimmed as needed. No fertilizer shall be used on the plants. Irrigation per the recommendation of the manufacturer and or landscape architect. Different types of vegetation requires different amounts of irrigation.


# Inspection Form

Modular Wetland System, Inc.
P. 760.433-7640
F. 760-433-3176
E. Info@modularwetlands.com

www.modularwetlands.com

# Inspection Report
# Modular Wetlands System

| For Office Use Only |
|---|
| (Reviewed By) |
| (Date) Office personnel to complete section to the left. |

Project Name ____________________

Project Address ____________________ (city) (Zip Code)

Owner / Management Company ____________________

Contact ____________________ Phone ( ) –

Inspector Name ____________________ Date ____/____/______ Time __________ AM / PM

Type of Inspection ☐ Routine ☐ Follow Up ☐ Complaint ☐ Storm Storm Event in Last 72-hours? ☐ No ☐ Yes

Weather Condition ____________________ Additional Notes ____________________

## Inspection Checklist

Modular Wetland System Type (Curb, Grate or UG Vault): __________ Size (22', 14' or etc.): __________

| **Structural Integrity:** | **Yes** | **No** | **Comments** |
|---|---|---|---|
| Damage to pre-treatment access cover (manhole cover/grate) or cannot be opened using normal lifting pressure? | | | |
| Damage to discharge chamber access cover (manhole cover/grate) or cannot be opened using normal lifting pressure? | | | |
| Does the MWS unit show signs of structural deterioration (cracks in the wall, damage to frame)? | | | |
| Is the inlet/outlet pipe or drain down pipe damaged or otherwise not functioning properly? | | | |
| **Working Condition:** | | | |
| Is there evidence of illicit discharge or excessive oil, grease, or other automobile fluids entering and clogging the unit? | | | |
| Is there standing water in inappropriate areas after a dry period? | | | |
| Is the filter insert (if applicable) at capacity and/or is there an accumulation of debris/trash on the shelf system? | | | |
| Does the depth of sediment/trash/debris suggest a blockage of the inflow pipe, bypass or cartridge filter? If yes specify which one in the comments section. Note depth of accumulation in in pre-treatment chamber. | | | Depth: |
| Does the cartridge filter media need replacement in pre-treatment chamber and/or discharge chamber? | | | Chamber: |
| Any signs of improper functioning in the discharge chamber? Note issues in comments section. | | | |
| **Other Inspection Items:** | | | |
| Is there an accumulation of sediment/trash/debris in the wetland media (if applicable)? | | | |
| Is it evident that the plants are alive and healthy (if applicable)? Please note Plant Information below. | | | |
| Is there a septic or foul odor coming from inside the system? | | | |

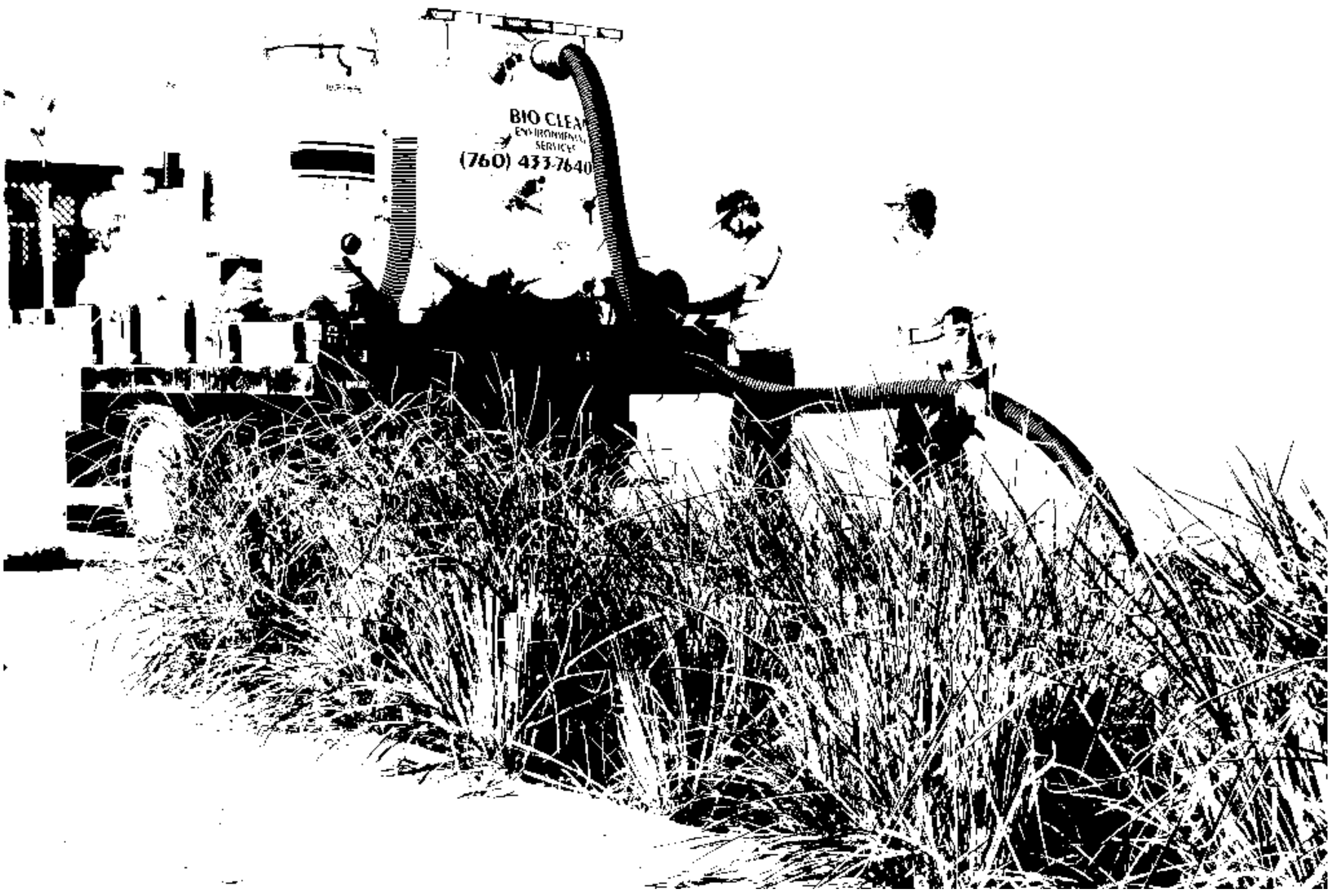
| **Waste:** | **Yes** | **No** |
|---|---|---|
| Sediment / Silt / Clay | | |
| Trash / Bags / Bottles | | |
| Green Waste / Leaves / Foliage | | |

| **Recommended Maintenance** | |
|---|---|
| No Cleaning Needed | |
| Schedule Maintenance as Planned | |
| Needs Immediate Maintenance | |

| **Plant Information** | |
|---|---|
| Damage to Plants | |
| Plant Replacement | |
| Plant Trimming | |

Additional Notes: ____________________

# Maintenance Report




Modular Wetland System, Inc.
P. 760.433-7640
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www.modularwetlands.com

# Cleaning and Maintenance Report
# Modular Wetlands System

Project Name ____________________

Project Address ____________________ (city) (Zip Code)

Owner / Management Company ____________________

Contact ____________________ Phone ( ) –

Inspector Name ____________________ Date ___/___/_____ Time ________ AM / PM

Type of Inspection ☐ Routine ☐ Follow Up ☐ Complaint ☐ Storm Storm Event in Last 72-hours? ☐ No ☐ Yes

Weather Condition ____________________ Additional Notes ____________________

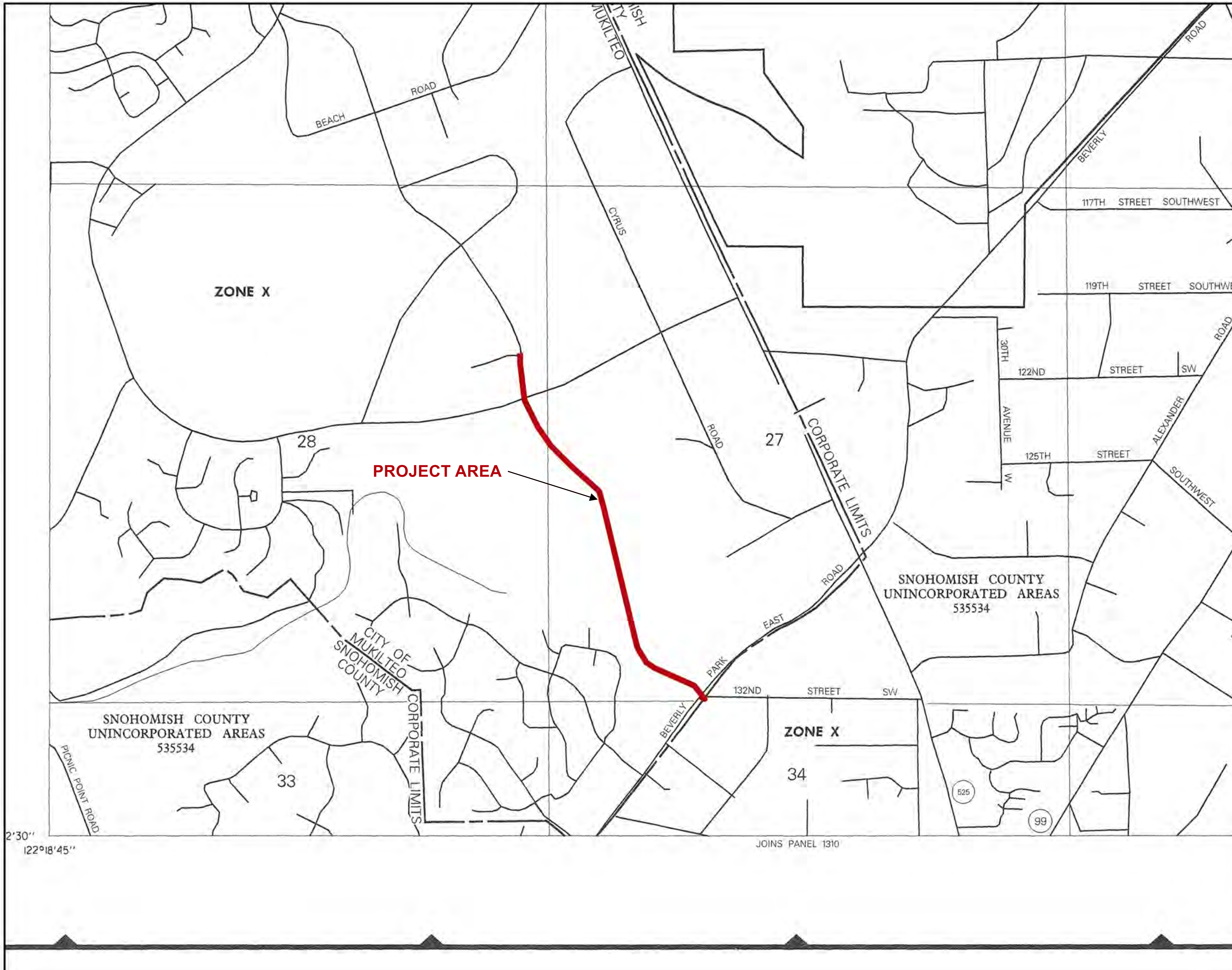
| For Office Use Only |
|---|
| (Reviewed By) |
| (Date) Office personnel to complete section to the left. |

| Site Map # | GPS Coordinates of Insert | Manufacturer / Description / Sizing | Trash Accumulation | Foliage Accumulation | Sediment Accumulation | Total Debris Accumulation | Condition of Media 25/50/75/100 (will be changed @ 75%) | Operational Per Manufactures' Specifications (If not, why?) |
|---|---|---|---|---|---|---|---|---|
| | Lat:<br>Long: | MWS Catch Basins | | | | | | |
| | | MWS Sedimentation Basin | | | | | | |
| | | Media Filter Condition | | | | | | |
| | | Plant Condition | | | | | | |
| | | Drain Down Media Condition | | | | | | |
| | | Discharge Chamber Condition | | | | | | |
| | | Drain Down Pipe Condition | | | | | | |
| | | Inlet and Outlet Pipe Condition | | | | | | |

Comments:

APPENDIX G

# FEMA Map




APPROXIMATE SCALE IN FEET

1000 0 1000

**NATIONAL FLOOD INSURANCE PROGRAM**

# FIRM

## FLOOD INSURANCE RATE MAP

SNOHOMISH COUNTY, WASHINGTON AND INCORPORATED AREAS

**PANEL 1020 OF 1575**

(SEE MAP INDEX FOR PANELS NOT PRINTED)

CONTAINS:

| COMMUNITY | NUMBER | PANEL | SUFFIX |
|---|---|---|---|
| EVERETT, CITY OF | 530164 | 1020 | E |
| MUKILTEO, CITY OF | 530235 | 1020 | E |
| SNOHOMISH COUNTY UNINCORPORATED AREAS | 535534 | 1020 | E |

**MAP NUMBER 53061C1020 E**

**EFFECTIVE DATE: NOVEMBER 8, 1999**

Federal Emergency Management Agency

This is an official copy of a portion of the above referenced flood map. It was extracted using F-MIT On-Line. This map does not reflect changes or amendments which may have been made subsequent to the date on the title block. For the latest product information about National Flood Insurance Program flood maps check the FEMA Flood Map Store at www.msc.fema.gov

# APPENDIX H

## Pre-Design Record

# PRE-DESIGN RECORD
## DRAINAGE ANALYSIS & DESIGN CRITERIA SUMMARY

Project Name: Harbour Reach Extension Project

Perteet Job No: 20150051.000
Date: November 3, 2016

Drainage Engineer: Brian Caferro, P.E.
Client: City of Mukilteo
City or County: City of Mukilteo

**Project Description:**
The City of Mukilteo desires to construct a new arterial connection between Beverly Park Road and Harbour Point Boulevard North. The new roadway shall be two travel lanes, bike lanes and curb, gutter and sidewalk on both sides. Improvements will also include new stream crossings, new stormwater infrastructure, intersection improvements and illumination.

**Provided below is a summary of the major drainage design standards which will be followed on the Harbour Reach Extension Project.**

- The project's stormwater design will follow the Mukilteo Municipal Code (MMC), City of Mukilteo Development Standards (MDS), 2012 Stormwater Management Manual for Western Washington as amended in December 2014 (SWMMWW) and the 2012 Low Impact Development Technical Guidance Manual for Puget Sound (LID Manual).
- Storm conveyance systems will be designed in accordance with the MDS and the 2015 WSDOT Hydraulics Manual (HM).
- Storm Pipe Conveyance, per City EDDS: Design to the 25 yr storm event, with no overtopping of the catch basins at the rim elevation.
- Flow Control and Water Quality Hydrologic Analysis: It is acceptable to use the MGS Flood™ model or WWHM™ model.
- Conveyance Model: Rational or SBUH.
- Basic Treatment: This criterion is a function of ADTs. This defines whether or not the water quality treatment facilities are to be designed to 'basic' or 'enhanced' treatment levels. ***(Note: the project will require enhanced treatment since the ADT levels expected for this project exceed the thresholds for enhanced treatment).***
- Oil Control Treatment: This criterion applies to sites considered as high use or intersections considered as high use on roadway projects. This roadway project will not have ADT levels high at the intersections to exceed the thresholds for oil control. Therefore oil control treatment will not be required for this project.
- Phosphorous Control: The downstream creeks and tributaries are not listed as phosphorous sensitive on the Ecology 303d list. Therefore phosphorous control will not be a requirement on this project.

**Source Document Locations**
http://www.codepublishing.com/WA/Mukilteo/
http://mukilteowa.gov/wp-content/uploads/2015/11/Development-Standards-w-standard-plans.pdf
https://fortress.wa.gov/ecy/publications/summarypages/1210030.html
http://www.psp.wa.gov/downloads/LID/20121221_LIDmanual_FINAL_secure.pdf

## Documentation Summary of Drainage Design Standards

| Design Element | Standard Requirement | Source |
|---|---|---|
| **Threshold Analysis/ Minimum Requirements:** | This project shall follow the threshold and minimum requirement determination and application procedures as outlined in Vol. I, Section 2.4 and 2.5 of the SWMMWW. | SWMMWW Vol. I, 2.4<br>MDS Ch. 4, pg. 30<br>MMC 12.12.040 |
| **Hydrologic Model:** | | |
| Flow Control: | Continuous Simulation Modeling, such as WWHM4 or MGS Flood (Version 4) | SWMMWW Vol. III, 2.1 |
| Water Quality: | Continuous Simulation Modeling, such as WWHM4 or MGS Flood (Version 4) | SWMMWW Vol. III, 2.1 |
| Conveyance: | StormShed3G (Rational Method for < 1,000 acres)<br>StormShed3G (SBUH Method for up to 1,000 acres)<br>Minimum Time of Concentration (Tc) is 5.0 minutes | HM pg. 2-4<br>HM pg. 2-4<br>HM pg. 2-11 |
| | WSDOT backwater spreadsheet is also allowed to be used for conveyance calculations | |
| | Runoff coefficients to be used for the Rational Method shall be taken from Figure 2-5.2 of the 2010 WSDOT Hydraulics Manual (HM). Intensities to be used shall be taken from Figure 2-5.4A of the HM | HM pg. 2-10<br>HM pgs. 2-13,14 |
| | Runoff Curve numbers to be used for the SBUH or SCS TR 55 Method shall be taken from Appendix 4B of the WSDOT Highway Runoff Manual. | HM pg. 2-13. |
| Inlet Spacing: | Catch basins shall be spaced no greater than 150 feet apart. | Per new MDS standards due out in 2017 |
| Infiltration: | Continuous Simulation Modeling, such as MGS Flood (Version 4) or WWHM4 | SWMMWW Vol. III, 3.3.4 |

| Design Element | Standard Requirement | Source |
|---|---|---|
| | | |
| **Design Storm Events:**<br>Flow Control: | Stormwater discharges shall match developed discharge durations to pre-developed durations for the range of pre-developed discharge rates from 50% of the 2-year peak flow up to the full 50-year peak flow. The pre-developed condition to be matched shall be a forested land cover. | SWMMWW Vol. I, 2.5.7 |
| Water Quality: | Water Quality design flow preceding detention<br>The flow rate at or below which 91% of the runoff volume, as estimated by an approved continuous runoff model, will be treated. | SWMMWW Vol. I, 2.5.6 |
| | Water Quality design flow downstream of detention<br>The water quality design flow rate must be the full 2-year release rate from the detention facility. | SWMMWW Vol. I, 2.5.6 |
| | Water Quality flow volume<br>The water quality design storm volume shall be equal to the simulated daily volume that represents the upper limit of the range of daily volumes that accounts for 91% of the entire runoff volume over a multi-decade period of record. | SWMMWW Vol. I, 2.5.6 |
| Conveyance: | Closed drainage systems or culverts on a major stream or creek as determined by the Public Works Director, or designee, shall be designed to convey flows from a 100 year recurrence storm event. All other closed drainage systems shall be designed to convey flows from a 25 year recurrence storm event, unless otherwise required by the Public Works Director or designee. | MDS Ch. 4, pg. 31 |
| Infiltration: | For infiltration basins sized to meet the flow control standard, the basin must infiltrate either all of the influent file, or a sufficient amount of the influent file such that any overflow/bypass meets the flow duration standard. In addition, the overflow/bypass must meet the LID performance standard if it is the option chosen to meet Minimum Requirement #5. The project must either choose List #2 or the LID performance standard to meet Minimum Requirement #5. This requirement is separate from Minimum Requirement #7 (flow control). | SWMMWW Vol. III, |
| **Precipitation Data Source:** | Rational Method: Rainfall intensity values from Figure 2-5.4A (Everett):<br>2 yr: m = 3.69, n = 0.556<br>10 yr: m = 6.31, n = 0.575<br>25 yr: m = 7.83, n = 0.582 | HM pg. 2-14 |

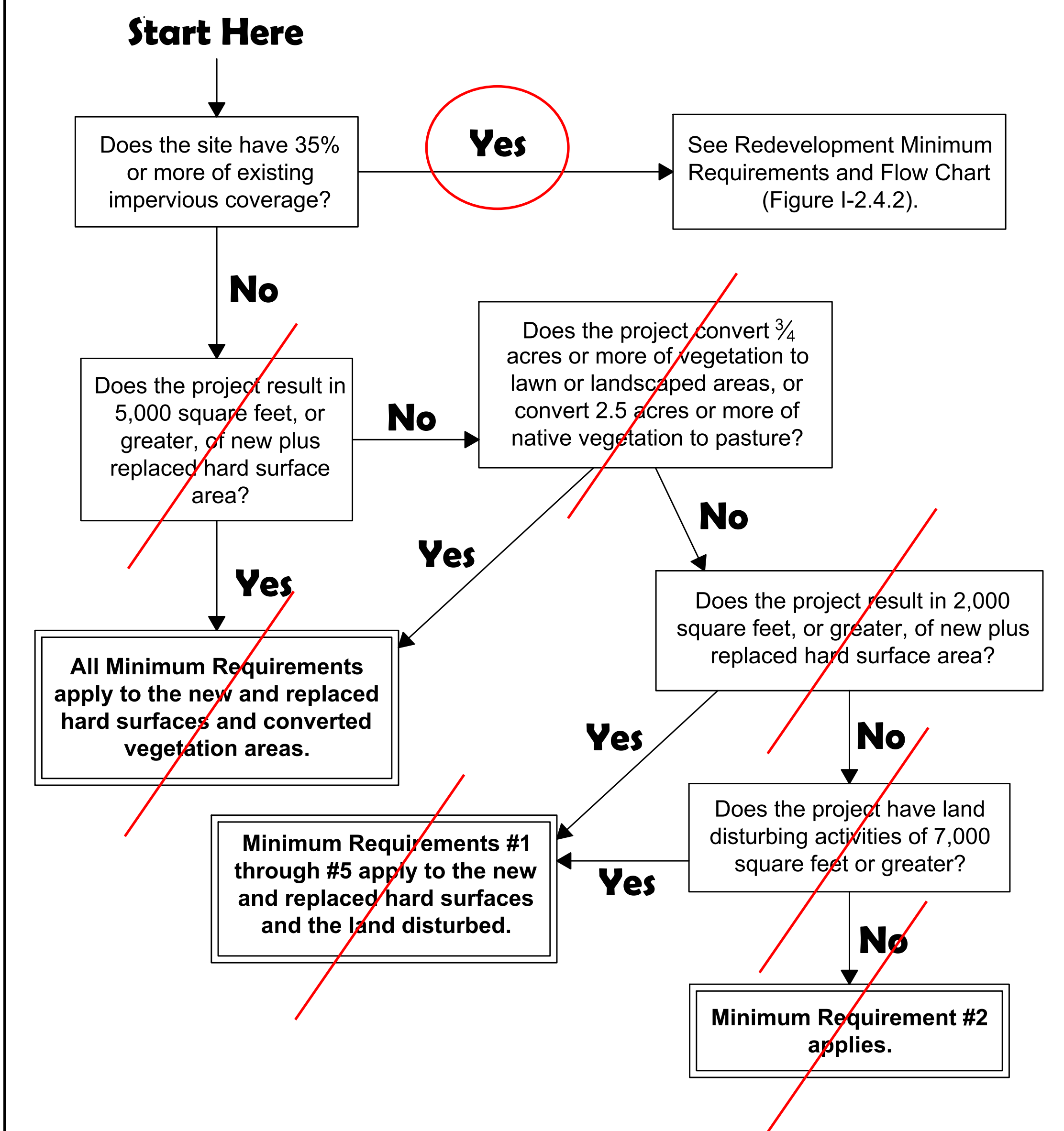
| Design Element | Standard Requirement | Source |
|---|---|---|
| | 100 yr m = 10.07, n = 0.586<br><br><u>SBUH Method (Type 1A storm):</u><br>Precipitation isopoluvial maps: Appendix III-A<br>2 yr: 1.50" 10 yr: 2.00" 25 yr: 2.50" 100 yr: 3.00"<br><br><u>Continuous Simulation:</u><br>Extended Time Series Region Map: Puget East 40 in MAP | <br><br>HM Appendix 2-3<br><br><br><br>Model Specific |
| **<u>Pre-Developed Conditions:</u> <u>(Forested, etc.)</u>** | Forested conditions. | SWMMWW Vol. I, 2.5.7 |
| **<u>Infiltration & LID Design Criteria</u>:** | <u>Infiltration facilities:</u><br>Refer to SWMMWW Vol III, Section 3.3 for design requirements associated with infiltration facilities.<br><u>LID Facilities:</u><br>Refer to SWMMWW Vol III, Appendix III-C and LID Manual | SWMMWW Vol. III, 3.3<br><br><br>SWMMWW Vol. III, Appendix III-C |
| **<u>Detention Facility Design Criteria</u>** | Design criteria for detention ponds, vaults and tanks can be found in SWMMWW Vol. III, Section 3.2 | SWMMWW Vol. III, 3.2 |
| **<u>Conveyance Pipe and Open channel Design (Criteria)</u>** | 1. All ditches and channels shall be designed to the 10 year event with a 0.5' freeboard.<br>2. Channels are to be vegetated when the longitudinal slope < 6% and velocities are less than 5 fps. For channel slopes exceeding 6% and velocities more than 5 fps the channel shall have more protection such as a rock lining.<br>3. For open channel and closed conduit flow analysis, use the Manning coefficients listed in HM Appendix 4-1.<br>4. Minimum pipe size = 12" (8" may be permitted on cross street laterals to avoid utility conflict or meet shallow gradient), 3 fps minimum velocity (full flow), and minimum 0.44% slope.<br>5. For culvert design see Shannon and Wilson's design criteria for this project.<br>6. Allowable Pipe Materials listed in MDS Chapter 4, pg. 36.<br>7. Catch basins shall be spaced no greater than 150 feet apart, regardless of road grade. Spacing analysis is required only if width of tributary road surface exceeds 35 feet and the cross slope exceeds four percent.<br>8. Allowable frames, grates and covers: Unless specified otherwise in these Standards, use vaned grates with standard frames in the traveled way, gutter, or shoulder. Vaned grates shall not be located within cross walks (see Standard Plan 4-080-016). At sag curves or | HM pg. 4-11<br>HM pg. 4-11<br><br><br>HM pg. A4-1-1<br><br>MDS Ch. 4, pg. 36<br>HM pg. 6-3<br><br>N/A<br>MDS Ch. 4, pg. 36<br>MDS Ch. 4, pg. 37 and City preference<br><br><br>MDS Ch. 4, pg. 38 |

| Design Element | Standard Requirement | Source |
|---|---|---|
| | before intersections with a grade 3% or greater, use through curb inlet frames.<br>9. Manholes may be used in lieu of catch basins if they do not collect surface water. See Standard Plans 4-080-012 through 4-080-014. | MDS Ch. 4, pg. 37 |

APPENDIX I

# Flow Chart for Determining Requirements for Redevelopment

## Figure I-2.4.1 Flow Chart for Determining Requirements for New Development

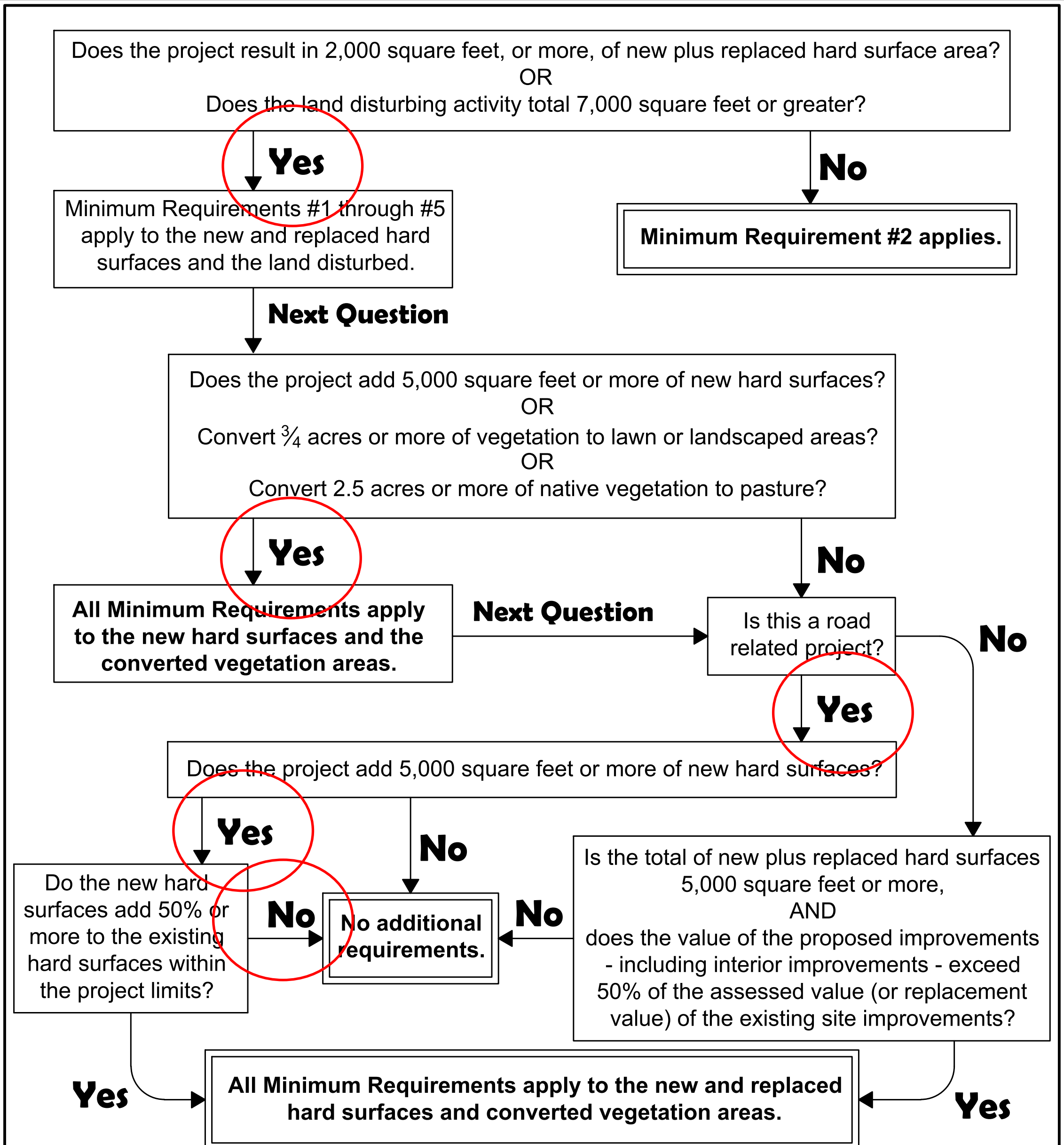



DEPARTMENT OF ECOLOGY
State of Washington

Figure I-2.4.1
Flow Chart for Determining Requirements for New Development

Revised June 2015

## Figure I-2.4.2 Flow Chart for Determining Requirements for Redevelopment




DEPARTMENT OF
ECOLOGY
State of Washington

Figure I-2.4.2
Flow Chart for Determining Requirements for Redevelopment

Revised June 2015