KITSAP COUNTY STORMWATER POND RETROFIT DESIGN GUIDANCE MANUAL

Kitsap County
Public Works Department

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INTRODUCTION

Public entities and private landowners in the Puget Sound area and throughout the United States have responsibility for the operation and maintenance of an abundance of existing stormwater management ponds. This is in addition to trying to address significant surface water quality problems at a larger geographic scale. Most of the stormwater ponds in developed areas were designed and constructed according to now outdated guidance and criteria. Most older ponds are undersized and do not have effective water quality treatment features. Much has been learned and design guidance significantly updated as the science of effective stormwater management has evolved. Retrofitting existing stormwater ponds to today's guidance and criteria can effectively improve surface water quality without adding new facilities.

Retrofit (Verb)

1. to install (new or modified parts or equipment) in something previously manufactured or constructed
2. to adapt to a new purpose or need : modify

In Kitsap County, there are over 600 stormwater ponds that collectively receive a large proportion of the runoff from developed areas and roadways. The effectiveness of these ponds in controlling stormwater flows, and in some cases removing pollutants in stormwater runoff, has a direct influence on the condition of receiving water bodies downstream such as wetlands, streams, and marine embayments. However, most of the stormwater ponds in Kitsap County were not originally designed to serve a water quality function; rather they are detention ponds that reduce peak runoff flow rates and minimize local flooding. If these ponds can be reconfigured in cost-effective ways that accomplish and maximize pollutant removal without sacrificing necessary runoff detention and flood-control functions, the quality of the County's surface waters could be improved.

Once there is a decision to fund a retrofit plan for stormwater management facilities, there are two major challenges:

1. Prioritizing which facilities would provide the most system-wide benefit from modifications to maximize water quality and/or flow control performance.

2. Selecting the best type of retrofit for the existing site constraints that would most effectively improve facility performance.

General guidance is available for stormwater management facility retrofits from regional and national sources, but no one reference focuses specifically on assessing and retrofitting stormwater ponds to achieve better water quality performance. This guidance manual was developed to assist users with that task. The purpose, intended audience, and a description of how to use this manual are outlined below.

Photo 1. Stormwater pond in Kitsap County.

What is a stormwater pond?

A stormwater pond is a drainage facility designed either to provide flow control (typically called a detention or retention pond), water quality treatment (typically called a wet pond), or a combination of flow control and water quality treatment functions.

What is a detention pond?

A detention pond is designed to hold stormwater for a short period of time and release it slowly to the storm drainage system, thereby reducing peak rates of runoff from a developed site to protect the capacity of the downstream system (whether natural or constructed) that receives the site runoff.

What is a retention pond?

A retention pond is designed to hold water for a period of time and then release it by evaporation, plant transpiration, and/or infiltration into the ground.

What is a wet pond?

A wet pond is designed to have a permanent pool of water that is filled during the initial runoff from a storm event (displacing the water that has been in the pond for a while) and treats pollutants via settling and biological activity.

What is a constructed stormwater wetland?

A constructed stormwater wetland is a shallow man-made pond designed to treat stormwater through the biological and chemical processes associated with emergent and aquatic plants and soil.

Definitions based on the Washington Department of Ecology *Stormwater Management Manual for Western Washington*.

Purpose

This design guidance manual provides methods and criteria for assessing the retrofit potential of existing stormwater ponds, and selection and design guidance for stormwater pond retrofits that improve water quality treatment performance. The Kitsap County Public Works Department currently has responsibility for operation and maintenance of over 300 of the approximately 600 stormwater ponds in the County. The County conducted a study of these ponds to assess water quality retrofit potential and identify retrofit solutions, and ultimately developed conceptual designs to retrofit the highest ranking ponds. The methods used to evaluate the County-owned ponds and identify preferred water quality retrofit solutions for those high-priority ponds are summarized in this manual and can be used as templates for other retrofit evaluations across the region.

Audience

This design guidance manual is intended for use by Kitsap County maintenance crews and engineering staff, other government entities in the region, private landowners, environmental stewardship organizations, and consultants who support public and private clients in design of stormwater management facilities. This manual is a useful guide for anyone who is interested in retrofitting a stormwater pond to maximize its water quality performance, in settings that are similar to Kitsap County.

How to Use This Manual

This manual is organized into the following sections:

- **Information Gathering** – covers pond site and drainage area information that will be important to have in understanding how the existing pond is intended to work, and issues that will affect water quality retrofit options
- **Field Assessment** – discusses what to look for at the pond site to understand existing pond functions, and opportunities and constraints for retrofit
- **Retrofit Selection** – outlines how to go about evaluating potential pond retrofit options and selecting the best retrofit approach for the site conditions
- **Conceptual Design** – provides background information, design considerations, and maintenance considerations for each of the pond retrofit options

Depending on the user's interests, some sections of this manual may be more useful than others.

INFORMATION GATHERING

This chapter describes the wide range of site information that can be used to help determine how an existing stormwater pond is intended to work, and important features and issues that will affect the selection of the most appropriate water quality retrofit solution. The user should compile the stormwater facility information, downstream water quality information, site and drainage area characteristics, and known maintenance and/or design deficiency issues summarized below (if available) to assist with identifying and prioritizing stormwater pond retrofit potential and to select the retrofit solution.

Along with the data recommendations, the following tables include a brief definition of data it will be helpful to have, and identify potential sources of data from the following list:

How much information do you need?

For users that do not have multiple ponds in their ownership or that are focused specifically on a single pond, most of the information described in Tables 1 through 4 is relevant to retrofit selection, but not all of it is necessary. For users that are evaluating numerous ponds to determine which ponds are a higher priority for a retrofit, all of the information presented in Tables 1 through 4 is relevant.

- Record drawings — original hard copy drawings, CAD files, or construction drawings
- Database — spreadsheet, electronic database, or hard copy forms or lists
- Drainage report — a report prepared during the design process that should contain information on the contributing drainage area and the pond sizing methodology
- Field crews — discussions with operation and maintenance staff familiar with the pond(s)
- GIS — Geographic Information System shapefiles or geodatabases
- Landowner complaints — phone calls from nearby landowners reporting issues with flooding and/or water quality
- Pipe network — visual or video inspections of the existing drainage system
- Websites — water quality data, aerial photography, and soil information that is publicly available.

Table 1 highlights basic stormwater facility information that is useful for most retrofit designs.

Table 1. Stormwater facility information.

Type of Data	Definition	Source
ID	Pond name and/or number	Record drawings, database, field crews
Location	Address; closest major intersection; subdivision name; or section, township, and range	Record drawings, database, field crews
Type	Wet pond, constructed wetland, dry pond, sediment pond, infiltration pond, retention pond, detention pond	Record drawings, database, field crews
Original design method	Rational method, Y&W method, SBUH, SCS, continuous flow modeling (e.g., WWHM, MGS Flood)	Drainage report, database
Date of construction	Year (at minimum), month and date (if available)	Database
"Live" storage capacity (if any) for water quality treatment	Available volume for peak flow control above the permanent wet pool	Record drawings, database, field crews
"Dead" storage capacity (if any) for water quality treatment	Available volume for a permanent pool of water during the wet season	Record drawings, database, field crews
Contributing drainage area	Onsite and offsite area draining to the pond	Drainage report, database
Receiving water	Ultimate discharge point for the water that exits the pond	Drainage report, database, GIS, pipe network

Design Methods

- The Rational Method computes a peak flow rate (Q) using the formula Q=CIA, where C is a coefficient characterizing the physical drainage area, I is rainfall intensity, and A is the drainage area. This method is no longer used, but may have been used to size older ponds.
- The Y+W Method was developed by Yrjanainen and Warren in 1973. It uses the Rational Method to estimate peak flows along with a set of equations to estimate the required storage volume. This method is no longer commonly used, but may have been used to size older ponds.
- The Santa Barbara Urban Hydrograph (SBUH) and Soil Conservation Service (SCS) methods use a single 24-hour storm event for pond sizing.
- Continuous flow models such as the Western Washington Hydrology Model (WWHM) and MGS Flood use a continuous rainfall record to more accurately reflect storm events that occur back to back, and to better account for runoff processes in pervious surface areas (open space, lawns, and landscaped areas). These models are used to size ponds with a 25- to 158-year precipitation record.

Table 2 highlights downstream water quality information that could be useful for most retrofit designs, but is very useful for prioritizing retrofit potential. The data can be used to prioritize stormwater ponds that, if retrofitted, could yield the greatest improvements in downstream water quality.

Table 2. Downstream water quality information.

Type of Data	Definition	Source
Benthic Index of Biotic Integrity [B-IBI] data	A quantitative method for determining and comparing the biological condition of streams	Puget Sound Stream Benthos website: http://pugetsoundstreambenthos.org
Washington State Department of Ecology Clean Water Act Section 303(d) listings (Category 5)	Placement in Category 5 (polluted waters that require a TMDL) means that collected data shows that water quality standards have been violated for one or more pollutants, and that there is no TMDL or pollution control plan	Ecology website: www.ecy.wa.gov/programs/wq/links/wq_assessments.html
Washington State Department of Ecology Water Quality Assessment (Category 4a or 4b)	Placement in Category 4a (has a TMDL) indicates water bodies that have an approved TMDL in place and are actively being implemented Placement in Category 4b (has a pollution control program) indicates water bodies that have a program (not a TMDL) in place to solve the pollution problems	Ecology website: www.ecy.wa.gov/programs/wq/links/wq_assessments.html
Total Maximum Daily Load (TMDL) Implementation reports	A TMDL implementation plan includes: • Activities to reduce pollution • Timelines when actions will be completed • Who is responsible for the activities • Resources needed (funding)	Ecology TMDL website: www.ecy.wa.gov/programs/wq/tmdl/TMDLsbyWria/TMDLbyWria.html
Other water quality studies	Local, regional, or statewide water quality studies	Various (city, county, local health district, regional watershed group, statewide study)

Table 3 highlights site and drainage area characteristics that are useful in the retrofit selection and conceptual design stage. Contributing drainage area and land use associated with a stormwater facility can reveal the types of pollutants likely entering the facility, enabling retrofit selection to target the most effective unit treatment processes for the pollutant(s) of concern for that land use. Information on soil types, facility size, depth to groundwater, and proximity to wellhead protection areas can help to refine the list of possible retrofit solutions.

What is a unit treatment process?

A unit treatment process is a physical, biological, or chemical process that removes pollutants from stormwater. In stormwater ponds, these processes may be functioning well or be in need of improvement to provide optimal water quality treatment. Unit treatment processes can be improved or created via targeted retrofitting.

Table 3. Site and drainage area characteristics.

Type of Data	Definition	Source
Aerial photography	Photographic images typically taken from an airplane	Various (city, county, Ecology [http://apps.ecy.wa.gov/shorephotos], University of Washington [http://www.lib.washington.edu/maps/MapResources/airphoto2.html]
Pond footprint	Existing pond bottom and top area	GIS or record drawings
Surrounding topography	5' contours (minimum); 2' and 1' contours are quite useful if available	GIS or record drawings
Contributing drainage basin boundary	Size of drainage area contributing to pond	GIS or drainage report
Land use in contributing drainage basin	Residential, commercial, industrial, highway, etc.	GIS, drainage report, and/or visual reconnaissance
Soil types	Outwash (Class A and B), Till (Class C), or Wetland (Class D) soils	GIS or NRCS Web Soil Survey: http://websoilsurvey.nrcs.usda.gov/app
Wellhead protection areas	Surface and subsurface areas around a well or well field that contaminants are likely to pass through to reach the drinking water source. For stormwater facilities, the Zone 1 delineation (6-month and 1-year horizontal time-of-travel boundary) is evaluated.	GIS or available wellhead protection plan report
Depth to groundwater	Depth measured from the ground surface to the standing level of water in a well, or water level observed in a geotechnical test pit or boring	GIS, geotechnical exploration results associated with previous site development (sometimes contained in a drainage report), or well data
Flow pathway to receiving water	Where the water flows after exiting the pond until it discharges to a receiving water	Drainage report, database, GIS, pipe network
Parcel boundaries	Existing parcel size where stormwater facility is located (including information on ownership or easement)	GIS or record drawings
Storm drain networks (catch basins and connecting pipes)	Existing drainage system	GIS or record drawings

Table 4 highlights known maintenance and/or design deficiency issues. Knowledge of these kinds of issues is helpful for prioritizing amongst numerous ponds as well as selecting the most beneficial retrofit option.

Table 4. Known maintenance and/or design deficiency issues.

Type of Data	Examples	Source
Maintenance issues	• Clogged or damaged inlet or outlet structure • Heavy sediment accumulation • Difficulty with vegetation management • Excessive vegetation • Lack of vegetation • Invasive species present • Pond does not drain well (always has standing water when it is supposed to be infiltrating water) • Trash and debris accumulation • Poor maintenance access	Field crew observations or landowner complaints
Design deficiency issues	• Lack of sediment forebay • Lack of dead storage capacity or other water quality treatment BMP • Short flow path through pond • Undersized pond • Flooding concerns • Downstream erosion concerns • Pond does not drain well (always has standing water when it is supposed to be infiltrating water)	Field crew observations, record drawings, or landowner complaints

Desktop Screening

For those interested in analyzing numerous ponds to determine which of them should be carried forward as a retrofit priority, a desktop screening should be performed. This screening process does not apply to those who have a single pond of interest.

Once the stormwater facility information, water quality information, site and drainage area characteristics, and known maintenance and/or design deficiency issues outlined above have been gathered and evaluated for multiple pond sites, a desktop screening can be performed to prioritize stormwater ponds for further evaluation through field screening. The specific screening processes and criteria applied will depend on the goals of the given retrofit program. Kitsap County's program (that led to development of this manual) was focused specifically on retrofits that could maximize receiving water quality improvements. Therefore, the example screening processes and criteria summarized below and presented in Figure 1 emphasize screening for potential water quality improvement. Additional or alternative screening criteria can be developed based on the specific goals of each retrofit program.

Examples are provided that relate to infiltration capacity, water quality treatment performance, receiving water quality, and known maintenance and/or design deficiency issues. The *Optional Screening Criteria* section includes a few examples of additional criteria that may be useful for further prioritizing stormwater ponds for retrofit projects.

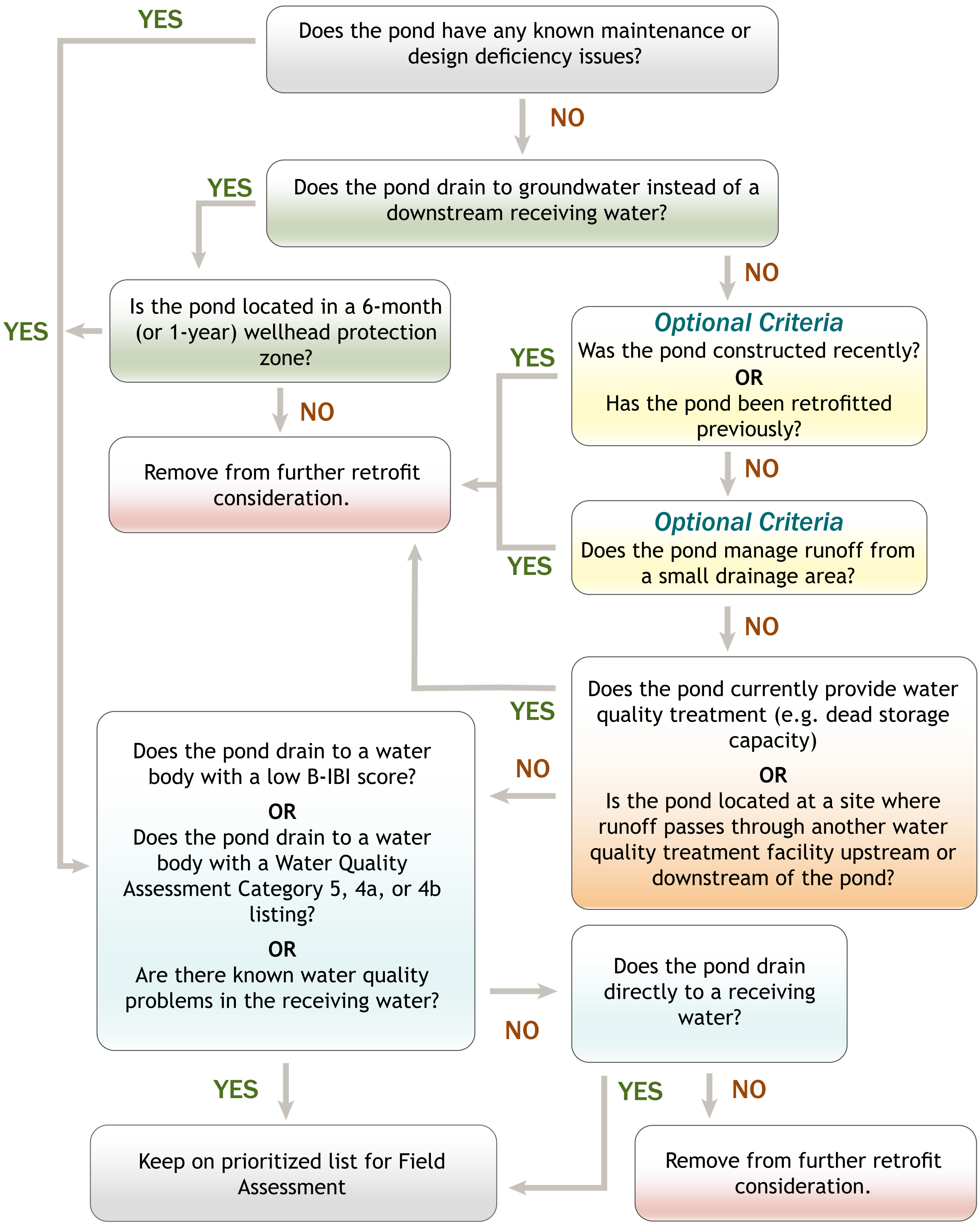

Figure 1. Example desktop screening prioritizing pond water quality retrofits.

Known Maintenance and/or Design Deficiency Issues

Stormwater ponds can be divided into high, medium, and low priority groupings for water quality improvement retrofitting based on the identification of major maintenance or design deficiency issues, minor maintenance or design deficiency issues, or no known maintenance or design deficiency issues. The division between major and minor maintenance or design deficiency issues will vary depending on the assessment of field crews and other staff evaluating a pond. Thus, users of this manual should determine what issues are major or minor for their program and categorize and prioritize their ponds accordingly. Identifying known maintenance and design deficiency issues is important for determining which ponds should be retrofitted. This evaluation is best completed first as indicated by the flowchart in Figure 1 and is part of the screenings for *Infiltration Capacity and Water Quality Treatment Performance* that follow.

Infiltration Capacity

An evaluation of the current infiltration capacity of the pond will provide useful information on current water quality treatment effectiveness. A stormwater pond may be assumed to have a lower priority for water quality treatment improvements if it meets the following criteria related to infiltration:

- Infiltrates stormwater effectively (if a pond drains to groundwater instead of a downstream receiving water, and provides sufficient pollutant removal to protect groundwater quality)
- Is not located in a wellhead protection zone
- Does not have any known maintenance or design deficiency issues.

If a pond drains to groundwater, but is located in a 6-month (or 1-year) wellhead protection area and/or has maintenance or design deficiency issues that impact water quality performance, then it should be assigned a higher priority. Criteria related to infiltration capacity screening are summarized in the green boxes in Figure 1.

Water Quality Treatment Performance

A stormwater pond may be assumed to be a lower priority for water quality retrofitting if it meets the following criteria related to water quality treatment:

- Provides water quality treatment (e.g., dead storage capacity as a semi-permanent wet pool for pollutant settling) as part of the existing configuration
- Is located at a site where runoff passes through another water quality treatment BMP (such as a biofiltration swale or filtration system) upstream or downstream of the pond
- Does not have any known maintenance or design deficiency issues.

If the pond includes water quality treatment as part of the design and/or is located at a site where another water quality treatment BMP is in use, but has been identified to have maintenance or design deficiency issues that impact treatment performance, then it should be assigned a higher priority. Criteria related to water quality treatment performance screening are summarized in the orange box in Figure 1.

Receiving Water Quality

Stormwater ponds can be prioritized based on the quality of downstream receiving waters. The quality of the receiving water is assessed using the following data:

- Drains to a water body with a low B-IBI score (see Table 2 for definition of B-IBI)
- Drains to a surface water body with a Water Quality Assessment Category 5, 4a, or 4b listing (see Table 2)
- There are known water quality problems in the receiving water based on city, county, local health district, regional watershed group, or statewide water quality studies.

In addition to water quality data, the flow pathway should also be assessed to determine the travel distance from the stormwater pond discharge location to the receiving water. The longer the flow pathway, the better opportunity there will typically be for incidental or purposeful pollutant removal in the system. If the pond drains directly to a receiving water, then it should be assigned a higher priority. Criteria related to receiving water quality screening are summarized in the blue boxes in Figure 1.

Optional Screening Criteria

Optional screening criteria that can be used to evaluate and prioritize stormwater ponds include, but are not limited to, the following:

- Ponds that manage runoff from small drainage areas (lower priority)
- Ponds that were recently constructed and have no known maintenance or design deficiency issues (lower priority)
- Ponds that have previously been retrofitted and have no known maintenance or design deficiency issues (lower priority).

Optional screening criteria are summarized in the yellow boxes in Figure 1.

FIELD ASSESSMENT

Once a single pond or list of prioritized ponds has been identified following the information gathering stage, a field assessment can provide critical information for determining how each pond is currently functioning and what the condition of the pond is in terms of vegetation, aesthetics, and retrofit feasibility.

The Field Assessment Checklist in *Appendix A* should be filled out to assess the water quality unit treatment processes (described below), vegetation and aesthetics, and retrofit feasibility for each pond. The Field Assessment Checklist includes the following main categories discussed in this section:

- Existing Pond Information
- Land Use in Drainage Basin
- Unit Treatment Processes
- Vegetation and Aesthetic Assessment
- Retrofit Feasibility Assessment.

Existing Pond Information

The following information should be collected or developed during the information gathering process and included on the Field Assessment Checklist, before embarking on the field visit. This background information on the stormwater pond helps to clearly identify the facility and place the field observations in a broader context. Information to enter on the Field Assessment Checklist includes:

- What is the pond called (include pond identification number, name, or identification code)?
- Where is the pond located (intersection or subdivision name)?
- Where does the pond ultimately drain to (name of receiving water)?
- Does the pond drain directly to a receiving water?
- Are there any other water quality treatment facilities onsite?
- Are there any known maintenance issues?
- Are there any known design deficiency issues?
- Was the pond prioritized as a low, medium, or high priority (0, 1, or 2) based on maintenance and/or design deficiency issues?
- Does the pond have high visibility (located within a residential development or along a major roadway)?

Land Use in Drainage Basin

Land use information is useful to understand the characteristics of the drainage area and the expected pollutant loading from stormwater. The following land use information should be entered on the *Field Assessment Checklist* from available data collected during the information gathering process before embarking on the field visit:

- Residential land use (percent of drainage area)
- Commercial land use (percent of drainage area)
- Other land uses (such as industrial or roadway) (percent of drainage area).

What is sedimentation?

Sedimentation is a unit treatment process where gravity settling of entrained and suspended particles and associated pollutants adsorbed to the particles (e.g., hydrocarbons, heavy metals, and nutrients) in stormwater occurs.

Photos 2 and 3. Examples of short-circuiting ponds. Photo 4. Pond with excessive sediment deposition.

Unit Treatment Processes

A unit treatment process is a physical, biological, or chemical process that removes pollutants from stormwater. The following unit treatment processes should be assessed in the field and recorded on the *Field Assessment Checklist*:

- Sedimentation
- Filtration and biological uptake
- Adsorption, sorption, anion exchange, and cation exchange
- Infiltration.

By identifying which of these processes are in need of improvement, preferred retrofit options can be determined. Each of these processes and what to look for is described below.

Sedimentation

Pond characteristics that provide high sedimentation function include adequate treatment storage volume and retention time. Retention time can be assessed by observing the flow path in the pond between the inlet and outlet. Indicators of degraded sedimentation conditions in a pond include:

- **Undersized Pond** — Sediments passing through pond and being deposited downstream
- **Short-circuiting** — inlet and outlet are located near each other

What is filtration?

Filtration is a unit treatment process that involves mechanically passing particles suspended in stormwater through substrate, aquatic flora, or fauna.

What is biological uptake?

Biological uptake is the transfer of substances from the environment to plants and animals.

Photo 5. Pond with excessive sediment deposition.

In addition to problems of inadequate sedimentation function, it is possible that sedimentation in stormwater ponds may be excessive, indicated by:

- Observations of excessive sediment deposition
- Chronic maintenance problems related to excess sediment.

Data collected during the information gathering process may indicate whether the pond is properly designed and if it has any dead storage capacity for sedimentation. Information gathered from maintenance crews may reveal whether the pond has been functioning adequately or if there are chronic maintenance issues related to excess sediment.

Filtration and Biological Uptake

The field assessment should focus on evaluating the biological uptake potential through observation of the vegetation found in the pond. The vegetation growing in a stormwater pond can act both as a physical filter (causing gravity settling of particulates by regulating velocity of flow) and also as a biological sink (via direct uptake of dissolved pollutants). The physical filtration process results in sediment removal, while the biological uptake component can result in removal of metals, phosphorus, and nitrogen from the water. Dense, healthy vegetation will provide good filtration and biological uptake in a stormwater pond. Indicators of degraded filtration and biological uptake include:

- **Low Plant Density** — Bare soil and sparse vegetation on pond bottom and side slopes
- **Unhealthy Plant Community** — Poor apparent health of the plant community

Photos 6 and 7. Ponds with large bare spots or low vegetation density on pond bottom or side slopes.

Photo 8. This pond is dominated by cattails and is an example of an unhealthy plant community. Supporting a diversity of plant species allows ponds to adapt to changing environmental conditions without compromising water quality goals.

An indicator of proper filtration and biological uptake functioning is a diverse and healthy plant community. Specifically, a diverse and healthy plant community is comprised of a variety of native species, with little or no invasive species present, and shows little to no stress indicating plants are adapted to the site conditions and water fluctuations.

Adsorption, Sorption, Anion Exchange, and Cation Exchange

To assess adsorption, sorption, anion exchange, and cation exchange in the field, field inspectors should dig a hole in the bottom and on the side slopes of the pond to look at the soil texture, composition (i.e., general balance of sand, silt, and clay), and for evidence of saturation. Pond characteristics that provide good function include ponds that readily infiltrate stormwater into soils (sizeable soil and water contact area, and permeable soils) and ponds with long sinuous flow paths (long retention time, and significant contact area between stormwater and pond soils). Indicators of degraded adsorption, sorption, anion exchange, and cation exchange can include:

- **Short-circuiting** — Pond inlet and outlet are located near each other.
- **Low sinuosity** — Pond flow path is straight from inlet to outlet, minimizing the area of potential stormwater infiltration over the soil contact area.
- **Ponded Water** — Permanent pool of standing water persists between runoff events or throughout the dry season. An exception to this indication is a permanent pool that is part of the design such as for a wet pond.
- **Poor infiltration** — Dense, compacted soils.

Photo 9. Dig a hole to evaluate the soil texture, composition, and to look for evidence of saturation.

Photo 10. This permanent pool of standing water is a sign of minimal soil and water contact time.

What is adsorption?

Adsorption is the adhesion of a substance to the surface of a solid or liquid. Heavy metals such as zinc and lead often adsorb onto sediment particles.

What is sorption?

Sorption is the physical or chemical binding of pollutants to sediment or organic particles.

What is anion exchange?

Anion exchange is the chemical process where negative ions of one chemical are preferentially replaced by negative ions of another chemical.

What is cation exchange?

Cation exchange is a process where positively charged ions of one chemical are preferentially replaced by positive ions of another chemical.

Why are these unit treatment processes lumped together?

Adsorption, sorption, anion exchange, and cation exchange collectively refer to a set of unit treatment processes that occur when stormwater interacts with soils. The processes involve the physical or chemical bonding of ions in infiltrated stormwater to soil, which can result in the removal of hydrocarbons, phosphorus, nitrogen, and heavy metals from the stormwater.

Definitions based on the *Stormwater Management Manual for Western Washington* and the *Technical Guidance Manual for Evaluating Emerging Stormwater Treatment Technologies – Technology Assessment Protocol –* Ecology (TAPE).

Infiltration

> **What is infiltration?**
>
> Infiltration is a unit treatment process that involves the downward movement of stormwater from the surface to the subsoil and can result in multiple benefits including pollutant removal, peak flow control, groundwater recharge, and flood control.
>
> Definition based on the *Stormwater Management Manual for Western Washington*.

Infiltration should be assessed based on a combination of the soil classification data (GIS data) for the pond location, feedback from field crews regarding whether the pond has routinely been observed to have standing water in it (or not), and current field observations. Field inspectors should dig a hole in the bottom and on the side slopes of the pond to look at the type of soil and evidence of saturation. Inspection for infiltration performance should be done in the wet season (such as between December and March in Kitsap County) to provide a more accurate indication of the ability of the pond to infiltrate runoff when it is subjected to repeated runoff events in succession, and when the depth to underlying groundwater is less than it is in the dry season. Pond characteristics that provide high infiltration are permeable soils (Hydrologic Soil Group A or B), and a separation between the pond base elevation and seasonal high groundwater. These conditions are usually controlled by the pond's physical location and cannot be improved through retrofitting. Therefore, without these characteristics, enhancement of infiltration is not likely feasible. Indicators of degraded infiltration include:

- **Ponded Water** — Permanent pool of standing water persists between runoff events or throughout the dry season.
- **Pond Liner** — Observations of an impermeable pond liner
- **Poor Infiltration** — Dense, compacted soils.

Reading the Soil

Complex chemical interactions occur within soil when it comes in contact with water and air. The color and characteristics of a soil can provide general information about how long it has been saturated or inundated. This portion of the manual is a guide to recognizing these soil characteristics, but a soil and/or wetland professional should be contacted to verify what has been observed and to obtain more information.


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Redoximorphic Features

Soils with dark backgrounds and rusty and/or yellow splotches could indicate soils were saturated for a temporary period of time (2 weeks or a month) and then dried out allowing air to enter the soil pores. The rust and yellow splotches are referred to as redoximorphic features. These features indicate that iron has gone into solution and then been exposed to air; oxidizing the iron and creating rust colors in the soil. If you observe soils with these characteristics, contact a soil or wetland professional to get more information.

Depleted Soils

Soils that have a light grey background can be what is referred to as "depleted soils." Depleted soils often also contain redoximorphic features (rust and yellow splotches). Soils exhibiting these characteristics are likely to have been saturated for a longer period (up to several months) than the soils shown in Photo 11. Much of the iron in these soils has been leached out and down the soil column during the time they are saturated. When soils dry out, air enters the soil's pores and creates redoximorphic features (rusty/yellow splotches). Soils with this characteristic may indicate shallow groundwater is present and affecting drainage of the stormwater facility.


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Gleyed Soils

Soils that are saturated or inundated all year round typically have light grey-greenish or bluish colors. Nearly all of the iron and manganese in these soils have been leached down the soil column leaving the light grey-greenish, bluish color, indicating permanent or long term saturation. Soils that have this characteristic could indicate that shallow groundwater is present and may affect the drainage of the stormwater facility.

Saturated Soils

Soils are saturated when 100 percent of the soil pores are filled with water. It can be difficult to determine whether soils are saturated just by looking at them. Once a hole is excavated, soils may be seen glistening or water may be pouring out of the side of the hole. This is an indication that soils are saturated, but closer observation of the soils is best. If you can squeeze water out of the soil easily, it is likely saturated even if you do not see water pouring out of the side of the hole. Contact a soils or wetland scientist to assist with verification of soil saturation.

Shallow Water Table

A shallow groundwater table may be present beneath a stormwater pond, at least for part of the year. It is important to recognize that the water levels can rise with rainwater from winter storms, adversely affecting drainage of the stormwater facility. Shallow water tables are typically in low elevation areas near streams or other water bodies. The presence of shallow groundwater can be determined during the dry season (May through September in western Washington) when the stormwater pond is not receiving much inflow. While the surface of the stormwater facility may be dry, the water table may be just below the surface. Excavate soils to a depth of at least 24 inches to determine if shallow groundwater is present. Leave the soil pit open for at least 30 minutes or an hour to allow the water (if present) to fill up part of the hole, especially if soils are fine-textured such as clay and silt that transmit water slowly. If shallow groundwater fills the soil pit during this test, dig another soil pit elsewhere in the pond bottom, and allow time for water to fill it in. If pooled water is observed in one or more test pits, it is likely that a shallow water table is present at a similar elevation beneath the entire pond.

Well-drained Soils

Soils may also be dry below the surface indicating they are well-drained. Excavate a soil pit to at least 24 inches to determine whether soils are well-drained. Soils that are light or bright in color and that do not have redoximorphic features also indicate well-drained soils. Well-drained soils are typically coarse-textured such as sandy soils, unless there is a high water table that keeps soils saturated near the soil surface. Soils that are well drained should be dry during most of the year except within a couple days after a rainstorm has occurred. Well-drained soils typically infiltrate rainwater within a short period of time (no longer than a week).

Vegetation and Aesthetic Assessment

Ponds should be evaluated for the condition of vegetation composition and cover, aesthetic value, and observations of adjacent lands should be made (both current use and potential) to provide site context for selecting the most beneficial retrofit design. Traditionally, stormwater ponds are planted with a mix of native and non-native turf grass or groundcover species that provide low water quality treatment value, require frequent mowing, and often do not blend aesthetically or function ecologically with surrounding natural areas or neighborhoods. Enhancing and diversifying vegetation in stormwater ponds can significantly improve water quality treatment effectiveness, improve ecological function, and provide a neighborhood amenity.

Vegetation

Vegetation improves water quality by:

- **Reducing sediment load** — The stems and leaf blades of vegetation intercept stormwater and act as physical filters by capturing sediment and associated pollutant particles. Emergent plant species are particularly suited to reducing sediment load because of their plant structure and adaptation to water inundation and saturated soils.

- **Reducing water velocity** — Vegetation reduces the velocity of water moving through a pond, allowing more time for pollutants to settle to the bottom and minimizing turbulence that may otherwise induce re-suspension of sediments previously deposited in the pond bottom.

- **Increasing ability of soil to absorb and filter pollutants** — Root systems increase the potential for water to filter through soil, which increases the adsorption, sorption, anion exchange, and cation exchange interactions that remove pollutants in stormwater.

- **Absorbing pollutants into plant matter** — Plants will absorb some pollutants through their root systems and transfer them into their tissue.

Vegetation also provides the following aesthetic benefits:

- Healthy native vegetation helps prevent the establishment of non-native invasive vegetation.

- Native plant species placed in natural looking clusters can better blend stormwater facilities into adjacent natural areas and neighborhoods.

- A diversity of native plants and use of trees and shrubs in addition to low-growing species creates a more park-like visual experience for the community.

Vegetation is assessed based on the dominance or absence of a well-established, healthy native plant community, one with at least five native species present. In addition, the relative abundance or absence of undesirable or invasive vegetation is evaluated and little to no invasive species or undesirable vegetation present is preferred. Indicators of degraded vegetation include:

- **Invasive Species Presence** — ranging from moderate invasive species presence and cover to invasive species dominating pond and/or surrounding area.
- **Lack of Native Vegetation** — ranging from few (four or less) native species within the vegetation community to no native vegetation is present.

Aesthetics

Thoughtful aesthetics provide a visual cue to the public that a landscape is important. Studies have shown that people react positively to places that have a moderate amount of landscape complexity, but that also show "cues of care," like maintained paths, mowed borders, bird houses, or other signals that let people know a landscape is not neglected (Nassauer 1997).

Traditionally, aesthetics have not been a design criteria or goal for most stormwater facilities. Primary goals have focused on storage, flood mitigation, or water quality, but rarely on how well facilities blend into a neighborhood, natural area, or surrounding site context. Successful facilities have been those that are free of debris, regularly mown, and have few invasive species. As stormwater design and engineering professionals respond to new water quality requirements, and low impact development brings stormwater facilities into the public eye, the aesthetics of stormwater facilities become increasingly important. While evaluating site aesthetics is somewhat subjective, most can agree that poorly functioning stormwater ponds are almost always unsightly. As such, retrofitting provides an opportunity to improve site aesthetics and community acceptance of stormwater facilities along with improving water quality treatment.

The subjective nature of this category and the variability between local ecology, aesthetic preferences, and cultural values, indicate it is best to evaluate site aesthetics through site observations and conversations with community members and/or maintenance staff, as opposed to using explicit indicators and criteria. Potential evaluation questions may include:

- What is the pond vegetation and what is the surrounding vegetation like? Does the pond blend in aesthetically and seamlessly with the surrounding land use?
- Is there noticeable bare ground on the pond bottom or side slopes?

Photo 17. Fences are placed around ponds for safety reasons, but can also send a message to neighbors that the pond is an off-limits, dangerous place. Fences create a barrier between the community and landscape and the pond facility.

- Does the shape and form of the pond blend in well with the surrounding landscape?
- Are there signs of neighbors trying to block their view of the pond (vegetation screens or fences) or is there a physical or visual connection between the surrounding land use and the facility?
- Is there garbage and evidence of neglect from neighboring land users or are there signs of upkeep and local ownership of the pond?

- Is there a fence surrounding the pond (signaling danger or a message that the area involves a restricted land use) or is the pond open?

Fencing Requirements

When is a fence required?

- When the pond interior side slopes are steeper than 3:1 (horizontal:vertical)
- When a vertical retaining wall (reinforced concrete, rockery, masonry unit, or keystone type) is part of the pond design

When is a fence sometimes required?

- To discourage access to portions of a pond with steep side slopes that may be hazardous
- To guide those who have fallen into a pond to side slopes (flatter than 3:1 and unfenced) to allow for easy escape

What types of material can be used for a fence?

- Chain link fence (4 to 6 feet high)
- Vertical metal balusters
- Galvanized steel fabric with bonded vinyl coating
- Wood (if maintained by an entity such as a homeowners association or by adjacent lot owners)
- Densely planted thorny hedges (for short stretches of the pond perimeter with side slopes steeper than 3:1)

Requirements summarized from the Stormwater Management Manual for Western Washington and the Kitsap County Stormwater Design Manual.

Surrounding Context

The surrounding context evaluation requires the engineer and/or designer to evaluate aspects of the immediate facility location different from drainage area and land use. This category asks the field investigator to observe and document surrounding infrastructure, ecology, and social factors that could affect the prioritization and design of a retrofit project. The purpose of this evaluation is to select sites and retrofit designs that function more as a community asset. Examples that describe a number of potential surrounding context elements and corresponding design considerations are provided below.

Surrounding Context and Other Considerations

Surrounding Context	Design Considerations	Photo Example
Road is near the pond →	Contaminants from roadway may influence targeted unit treatment processes; Highly visible site; Potential weed and debris source	

Surrounding Context	Design Considerations	Photo Example
Residential neighborhood is nearby	Blend in with neighborhood character; Create community appropriate space	 19
Natural area nearby	Transition pond into natural area to blend habitat value and aesthetics; Consider species that will migrate from nearby natural area to pond, and design to enhance habitat and attract or deter particular species	 20
Horse pasture or livestock is nearby	Need additional buffer from land use; Provide living fence, native vegetation buffer, or fence	 21
Ornamental landscaping is nearby	Consider grouping plantings and blending transitions between adjacent land uses; Potential contaminants from neighboring landscape maintenance	 22
Commercial landscape is adjacent	Use facility to compliment site identity; Consider a more formal planting layout	 23

Retrofit Feasibility Assessment

Assessing the feasibility of retrofit strategies during the field assessment is critical to retrofit selection and to design for improving unit treatment processes, vegetation, and aesthetics. The retrofit feasibility questions and examples of preferred conditions in Table 5 and the Field Assessment Checklist were developed based on information contained in the Urban Stormwater Retrofit Practices manual (CWP 2007), and should be included in the field assessment.

Table 5. Retrofit feasibility questions and preferred conditions.

Retrofit Feasibility Question	Example(s)
Potential for excavating pond bottom?	Dry, flat pond bottom with no evidence of standing water
Potential for raising the pond embankment?	Available space at the toe of the embankment to support a wider footprint, invert elevation of pond inlet pipes does not cause tailwater issues
Potential for modifying outlet structures?	Outlet access and existing structures may allow installation of a multiple orifice outlet, or changes to the outlet elevation
Potential for modifying the pond outlet riser?	Large diameter low flow outlet, concrete riser with additional weir capacity, or oversized detention pond
Potential for modifying internal design?	Internal flow path can be extended, wetland elements can be added, or a forebay can be installed
Space to expand pond/BMP footprint?	Is the parcel large enough to accommodate an expansion?
Evidence of shallow groundwater seepage in pond or nearby area?	Potential for complications with excavation and pond expansion
Is there space available onsite to stage construction materials and equipment for retrofit construction work?	More space will mean easier construction
Are there onsite utilities that could present conflicts with retrofit construction (buried and overhead)?	Sanitary sewer, water lines, gas, phone, cable, electric, etc. Look for indicators such as sewer stacks, fire hydrants, electric box grates, overhead wires, gas meters, or cable boxes

RETROFIT SELECTION

This manual covers preferred retrofit options developed by Kitsap County based in part on field observations at over 40 pond sites, with reference to published literature on stormwater management facilities. The nine preferred retrofit options developed in this study include the following:

- **Wetland conversion** — Modify pond geometry to create shallow water zones with long sinuous flow paths where water, soil, and plant contact zones are maximized, and where wetland plants can thrive.
- **Bioretention** — Use a combination of soil amendments and vegetation to retain runoff and infiltrate it into the ground.
- **Pond expansion** — Expand spatial footprint and/or excavate to deepen the pond and increase storage capacity, thereby enhancing particulate settling that accomplishes greater pollutant removal.
- **Pond outlet modification** — Alter the outlet control structure on a detention pond to increase runoff retention within the pond.
- **Configuration change** — Convert to a multi-celled pond, or increase the length of the flow path through the pond.
- **Vegetation improvement** — Create vegetation diversity for improved water quality performance, wildlife habitat, and aesthetic appeal.
- **Infiltration** — Create or increase the pond's ability to infiltrate a large proportion of the inflowing runoff into the ground.
- **Multiple uses** — Improve accessibility of the pond for neighbors and/or the general public as a park-like feature by adding a path, bench(es) for seating, educational signage, or improving or removing fencing.
- **Subsurface gravel wetland** — Modify the pond by creating a sedimentation basin (forebay) and two flow-through wetland treatment cells underlain by gravel that hosts desired algal and microbial growth in saturated conditions, resulting in improved pollutant removal.

Additional retrofit options not discussed in this manual include:

- **Raising the pond perimeter embankment** — Widen the embankment footprint and increase the height of the embankment to provide additional stormwater storage volume
- **Trading storage** — Modify the outlet structure of a pond with multiple riser outlets to provide water quality treatment in a portion of the pond depth that was previously used for intermittent runoff detention (e.g., trading detention function for water quality function).

Figure 2 walks the user through the steps of the retrofit selection process. The Pre-Design Checklist in Appendix B referenced in Figure 2 should be filled out to assist with selection of the most appropriate retrofit option. Table 6 summarizes criteria for assessing feasibility based on unit treatment processes, vegetation and aesthetic considerations, and retrofit feasibility based on data collected and summarized in the Field Assessment section. These criteria are cross-referenced with the nine retrofit options to help the user select the best retrofit option for a particular pond.

The first step in selecting a pond retrofit option is to identify those options that are appropriate for improving the existing conditions that have been identified in the pond assessment. Table 6 identifies which retrofit options can be used to effectively improve unit treatment processes.

The next step in selecting a retrofit option is to determine the feasibility of the potentially effective options identified for the specific pond site. Table 7 provides a matrix listing site conditions that are favorable for each retrofit option. Once the preferred retrofit option or combination of retrofit options has been selected, the Conceptual Design section of this manual provides guidance on how to design the retrofit.

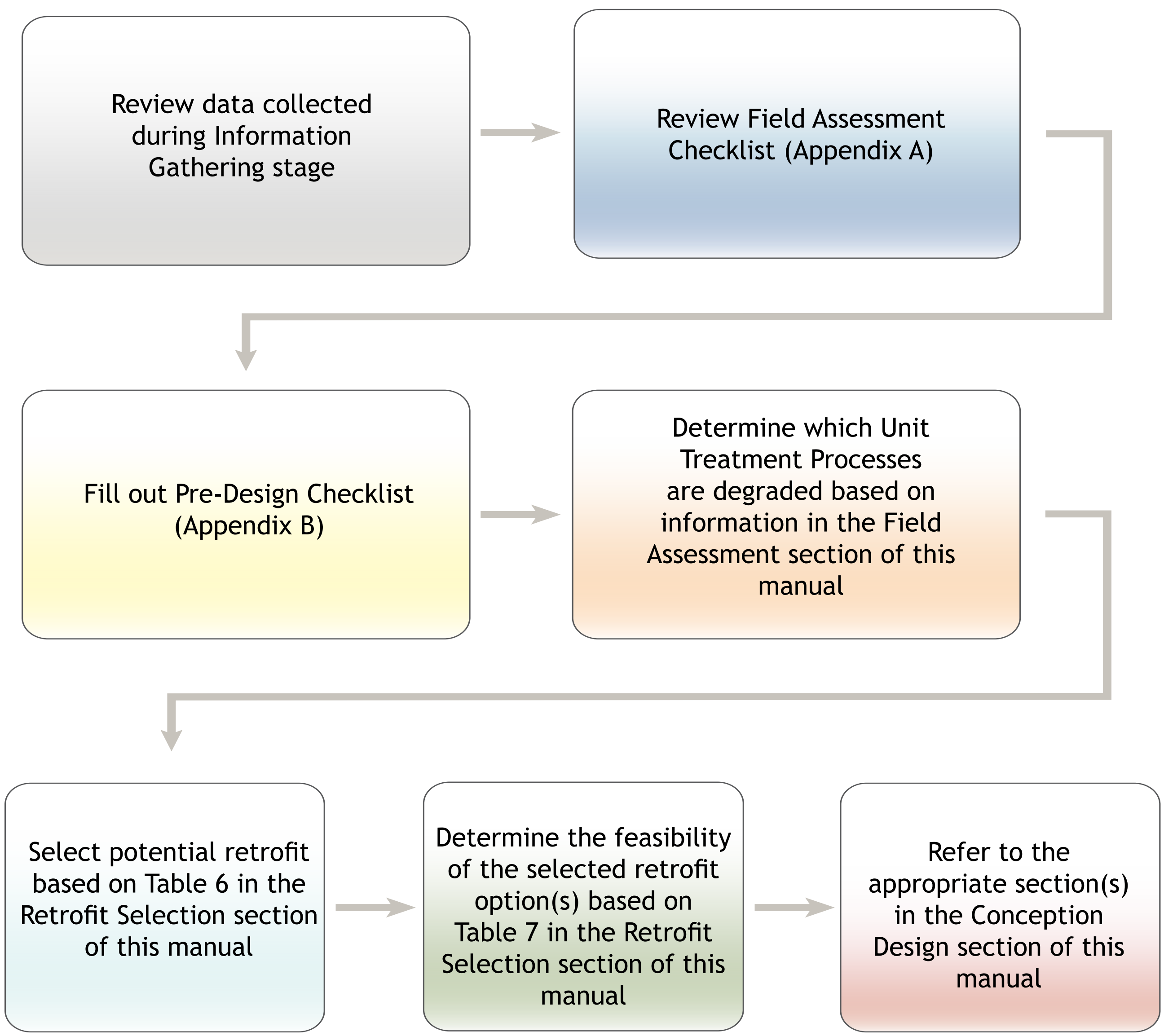


Figure 2. Retrofit selection process.

Table 6. Effective retrofit options for degraded unit treatment processes.

Indicator of Degraded or Inhibited Unit Treatment Process	Potential Retrofit Options
Sedimentation	
Undersized Pond	Pond Expansion Pond Outlet Modification
Short-circuiting	Configuration Change Subsurface Gravel Wetland
Excess Sedimentation	None, but can be addressed through source control, pretreatment, and/or increased maintenance frequency
Filtration and Biological Uptake	
Low Plant Density	Vegetation Improvement (can be integrated with Multiple Uses)
Unhealthy Plant Community	Vegetation Improvement (can be integrated with Multiple Uses)
Adsorption, Sorption, Anion Exchange, and Cation Exchange	
Short-circuiting	Configuration Change Subsurface Gravel Wetland
Low Sinuosity	Configuration Change
Ponded Water (significant amount)	Wetland Conversion Subsurface Gravel Wetland
Dense, Compacted Soils	Wetland Conversion Bioretention Infiltration Subsurface Gravel Wetland
Infiltration	
Ponded Water (minimal amount)	Bioretention Infiltration
Pond Liner	Bioretention Infiltration (if pond liner is removed)
Dense, Compacted Soils	Bioretention Infiltration (if soils are loosened)

Table 7. Stormwater pond retrofit options and criteria for assessing their feasibility.

	Stormwater Pond Retrofit Options								
Criteria for Assessing Feasibility	Wetland Conversion	Bioretention	Pond Expansion	Pond Outlet Modification	Configuration Change	Vegetation Improvement	Infiltration	Multiple Uses	Subsurface Gravel Wetland
Unit Treatment Processes									
Class A/B soils		✓					✓		
Class D soils	✓								✓
Evidence of good infiltration		✓					✓		
Loam, sandy loam, or sand		✓					✓		
Minimal amount of standing water		✓					✓		
Significant amount of standing water	✓								✓
Outlet located near inlet					✓				✓
Vegetation and Aesthetic Assessment									
Functioning similarly to a wetland	✓								✓
Invasive species dominant						✓			
Low species diversity (non-native plants)						✓			
High visibility	✓	✓	✓			✓		✓	✓
Potential for community amenity								✓	
Shallow with minimal side slopes								✓	✓
Retrofit Feasibility Assessment									
Evidence of groundwater seepage into pond	✓								✓
Long linear pond		✓							
Single-cell pond		✓			✓				
Deepen pond to increase the storage volume			✓						
Space on parcel not fully utilized			✓						
Add a new outlet structure				✓					
Modify existing outlet structure				✓					
Raise or lower existing outlet structure				✓					

CONCEPTUAL DESIGN

This section includes conceptual design guidance for each of the following preferred retrofit options discussed in this manual:

- Wetland conversion
- Bioretention
- Pond expansion
- Pond outlet modification
- Configuration change
- Vegetation improvement
- Infiltration
- Multiple uses
- Subsurface gravel wetland

Each conceptual design section is 2 to 5 pages long and includes information on the following topics:

- Applications
- Unit treatment processes
- Limitations
- Integrated solutions
- Retrofit considerations
- Conceptual drawings
- Design standards
- Maintenance considerations
- Planning level cost estimate

A brief description of the types of information included for each of the topics is provided in Figure 3.

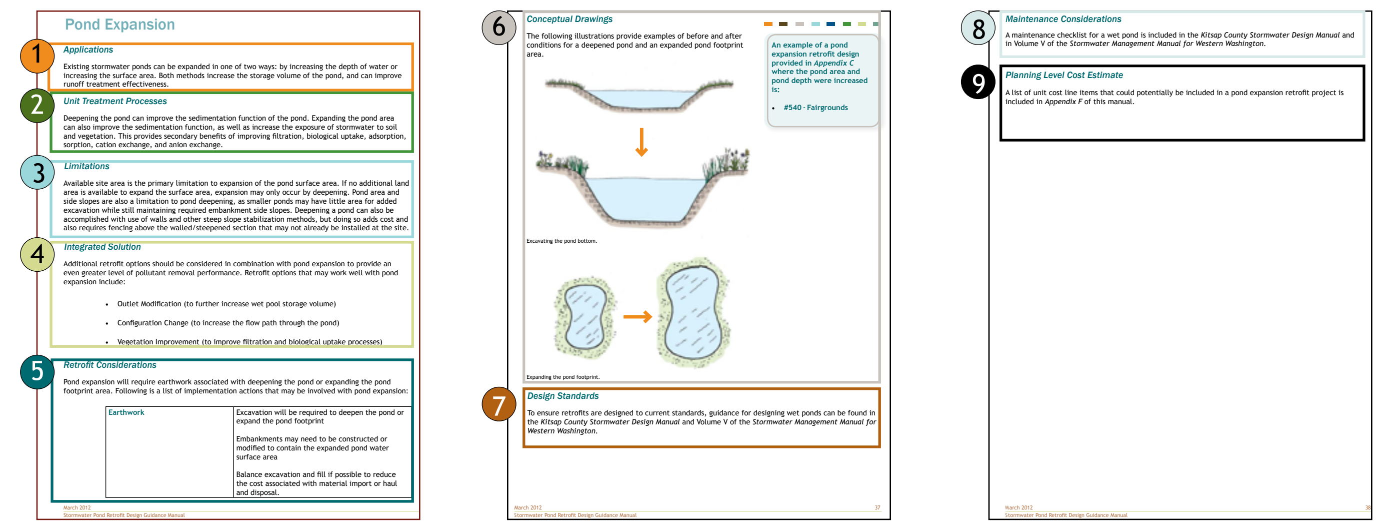
1 **Applications** are a list of site-specific characteristics that are conducive to a particular retrofit option.

2 **Unit treatment processes** are a description of the unit treatment processes that could be improved by selection of the retrofit option.

3 **Limitations** are site-specific characteristics or considerations that must be taken into account to determine if a retrofit option is feasible or not.

4 **Integrated solutions** are other retrofit options that should be considered in combination with the selected retrofit option.

5 **Retrofit considerations** are potential implementation actions that could be associated with the selected retrofit option.



6 **Conceptual drawings** include sketches of the pond prior to retrofit and post-retrofit. References are also provided to conceptual design drawings (included in *Appendix C*) developed as part of the Kitsap County pond retrofit study that was completed in conjunction with preparation of this manual.

7 **Design standards** are general design principles and provide linkage to the *Kitsap County Stormwater Design Manual*, the *Stormwater Management Manual for Western Washington*, and other resources.

8 **Maintenance considerations** include routine inspections and activities associated with each retrofit option that are recommended for proper functioning. References to the *Kitsap County Stormwater Design Manual*, the *Stormwater Management Manual for Western Washington*, plant maintenance recommendations in *Appendix D*, and subsurface gravel wetland maintenance recommendations in *Appendix E* are also provided.

9 **Planning level cost estimate** information includes a reference to *Appendix F* which lists potential unit cost line items that should be considered when developing a cost estimate for the selected retrofit option. Unit costs will vary depending on who will construct the pond retrofit (local government, contractor, etc.) and site-specific factors that may increase or decrease the overall retrofit cost.

Figure 3. General content and layout of the conceptual design sections.

Wetland Conversion

Wetland conversion involves modifying the bathymetric shape of a stormwater pond to operate as a constructed stormwater treatment wetland or stormwater wetland. A stormwater wetland relies on modifying pond geometry to create long, sinuous, and relatively shallow flow paths where water, soil, and plant contact zones are maximized and where wetland plants can thrive (see Appendix C, Pond 540 Plan).

Where feasible, a stormwater wetland is designed with a two-cell configuration, with the first cell being smaller and deeper to treat stormwater via sedimentation, and the second cell being larger and shallower to treat stormwater using the biological and chemical processes found in naturally-occurring wetlands (see Appendix C, Pond 540 Plan). When retrofitting a stormwater pond to create a stormwater wetland, the two-cell configuration may not be feasible due to site restrictions or existing facility elevations. When that is the case, the retrofit design should maximize the extents of shallow, sinuous flow paths planted with a diversity of plant species.

Stormwater wetlands have a high capability to remove total suspended solids (TSS), polycyclic aromatic hydrocarbons (PAHs), and dissolved metals (ODOT 2008). Effective functioning of a stormwater wetland depends on proper design, and on maintaining a sufficient period of soil saturation each year to support the wetland plants. In addition to water quality benefits, a well-constructed and maintained stormwater wetland can provide a community amenity for aesthetic enjoyment.

Applications

Stormwater wetlands are most appropriate for treating stormwater where there is available space to provide shallow water, and to create extensive soil, water, and plant interface conditions. Larger stormwater ponds tend to be better candidates for wetland retrofits than smaller ponds, but even the treatment performance of a small stormwater pond can be improved with the addition of wetland benches in key areas (see Appendix C, Pond 193 Plan). Stormwater wetlands also benefit communities and property owners that want to maximize use of natural water quality treatment processes and the availability of attractive green space in the landscape.

Wetland conversion is most successful when stormwater pond sites have Class D soils, high groundwater levels, and/or a tendency to accumulate standing water.

Stormwater wetlands are typically not a preferred retrofit solution for stormwater flow control because rapidly fluctuating water levels during and following storms can hinder growth of the desired plants; however, the treatment effectiveness of a detention facility can be improved when stormwater wetland features are added.

Several stormwater wetland designs that exemplify ways to retrofit stormwater detention ponds are provided in this document including a standard stormwater wetland design, a stormwater wetland with benches, and a stormwater wetland with terracing. Benching and terracing are used to increase the area of soil, plant, and water contact within a confined space.

Stormwater wetlands are well suited for sites where a wet pond might conventionally be used. A stormwater wetland typically requires more land area than a wet pond for a given tributary drainage area because a number of the unit treatment processes provided by a stormwater wetland rely on shallow water which requires more space for storing the required/targeted volume of water. The use of vegetation (see *Appendix C*, Pond 540) in conjunction with shallow water, however, provides more effective treatment and greater potential beauty than a simple wet pond. Variations in depth and irregularly-shaped pools also make a stormwater wetland more natural looking. Topography designed to create a lengthy and irregular flow path, and vegetation cover within the wetland will decrease the potential for short-circuiting (water flowing through the wetland from inlet to outlet more rapidly than desired) that can occur from wind, high flows, and poor design.

Unit Treatment Processes

Wetland conversion can improve several unit treatment processes including adsorption, sorption, anion exchange, and cation exchange; infiltration; and filtration and biological uptake. Adsorption, sorption, anion exchange, and cation exchange can be improved through maximizing contact of stormwater with wetland soil that typically has a high organic content. Infiltration can be improved by incorporating a diversity of plant species with varying depth of root systems which provide conduits for water infiltration. Soils that are high in organic matter can also increase water storage capacity. Diverse vegetation species increase overall biological uptake as different species are capable of taking up different water quality constituents more or less effectively.

Limitations

If not lined to retain water, stormwater wetlands typically require at least a seasonal source of baseflow to maintain wetland vegetation. Including a liner adds to the construction cost. Stormwater wetlands are not appropriate for steep or unstable slopes.

If there are stagnant water pools within the wetland during the warm summer months, they may attract breeding mosquitoes. This problem can be addressed by designing a wetland that does not retain stagnant pools through the summer or by the installation of bat boxes adjacent to or within the wetland.

There is a potential for nutrient release in late fall and early winter when plants become senescent and their above ground organic material decomposes. Over time the hydraulic capacity of the wetland may be reduced due to plant overgrowth if plant maintenance is not performed, and/or if the wetland planting plan is not carefully crafted to reduce the potential for this to occur.

Integrated Solution

Additional retrofit options should be considered in combination with wetland conversion. Retrofit options that may work well with stormwater wetlands include:

- Pond Expansion
- Pond Outlet Modification
- Configuration Change
- Multiple Uses
- Vegetation Improvement

Retrofit Considerations

Converting an existing stormwater pond to a stormwater wetland will generally involve designing a sedimentation forebay (4 to 8 feet deep) and then a second cell (or even third cell if feasible) that would hold shallower water depths varying between 1 and 3 feet and averaging 1.5 feet overall. To do this without reducing existing stormwater detention storage, the pond needs to be deepened in some locations to retain storage volume while increasing the base elevation in other areas to provide shallow wetland conditions. Volume V of the *Stormwater Management Manual for Western Washington* provides general guidance on the distribution of water depths for a stormwater wetland. The outlet in some wetland retrofits may also need to be modified to lower the permanent water surface elevation.

Following is a list of implementation actions that may be involved with conversion of a stormwater pond to a stormwater wetland:

Earthwork	Grading may be required to raise the base pond elevation for shallower wetland conditions. The shape of the pond bottom should be modified to provide variable water depth zones and sinuous flow paths throughout the facility. To reduce costs, balance cut and fill volumes to minimize offsite hauling of excess soil.
Inlet/Outlet Modifications	Lower the outlet elevation of the existing pond to provide shallower permanent pool water surface conditions.
Soil Amendments	Evaluate pond soil to determine if amendments are needed. Conversion of a pond to a stormwater wetland may require importing topsoil or adding compost to amend the native material. Assess current infiltration rates. If the pond has infiltrative soils and a stormwater wetland is still the best retrofit alternative, installing a low permeability liner topped with native amended soil, or installing a treatment liner may improve performance. Refer to Volume V of the current version of the *Stormwater Manual for Western Washington* for guidance on the use of facility liners.
Wetland Vegetation Planting	Plant to create dense and diverse vegetation communities; do not allow natural vegetation colonization of the site as that will likely lead to noxious and invasive plant infestations and monocultures. Plant constructed wetlands to look natural and blend in with the context of the surrounding landscape. Establish vegetation appropriate to the different hydrologic zones or water levels of a wetland. Refer to *Appendix D* for a list of plant species native to Kitsap County and planting details.

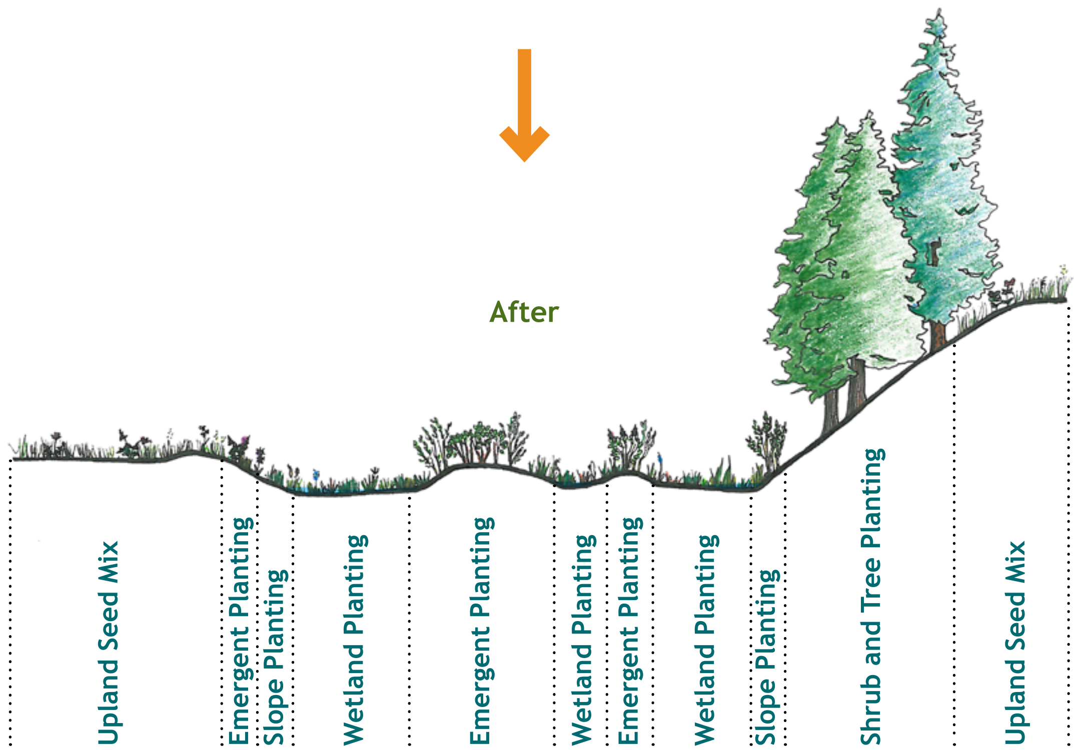
The following examples of wetland conversion conceptual drawings for Kitsap County are found in *Appendix C*:

- **#193 - Harbor Lights**
- **#460- Blueberry Meadows**
- **#540- Fairgrounds**

Conceptual Drawings

The following illustrations provide an example of before and after conditions for a pond retrofitted into a constructed wetland.

The pond has a uniform bottom elevation and has been seeded with a water quality seed mix dominated by grasses.



The constructed wetland is created by fluctuating the topography and creating diverse microhabitats. Each zone is planted with species adapted to thrive under particular site conditions.

Design Standards

Stormwater wetlands require adequate space (typically 1 to 2 percent of the tributary drainage area) to be most effective as a retrofit option. Soils should also be suitable for the establishment of wetland vegetation to minimize the cost of importing soil and/or amendments to create the necessary soil characteristics.

In addition to the general design guidance provided in this manual, Kitsap County provides guidance for stormwater wetlands in the *Kitsap County Stormwater Design Manual*, and Ecology provides guidance for designing stormwater wetlands in Volume V of the *Stormwater Management Manual for Western Washington*.

When applying the design standards referenced above, maximize the following design elements:

- Variable water depth zones
- Sinuous flow paths
- Wetland vegetation diversity
- Low gradient slopes no steeper than 3H:1V (horizontal to vertical) and preferably closer to 10H:1V
- Overall flow path length to width ratios of 4:1 from inlet to outlet where feasible.

Maintenance Considerations

Stormwater wetlands require periodic inspections and maintenance. General maintenance considerations are found in the current version of the *Stormwater Management Manual for Western Washington*. A maintenance checklist for a stormwater wetland is included in the *Kitsap County Stormwater Design Manual*. Sediment will need to be removed and disposed of once accumulation begins to inhibit the growth of wetland plants or sediment reduces the wetland volume. Inclusion of a sedimentation forebay in the retrofit design, coupled with occasional sediment removal from the forebay, will minimize the potential for this to happen over the long term. Vegetation maintenance considerations can be found in *Appendix D* of this manual.

Planning Level Cost Estimate

A list of unit cost line items that could potentially be included in a wetland conversion retrofit project is included in *Appendix F* of this manual.

Bioretention

Applications

Bioretention cells are shallow depressions with a designed soil mix (bioretention soil) and plants adapted to the local climate and soil moisture conditions. The healthy soil biology, soil structure and vegetation in bioretention facilities promote water quality treatment, shallow ponding storage, and infiltration to the ground. Bioretention facilities may be single cells or cells connected in series, with the overflows of upstream cells directed to downstream cells to provide both flow control and conveyance of water not retained in the previous (upstream) cell.

Bioretention is typically only applied at sites where infiltration is permitted; however, underdrains can be installed beneath bioretention cells where infiltration rates are low or unknown, and where infiltration of stormwater is either prohibited for aquifer protection purposes or discouraged for another reason such as prevention of soil saturation atop a steep slope. Conversion of a stormwater pond to a bioretention facility is a retrofit option to consider when there is evidence of good infiltration, Class A/B soils underlying the existing pond, and a minimal amount of standing water observed during the field assessment.

Bioretention facilities are intended to be small, distributed facilities that manage stormwater runoff from small drainage areas. For smaller contributing drainage areas (less than 5,000 square feet of impervious surface), a pond may be converted to an individual bioretention cell. For larger drainage areas, a series of bioretention cells is recommended. A series of cells may also be most appropriate for stormwater ponds that have a long, linear shape and significant longitudinal slope, and potentially for ponds that are reconfigured to have a longer flow path.

Unit Treatment Processes

Bioretention conversion can improve several unit treatment processes including adsorption, sorption, anion exchange, and cation exchange; infiltration; and filtration and biological uptake. Adsorption, sorption, anion exchange, and cation exchange can be improved by incorporating bioretention soil which has a high organic content and cation exchange capacity. Bioretention soil can also improve the infiltration capacity of the facility and reduce the amount of ponded water. A secondary benefit of bioretention is vegetation improvement which increases filtration and biological uptake by increasing plant diversity and establishing a healthy plant community.

Limitations

Limitations on bioretention conversion include poorly infiltrating soils underlying the existing pond (Class D soils), evidence of poor infiltration performance in the pond, and significant ponded water observed during the field assessment (for a pond that is supposed to drain “dry” in the hours and days following a storm). While bioretention facilities may be appropriate for sites with moderately infiltrative soils (Class C, or till), the size of the stormwater facility may need to be increased significantly beyond the existing pond footprint in order to rely on infiltration as the primary treatment mechanism.

Bioretention facilities without underdrains are not appropriate for areas where infiltration is prohibited. Infiltration is typically restricted in areas with steep slopes, shallow depth to groundwater (or other impermeable layer), contaminated soils, and land uses such as maintenance facilities and gas stations where potential stormwater contamination could be a concern (Kitsap Home Builders Foundation 2009). Setbacks from wellheads, on-site sewerage systems, basements, and foundations should also be reviewed to determine if infiltration is a feasible retrofit option for the site.

For areas where infiltration is not appropriate, lined bioretention cells with underdrains may be used.

Integrated Solution

Additional retrofit options should be considered in combination with bioretention. Retrofit options that may work well with bioretention include:

- Pond Outlet Modification
- Configuration Change
- Multiple Uses
- Vegetation Improvement

What is a Pilot Infiltration Test?

A Pilot Infiltration Test (PIT) is a relatively large-scale infiltration test used to better approximate actual infiltration rates for design of stormwater infiltration facilities. A standard PIT involves excavating a test pit with a bottom area of approximately 100 square feet. The modified PIT used by the City of Seattle involves a much smaller test pit with a minimum bottom area of approximately four square feet (Seattle 2009). Guidelines for infiltration testing can be found in the current version of *Stormwater Management Manual for Western Washington*.

Retrofit Considerations

Converting an existing pond to a bioretention facility will generally involve importing bioretention soil and developing individual or multiple shallow depressions (cells) with a maximum ponding depth of 10 or 12 inches. Most ponds will require some excavation to accommodate the required 18 inches of imported bioretention soil. The retrofit may also involve adjusting the outlet pipe or modifying the outlet control structure to meet the design ponding depth. Following is a list of implementation actions that may be involved with conversion of a pond to a bioretention facility:

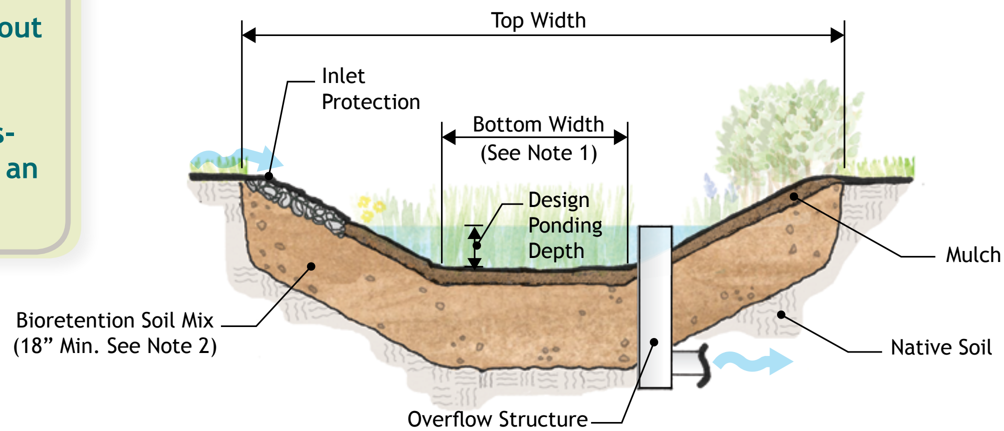
Earthwork	Excavation may be required to accommodate the required 18 inches of bioretention soil depth. If the facility consists of a series of cells, earthen or other berms will be required to separate the cells.
Outlet Modifications	The outlet pipe may need to be lowered or other modifications made to the outlet control structure to meet the design ponding depth (maximum of 10 or 12 inches).
Bioretention Soil	The bioretention soil will need to be tested to ensure that it meets the proper specifications for organic content, cation exchange capacity, and infiltration rate (based on the current version of the *Stormwater Management Manual for Western Washington*).
Infiltration Rate	The native soil infiltration rate should also be assessed using a Pilot Infiltration Test (PIT) or a modified PIT to determine the infiltration capacity of the soils underlying the proposed bioretention facility.
Drawdown Time	Ponded water should infiltrate within 24 hours of the end of a storm.
Bioretention Vegetation Planting	Vegetation is essential to the proper functioning of the bioretention facility. Shrubs and grasses that can withstand short periods of partial inundation as well as drought conditions should be selected for the facility. Refer to *Appendix D* for a list of plant species native to Kitsap County and planting details.

The following examples of bioretention retrofit conceptual drawings for pond sites in Kitsap County are found in *Appendix C*:

- #76 - Southwood- bioretention cell without an underdrain
- #92 - Silverhill Estates- bioretention cell with an underdrain

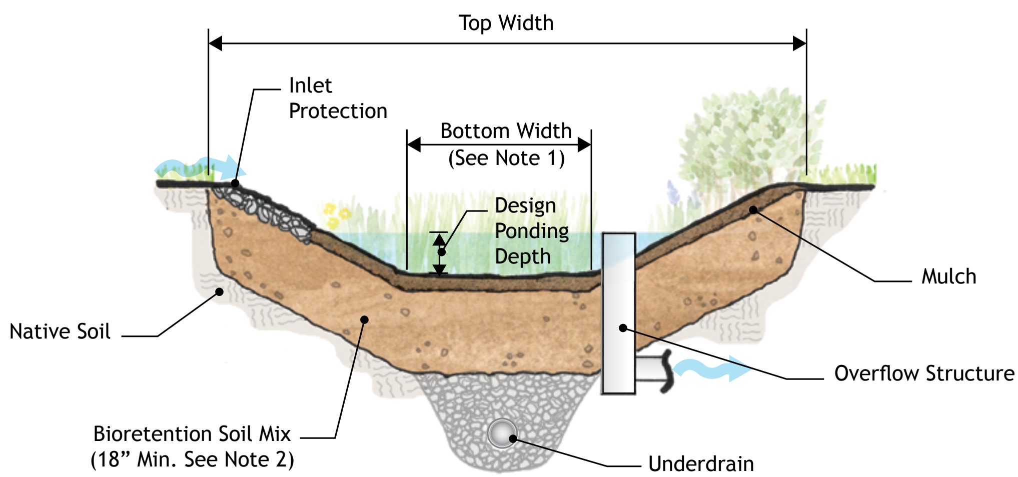
Conceptual Drawings

The following illustrations provide examples of a bioretention cell without an underdrain and a bioretention cell with an underdrain.



Notes:
1. Bottom width shall be a minimum of 2 feet and bottom area shall be flat (0% slope).
2. Imported bioretention soil shall meet City of Seattle specifications.

Bioretention Cell Sized for Treatment.



Notes:
1. Bottom width shall be a minimum of 2 feet and bottom area shall be flat (0% slope).
2. Imported bioretention soil shall meet City of Seattle specifications.

Bioretention Cell With Underdrain.

Design Standards

Guidance for bioretention design in Kitsap County is found in the *Low Impact Development (LID) Guidance Manual – A Practical Guide to LID Implementation in Kitsap County* (Kitsap Home Builders Foundation 2009).

In order to support a consistent bioretention soil standard for Western Washington, the *LID Guidance Manual* recommends the use of the bioretention soil specification developed by the City of Seattle. For other locations in Western Washington, guidance for designing bioretention can be found in Volume V of the *Stormwater Management Manual for Western Washington* and the *Low Impact Development Technical Guidance Manual for Puget Sound*.

Maintenance Considerations

Maintenance considerations for bioretention facilities primarily address soil and plant maintenance. A maintenance checklist for a bioretention facility is included in the *Kitsap County Stormwater Design Manual* and the *Stormwater Management Manual for Western Washington*. Vegetation maintenance considerations can be found in Appendix D of this manual.

Soil Maintenance

Bioretention soil mixes are designed for long-term effectiveness and should have a lifespan of at least 20 years unless heavy metal deposition is observed at the site (PSAT 2005). Mulch replacement, however, is a critical component of soil maintenance to ensure a continuous supply of organic matter is available. Mulch should be replaced as needed (typically once every 2 years) to maintain a 2- to 3-inch mulch depth in the bioretention facility (Seattle 2009). The recommended type of mulch is a leaf litter and arborist wood chip mulch (Seattle 2009). Mulch that includes isolated parts of trees (i.e., beauty bark, fir bark mulch, washed play chips) can negatively impact bioretention systems and should not be used (Seattle 2009).

Plant Maintenance

Plants selected for bioretention facilities should be watered during establishment (2 to 3 years), but should be drought tolerant and not require ongoing irrigation after establishment, except during prolonged dry periods (PSAT 2005). Additional required maintenance for bioretention facilities includes occasional pruning, removal of dead plant material, and periodic weeding (less frequent once plants are established). Fertilizer and pesticides are not required or recommended since they may degrade the pollutant processing capability of the bioretention facility as well as degrade receiving waters (PSAT 2005).

Planning Level Cost Estimate

A list of unit cost line items that could potentially be included in a bioretention retrofit project is included in *Appendix F* of this manual.

Pond Expansion

Applications

Existing stormwater ponds can be expanded in one of two ways: by increasing the depth of water or increasing the surface area. Both methods increase the storage volume of the pond, and can improve runoff treatment effectiveness.

Unit Treatment Processes

Deepening the pond can improve the sedimentation function of the pond. Expanding the pond area can also improve the sedimentation function, as well as increase the exposure of stormwater to soil and vegetation. This provides secondary benefits of improving filtration, biological uptake, adsorption, sorption, cation exchange, and anion exchange.

Limitations

Available site area is the primary limitation to expansion of the pond surface area. If no additional land area is available to expand the surface area, expansion may only occur by deepening. Pond area and side slopes are also a limitation to pond deepening, as smaller ponds may have little area for added excavation while still maintaining required embankment side slopes. Deepening a pond can also be accomplished with use of walls and other steep slope stabilization methods, but will require fencing above the walled/steepened section.

Integrated Solution

Additional retrofit options should be considered in combination with pond expansion to provide an even greater level of pollutant removal performance. Retrofit options that may work well with pond expansion include:

- Outlet Modification (to further increase wet pool storage volume)
- Configuration Change (to increase the flow path through the pond)
- Vegetation Improvement (to improve filtration and biological uptake processes)

Retrofit Considerations

Pond expansion will require earthwork associated with deepening the pond or expanding the pond footprint area. Following is a list of implementation actions that may be involved with pond expansion:

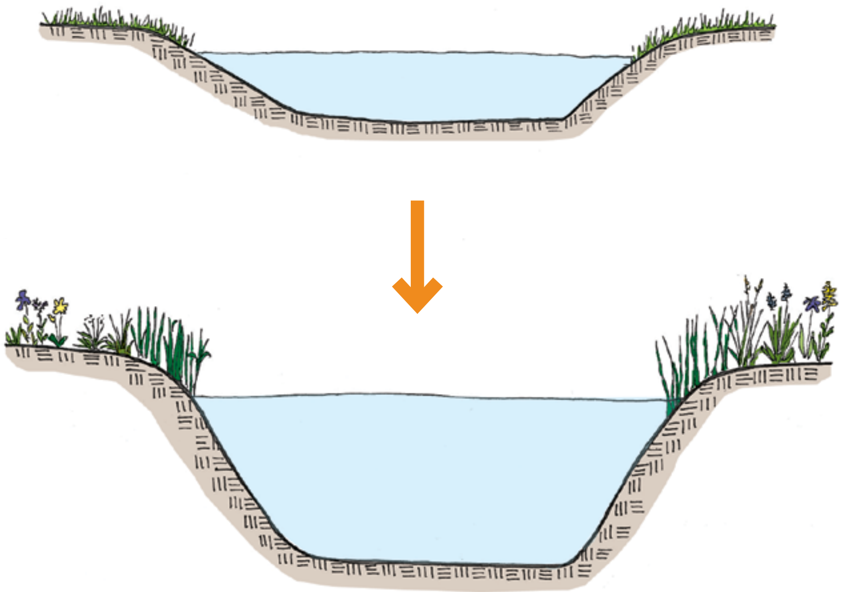
Earthwork	Excavation will be required to deepen the pond or expand the pond footprint Embankments may need to be constructed or modified to contain the expanded pond water surface area Balance excavation and fill if possible to reduce the cost associated with material import or haul and disposal.

Conceptual Drawings

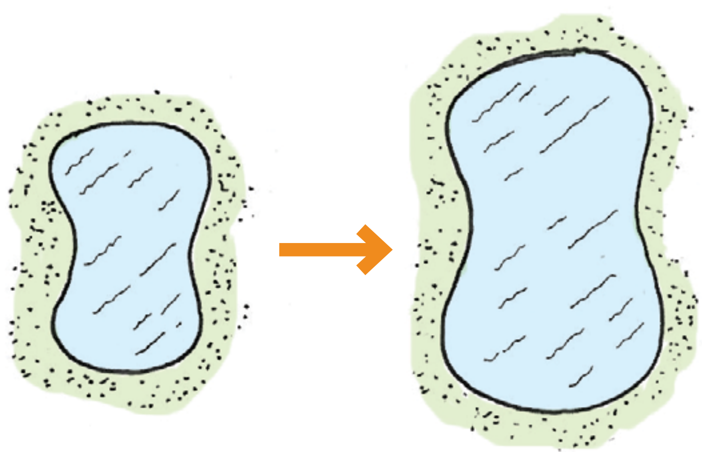
The following illustrations provide examples of before and after conditions for a deepened pond and an expanded pond footprint area.

An example of a pond expansion retrofit design provided in *Appendix C* where the pond area and pond depth were increased is:

- #540 - Fairgrounds



Excavating the pond bottom.



Expanding the pond footprint.

Design Standards

To ensure retrofits are designed to current standards, guidance for designing wet ponds can be found in the *Kitsap County Stormwater Design Manual* and Volume V of the *Stormwater Management Manual for Western Washington*.

Maintenance Considerations

A maintenance checklist for a wet pond is included in the *Kitsap County Stormwater Design Manual* and in Volume V of the *Stormwater Management Manual for Western Washington*.

Planning Level Cost Estimate

A list of unit cost line items that could potentially be included in a pond expansion retrofit project is included in *Appendix F* of this manual.

Pond Outlet Modification

Applications

A variety of outlet modifications can be incorporated into a pond retrofit design including, but not limited to, the following:

- Raising the outlet pipe invert elevation
- Reducing water depth below the outlet pipe invert elevation
- Constricting the low flow outlet
- Replacing the outlet control structure

Unit Treatment Processes

Deepening the pond by raising the elevation of the outlet pipe can improve the sedimentation function of the pond. Creating a shallower pond by lowering the outlet pipe invert elevation or raising the pond bottom can be beneficial for converting a pond to a wetland or a bioretention facility where a shallower ponding depth is a requirement of the design guidelines. Constricting the low flow outlet will increase the pond's water retention time and may facilitate conversion of the pond to a wetland system with a slower release rate. The outlet control structure may need to be replaced if it has been damaged, is difficult to maintain, or would need to be altered so significantly for the retrofit that the cost is less to replace it entirely.

Limitations

Due to the variety of outlet modifications that can be implemented, there are few, if any, limitations to incorporating this retrofit option into a pond retrofit design.

Integrated Solution

Modifying the outlet of a stormwater pond can improve stormwater unit treatment processes; however, additional retrofit options should be considered in combination with outlet modification. Retrofit options that may work well with outlet modification include:

- Wetland Conversion
- Bioretention
- Infiltration
- Pond Expansion

Retrofit Considerations

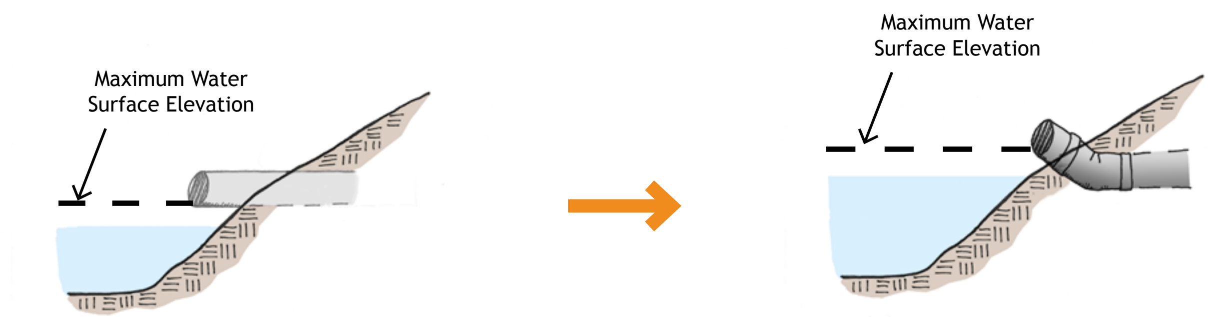
Outlet modifications will most likely require some earthwork in combination with modifications to the outlet pipe and/or outlet control structure. Following is a list of implementation actions that may be involved with outlet modifications:

Earthwork	Excavation may be required to adjust the existing outlet pipe or install a new outlet control structure and/or outlet pipe.
Outlet Modifications	The outlet pipe may need to be raised or lowered to adjust the pipe invert elevation. Modifications and/or replacement of the outlet control structure may also be necessary.

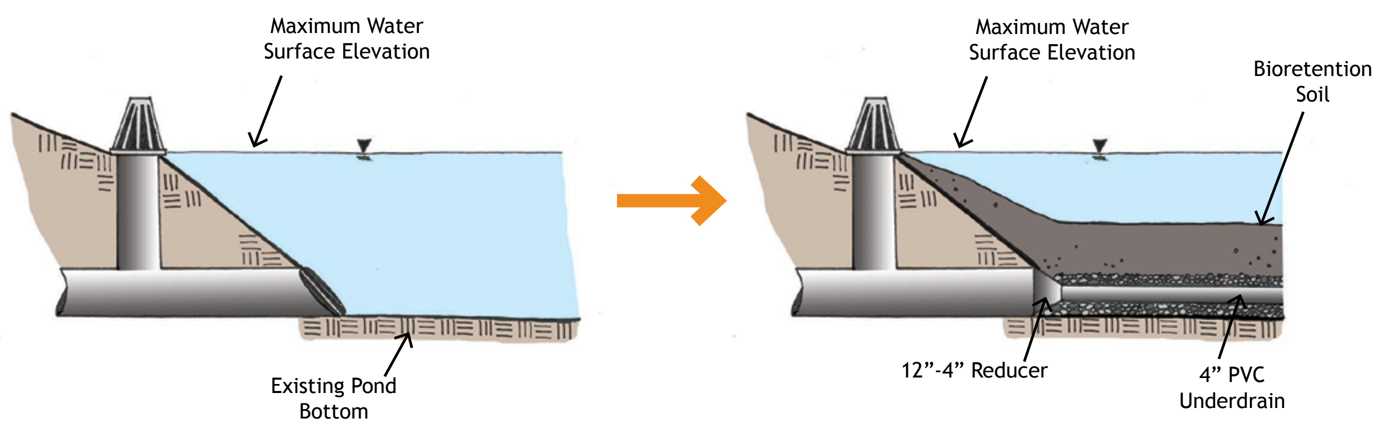
Examples of pond outlet modification conceptual drawings for Kitsap County are found in *Appendix C*:

- #76 - Southwood- raising the outlet pipe invert elevation
- #92 - Silverhill Estates- incorporating the existing outlet pipe into the retrofit design
- #114- Wilshire Div. 1 & 2- modifying the outlet by keeping the existing outlet control structure and adding a new outlet control structure

Conceptual Drawings



Raising the outlet pipe invert elevation.



Incorporating the existing outlet pipe into the retrofit design (bioretention with underdrain example).

Design Standards

Guidance for designing wet ponds in Kitsap County is found in the *Kitsap County Stormwater Design Manual* and in Volume V of the *Stormwater Management Manual for Western Washington*.

Maintenance Considerations

A maintenance checklist for a wet pond is included in the current version of the *Kitsap County Stormwater Design Manual* and in Volume V of the *Stormwater Management Manual for Western Washington*.

Planning Level Cost Estimate

A list of unit cost line items that could potentially be included in an outlet modification retrofit project is included in Appendix F of this manual.

Configuration Change

Applications

The configuration of an existing pond can be modified in one of two ways: 1) converting a single-celled pond to a multi-celled pond or 2) increasing the flow path. Both methods increase the retention time of water in the pond, and can improve treatment effectiveness.

Unit Treatment Processes

Creating a multi-celled pond or increasing the flow path through a pond can improve the sedimentation function of the pond. Increasing the amount of time that stormwater is exposed to soil and vegetation through either of these configuration changes can also improve adsorption, sorption, cation exchange, and anion exchange.

Limitations

There are few limitations, if any, to configuration changes since this type of pond retrofit can be incorporated within the existing pond footprint. If the pond footprint cannot be expanded during the retrofit design incorporation of a berm to convert the pond into a multi-celled pond or to create a more sinuous flow path will likely result in a loss of storage volume. The improved stormwater treatment provided by the remaining storage volume may outweigh the storage loss in terms of overall water quality.

Integrated Solution

Conversion to a multi-celled pond or increasing the flow path in a pond can improve stormwater treatment effectiveness; however, additional retrofit options should be considered in combination with configuration change to provide an even higher level of treatment. Retrofit options that may work well with configuration change include:

- Pond Expansion
- Pond Outlet Modification

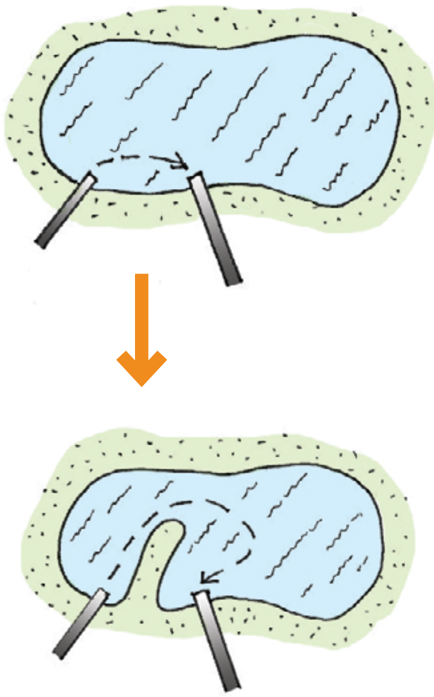
Retrofit Considerations

If the retrofit design involves constructing an earthen berm to divide the pond into multiple cells or increase the flow path, material could be taken from the base of the pond by excavating to increase the pond depth or by creating a settling basin at the pond inlet. Other materials could be used to create a berm, such as jersey barriers or ecology blocks, but may result in increased construction costs and degraded aesthetics. Following is a list of potential implementation actions involved with configuration change:

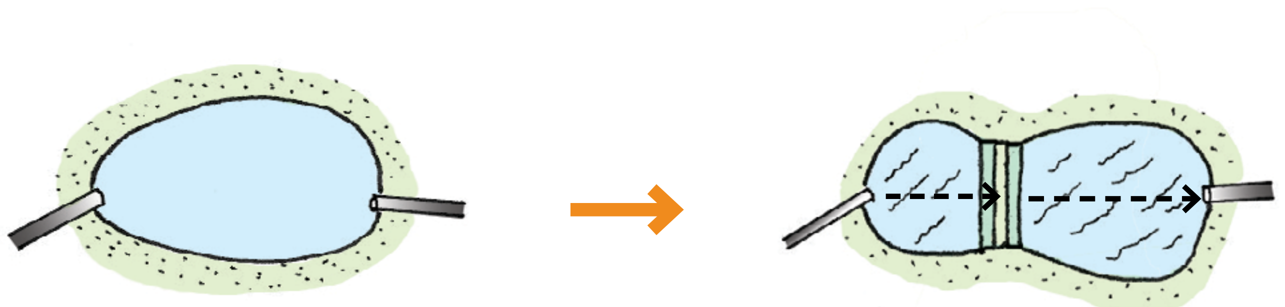
Earthwork	Excavation may be required to create a settling basin near the pond inlet and to obtain material for constructing an earthen berm. Excavation and fill placement should be balanced if possible to reduce the cost associated with material import or haul and disposal.

Conceptual Drawings

The following illustrations provide examples of before and after conditions for increasing the flow path and conversion to a two-celled pond.



This pond adds a berm in order to increase the flow path of water through the pond.



This pond was converted to a two-celled pond by excavating along the perimeter and adding a berm to create two cells.

Examples of configuration change conceptual drawings can be found in *Appendix C*.

An example of increasing the flow path through installation of a berm:

- **#116 - Burley Estates**

An example of a conversion from a single cell to multiple cell configuration. In this case, the original pond was designed with two cells, but site inspection showed only one was constructed.

- **#193 - Harbor Lights**

Design Standards

Guidance for designing wet ponds can be found in the *Kitsap County Stormwater Design Manual* and in Volume V of the *Stormwater Management Manual for Western Washington.*

Maintenance Considerations

A maintenance checklist for a wet pond is included in the *Kitsap County Stormwater Design Manual* and in Volume V of the *Stormwater Management Manual for Western Washington*.

Planning Level Cost Estimate

A list of unit cost line items that could potentially be included in a configuration change retrofit project is included in *Appendix F* of this manual.

Vegetation Improvement

Vegetation improvement is a pond retrofit solution where a diversity of native herbaceous, shrub, and tree species are planted to replace vegetation communities dominated by non-native grass and forbs or that are a monoculture (comprised primarily of one species). Vegetation improvement may also create or enhance wildlife habitat and improve the aesthetics of a stormwater pond. This section provides a brief overview of vegetation improvements as a pond retrofit solution. Additional detail regarding planting design, establishment, and maintenance along with a plant list can be found in *Appendix D*.

Applications

Vegetation improvement can be applied to any above-ground stormwater facility with existing vegetation or conditions allowing for plant growth.

Unit Treatment Processes

Vegetation improvement uses plant species diversity to reduce flow velocity that in turn improves sedimentation function, root structures to increase infiltration, and enhanced mechanisms for biological uptake of dissolved pollutants. Dense, healthy vegetation will provide more effective filtration and biological uptake in a stormwater facility.

Limitations

There is a potential for nutrient release in late fall and early winter when plants become senescent and their above ground organic material decomposes. Over time the hydraulic capacity of the facility may be reduced due to plant overgrowth if plant maintenance is not performed, and/or if a planting plan is not carefully crafted to reduce the potential for this to occur.

Integrated Solution

Additional retrofit options should be considered in combination with vegetation improvement. Retrofit options that may work well with vegetation improvements include all of the other retrofit options discussed in this manual:

- Wetland Conversion
- Bioretention
- Pond Expansion
- Pond Outlet Modification
- Configuration Change
- Infiltration
- Multiple Uses
- Subsurface Gravel Wetland

Retrofit Considerations

Following is a list of implementation actions that may be involved with vegetation improvement:

Soil Amendments	Evaluate soil to determine if amendments are needed. Vegetation improvement may require importing topsoil or adding compost to amend the native material.
Vegetation Planting	Establish vegetation appropriate for the soil, light, and hydrologic conditions of the site. Refer to *Appendix D* for a list of plant species native to Kitsap County and planting details.

Conceptual Drawings

Examples of vegetation improvement conceptual drawings are found in *Appendix C* and include the following Kitsap County pond sites:

- #114 - Wilshire Div. 1 & 2
- #540 - Fairgrounds

Design Standards

Minimal guidance on vegetation is provided in the *Kitsap County Stormwater Design Manual* and the *Stormwater Management Manual for Western Washington*. More detailed guidance on planting design can be found in *Appendix D* of this manual.

Maintenance Considerations

Vegetation maintenance considerations are presented in *Appendix D* of this manual.

Planning Level Cost Estimate

A list of unit cost line items that could potentially be included in a vegetation improvement project is included in *Appendix F* of this manual.

Photo 24. This pond provides an example of how to utilize a diversity of native herbaceous, shrub, and tree species to improve water quality while blending the site in with the surrounding neighborhood context.

Infiltration

Infiltration ponds retain stormwater and allow the water to percolate to groundwater through porous subsurface soils.

Applications

Infiltration retrofits can be used to create or increase a pond's ability to infiltrate a large proportion of the inflowing stormwater runoff into the ground. This can be accomplished by converting a pond to a bioretention facility (discussed in the Bioretention conceptual design section above), amending the existing soils to increase the organic content and infiltration capacity, or loosening dense, compacted soils to promote infiltration.

Unit Treatment Processes

Infiltration retrofits can improve adsorption, sorption, anion exchange, and cation exchange through amending site soils to increase the organic content, as well as improving the targeted infiltration function.

Limitations

Limitations to infiltration retrofits include poor (Class D) soils underlying the pond site, evidence of poor infiltration performance in the pond, and significant ponded water observed during the field assessment (for a pond that is supposed to drain "dry" in the hours and days following a storm). These are all pond characteristics that may not respond effectively to soil amendments. The presence of a shallow till layer may also inhibit infiltration. Setbacks from wellheads, on-site sewerage systems, basements, and foundations should also be evaluated to determine if infiltration is a feasible retrofit option.

Other limitations to infiltration retrofits include areas with steep slopes, contaminated soils, and land uses such as maintenance facilities and gas stations where potential stormwater contamination could be a concern (Kitsap Home Builders Foundation 2009).

Integrated Solution

Additional retrofit options should be considered in combination with infiltration. Retrofit options that may work well with infiltration include:

- Pond Outlet Modification
- Configuration Change
- Multiple Uses
- Vegetation Improvement

Retrofit Considerations

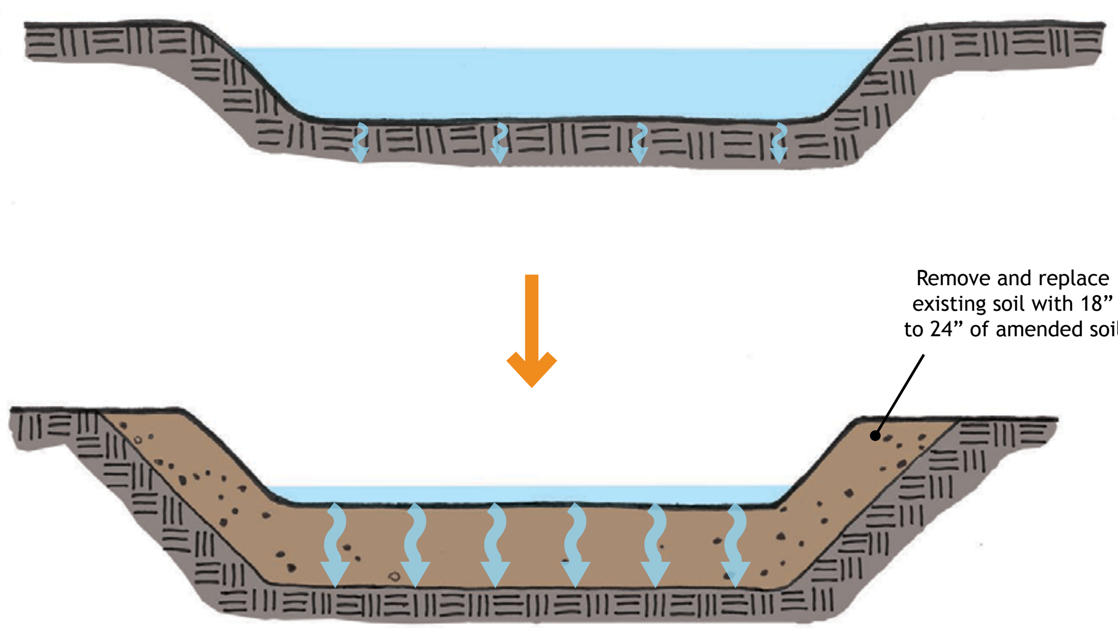
Amending the existing soils to increase the organic content will generally involve tilling in compost and/or mulch into the bottom and side slopes of the pond. Loosening dense, compacted soils to promote infiltration will generally involve using a rotary hoe or row cultivator to disrupt the surface crust. Most ponds will require some excavation to accommodate the required 18 to 24 inches of amended soil depth to meet the requirements for infiltration treatment. If a shallow till layer is observed, punching through the till layer can be evaluated as a retrofit option.

Following is a list of implementation actions that may be involved with infiltration retrofits:

Earthwork	Excavation may be required to accommodate the required 18 to 24 inches of amended soil.
Amended Soil	The amended soil will need to be tested to ensure that it meets the requirements for infiltration treatment.
Infiltration Rate	The native soil infiltration rate should be assessed using a PIT test or a modified PIT test to determine the infiltration capacity of the soils underlying the pond.
Groundwater Monitoring	If it is uncertain whether shallow groundwater could impede infiltration, groundwater depth monitoring should be conducted. This monitoring should focus on the wet season (October through April).
Vegetation Planting	Sufficient vegetation should be established on the pond bottom and side slopes to prevent erosion and sloughing. Refer to *Appendix D* for a list of plant species native to Kitsap County and planting details.

Conceptual Drawings

The following illustration provides an example of before and after conditions for a pond that is retrofitted to infiltrate a greater amount of the inflowing runoff.



The infiltration capacity of this pond was enhanced by removing and replacing the existing soil with amended soil.

Design Standards

Guidance for designing infiltration ponds can be found in the *Kitsap County Stormwater Design Manual* and in Volume III of the *Stormwater Management Manual for Western Washington*.

Additionally, infiltration retrofits shall meet the Site Suitability Criteria (SSC) specified in Volume III of the *Stormwater Management Manual for Western Washington*. SSC-6 (Soil Physical and Chemical Suitability for Treatment) applies specifically to infiltration facilities used for stormwater treatment and includes the following soil property requirements for amended soils:

- Minimum cation exchange capacity (CEC) of 5 milliequivalents (meq) per 100 grams dry soil
- Minimum depth of soil of 18 inches
- Minimum organic content of 0.5 percent

Kitsap County requires the same minimum CEC and organic content in the *Kitsap County Stormwater Design Manual*, but requires a minimum soil depth of 24 inches for infiltration facilities.

Maintenance Considerations

A maintenance checklist for an infiltration facility is included in the *Kitsap County Stormwater Design Manual*. Vegetation maintenance considerations can be found in *Appendix D* of this manual.

Planning Level Cost Estimate

A list of unit cost line items that could potentially be included in an infiltration retrofit project is included in *Appendix F* of this manual.

Multiple Uses

Multiple uses can be provided where a stormwater pond or constructed wetland is designed or retrofitted to provide other uses in addition to stormwater management functions. A pond or constructed wetland can be integrated into a park, open-space, or outdoor recreation facility. Thoughtful landscape design can incorporate park-like amenities such as recreational trails, benches, educational signage, wildlife viewing areas, and improved aesthetics into retrofit stormwater facilities. The design goals and opportunities of each facility will depend on the unique site conditions, surrounding context, and community interests.

Many stormwater ponds include fencing around the pond perimeter to block the view of the facility or keep people away from steep slopes and standing water. If fencing is present at a pond site, consider removal or, if fencing is required by the *Kitsap County Stormwater Design Manual*, consider a more aesthetically pleasing fence design. An example of creating a multiple-use retrofit would be to flatten steep slopes to allow fence removal and add a mix of plant types (herbs, shrubs, and trees) to better blend the pond into the surrounding landscape.

Applications

Multiple uses can potentially be accomplished with any of the pond retrofit options discussed in this manual, and are especially suited to facility locations in neighborhoods or districts where additional green space is desirable. Creating public amenities can also increase community ownership of ponds and constructed wetlands and may create a sense of stewardship and pride. Multiple uses can be especially effective where there is connectivity between the pond location and other natural areas, thus increasing opportunities for people to connect to nature, and allowing wildlife to move to other habitats.

Unit Treatment Processes

Multiple uses are typically associated with vegetation improvement, which can increase the effectiveness of infiltration, filtration, and biological uptake. Infiltration is improved through incorporating a diversity of plant species with varying depth of root systems which provide conduits for water infiltration. In addition, a diversity of plant species increases overall biological uptake as different species are capable of taking up different constituents more or less effectively.

Limitations

The limitation for a multiple-use pond retrofit is predominantly having sufficient space for safe public access to the site. If promoting greater public access to, and use of, a pond site would encourage criminal activity, then this type of retrofit should not be pursued unless other measures are taken in the site area to discourage such activity.

Integrated Solution

Retrofit options that may work well with multiple uses include:

- Wetland Conversion
- Bioretention
- Pond Expansion
- Configuration Change
- Vegetation Improvement
- Subsurface Gravel Wetland

Retrofit Considerations

Following is a list of implementation actions that may be involved with a multiple use retrofit:

Earthwork	Excavation and fill may be needed to create a variety of habitat types and "spaces" for user experience.
Public Use Features	A walking trail, bench(es), and/or unique signage may be desirable as part of a multiple-use retrofit. Each of these features could require engaging the local community for their input in the design process to enable the best results.
Vegetation Planting	Establish vegetation appropriate to the soil, light, and hydrologic conditions of the site. Refer to Appendix D for a list of plant species native to Kitsap County and planting details.

Conceptual Drawings

An example of a Kitsap County pond site retrofit design to accommodate multiple uses is the following in *Appendix C*:

- **#460 - Blueberry Meadows**

Conceptual Drawings

Trails can be incorporated into the pond design as shown in the following design detail:

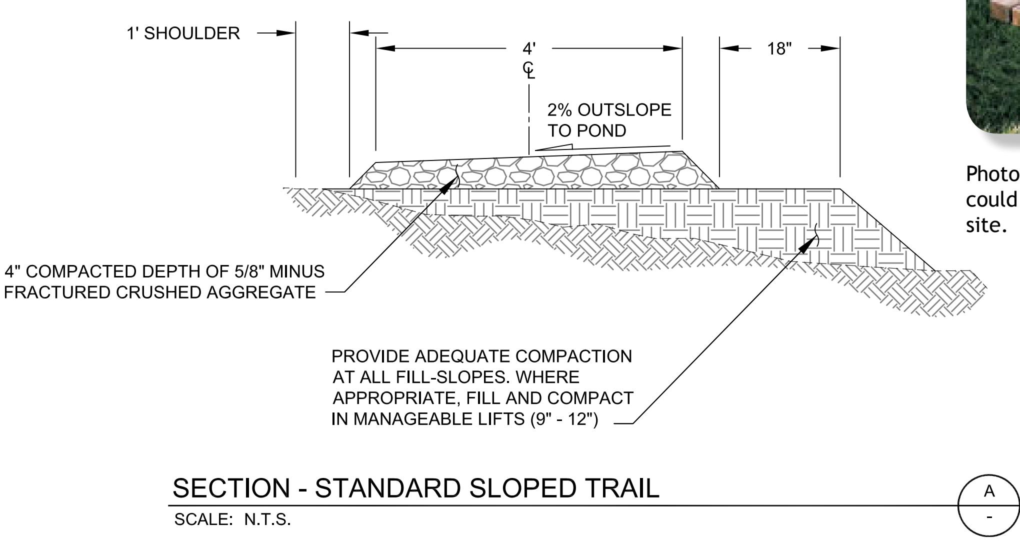


Photo 25. An example of a park bench that could be installed at a multiple use pond site.

Design Standards

Design standards that may apply to a multiple-use retrofit will vary depending on the unique features included in the retrofit design. The local authority should be contacted in advance of developing the retrofit design to confirm if any particular standards apply. For example the designs for trails or signage often have different design parameters depending on the retrofit location. Standard bench and trail sections such as those developed by Seattle Parks and Recreation Department (Seattle 2011) can be incorporated into a pond retrofit design.

Maintenance Considerations

Maintenance for multiple-use stormwater facilities may include inspection and maintenance of trails, benches, wildlife viewing platforms, and any other amenities included in site design. Vegetation maintenance considerations can be found in *Appendix D* of this manual.

Planning Level Cost Estimate

A list of unit cost line items that could potentially be included in a multiple-use pond retrofit project is included in *Appendix F* of this manual.

Photo 26. An example of incorporating public use and metal sculptural walls into a commercial stormwater facility landscape.

Photo 27. Public art in a stormwater swale.

Subsurface Gravel Wetland

Subsurface gravel wetlands are a relatively new type of stormwater treatment facility that has not yet been broadly implemented in the Pacific Northwest or elsewhere in the United States. Pilot installations of these types of facilities have shown great promise for effective stormwater pollutant removal and are also visually attractive.

Applications

A subsurface gravel wetland includes a sedimentation basin (forebay) and two horizontal flow-through wetland treatment cells. The soils in the wetland cells are designed to be continuously saturated and are underlain by a minimum of 24 inches depth of crushed stone The crushed stone shall have a nominal size distribution between 3/4-inch and 2 inches. Subsurface gravel wetlands are applicable in many settings since there is a limited hydraulic head requirement (approximately 4 inches), the wetland cells can be lined and do not require separation from groundwater. This type of treatment system can be easily placed within the footprint of existing stormwater ponds (UNHSC 2009).

Unit Treatment Processes

Unit treatment processes that occur in a subsurface gravel wetland include sedimentation; filtration and biological uptake; and adsorption, sorption, cation exchange, and anion exchange (UNHSC 2009).

Limitations

There are few restrictions to where subsurface gravel wetlands can be installed since they can fit within the footprint of a typical stormwater pond, and they have a decreased reliance on the native soils for infiltration capacity and treatment.

Integrated Solution

Additional retrofit options that may be considered in combination with subsurface gravel wetlands include:

- Pond Expansion
- Pond Outlet Modification
- Configuration Change
- Multiple Uses
- Vegetation Improvement

Conceptual Drawings

The following subsurface gravel wetland conceptual drawing example for a Kitsap County pond site is included in *Appendix C*:

- #114 - Wilshire Div. 1 & 2

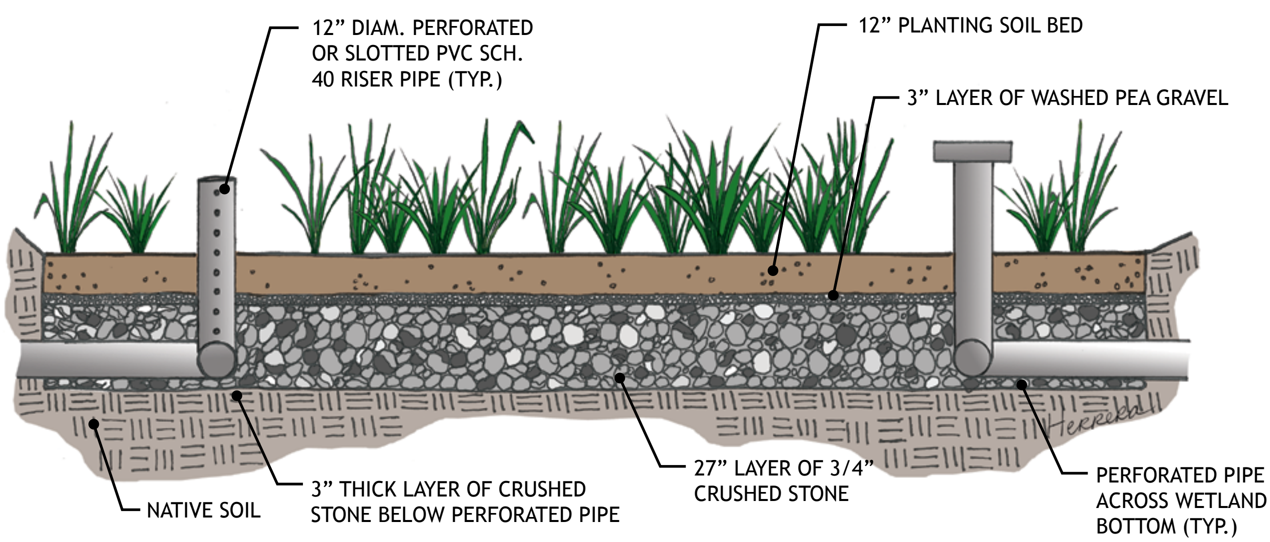
Retrofit Considerations

Converting an existing pond to a subsurface gravel wetland may involve earthwork, outlet modifications, imported treatment media, and vegetation planting. Following is a list of implementation actions that may be involved with conversion of a stormwater pond to a subsurface gravel wetland:

Earthwork	Excavation may be required to accommodate the various subsurface layers required for the subsurface gravel wetland design.
Outlet Modifications	The outlet pipe or spillway may need to be lowered or other modifications made to the outlet control structure to maintain a 4-inch vertical difference between the bottom of the wetland soil and the outlet invert elevation.
Imported Material	The wetland soil will need to be tested to ensure that it meets the proper specifications.
Vegetation Planting	Vegetation is essential to the proper functioning of the subsurface gravel wetland. Refer to *Appendix D* for a list of wetland plant species native to Kitsap County and planting details.

Conceptual Drawings

The following design detail provides an example of a gravel wetland cell.



Design Standards

Guidance for subsurface gravel wetland design is found in the NJ Stormwater Management Best Management Practices Manual (New Jersey 2011) and the *UNHSC Subsurface Gravel Wetland Design Specifications* (UNHSC 2009).

Maintenance Considerations

Maintenance considerations for subsurface gravel wetlands are included in the *UNHSC Subsurface Gravel Wetland Design Specifications* (UNHSC 2009) and the NJ Stormwater Management Best Management Practices Manual (New Jersey 2011), and are also summarized in *Appendix E* of this manual. Maintenance concerns specific to subsurface gravel wetlands that differ from typical pond maintenance include plant and gravel bed maintenance.

Plant Maintenance

The outlet control structure associated with a subsurface gravel wetland typically has an adjustable outlet to allow for the initial establishment of vegetation (New Jersey 2011). Once the vegetation has been established, the outlet control structure must be adjusted to maintain the water elevation at four inches above the bottom of the wetland soil.

Since this treatment technology does not use mulch (like bioretention and other stormwater treatment facilities), establishment of a dense root mat over a minimum of 85 percent of the subsurface gravel wetland is necessary for the treatment system to operate as designed (New Jersey 2011, UNHSC 2009).

During the first growing season following construction, plants will likely need to be watered as necessary (New Jersey 2011). Vegetated areas with greater than 50 percent damage must be reestablished in accordance with the original specifications. Vegetation deficiencies should be addressed without the use of fertilizers and pesticides whenever possible.

Additional vegetation maintenance considerations can be found in *Appendix D* of this manual.

Gravel Bed Maintenance

Sediment should be removed when accumulations reach a depth of several inches across the wetland surface (UNHSC 2009). Sediment should be removed using rakes rather than heavy equipment to avoid compaction.

Planning Level Cost Estimate

A list of unit cost line items that could potentially be included in a subsurface gravel wetland retrofit project is included in *Appendix F* of this manual.

REFERENCES

CTDEP. 2004. Connecticut Stormwater Quality Manual. Developed by the Connecticut Department of Environmental Protection. Hartford, CT.

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* References designated with an asterisk were used to prepare this manual; however, these manuals are either in the process of being updated or are expected to be updated in the next few years. Users should refer to the most current versions of these manuals for guidance regarding unit treatment processes and pond retrofits.

APPENDIX A

Field Assessment Checklist

Field Assessment Checklist

Inspector(s): ______________________
Date and Time of Field Visit: ______________________

Existing Pond Information

Pond number:		
Pond name:		
Pond location (intersection or subdivision name):		
Receiving water:		
Drains directly to receiving water?	Y / N	
Other BMPs onsite?	Y / N	
Maintenance issues?	Y / N	
Design deficiency issues?	Y / N	
Prioritization	0 / 1 / 2	
High visibility?	Y / N	

Land Use in Drainage Basin

Land Use Type	Percent Drainage Area	Description/Comments
Residential		
Commercial		
Other		

Unit Treatment Processes

Process	Score	Criteria	Reason for Assigning Score
Sedimentation	1	Properly designed and maintained pond with some dead storage capacity	
	2	Inadequately maintained pond and/or no dead storage capacity	
	3	Poorly designed, inadequately maintained pond, and/or no dead storage capacity	
Filtration and Biological Uptake	1	High vegetation density, diverse and healthy plant community	
	2	Moderate vegetation density	
	3	Low vegetation density, unhealthy plant community	
Adsorption, Sorption, Anion Exchange, and Cation Exchange	1	Maximum exposure of water to soil	
	2	Moderate exposure of water to soil	
	3	Minimal exposure of water to soil	
Infiltration	1	Highly permeable soils, no liner, no standing water in pond	
	2	Moderately permeable soils	
	3	Low permeable soils, liner, standing water in pond	

Vegetation and Aesthetic Assessment

Observation	Score	Criteria	Reason for Assigning Score
Invasive Vegetation Presence and Dominance	1	Little to no invasive species or undesirable vegetation present, intended plant community intact	
	2	Moderate invasive species presence and cover	
	3	Invasive species dominate pond and/or surrounding area	

Aesthetics (Field Notes and Observations)

Retrofit Feasibility Assessment

Question	Yes/No	Examples	Notes
Potential for excavating pond bottom?	Y / N	Dry, flat pond bottom with no evidence of standing water	
Potential for raising the pond embankment?	Y / N	Available space at the toe of the embankment to support a wider footprint, invert elevation of pond inlet pipes does not cause tailwater issues	
Potential for modifying outlet structures?	Y / N	Multiple riser outlets	
Potential for modifying the pond outlet riser?	Y / N	Large diameter low flow outlet, concrete riser with additional weir capacity, or oversized detention pond	
Potential for modifying internal design?	Y / N	Internal flow path can be extended, wetland elements can be added, or a forebay can be installed	
Space to expand pond/BMP footprint?	Y / N	Is the parcel large enough to accommodate an expansion?	
Evidence of shallow groundwater seepage in pond or nearby area?	Y / N	Potential for complications with excavation and pond expansion	
Is there space available onsite to stage construction materials and equipment for retrofit construction work?	Y / N	More space will mean easier construction	
Are there onsite utilities that could present conflicts with retrofit construction (buried and overhead)?	Y / N	Sanitary sewer, water lines, gas, phone, cable, electric, etc. Look for indicators such as sewer stacks, fire hydrants, electric box grates, overhead wires, gas meters, or cable boxes.	

Additional Notes:

APPENDIX B

Pre-Design Checklist

Pre-Design Checklist

Pond Number: ______________________

Pond Name: ______________________

Item/Information	Data	Notes
As-built drawing set		
Aerial photographs		
Year built		
Year retrofitted (if applicable)		
Contributing area		
Live storage capacity		
Dead storage capacity		
Total pond volume		
Soil type(s)		
Inlet elevation(s)		
Inlet pipe diameter(s)		
Outlet elevation		
Outlet type		
Live storage bottom elevation		
Dead storage bottom elevation (if applicable)		
Maximum water surface elevation		
Overflow elevation		
Receiving water		
Pollutants of concern in receiving water(s)		

Additional site notes

Pre-Design Checklist

Pond Number: ______________________

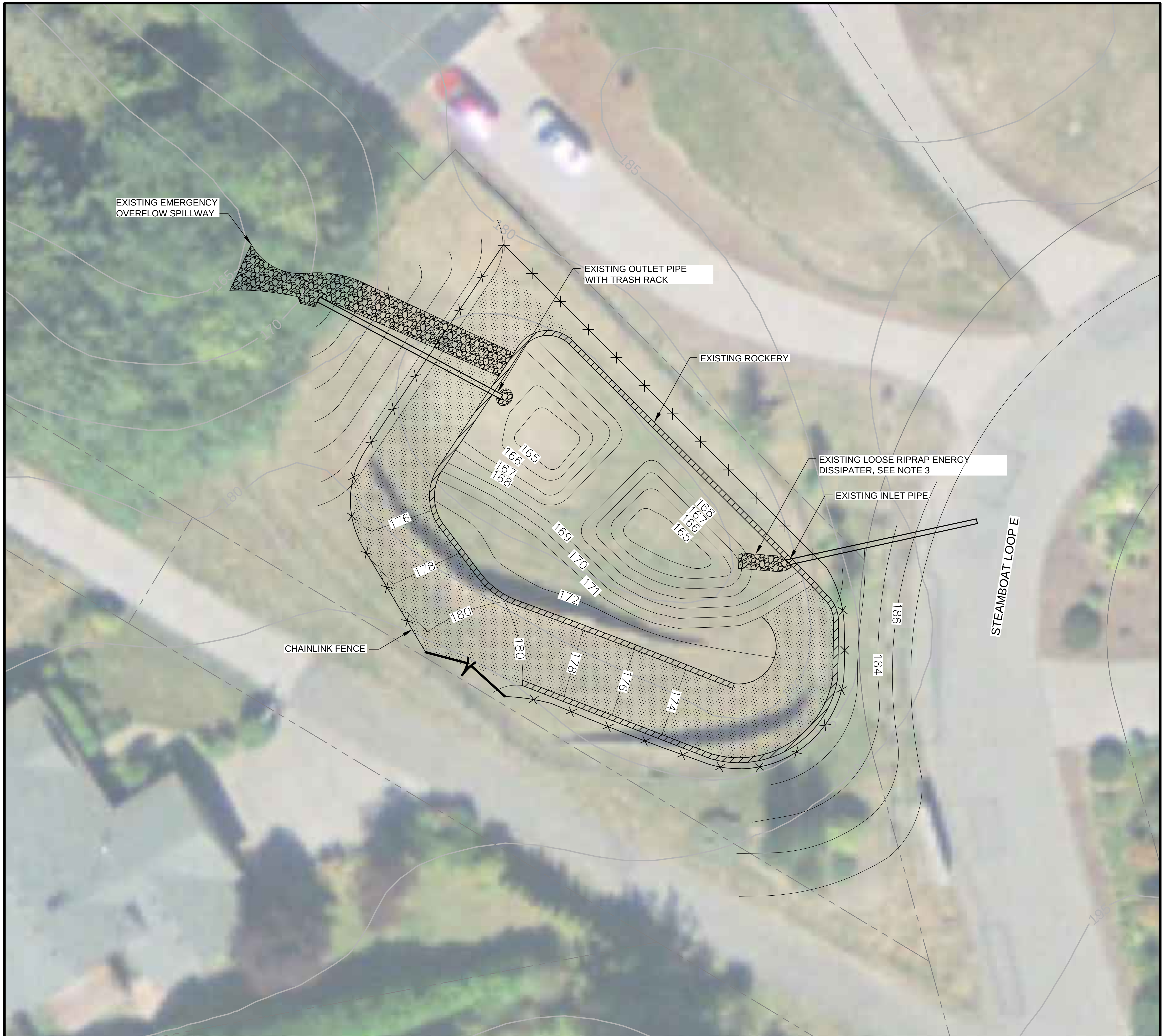
Pond Name: ______________________

Pre-Design Questions

Current vegetation type:	
Are there weeds or invasive species that need to be managed prior to retrofit?	
Are there native species present that can be protected, salvaged, or used on site?	
Pond location/surrounding context:	
Is the pond located within a commercial area, neighborhood, along a road margin, or public area?	
Is the pond located near a wetland, forest, meadow, lawns, or potential future weed source?	
Are there opportunities to blend the site in with its current surroundings or create a community amenity?	
Hydrologic conditions:	
Does the pond interact with groundwater?	
Where does the water come from and where does it go after leaving the site?	
Maintenance issues:	
Are there known maintenance issues with vegetation, human disturbance, environmental impacts, or improper functioning?	
Are there particular maintenance requirements or needs for this site in the future?	
Known design deficiencies:	
Are there any known design deficiencies (i.e., undersized pond, short circuiting)?	

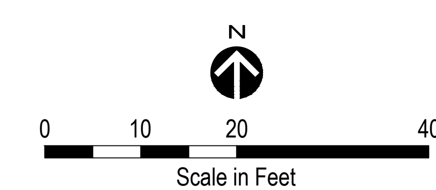
APPENDIX C

Conceptual Designs

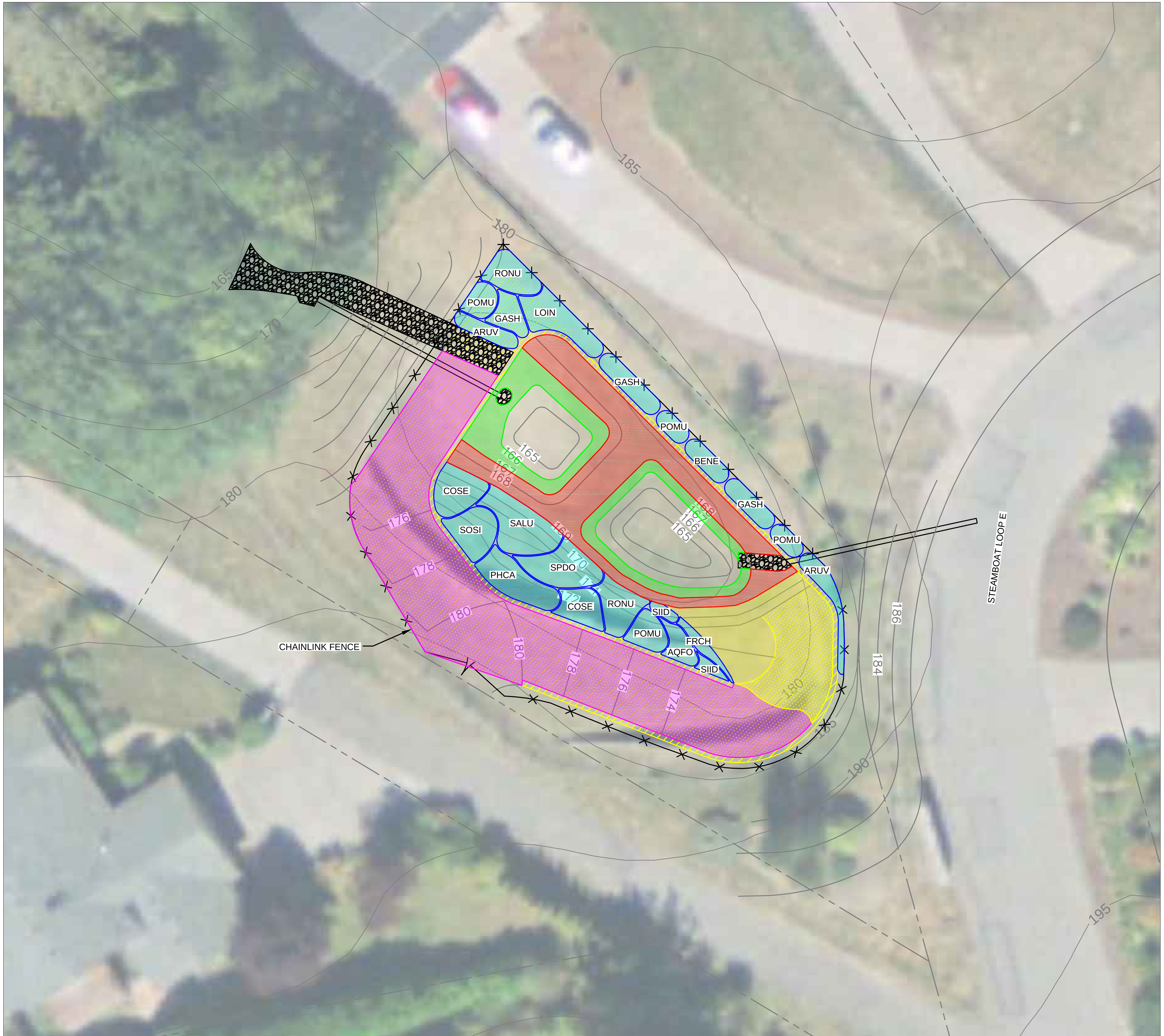


NOTES:

1. EXCAVATE POND BOTTOM AND SIDE SLOPES TO CONTOURS AS SHOWN.
2. PLACE RIPRAP IN SLOPED MANNER TO BOTTOM OF PIPE BARREL.



Pond 193 Retrofit Site Plan



LEGEND:

- KITSAP CO. UPLAND GRASS AND FORB SEED MIXES
- MOIST TO DRY PLANTING
- EMERGENT PLANTING
- WETLAND PLANTING
- GROUNDCOVER PLANTING

NOTES:

1. AREA SHOULD BE CLEARED AND GRUBBED TO REMOVE EXISTING VEGETATION PRIOR TO PLANTING.
2. SEEDING AND PLANTING SHOULD OCCUR BETWEEN SEPTEMBER 1 AND OCTOBER 1.
3. UPLAND GRASS SEED MIX ZONES CAN BE MOWED OR TRIMMED TO 4" HEIGHTS PRIOR TO DREDGING ACTIVITY, BUT SHOULD NOT BE MOWED DURING NON-DREDGING YEARS UNTIL LATE SUMMER/EARLY FALL, AFTER THE SEED HAS RIPENED AND RELEASED. PERENNIAL GRASSES PREFER NOT TO BE MOWED.

N

0 10 20 40

Scale in Feet

Pond 193 Planting Plan

Planting Schedule

Trees

Symbol	Latin Name	Common Name	Site Conditions	Mature Height	Wet Slopes (WS)	Dry Slopes (DS)	Top of Bank (TOB) or Upland (U)	Spacing On Center (O.C.)	Quantity
SALU	*Salix lucida var. lasiandra*	Pacific willow	Full sun. Moist, sand/gravelly soil. Flood tolerant.	40'	X	X	X	6'	4
SOSI	*Sorbus sitchensis*	Sitka mountain ash	Full sun. Moist, rich soil.	10'	X		X	6'	3

Shrubs

Symbol	Latin Name	Common Name	Site Conditions	Mature Height	Wet Slopes (WS)	Dry Slopes (DS)	Top of Bank (TOB) or Upland (U)	Spacing On Center (O.C.)	Quantity
ARUV	*Arctostaphylos uva-ursi*	Kinnikinnick	Full sun. Dry soil.	12"		X	X	2'	27
BENE	*Berberis nervosa*	Dull Oregon grape	Part shade. Moist, well drained soil.	2' -3'	X	X	X	3'	5
COSE	*Cornus sericea (stolonifera)*	Red-osier dogwood	Shady stream banks. Moist, well drained soils.	15'	X	X	X	4'	10
GASH	*Gaultheria shallon*	Salal	Part shade to full sun. Well drained soil.	3' -6'		X	X	3'	19
LOIN	*Lonicera involucrata*	Black twinberry	Part shade. Moist soils.	2' to 7'	X		X	4'	7
PHCA	*Physocarpus capitatus*	Pacific ninebark	Full sun. Moist soil.	6' -12'	X		X	3'	13
RONU	*Rosa nutkana*	Nootka rose	Full sun. Moist soil.	3' 6'	X	X	X	4'	10
SPDO	*Spiraea douglasii*	Douglas spirea	Full sun. Wetland or lake edge.	4' -7'	X		X	6'	3

Groundcovers

Symbol	Latin Name	Common Name	Site Conditions		Wet Slopes (WS)	Dry Slopes (DS)	Top of Bank (TOB) or Upland (U)	Spacing On Center (O.C.)	Quantity
AQFO	*Aquilegia formosa*	Western columbine	Part shade to full sun. Moist soil.	2'	X	X	X	12"	43
FRCH	*Fragaria chiloensis*	Coastal strawberry	Part shade to full sun. Sandy soil.	6"	X	X	X	12"- 18"	13
POMU	*Polystitchum munitum*	Sword fern	Moist to dry soil.	2'- 5'	X	X	X	24"	40
SIID	*Sisyrinchium idahoense*	Blue eyed grass	Part shade to full sun. Moist soils.	24"	X	X	X	12"	30

Kitsap County Emergent Seed Mix

Latin Name	Common Name	% Mix
Beckmannia syzigachne	American sloughgrass	20
Carex obnupta	Slough sedge	10
Eleocharis palustris	Common spikerush	10
Elymus glaucus	Blue wildrye	20
Glyceria occidentalis	Northwestern mannagrass	10
Juncus ensifolius	Dagger-leaf rush	10
Juncus tenuis	Slender rush	10
Schoenoplectus acutus	Hardstem bulrush	5
Schoenoplectus microcarpus	Soft stem bulrush	5

Kitsap County Wetland Bottom Seed Mix

Latin Name	Common Name	% Mix
Agrostis exarata	Spiked bentgrass	20
Carex stipata	Saw beaked sedge	30
Glyceria occidentalis	Northwestern mannagrass	20
Schoenoplectus microcarpus	Soft stem bulrush	30

Kitsap County Moist to Dry Slope Seed Mix

Latin Name	Common Name	% Mix
Deschampsia cespitosa	Tufted hairgrass	20
Hordeum brachyantherum	Meadow barley	30
Elymus glaucus	Blue wildrye	15
Festuca rubra var rubra	Red fescue	20
Bromus carinatus	California brome	15

Kitsap County Upland Grass Seed Mix

Latin Name	Common Name	% Mix
Bromus carinatus	California brome	20
Festuca rubra var. rubra	Red fescue	30
Hordeum brachyantherum	Meadow barley	50

Pond 193 Plant Schedule

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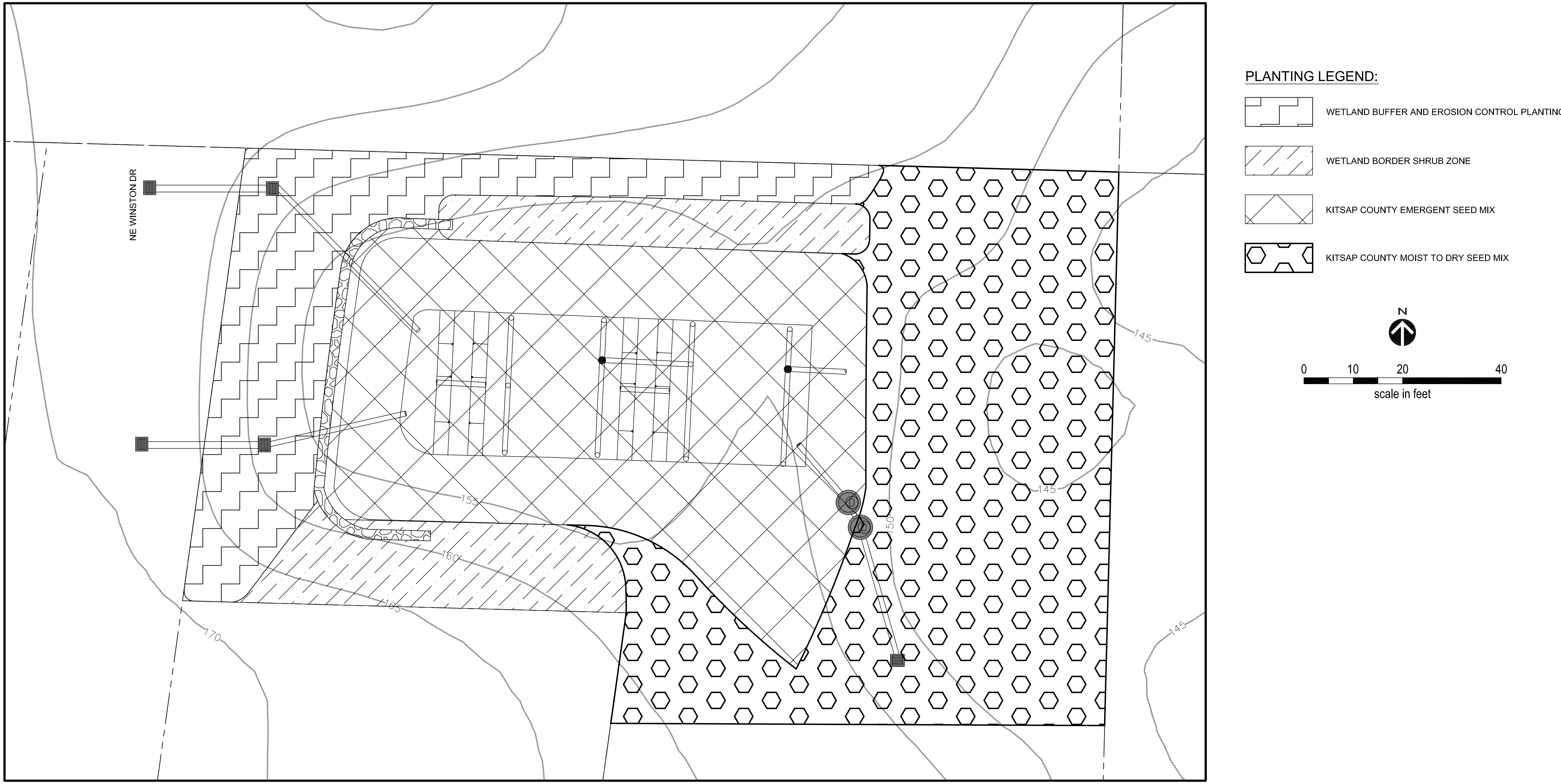

Pond 114 Retrofit Planting Plan

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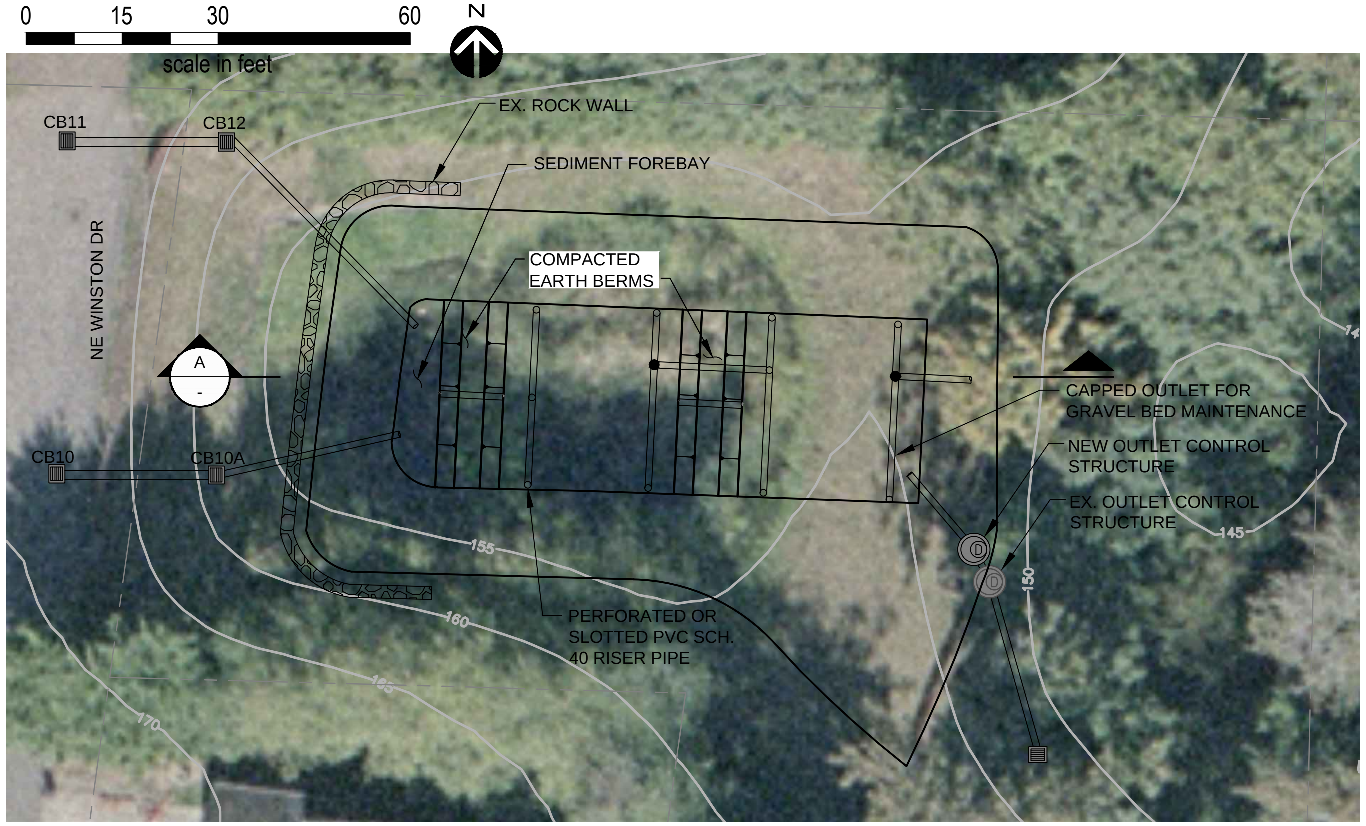
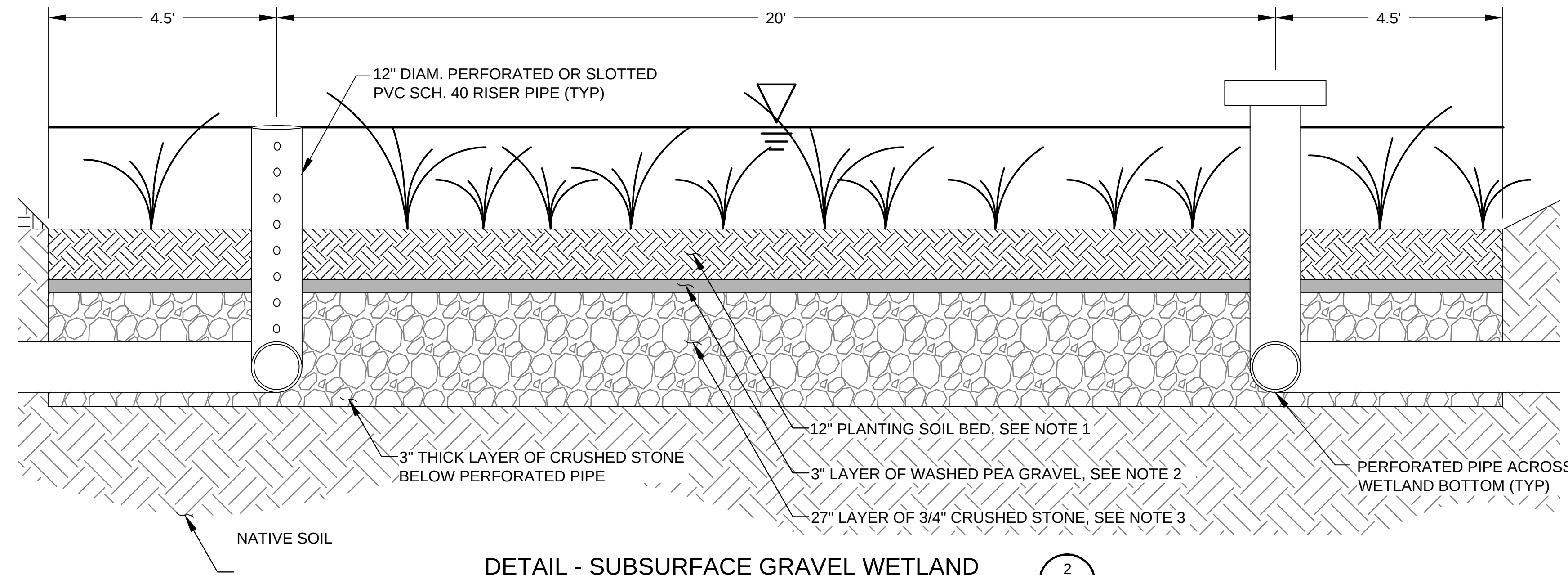
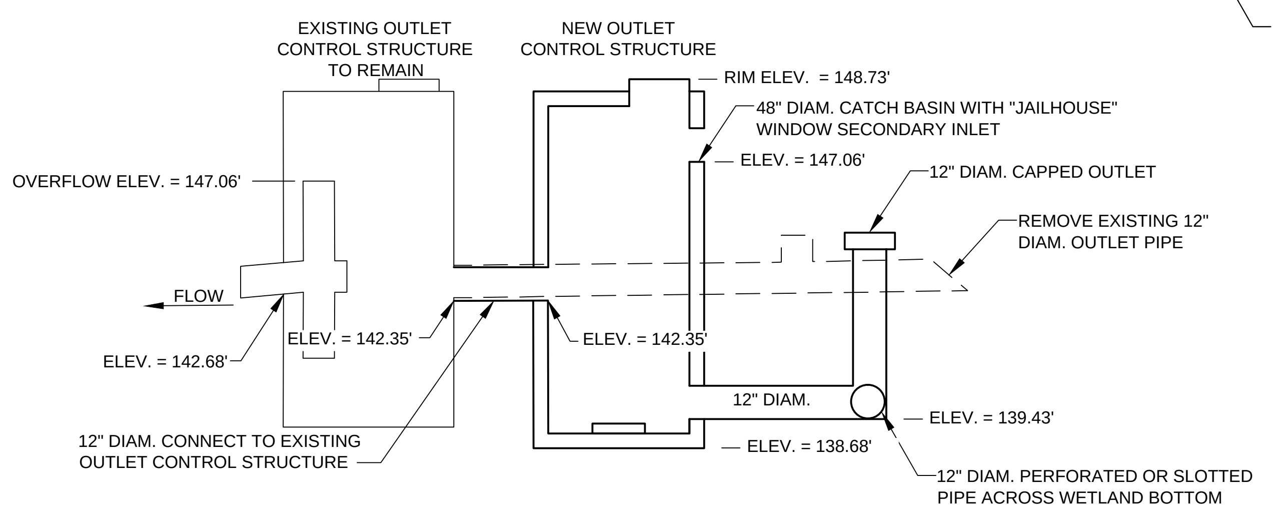




DETAIL - SUBSURFACE GRAVEL WETLAND (2/-)

SCALE: N.T.S.

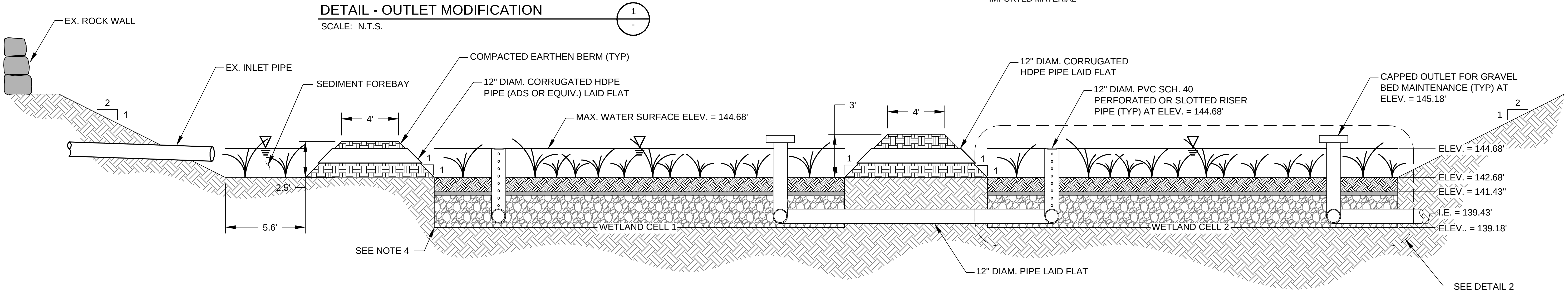


DETAIL - OUTLET MODIFICATION (1/-)

SCALE: N.T.S.

NOTES:

1. THE PLANTING SOIL SHALL BE MIXED USING A COMBINATION OF COMPOST, SAND, SILT, AND CLAY, WITH THE CLAY COMPONENT NOT EXCEEDING 15 PERCENT BY VOLUME. THE SOIL SHALL BE SILT LOAM WITH 10 TO 20 PERCENT ORGANIC CONTENT BY MASS. THE ORGANIC MATTER SHOULD CONSIST OF LEAF COMPOST OR PEAT. LEAF COMPOST SHOULD BE PROPERLY MATURED AND AT LEAST ONE YEAR OLD. THE LEAF COMPOST SHOULD BE MADE EXCLUSIVELY OF FALLEN DECIDUOUS LEAVES WITH LESS THAN 5 PERCENT DRY WEIGHT OF WOODY OR GREEN YARD DEBRIS OR OTHER MATERIALS. THE COMPOST SHOULD BE GENERALLY FREE OF TRASH AND OTHER DEBRIS.
2. PEA GRAVEL SHALL HAVE A NOMINAL SIZE DISTRIBUTION BETWEEN 1/8" AND 3/8".
3. CLEAN, CRUSHED, ANGULAR STONE SHALL HAVE A NOMINAL SIZE DISTRIBUTION BETWEEN 3/4" AND 2".
4. EXCAVATE POND FLOOR FLAT AS NECESSARY PRIOR TO INSTALLATION OF IMPORTED MATERIAL



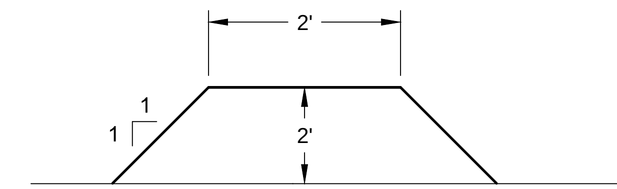
SECTION - SUBSURFACE GRAVEL WETLAND (A/-)

SCALE: N.T.S.

Pond 114 Retrofit Site Plan and Details

LEGEND:

PROPERTY LINE

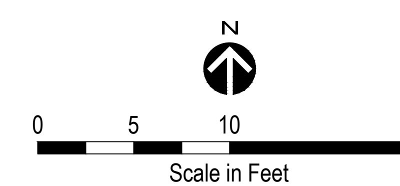


SECTION - EARTHEN BERM

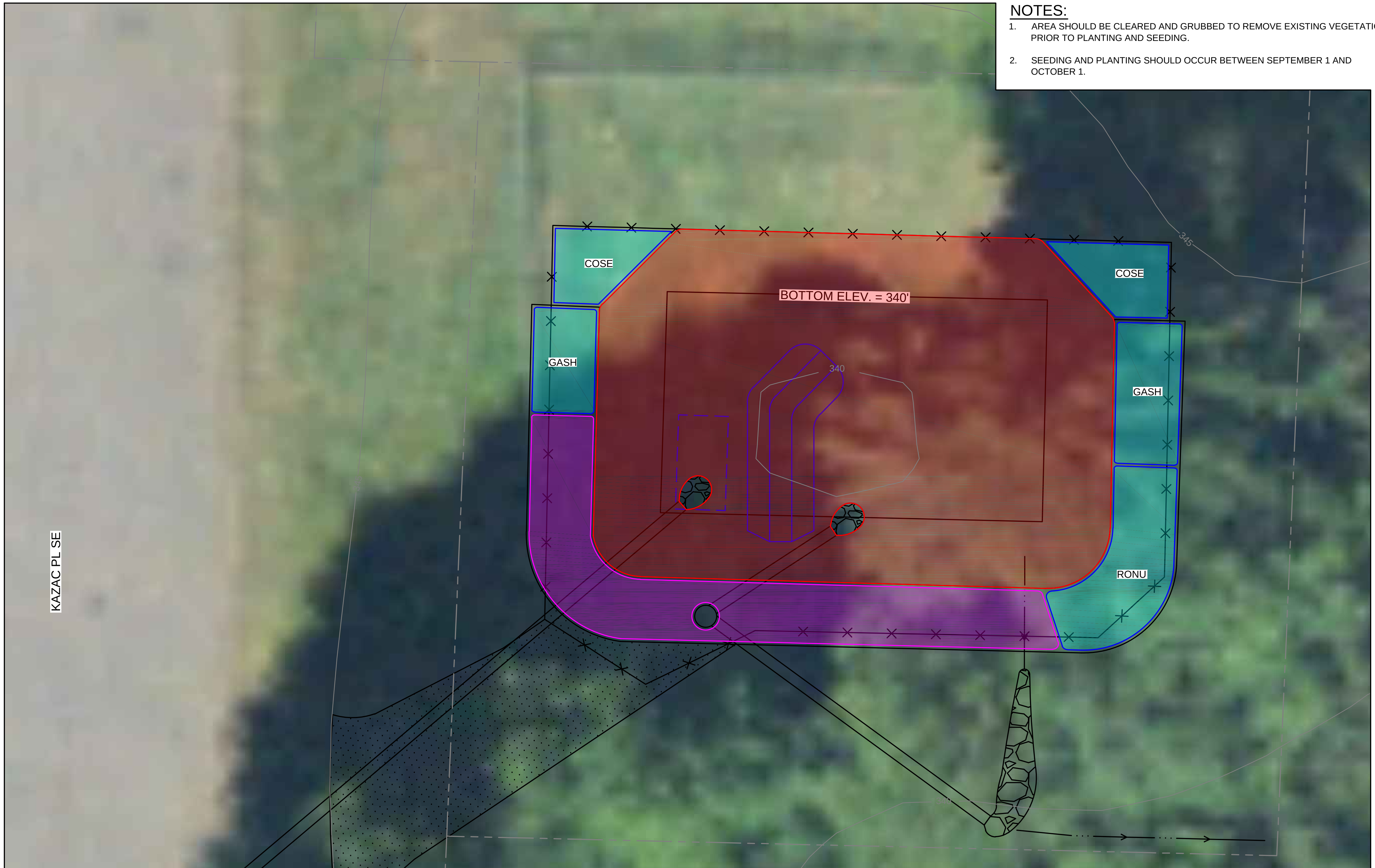
SCALE: N.T.S.

NOTES:

1. EARTHEN BERM TO BE CONSTRUCTED OF ONSITE SUITABLE EXCAVATED SOIL SUPPLEMENTED BY IMPORTED GRAVEL BORROW OR COMPARABLE MATERIAL.



Pond 116 Retrofit Site Plan



NOTES:

1. AREA SHOULD BE CLEARED AND GRUBBED TO REMOVE EXISTING VEGETATION PRIOR TO PLANTING AND SEEDING.
2. SEEDING AND PLANTING SHOULD OCCUR BETWEEN SEPTEMBER 1 AND OCTOBER 1.

LEGEND:

- KITSAP CO. UPLAND GRASS AND FORB SEED MIXES
- EMERGENT PLANTING
- GROUNDCOVER PLANTING

Kitsap County Emergent Seed Mix		
Latin Name	**Common Name**	**% Mix**
Beckmannia syzigachne	American sloughgrass	20
Carex obnupta	Slough sedge	10
Eleocharis palustris	Common spikerush	10
Elymus glaucus	Blue wildrye	20
Glyceria occidentalis	Northwestern mannagrass	10
Juncus ensifolius	Dagger-leaf rush	10
Juncus tenuis	Slender rush	10
Schoenoplectus acutus	Hardstem bulrush	5
Schoenoplectus microcarpus	Soft stem bulrush	5

Kitsap County Upland Grass Seed Mix		
Latin Name	**Common Name**	**% Mix**
Bromus carinatus	California brome	20
Festuca rubra var. rubra	Red fescue	30
Hordeum brachyantherum	Meadow barley	50

Planting Schedule

Shrubs

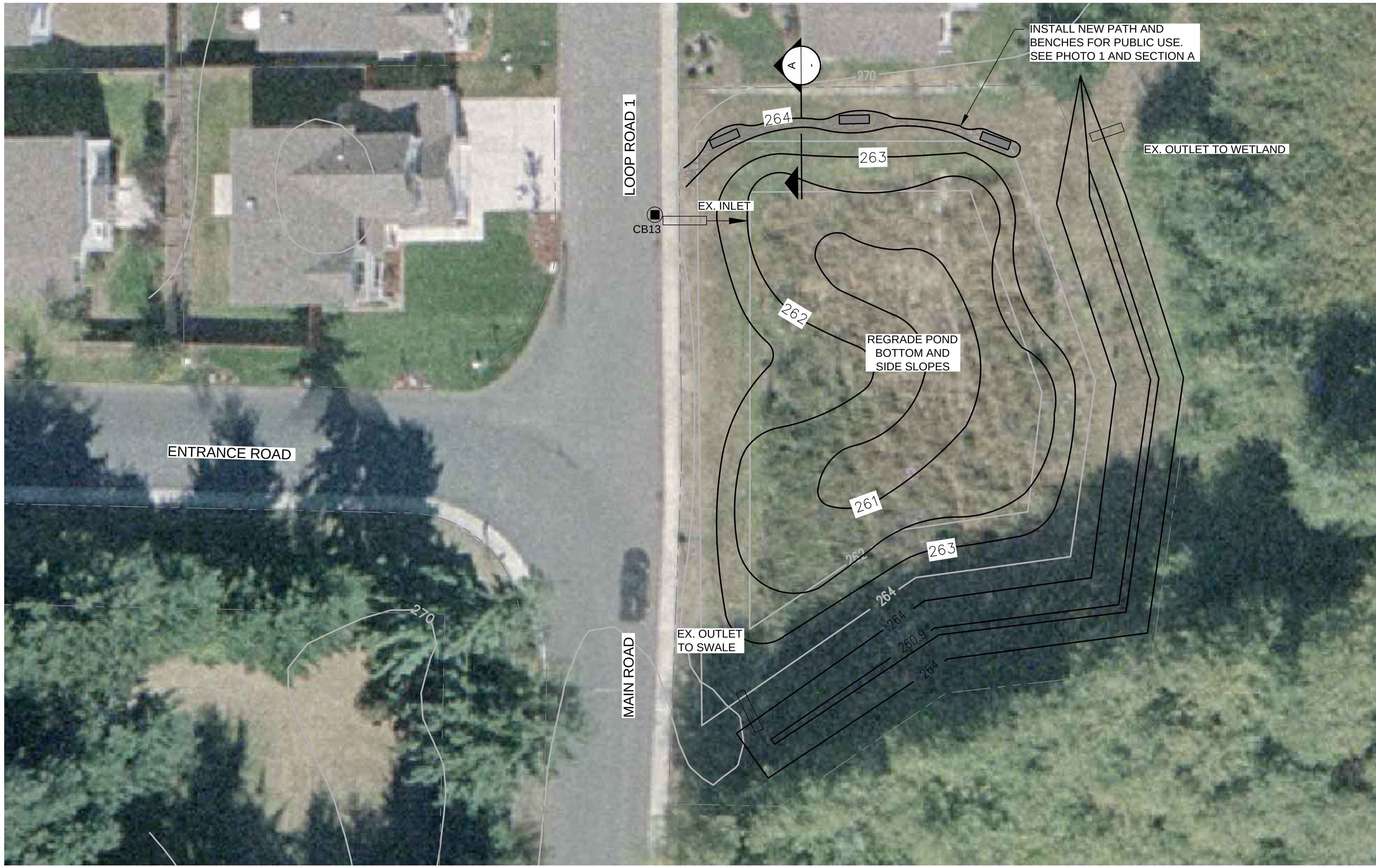
Symbol	Latin Name	Common Name	Site Conditions	Mature Height	Wet Slopes (WS)	Dry Slopes (DS)	Top of Bank (TOB) or Upland (U)	Spacing On Center (O.C.)	Quantity
COSE	*Cornus sericea (stolonifera)*	Red-osier dogwood	Shady stream banks. Moist, well drained soils.	15'	X	X	X	4'	7
GASH	*Gaultheria shallon*	Salal	Part shade to full sun. Well drained soil.	3' - 6'		X	X	3'	16
RONU	*Rosa nutkana*	Nootka rose	Full sun. Moist soil.	3' - 6'	X	X	X	4'	10

N

0 5 10 20

Scale in Feet

Pond 116 Planting Plan



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0 15 30 60
scale in feet

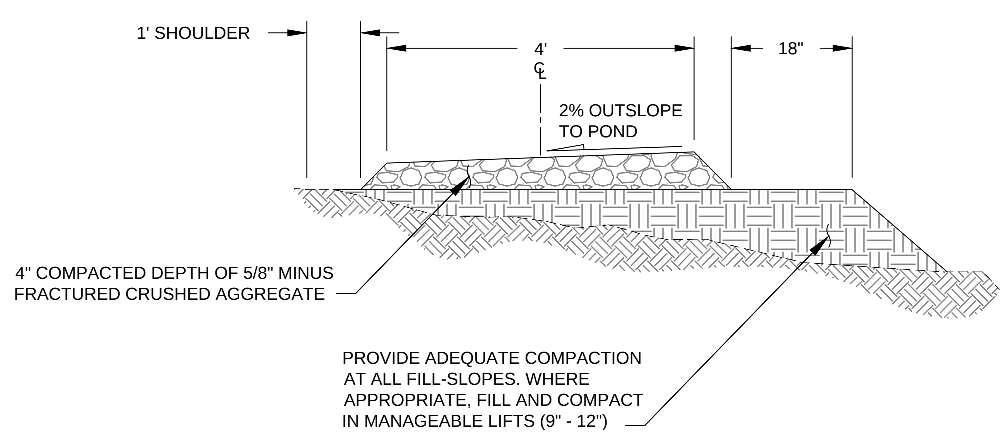
LEGEND:

	PROPERTY LINE
100	EXISTING LIDAR CONTOURS IN FEET
100	EXISTINGPOND CONTOURS IN FEET
100	PROPOSED POND CONTOURS IN FEET
	CRUSHED GRAVEL PATH, 4" MIN. THICKNESS
	BENCH
CB13	CATCH BASIN

NOTES:

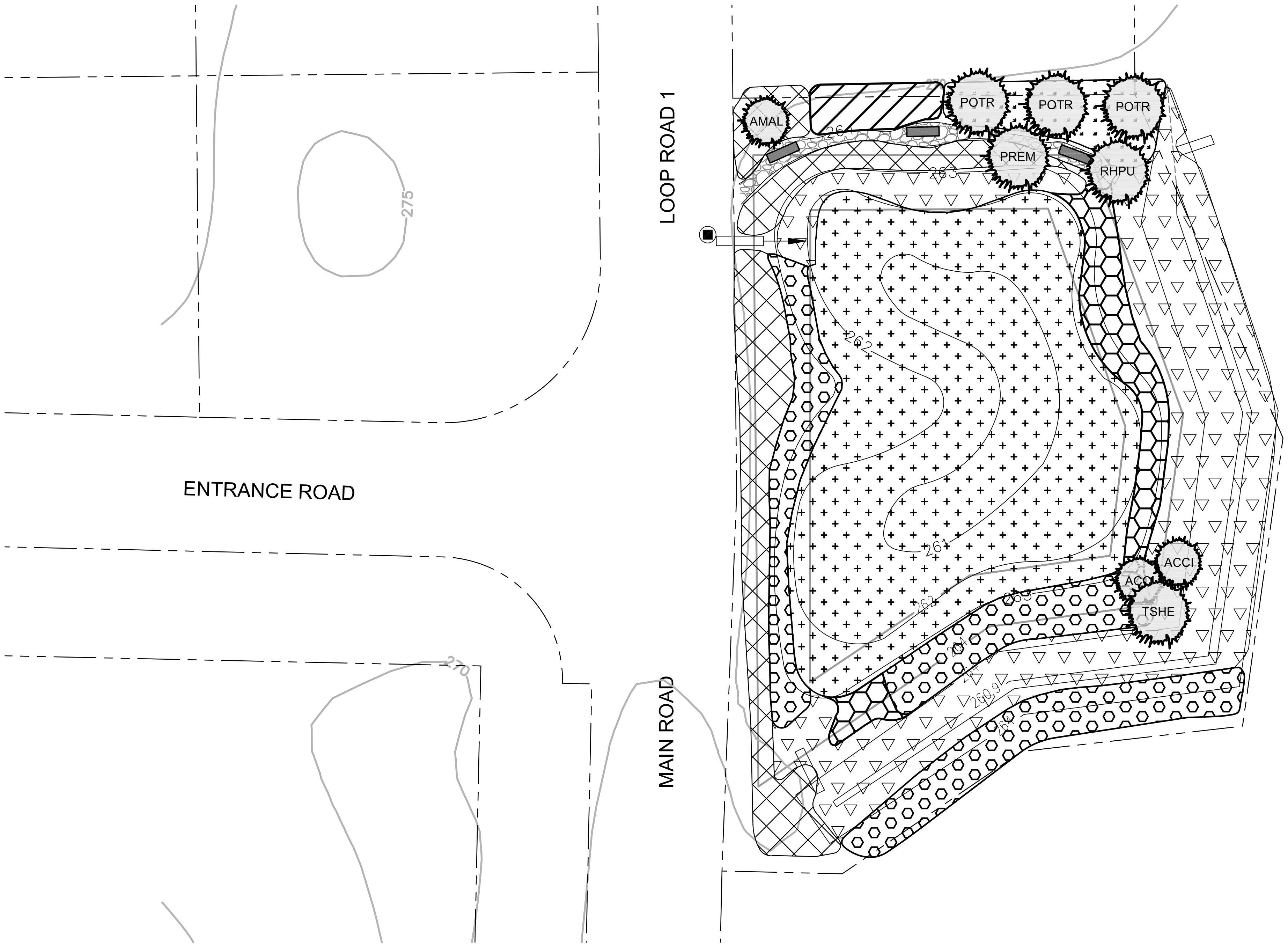
1. BENCHES SHALL BE PILOT ROCK TRAILSIDE 6' BACKLESS PARK BENCH (SWB/G-6TP34) OR EQUIVALENT.
2. REMOVE ALL ROOTS AND ORGANIC DEBRIS TO A DEPTH OF 6" PRIOR TO IMPORTING TRAIL AGGREGATE.
3. ESTABLISH DESIGN CROSS-SLOPE IN SUBGRADE MATERIALS.
4. TRAIL AGGREGATE SHALL BE 5/8" MINUS CRUSHED ROCK. PLACE MATERIAL UNIFORMLY, PROVIDING FULL DESIGN WIDTH ACROSS SURFACE. TAPER EDGES AT A 45 DEGREE ANGLE INTO THE SUBGRADE, LEAVING APPROX. 1" OF TREAD ABOVE GRADE. WHERE DESIRED, PROVIDE COMPLETE MECHANICAL COMPACTION. WHERE THIS IS IMPRACTICAL OR IMPOSSIBLE, COMPACT BY HAND WITH AN APPROPRIATELY WEIGHTED IMPLEMENT.
5. FOLLOWING IMPORT AND PLACEMENT OF TRAIL AGGREGATE, PERFORM RESTORATION AND REVEGETATION.

PHOTO - PILOT ROCK TRAILSIDE BACKLESS PARK BENCH (1 / -)
SCALE: 1" = 5'



SECTION - STANDARD SLOPED TRAIL (A / -)
SCALE: N.T.S.

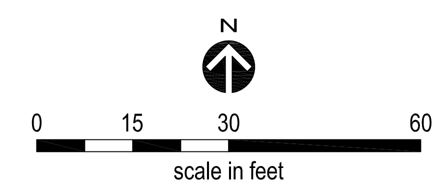
Pond 460 Retrofit Site Plan



PLANTING LEGEND:

Cross-hatch	KITSAP COUNTY UPLAND FORB SEED MIX
Diagonal hatch	HUCKLEBERRY PATCH
Dots	KITSAP COUNTY UPLAND GRASS SEED MIX
Small hexagons	SHRUB ZONE
Triangles	KITSAP COUNTY EMERGENT SEED MIX
Plus signs	KITSAP COUNTY WETLAND BOTTOM SEED MIX
Large hexagons	KITSAP COUNTY EMERGENT WILD FLOWER SEED MIX

ACCI	VINE MAPLE (ACER CIRINATUM)
AMAL	SERVICEBERRY (AMELANCHIER ALNIFOLIA)
POTR	QUAKING ASPEN (POPULUS TREMULOIDES)
PREM	BITTER CHERRY (PRUNUS EMARINATA)
RHPU	CASCARA (RHAMNUS PURSHIANA)
TSHE	WESTERN HEMLOCK (TSUGA HETEROPHYLLA)



Pond 460 Retrofit Planting Plan

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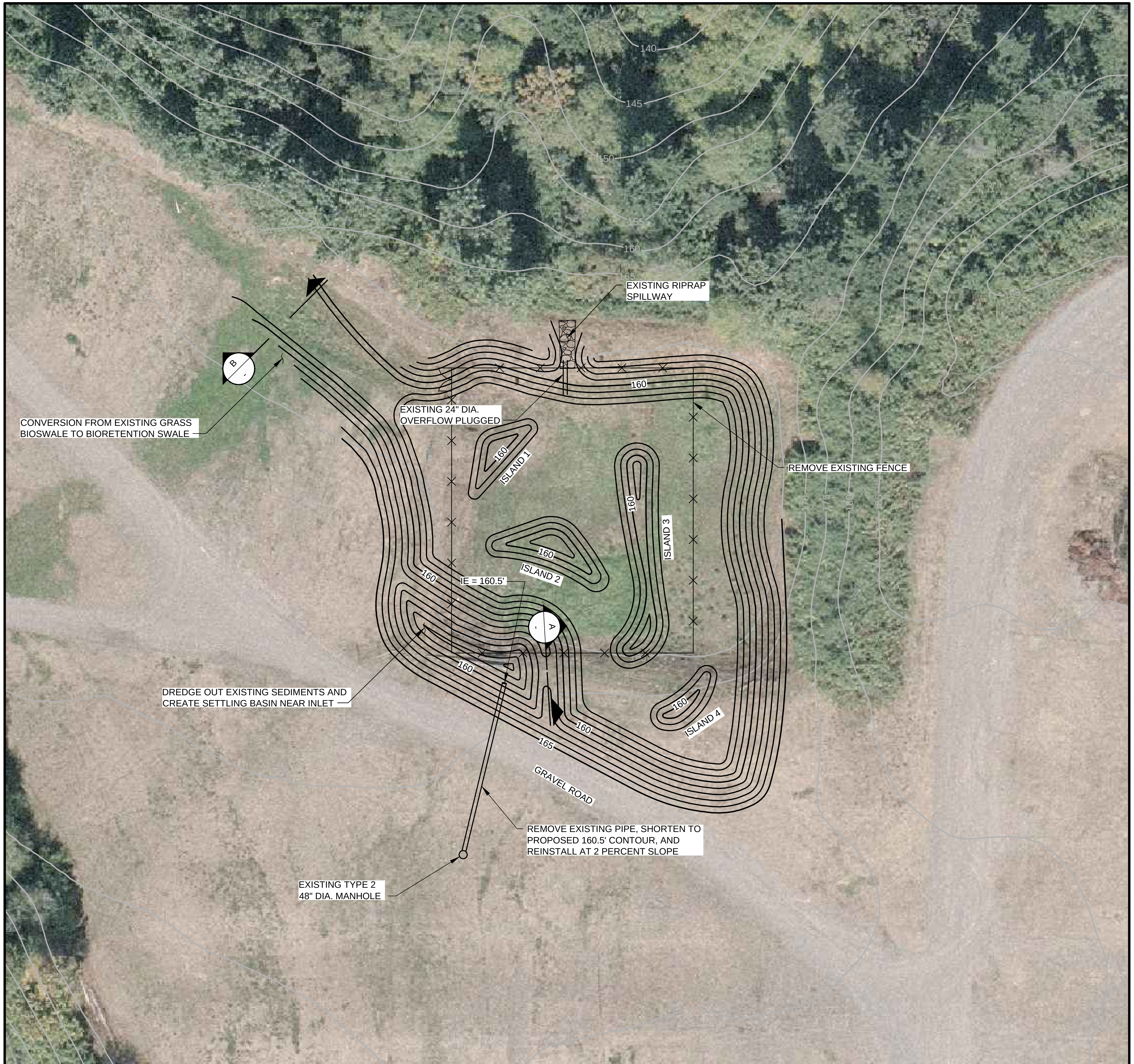


LEGEND:

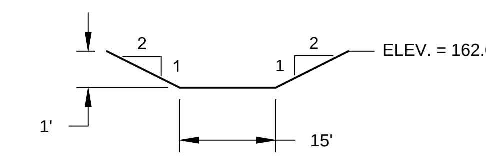
— — — —	PROPERTY LINE
100	EXISTING LIDAR CONTOURS IN FEET
100	EXISTING POND CONTOURS IN FEET
100	PROPOSED POND MAJOR CONTOURS IN FEET
100	PROPOSED POND MINOR CONTOURS IN FEET

NOTES:

1. EXCAVATE POND BOTTOM AND SIDE SLOPES TO CONTOURS AS SHOWN.
2. EXCAVATED MATERIAL CAN BE USED ONSITE TO CREATE THE ISLANDS IN THE POND, (SEE TABLE 1).

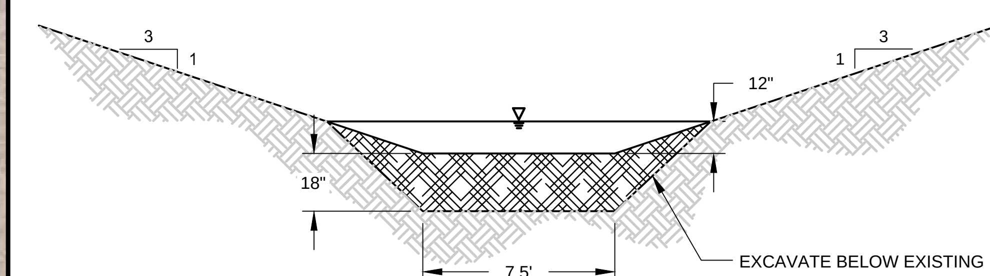
TABLE 1 - CONSTRUCTED ISLAND AREAS:

ISLAND NUMBER	AREA (SQ. FT. AT ELEV. 160')
1	112.93
2	357.80
3	625.16
4	70.27



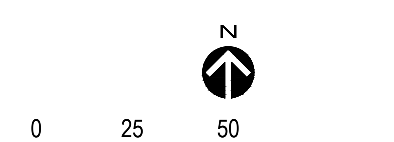
SECTION - SPILLWAY (A / -)

SCALE: 1" = 5'



SECTION - BIORETENTION SWALE (B / -)

SCALE: 1" = 5'



Pond 540 Retrofit Site Plan

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LEGEND:

- KITSAP CO. UPLAND GRASS AND FORB SEED MIXES
- MOIST TO DRY PLANTING
- EMERGENT PLANTING
- WETLAND PLANTING
- GROUNDCOVER PLANTING
- SHADE PLANTING
- SHRUB ZONE PLANTING
- PROPOSED TREES (ACCI, THPL)

NOTES:

1. AREA SHOULD BE CLEARED AND GRUBBED TO REMOVE EXISTING VEGETATION PRIOR TO PLANTING.
2. GROUNDCOVER PLANTINGS SHALL BE INTER-PLANTED IN GROUPINGS WITHIN BARE AREAS BETWEEN SHRUB AND TREE PLANTING TO PROVIDE SOIL COVER AND PREVENT EROSION OF SLOPES.
3. SEEDING SHOULD OCCUR BETWEEN SEPTEMBER 1 AND OCTOBER 1.

N

0 25 50 100

Scale in Feet

Pond 540 Planting Plan

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Planting Schedule

Trees

Symbol	Latin Name	Common Name	Site Conditions	Mature Height	Wet Slopes (WS)	Dry Slopes (DS)	Top of Bank (TOB) or Upland (U)	Spacing On Center (O.C.)	Quantity
ACCI	*Acer circinatum*	Vine maple	Part shade. Moist soil.	10' to 15'	X	X	X	10'	**3**
ACMA	*Acer macrophyllum*	Big-leaf maple	Part shade to full sun. Moist, well drained soils.	90'			X	30'	**2**
COCO	*Corylus cornuta*	Western hazelnut	Part shade to full sun. Well drained soil. Understory species.	20'			X	15'	**2**
PREM	*Prunus emarginata*	Bitter cherry	Part shade to full sun. Dry to moist sites.	30'	X	X	X	15'	**1**
RHPU	*Rhamnus purshiana*	Cascara	Part shade. Moist, well drained soils.	30'			X	15'	**1**
SOSI	*Sorbus sitchensis*	Sitka mountain ash	Full sun. Moist, rich soil.	10'	X		X	6'	**1**
PISI	*Picea sitchensis*	Sitka spruce	Part shade to full sun. Moist or saturated soils.	250'	X		X	30'	**2**
PSME	*Pseudotsuga menziesii*	Douglas' fir	Part shade to full sun. Moist to dry soils.	200'			X	30'	**2**
THPL	*Thuja plicata*	Western red cedar	Full shade to full sun. Moist to swampy soil.	100'	X	X	X	30'	**3**

Shrubs or Small Trees

Symbol	Latin Name	Common Name	Site Conditions	Mature Height	Wet Slopes (WS)	Dry Slopes (DS)	Top of Bank (TOB) or Upland (U)	Spacing On Center (O.C.)	Quantity
COSE	*Cornus sericea (stolonifera)*	Red-osier dogwood	Shady stream banks. Moist, well drained soils.	15'	X	X	X	4'	**80**
PHCA	*Physocarpus capitatus*	Pacific ninebark	Full sun. Moist soil.	6' -12'	X		X	3'	**21**
SPDO	*Spiraea douglasii*	Douglas spirea	Full sun. Wetland or lake edge.	4' -7'	X		X	6'	**29**
SALA	*Salix lasiandra*	Pacific willow	Full sun. Moist, sand/gravelly soil. Flood tolerant.	40'	X	X	X	6'	**27**
SASC	*Salix scouleriana*	Scouler's willow	Full sun. Moist, sand/gravel soil.	30'	X	X	X	6'	**14**

Shrubs Zone Species

Latin Name	Common Name	Site Conditions	Mature Height	Wet Slopes (WS)	Dry Slopes (DS)	Top of Bank (TOB) or Upland (U)	Spacing On Center (O.C.)	Quantity
Holodiscus discolor	Ocean spray	Part shade to full sun. Well drained, dry soil.	15'			X	4'	**10**
Rosa nutkana	Nootka rose	Full sun. Moist soil.	3' 6'	X	X	X	4'	**10**
Rubus parviflora	Thimbleberry	Part shade to full sun. Moist to dry soil.	4' -6'		X	X	4'	**10**
Symphoricarpus albus	Snowberry	Part shade to full sun. Moist to dry, well drained soil.	2' -6'	X	X	X	3'	**32**

Shade Groundcover Zone

Latin Name	Common Name	Site Conditions		Wet Slopes (WS)	Dry Slopes (DS)	Top of Bank (TOB) or Upland (U)	Spacing On Center (O.C.)	Quantity
Aquilegia formosa	Western columbine	Part shade to full sun. Moist soil.	2'	X	X	X	12"	**22**
Gaultheria shallon	Salal	Part shade to full sun. Well drained soil.	3' -6'		X	X	3'	**11**
Polystitchum munitum	Sword fern	Moist to dry soil.	2'- 5'	X	X	X	24"	**14**

Moist to Dry Planting

Latin Name	Common Name	Site Conditions	Mature Height	Wet Slopes (WS)	Dry Slopes (DS)	Top of Bank (TOB) or Upland (U)	Spacing On Center (O.C.)	Quantity
Bromus sitchensis	Sitka brome	Full sun. Dry soils.	6"- 18"			X	12"	**1704**
Danthonia californica	California oat grass	Full sun. Dry to moist soil.	10"- 12"		X	X	12"	**1704**
Deschampsia cespitosa	Tufted hairgrass	Full sun. Moist to wet soil.	18"- 4'	X	X	X	12"	**1704**
Elymus glaucus	Blue wildrye	Full shade to full sun. Dry to moist soil.	2'-4'	X	X	X	12"	**1704**
Festuca idahoensis	Idaho fescue	Full sun. Dry soil.	1'-3'			X	12"	**1704**
Festuca rubra	Red fescue	Full sun to full shade. Dry to moist soil.	2'		X	X	12"	**1704**
Hordeum brachyantherum	Meadow barley	Full sun. Moist to seasonally wet soil.	1'-3'	X	X		12"	**1704**

Emergent Planting

Latin Name	Common Name	Site Conditions	Mature Height	Wet Slopes (WS)	Dry Slopes (DS)	Top of Bank (TOB) or Upland (U)	Spacing On Center (O.C.)	Quantity
Beckmannia syzigachne	American sloughgrass	Full sun. Moist, seasonally wet, or perennially wet soils.	3'	X			12"	**1450**
Camassia quamash	Common camas	Part to full sun. Moist to seasonally wet soils.	8"-30"	X	X		12"	**480**
Carex obnupta	Slough sedge	Part to full sun. Moist to seasonally wet soils.	2'-5'	X	X	X	12"	**1200**
Eleocharis palustris	Common spikerush	Part to full sun. Moist to seasonally wet soils.	30"	X	X		12"	**1450**
Elymus glaucus	Blue wildrye	Full shade to full sun. Dry to moist soil.	2'-4'	X	X	X	12"	**1200**
Erigeron speciosus	Aspen daisy	Full sun. Moist to dry soils.	2'-3'	X	X	X	12"	**500**
Glyceria occidentalis	Northwestern mannagrass	Part to full sun. Moist, seasonally wet, or perennially wet soils.	2'-3'	X			12"	**1200**
Juncus ensifolius	Dagger-leaf rush	Part to full sun. Moist to submerged soils.	6"-20"	X			12"	**1200**
Juncus tenuis	Slender rush	Full sun. Moist to perennially wet soils.	3'	X			12"	**1200**
Lupinus polyphyllus	Large-leaf lupine	Part to full sun. Moist to seasonally wet soils.	3'	X	X		12"	**400**
Schoenoplectus acutus	Hardstem bulrush	Part of full sun. Perennially wet to submerged soils.	3'-9'	X			12"	**600**
Schoenoplectus microcarpus	Soft stem bulrush	Part of full sun. Perennially wet to submerged soils.	2'-4'	X			12"	**600**
Sisyrinchium idahoense	Blue eyed grass	Part to full sun. Moist to wet soils.	6"	X			12"	**500**

Pond 540 Plant Schedule

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Wetland Bottom Planting								
Latin Name	**Common Name**	**Site Conditions**	**Mature Height**	**Wet Slopes (WS)**	**Dry Slopes (DS)**	**Top of Bank (TOB) or Upland (U)**	**Spacing On Center (O.C.)**	**Quantity**
Agrostis exarata	Spiked bentgrass	Part to full sun. Moist to perennially wet soils.	4"-10"	X			12"	**3550**
Carex stipata	Saw beaked sedge	Part to full sun. Perennially wet to submerged soils.	30"	X			12"	**5300**
Glyceria occidentalis	Northwestern mannagrass	Part to full sun. Moist, seasonally wet, or perennially wet soils.	2'-3'	X			12"	**3550**
Schoenoplectus microcarpus	Soft stem bulrush	Part of full sun. Perennially wet to submerged soils.	3'-9'	X			12"	**5300**

Kitsap County Upland Grass Seed Mix		
Latin Name	**Common Name**	**% Mix**
Bromus carinatus	California brome	20
Festuca rubra var. rubra	Red fescue	30
Hordeum brachyantherum	Meadow barley	50

Kitsap County Upland Forb Seed Mix		
Latln Name	**Common Name**	**% Mix**
Achillea millefolium	Yarrow	25
Clarkia amoena	Farewell-to-spring	25
Lupinus bicolor	Bicolor lupine	25
Solidago canadensis	Canada goldenrod	25

Pond 540 Plant Schedule

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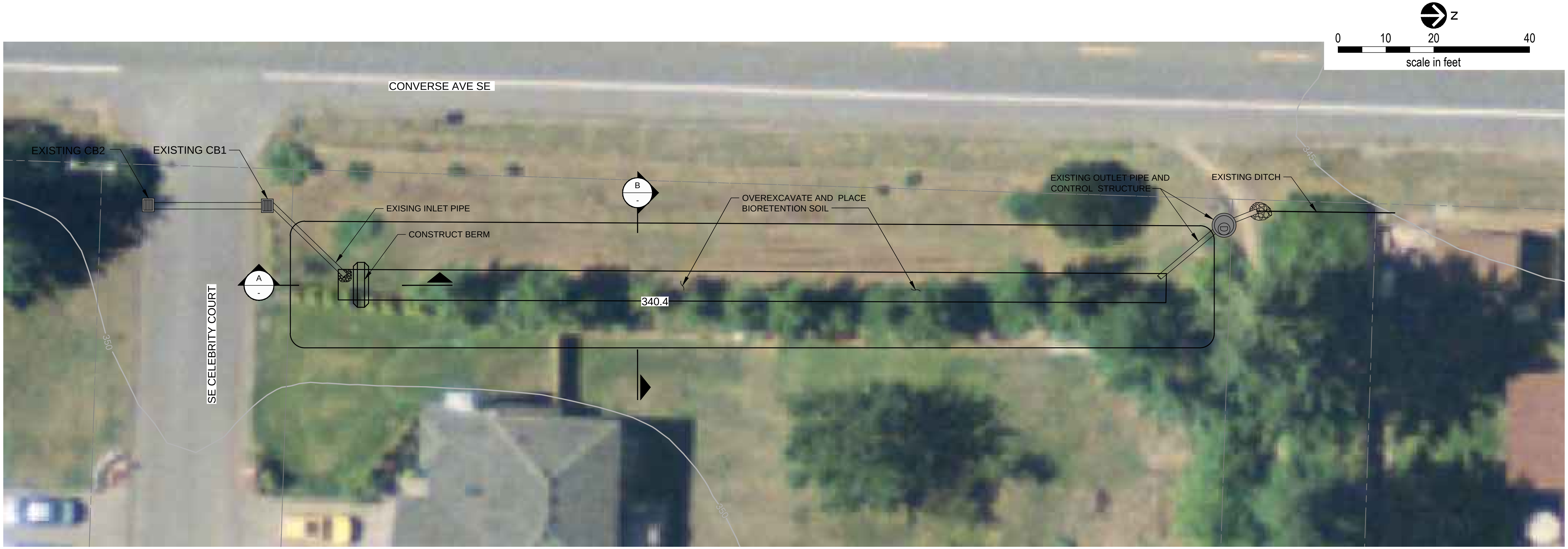
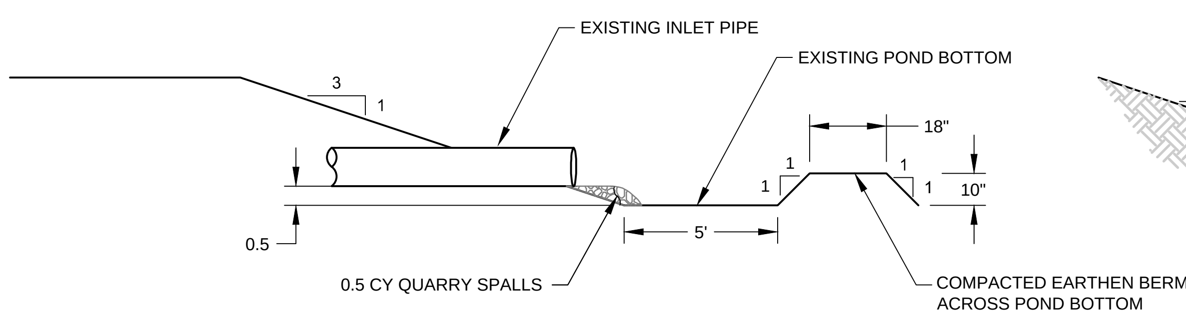
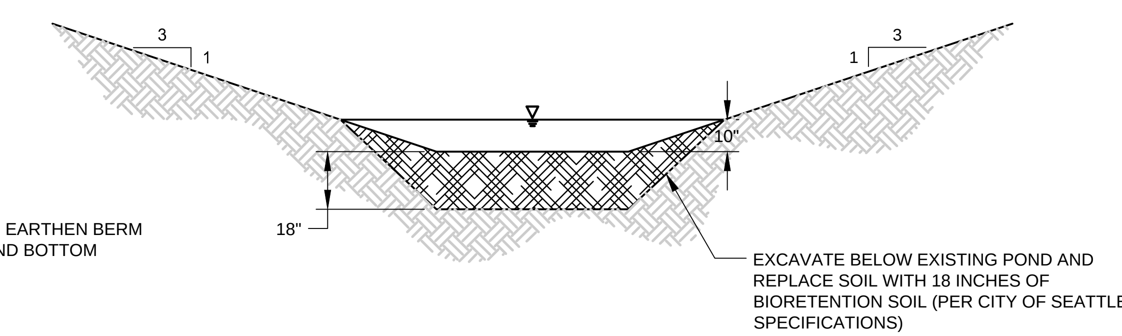




SECTION - INLET MODIFICATION

SCALE: 1" = 5'

A



SECTION - BIORETENTION SWALE

SCALE: 1" = 5'

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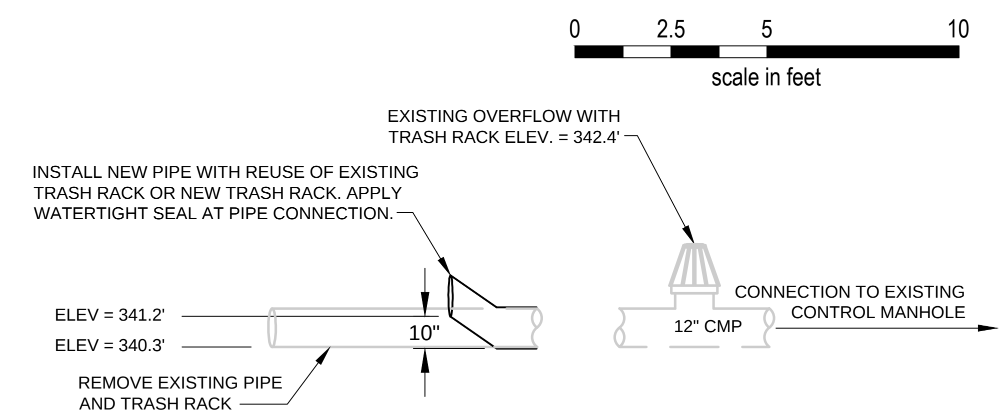

DETAIL - OUTLET MODIFICATION

SCALE: 1" = 5'

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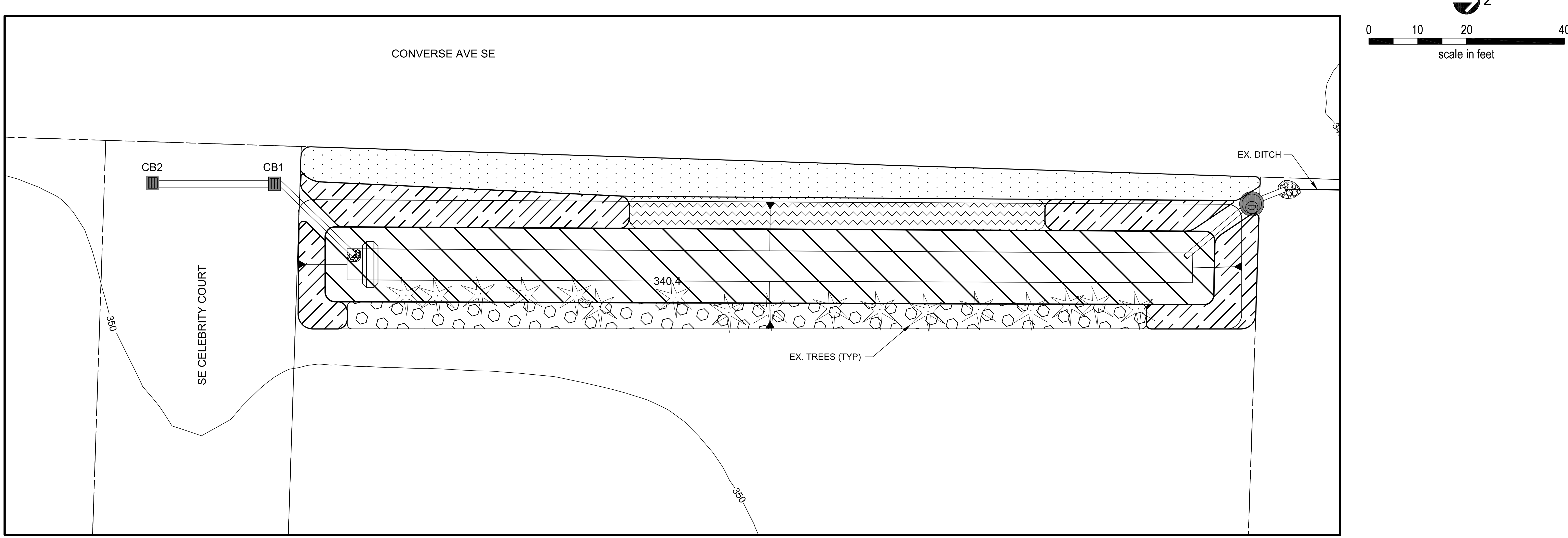
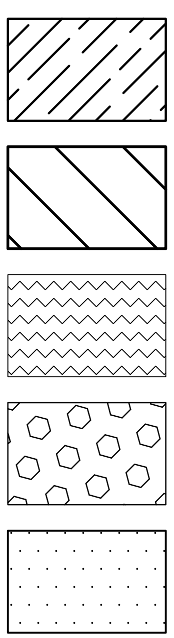
Pond 76 Retrofit Site Plan



PLANT LEGEND:



LOW GROWING SHRUB

EMERGENT SEED MIX

MEDIUM HEIGHT SHRUB

MOIST TO DRY SEED MIX

KITSAP UPLAND MIX

Pond 76 Retrofit Planting Plan

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APPENDIX D

Vegetation Maintenance and Plant List

Vegetation, Planting, and Maintenance

Plant Selection and the Plant List

The plant list created for this manual includes species that are native to Kitsap County. Planting native plants should be a priority for stormwater facilities for several reasons.

- Native plants are adapted to local soil, hydrology, and climate conditions.
- Native plants compete with invasive species that threaten to overtake facilities and create monocultures.
- Native plants soften the transition from developed landscapes into natural areas.
- Native plants provide habitat.

There are some non-native, horticultural species that are suitable for pond facilities. These species are usually chosen when a site is located within a highly developed area where a designer has a specific design goal in mind. In these instances, plant lists should be reviewed and approved by a local botanist or landscape architect.

Plants in Design

Each facility should be designed for the unique environmental conditions, surrounding context, and aesthetic requirements for that site. Plants should be chosen based on the following criteria (not a conclusive list):

- Hydrologic regime
  - Infiltration facilities need plants that tolerate both saturated and dry periods
- Local soils
- Light requirements
  - Shady versus sunny
- Surrounding context
  - Is the site located near a natural area, within a neighborhood, or along a busy roadside?
  - Be aware of line of sight concerns and plant size.
- Proximity to natural areas
  - Are there particular species that may be attracted to the site (e.g., bird populations, amphibians, butterflies, etc.) and may benefit or be impacted by its location?
  - Are there reference habitats nearby that provide clues to choosing an appropriate plant selection?

The design examples shown in this manual demonstrate one design solution for a particular site. There are several design solutions that may be appropriate for any one site. Reference these designs for inspiration or ideas, but respond thoughtfully to individually site conditions.

Plant Maintenance

Dying Plants and Bare Soil

When a plant shows signs that it is dead or dying, it needs to be replaced with the appropriate species for that location. In some cases, this may mean replacing the same species of plant. However, if plant mortality is the result of a poor species choice and is an inappropriate plant for that location, a more suitable species should be used to replace it.

General Pruning

In general, if native plants are carefully selected and sited, pruning is not needed. Pruning should work with the natural growth form of the plant and only be done when necessary and at the appropriate time of year. Some plants benefit from pruning, while others are weakened by it. Pruning may be necessary to maintain visibility for pedestrians and cars, but ideally, appropriate plant selection will decrease the amount of pruning necessary. Most shrub plantings are meant to become a plant massing or a vegetated wall. As a general rule, trees and shrubs should not be pruned into geometric shapes (e.g., circles and squares). Pruning trees and shrubs into geometric shapes takes extra maintenance effort and time and does not allow the plants to grow to their full healthy form or cover the soil and out-compete weeds.

Shrub Pruning

Some species of shrubs, like willow and dogwood, will sprout multiple stems from the base of the plant when pruned. Shrubs with multiple stems can be valuable for erosion control, bank stabilization, and sediment removal. These shrubs can also add important aesthetic qualities to a site. Dogwood, for example, has bright red new shoot growth that provides vibrant color to a landscape year-round. The new shoot growth on willows can be orange to bright green, depending on the species. If facility managers wish to prune multi-stemmed shrubs for any of the above reasons, it is best to trim two or three of the largest branches at the base of each plant to stimulate sprouting of new stems and new lateral growth.

Pruning Native Grasses and Sedges

Ornamental and landscape grasses rarely need to be pruned. Even when they die and turn yellow at the end of their growing season, they often retain showy seed heads and maintain their growth form. They are often considered aesthetically valuable for the texture and winter interest they add to a landscape. If grasses do need to be pruned, the timing of the pruning will depend on whether they are a warm or cool season grass. Most landscape grasses are warm season grasses. Warm season grasses can be pruned in spring before new summer growth begins. Cool season grasses are pruned in late summer or fall before their cool season growth begins. If a grass is pruned at the inappropriate time, it may be forced to put on new growth when it is naturally supposed to be in a dormant period. Dead leaves on evergreen grasses can be raked or combed out if desired.

Photo 28. These grasses were pruned at the wrong time of year and resulted in an accumulation of dying plant material at its center.

Mowing

Facilities with native grasses and forbs in the pond and within its surrounding context should not be mowed on a regular basis. If a site needs to be mowed due to access, visibility, or other maintenance needs, it is best to wait until after all native plants have set seed. Establishing a good native seed bank ensures that additional native plants will grow after the initial planted species is gone. A native seed bank also allows a site to adapt more easily to changing climate and environmental conditions and seeds from multiple species disperse themselves within the site. Mow during late summer or early fall in order to ensure prairie plants have seeded.

Weeding

Removing weeds and unwanted plants from retrofitted facilities is a necessary part of maintenance during the first few years of plant establishment. Invasive species should be removed from the site as soon as possible after they are located. If undesirable populations of plants are identified and removed early during plant establishment, they are less likely to become an issue after native plants are well-established.

Pesticides and herbicides should not be used within stormwater treatment facilities. Hand removal techniques should be used to remove weeds within and around facilities. Early detection and removal of weeds is the most effective way to avoid long-term weed issues. When weeds are removed and ground is disturbed, evaluate whether mulch, native seed, or additional planting is needed to address weed competition.

Consult with the Kitsap County Noxious Weed Control Program for the most effective weed control strategy for the site.

Watering

New plantings may need to be watered for the first 2 to 3 growing seasons or longer during dry summer months until plants are fully established. Watering should consist of an irrigation schedule that waters plants less often, but saturates soils in order to promote better root growth.

Mulching

After planting shrubs and trees, incorporate a 3-inch layer of mulch within a 3-foot diameter radius around each plant in order to conserve moisture, moderate soil temperature, protect soil, and suppress weed establishment. Maintain the 3-inch layer of mulch for the first 3 years after planting, by replenishing the mulch layer each spring.

Deciduous Trees				Plant Placement					Seasonal Water Level Tolerance				
Latin Name	**Common Name**	**Site Conditions**	**Mature Height**	**Wet Slopes (WS)**	**Dry Slopes (DS)**	**Top of Bank (TOB) or Upland (U)**	**Spacing On Center (O.C.)**	**Maintenance Notes and Aesthetic Qualities**	**Dry**	**Moist to Saturated**	**0 to 1 foot**	**1 to 2 feet**	**2 to 3 feet**
Acer circinatum	Vine maple	Part shade. Moist soil.	10' to 15'	✓	✓	✓	10'	Provides vibrant fall color. Good for seasonally wet soils.	✓	✓			
Acer macrophyllum	Big-leaf maple	Part shade to full sun. Moist, well drained soils.	90'			✓	30'	Vigorous grower. Good for seasonally wet or seasonally dry soils. Plant away from pond inlets and outlets to avoid leaf litter debris clogging structures.	✓	✓			
Alnus rubra	Red alder	Full sun. Poor, moist soil.	100'			✓	15'	Short lived tree. Plan on harvesting and/or replacing in 50 year cycle. Important species for nitrogen fixation. They establish well on disturbed sites.		✓	✓		
Amelanchier alnifolia	Serviceberry	Full sun. Well drained soil. Very drought tolerant.	10'			✓	10'	Early spring bloomer. Use this tree for Spring interest. Good for seasonally dry soils.	✓	✓			
Arbutus menziesii	Pacific madrone	Full sun. Well drained, poor, dry rocky soil.	50'			✓	20'	Difficult species to transplant.	✓				
Corylus cornuta	Western hazelnut	Part shade to full sun. Well drained soil. Understory species.	20'			✓	15'	This small tree is sometime classified as a shrub. The spring flowers appear before the leaves in yellow catkins. The fall leaves are pale yellow.	✓				
Fraxinus latifolia	Oregon ash	Part shade to full sun. Moist to saturated soils.	75'	✓		✓	20'	Fast growing for first third of life span and long lived. Good for seasonally wet soils. This species is often found growing in dense stands.		✓			
Populus tremuloides	Quaking aspen	Full sun. Moist to dry soils.	80'		✓	✓	15'	Plant in areas with good air circulation, including only low-growing shrubs or groundcovers. Species can develop fungal problems with poor air circulation. Excellent fall and winter interest plant. Use outside of stormwater facilities.	✓	✓			

Prunus emarginata	Bitter cherry	Part shade to full sun. Dry to moist sites.	30'	✓	✓	✓	15'	Short lived. Plan on harvesting and/or replacing within 40 to 50 years.	✓	✓			
Rhamnus purshiana	Cascara	Part shade. Moist, well drained soils.	30'			✓	15'	Usually an understory species, Cascara is a beautiful small tree that produces berries attractive to birds and small mammals.	✓	✓			
Salix lucida var. *lasiandra*	Pacific willow	Full sun. Moist, sand/gravelly soil. Flood tolerant.	40'	✓	✓	✓	6'	This fast growing species is one of the tallest native willows.		✓	✓	✓	✓
Salix scouleriana	Scouler's willow	Full sun. Moist, sand/gravel soil.	30'	✓	✓	✓	6'	A native to moist woodland and meadow areas, Scouler's willow grows rapidly and can reseed after soil disturbance.		✓	✓	✓	
Sorbus sitchensis	Sitka mountain ash	Full sun. Moist, rich soil.	10'	✓		✓	6'	A small tree or shrub, this species is often multi-stemmed with a rounded crown. Flowers are creamy white and the fruits persist in winter, providing important winter forage for birds and wildlife.		✓	✓		

Conifers				**Plant Placement**					**Seasonal Water Level Tolerance**				
Latin Name	**Common Name**	**Site Conditions**	**Mature Height**	**Wet Slopes (WS)**	**Dry Slopes (DS)**	**Top of Bank (TOB) or Upland (U)**	**Spacing On Center (O.C.)**	**Maintenance Notes and Aesthetic Qualities**	**Dry**	**Moist to Saturated**	**0 to 1 foot**	**1 to 2 feet**	**2 to 3 feet**
Pinus contorta	Shore pine	Full sun. Well drained soil.	50'			✓	30'	This slender evergreen has orange-brown twigs that darken with age. Cones are asymmetrical and 1" to 2" long. Good to plant along the upland border of a pond.	✓				
Picea sitchensis	Sitka spruce	Part shade to full sun. Moist or saturated soils.	250'	✓		✓	30'	Large evergreen with sage green or light green foliage.		✓	✓		

Thuja plicata	Western red cedar	Full shade to full sun. Moist to swampy soil.	100'	✓	✓	✓	30'	Long-lived western native that can survive moist, mucky conditions.		✓	✓		
Tsuga heterophylla	Western hemlock	Full shade. Wet soil.	150'	✓	✓	✓	30'	Young trees have foliage with a feathery appearance. The 1" long cones are small and papery. Species can be shallow rooted and prone to blow down in some locations.		✓	✓		

Deciduous Shrubs				Plant Placement					Seasonal Water Level Tolerance				
Latin Name	**Common Name**	**Site Conditions**	**Mature Height**	**Wet Slopes (WS)**	**Dry Slopes (DS)**	**Top of Bank (TOB) or Upland (U)**	**Spacing On Center (O.C.)**	**Maintenance Notes and Aesthetic Qualities**	**Dry**	**Moist to Saturated**	**0 to 1 foot**	**1 to 2 feet**	**2 to 3 feet**
Cornus sericea (stolonifera)	Red-osier dogwood	Shady stream banks. Moist, well drained soils.	15'	✓	✓	✓	4'	Plant minimum of 4' from all walkways, roads, and fences in order to avoid pruning. Prune 2-3 branches of a multi-stemmed specimen to the base every other year to stimulate new branch development. New branches have bright red color and will provide winter interest.		✓	✓		
Holodiscus discolor	Ocean spray	Part shade to full sun. Well drained, dry soil.	15'			✓	4'	Large, vase-shaped shrub with arching branches. The big foamy white clusters of flowers bloom throughout the summer months, making this an excellent pollinator species. Good for seasonally dry soil.	✓	✓			
Lonicera involucrata	Black twinberry	Part shade. Moist soils.	2' to 7'			✓	4'	This erect, thinly branches species has twin tubular yellow flowers. The shiny black fruits are cupped by two showy purplish-maroon bracts.	✓				

Myrica gale	Sweet gale	Part shade to full sun. Moist to wet soils.	5'	✓		✓	4'	Upright growth form. Can be used as a windbreak when planted in rows. Good nitrogen-fixing soil properties. Has a spicy scent on hot summer days. Can grow in relatively poor soils.		✓			
Myrica californica	California gale	Part shade to full sun. Moist to wet soils.	6'-18'	✓		✓	4'	A large shrub to small tree with an upright growth pattern. Great for border planting.		✓			
Oemleria cerasiformis	Indian plum	Part shade. Moist to dry, well-drained soil.	5'- 16'			✓	4'	An early bloomer, Indian plum is one of the first shrubs to flower in the spring. The drooping chains of white flowers appear just before the leaves. Birds love the small fruit that begin as yellow-gold and transform into a bluish-black color later in the summer. In the sun, this species can grow as a large, dense plant, but in the shade it will take on a more open and sprawling growth form.	✓	✓			
Philadelphus lewisii	Mock orange	Part shade to full sun. Well drained soil.	5' -10'			✓	4'	This species is an ornamental favorite. The white flowers that appear in late spring and early summer have a lovely sweet smell. This species is great for pollinators, along borders, and clustered in odd numbers.	✓	✓			
Physocarpus capitatus	Pacific ninebark	Full sun. Moist soil.	6' -12'	✓			3'	This multi-stemmed shrub has interesting bark that looks as if it is shedding layers. The flowers appear as white clusters in later spring and early summer.		✓			
Ribes sanguineum	Red-flowering currant	Part shade to full sun. Moist to dry, well drained soil.	8' -10'		✓	✓	4'	The pink to deep red sprays of flowers on this shrub are a favorite early source of food for hummingbirds. Other birds eat the blue-black berries before the end of summer.	✓	✓			

Rosa nutkana	Nootka rose	Full sun. Moist soil.	3' 6'	✓	✓	✓	4'	Fast growing. Good for seasonally wet or seasonally dry soils. Bright pink flowers May through June. Rose hips are purplish-red in fall.		✓			
Rubus parviflora	Thimbleberry	Part shade to full sun. Moist to dry soil.	4' -6'		✓	✓	4'	Medium growth rate. Tolerates dry to seasonally wet soil. Spreads through rhizomes. Large leaves emerge in Spring. Flowers are large, papery, and white. Edible red berries look like raspberries.	✓				
Rubus spectabilis	Salmonberry	Full shade to full sun. Moist soil.	3'- 10'	✓	✓	✓	4'	Fast growing. Bright pink to magenta flowers appear single or in small groups from March through April. The yellow to reddish fruit provide wildlife forage.	✓	✓	✓		
Sambucus racemosa	Red elderberry	Part shade to full sun. Moist soil.	5' -8'			✓	10'	Fast growing. Good for seasonally wet or seasonally dry soils. This shrub can grow into the form of a small tree. Clusters of white flowers in May. Red berries appear June through July.		✓			
Spiraea douglasii	Douglas spirea	Full sun. Wetland or lake edge.	4' -7'	✓		✓	6'	Fast growing. Prefers moist to wet soils. Will tolerate dry soils once established, but will do best on moist or boggy sites. Needs regular water during establishment. Can form thickets in boggy areas. Large clusters of tiny pinkish red flowers. Flower plumes dry and remain on plant through winter.		✓	✓	✓	✓
Symphoricarpus albus	Snowberry	Part shade to full sun. Moist to dry, well drained soil.	2' -6'	✓	✓	✓	3'	Good for seasonally wet or seasonally dry soils. If pruned to ground in early spring, plant will resprout vigorously with more fruit. White to pink bell-shaped flowers. White waxy, non-edible fruit.					

Symphoricarpus mollis	Creeping snowberry	Full shade to full sun. Moist to dry, well drained soil.	2'	✓	✓	✓	3'	This trailing species spreads by sending out new roots from along its stem. This low growing shrub is an excellent groundcover in areas where visibility needs to be maintained.	✓	✓			

Evergreen Shrubs				Plant Placement					Seasonal Water Level Tolerance				
Latin Name	Common Name	Site Conditions	Mature Height	Wet Slopes (WS)	Dry Slopes (DS)	Top of Bank (TOB) or Upland (U)	Spacing On Center (O.C.)	Maintenance Notes and Aesthetic Qualities	Dry	Moist to Saturated	0 to 1 foot	1 to 2 feet	2 to 3 feet
Arctostaphyllos uva-ursi	Kinnikinnick	Full sun. Dry soil.	12"		✓	✓	2'	Low-growing evergreen shrub that is also commonly used as a groundcover.	✓				
Berberis aquifolium	Tall Oregon grape	Part shade. Well drained soil.	5' -8'			✓	4'	Tall shrub with bright yellow clusters of flowers and clusters of blue fruit in late summer and fall. Good for seasonally dry soil and open areas. Good bird forage species.	✓				
Berberis nervosa	Dull Oregon grape	Part shade. Moist, well drained soil.	2' -3'	✓	✓	✓	3'	Low-growing shrub that prefers shade, but will tolerate open areas. Flowers are bright yellow clusters and fruits are in blue berry-like clusters.	✓	✓			
Ceanothus velutinus	Snowbrush	Full sun. Moist to dry soil, well drained.	20'			✓		Large, pyramidal-shaped clusters of small white flowers. This shrub has a spicy scent. The new bark is reddish or purplish in color.	✓	✓			
Gaultheria shallon	Salal	Part shade to full sun. Well drained soil.	3' -6'		✓	✓	3'	Good for seasonally dry soil. The more sun, the less the plant will spread. Spreads by layering, suckering, and sprouting. Does best with some moisture and part shade. Deer, rabbit, and snail resistant.	✓				

Vaccinium ovatum	Evergreen huckleberry	Shade to full sun. Moist, well drained soil.	3' in full sun. 15' in deep shade.	✓		✓	4'	This shrub has shiny, leathery leaves and tiny pink bell-shaped flowers that bloom from April through July. In areas with full sun, this shrub will have a more open form		✓			

Groundcovers				Plant Placement					Seasonal Water Level Tolerance				
Latin Name	**Common Name**	**Site Conditions**	**Mature Height**	**Wet Slopes (WS)**	**Dry Slopes (DS)**	**Top of Bank (TOB) or Upland (U)**	**Spacing On Center (O.C.)**	**Maintenance Notes and Aesthetic Qualities**	**Dry**	**Moist to Saturated**	**0 to 1 foot**	**1 to 2 feet**	**2 to 3 feet**
Adiantum aleuticum	Maidenhair fern	Full shade. Moist to wet soil.	2'	✓		✓	24"	A black-stemmed fern with delicate palmately arranged leaves.	✓	✓			
Aquilegia formosa	Western columbine	Part shade to full sun. Moist soil.	2'	✓	✓	✓	12"	The beautiful red and yellow flowers bloom in spring and summer. The delicate leaves die back in the winter months and resprout in the spring.	✓	✓			
Aruncus sylvester	Goat's beard	Part shade. Moist soil.	3'- 5'	✓		✓	4'	A deciduous wildflower with large masses of airy white flowers that turn brownish-red as the seasons progress. This plant has a great form throughout the winter and resprouts new arching stems each spring.		✓			
Athyrium filix-femina	Lady fern	Full shade. Moist to wet soil.	2'-5'	✓		✓	24"	This fern has delicate feathery fronds and red stems. It is a reliable groundcover.		✓	✓		
Blechnam spicant	Deer fern	Full shade. Moist soil.	2'	✓		✓	24"	A low-growing, hardy fern that does well under the shade of plants.		✓			
Camassia quamash	Common camas	Part shade to full sun. Moist to moderately dry soils.	18"-24"	✓	✓	✓	12"	This pale to deep blue, occasionally white, lily has spike with 5 to many flowers. This showy plant blooms over a short few weeks in late spring.	✓	✓			

Clarkia amoena	Dwarf godetia	Full sun. Moist to moderate soils.	8"- 14"	✓	✓	✓	18"	This pink to rose-purple flower blooms in mid-summer and continues to bloom for several weeks. A taprooted species, it is good for drier sites.	✓	✓			
Dicentra formosa	Pacific bleeding heart	Full shade. Moist soil.	18"	✓	✓	✓	24"	A delicate-leaved plant with little pink heart-shaped flowers, this plant spreads by rhizomes (underground root systems).	✓	✓			
Epilobium angustifolium	Fireweed	Full sun. Moist to dry soil.	2'-6'		✓	✓	24"	Showy rose to purple flowers in tall spike-like clusters. This plant spreads by seed and rhizome and will continue to thrive as long as it gets sun.	✓	✓			
Fragaria chiloensis	Coastal strawberry	Part shade to full sun. Sandy soil.	6"	✓	✓	✓	12"- 18"	A hardy, small strawberry plant that will colonize open areas and create a dense groundcover.	✓	✓			
Heuchera micrantha	Alumroot	Full shade. Moist soil.	18"-24"	✓		✓	18"	A delicate native with a tall spike of small white flowers. Great for shady sites.	✓	✓			
Lupinus polyphyllus	Large-leaf lupine	Part shade. Moist soil.	12"-36"	✓	✓	✓	12"	Big, robust plant with bold, rich-green palmate leaves. The flowers are large spikes of deep-blue to purplish flowers. This plant blooms biennially and will spread from seed.	✓	✓			
Mimulus guttatus	Yellow monkey flower	Full sun. Moist to wet soil.	18"- 30"	✓		✓	24"	This perennial herb spread by rhizomes and has bright happy yellow flowers with crimson to reddish-brown spots.		✓	✓		
Oxalis oregana	Sorrel	Full shade. Moist soil.	12"	✓	✓	✓	14"	This clover-like species spreads by rhizomes and forms a nice groundcover. The small white flowers bloom in spring and summer.	✓	✓			
Plectritis congesta	Sea blush	Full sun. Moist to wet soil.	6"-24"	✓		✓	12"	This small herb has an upright stem that supports a head of showy pink flowers.	✓	✓			

Polystitchum munitum	Sword fern	Moist to dry soil.	2'- 5'	✓	✓	✓	24"	One of the most adaptable, hardy ferns this species stays green year-round.	✓	✓			
Sisyrinchium idahoense	Blue eyed grass	Part shade to full sun. Moist soils.	24"	✓	✓	✓	12"	This perennial herb has grass-like leaves, but has a light blue to dark purple (sometimes white) flower.	✓	✓			
Tellima grandiflora	Fringecup	Part shade. Moist soil.	14"- 30"	✓		✓	18"	A perennial herb with a spike of fragrant, greenish-white flowers that turn pink or reddish as the flowers age.	✓	✓			
Tolmiea menziesii	Youth-on-age	Full shade. Moist soil.	6" -12"	✓		✓	12"	Small plant that forms a delicate groundcover. The tiny flowers are brownish-purple.	✓	✓			

Grasses, Sedges, and Rushes				**Plant Placement**					**Seasonal Water Level Tolerance**				
Latin Name	**Common Name**	**Site Conditions**	**Mature Height**	**Wet Slopes (WS)**	**Dry Slopes (DS)**	**Top of Bank (TOB) or Upland (U)**	**Spacing On Center (O.C.)**	**Maintenance Notes and Aesthetic Qualities**	**Dry**	**Moist to Saturated**	**0 to 1 foot**	**1 to 2 feet**	**2 to 3 feet**
Agrostis exarata	Spiked bentgrass	Full sun to part shade. Moist, saturated, or seasonally to permanently flooded conditions.	1'-3'	✓			12"	A perennial grass that grows in tufted form and has erect spikes, as its name suggests.		✓	✓		
Beckmannia syzigachne	American sloughgrass	Full sun to part shade. Moist, saturated, or seasonally to permanently flooded conditions.	1'-3'	✓			12"	A stout grass with somewhat spongy stems, this plant grows on its own or in groups. This species can be planted or seeded.		✓	✓		
Bromus sitchensis	Sitka brome	Full sun. Dry soils.	6"- 18"			✓	12"	A stout perennial grass with flowers in open, airy panicles.	✓				
Carex obnupta	Slough sedge	Full sun to part shade. Moist, saturated, or seasonally to permanently flooded conditions.	1'-3'	✓			12"	A large tufted sedge with erect, then arching leaf blades and large brown arching flower heads.		✓	✓	✓	
Carex stipata	Saw beaked sedge	Full sun to part shade. Moist, saturated, or seasonally to permanently flooded conditions.	1'-3'	✓			12"	A tufted arching sedge, this plant has pyramidal flower clusters that turn from light green to golden as they mature. Flower stems are erect and leaves are bright spring green.		✓	✓		
Danthonia californica	California oat grass	Full sun. Dry to moist soil.	10"- 12"		✓	✓	12"	A delicate, native, clumping grass with purplish-red flowers.	✓	✓			

Deschampsia cespitosa	Tufted hairgrass	Full sun. Moist to wet soil.	18"- 4'	✓	✓	✓	12"	This large, clumping grass has big feathery flower heads with bronze arching flowers.	✓	✓	✓		
Eleocharis palustris	Common spikerush	Full sun to part shade. Moist, saturated, or seasonally to permanently flooded conditions.	1'-3'	✓			12"	A mat-forming perennial spikerush with erect slender stems.		✓	✓	✓	✓
Elymus glaucus	Blue wildrye	Full shade to full sun. Dry to moist soil.	2'-4'	✓	✓	✓	12"	A tufted perennial grass that forms small clumps and has light blue-green green leaf blades.	✓	✓			
Festuca idahoensis	Idaho fescue	Full sun. Dry soil.	1'-3'	✓		✓	12"	A clumping grass with fine-textured blue-green leaves. Adds soft texture to the landscape.	✓				
Festuca rubra	Red fescue	Full sun to full shade. Dry to moist soil.	2'	✓	✓	✓	12"	A versatile grass that spreads by rhizome. One of the few shade tolerant grasses.	✓	✓			
Glyceria occidentalis	Northwestern mannagrass	Full sun to part shade. Moist, saturated, or seasonally to permanently flooded conditions.	1'-5'	✓			12"	A tall perennial wetland grass.		✓	✓	✓	✓
Hordeum brachyantherum	Meadow barley	Full sun. Dry to moist soil.	1'-3'	✓	✓	✓	12"	A hardy native tolerant of wet, dry, and saline sites. This species is used for erosion control and as a groundcover. Can sometimes compete with reed canary grass.	✓	✓			
Juncus ensifolius	Dagger-leaf rush	Full sun to part shade. Moist, saturated, or seasonally to permanently flooded conditions.	6" to 2.5'	✓			12"	A small rush with an erect form, this wetland species spreads by rhizome.		✓	✓	✓	
Juncus tenuis	Slender rush	Full sun to part shade. Moist, saturated, or seasonally to permanently flooded conditions.	6" to 2'	✓			12"	This rush is best planted, due to its low seed fertility rate. A clump forming perennial rush.		✓	✓	✓	
Schoenoplectus acutus	Hardstem bulrush	Full sun to part shade. Moist, saturated, or seasonally to permanently flooded conditions.	3' to 6'	✓			12"	A good wetland species to use for soil stabilization and water treatment. Birds eat the seeds, but this plant is not a preferred food of deer and elk.		✓	✓	✓	✓
Schoenoplectus microcarpus	Soft stem bulrush	Full sun to part shade. Moist, saturated, or seasonally to permanently flooded conditions.	2' to 3'	✓			12"	A good soil stabilization and water quality species, this plant spreads readily by rhizome.		✓	✓	✓	

Kitsap County Emergent Seed Mix			Seasonal Water Level Tolerance				
Latin Name	**Common Name**	**% Mix**	**Dry**	**Moist to Saturated**	**0 to 1 foot**	**1 to 2 feet**	**2 to 3 feet**
Beckmannia syzigachne	American sloughgrass	20		✓	✓	✓	
Carex obnupta	Slough sedge	10					
Eleocharis palustris	Common spikerush	10					
Elymus glaucus	Blue wildrye	20					
Glyceria occidentalis	Northwestern mannagrass	10					
Juncus ensifolius	Dagger-leaf rush	10					
Juncus tenuis	Slender rush	10					
Schoenoplectus acutus	Hardstem bulrush	5					
Schoenoplectus microcarpus	Soft stem bulrush	5					

Kitsap County Wetland Bottom Seed Mix			Seasonal Water Level Tolerance				
Latin Name	**Common Name**	**% Mix**	**Dry**	**Moist to Saturated**	**0 to 1 foot**	**1 to 2 feet**	**2 to 3 feet**
Agrostis exarata	Spiked bentgrass	20		✓	✓	✓	✓
Carex stipata	Saw beaked sedge	30					
Glyceria occidentalis	Northwestern mannagrass	20					
Schoenoplectus microcarpus	Soft stem bulrush	30					

Kitsap County Moist to Dry Slope Seed Mix			Seasonal Water Level Tolerance				
Latin Name	**Common Name**	**% Mix**	**Dry**	**Moist to Saturated**	**0 to 1 foot**	**1 to 2 feet**	**2 to 3 feet**
Deschampsia cespitosa	Tufted hairgrass	20	✓	✓			
Hordeum brachyantherum	Meadow barley	30					
Elymus glaucus	Blue wildrye	15					
Festuca rubra var *rubra*	Red fescue	20					
Bromus carinatus	California brome	15					

Kitsap County Emergent Wildflower/Pollinator Seed Mix			Seasonal Water Level Tolerance				
Latin Name	**Common Name**	**% Mix**	**Dry**	**Moist to Saturated**	**0 to 1 foot**	**1 to 2 feet**	**2 to 3 feet**
Camassia quamash	Common camas	25	✓	✓			
Erigeron speciosus	Aspen daisy	25					
Lupinus polyphyllus	Large-leaf lupine	25					
Sisyrinchium idahoense	Blue eyed grass	25					

Kitsap County Upland Grass Seed Mix			Seasonal Water Level Tolerance				
Latin Name	**Common Name**	**% Mix**	**Dry**	**Moist to Saturated**	**0 to 1 foot**	**1 to 2 feet**	**2 to 3 feet**
Bromus carinatus	California brome	20	✓				
Festuca rubra var. rubra	Red fescue	30					
Hordeum brachyantherum	Meadow barley	50					

Kitsap County Upland Forb Seed Mix			Seasonal Water Level Tolerance				
Latin Name	**Common Name**	**% Mix**	**Dry**	**Moist to Saturated**	**0 to 1 foot**	**1 to 2 feet**	**2 to 3 feet**
Achillea millefolium	Yarrow	25	✓				
Clarkia amoena	Farewell-to-spring	25					
Lupinus bicolor	Bicolor lupine	25					
Solidago canadensis	Canada goldenrod	25					

APPENDIX E

Inspection and Maintenance Recommendations

Inspection and Maintenance Recommendations

General maintenance considerations and inspection and maintenance checklists for the following facility types can be found in the current version of the *Stormwater Management Manual for Western Washington* and the *Kitsap County Stormwater Design Manual*:

- Stormwater wetland
- Bioretention facility
- Wet pond
- Infiltration facility

Maintenance considerations for subsurface gravel wetlands are not currently included in the *Stormwater Management Manual for Western Washington* nor the *Kitsap County Stormwater Design Manual*, thus they are summarized in this appendix.

Inspection and Maintenance Recommendations for Subsurface Gravel Wetlands

Inspection and maintenance recommendations for subsurface gravel wetlands are based on the *UNHSC Subsurface Gravel Wetland Design Specifications* (UNHSC 2009) and *NJ Stormwater Management Best Management Practices Manual* (New Jersey 2011) which are largely adapted from the *Connecticut Stormwater Quality Manual* (CTDEP 2004) for filtration systems.

Inspection schedules typically include two periods: 1) 1st Year Post-Construction, 2) Post-Construction Routine Monitoring. Maintenance is critical for the proper operation of subsurface gravel wetland systems. The 1st Year Post-Construction monitoring differs primarily by its increased frequency to assure proper vegetative establishment and system functioning. Post-Construction Routine Monitoring is based on USEPA requirements for Good Housekeeping practices.

Unlike other filtration systems, a subsurface gravel wetland is a subsurface, horizontal filtration system and does not rely upon the surface soils for treatment. As such, surface infiltration rates are expected to be low and are not used for the criteria for cleaning/maintenance. Rather, stormwater access to the subsurface gravel layer is the critical hydraulic performance measure.

1st Year Post-Construction

Inspection frequency should be after every major storm in the first year following construction.

- Inspect to be certain system drains within 24-72 hrs (within the design period, but also not so quickly as to minimize stormwater treatment)
- Water plants as necessary during the first growing season
- Re-vegetate poorly established areas as necessary
- Treat diseased vegetation as necessary
- Inspect soil quarterly and repair eroded areas, especially on slopes
- Check inlets, outlets, and overflow spillway for blockage, structural integrity, and evidence of erosion.

Post-Construction

Inspection frequency should be at least every six months thereafter, as per USEPA Good House-Keeping Requirements. Inspection frequency can be reduced to annually following two years of monitoring that indicates the rate of sediment accumulation is less than the cleaning criteria listed below. Inspections should focus on:

- Checking the filter surface for dense, complete, root mat establishment across the wetland surface. Thorough revegetation with grasses, forbs, and shrubs is necessary. Unlike bioretention, where mulch is commonly used, complete surface coverage with vegetation is needed.

- Checking the gravel wetland surface for standing water or other evidence of riser clogging, such as discolored or accumulated sediments.

- Checking the sedimentation chamber or forebay for sediment accumulation, trash, and debris.

- Inspecting the sedimentation forebay to ensure that it drains within 24 to 72 hrs. If the drain time is significant longer than 72 hours or shorter than 24 hours for a storm event of one-inch or more, the wetland's outlet structure, perforated pipe performance, forebay, valves, and other components that may provide hydraulic controls must be evaluated and appropriate measures taken to comply with the minimum and maximum drain time requirements to maintain the proper functioning of the subsurface gravel wetland.

- Checking inlets, outlets, and overflow spillway for blockage, structural integrity, and evidence of erosion. All structural components must be inspected for cracking, subsidence, spalling, erosion, and deterioration.

- Removing decaying vegetation, litter, and debris. Dispose of debris, trash, sediment, and other waste material at suitable disposal/recycling sites and in compliance with all applicable local, state, and federal waste regulations.

Vegetated Area Maintenance

Mowing or trimming of vegetation must be performed on a regular schedule based on specific site conditions. The wetland vegetation must be harvested at least once every three years and no more frequently than once a year.

When establishing or restoring vegetation, biweekly inspections of vegetation health should be performed during the first growing season or until the vegetation is established. Once established, inspections of vegetation health, density, and diversity should be performed at least twice annually during both the growing and non-growing seasons. The vegetative cover must be maintained at 85 percent. If vegetation has greater than 50 percent damage, the area must be reestablished in accordance with the original specifications and the inspection requirements presented above.

The types and distribution of the dominant plants must also be assessed during the semi-annual wetland inspections. This assessment should be based on the health and relative extent of both the original species remaining and all volunteer species that have subsequently grown in the wetland. Appropriate steps must be taken to achieve and maintain an acceptable balance of original and volunteer species in accordance with the intent of the wetland's original design.

All use of fertilizers, mechanical treatments, pesticides and other means to assure optimum vegetation health should not compromise the intended purpose of the subsurface gravel wetland. All vegetation deficiencies should be addressed without the use of fertilizers and pesticides whenever possible.

Cleaning Criteria for Sedimentation Forebay

Sediment should be removed from the sedimentation chamber (forebay) when it accumulates to a depth of more than 12 inches (30 centimeters) or 10 percent of the pretreatment volume (UNHSC 2009). New Jersey (2011) recommends that the forebay be cleaned when it accumulates to either six inches or 10 percent of the forebay volume or if it remains wet nine hours after the end of a storm event.

The sedimentation forebay should be cleaned of vegetation if persistent standing water and wetland vegetation becomes dominant. The cleaning interval is approximately every four years. A dry sedimentation forebay is the optimal condition while in practice this condition is rarely achieved. The sedimentation chamber, forebay, and treatment cell outlet devices should be cleaned when drawdown times exceed 60 to 72 hours. Materials can be removed with heavy construction equipment; however this equipment should not track on the wetland surface. Disturbed areas should be revegetated as necessary. Removed sediments should be dewatered (if necessary) and disposed of in an acceptable manner.

Cleaning Criteria for Gravel Wetland Treatment Cells

Sediment should be removed from the gravel wetland surface when it accumulates to a depth of several inches (> 10 centimeters) across the wetland surface. Materials should be removed with rakes rather than heavy construction equipment to avoid compaction of the gravel wetland surface. Heavy equipment could be used if the system is designed with dimensions that allow equipment to be located outside the gravel wetland, while a backhoe shovel reaches inside the gravel wetland to remove sediment. Removed sediments should be dewatered (if necessary) and disposed of in an acceptable manner.

Draining and Flushing Gravel Wetland Treatment Cells

For maintenance it may be necessary to drain or flush the treatment cells. The optional drains will permit simpler maintenance of the system if needed. The drains need to be closed during standard operation. Flushing of the risers and horizontal subdrains is most effective with the entire system drained. Flushed water and sediment should be collected and properly disposed.

APPENDIX F

Planning Level Cost Considerations

Planning Level Cost Considerations for Stormwater Pond Retrofits

This appendix includes information that will help in developing cost estimates for stormwater pond retrofit projects. The information presented in this appendix breaks down pond retrofit design, permitting, and construction into line items for various components that may be involved in the project. Unit costs for each line item will vary depending on many factors, but the information contained in this appendix will help when thinking about the types of costs that a retrofit project will include. There are several site-specific factors that can either increase or decrease the cost of a selected retrofit option. These factors should be evaluated when developing a planning level cost estimate for a particular retrofit project.

Site-specific factors that may increase the cost of the selected retrofit option include the following (CWP 2007):

- Changing or replacing of pond outlet risers
- Dewatering required for earthwork in wet or saturated soils
- Difficult site access and/or inadequate space for construction staging
- Hauling excavated material offsite
- Importing fill to the site
- Little or no additional space within parcel boundaries
- Permitting required for working in or close to a stream or wetland
- Reinforcement of pond embankments
- Wetland mitigation required for the project

Site-specific factors that may decrease the cost of the selected retrofit option include the following (CWP 2007):

- Available space within parcel boundaries for expanding pond footprint
- Dry pond bottom (decreased need for dewatering)
- Limited or no adjustments proposed to the pond outlet riser or embankments
- Limited or no permitting (e.g., wetland, in-stream) required
- Little or no conflicts with existing utilities
- Neutral earthwork balance (i.e., equal amounts of cut and fill)
- Site access is adequate for construction staging

Table F-1 summarizes line items for potentially applicable components of a stormwater pond retrofit project. The sections following Table F-1 summarize the unit cost elements that could potentially be included for the following retrofit categories highlighted in this manual:

- Wetland conversion
- Bioretention
- Pond expansion
- Pond outlet modification
- Configuration change
- Vegetation improvement
- Infiltration
- Multiple uses
- Subsurface gravel wetland

Table F-1. Unit cost elements that could be included in stormwater pond retrofit projects.

Item	Typical Units
Design and Permitting	
Design	Lump Sum
Permitting	Lump Sum
Site Preparation	
Mobilization and Staging of Construction Equipment and Materials	Lump Sum
Clearing and Grubbing	Square Yard
Erosion and Sediment Control	Lump Sum
Temporary Bypass of Pond Inflow	Lump Sum
Earthwork	
Berm or Embankment Construction	Cubic Yard
Excavation	Cubic Yard
Pond Dewatering (in high groundwater areas)	Lump Sum
Offsite Haul of Excess Excavated Material	Cubic Yard
Discing or Tilling Compacted Soils	Square Yard
Soil and Other Planting Media	
Bioretention Soil (Material and Placement)	Cubic Yard
Planting Soil (Material and Placement)	Cubic Yard
Topsoil (Material and Placement)	Cubic Yard
Compost (Soil Amendment)	Cubic Yard
Mulch	Cubic Yard
Vegetation	
Emergent Planting and Establishment	Square Feet
Emergent Seeding	Acre
Riparian and Upland Planting and Establishment	Square Feet
Riparian and Upland Seeding	Acre
Inlet, Outlet, and Other Drainage Piping	
Remove Existing Inlet or Outlet Pipe	Lineal Feet
New Inlet Pipe (6- to 12-inch PVC or concrete)	Lineal Feet

Table F-1 (cont.). Unit cost elements that could be included in stormwater pond retrofit projects.

Item	Typical Units
Inlet, Outlet, and Other Drainage Piping (cont.)	
New Outlet Pipe (6- to 12-inch PVC or concrete)	Lineal Feet
Perforated or Slotted PVC Sch. 40 Underdrain Pipe (4- to 8-inch diam.)	Lineal Feet
Capped Outlet PVC Pipe for Maintenance	Each
Outlet Structure Modifications	
New Outlet Structure	Each
Replacement of Outlet Structure	Each
Installing an Anti-Vortex Device	Each
Installing an Orifice Plate	Each
Installing a Trash Rack	Each
Installing a Weir	Each
Aggregate Materials	
Rip Rap for Energy Dissipation	Ton
Pea Gravel	Ton
Clean, Crushed Angular Stone	Ton
Multiple Use Components	
Trailside Bench (not including tax and shipping)	Each
Gravel Path	Cubic Yard
Mulched Path	Cubic Yard
Removing Fencing	Lineal Feet
Educational Signage	Lump Sum

Wetland Conversion

Cost items potentially included in a wetland conversion retrofit project include the following:

- Design
- Permitting
- Mobilization
- Clearing and grubbing

- Temporary bypass of pond inflow
- Erosion and sediment control
- Excavation
- Offsite haul of excess excavated material
- Pond dewatering (in high groundwater areas)
- Berm construction
- Emergent planting and establishment
- Emergent seeding
- Riparian and upland planting and establishment
- Riparian and upland seeding
- Topsoil
- Compost
- Mulch
- Replacement of outlet structure
- Replacement of outlet pipe
- Rip rap for energy dissipation

Bioretention

Cost items potentially included in a bioretention retrofit project include the following:

- Design
- Permitting
- Mobilization
- Clearing and grubbing
- Temporary bypass of pond inflow
- Erosion and sediment control
- Excavation
- Offsite haul of excess excavated material
- Discing or tilling compacted soil
- Bioretention soil placement
- Emergent planting and establishment
- Emergent seeding
- Riparian and upland planting and establishment
- Riparian and upland seeding
- Compost
- Mulch
- Replacement of outlet structure
- Replacement of outlet pipe
- Rip rap (or large cobble) for energy dissipation at inlet

Pond Expansion

Cost items potentially included in a pond expansion retrofit project include the following:

- Design
- Permitting
- Mobilization
- Clearing and grubbing
- Temporary bypass of pond inflow
- Erosion and sediment control
- Excavation
- Offsite haul of excess excavated material
- Pond dewatering (in high groundwater areas)
- Berm or embankment construction
- Topsoil placement
- Emergent planting and establishment
- Emergent seeding
- Riparian and upland planting and establishment
- Riparian and upland seeding
- Replacement of outlet structure
- Replacement of inlet pipe
- Replacement of outlet pipe
- Rip rap for energy dissipation

Pond Outlet Modification

Cost items potentially included in an pond outlet modification retrofit project include the following:

- Design
- Permitting
- Mobilization
- Temporary bypass of pond inflow
- Excavation
- Dewatering (if excavation is needed to a depth that encounters groundwater)
- Topsoil placement
- Riparian and upland seeding
- Installing an anti-vortex device
- Installing an orifice plate
- Installing a trash rack
- Installing a weir
- Replacement of outlet structure
- Replacement of outlet pipe
- Rip rap for energy dissipation

Configuration Change

Cost items potentially included in a configuration change retrofit project include the following:

- Design
- Permitting
- Mobilization
- Clearing and grubbing
- Temporary bypass of pond inflow
- Erosion and sediment control
- Excavation
- Berm construction
- Replacement of inlet or outlet pipe
- Replacement (or relocation) of outlet control structure
- Emergent planting and establishment
- Emergent seeding
- Riparian and upland planting and establishment
- Riparian and upland seeding

Vegetation Improvement

Cost items potentially included in a vegetation improvement retrofit project include the following:

- Design
- Permitting
- Mobilization
- Erosion and sediment control
- Temporary bypass of pond inflow
- Topsoil placement
- Compost
- Mulch
- Emergent planting and establishment
- Emergent seeding
- Riparian and upland planting and establishment
- Riparian and upland seeding

Infiltration

Cost items potentially included in an infiltration retrofit project include the following:

- Design
- Permitting
- Mobilization
- Clearing and grubbing
- Temporary bypass of pond inflow
- Erosion and sediment control
- Excavation
- Offsite haul of excess excavated material
- Discing or tilling of compacted soil
- Compost
- Riparian and upland planting and establishment
- Riparian and upland seeding
- Mulch
- Replacement of outlet structure
- Replacement of outlet pipe
- Rip rap (or large cobbles) for energy dissipation at inlet

Multiple Uses

Cost items potentially included in a multiple-use retrofit project include the following:

- Design
- Permitting
- Mobilization
- Trailside bench
- Gravel path
- Mulched path
- Removing fencing
- Educational signage

Subsurface Gravel Wetland

Cost items potentially included in a subsurface gravel wetland retrofit project include the following:

- Design
- Permitting
- Mobilization
- Clearing and grubbing

- Temporary bypass of pond inflow
- Erosion and sediment control
- Excavation
- Offsite haul of excess excavated material
- Pond dewatering (in high groundwater areas)
- Planting soil placement
- Pea gravel
- Clean, crushed angular stone
- Emergent planting and establishment
- Emergent seeding
- Riparian and upland planting and establishment
- Riparian and upland seeding
- New or replaced outlet structure
- Remove existing outlet pipe
- New or replaced outlet pipe
- Perforated or slotted PVC Sch. 40 pipe
- Capped outlet PVC pipe for gravel bed maintenance