SvR DESIGN COMPANY

Aurora Corridor
North 165TH Street to North 205TH Street

CONCEPT STORMWATER MANAGEMENT REPORT

August 20, 2007
Revised November 2, 2007

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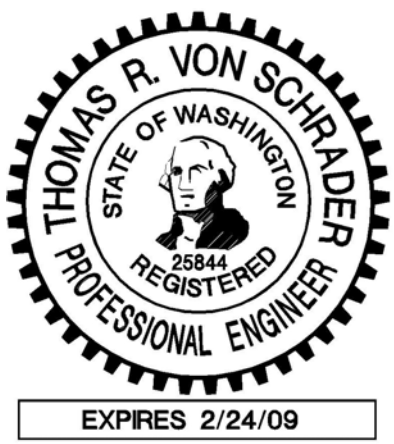

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Executive Summary

The purpose of this report is to outline concept stormwater management recommendations for the City of Shoreline (“Shoreline”) for the Aurora Corridor project, between North 165th Street and N 205th Street (see Figure 1).This report examines: current stormwater regulations and “target” stormwater management goals, identifies stormwater management methods including conventional underground pipe systems and Low Impact Development (LID) elements. This report makes recommendations on how LID elements can be incorporated into the proposed Aurora Corridor improvements.

In the context of this report, LID is a stormwater management facility or natural drainage system that emphasizes the use of natural features to improve stormwater quality and attenuate peak flows.

Conventional and LID elements were sized to meet current Shoreline stormwater management requirements (1998 King County Surface Water Design Manual per Shoreline Municipal Code) and also to meet target stormwater requirements recommended by Shoreline staff (2005 King County Surface Water Design Manual). In addition to sizing facilities to meet current regulations, stormwater management facilities were also sized to meet “target” stormwater management goals related to the 2005 King County Surface Water Design Manual and specific to Shoreline Creek Drainage Basins located within the project area. Table 1 contains a summary of current stormwater regulations and Shoreline’s targets.

Table 1: Summary of Stormwater Regulations and Targets

	Current Regulations – 1998 KCSWDM	Shoreline Specific Stormwater Management Targets – 2005 KCSWDM		
	All Basin and Drainage Areas	Boeing Creek Basin	McAleer Creek Basin: Echo Lake Drainage Area	McAleer Creek Basin: Lake Ballinger Drainage Area
Flow Control	Not Required	Flood Problem	Conservation	Conservation
Water Quality (WQ)	**Basic WQ Treatment** for Total Suspended Solids	**Basic WQ Treatment** for Total Suspended Solids	**Basic WQ Treatment** for Total Suspended Solids **Enhanced Basic WQ Treatment** for Zinc Removal and **Sensitive Lake Treatment** for Phosphorus Removal	**Basic WQ Treatment** for Total Suspended Solids **Enhanced Basic WQ Treatment** for Zinc Removal and **Sensitive Lake Treatment** for Phosphorus Removal

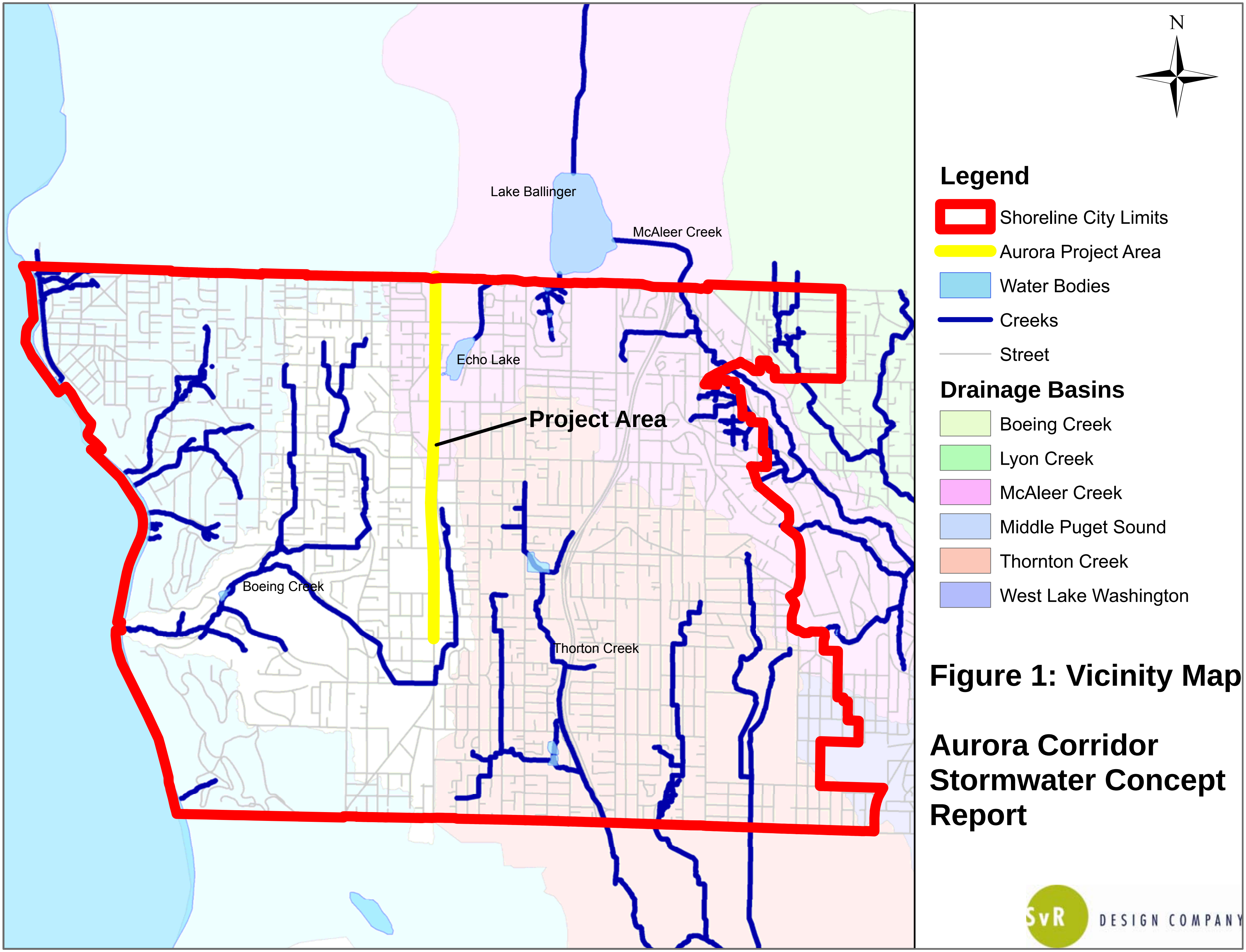


Figure 1: Vicinity Map

Aurora Corridor Stormwater Concept Report

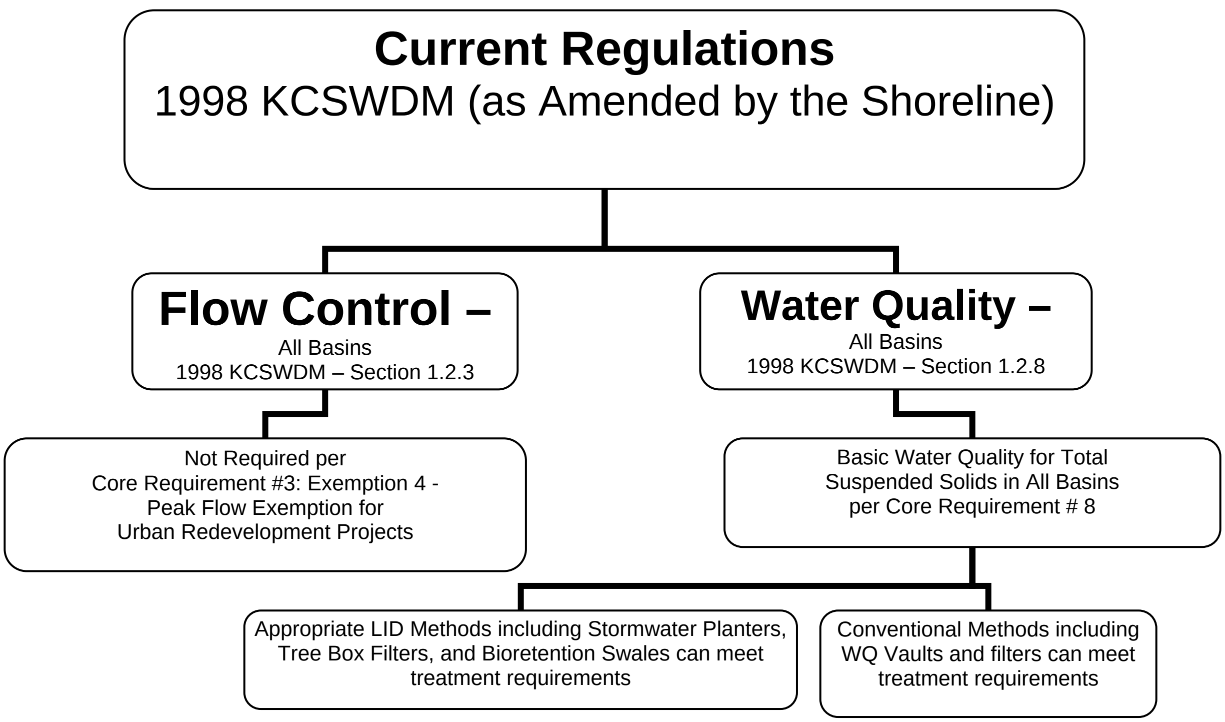
Information Courtesy of the City of Shoreline Map NTS

SvR Project # 06052

Using the Department of Ecology Western Washington Hydrology Model, a continuous simulation hydrologic model, LID and conventional stormwater methods were designed within the Aurora Corridor project limits to meet Shoreline's current regulations and targets.

As a result of the modeling, the following conclusions were made as they relate to Shoreline meeting the 1998 King County Surface Water Design Manual Stormwater Management requirements:

- Flow control is not required since there is no increase in runoff from Aurora Avenue between the existing conditions and the proposed alignment (no new impervious surfaces)
- LID elements can be used to meet Basic Water Quality Treatment requirements for total suspended solids removal
- Conventional oil/water separators or catch basins with filter media must be used to meet the Oil Control special requirements at high-use intersections



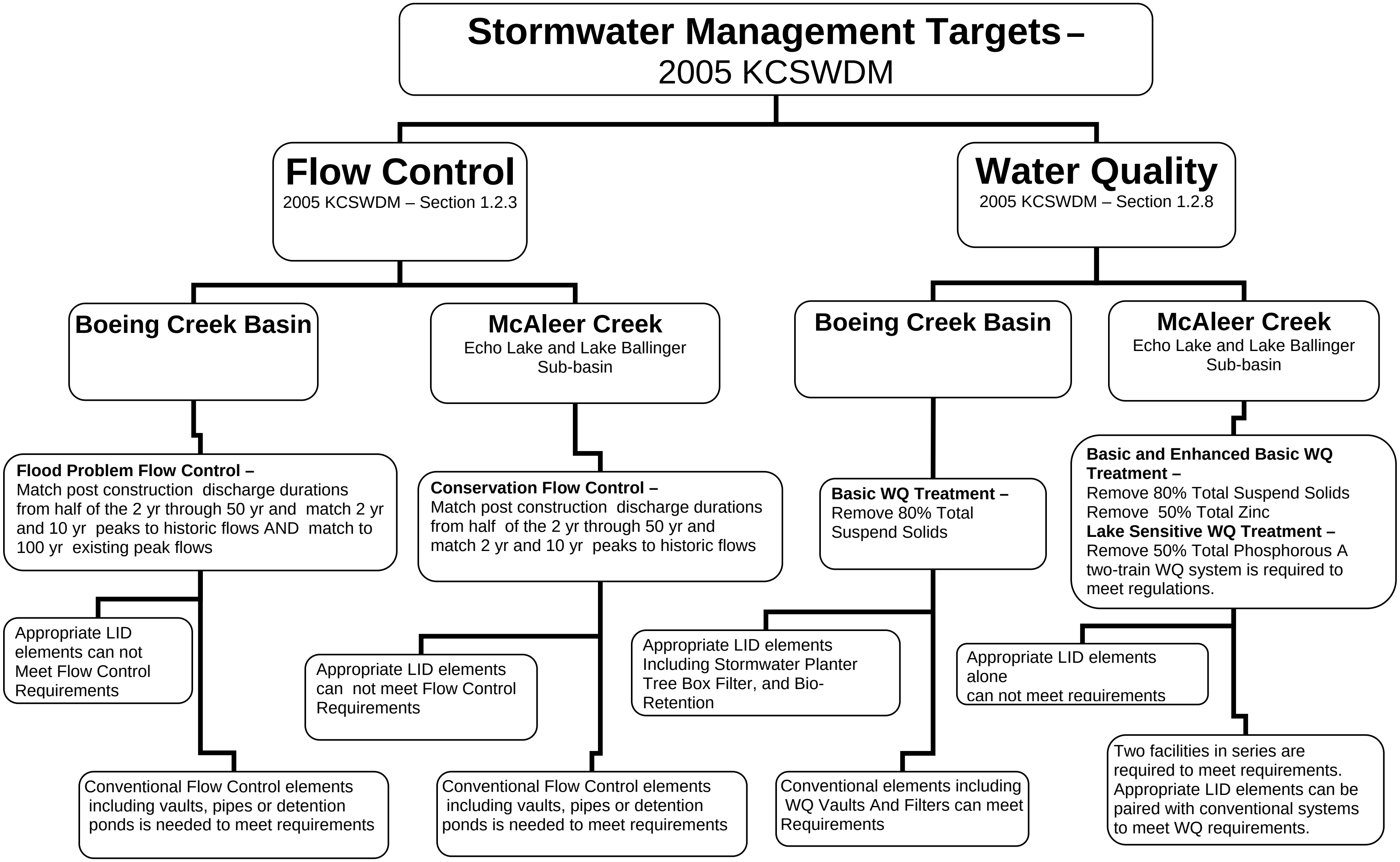
The following conclusions were made related to how the project can meet stormwater targets based on the Shoreline staff recommended stormwater management targets from the 2005 King County Surface Water Design Manual:

- Flow control is based on the amount of pavement that is replaced down to the base course
- Flow control is based when pavement, including the base course, is completely replaced along the roadways
- No additional water quality targets were recommended for Boeing Creek
- Enhanced Basic Water Quality Treatment and Sensitive Lake Water Quality Treatment is the target for McAleer Creek
- LID elements can be used to meet Basic Water Quality Treatment requirements for total suspended solids removal in Boeing Creek and McAleer Creek
- Additional conventional treatment systems will be required to meet the targets for zinc (Enhanced Basic) and phosphorus removal (Sensitive Lake).
- Conventional oil/water separators or facilities with filter media must be used to meet the Oil Control special requirements at high-use intersections

Please see Page 4 for a flow chart summarizing stormwater management and treatment systems can be used to meet the stormwater targets.

As the Aurora Corridor project's design advances, Shoreline will have to investigate further into feasible locations of the LID elements as they relate to the underground utilities and the cross section of the roadway. Referencing construction documents for 145th to 165th, an average of 40 lf of amenity zones were constructed per 100 lf of improvements. This area could be available to construct feasible LID elements.

In addition to meeting some of the current and target stormwater management objectives, LID elements can also provide pedestrian safety, increase aesthetics along the commercial corridor, improve the function of the installed infrastructure, and expand on the "green" and sustainable goals that the Shoreline Council has set forth for the community.


Stormwater Management Targets – 2005 KCSWDM
Flow Control
2005 KCSWDM – Section 1.2.3
Water Quality
2005 KCSWDM – Section 1.2.8
Boeing Creek Basin
McAleer Creek
Echo Lake and Lake Ballinger Sub-basin
Boeing Creek Basin
McAleer Creek
Echo Lake and Lake Ballinger Sub-basin
Flood Problem Flow Control – Match post construction discharge durations from half of the 2 yr through 50 yr and match 2 yr and 10 yr peaks to historic flows AND match to 100 yr existing peak flows
Conservation Flow Control – Match post construction discharge durations from half of the 2 yr through 50 yr and match 2 yr and 10 yr peaks to historic flows
Basic WQ Treatment – Remove 80% Total Suspend Solids
Basic and Enhanced Basic WQ Treatment – Remove 80% Total Suspend Solids Remove 50% Total Zinc
Lake Sensitive WQ Treatment – Remove 50% Total Phosphorous A two-train WQ system is required to meet regulations.
Appropriate LID elements can not Meet Flow Control Requirements
Appropriate LID elements can not meet Flow Control Requirements
Appropriate LID elements Including Stormwater Planter Tree Box Filter, and Bio-Retention
Appropriate LID elements alone can not meet requirements
Conventional Flow Control elements including vaults, pipes or detention ponds is needed to meet requirements
Conventional Flow Control elements including vaults, pipes or detention ponds is needed to meet requirements
Conventional elements including WQ Vaults And Filters can meet Requirements
Two facilities in series are required to meet requirements. Appropriate LID elements can be paired with conventional systems to meet WQ requirements.

Project Context

The project limits include two miles of Aurora Avenue North ("Aurora"), also known as Washington State Route 99, between N 165th St and N 205th St. Aurora, along with Interstate 5, is the major north-south transportation routes through Shoreline. The Average Daily Traffic (ADT) along this portion of Aurora ranges from 33,000 to 39,000 vehicles. Aurora is a major bus route, connecting the Snohomish County Community Transit bus system with the King County Metro bus system at the Aurora Village Transit Center at N 200th St.

The commercial core of Shoreline is along the Aurora Corridor and consists of a variety of businesses that require access and bus service. In addition to being an important corridor for commercial, transit, and single-occupancy vehicles, the nearly complete Interurban Trail will also make Aurora an important bicycle and pedestrian corridor.

Existing Conditions

From 165th to 205th, a majority of Aurora does not have sidewalks. Wide shoulders transition directly into parking for businesses or unimproved right-of-ways. Typical existing conditions along this corridor include five lanes with asphalt shoulders on both sides. Currently, stormwater runoff sheet flows into catch basins within the existing Aurora right-of-way or sheet flows into catch basins on adjacent property. Generally, the catch basins are connected to the existing storm drain mainlines that discharge into the upper reaches of Boeing Creek and McAleer Creek Basin water bodies – Echo Lake and Lake Ballinger.

Based on information obtained from soil borings along Aurora and on adjacent properties, glacial till soils are present in the project area. This is consistent with the surrounding areas and the hydrology of the nearby streams. Surface and shallow subsurface flows unable to infiltrate into the soils, that were compacted when the glaciers moved over them, feed streams and lakes.

Specific drainage basin information for Boeing Creek and McAleer Creek are described in the following sections.

Drainage Basins

The Aurora Corridor project is within two Creek Basins (see Figure 2). Between N 165th St and N 183rd St, Aurora drains to the Boeing Creek Basin. Between N 183rd St and N 205th St, Aurora drains to McAleer Creek Basin. A series of catch basins and conveyance pipes collect the runoff from Aurora. Prior to 1995, before the City became incorporated, the Washington State Department of Transportation (WSDOT) maintained the conveyance system. Currently, the City maintains the stormwater system. For more information on Existing Conditions, see Appendix A.

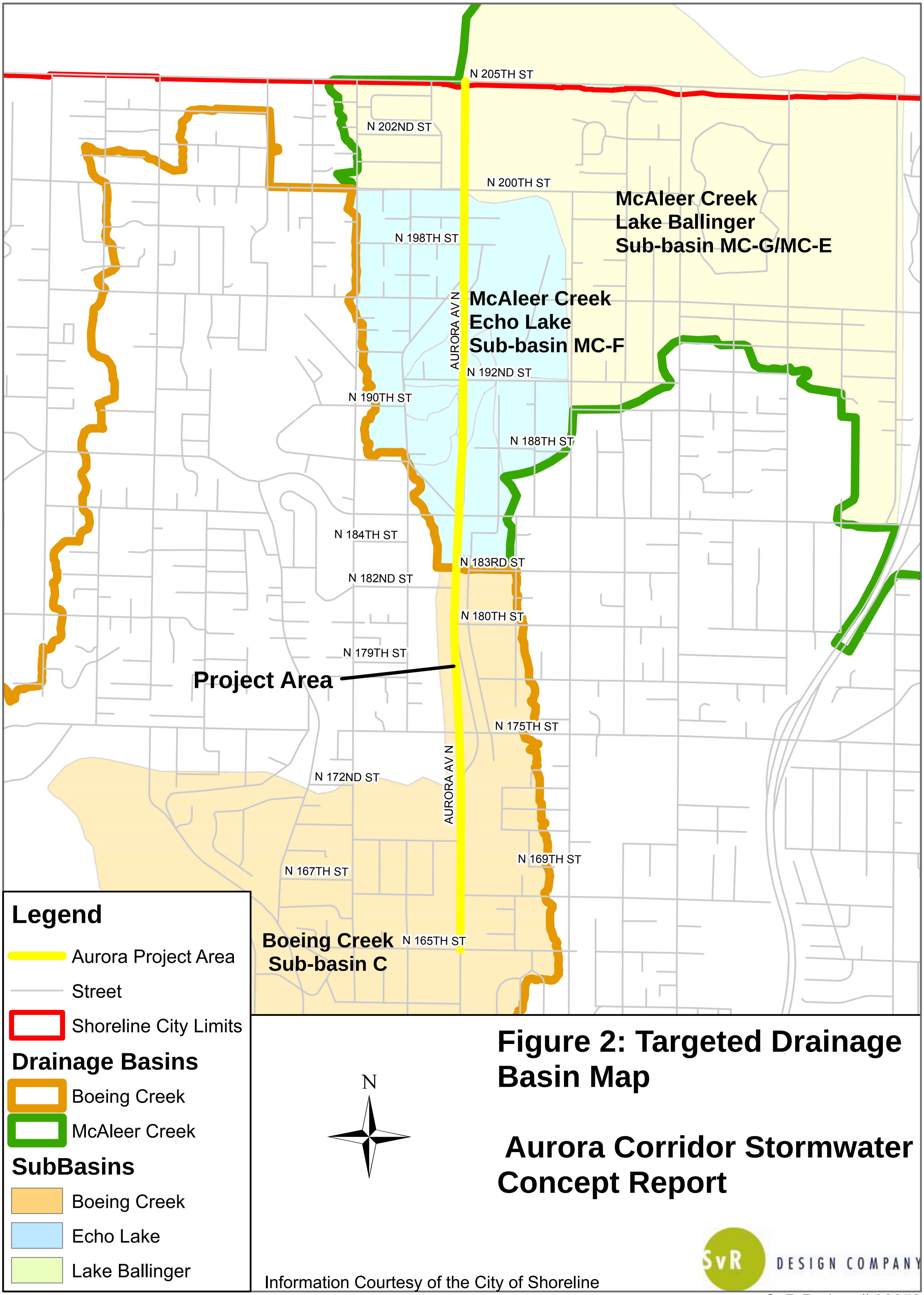


Figure 2: Targeted Drainage Basin Map

Aurora Corridor Stormwater Concept Report

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Information Courtesy of the City of Shoreline

Map NTS

SvR Project # 06052

Boeing Creek Drainage Basin

The Boeing Creek Drainage Basin is divided into four sub-basins. The section of Aurora between N 165th St and N 183rd St is located in Sub-basin "C"[1]. Boeing Creek flows west through Shoreline and drains into Puget Sound. Boeing Creek basin is 1,600 acres and Sub-basin C is approximately 720 acres. The project area is approximately 0.8-percent (5.8 acres) of Boeing Creek's Sub-basin "C" area. 90-percent of the Boeing Creek Basin is developed and an estimated 51-percent of the basin is impervious. Most of the upper reaches of Boeing Creek have been routed into pipes that collect water from nearby residences and businesses.

Based on discussions with Shoreline, there are erosion issues within Boeing Creek. Soils in the lower reaches of the stream, in Shoreview Park, are sandy and erosion may occur during high flows. Stormwater detention and sediment ponds have been constructed along the creek channel to collect this material and control high flows. The upper tributaries of Boeing Creek are piped, with some exceptions.

The area of Aurora located within Boeing Creek Basin is predominantly a roadway and paved right-of-way. There are limited patches of vegetated planting strips and landscaping in front of adjacent buildings. There are no large "green" open spaces along this portion of the Aurora Corridor.

McAleer Creek Drainage Basin

Aurora Avenue from N 183rd St to N 205th St is located in the McAleer Creek Drainage Basin[2]. The McAleer Creek Drainage Basin is approximately 5,100 acres and divided into two drainage basins, Echo Lake and Lake Ballinger. Between N 183rd Street and N 200th Street, Aurora is located in the Echo Lake Sub-basin. Echo Lake Sub-basin is approximately 215 acres and currently 56-percent impervious. The project area is approximately 7-percent (15 acres) of the McAleer Creek – Echo Lake Sub-Basin area. In addition to collecting runoff from the Aurora collection system, Echo Lake also receives runoff from residential neighborhoods to the east and west of Aurora, between N 183rd St and 200th St.

Between N 200th St and N 205th St, the Aurora Corridor is within the Lake Ballinger Sub-basin. The Lake Ballinger Sub-basin is approximately 560 acres and 65-percent impervious. The project area is approximately 0.5-percent (3.2 acres) of the McAleer Creek – Lake Ballinger Sub-Basin area. This basin is highly impervious due to the intersection of State highways, the Aurora Village Transit Center, and the commercial zoning at 205th Street. Aurora Avenue collects runoff in a series of catch basins along the shoulders, and conveys to the east along 205th Street, before entering Lake Ballinger.

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[1] City of Shoreline, Boeing Creek Basin, "Characterization Report" May 2004

[2] City of Shoreline, McAleer Creek and Lyon Creek Basins, "Characterization Report" May 2004

Process for Community Involvement

As part of the National Environmental Policy Act (NEPA) and the State Environmental Policy Act (SEPA), Shoreline worked with consultants to prepare Discipline Reports for various environmental aspects pertaining to the Aurora Corridor project. These reports have been submitted for approval by WSDOT. A water quality discipline report was prepared to summarize the stormwater management requirements and the drainage system improvements along Aurora. This report will be available for viewing by the public after approval by the Federal Highway Administration (FHWA). As part of environmental process, Shoreline reviewed all comments and held three public meetings to review the project (two scoping and one results summary).

In addition to obtaining regulatory approval, Shoreline also worked with surrounding residential and business communities. Part of this process included creating a stakeholder group named the Aurora Business and Community Team (ABCT). This group eleven times to discuss project issues, including the drainage and stormwater management facilities along Aurora. As this report was being developed, SvR met with the ABCT to provide information to the group about the stormwater management regulations and the recommendations that were being made concerning incorporating LID elements into right-of-way improvements.

Shoreline also hosted a Stormwater Management Charrette at the end of March 2007. The group included Shoreline Council members, Planning Commissioner, Shoreline Staff, and stormwater professionals. The purpose of the charrette was to brainstorm possible stormwater management strategies for Aurora. Another outcome of the charrette was the increased interest in encouraging LID and promoting sustainable development throughout Shoreline.

Stormwater Management Regulations

The proposed repaving and widening of Aurora is considered redevelopment of an existing roadway. At a minimum, stormwater management requirements must meet current Shoreline stormwater drainage regulations. However, Shoreline also wants to take the opportunity to make stormwater management improvements that would promote the City's goal of sustainability and protect downstream water bodies.

Current Stormwater Regulations

Drainage facilities should be designed per the Shoreline Municipal Code (SMC), Title 20 - Development Code, Shoreline (20.60.3) and the 1998 King County Surface Water Design Manual (1998 KCSWDM). The 2005 Shoreline Surface Water Design Manual (part of Shoreline 2007 Engineering Development Guide) amends the 1998 KCSWDM criteria for requiring drainage review. For more information on regulations, see Appendix B.

Drainage review is required for any proposed project (except those proposing only routine maintenance, repair, or emergency modifications) that is subject to a Shoreline development proposal, permit or approval listed in Section 1.1.1, AND which meets any of the following conditions (P-10 2007 Engineering Development Guide):

1. Adds 1,500 square feet or more of **new impervious surface**, OR
2. Proposes to **construct or modify** a drainage pipe/ditch that is 12 inches or more in size/depth, or receives surface and storm water runoff for a drainage pipe/ditch that is 12 inches or more in size/depth, OR
3. Contains or is adjacent to a floodplain, stream, lake, wetland or closed depression, or a sensitive area as defined by the Critical Areas Ordinance, excluding seismic, coal mining, and volcanic hazard area, OR
4. Is located within a **Landslide Hazard Drainage Area** and adds 500 square feet or more of new impervious surface, OR
5. Is located within an identified **Critical Drainage Area**, OR
6. Is a redevelopment project proposing $100,000 or more of improvements to an existing **high-use site**, OR
7. Is a redevelopment project proposing $500,000 or more of site improvements and would create 1,500 square feet or more of contiguous **pollution-generating impervious surface** through any combination of **new and/or replaced impervious surface**.

Stormwater runoff from Aurora is conveyed in 12-inch pipes. Pipes will be replaced and added as part of the project, therefore drainage review is required. As part of the review, it must be shown that the proposed project can meet the eight core requirements and the five special requirements of the 1998 KCSWDM (Pages 1-8):

Core Requirement #1. Discharge at the Natural Locations

The project is not proposing to change the existing creek basin boundaries.

Core Requirement #2. Offsite Analysis

Curbs and gutters will be added as part of this project. The addition of these conveyance features will prevent stormwater runoff going onto private property from Aurora.

Core Requirement #3. Flow Control

Flow control is not required based on Exemption 4 – Peak Flow Exemption for Urban Redevelopment Projects. This exemption is for any redevelopment projects located within the Urban Growth Boundary where the proposed improvements within a natural discharge area do not generate more than a 0.1 CFS increase in the existing condition's 100-year peak flow. The 2007 Engineering Development Guide defines existing site conditions as what surface features existed prior to August 1995. Aurora is predominantly impervious and was that way before incorporation in 1995. Since the project is proposing to add vegetation to medians and amenity zones, the Recommend Alternative shows a reduction in peak flows because the project will reduce the amount of impervious surfaces.

Core Requirement #4. Conveyance System

The pipe system will be designed to meet or exceed the necessary capacity to convey the 25-year peak flow and not cause severe flooding during the 100-year peak flow.

Core Requirement #5. Erosion and Sediment Control

Erosion and sediment control measures will be included as part of construction.

Core Requirement #6. Maintenance and Operations

Shoreline Public Works will be responsible for the operations and maintenance of the proposed drainage facilities needed to meet these requirements. All stormwater conveyance pipes will have a minimum diameter of 12 inches to meet maintenance requirements.

Core Requirement #7. Financial Guarantees and Liability

Shoreline will be constructing and maintaining any proposed drainage facilities.

Core Requirement #8. Water Quality

Basic water quality treatment is required because the project will likely replace more than 5,000 square feet or more of contiguous pollutant generating services. Basic water quality treatment goals include removing 80-percent of Total Suspended Solids (TSS) for a typical rainfall year. As the design is refined, the project may be exempt from this requirement by the Surface Area Exemption because this is a roadway redevelopment project.

Special Requirement #1. Other Adopted Requirements

Critical areas including wetlands were considered as part of the conceptual stormwater management recommendations.

Special Requirement #2. Floodplain/Flood Way Delineation

There are no floodplains located within the project area.

Special Requirement #3. Floodplain Protection Facilities

There are no flood protection facilities located within the project area.

Special Requirement #4. Source Control

The project will meet the requirements of SMC Chapter 13.10 Shoreline Source Control BMP Manual where applicable.

Special Requirement #5. Oil Control

Aurora has an ADT of more than 25,000 vehicles and runoff from Aurora must be treated to reduce the petroleum hydrocarbons to less than 10mg/L. Oil control facilities will be designed include catch basin inserts containing filter media or oil/water separators to remove the oil from the stormwater.

Western Washington Phase II Municipal Stormwater NPDES Permit

In January 2007, Ecology issued the Western Washington Phase II Municipal Stormwater NPDES Permit ("NPDES Permit") for owners or operators of regulated, small municipal separate storm sewer systems (MS4s) located in the following counties: Whatcom, Skagit, Snohomish, King, Pierce, Lewis and Skamania.

As part of the permit, by 2009 Shoreline must adopt the 2005 Department of Ecology Western Washington Stormwater Management Manual (2005 DOE WWSMM) or a stormwater management manual that has been approved as an equivalent by Ecology. The permit requires these municipalities to meet the equivalent Minimum Technical Requirements for New Development and Redevelopment listed in the 2005 DOE WWSMM. The following information for roadway redevelopment and utility underground projects is an excerpt from the DOE NPDES Permit (Appendix 1 P1).

- **The following road maintenance practices are exempt:** pothole and square cut patching, overlaying existing asphalt or concrete pavement with asphalt or concrete without expanding the area of coverage, shoulder grading, reshaping/regrading drainage systems, crack sealing, resurfacing with in-kind material without expanding the road prism, and vegetation maintenance.
- **The following road maintenance practices are considered redevelopment and therefore, would not be categorically exempt:**
  - Removing and replacing a paved surface to base course or lower, or repairing the roadway base: If impervious surfaces are not expanded, 2005 DOE WWSMM Minimum Requirements #1 - #5 apply. However, in most cases, only Minimum Requirement #2, Construction Stormwater Pollution Prevention, will be germane. Where appropriate, project proponents are encouraged to look for opportunities to use permeable and porous pavements.
  - Extending the pavement edge without increasing the size of the road prism, or paving graveled shoulders: These are considered new impervious surfaces and are subject to the minimum requirements that are triggered when the thresholds identified for redevelopment projects are met.
  - Resurfacing by upgrading from dirt to gravel, asphalt, or concrete; upgrading from gravel to asphalt, or concrete; or upgrading from a bituminous surface treatment ("chip seal") to asphalt or concrete: These would be considered new impervious surfaces and are subject to the minimum requirements that are triggered when the thresholds identified for redevelopment projects are met.
- **Underground utility projects that replace the ground surface with in-kind material or materials with similar runoff characteristics are only subject to Minimum Requirement #2, Construction Stormwater Pollution Prevention.**

Shoreline currently uses the 1998 KCSWDM. Shoreline must amend any existing stormwater or drainage codes on or before mid-August 2009 to comply with this requirement of the permit. Ecology is currently reviewing the 2005 KCSWDM to confirm that it meets the requirements of the Phase I and Phase II Western Washington Phase II Municipal Stormwater NPDES Permit.

Shoreline staff recommends that the 2005 KCSWDM be used as the stormwater management targets for the Aurora Corridor project. The 2005 KCSWDM includes many updates to the 1998 KCSWDM Core Requirements and changes many of the thresholds and required flow control and treatment options. This project will target the future 2005 KCSWDM stormwater management requirements as a goal when designing the drainage and stormwater management facilities within the project area to promote the City's goals of sustainability.

Shoreline Stormwater Management Targets – 2005 King County Manual

Based on the Core Requirements of the 2005 KCSWDM, Shoreline staff recommends the following targets for flow control and water quality be used for Aurora.

Core Requirement #3 – Flow Control

Boeing Creek has been severely damaged over the past 40 to 50 years from high flows due to the loss of wetland area (beginning with the current Aurora Square in the early 1960s) and the placing of impervious surfaces, which cause increased flows to be directed to highly erodible stream banks. Areas near Darnell Park are often partially flooded due to runoff from Aurora that comes from as far away as Fred Meyer on N. 185th St.

- ***Flood Problem Flow Control Area (Level 3)*** - Shoreline staff recommend that Flood Problem Flow Control (KC 2005 Manual) be the target for the area that drains to Boeing Creek. This target would require discharge from the project in the Boeing Creek basin to match the duration for 50-percent of the two-year through 50-year peaks, match the two-year through 10-year peaks for historic site conditions, AND match existing site conditions for the 100-year peaks. This assumes the following definitions:
  - ***historic site conditions*** *– the condition of the site prior to any development, or a forested condition. There is an exception for the forested condition for sites in a stream that had 80 percent of the developable land developed prior to 1975 (enactment of the Clean Water Act). This exception allows the historic conditions be modeled as 75% forest, 15% grass and 10% impervious. (P1-35 2005 KCSWDM).*

- ***existing site conditions** – conditions that existed prior to May 1979 as determined by aerial photos and/or record drawings (P1-2 2005 KCSWDM).*

McAleer Creek Basin includes Echo Lake and Lake Ballinger, which act as natural detention areas in the upper sub-basins. The project area lies within the Echo Lake and Lake Ballinger sub-basins.

- ***Conservation Flow Control (Level 2)*** - Shoreline staff recommend that Conservation Flow Control be the target for the McAleer Creek basin. This target requires the runoff from the proposed improvements match the duration for 50-percent of the two-year through 50-year peaks AND match the two-year through 10-year peaks for historic site conditions, assuming 75-percent forest, 15-percent grass and 10-percent impervious (similar to the Boeing Creek Basin).

Core Requirement #8 –Water Quality Treatment

McAleer Basin contains Echo Lake, Lake Ballinger, and the salmon runs primarily in the lower reaches of McAleer Creek in the City of Lake Forest Park.

Shoreline staff recommends that improvements within the McAleer Basin should target various water quality treatment measures, including high-use intersection oil control treatment, and total suspended solids, zinc, and phosphorus reduction.

- ***Basic Water Quality Treatment*** – the goal is to achieve 80-percent removal of total suspended solids on an annual basis through the use of various treatment devices.
- ***Enhanced Basic Water Quality Treatment*** - the goal is to remove 50-percent of the total zinc (found on highways from brakes and tires). High zinc concentrations are toxic to fish.
- ***Sensitive Lake Water Quality Treatment*** - the goal is to reduce 50-percent of the total phosphorus, assuming the typical concentrations in urban runoff. Phosphorus is a major component of unsightly algae blooms that affect lakes and the Aurora project can be the impetus in the basin to promote phosphorus treatment in the McAleer Creek basin.
- ***High-use intersection treatment*** would reduce the effluent total petroleum hydrocarbon level to less than 10 mg/L OR no visible sheen. Various facilities are available for this level of treatment.

Boeing Creek Basin – Shoreline staff recommends that Basic Water Quality treatment be the target for this basin. In addition, high-use treatment to reduce oil will be required in the locations where the ADT exceeds the thresholds.

Shoreline staff recommended Stormwater Management Targets. Proposed targets for flow control and water quality are summarized in Table 2.

Table 2: City of Shoreline Stormwater Targets

		Boeing Creek Drainage Area	McAleer Creek Drainage Basin	
			Echo Lake Drainage Area	Lake Ballinger Drainage Area
City of Shoreline Targets	Flow Control	Flood Problem	Conservation	Conservation
	Water Quality	Basic	Enhanced Sensitive Lake	Enhanced Sensitive Lake

City of Shoreline targets are based on 2005 KCSWDM.

In an effort to meet the current standards, as well as protecting the existing drainage resources in Shoreline, this project will target these stormwater management requirements as a goal when designing the drainage and stormwater management facilities within the project area.

Low Impact Development (LID) Options Reviewed

In addition to conventional stormwater drainage facilities typically used to meet requirements for flow control and water quality, Shoreline is considering LID elements. LID stormwater systems use vegetative areas to collect, filter, and detain stormwater. When LID is coupled with conventional methods, it reduces/removes the need and cost for large-scale conventional stormwater management methods like detention pipes and vaults. In addition to mimicking the natural process for stormwater management, LID stormwater elements can improve the aesthetics of area by increasing vegetative areas (green space). Many of the LID options that were discussed at the project charrette are described below.

The City of Shoreline 2007 Engineering Development Guide does allow for designers to use LID to meet stormwater management requirements. The following information is an excerpt from the 2007 Engineering Development Guide:

> *Section 1.2.9 – Alternative Methods. As provided for in Section 20.10.050 of the SMC and for the purpose of meeting the need to consider LID and LEED systems as acceptable "alternate facility designs", LID designs that are consistent with the BMPs outlined in Low Impact Development Technical Guidance Manual for Puget Sound, the 2005 King County Surface Water Design Manual, and/or LEED techniques employed to meet the intent of the adopted Surface Water Management Code shall be considered as a Blanket Stormwater Adjustment and individual variances to use these design methodologies are not required.*

Provided, developments that employ LID BMPs and LEED technologies must be designed using the methodologies outlined in the 2005 KCSWDM.

As part of this project, the design team will have to request a Blanket Stormwater Adjustment to use LID element in place of conventional system components. The adjustment will come from City of Shoreline during the permitting phase.

Infiltration Trenches

Infiltration trenches can be used to collect and detain stormwater so that it can infiltrate into the ground as subsurface flows. The effectiveness of infiltration trenches is dependent on the native soils. Gravely and sandy soils have higher infiltration rates and indicate that historic hydrologic processes included infiltration and subsurface recharge to groundwater and surface water bodies at lower elevations. Typically, the soils in Western Washington are glacial till. Glacial till has very low infiltration rates, indicating that historic hydrologic processes included surface water flows in creeks and streams to water bodies and wetlands.

Because of the presence of glacial till along Aurora, infiltration trenches are not financially or functionally feasible as a LID option. An option was presented to construct very deep infiltration trenches along Aurora that would have the capacity to infiltrate the stormwater runoff. Deep narrow trenches will be expensive to construct, difficult to maintain, and there is no guarantee that once constructed, these trenches will function as intended.

Bioretention Swales and Rain Gardens

Bioretention swales and rain gardens are engineered, unboxed depressions that contain plants, mulch, amended soils. These elements are designed with a ponding depth to store water during large storm events. Swales and rain gardens can be designed to meet flow control and water quality regulatory requirements. Swales and rain gardens can collect and treat parking lot, streets, and roof runoff.

Bioretention swales will be considered in the medians and in amenity zones along side streets. Overflow to the conveyance system will be required to maintain safety and prevent flooding along the roadway. Reversing the crown of the roadway may be an option to collect stormwater runoff in center swales. However the length of the proposed medians may limit the available stormwater treatment opportunities. This is a feasible LID option only if center medians can be designed to meet stormwater treatment requirements within the available area.

Rain gardens will not be considered as a LID option for Aurora as they are often more organic in shape and are more appropriate on private property. They could be incorporated as businesses redevelop along the corridor.

Stormwater Planter Boxes

Stormwater planter boxes are similar to rain gardens or bioretention cells; however, they are usually contained by small concrete walls along their perimeter with an open or closed bottom. Planter boxes have a more defined shape than rain gardens and are more suitable for more confined urban settings. In general, planter boxes have minimal side slope, but function and are designed in a similar way. Planters typically have about one-foot of ponding depth over three to five feet of amended soils, water and drought tolerant plants, and mulch, and overflow into the conveyance system. Planter boxes can be designed to control flow and improve water quality to meet regulatory requirements.

Stormwater planter boxes will be considered in the proposed amenity zones along Aurora. Stormwater planter boxes can be designed to overflow to the conveyance system to manage higher flows.

Tree Box / Tree Pit Filters

Tree pits are generally used to house trees in urban settings. Tree pits can function as a LID feature by detaining and filtering stormwater in the soil and the plant roots can absorb stormwater. Tree pits function best when drought and water-tolerant trees are used, are connected with under drains, and gutter flow is directed into the tree pits. Under drains are required so the tree's roots do not stay saturated over an extended amount of time.

Tree box filters are similar to tree pits; however, they are a pre-cast structure that contains mulch, soil filter media, under drain and a small tree or shrub. Tree box filters are designed to capture and filter stormwater from micro drainage areas; however, many tree box filters can be distributed across a large drainage basin to effectively treat large volumes of stormwater. Tree box/tree pit filters can be designed to meet water quality goals. In addition to stormwater treatment, detention or infiltration can be added below the tree box filters to manage low water flows and overflow to the conveyance system during high flow events. Tree box/tree pit filters will be considered in the proposed amenity zones along Aurora.

Porous Pavements

Pavements could be constructed with porous asphalt, concrete, or paver blocks over a gravel sub-base and under drain. The sub-base under the porous material provides both detention and water quality benefits. The sub-base filters out the suspended solids from stormwater that passes through, the leading contributor to pollution in stormwater. Porous gutters and medians can detain and filter stormwater to meet regulatory requirements.

Due to the lack of empirical data available regarding the durability of porous pavements on arterials, WSDOT approval is highly unlikely. However, there are opportunities to incorporate porous pavements along the corridor in other applications. Porous pavement could be used on sidewalks along Aurora. In addition, there may be an opportunity to use porous pavements on the more residential side streets or as a property restoration options for parking lots or driveways along the street that are being redeveloped as part of the project.

Detention Pond

Detention ponds are designed to collect runoff from a tributary area and control the rate at which the water is released. The ponds usually do not have a permanent pool of water and can be used to provide flood control by including additional detention storage above the extended detention level. Detention ponds are typically not designed with enough residence time to meet water quality requirements and often have to be coupled with other stormwater facilities to meet these requirements. Residence time is the amount of time the stormwater will be detained with the detention pond.

Detention ponds require large areas and are typically not a feasible, cost-effective way to control and treat stormwater along an urban corridor where land prices are high and space is limited. Detention ponds are not recommended for this project.

Retention Pond

Retention ponds are constructed basins that have a permanent pool of water through the wet season. Retention ponds detain the stormwater runoff from a water quality "storm" for some minimum duration (e.g. 24 hours), which allows sediment particles and associated pollutants to settle out. Ponds treat incoming stormwater runoff by settling, and biological and microbial actions.

Similar to detention ponds, retention ponds are not a feasible or cost-effective way to control and treat stormwater along Aurora. In addition, Seattle City Light has expressed concern about standing water under the transmission lines adjacent to Aurora. Retention ponds are not recommended for this project.

Rainwater Harvesting/Cisterns

Rainwater harvesting is the collection of rainwater for later use. The most common captures roof runoff in a rain barrel, which is used during dry spells for irrigation. Most often rainwater harvesting is captured from roof runoff; however, there are instances in which underground cisterns capture filtered stormwater that pass through rain gardens and swales for later use.

These options are better used to reduce flows off large roof areas along the roadway to provide attenuation for the stormwater flows off adjacent properties. However, rainwater harvesting is currently not approved for commercial properties. Rainwater harvesting is not recommended for this project.

Green Roofs

Green roofs (also known as vegetated roof covers, eco-roofs or nature roofs) are multi-beneficial structural components that help to mitigate the affects of urbanization on water quality by filtering, absorbing or detaining rainfall. They are typically constructed of a lightweight soil media, underlain by a drainage layer, and a high quality impermeable membrane that protects the building structure. Vegetation can be selected that will survive during all seasons, as well as the direct sunlight, wind and rain.

Green roofs are another LID option that is more effective on adjacent properties along the roadway to reduce stormwater runoff from surrounding buildings. There was a recommendation to install a lightweight structure with a green roof over Aurora. However, this is not an economically feasible option for this project.

Feasible Low Impact Development (LID) Options

The preferred alternative has opportunities to incorporate LID elements coupled with conventional stormwater management to meet the current requirements and target stormwater management goals. The proposed amenity zone can provide opportunities to combine aesthetic landscaping and a pedestrian safety buffer zone with stormwater management and treatment facilities. The center median could also be used to convey and treat stormwater.

Feasible and recommended LID options were selected from the LID options reviewed that that could reasonably be incorporated with the adopted Preferred Alternative layout. Infiltration facilities to reduce runoff are not recommended. Soils in the area of Aurora are not conducive to infiltrating significant amounts of stormwater. LID elements that are feasible will include an under drain system that will connect the elements to the conveyance system.

Stormwater Planters and Tree Box Filters in the Amenity Zone

Stormwater planters and tree filters can be located in the amenity zone and collect water as it flows along the curb line. Stormwater will enter the stormwater planters and tree box filters through curb cuts and filter through the soil media to an under drain. The stormwater planters and tree box filters can be installed in pre-cast vaults. Typical sizes for tree box filter range from four-foot-by-six-foot to ten-foot-by-12-foot. These boxes can also be constructed with cast-in-place concrete to fit within spaces that are not rectangular or where standard precast boxes will not fit. Stormwater planters and tree box filters used for water quality treatment are sized to capture and treat 91-percent of the total annual volume of rainfall.

Stormwater planters and tree box filters can also have open bottoms to allow some natural infiltration. A six-inch overflow pipe located in the facility will be connected into the conveyance system. See Figure 3 for a schematic of a stormwater planter and see Figure 4 for a schematic of a tree box filter that will fit in the amenity zones.

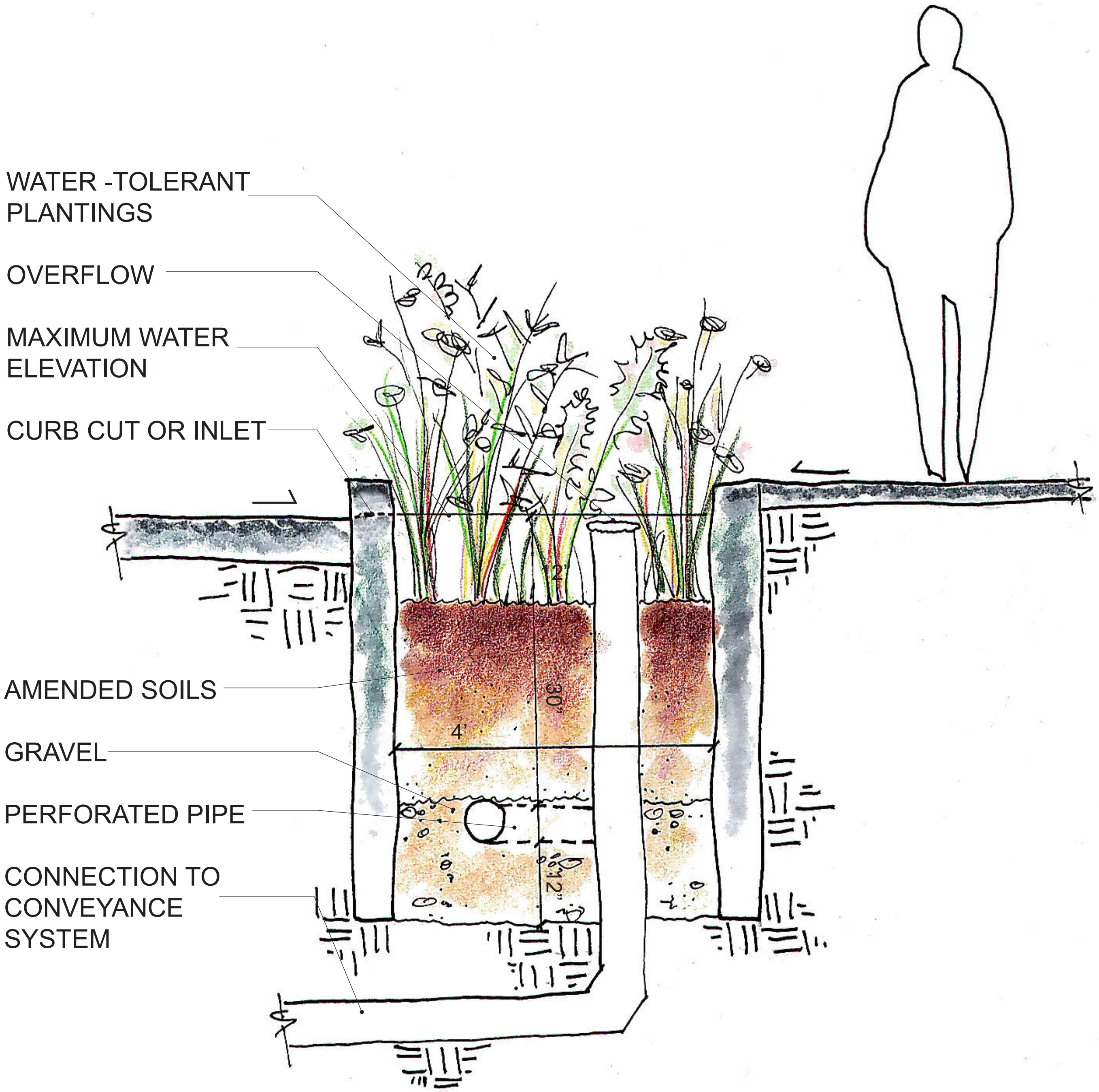

FIGURE 3
STORMWATER PLANTER
NOT TO SCALE

SvR DESIGN COMPANY

Aurora Corridor
Draft Stormwater Concept Report

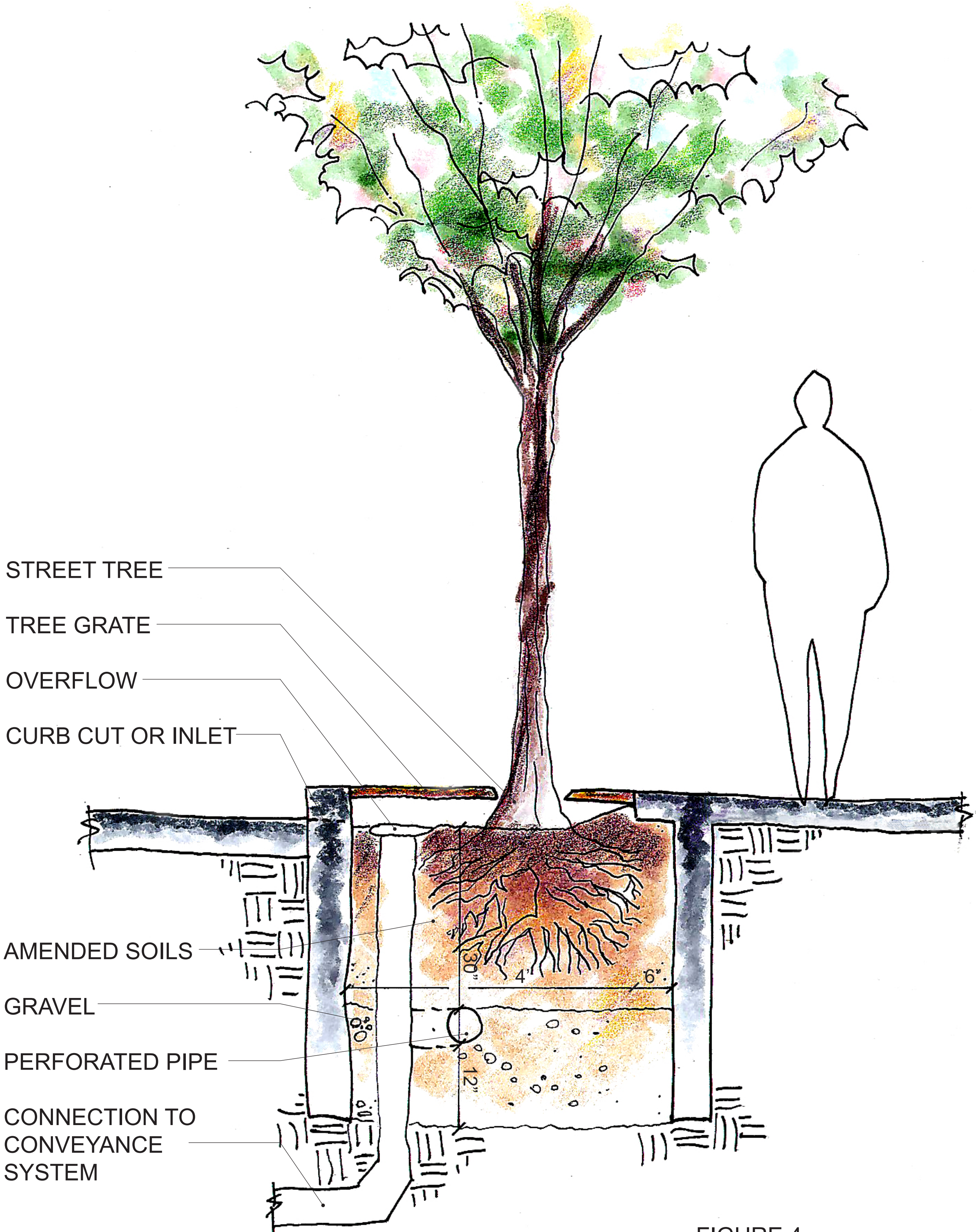

FIGURE 4
TREE BOX FILTER
NOT TO SCALE

SvR DESIGN COMPANY

Aurora Corridor
Draft Stormwater Concept Report

Bioretention Swales in the Medians

The bioretention areas located in the medians would overflow to structures that connect to underground pipes. This will manage high-flow storms and convey water off the roadway. Stormwater will enter the bioretention swales through curb cuts and filter through the amended soil media to an under drain. A six-inch overflow will be connected into the conveyance system. The bioretention swales could be designed with open bottoms to take advantage of the limited natural infiltration. However, care must be taken to keep the roadway subgrade from becoming saturated. See Figure 5 for a schematic of a bioretention swale.

Regrading the existing contours along Aurora would be required to direct storm water runoff into the center median bioretention swale. A reverse crown along Aurora would also need WSDOT approval. There could be high construction costs especially if existing fiber optics and extensive pavement removal are required.

Porous Pavement Sidewalks and Residential Side Streets

Permeable pavements, including porous concrete and asphalt and permeable pavers, could be installed along the sidewalks and in residential side streets. These surface treatments can reduce and slow the amount of water entering the Aurora stormwater management system from the adjacent right-of-ways and private property while maintaining an urban feel along the corridor. The storage volume is directly related to depth of sub-base below the porous pavement. See Figure 6 for an image and cross section of porous concrete. Porous pavement also improves water quality of stormwater that passes through the pavement by filtering out suspending solids.

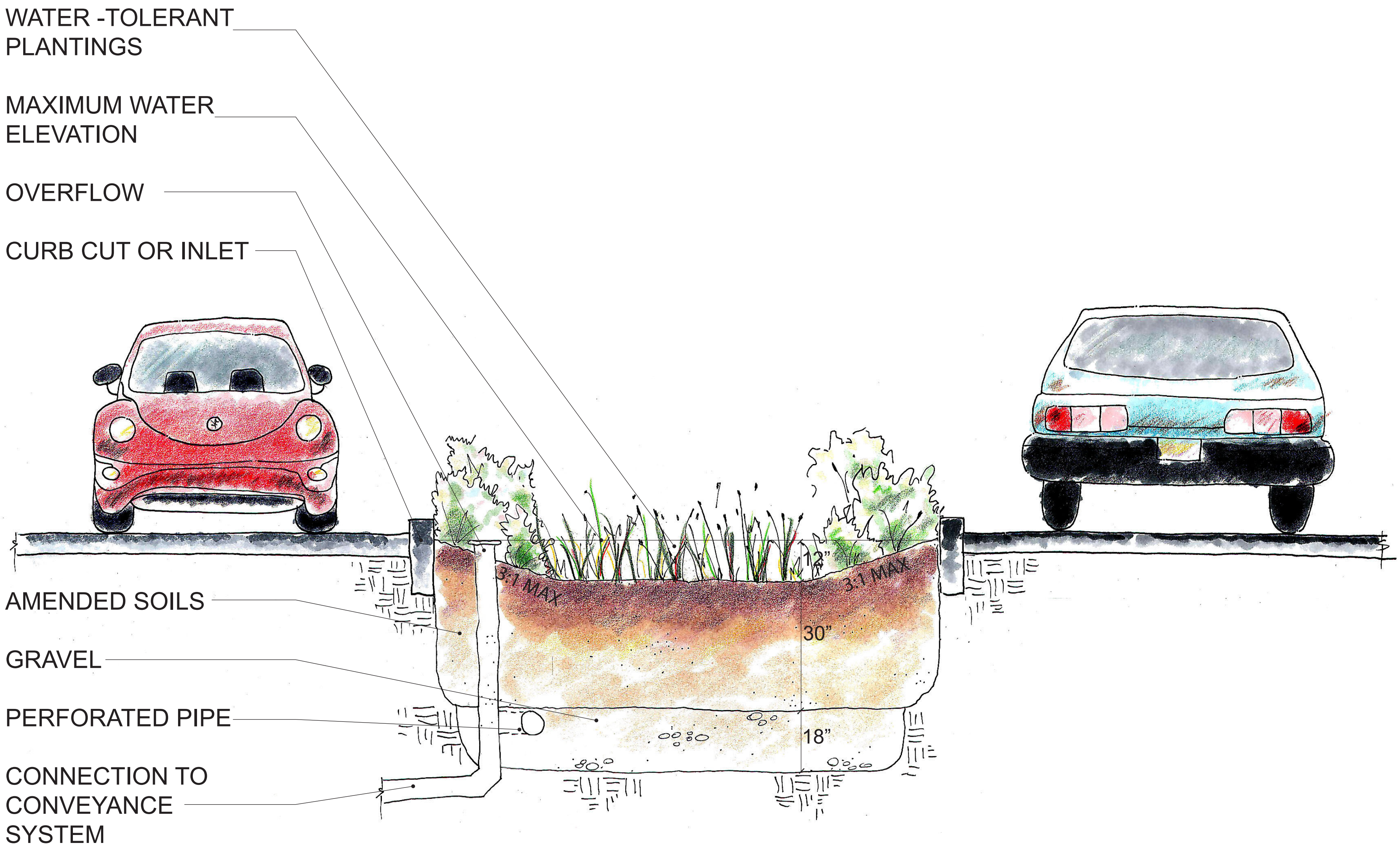

FIGURE 5
BIORETENTION SWALE
NOT TO SCALE

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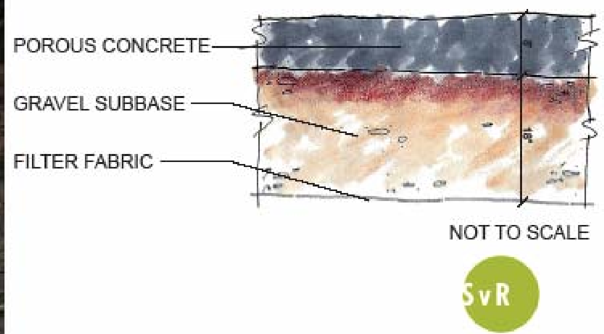
Draft Stormwater Concept Report

Shoreline Porous Sidewalk



Typical Porous Pavement Section

FIGURE 6
POROUS PAVEMENT SECTION

Feasible LID Elements Summary

Because the soils along Aurora are predominantly glacial till, the soils are not conducive to infiltration. Bioretention and bioinfiltration facilities will be the most feasible. Porous pavements can be designed with subgrade gravel reservoirs to attenuate the flows in lieu of infiltrating.

Table 3 is a summary of feasible LID options, possible locations, estimated ease of construction, typical maintenance, relative maintenance costs, and relative rankings. Within the two LID categories of bioretention facilities and porous pavements, the elements were ranked against each other to identify the potential benefits to the project.

For bioretention facilities, stormwater planters were given the highest ranking. Incorporating stormwater planters into the amenity strip would allow the existing cross slope of the roadway to be maintained and maintenance would be similar to a planting strip. Water tolerant plantings can be selected to increase the detention time in a stormwater planter. In contrast, a low rank was given to a bioretention swale in the center median. The center median would require Aurora to be redesigned with a reverse crown, which may increase construction costs by requiring more pavement replacements to meet the elevations required to collect runoff.

For the porous pavements, sidewalks were given a higher ranking because they require less maintenance and last longer than porous pavements on streets. Porous streets will require a thicker pavement section and subgrade, and often require more maintenance than sidewalks. This is due to the increased loading from vehicles.

In addition to fitting within the proposed amenity zones, tree boxes or stormwater planters can be installed adjacent to other utilities including electrical and communication systems. Because the proposed LID elements can be installed in a precast or cast-in-place concrete structure they can be located next to other utility vaults. Typically separation between utility vaults and any other structure (including LID elements) is ten feet. This allows for conduits to sweep around the other structures at the required radius.

Table 3: Summary of Feasible LID Options for Aurora Corridor 165th St. to 205 St.

Categories	LID Element	Possible Locations	Change WSDOT Standards	Ease of Placement/ Construction	Typical Maintenance	Maintenance Cost	Ranking within Category
Bioretention Facilities	Stormwater Planters	4 ft Amenity Zone	No	Easy -Construct in proposed amenity zone, which is to be vegetated	Remove Garbage/Debris Replace topsoil – 10-15 years Maintain/replace vegetation	Low	1
	Boxes Tree Box Filter	4 ft Amenity Zone	No	Easy -Construct in proposed amenity zone, which is to be vegetated	Remove Garbage/Debris Replace topsoil – 10-15 years Maintain/replace vegetation	Low	2
	Bioretention Swales (Median)	Medians	Yes -would require reverse crown	Difficult -Remove concrete, connect to conveyance system and change road crown	Remove Garbage/Debris Replace topsoil – 10-15 years Maintain/replace vegetation	Low	4
	Bioretention Swales (Side streets)	Side streets	No	Easy -Construct in proposed amenity zone, which is to be vegetated	Remove Garbage/Debris Replace topsoil – 10-15 years Maintain/replace vegetation	Low	3
Porous Pavements*	Sidewalk	Along Side Streets and Select Locations Along Aurora	No	Easy -Porous pavement sidewalks, driveways, or parking lots within or adjacent to the project area. Porous pavements on private property would be approved and maintained by owner.	Remove Garbage/Debris Vacuuming of Sediment from Voids (Typically twice per year)	Low	1
	Side Street	Residential Areas	Yes	Moderate - WSDOT unlikely to consent due to lack of available empirical strength data.	Remove Garbage/Debris Monthly Street Sweeping Vacuuming of Sediment from Voids (Typically quarterly) May need frequent replacing due to traffic movements such as stopping or turning	High	2

*Porous Paving in not recommended in the roadway because of the unknown durability of porous pavement under heavy loads and high maintenance costs. Porous pavement could be used on residential side streets

LID elements can provide flow attenuation and stormwater treatment. The following sections describe if and how LID elements can meet Aurora Corridor stormwater management requirement and targets considering the areas outlined for amenity zones and the medians in the preferred alternative

Stormwater Management Facilities per 1998 KCSWDM

Current stormwater regulations are based on the 1998 KCSWDM, as amended by the Shoreline's Surface Water Design Manual (part of Shoreline 2007 Engineering Development Guide). Shoreline's Surface Water Design Manual does not list specific requirements for either Boeing Creek or McAleer Creek. Flow control and water quality requirements are the same for each creek basin and all three target drainage basins.

Flow Control Requirements – 1998 KCSWDM

Based on current project alternatives and conversations with Shoreline staff about the construction of the project, flow control measures will not be required per the 1998 KCSWDM as amended by the SMC because there will not be an increase in impervious surfaces. Table 4 shows existing conditions in each sub-basin, a reduction in impervious area and an increase in pervious area.

Table 4: Existing and Proposed Preferred Alternative Areas

	Boeing Creek Drainage Area	McAleer Creek Drainage Basin	
		Echo Lake Drainage Area	Lake Ballinger Drainage Area
Existing Conditions 100% Impervious	**5.8 acres**	**15.0 acres**	**3.2 acres**
Proposed Preferred Alternative Impervious Area	5.4 acres	13.9 acres	3.0 acres
Proposed Preferred Alternative Pervious Area (7%)	0.4 acre	1.1 acre	0.2 acre
Proposed Preferred Alternative Total Area	**5.8 acres**	**15.0 acres**	**3.2 acres**
Total Drainage Basin Area (subbasin)	720 acres	217 acres	565 acres
Percentage of Total Project Area within Creek Basin	**0.8%**	**7%**	**0.5%**

Table 5 displays the output from the King County Run Time Series 100-year peak flow using inputs from Table 4 and verifies the assumption that reducing impervious area and increasing pervious area reduces the 100-year peak flows. Therefore, under current City of Shoreline Stormwater Management requirements, the project is exempt from flow control requirements per Exemption 4 – Peak Flow Exemption (p. 1-28 1998 KCSWDM). See Appendix C for more information.

Table 5: Existing and Proposed 100-yr Peak Flows for Preferred Alternative

	Boeing Creek Drainage Basin	McAleer Creek Drainage Basin	
		Echo Lake Subbasin	Lake Ballinger Subbasin
Existing Runoff	6.83 CFS	17.65 CFS	3.79 CFS
Proposed Runoff	6.57 CFS	16.96 CFS	3.64 CFS
Net Change of Runoff (Proposed –Existing)	**-0.26 CFS**	**-0.69 CFS**	**-0.15 CFS**

Water Quality Treatment Requirements – 1998 KCSWDM

The project may be exempt from providing water quality measure by the Surface Area Exemption because this is a roadway redevelopment project. Table 6 displays existing Pollution Generating Impervious Surface (PGIS), proposed PGIS, and new and possible replaced PGIS, as described by 1998 KCSWDM, as amended by Shoreline. Non-pollution generating surfaces, sidewalks and amenity zones, will replace existing pollution generating pavement on the shoulders. Table 6 also shows no addition of new PGIS and a net reduction of PGIS in each drainage basin.

Based on conversations with Shoreline concerning construction methods related to the redevelopment of Aurora, the current construction plans do not trigger water quality requirements based on the 1998 KCSWDM, as amended by Shoreline. However, if during the design it is found that 5,000 square feet or more of replaced contiguous PGIS are necessary due to pavement removal for base repair (not related to utility or drainage facility installations) Basic Water Quality treatment will be required.

If similar design and construction techniques from the first mile are used on Aurora from 165th to 205th, replaced PGIS would likely exceed the 5,000 square feet of contiguous replaced PGIS threshold. Basic Water Quality Treatment for TSS will be required per the 1998 KCSWDM. There is a 40-foot wide slab of concrete, most likely a remnant of an early road under the current Aurora Avenue. Construction documents from the completed section of Aurora, 145th to 165th, show base repair in areas where the concrete slab is not present. "Possible Replaced PGIS" in Table 6 is the estimated largest possible PGIS that the project would replace during construction if the concrete slab is not removed.

Table 6: Existing and Proposed Pollutant Generating Impervious Surfaces

		Boeing Creek Drainage Basin	McAleer Creek Drainage Basin	
			Echo Lake Subbasin	Lake Ballinger Subbasin
Existing	PGIS *	5.5 acre	14.3 acre	3.0 acre
Proposed	PGIS	4.57 acre	11.15 acre	2.6 acre
	New PGIS	0 acre	0 acre	0 acre
	Possible Replaced PGIS	2.2 acre	5.6 acre	1.1 acre

*Sidewalks and other impervious surfaces where vehicles are not allowed are not considered PGIS

Basic Water Quality Treatment Facility Sizing

Water quality treatment facility sizing uses three modeling methods: WWHM facility sizing, WWHM water quality method, and SBUH water quality volume. For estimated size for each model method to meet current 1998 KCSWDM regulations (assuming the existing roadway base is replaced except for the concrete slab) see Table 9. These modeling methods were designed to size a facility to capture 95-percent of the annual average runoff volume as described in the 1998 KCSWDM. Each method used a typical drainage area estimated to be 43 feet by 100 feet. 43 feet is half of the street PGIS cross-section for the preferred alternative. See Appendix D (Water Quality) for a detailed description of water quality modeling and sizing methods. Space constraints in the Aurora Corridor limit the basic water quality menu to any one of the following: wet vault, catch basin filters, sand filters, or surface treatment options, including feasible LID elements.

Basic Water Quality – All Basins

- Proposed LID elements in the amenity zone are four feet wide and range from nine to 23 LF to capture and treat the runoff from the roadway. Later in the report, Table 10 shows the estimated cost of the feasible LID options to meet basic water quality, assuming the maximum replaced pavement

Oil Control Facilities

Since in general Aurora has an ADT of more than 25,000 vehicles, oil control facilities will be installed at intersections with an ADT count higher than 25,000. Oil control measures that meet the 1998 KCSWDM requirements are pre-cast vaults with baffle, oil/water separators coalescing plates or vaults/catch basins with filters inserts.

Stormwater Management Facilities per Shoreline Targets 2005 KCSWDM

Based on conversations with Shoreline about construction methods for pavement replacement, the project meets the target 2005 KCSWDM Exemptions # 2 Impervious Surface Exemption for Transportation Redevelopment Projects (1 - 27). **A transportation project is exempt if less than 2,000 square feet of new impervious area are created within a targeted drainage area.** Based on current conditions, the project is not projected to create greater than 2,000 square feet of new impervious area in a targeted drainage basin. There is actually a reduction of impervious area proposed. However, in an effort to create an environmentally sustainable community and move toward meeting future NPDES requirements, Shoreline would like to set the flow control targets.

Table 7 is a summary of existing impervious, proposed impervious, and proposed pervious in each sub-basin. Historic conditions areas are broken down by drainage area in Appendix C (Flow Control) along with further description of modeling techniques. Target peak flows for the 2-year and 10-year peak flows are included. Aurora Corridor does not have to match manage 100-year peak flows since impervious surfaces are being reduced and as a result there is not increase from the existing 100-year flows.

Table 7: Drainage Areas Existing and Proposed

	Boeing Creek Drainage Area	McAleer Creek Drainage Basin	
		Echo Lake Drainage Area	Lake Ballinger Drainage Area
Existing Impervious	5.8 acre	15.0 acre	3.2 acre
Proposed Impervious Area	5.4 acre	13.9 acre	3.0 acre
Proposed Pervious Area (7%)	0.4 acre	1.1 acre	0.2 acre
Proposed Total Area	5.8 acre	15.0 acre	3.2 acre
Target Historic 2yr Peak Flow	0.312 cfs	0.807 cfs	0.172 cfs
Target Historic 10yr Peak Flow	0.509 cfs	1.32 cfs	0.281 cfs

Flow Control Requirements – Shoreline Targets 2005 KCSWDM

Boeing Creek – Flood Control Flow Control

Flood Control Flow Control (Level 3) - This target requires the discharge from the project in the Boeing Creek basin to match the duration for 50-percent of the two-year through 50-year peaks, match the two-year through 10-year peaks for historic site conditions, AND match existing site conditions for the 100-year event. This assumes peak historic site conditions, i.e. 75-percent forest, 15-percent grass and 10-percent impervious, based on discussions with Shoreline staff. Modeling with WWHM 3 LID features could not be designed to meet historic two-year and 10-year peak flow requirements. As shown in Table 5, the project will reduce existing 100-year peak flows.

McAleer Creek – Conservation Flow Control

Conservation Flow Control (Level 2) - This target requires the runoff from the proposed Aurora Corridor in the McAleer Creek basin match the duration for 50-percent of the two-year through 50-year peaks AND match the two-year through 10-year peaks for historic site conditions, assuming 75-percent forest, 15-percent grass and 10-percent impervious. The McAleer basin has two targeted drainage basins, Echo Lake and Lake Ballinger, and Conservation Flow Control applies to each of these drainage areas.

Flow Control Facility Sizing

Preliminary modeling indicates target flow control cannot be detained using LID alone. There is not enough room in the amenity zone or under the sidewalk to size LID features to capture the full “Flood Problem Flow Control” or the “Conservation Flow Control” as defined by the 2005 KCSWDM. LID features can capture the two-year to 50-year flow durations, but not peak flows for historic conditions required to meet “Flood Problem Flow Control” or “Conservation Flow Control”. Appendix C, Report 1 shows stormwater planters that are sized to receive runoff from half of the available amenity zone in the typical 100 foot section. There is not enough space available in the amenity zone to control the two-year and 10-year historic peaks needed to meet the stormwater target for either Flood Problem or Conservation Flow Control.

It is often recommended to install conventional underground flow control structures at each of the basin discharge locations within the project area. Having only three large facilities would require less maintenance than installing multiple facilities throughout the basins. Table 8 displays the estimated sizing and cost to meet Flood Problem Flow Control and Conservation Flow Control with conventional methods in Boeing and McAleer Creeks. It may be cost prohibitive for Shoreline to meet the stormwater targets for flow control using even conventional methods.

Table 8: Estimate of Probable Construction Cost and Size of Conventional Detention Facilities to Meet 2005 KCSWDM Targets Flow Control

	Boeing Creek - Level 3 Flow Control (5.8 Acres)				**McAleer Creek Drainage Basin - Level 2 Flow Control**							
					Echo Lake (15 Acres)				**Lake Ballinger (3.2 Acres)**			
Peak Flows**	Historic 2-year	Developed 2-year	Historic 10-year	Developed 10-year	Historic 2-year	Developed 2-year	Historic 10-year	Developed 10-year	Historic 2-year	Developed 2-year	Historic 10-year	Developed 10-year
	0.312 cfs	2.57 cfs	0.509 cfs	3.50 cfs	0.807 cfs	6.64 cfs	1.32 cfs	9.05 cfs	0.172 cfs	1.42 cfs	0.281 cfs	1.94 cfs
Comparison of Flow Control Methods: Detention Pipe and Detention Pond within Each Basin												
Type of Detention	*Pipe* - 10 foot diameter		*Detention Pond* 6ft Effective Depth w/1ft Freeboard		*Pipe* - 10 foot diameter		*Detention Pond* 6ft Effective Depth w/1ft Freeboard		*Pipe* - 10 foot diameter		*Detention Pond* 6ft Effective Depth w/1ft Freeboard	
Estimated Storage Volume	70,000 CF		73,200 CF		186,200CF		235,900 CF		40,200 CF		42,000 CF	
Approximate Dimensions	940 LF		115 FT x106 FT		2,500 LF		180 FT x180 FT		540 LF		65 FT x65 FT	
Estimate Of Probable Construction Cost †	$1.13 Million		$1.1 Million		$3.0 Million		$2.4 Million		$0.65 Million		$0.5 Million	

*Volume Calculation Based on King County Run Time Series in accordance with the 1998 KCSWDM as amended by the city. (Appendix C). Western Washington Hydraulic Model Version 3 (WWHM 3) modeling results are provided in Appendix C for comparison.

** This compares historic peak flows to developed peak flows, used size the detention facilities. Discharge from detention facility is design to meet duration curves from half the 2 year through the 50 year storm event as listed in the target flow requirements.

†All costs are in 2007 dollars and no contingency price was added to base cost. Pipe costs include excavation, pipe bedding and pipe costs. Detention pond costs include land cost, excavation, and fine grading. 2007 land costs only were provided by the City of Shoreline at $50/SF. Land costs assume vacant property and do not account for any building value or loss of tax revenue from existing business.

Water Quality Treatment Requirements – Shoreline Targets 2005 KCSWDM

Based on conversations about constructions methods for the redevelopment of Aurora and current plans, the project may be exempt from the Water Quality requirement, based on Exemption #2 "Impervious Surface Exemption for Transportation Redevelopment Project". Transportation Redevelopment Projects are exempt if:

a) The total new impervious surface within the project limits is less than 50-percent of the existing impervious area AND

b) Less than 5,000 square feet of new PGIS will be added AND

c) Less than 35,000 square feet of new Pollution Generating Pervious Surface (PGPS) is created.

Based on current conditions and current plans, the project will meet all the conditions of Transportation Redevelopment Projects in each targeted drainage basin. However, in effort to create an environmentally sustainable community Shoreline would like to meet the following water quality targets in each Creek Basin.

Boeing Creek – Basic Water Quality Target

Shoreline recommends that Boeing Creek Basin runoff receive Basic Water Quality Treatment. Basic Water Quality is a general, cost-effective level of treatment sufficient for most areas. The basic water quality treatment goal is to remove 80-percent of total suspended solids within the selected basin. Space constraints in the Aurora Corridor limit the basic water quality menu to the any one of the following: wet vault, catch basin filters, or biofiltration LID elements.

McAleer Creek – Enhanced Basic and Lake Sensitive Water Quality Target

Shoreline recommends that McAleer Creek Basin runoff receive Lake Sensitive (phosphorus) and Enhanced Basin (zinc) Water Quality Treatment. The Enhanced Basic and Lake Sensitive Water Quality have similar menus in 2005 KCSWDM. Space constraints in the Aurora Corridor limits the enhanced and basic water quality menu to the following: sand filters, or two facility treatment train including storm filters and LID. For feasible LID options, see the discussion earlier in this report.

Water Quality Sizing Target

Water quality sizing uses three modeling methods, WWHM facility sizing, WWHM water quality method, and SBUH water quality volume. These modeling methods were designed to size a facility to capture 95-percent of the annual average runoff volume as described in the 2005 KCSWDM. Each method used a typical drainage area estimated to be 43 feet by 100 feet. 43 feet is half of the PGIS cross-section for the staff-recommended alternative. See Appendix D for a detailed description of water quality modeling and sizing methods. Space constraints in the Aurora Corridor limits the basic water quality menu to the any one of the following: wet vault, catch basin filters, sand filters, or surface treatment options, including LID elements.

PondCalc estimates that 1,840 CF of water quality volume is needed to meet Conservation Flow requirements. A typical amenity zone with no utility vaults, soil or driveways has only 100 feet by four feet by four feet or 1,600 CF of storage (see Appendix C, Spreadsheet 4). LID features can mitigate and detain water from most storm events, but cannot be sized to capture larger peak events.

LID features need to be coupled with conventional detention methods to capture the Flood Control Flow Control or the Conservation Control Flow. LID features sized for water quality provide some flow control by attenuating and decreasing peak flows, particularly of smaller storms. Space constraints also limit Enhanced Basic and Lake Sensitive water quality menu to sand filters and two facility treatment trains. The most feasible alternative to meet Enhanced Basic and Lake Sensitive Water Quality is to couple LID features with a storm filter or wet vault.

Basic Water Quality – Boeing Creek

- Feasible LID features are four feet wide and range from 15 LF to 42 LF per 100 FT section per side to capture the water quality volume.

Enhanced Basic (zinc) and Lake Sensitive (phosphorous) – McAleer Creek

- Feasible LID elements are would be the same size as Basic Water Quality, four feet wide and from 15 to 42 LF, but needs to be coupled with conventional methods to meet paired facilities treatment train for Enhanced Basic Treatment (2005 KCSWDM – Section 6.1.2, Pg 6-6) and Lake Protection Treatment requirements (2005 KCSWDM – Section 6.1.3, Pg 6-8).

Table 9 summarizes the size and water quality modeling of feasible LID options to meet basic water quality treatment. Sizing for additional facilities required to meet Enhanced Basic Treatment and Lake Protection Treatment requirements are included in Tables 11, 12, and 13 in the Estimate of Probable Cost for Construction section.

Oil Control Facilities

Since Aurora generally has an ADT of more than 25,000 vehicles, oil control facilities will be installed at intersections with an ADT count higher than 25,000. Oil control measures that meet the 2005 KCSWDM requirements are pre-cast vaults with baffle, oil/water separators, coalescing plates or vaults/catch basins with filters inserts.

Department of Ecology Stormwater Treatment Technologies

Department of Ecology also allows cities to test proprietary stormwater treatment facilities. As of November 2006, a Conditional Short-Term Use Level Designation for Basic (TSS) & Phosphorus Treatment & Pilot Use Level Designation for Enhanced & Oil Treatment for Americast's filterra®, a tree box bioretention filtration system, was approved by Ecology.

CUD - Conditional Use Level Designation
Conditional Use Level Designation (CUD) allows continued use of the technology for a specified time period during which field testing must be completed by the vendor and/or developer. Not all CUD technologies are required to conduct field testing. Units that are in place do not have to be removed after the specified time period. Use is subject to the use level designation conditions.

PLD - Pilot Level Designation
Pilot Use Level Designation (PLD) allows limited use of the technology to allow field testing to be conducted. PLD technologies may be installed provided that the vendor and/or developer agree to conduct field testing based on the TAPE at all installations.

According to the Ecology website, governments covered by a municipal stormwater NPDES permit must notify Ecology when a PLD technology is proposed (form available from Ecology http://www.ecy.wa.gov/PROGRAMS/WQ/stormwater/newtech/technologies.html#enhanced). Use is subject to the use level designation conditions.

Americast's filterra® are precast concrete boxes that include a highly filtering media that removed the various pollutants from the stormwater prior to overflowing into an adjacent catch basin. These precast concrete boxes are typically four feet wide and six feet long and would fit within the amenity zone. Table 13 includes the number of filterra® boxes needed to meet the target stormwater requirements.

Table 9: Stormwater Management Options to meet 2005 KCSWDM Water Quality Basic Water Quality Treatment for Boeing Creek Basin

Categories	LID Element	Possible Locations	Sizing Based on 100 ft Road Sections	WWHM Facility Sizing Method* Length of LID Element (LF)		WWHM WQ Volume Method** Length of LID Element (LF)	
				Req. (1998 KCSWDM)	Targets (2005 KCSWDM	Req. (1998 KCSWDM)	Targets (2005 KCSWDM
Bioretention	Stormwater Planters	4 ft Amenity Zone	Width – 4 ft Soil Depth – 4 ft Ponding Depth – 1 ft	10	20	9	15
	Tree Box Filter	4 ft Amenity Zone	Width – 4 ft Soil Depth – 4 ft Ponding Depth – 0 ft	11	21	11	18
	Bioretention Swales (Median)	Medians (assumes reverse crown along Aurora Ave)	Width – 12 ft Soil Depth – 4 ft Ponding Depth – 1 ft	7	14	8	12
	Bioretention Swales (Side streets)	Side streets	Width – 12 ft Soil Depth – 4 ft Ponding Depth – 1 ft	3.5	7	4	6
Conventional Stormwater Measures	Water Quality Vault (WQ)	Under Roadway or Amenity Zone/ Sidewalk	Following guideline in 2005 KCSWDM wet vaults for a typical water quality section (4,300 SF of roadway runoff) require about 450 CF of volume.				
	Stormwater Filter	In vaults or catch basins	Contech, a stormwater filter insert supplier, estimates about 138 storm filters will be needed. Filters are inserted into CBs or in vaults				

*WWHM Facility Sizing method Sized Sand Filters with 2 in/hr Hydraulic Conductivity City of Seattle Tracy Tackett Presentation (Accessed 6/12/2007 http://depts.washington.edu/urbhort/html/education/BioretentionModelingBasics.pdf) to filter 95% of the runoff from storm events from 1948-1998 See Appendix D.

**WWHM Method 95% of annual volume WQ Flow Volume per 1998 KCSWDM (p. 6-17). Continuous modeling was request in conversation with the City of Shoreline Stormwater Staff. See Appendix D.

Concept Road Layout

Aurora is a linear transportation project with limited right-of-way for surface stormwater elements. Driveways and utility vaults vary along the length of Aurora and other features such as bus stops and light poles that may affect the possible location of stormwater features.

Using Conventional Facilities for Target Flow Control – 2005 KCSWDM

Conventional methods used to meet flow control requirements are generally placed near or at the discharge location; they generally take advantage of economies of scale and include a combination of vaults, pipes and catch basins with filter inserts. Table 8, in the previous section, showed the approximate sizes and costs for flow control developed by SvR to meet the flow control targets as recommended by Shoreline stormwater staff.

Incorporating LID Elements for Stormwater Treatment – Current 1998 KCSWDM and 2005 KCSWDM

The amenity zone provides the best opportunities to combine aesthetic landscaping and a safety buffer zone with stormwater management and treatment. Stormwater planters and tree filters can be located in the amenity zone and collect water as it flows along the curb line. Instead of using the amenity zone, there may also be an opportunity to locate bioretention within the planted medians. See Figure 7 for possible locations of LID.

Bioretention swales in the median will require coordination with WSDOT to reverse the crown of Aurora. In addition, Shoreline is investigating the depth and width of a concrete panel down the center of the existing roadway. Also a fiber optic cable was installed in the middle of Aurora. These may conflict with the installation of a bioswale median and any connections back to the stormwater conveyance on the east and west side of Aurora.

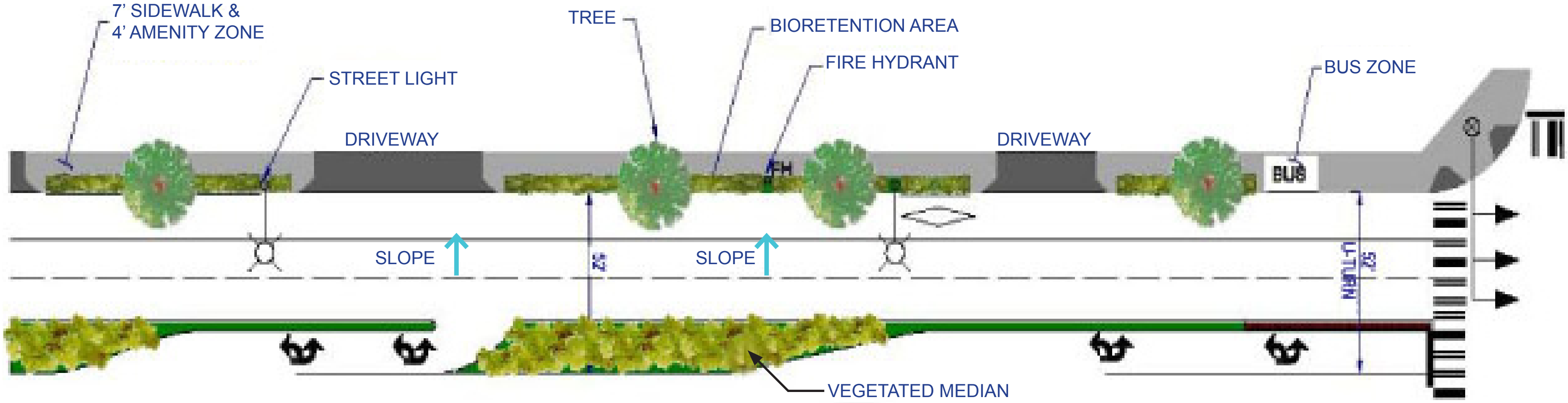
Coordinating with Other Utilities

Utility vaults placed in the amenity zone will need to be placed ten feet from a stormwater planter or tree box filter. Ten feet is the space needed to sweep the four-inch electrical conduit from the utility vault out around the side of the stormwater planter or tree box filter. This typically would not require a wider or deeper trench. Utility vaults and light poles have been installed in roadway projects with LID elements in Seattle at High Point and also in the City of Kirkland along private roadways in subdivisions. Stormwater planters or tree pits installed in the amenity zone along Aurora or along side streets will need to be coordinated with the Seattle City Light utility vaults installed during future design phases of this project.

Estimates of Probable Cost for Construction

Estimated costs are based on current costs and have not been adjusted for possible inflations. In addition, costs do not include catch basins, drainage maintenance holes, or stormwater conveyance pipe that will also be required along Aurora. Estimates of probable costs for constructing various LID measures to meet Basic Water Quality 1998 KCSWDM Requirements are summarized in Table 10.

Low Impact Development Option in Amenity Zone



Low Impact Development Option in Center Median

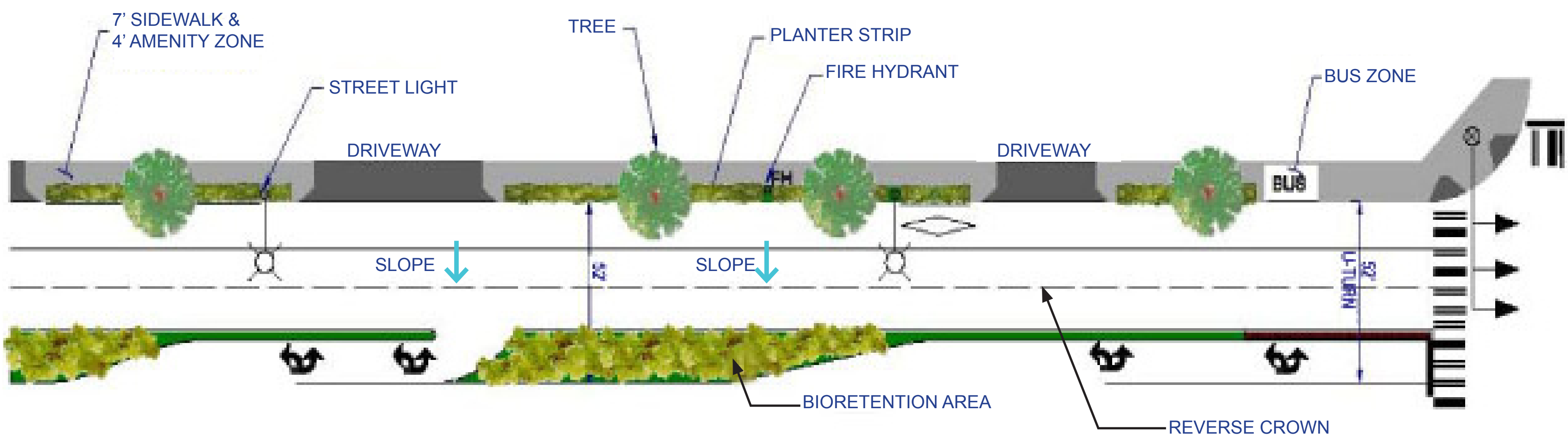


FIGURE 7
Roadway Options with LID
Preferred Alternative

SvR DESIGN COMPANY

Table 10: Preliminary Sizing and Estimate of Probable Construction Cost to Meet Basic Water Quality Measure

Categories	LID Element/ Stormwater Management Facility	Possible Locations	Sizing Based on Road Sections	Approximate Length of LID Element per 100 ft of Roadway	Total to Meet Basic Water Quality Current Requirements – 1998 KCSWDM		Cost to Meet Basic Water Quality Targets – 2005 KCSWDM	
					Cost per 100 LF Roadway	Cost for Project Length	Cost to per 100 LF of Roadway	Cost for Project Length
Bioretention	Stormwater Planters	4 ft Amenity Zone	Width – 4 ft Soil Depth – 4 ft Ponding Depth – 1 ft	Current (1998 KCSWDM) 10 ft Target (2005 KCSWDM) 20 ft	$4,500	$0.97 Million	$9,000	$1.9 Million
	Tree Box Filter	4 ft Amenity Zone	Width – 4 ft Soil Depth – 4 ft Ponding Depth – 0 ft	Current (1998 KCSWDM) 11 ft Target (2005 KCSWDM) 21 ft	$5,000	$1.08 Million	$10,000	$2.16 Million
	Bioretention Swales (Aurora Median)	Medians	Width – 12 ft Soil Depth – 4 ft Ponding Depth – 1 ft	Current (1998 KCSWDM) 8 ft Target (2005 KCSWDM) 14 ft	$7,000	$0.76 Million	$15,000	$1.58 Million
	Bioretention Swales (Side streets)	Side streets	Width – 12 ft Soil Depth – 4 ft Ponding Depth – 1 ft	Current (1998 KCSWDM) 4 ft Target (2005 KCSWDM) 7 ft	$4,800	$0.52 Million,	$9,000	$0.95 Million

- Referencing construction documents for 145th to 165th, an average of 40 lf of amenity zones were constructed per 100 lf of improvements.
- Costs were determined using modeled estimated sizes in Table 9 and current and past unit prices from regional projects. Cost in 2007 dollars, no contingency costs were added.
- Costs for stormwater planter include a 6 foot cast-in-place wall along curb line, 1cy of amended soil, 4 sf of plantings, 1 cy of excavation, 1 feet of under drain, and one overflow or curb cut
- Costs for bioretention swales include 1cy of amended soil, 4 sf of plantings, 1 cy of excavation, 1 feet of under drain, and one overflow or curb cut
- Project is about 10,800 linear feet about 108 -100 foot sections to treat both sides of the roadway 216 section are required. Bioretention swales capture whole roadway width (108 sections). Cost to change road crown not included.

In order to meet the target stormwater goals a two facility treatment train is required. LID can be coupled with stormfilters to meet the treatment enhance basic and lake sensitive treatment train requirements. Table 11 summarizes additional costs to provided Enhanced Basic and Lake Sensitive Water Quality Treatment per target requirements by pairing stormfilters with LID elements - 2005 KCSWDM to McAleer Basin. These values are estimated based on the facilities required for the design catchment area and the entire length of the project.

Table 11: Stormfilter Paired with LID Measure Meet Enhanced Basic and Lake Sensitive Water Quality–Targets 2005 KCSWDM

Stormwater Management Facility	Possible Locations	Cost per Catch Basin with 2 Stormfilters	Additional Cost to Meet Basic Water Quality Targets (Cost for Increase for McAleer Basin)	
			Echo Lake	Lake Ballinger
Stormwater Filter	Catch basins*	$20,000**	$920,000 (Assume 46 Stormfilter cartridges)***	$200,000 (Assumes 10 Stormfilter cartridges)***

* Stormfilters can be place in one large vault per subbasin or placed individually next to catch basins.
** Cost assumes 2 stormfilters per catch basin filter. Maximum distance between stormfilters with catch basin is 220 LF. Stormfilter are installed with catch basins, catch basins are part of the overall cost.
*** Costs are in 2007 dollars and no contingency was added to cost.

Shoreline staff may also want to investigate using the Ecology pilot and conditional use designated stormwater treatment technologies then the following Table 12 shows approximate costs and sizing for the Americast's Filterra tree box system. Filterra has a Conditional Short-Term Use Designation issued by the Ecology for Lake Sensitive Water Quality Treatment (phosphorus) and a Pilot Level Use Designation for Enhanced Basic Water Quality Treatment (zinc) and Oil Treatment.

Table 12: Americast's Filterra System to Meet Enhanced Basic and Lake Sensitive Water Quality Targets – 2005 Ecology Stormwater Management Western Washington.

Stormwater Management Facility	Possible Locations	Cost per 4'x6' Filterra Vault	Additional Cost to Meet Basic Water Quality Targets (Cost for Increase for McAleer Basin)	
			Echo Lake	Lake Ballinger
Filterra	Upstream of standard catch basins	$20,000*	$760,000 (Assumes 38 Filterra)**	$160,000 (Assumes 8 Filterra)**

* Cost assumes 1 Filterra per catch basin filter. Maximum distance between stormfilters with catch basin is 260 LF.

** Costs are in 2007 dollars and no contingency was added to cost.

Porous pavements are recommended for sidewalks and residential side streets only. These installations would likely be for demonstration only and would not be designed to meet stormwater flow control or water quality treatment requirements for the project area. The preferred alternative indicates that most side streets will be improved 250 feet from Aurora. This will not provide enough surface area to manage off runoff from Aurora considering the infiltration rate of the glacial till. Porous pavement costs are summarized in Table 13. A unit cost was provided since the location and amount of the porous pavements have not been indicated. The costs listed are for porous concrete only.

Table 13: Porous Pavement Estimated Costs

Porous Sidewalk	Sidewalk	$30-$60/SY (40/SY Conventional)*	This would be a demonstration. No Water Quality treatment credit will occur. Because of the sidewalks small size and sidewalks classification as a non pollution generating surface
Porous Side Street	Residential Street	$85-$165/SY ($65/SY Conventional)*	Porous streets may have a residential application. Porous pavement is not recommended on arterials due to high sediment loading that will clog the porous pavement.

2007 Construction Costs, no contingency costs were added
*Cost Assumptions for porous pavement include 12" drainage subgrade
**Conventional Concrete Pavements include 12" subgrade

Summary

The 2007-2008 Shoreline City Council goals for this project include Goal No 4. to complete the Aurora improvements from 165th to 205th Streets including, but not limited to, sidewalks, drainage and transit, and Goal No. 6 to create an "environmentally sustainable community". This report investigated the potential of incorporating Low Impact Development (LID) with the conventional methods to meet Shoreline stormwater management requirements and the other council goals. It was found that by effectively using the right-of-way, LID can meet water quality requirements, pedestrian safety and access, improved aesthetics for the community and the businesses, and increase the amount of vegetation and green space along this highly visible corridor.

LID elements can be incorporated into the Aurora Corridor project to meet current 1998 KCSWDM requirements for stormwater management. LID elements can also be installed to help Shoreline move toward the stormwater management targets taken from the 2005 KCSWDM. However, LID facilities alone cannot meet the flow control requirements or the specific water quality treatment targets within Boeing and McAleer Creeks. They could be used to reduce the size and number of conventional facilities that need to be installed.

LID elements can be used locally within the amenity zone (and potentially in the larger medians) and be coordinated with the required utilities, driveways, curbs and bus stops. These bioretention areas can be designed and installed in precast vaults with overflows to convey higher flows directly into the adjacent conveyance system. Referencing the Construction Documents for 145th to 165th Streets, an average of 40 linear feet of amenity zones were constructed per 100 linear feet of improvements. This area could be available to construct feasible LID elements.

In addition, utility vaults and light poles have been installed adjacent to bioretention facilities at High Point Redevelopment in Seattle, and in a private development in Kirkland. As Shoreline continues to further refine the design of Aurora through coordination with WSDOT and Seattle City Light, we recommend that these drainage and stormwater management facilities, including LID options, be included in the analysis.

It is not recommended that porous pavements be used to meet current target stormwater management requirements due to the lack of empirical data for highways with high Average Daily Traffic (ADT) counts and many turning movements. Porous pavements used on sidewalks and residential side streets will be more for demonstration and informational purposes for the surrounding communities and businesses that use Aurora Corridor.

1998 KCSWDM Requirements

LID elements can be used to meet the current regulations of basic water quality treatment for total suspended solids along Aurora; flow control is not required. As a result of the preliminary modeling, the following conclusions were made as they relate to

Shoreline meeting the 1998 King County Surface Water Design Manual Stormwater Management requirements:

- Flow control is not required since there is no increase in runoff from Aurora Avenue between the existing conditions and the proposed alignment (no increase in square footage of impervious surfaces).
- LID elements can be used to meet Basic Water Quality Treatment requirements for total suspended solids removal.
- Conventional oil/water separators or catch basins with filter media must be used to meet the Oil Control special requirements at high-use intersections.
- It is estimated that costs for using LID to meet Basic Water Quality Treatment targets will be approximately $1Million.

2005 KCSWDM Targets

LID elements can also be used in addition to conventional stormwater treatment facilities to meet the targeted goals of enhanced basic treatment, and stream protection treatment to remove zinc and phosphorus. Due to the upcoming changes in stormwater regulation, the following stormwater management design parameters were identified to help meet Shoreline targets in the 2005 King County Surface Water Design Manual:

- Flow control facility sizing based on the amount of pavement that is estimated to be replaced down to the base course.
- Basic Water Quality Treatment for total suspended solids is required for Boeing Creek.
- Enhanced Basic Water Quality Treatment and Sensitive Lake is the target for McAleer Creek.
- LID elements can be used to meet Basic Water Quality Treatment requirements for total suspended solids removal in Boeing Creek and McAleer Creek.
- Additional conventional treatment systems will be required to meet the targets for zinc and phosphorus removal.
- Conventional oil/water separators or facilities with filter media must be used to meet the Oil Control special requirements at high-use intersections.
- In order to meet the target 2005 KCSWDM flow control, large detention facilities would have to be constructed. Two main options to meet these requirements include; installing large pipes or vaults sized to hold water for large storm events, or purchasing property adjacent to Aurora and constructing a surface detention pond. These facilities are costly and may be difficult to locate and maintain. Estimated costs for construction of these water quality and flow control systems are:
    - $1Million -$2 Million to meet Basic Water Quality Treatment targets.
    - $1Million in addition to Basic Water Quality Treatment targets to meet Enhanced Basic and Lake Sensitive Water Quality Treatment targets.

- Range from $4 -$5 Million to meet flow control targets as described in this report. If above ground flow control facilities were constructed, additional private property would need to be purchased.

Basic Water Quality Treatment measures are required based on 1998 KCSWDM, and will benefit the surrounding watersheds by reducing the amount of total suspended solids entering downstream water bodies. Increasing the water quality treatment measures to meet the City of Shoreline targets based on the 2005 KCSWDM could impact water quality in the project's watershed by reducing zinc and phosphorus levels in the runoff from Aurora Corridor. Meeting these targets will incrementally improve water quality in the immediate Echo Lake, Lake Ballinger and Boeing Creek sub-basins, but less so in the greater watershed basins.

The water quality facilities and recommended LID elements discussed do not replace the need for a stormwater conveyance system, including pipes and catch basins, to direct stormwater to the appropriate surface water discharge locations within each basin. Adding a curb and gutter along Aurora Corridor will better manage the surface water from current ponding along the right-of-way and private property.

Comparing the project area to the total area of each sub-basin, detaining the runoff from the Aurora Corridor to meet the target 2005 KCSWDM may not provide the most cost-effective benefit to the streams and downstream water bodies because of existing regional detention facilities. As the roadway design continues, additional modeling will have to be done to more accurately size these Aurora Corridor systems at the optimal locations based on final roadway grades and proximity to discharge locations within each sub-basin. Investing in improvements to the existing regional detention facilities may be a more cost-effective solution to improve downstream water bodies than large facilities along Aurora Avenue.

Aurora Corridor is a large project, affecting three watersheds, and it could provide a unique opportunity to improve water quality and mitigate peak flows throughout the City of Shoreline and surrounding communities. It is unlikely that another single project will have an impact on multiple sub-basins. However, the project area covers only a small percentage of the drainage surface areas in the sub-basins and watersheds, and stormwater improvements on this project will have to be coupled with stormwater retrofits and redevelopment projects throughout the city in order to have a significant impact on the storm water quantity and quality issues facing the City of Shoreline.

APPENDIX A

Memo 2 - Existing Conditions – Water Quality Discipline Report

SvR DESIGN COMPANY

MEMORANDUM # 2

DATE: April 18, 2007

TO: Jennifer Barnes, PE, Jones and Stokes

FROM: Amalia Leighton, PE
Gibson Peters, EIT

RE: Existing Conditions – Water Quality Discipline Report
Aurora Corridor
SvR Project # 06052

The following memorandum summarizes the existing conditions along the Aurora Avenue Corridor ("Aurora Corridor") from North 165th Street to North 205th Street in Shoreline, Washington. Existing conditions will be used as the baseline condition for modeling the current and proposed stormwater runoff along the Aurora Corridor.

The project limits include two miles of Aurora Avenue North (Washington State Highway 99), between N 165th Street and N 205th Street. Along this corridor, Aurora Avenue is typically five lanes wide with asphalt shoulders on both sides. The commercial core of the City of Shoreline ("City") is along the Aurora Avenue. In addition, this is a major bus route, connecting the Snohomish County Community Transit bus system with the King County Metro bus system. The average daily traffic along this portion of Aurora Avenue ranges from 38,000 to 40,000 vehicles.

The Aurora Corridor lies within two Creek Basins. Between 165th Street and 183rd Street, Aurora Avenue drains to the Boeing Creek Basin. Between 183rd and 205th, Aurora Avenue drains to McAleer Creek Basin. A series of catch basins and conveyance pipes collect the runoff from Aurora Avenue. Prior to 1995, before the City became incorporated, the Washington State Department of Transportation (WSDOT) maintained the conveyance system. Currently, the City maintains the stormwater system.

The Boeing Creek Basin is divided into four sub-basins. The section of Aurora Avenue between 165th Street and 183rd Street is located in Sub-basin "C". Boeing Creek flows west through the City and drains into Puget Sound. Boeing Creek basin is 1,600 acres and Sub-basin C is approximately 720 acres. 90-percent of the Boeing Creek Basin is developed and an estimated 51-percent of the basin is impervious. Most of the upper reaches of Boeing Creek have been routed into pipes and collect water from nearby residences and businesses.

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Based on discussions with the City, there are erosion issues within Boeing Creek. Soils in the lower reaches of the stream, in Shoreview Park, are sandy and erosion occurs during high flows. Stormwater detention and sediment ponds have been constructed along the creek channel to collect this material and control high flows. The upper tributaries of Boeing Creek are piped, with some exceptions.

The Corridor area located within Boeing Creek Basin is predominantly roadway and paved right-of-way. There are limited patches of vegetated planting strips and landscaping in front of adjacent buildings. There are no large "green" open spaces along this portion of the Aurora Corridor.

Aurora Avenue from 183rd Street to 205th Street is located in the McAleer Creek Drainage Basin. The McAleer Creek Basin is approximately 5,100 acres. Between 183rd Street and 200th Street, Aurora Avenue is located in the Echo Lake Sub-basin. Echo Lake Sub-basin is approximately 215 acres and currently 56-percent impervious. Echo Lake is a 303d water body, listed for fecal coliform levels. In addition to collecting runoff from the Aurora Avenue collection system, Echo Lake also receives runoff from residential neighborhoods to the east and west of Aurora Avenue, between 183rd Street and 200th Street.

Two small ditches were delineated along Aurora Avenue in the Echo Glen Basin. Ditch 1 is approximately four feet wide and five inches deep, approximately 227 square feet long, and is located along the west side of Aurora Avenue North, just north of North 192nd Street. Ditch 1 is a shallow depression/slope that drains south towards Ditch 2. Ditch 2 is approximately 4.5 feet wide, five inches deep, and approximately 108 square feet long. It too is a shallow depression/slope, draining south into a culvert that carries water to a piped underground stormwater system.

Between 200th Street and 205th Street, the Aurora Corridor is within the Lake Ballinger Sub-basin. The Lake Ballinger Sub-basin (MC-G) is approximately 560 acres and 65-percent impervious. This basin is highly impervious due to the intersection of State highways, the Community Transit Park and Ride, and the commercial zoning at 205th Street. Aurora Avenue collects, in a series of catch basins along the shoulders, and conveys to the east along 205th Street, before entering Lake Ballinger.

One small ditch was delineated along Aurora Avenue in the Lake Ballinger Sub-basin. Ditch 3 is approximately 19 inches wide, nine inches deep, and approximately 66 square feet long. Ditch 3 is a slope draining to the north into a catch basin that carries water to a piped underground stormwater system.

APPENDIX B

Memo 3 - Stormwater Modeling Review [Preliminary Drainage Review]

SvR DESIGN COMPANY

MEMORANDUM #3

DATE: April 10, 2007

TO: Jennifer Barnes, PE, Jones and Stokes

FROM: Amalia Leighton, PE
Gibson Peters, EIT

RE: Stormwater Modeling Review [Preliminary Drainage Review]
Aurora Corridor - Shoreline
SvR Project # 06031

According to the City of Shoreline Municipal Code (SMC), Title 20. Development Code, the City uses the 1998 King County Surface Water Design Manual (1998 KCSWDM), with some City-specific amendments. The City 2005 Engineering Development Guide lists adopted amendments or additions to the 1998 KCSWDM.

The City Surface Water Design Manual, which is part of The City 2005 Engineering Development Guide, appends the 1998 KCSWDM criteria for requiring drainage review. The Aurora Corridor Project meets the following conditions for drainage review (p-10 2005 Engineering Development Guide)

7. Is a redevelopment project proposing $500,000 or more of site improvements and would create 1,500 SF or more of contiguous **pollution-generating impervious surface** through any combination of **new and/or replaced impervious surface.**

The Aurora Corridor Project must be evaluated for compliance with Core Requirements and Special Requirements through the drainage review. Upon review, the project will be required to meet the follow Core Requirements:

1. Discharge at the Natural Locations
2. Offsite Analysis
4. Conveyance System
5. Erosion and Sediment Control
6. Maintenance and Operation
7. Financial Guarantee

The project will also be required to meet Special Requirement #5: Oil Control at the intersections.

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According to the 1998 KCSWDM, the Aurora Corridor project will be exempt from the following Core Requirements:

3. Flow Control
8. Water Quality

Flow Control Exemptions that apply to this project include:

1. Impervious Surface Exemption
   A proposed project or any **threshold discharge area** within a project is exempt if less than 5,000 square feet of new impervious surface will be added and the project or threshold discharge area is not within a Landslide Hazard Drainage Area

Or

4. Peak Flow Exemption:
   Any **natural discharge area** of a redevelopment project located within the Urban Growth Area is exempt if the project improvements within the natural discharge area generate less than 0.1 cfs increase in the existing site conditions 100-year peak flow AND all of the following criteria are meet:
   a) The application of this exemption to natural discharge areas within a proposed project must not result in more than a 0.4 cfs increase in the existing site conditions 100-yeat peak flow rate for any **threshold discharge area** of the project, AND
   b) **Flow Control BMPs** must be applied to the runoff from new impervious surface as specified in Section 5.2.1, AND
   c) The project improvements within the natural discharge area must not be located within a Landslide Hazard Drainage Area and must not significantly impact "**severe erosion impact problem**" or "**severe flooding problem**", AND
   d) The **manner which runoff is discharged** from the project must not create a significant adverse impact per Core Requirements #1

The project area is predominantly roadway and paved right-of-way. There are limited patches of vegetated planting strips and landscape in front of adjacent buildings (see Memorandum #2 Existing Conditions). Because there are no large green, open spaces along Aurora, it is assumed that less than 5,000 square feet of new impervious area will be created, exempting the project from Flow Control per Exemption # 1.

To determine if the Aurora Corridor project is exempt of Flow Control per Exemption #4, modeling was performed using the King County Runoff Time Series (KCRTS) software. Existing Site conditions were assumed to be 100 percent impervious (see Memorandum #2 Existing Conditions). Because the existing right-of-way is not a set width and the project expects to purchase land to increase the width of the right-of-way, the existing condition area set to equal the proposed area. Alternative A was modeled assuming a 98-foot right-of-way width. It was estimated, using a cross-section (see Figure 1) and CADD files provided by Jones and Stokes, that the pervious median areas was approximately 10 feet wide and represent approximately 1/5 of the linear length of the project. A conservative estimate of three-percent pervious area was used to model the area (see Table 1).

Table 1: Alternative A- Area Conditions

Alternative A: Area	Boeing Creek Drainage Area (Acre)	McAleer Creek Drainage Basin	
		Echo Lake Drainage Area (Acre)	Lake Ballenger Drainage Area (Acre)
Existing	5.4	14.0	3.0
Impervious Area	5.2	13.4	2.9
Pervious Area (3%)	0.2	0.60	0.1
Total Area	5.4	14.0	3.0

Using these assumptions, the 100-year peak flow for Alternative A was decreased in each drainage basin therefore no flow control is required (See Table 2).

Table 2: Alternative A- 100-year Peak Flows

Alternative A: 100-year Peak Flow	Boeing Creek Drainage Area (CFS)	McAleer Creek Drainage Basin	
		Echo Lake Drainage Area (CFS)	Lake Ballenger Drainage Area (CFS)
Existing	6.4	16.5	3.5
Proposed	6.2	16.1	3.4

Alternative B and C have the same cross-section, and were modeled to have an identical 110-foot right-of-way width. Alternative B and C are proposed to have a four-foot pervious amenity zone on both sides of Aurora that is interrupted by driveways and vehicular access to Aurora. It was estimated using the cross-section (see Figure 1) and the CADD files that these amenity zones account for about four percent of the total impervious area. Medians have approximately the same area as Alternative A: three-percent. A conservative estimate indicates the total pervious area for Alternatives B and C at seven-percent (see Table 3).

Table 3: Alternatives B/C Area Conditions

Alternative B/C: Areas	Boeing Creek Drainage Area (Acre)	McAleer Creek Drainage Basin	
		Echo Lake Drainage Area (Acre)	Lake Ballenger Drainage Area (Acre)
Existing	5.8	15.0	3.2
Impervious Area	5.4	13.9	3.0
Pervious Area (7%)	0.4	1.1	0.2
Total Area	5.8	15.0	3.2

Using these assumptions, the 100-year peak flow was decreased in each drainage basin therefore no flow control is required (see Table 4).

Table 4: Alternative B/C- 100-year Peak Flow

Alternative B/C: 100-year Peak Flow	Boeing Creek Drainage Area (CFS)	McAleer Creek Drainage Basin	
		Echo Lake Drainage Area (CFS)	Lake Ballenger Drainage Area (CFS)
Existing	6.83	17.65	3.79
Proposed	6.57	16.96	3.64

Water Quality Exemptions that apply to this project are:

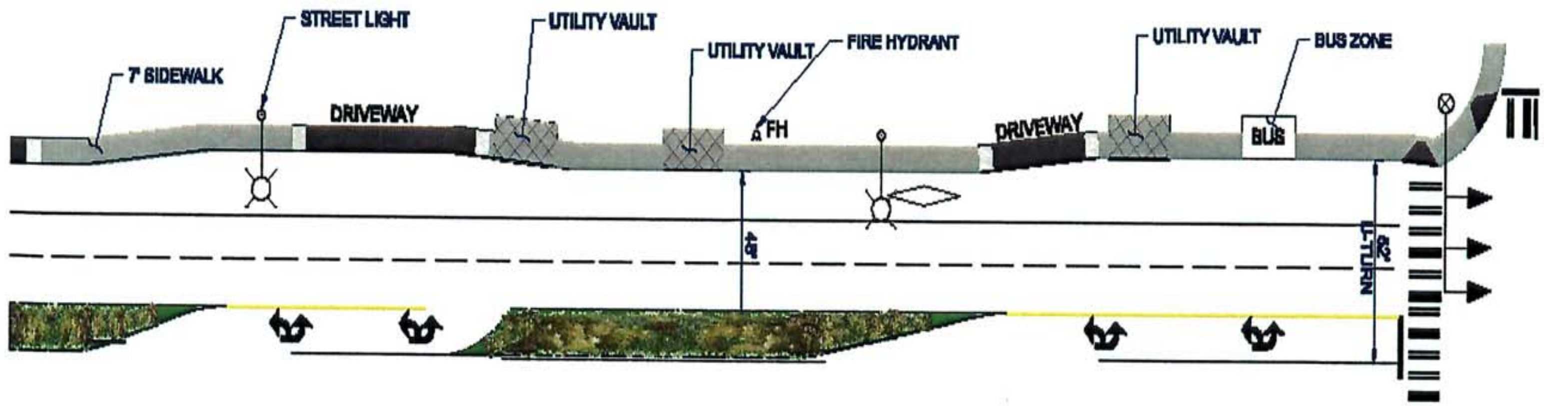
1. Surface Area Exemptions
   A proposed project or any **threshold discharge area** within a project is exempt if it meets all of the following criteria:
   a) Less than 5,000 square feet of new PGIS will be added, AND
   b) Less than 5,000 square feet of contiguous PGIS will be created through any combination of new and/or replaced impervious surface as part of a redevelopment project, AND
   c) Less than 1 acre of contiguous PGPS will be added and/or modified

It is estimated that the Aurora Corridor project will meet all of the above criteria based on site conditions and if contiguous base repair work is limited to less than 5,000 square feet. Conversations with the City indicate no large base repair is planned. Sidewalks are not considered pollutant generating and will not be counted towards the PGIS threshold.

However, in the event that more that 5,000 square-feet of contiguous base is replaced Basic Water Quality measure will be required. The goal of Basic Water Quality is reduce the amount of Total Suspend Solids from entering the stormwater system.

Following the 1998 KCSWDM and the addendums described in The City Engineering Development Guide 2005, it is estimated that the proposed work, given the existing conditions, will not trigger water quality or flow control measures.

Alternatives A



Alternatives B and C

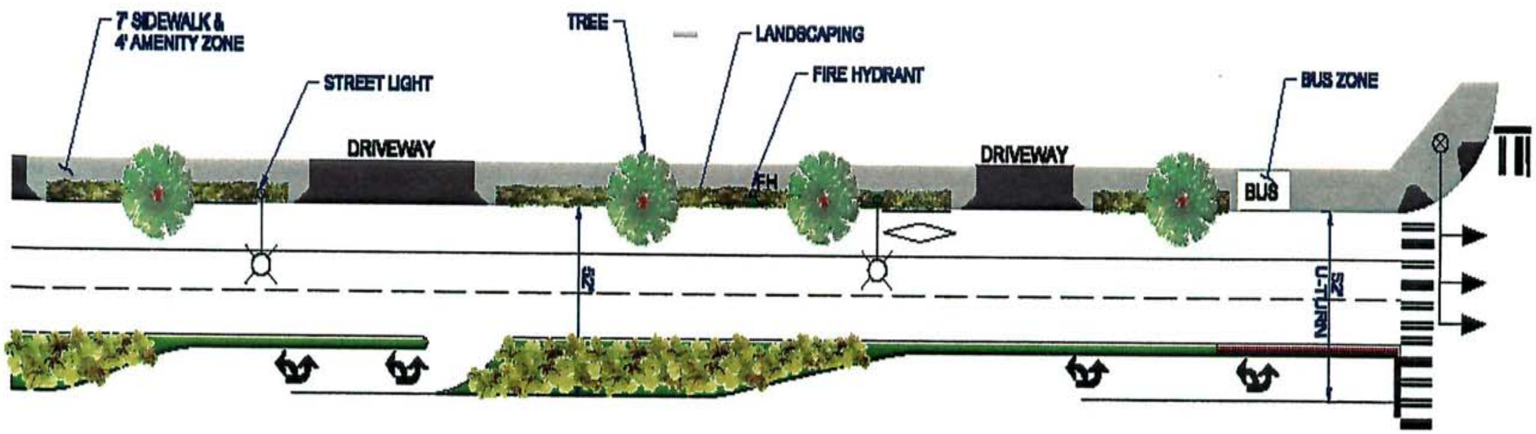


Figure 1: Alternative Cross-Section

APPENDIX C

Flow Control Sizing and Modeling

Flow Control Facility Sizing

Current Requirements -1998 KCSWDM

Modeling for the 100-year peak flow using KCRTS indicates a reduction in peak flow. Therefore, the project is exempt from flow control requirements per Exemption 4 – Peak Flow Exemption (Pages 1-28, 1998 KCSWDM). For existing and proposed area used in KCRTS 100-year peak flow modeling, see Table 1.

Target Requirements – 2005 KCSWDM

Basin areas were based on area taken from electronic files provided by CHM2HILL, see Table 1. Historic Areas were used for modeling target flow control based on conversations with the City of Shoreline's staff and definitions in 2005 KCSWDM.

Table 1: Existing, Proposed Preferred Alternative, and Historic Areas

		Boeing Creek Drainage Area	McAleer Creek Drainage Basin	
			Echo Lake Drainage Area	Lake Ballinger
Existing Area	Impervious	5.8 acre	15.0 acre	3.2 acre
	Pervious	0 acre	0 acre	0 acre
	Total	**5.8 acre**	**15.0 acre**	**3.2 acre**
Proposed Area	Impervious	5.4 acre	13.9 acre	3.0 acre
	Pervious (7%)	0.4 acre	1.1 acre	0.2 acre
	Total	**5.8 acre**	**15.0 acre**	**3.2 acre**
Historic Area*	Till Forest (75%)	4.35 acre	11.25 acre	2.4 acre
	Till Grass (15%)	0.87 acre	2.25 acre	0.48 acre
	Impervious (10%)	0.58 acre	1.5 acre	0.32 acre
	Total	**5.8 acre**	**15.0 acre**	**3.2 acre**

*Historic Areas were modeled based on 2005 KCSWDM

For a preliminary estimation of the volume required to size a flow control facility for different basins, the PondCalc spreadsheet and King County Run Time Series (KCRTS) was used, see Table 2. The PondCalc spreadsheet was developed by King County to provide conservative flow control estimates and is based on KCRTS. See Spreadsheets 1-4 for PondCalc outputs, and KCRTS Reports 1-6 for more information.

Table 2: Summary of PondCalc Volume s for Targeted Drainage Areas

Flow Control Volume		Boeing Creek (Level 3 Flow Control)	McAleer Creek Drainage Basin (Level 2 Flow Control)		Total
			Echo Lake	Lake Ballinger	
PondCalc		88,087 CF	218,115 CF	46,531 CF	352,733 CF
KCRTS Detention	Pond	73,200 CF	235,900 CF	42,000 CF	351,100 CF
	Tank	70,000 CF	186,200 CF	40,200 CF	296,400 CF

Low Impact Development (LID)

The WWHM modeling flow control area was conservatively estimated at 55 feet wide, which is half of the recommended alternative cross-section, and 100 feet long (5,500 SF or 0.126 acres). This method of sizing stormwater facilities enables the City to easily scale from the typical section to a drainage basin or project area.

There is not enough room in the amenity zone to size LID features to capture the full “Flood Problem Flow Control” or the “Conservation Flow Control” as defined by the 2005 KCSWDM. However, LID features can capture 50-percent of the two-year to 50-year flow durations. LID features cannot capture peak flows for historic conditions required to meet “Flood Problem Flow Control”, Output File for WWHM.

WWHM Report 1 Appendix C shows that the stormwater planters, utilizing half of the available space in the amenity zone, match duration curves for the typical area. It was assumed that half of the space in the amenity zone would be required for utility vaults and driveways. Therefore, there is not enough room in the amenity zone to capture the two-year and 10-year peak flows. In order to capture the two-year and 10-year peak flows, LID has to be combined with conventional detention systems.

Flow Control Appendix Spreadsheet 1

Pondcalc Worksheet Boeing Creek

Flood Problem Flow Control (Level 3 Protection)

Instructions:

1 Enter site information in the yellow highlighted cells
2 Verify no error message is displayed
3 Results are displayed in Green Box

*Note: pondcalc will not work for negative landcover conversions.
pondcalc does not handle existing EI or TG very well.

Disclaimer: This spreadsheet is provided without warranty of any kind. Use this spreadsheet at your own risk. All facility sizes should be verified using KCRTS software.

Rainfall Region	ST	{either ST or LA see rainfall regions map}
Scale Factor:	1.00	{ 0.8 - 1.2 see rainfall regions map}
FC Level:	3	{ 1, 2, or 3 see flow control app map}
Basin Area	5.8	

Predeveloped acres	Landcover type	Postdeveloped acres	Adjusted Acres converted cover	Error Messages
4.35	TF		4.35	
0.87	TP		0.87	
0	TG	0.406	0.406	
0.58	EI	5.39	4.814	

Acreage Check:		post	pre
	gross	5.8	5.8
	adjusted	5.22	5.22

Storage Estimate:

4.6 inches per converted acre
4.2 inches per gross acre
2.0 ac-ft
88,087 cubic-ft

Flow Control Appendix Spreadsheet 2

Pondcalc Worksheet Echo Lake

Conservation Flow Control (Level 2 Protection)

Instructions:

1 Enter site information in the yellow highlighted cells
2 Verify no error message is displayed
3 Results are displayed in Green Box

*Note: pondcalc will not work for negative landcover conversions.
pondcalc does not handle existing EI or TG very well.

Disclaimer: This spreadsheet is provided without warranty of any kind. Use this spreadsheet at your own risk. All facility sizes should be verified using KCRTS software.

Rainfall Region	ST	{either ST or LA see rainfall regions map}
Scale Factor:	1.00	{ 0.8 - 1.2 see rainfall regions map}
FC Level:	2	{ 1, 2, or 3 see flow control app map}
Basin Area	15.0	

Predeveloped acres	Landcover type	Postdeveloped acres	Adjusted Acres converted cover	Error Messages
11.25	TF		11.25	
2.25	TP		2.25	
0	TG	1.05	1.05	
1.5	EI	13.95	12.45	

Acreage Check:

	post	pre
gross	15	15
adjusted	13.5	13.5

Storage Estimate:

4.5 inches per converted acre
4.0 inches per gross acre
5.0 ac-ft
218,115 cubic-ft

Flow Control Appendix Spreadsheet 3

Pondcalc Worksheet Lake Ballinger

Conservation Flow Control (Level 2 Protection)

Instructions:

1 Enter site information in the yellow highlighted cells
2 Verify no error message is displayed
3 Results are displayed in Green Box

*Note: pondcalc will not work for negative landcover conversions.
pondcalc does not handle existing EI or TG very well.

Disclaimer: This spreadsheet is provided without warranty of any kind. Use this spreadsheet at your own risk. All facility sizes should be verified using KCRTS software.

Rainfall Region	ST	{either ST or LA see rainfall regions map}
Scale Factor:	1.00	{ 0.8 - 1.2 see rainfall regions map}
FC Level:	2	{ 1, 2, or 3 see flow control app map}
Basin Area	3.2	

Predeveloped acres	Landcover type	Postdeveloped acres	Adjusted Acres converted cover	Error Messages
2.4	TF		2.4	
0.48	TP		0.48	
0	TG	0.224	0.224	
0.32	EI	2.98	2.656	

Acreage Check:		post	pre
	gross	3.2	3.2
	adjusted	2.88	2.88

Storage Estimate:

4.5 inches per converted acre
4.0 inches per gross acre
1.1 ac-ft
46,531 cubic-ft

Flow Control Appendix Spreadsheet 4

Pondcalc Worksheet Typical Flow Control Cross-section

Flood Problem Flow Control (Level 2 Protection)

(55 ft wide by 100 ft long)

Instructions:

1 Enter site information in the yellow highlighted cells
2 Verify no error message is displayed
3 Results are displayed in Green Box

*Note: pondcalc will not work for negative landcover conversions.
pondcalc does not handle existing EI or TG very well.

Disclaimer: This spreadsheet is provided without warranty of any kind. Use this spreadsheet at your own risk. All facility sizes should be verified using KCRTS software.

Rainfall Region	ST	{either ST or LA see rainfall regions map}
Scale Factor:	1.00	{ 0.8 - 1.2 see rainfall regions map}
FC Level:	2	{ 1, 2, or 3 see flow control app map}

Predeveloped acres	Landcover type	Postdeveloped acres	Adjusted Acres converted cover	Error Messages
0.095	TF		0.095	
0.019	TP		0.019	
0	TG	0.009	0.009	
0.013	EI	0.118	0.105	

Acreage Check:

	post	pre
gross	0.127	0.127
adjusted	0.114	0.114

Storage Estimate:

4.4 inches per converted acre
4.0 inches per gross acre
0.0 ac-ft
1,840 cubic-ft

Retention/Detention Facility – Boeing Creek Basin

Type of Facility:	Detention Pond	
Side Slope:	0.00	H:1V
Pond Bottom Length:	115.00	ft
Pond Bottom Width:	106.00	ft
Pond Bottom Area:	12190.	sq. ft
Top Area at 1 ft. FB:	12190.	sq. ft
	0.280	acres
Effective Storage Depth:	6.00	ft
Stage 0 Elevation:	0.00	ft
Storage Volume:	73140.	cu. ft
	1.679	ac-ft
Riser Head:	6.00	ft
Riser Diameter:	18.00	inches
Number of orifices:	3	

Orifice #	Height (ft)	Diameter (in)	Full Head Discharge (CFS)	Pipe Diameter (in)
1	0.00	1.80	0.215	
2	3.50	1.75	0.131	4.0
3	5.20	2.00	0.097	4.0

Top Notch Weir: None
Outflow Rating Curve: None

Stage (ft)	Elevation (ft)	Storage (cu. ft)	Storage (ac-ft)	Discharge (cfs)	Percolation (cfs)	Surf Area (sq. ft)
0.00	0.00	0.	0.000	0.000	0.00	12190.
0.02	0.02	244.	0.006	0.012	0.00	12190.
0.04	0.04	488.	0.011	0.017	0.00	12190.
0.06	0.06	731.	0.017	0.021	0.00	12190.
0.07	0.07	853.	0.020	0.024	0.00	12190.
0.09	0.09	1097.	0.025	0.027	0.00	12190.
0.11	0.11	1341.	0.031	0.029	0.00	12190.
0.13	0.13	1585.	0.036	0.032	0.00	12190.
0.15	0.15	1829.	0.042	0.034	0.00	12190.
0.27	0.27	3291.	0.076	0.045	0.00	12190.
0.39	0.39	4754.	0.109	0.055	0.00	12190.
0.50	0.50	6095.	0.140	0.062	0.00	12190.
0.62	0.62	7558.	0.174	0.069	0.00	12190.
0.74	0.74	9021.	0.207	0.076	0.00	12190.
0.86	0.86	10483.	0.241	0.081	0.00	12190.
0.97	0.97	11824.	0.271	0.087	0.00	12190.
1.09	1.09	13287.	0.305	0.092	0.00	12190.
1.21	1.21	14750.	0.339	0.097	0.00	12190.
1.33	1.33	16213.	0.372	0.101	0.00	12190.
1.44	1.44	17554.	0.403	0.106	0.00	12190.
1.56	1.56	19016.	0.437	0.110	0.00	12190.
1.68	1.68	20479.	0.470	0.114	0.00	12190.
1.80	1.80	21942.	0.504	0.118	0.00	12190.
1.91	1.91	23283.	0.535	0.122	0.00	12190.
2.03	2.03	24746.	0.568	0.125	0.00	12190.
2.15	2.15	26209.	0.602	0.129	0.00	12190.
2.27	2.27	27671.	0.635	0.132	0.00	12190.
2.39	2.39	29134.	0.669	0.136	0.00	12190.
2.50	2.50	30475.	0.700	0.139	0.00	12190.
2.62	2.62	31938.	0.733	0.142	0.00	12190.
2.74	2.74	33401.	0.767	0.145	0.00	12190.
2.86	2.86	34863.	0.800	0.149	0.00	12190.
2.97	2.97	36204.	0.831	0.152	0.00	12190.

3.09	3.09	37667.	0.865	0.155	0.00	12190.
3.21	3.21	39130.	0.898	0.157	0.00	12190.
3.33	3.33	40593.	0.932	0.160	0.00	12190.
3.44	3.44	41934.	0.963	0.163	0.00	12190.
3.50	3.50	42665.	0.979	0.164	0.00	12190.
3.52	3.52	42909.	0.985	0.165	0.00	12190.
3.54	3.54	43153.	0.991	0.168	0.00	12190.
3.55	3.55	43275.	0.993	0.171	0.00	12190.
3.57	3.57	43518.	0.999	0.176	0.00	12190.
3.59	3.59	43762.	1.005	0.182	0.00	12190.
3.61	3.61	44006.	1.010	0.189	0.00	12190.
3.63	3.63	44250.	1.016	0.197	0.00	12190.
3.65	3.65	44494.	1.021	0.200	0.00	12190.
3.76	3.76	45834.	1.052	0.213	0.00	12190.
3.88	3.88	47297.	1.086	0.224	0.00	12190.
4.00	4.00	48760.	1.119	0.234	0.00	12190.
4.12	4.12	50223.	1.153	0.244	0.00	12190.
4.23	4.23	51564.	1.184	0.252	0.00	12190.
4.35	4.35	53027.	1.217	0.260	0.00	12190.
4.47	4.47	54489.	1.251	0.268	0.00	12190.
4.59	4.59	55952.	1.284	0.275	0.00	12190.
4.70	4.70	57293.	1.315	0.282	0.00	12190.
4.82	4.82	58756.	1.349	0.289	0.00	12190.
4.94	4.94	60219.	1.382	0.295	0.00	12190.
5.06	5.06	61681.	1.416	0.301	0.00	12190.
5.18	5.18	63144.	1.450	0.307	0.00	12190.
5.20	5.20	63388.	1.455	0.309	0.00	12190.
5.22	5.22	63632.	1.461	0.311	0.00	12190.
5.24	5.24	63876.	1.466	0.314	0.00	12190.
5.26	5.26	64119.	1.472	0.319	0.00	12190.
5.28	5.28	64363.	1.478	0.326	0.00	12190.
5.30	5.30	64607.	1.483	0.334	0.00	12190.
5.33	5.33	64973.	1.492	0.344	0.00	12190.
5.35	5.35	65217.	1.497	0.354	0.00	12190.
5.37	5.37	65460.	1.503	0.361	0.00	12190.
5.48	5.48	66801.	1.534	0.381	0.00	12190.
5.60	5.60	68264.	1.567	0.397	0.00	12190.
5.72	5.72	69727.	1.601	0.412	0.00	12190.
5.84	5.84	71190.	1.634	0.426	0.00	12190.
5.95	5.95	72531.	1.665	0.439	0.00	12190.
6.00	6.00	73140.	1.679	0.444	0.00	12190.
6.10	6.10	74359.	1.707	0.916	0.00	12190.
6.20	6.20	75578.	1.735	1.770	0.00	12190.
6.30	6.30	76797.	1.763	2.870	0.00	12190.
6.40	6.40	78016.	1.791	4.180	0.00	12190.
6.50	6.50	79235.	1.819	5.660	0.00	12190.
6.60	6.60	80454.	1.847	7.090	0.00	12190.
6.70	6.70	81673.	1.875	7.630	0.00	12190.
6.80	6.80	82892.	1.903	8.130	0.00	12190.
6.90	6.90	84111.	1.931	8.600	0.00	12190.
7.00	7.00	85330.	1.959	9.040	0.00	12190.
7.10	7.10	86549.	1.987	9.470	0.00	12190.
7.20	7.20	87768.	2.015	9.870	0.00	12190.
7.30	7.30	88987.	2.043	10.260	0.00	12190.
7.40	7.40	90206.	2.071	10.630	0.00	12190.
7.50	7.50	91425.	2.099	10.990	0.00	12190.
7.60	7.60	92644.	2.127	11.340	0.00	12190.
7.70	7.70	93863.	2.155	11.680	0.00	12190.
7.80	7.80	95082.	2.183	12.010	0.00	12190.
7.90	7.90	96301.	2.211	12.330	0.00	12190.
8.00	8.00	97520.	2.239	12.640	0.00	12190.

Hyd Inflow Outflow Peak Storage
Target Calc Stage Elev (Cu-Ft) (Ac-Ft)

1	6.56	1.19	0.77	6.07	6.07	73993.	1.699
2	2.25	*******	0.33	5.28	5.28	64339.	1.477
3	1.86	*******	0.42	5.81	5.81	70835.	1.626
4	1.71	*******	0.28	4.67	4.67	56925.	1.307
5	2.21	*******	0.26	4.30	4.30	52412.	1.203
6	1.58	*******	0.16	3.47	3.47	42323.	0.972
7	1.69	*******	0.14	2.58	2.58	31469.	0.722
8	2.07	*******	0.14	2.51	2.51	30604.	0.703

Appendix C – Flow Control KCRTS Report 1

Retention/Detention Facility – Boeing Creek

Type of Facility: Detention Pipe
Tank Diameter: 10.00 ft
Tank Length: 940.00 ft
Effective Storage Depth: 9.00 ft
Stage 0 Elevation: 100.00 ft
Storage Volume: 69985. cu. ft
Riser Head: 9.00 ft
Riser Diameter: 18.00 inches
Number of orifices: 2

Orifice #	Height (ft)	Diameter (in)	Full Head Discharge (CFS)	Pipe Diameter (in)
1	0.00	1.62	0.214	
2	4.30	1.65	0.160	4.0

Top Notch Weir: None
Outflow Rating Curve: None

Stage (ft)	Elevation (ft)	Storage (cu. ft)	Storage (ac-ft)	Discharge (cfs)	Percolation (cfs)
0.00	100.00	0.	0.000	0.000	0.00
0.02	100.02	113.	0.003	0.009	0.00
0.03	100.03	170.	0.004	0.013	0.00
0.05	100.05	285.	0.007	0.016	0.00
0.07	100.07	401.	0.009	0.018	0.00
0.08	100.08	459.	0.011	0.021	0.00
0.10	100.10	576.	0.013	0.023	0.00
0.12	100.12	694.	0.016	0.024	0.00
0.14	100.14	813.	0.019	0.026	0.00
0.29	100.29	1735.	0.040	0.038	0.00
0.44	100.44	2703.	0.062	0.047	0.00
0.59	100.59	3713.	0.085	0.055	0.00
0.75	100.75	4835.	0.111	0.061	0.00
0.90	100.90	5924.	0.136	0.067	0.00
1.05	101.05	7047.	0.162	0.073	0.00
1.20	101.20	8200.	0.188	0.078	0.00
1.36	101.36	9462.	0.217	0.083	0.00
1.51	101.51	10673.	0.245	0.087	0.00
1.66	101.66	11907.	0.273	0.092	0.00
1.81	101.81	13164.	0.302	0.096	0.00
1.97	101.97	14527.	0.334	0.100	0.00
2.12	102.12	15825.	0.363	0.104	0.00
2.27	102.27	17140.	0.393	0.107	0.00
2.42	102.42	18470.	0.424	0.111	0.00
2.58	102.58	19905.	0.457	0.114	0.00
2.73	102.73	21263.	0.488	0.118	0.00
2.88	102.88	22632.	0.520	0.121	0.00
3.03	103.03	24011.	0.551	0.124	0.00
3.19	103.19	25491.	0.585	0.127	0.00
3.34	103.34	26886.	0.617	0.130	0.00
3.49	103.49	28286.	0.649	0.133	0.00
3.64	103.64	29690.	0.682	0.136	0.00
3.80	103.80	31192.	0.716	0.139	0.00
3.95	103.95	32601.	0.748	0.141	0.00
4.10	104.10	34011.	0.781	0.144	0.00
4.25	104.25	35420.	0.813	0.147	0.00
4.30	104.30	35890.	0.824	0.148	0.00
4.32	104.32	36077.	0.828	0.148	0.00

4.33	104.33	36171.	0.830	0.150	0.00
4.35	104.35	36359.	0.835	0.153	0.00
4.37	104.37	36546.	0.839	0.158	0.00
4.39	104.39	36734.	0.843	0.163	0.00
4.40	104.40	36827.	0.845	0.169	0.00
4.42	104.42	37015.	0.850	0.175	0.00
4.44	104.44	37202.	0.854	0.177	0.00
4.59	104.59	38605.	0.886	0.192	0.00
4.74	104.74	40002.	0.918	0.204	0.00
4.90	104.90	41486.	0.952	0.214	0.00
5.05	105.05	42868.	0.984	0.224	0.00
5.20	105.20	44242.	1.016	0.232	0.00
5.35	105.35	45606.	1.047	0.240	0.00
5.51	105.51	47047.	1.080	0.248	0.00
5.66	105.66	48384.	1.111	0.255	0.00
5.81	105.81	49706.	1.141	0.262	0.00
5.96	105.96	51012.	1.171	0.269	0.00
6.12	106.12	52385.	1.203	0.276	0.00
6.27	106.27	53652.	1.232	0.282	0.00
6.42	106.42	54897.	1.260	0.288	0.00
6.57	106.57	56119.	1.288	0.294	0.00
6.73	106.73	57394.	1.318	0.300	0.00
6.88	106.88	58561.	1.344	0.305	0.00
7.03	107.03	59699.	1.370	0.311	0.00
7.18	107.18	60804.	1.396	0.316	0.00
7.34	107.34	61944.	1.422	0.321	0.00
7.49	107.49	62974.	1.446	0.327	0.00
7.64	107.64	63962.	1.468	0.332	0.00
7.79	107.79	64906.	1.490	0.337	0.00
7.95	107.95	65858.	1.512	0.342	0.00
8.10	108.10	66694.	1.531	0.347	0.00
8.25	108.25	67470.	1.549	0.351	0.00
8.40	108.40	68177.	1.565	0.356	0.00
8.56	108.56	68844.	1.580	0.361	0.00
8.71	108.71	69372.	1.593	0.365	0.00
8.86	108.86	69778.	1.602	0.370	0.00
9.00	109.00	69985.	1.607	0.374	0.00
9.10	109.10	69985.	1.607	0.838	0.00
9.20	109.20	69985.	1.607	1.690	0.00
9.30	109.30	69985.	1.607	2.780	0.00
9.40	109.40	69985.	1.607	4.080	0.00
9.50	109.50	69985.	1.607	5.550	0.00
9.60	109.60	69985.	1.607	6.980	0.00
9.70	109.70	69985.	1.607	7.510	0.00
9.80	109.80	69985.	1.607	8.010	0.00
9.90	109.90	69985.	1.607	8.470	0.00
10.00	110.00	69985.	1.607	8.910	0.00
10.10	110.10	69986.	1.607	9.330	0.00
10.20	110.20	69986.	1.607	9.730	0.00
10.30	110.30	69986.	1.607	10.110	0.00
10.40	110.40	69986.	1.607	10.480	0.00
10.50	110.50	69986.	1.607	10.840	0.00
10.60	110.60	69986.	1.607	11.180	0.00
10.70	110.70	69986.	1.607	11.510	0.00
10.80	110.80	69986.	1.607	11.840	0.00
10.90	110.90	69986.	1.607	12.150	0.00

Hyd	Inflow	Outflow		Peak		Storage	
		Target	Calc	Stage	Elev	(Cu-Ft)	(Ac-Ft)
1	6.56	*******	2.04	9.23	109.23	69985.	1.607
2	4.95	0.80	0.27	5.94	105.94	50830.	1.167
3	3.50	*******	0.33	7.46	107.46	62751.	1.441
4	2.74	*******	0.21	4.82	104.82	40722.	0.935
5	2.07	*******	0.14	3.70	103.70	30230.	0.694

6	2.57	*******	0.59	9.05	109.05	69985.	1.607
7	2.90	*******	0.29	6.51	106.51	55661.	1.278
8	1.79	*******	0.14	3.75	103.75	30678.	0.704

Route Time Series through Facility
Inflow Time Series File:boeing_devel.tsf
Outflow Time Series File:Boeing-Tank-rdout

Inflow/Outflow Analysis
Peak Inflow Discharge: 6.56 CFS at 6:30 on Jan 9 in Year 8
Peak Outflow Discharge: 2.04 CFS at 9:45 on Jan 9 in Year 8
Peak Reservoir Stage: 9.23 Ft
Peak Reservoir Elev: 109.23 Ft
Peak Reservoir Storage: 69985. Cu-Ft
: 1.607 Ac-Ft

Flow Duration from Time Series File:boeing-tank-rdout.tsf

Cutoff CFS	Count	Frequency %	CDF %	Exceedence_Probability %	
0.008	159422	64.996	64.996	35.004	0.350E+00
0.025	15613	6.365	71.361	28.639	0.286E+00
0.041	17376	7.084	78.445	21.555	0.216E+00
0.058	15546	6.338	84.784	15.216	0.152E+00
0.074	13826	5.637	90.420	9.580	0.958E-01
0.091	9380	3.824	94.245	5.755	0.576E-01
0.107	6168	2.515	96.759	3.241	0.324E-01
0.124	3847	1.568	98.328	1.672	0.167E-01
0.140	2253	0.919	99.246	0.754	0.754E-02
0.157	732	0.298	99.545	0.455	0.455E-02
0.173	41	0.017	99.561	0.439	0.439E-02
0.189	176	0.072	99.633	0.367	0.367E-02
0.206	163	0.066	99.700	0.300	0.300E-02
0.222	117	0.048	99.747	0.253	0.253E-02
0.239	136	0.055	99.803	0.197	0.197E-02
0.255	133	0.054	99.857	0.143	0.143E-02
0.272	95	0.039	99.896	0.104	0.104E-02
0.288	87	0.035	99.931	0.069	0.689E-03
0.305	66	0.027	99.958	0.042	0.420E-03
0.321	40	0.016	99.974	0.026	0.257E-03
0.338	25	0.010	99.985	0.015	0.155E-03
0.354	21	0.009	99.993	0.007	0.693E-04
0.371	11	0.004	99.998	0.002	0.245E-04
0.387	3	0.001	99.999	0.001	0.122E-04
0.403	0	0.000	99.999	0.001	0.122E-04
0.420	1	0.000	99.999	0.001	0.815E-05
0.436	0	0.000	99.999	0.001	0.815E-05
0.453	0	0.000	99.999	0.001	0.815E-05
0.469	0	0.000	99.999	0.001	0.815E-05
0.486	0	0.000	99.999	0.001	0.815E-05
0.502	0	0.000	99.999	0.001	0.815E-05
0.519	0	0.000	99.999	0.001	0.815E-05
0.535	0	0.000	99.999	0.001	0.815E-05
0.552	1	0.000	100.000	0.000	0.408E-05
0.568	0	0.000	100.000	0.000	0.408E-05
0.585	0	0.000	100.000	0.000	0.408E-05

Duration Comparison Anaylsis
Base File: boeing_predevel.tsf
New File: boeing-tank-rdout.tsf
Cutoff Units: Discharge in CFS

	-----Fraction of Time-----			---------Check of Tolerance-------			
Cutoff	Base	New	%Change	Probability	Base	New	%Change

0.155	0.53E-02	0.46E-02	-14.4	0.53E-02	0.155	0.146	-6.0
0.225	0.19E-02	0.25E-02	30.2	0.19E-02	0.225	0.241	7.2
0.294	0.82E-03	0.56E-03	-31.0	0.82E-03	0.294	0.282	-4.2
0.364	0.23E-03	0.37E-04	-84.2	0.23E-03	0.364	0.324	-11.1
0.434	0.29E-04	0.82E-05	-71.4	0.29E-04	0.434	0.368	-15.0
0.503	0.82E-05	0.82E-05	0.0	0.82E-05	0.503	0.537	6.7
0.573	0.41E-05	0.41E-05	0.0	0.41E-05	0.573	0.585	2.1
0.642	0.41E-05	0.00E+00	-100.0	0.41E-05	0.642	0.585	-9.0
0.712	0.41E-05	0.00E+00	-100.0	0.41E-05	0.712	0.585	-17.9
0.781	0.41E-05	0.00E+00	-100.0	0.41E-05	0.781	0.585	-25.2

Maximum positive excursion = 0.075 cfs (14.7%)
occurring at 0.510 cfs on the Base Data:boeing_predevel.tsf
and at 0.585 cfs on the New Data:boeing-tank-rdout.tsf

Maximum negative excursion = 0.215 cfs (-26.9%)
occurring at 0.800 cfs on the Base Data:boeing_predevel.tsf
and at 0.585 cfs on the New Data:boeing-tank-rdout.tsf
Appendix C – Flow Control KCRTS Report 2

Retention/Detention Facility – Echo Lake Subbasin

Type of Facility:	Detention Pond	
Side Slope:	3.00	H:1V
Pond Bottom Length:	180.00	ft
Pond Bottom Width:	180.00	ft
Pond Bottom Area:	32400.	sq. ft
Top Area at 1 ft. FB:	49284.	sq. ft
	1.131	acres
Effective Storage Depth:	6.00	ft
Stage 0 Elevation:	100.00	ft
Storage Volume:	235872.	cu. ft
	5.415	ac-ft
Riser Head:	6.00	ft
Riser Diameter:	18.00	inches
Number of orifices:	2	

Orifice #	Height (ft)	Diameter (in)	Full Head Discharge (CFS)	Pipe Diameter (in)
1	0.00	2.90	0.559	
2	2.60	2.70	0.365	6.0

Top Notch Weir: None
Outflow Rating Curve: None

Stage (ft)	Elevation (ft)	Storage (cu. ft)	Storage (ac-ft)	Discharge (cfs)	Percolation (cfs)	Surf Area (sq. ft)
0.00	100.00	0.	0.000	0.000	0.00	32400.
0.03	100.03	973.	0.022	0.040	0.00	32465.
0.06	100.06	1948.	0.045	0.056	0.00	32530.
0.09	100.09	2925.	0.067	0.069	0.00	32595.
0.12	100.12	3904.	0.090	0.079	0.00	32660.
0.15	100.15	4884.	0.112	0.089	0.00	32725.
0.18	100.18	5867.	0.135	0.097	0.00	32790.
0.21	100.21	6852.	0.157	0.105	0.00	32855.
0.24	100.24	7838.	0.180	0.112	0.00	32920.
0.34	100.34	11141.	0.256	0.133	0.00	33139.
0.44	100.44	14466.	0.332	0.152	0.00	33357.
0.54	100.54	17813.	0.409	0.168	0.00	33577.
0.64	100.64	21182.	0.486	0.183	0.00	33797.
0.74	100.74	24572.	0.564	0.196	0.00	34018.
0.84	100.84	27985.	0.642	0.209	0.00	34240.
0.94	100.94	31420.	0.721	0.221	0.00	34462.
1.04	101.04	34878.	0.801	0.233	0.00	34685.
1.14	101.14	38357.	0.881	0.244	0.00	34909.
1.24	101.24	41859.	0.961	0.254	0.00	35134.
1.34	101.34	45384.	1.042	0.264	0.00	35359.
1.44	101.44	48931.	1.123	0.274	0.00	35585.
1.54	101.54	52501.	1.205	0.283	0.00	35812.
1.64	101.64	56094.	1.288	0.292	0.00	36039.
1.74	101.74	59709.	1.371	0.301	0.00	36267.
1.84	101.84	63347.	1.454	0.310	0.00	36496.
1.94	101.94	67008.	1.538	0.318	0.00	36726.
2.04	102.04	70692.	1.623	0.326	0.00	36956.
2.14	102.14	74400.	1.708	0.334	0.00	37187.
2.24	102.24	78130.	1.794	0.342	0.00	37419.
2.34	102.34	81883.	1.880	0.349	0.00	37652.
2.44	102.44	85660.	1.966	0.356	0.00	37885.
2.54	102.54	89460.	2.054	0.364	0.00	38119.
2.60	102.60	91752.	2.106	0.368	0.00	38259.
2.63	102.63	92901.	2.133	0.372	0.00	38330.

2.66	102.66	94052.	2.159	0.379	0.00	38400.
2.68	102.68	94820.	2.177	0.390	0.00	38447.
2.71	102.71	95974.	2.203	0.405	0.00	38518.
2.74	102.74	97131.	2.230	0.423	0.00	38589.
2.77	102.77	98290.	2.256	0.444	0.00	38659.
2.80	102.80	99451.	2.283	0.468	0.00	38730.
2.83	102.83	100614.	2.310	0.477	0.00	38801.
2.93	102.93	104506.	2.399	0.503	0.00	39038.
3.03	103.03	108421.	2.489	0.526	0.00	39275.
3.13	103.13	112361.	2.579	0.547	0.00	39513.
3.23	103.23	116324.	2.670	0.566	0.00	39752.
3.32	103.32	119911.	2.753	0.584	0.00	39968.
3.42	103.42	123920.	2.845	0.602	0.00	40208.
3.52	103.52	127953.	2.937	0.618	0.00	40449.
3.62	103.62	132010.	3.031	0.635	0.00	40691.
3.72	103.72	136091.	3.124	0.650	0.00	40933.
3.82	103.82	140197.	3.218	0.665	0.00	41177.
3.92	103.92	144327.	3.313	0.680	0.00	41420.
4.02	104.02	148481.	3.409	0.694	0.00	41665.
4.12	104.12	152660.	3.505	0.707	0.00	41910.
4.22	104.22	156863.	3.601	0.721	0.00	42156.
4.32	104.32	161091.	3.698	0.734	0.00	42403.
4.42	104.42	165344.	3.796	0.747	0.00	42651.
4.52	104.52	169621.	3.894	0.760	0.00	42899.
4.62	104.62	173923.	3.993	0.772	0.00	43148.
4.72	104.72	178251.	4.092	0.784	0.00	43397.
4.82	104.82	182603.	4.192	0.796	0.00	43648.
4.92	104.92	186980.	4.292	0.808	0.00	43899.
5.02	105.02	191383.	4.394	0.819	0.00	44150.
5.12	105.12	195810.	4.495	0.831	0.00	44403.
5.22	105.22	200263.	4.597	0.842	0.00	44656.
5.32	105.32	204741.	4.700	0.853	0.00	44910.
5.42	105.42	209245.	4.804	0.864	0.00	45165.
5.52	105.52	213774.	4.908	0.874	0.00	45420.
5.62	105.62	218329.	5.012	0.885	0.00	45676.
5.72	105.72	222910.	5.117	0.895	0.00	45933.
5.82	105.82	227516.	5.223	0.906	0.00	46191.
5.92	105.92	232148.	5.329	0.916	0.00	46449.
6.00	106.00	235872.	5.415	0.923	0.00	46656.
6.10	106.10	240551.	5.522	1.400	0.00	46916.
6.20	106.20	245255.	5.630	2.250	0.00	47176.
6.30	106.30	249986.	5.739	3.350	0.00	47437.
6.40	106.40	254743.	5.848	4.660	0.00	47699.
6.50	106.50	259526.	5.958	6.140	0.00	47961.
6.60	106.60	264335.	6.068	7.570	0.00	48224.
6.70	106.70	269170.	6.179	8.110	0.00	48488.
6.80	106.80	274032.	6.291	8.610	0.00	48753.
6.90	106.90	278921.	6.403	9.080	0.00	49018.
7.00	107.00	283836.	6.516	9.530	0.00	49284.
7.10	107.10	288778.	6.629	9.950	0.00	49551.
7.20	107.20	293746.	6.743	10.360	0.00	49818.
7.30	107.30	298741.	6.858	10.750	0.00	50086.
7.40	107.40	303764.	6.973	11.120	0.00	50355.
7.50	107.50	308813.	7.089	11.480	0.00	50625.
7.60	107.60	313889.	7.206	11.830	0.00	50895.
7.70	107.70	318992.	7.323	12.170	0.00	51166.
7.80	107.80	324122.	7.441	12.500	0.00	51438.
7.90	107.90	329279.	7.559	12.830	0.00	51711.
8.00	108.00	334464.	7.678	13.140	0.00	51984.

Hyd	Inflow	Outflow		Peak		Storage	
		Target	Calc	Stage	Elev	(Cu-Ft)	(Ac-Ft)
1	16.98	*******	0.84	5.24	105.24	201260.	4.620
2	5.82	2.07	0.75	4.48	104.48	167816.	3.853

3	4.43	*******	0.69	4.00	104.00	147521.	3.387
4	4.81	*******	0.81	4.98	104.98	189404.	4.348
5	5.71	*******	0.64	3.67	103.67	133990.	3.076
6	4.09	*******	0.53	3.03	103.03	108275.	2.486
7	5.35	*******	0.35	2.32	102.32	81104.	1.862
8	4.38	*******	0.35	2.38	102.38	83224.	1.911

Route Time Series through Facility
Inflow Time Series File:echo-develop.tsf
Outflow Time Series File:echo-rdout

Inflow/Outflow Analysis
Peak Inflow Discharge: 16.98 CFS at 6:30 on Jan 9 in Year 8
Peak Outflow Discharge: 0.844 CFS at 13:45 on Jan 9 in Year 8
Peak Reservoir Stage: 5.24 Ft
Peak Reservoir Elev: 105.24 Ft
Peak Reservoir Storage: 201260. Cu-Ft
: 4.620 Ac-Ft

Flow Duration from Time Series File:echo-rdout.tsf

Cutoff CFS	Count	Frequency %	CDF %	Exceedence_Probability %	
0.012	150233	61.250	61.250	38.750	0.388E+00
0.035	9324	3.801	65.051	34.949	0.349E+00
0.057	9736	3.969	69.020	30.980	0.310E+00
0.080	11082	4.518	73.538	26.462	0.265E+00
0.103	10778	4.394	77.933	22.067	0.221E+00
0.126	9688	3.950	81.882	18.118	0.181E+00
0.149	8924	3.638	85.521	14.479	0.145E+00
0.172	8138	3.318	88.838	11.162	0.112E+00
0.195	6695	2.730	91.568	8.432	0.843E-01
0.218	4972	2.027	93.595	6.405	0.640E-01
0.241	3732	1.522	95.117	4.883	0.488E-01
0.263	3127	1.275	96.391	3.609	0.361E-01
0.286	2295	0.936	97.327	2.673	0.267E-01
0.309	2103	0.857	98.185	1.815	0.182E-01
0.332	1289	0.526	98.710	1.290	0.129E-01
0.355	1216	0.496	99.206	0.794	0.794E-02
0.378	607	0.247	99.453	0.547	0.547E-02
0.401	97	0.040	99.493	0.507	0.507E-02
0.424	70	0.029	99.521	0.479	0.479E-02
0.447	55	0.022	99.544	0.456	0.456E-02
0.470	44	0.018	99.562	0.438	0.438E-02
0.492	157	0.064	99.626	0.374	0.374E-02
0.515	106	0.043	99.669	0.331	0.331E-02
0.538	102	0.042	99.711	0.289	0.289E-02
0.561	78	0.032	99.742	0.258	0.258E-02
0.584	81	0.033	99.775	0.225	0.225E-02
0.607	86	0.035	99.810	0.190	0.190E-02
0.630	110	0.045	99.855	0.145	0.145E-02
0.653	71	0.029	99.884	0.116	0.116E-02
0.676	51	0.021	99.905	0.095	0.950E-03
0.699	51	0.021	99.926	0.074	0.742E-03
0.721	56	0.023	99.949	0.051	0.514E-03
0.744	47	0.019	99.968	0.032	0.322E-03
0.767	31	0.013	99.980	0.020	0.196E-03
0.790	21	0.009	99.989	0.011	0.110E-03
0.813	23	0.009	99.998	0.002	0.163E-04

Retention/Detention Facility – Echo Lake

Type of Facility: Detention Pipe
Tank Diameter: 10.00 ft
Tank Length: 2500.00 ft
Effective Storage Depth: 9.00 ft
Stage 0 Elevation: 100.00 ft
Storage Volume: 186131. cu. ft
Riser Head: 9.00 ft
Riser Diameter: 18.00 inches
Number of orifices: 2

Orifice #	Height (ft)	Diameter (in)	Full Head Discharge (CFS)	Pipe Diameter (in)
1	0.00	2.65	0.571	
2	4.15	2.05	0.251	6.0

Top Notch Weir: None
Outflow Rating Curve: None

Stage (ft)	Elevation (ft)	Storage (cu. ft)	Storage (ac-ft)	Discharge (cfs)	Percolation (cfs)
0.00	100.00	0.	0.000	0.000	0.00
0.03	100.03	453.	0.010	0.032	0.00
0.06	100.06	912.	0.021	0.045	0.00
0.08	100.08	1221.	0.028	0.055	0.00
0.11	100.11	1689.	0.039	0.063	0.00
0.14	100.14	2163.	0.050	0.071	0.00
0.17	100.17	2643.	0.061	0.078	0.00
0.19	100.19	2965.	0.068	0.084	0.00
0.22	100.22	3454.	0.079	0.090	0.00
0.25	100.25	3947.	0.091	0.095	0.00
0.40	100.40	6490.	0.149	0.121	0.00
0.55	100.55	9149.	0.210	0.142	0.00
0.71	100.71	12103.	0.278	0.160	0.00
0.86	100.86	14975.	0.344	0.177	0.00
1.01	101.01	17937.	0.412	0.192	0.00
1.16	101.16	20984.	0.482	0.205	0.00
1.32	101.32	24319.	0.558	0.219	0.00
1.47	101.47	27520.	0.632	0.231	0.00
1.62	101.62	30786.	0.707	0.243	0.00
1.77	101.77	34114.	0.783	0.254	0.00
1.93	101.93	37725.	0.866	0.264	0.00
2.08	102.08	41163.	0.945	0.275	0.00
2.23	102.23	44648.	1.025	0.285	0.00
2.38	102.38	48176.	1.106	0.294	0.00
2.54	102.54	51981.	1.193	0.303	0.00
2.69	102.69	55585.	1.276	0.312	0.00
2.84	102.84	59218.	1.359	0.321	0.00
2.99	102.99	62879.	1.443	0.330	0.00
3.15	103.15	66809.	1.534	0.338	0.00
3.30	103.30	70513.	1.619	0.346	0.00
3.45	103.45	74234.	1.704	0.354	0.00
3.60	103.60	77967.	1.790	0.362	0.00
3.76	103.76	81958.	1.882	0.369	0.00
3.91	103.91	85706.	1.968	0.377	0.00
4.06	104.06	89456.	2.054	0.384	0.00
4.15	104.15	91705.	2.105	0.388	0.00
4.17	104.17	92205.	2.117	0.390	0.00
4.19	104.19	92705.	2.128	0.394	0.00
4.21	104.21	93204.	2.140	0.401	0.00

4.24	104.24	93954.	2.157	0.409	0.00
4.26	104.26	94453.	2.168	0.420	0.00
4.28	104.28	94952.	2.180	0.432	0.00
4.30	104.30	95451.	2.191	0.439	0.00
4.32	104.32	95950.	2.203	0.443	0.00
4.47	104.47	99689.	2.289	0.468	0.00
4.63	104.63	103664.	2.380	0.488	0.00
4.78	104.78	107377.	2.465	0.507	0.00
4.93	104.93	111071.	2.550	0.524	0.00
5.08	105.08	114745.	2.634	0.540	0.00
5.24	105.24	118635.	2.723	0.555	0.00
5.39	105.39	122253.	2.807	0.569	0.00
5.54	105.54	125838.	2.889	0.583	0.00
5.69	105.69	129387.	2.970	0.596	0.00
5.85	105.85	133128.	3.056	0.609	0.00
6.00	106.00	136589.	3.136	0.622	0.00
6.15	106.15	140000.	3.214	0.634	0.00
6.30	106.30	143358.	3.291	0.646	0.00
6.46	106.46	146876.	3.372	0.657	0.00
6.61	106.61	150108.	3.446	0.668	0.00
6.76	106.76	153271.	3.519	0.680	0.00
6.91	106.91	156360.	3.590	0.690	0.00
7.07	107.07	159565.	3.663	0.701	0.00
7.22	107.22	162480.	3.730	0.711	0.00
7.37	107.37	165301.	3.795	0.722	0.00
7.52	107.52	168018.	3.857	0.732	0.00
7.68	107.68	170794.	3.921	0.742	0.00
7.83	107.83	173269.	3.978	0.752	0.00
7.98	107.98	175611.	4.031	0.761	0.00
8.13	108.13	177804.	4.082	0.771	0.00
8.29	108.29	179961.	4.131	0.780	0.00
8.44	108.44	181788.	4.173	0.789	0.00
8.59	108.59	183398.	4.210	0.799	0.00
8.74	108.74	184744.	4.241	0.808	0.00
8.90	108.90	185798.	4.265	0.817	0.00
9.00	109.00	186131.	4.273	0.822	0.00
9.10	109.10	186131.	4.273	1.290	0.00
9.20	109.20	186131.	4.273	2.140	0.00
9.30	109.30	186131.	4.273	3.240	0.00
9.40	109.40	186131.	4.273	4.540	0.00
9.50	109.50	186131.	4.273	6.020	0.00
9.60	109.60	186131.	4.273	7.450	0.00
9.70	109.70	186131.	4.273	7.980	0.00
9.80	109.80	186131.	4.273	8.480	0.00
9.90	109.90	186131.	4.273	8.950	0.00
10.00	110.00	186131.	4.273	9.390	0.00
10.10	110.10	186131.	4.273	9.810	0.00
10.20	110.20	186131.	4.273	10.210	0.00
10.30	110.30	186132.	4.273	10.600	0.00
10.40	110.40	186132.	4.273	10.970	0.00
10.50	110.50	186132.	4.273	11.330	0.00
10.60	110.60	186132.	4.273	11.670	0.00
10.70	110.70	186132.	4.273	12.010	0.00
10.80	110.80	186132.	4.273	12.340	0.00
10.90	110.90	186132.	4.273	12.650	0.00

Hyd	Inflow	Outflow		Peak		Storage	
		Target	Calc	Stage	Elev	(Cu-Ft)	(Ac-Ft)
1	16.98	*******	3.99	9.36	109.36	186131.	4.273
2	9.05	2.07	0.72	7.31	107.31	164149.	3.768
3	6.64	*******	1.49	9.12	109.12	186131.	4.273
4	7.50	*******	0.65	6.39	106.39	145321.	3.336
5	12.80	*******	0.61	5.85	105.85	133160.	3.057
6	7.10	*******	0.50	4.71	104.71	105526.	2.423

7	5.35	*******	0.36	3.56	103.56	77089.	1.770
8	4.64	*******	0.36	3.61	103.61	78266.	1.797

Route Time Series through Facility
Inflow Time Series File:echo-develop.tsf
Outflow Time Series File:echo-tank-rdout

Inflow/Outflow Analysis
Peak Inflow Discharge: 16.99 CFS at 6:30 on Jan 9 in Year 8
Peak Outflow Discharge: 3.99 CFS at 10:00 on Jan 9 in Year 8
Peak Reservoir Stage: 9.36 Ft
Peak Reservoir Elev: 109.36 Ft
Peak Reservoir Storage: 186131. Cu-Ft
: 4.273 Ac-Ft

Flow Duration from Time Series File:echo-tank-rdout.tsf

Cutoff CFS	Count	Frequency %	CDF %	Exceedence_Probability %	
0.021	160785	65.552	65.552	34.448	0.344E+00
0.063	13805	5.628	71.180	28.820	0.288E+00
0.104	16763	6.834	78.014	21.986	0.220E+00
0.146	14933	6.088	84.102	15.898	0.159E+00
0.188	13798	5.625	89.728	10.272	0.103E+00
0.229	9529	3.885	93.613	6.387	0.639E-01
0.271	6410	2.613	96.226	3.774	0.377E-01
0.312	4220	1.720	97.946	2.054	0.205E-01
0.354	2416	0.985	98.931	1.069	0.107E-01
0.396	1317	0.537	99.468	0.532	0.532E-02
0.437	117	0.048	99.516	0.484	0.484E-02
0.479	271	0.110	99.627	0.373	0.373E-02
0.521	212	0.086	99.713	0.287	0.287E-02
0.562	171	0.070	99.783	0.217	0.217E-02
0.604	213	0.087	99.870	0.130	0.130E-02
0.645	103	0.042	99.912	0.088	0.885E-03
0.687	92	0.038	99.949	0.051	0.510E-03
0.729	69	0.028	99.977	0.023	0.228E-03
0.770	28	0.011	99.989	0.011	0.114E-03
0.812	19	0.008	99.996	0.004	0.367E-04
0.854	4	0.002	99.998	0.002	0.204E-04
0.895	0	0.000	99.998	0.002	0.204E-04
0.937	1	0.000	99.998	0.002	0.163E-04
0.978	0	0.000	99.998	0.002	0.163E-04
1.02	0	0.000	99.998	0.002	0.163E-04
1.06	0	0.000	99.998	0.002	0.163E-04
1.10	2	0.001	99.999	0.001	0.815E-05
1.14	0	0.000	99.999	0.001	0.815E-05
1.19	0	0.000	99.999	0.001	0.815E-05
1.23	0	0.000	99.999	0.001	0.815E-05
1.27	0	0.000	99.999	0.001	0.815E-05
1.31	0	0.000	99.999	0.001	0.815E-05
1.35	1	0.000	100.000	0.000	0.408E-05
1.39	0	0.000	100.000	0.000	0.408E-05
1.44	0	0.000	100.000	0.000	0.408E-05
1.48	0	0.000	100.000	0.000	0.408E-05

Retention/Detention Facility – Lake Ballinger Subbasin

Type of Facility:	Detention Pond	
Side Slope:	3.00	H:1V
Pond Bottom Length:	65.00	ft
Pond Bottom Width:	65.00	ft
Pond Bottom Area:	4225.	sq. ft
Top Area at 1 ft. FB:	11449.	sq. ft
	0.263	acres
Effective Storage Depth:	6.00	ft
Stage 0 Elevation:	0.00	ft
Storage Volume:	41982.	cu. ft
	0.964	ac-ft
Riser Head:	6.00	ft
Riser Diameter:	18.00	inches
Number of orifices:	2	

Orifice #	Height (ft)	Diameter (in)	Full Head Discharge (CFS)	Pipe Diameter (in)
1	0.00	1.25	0.104	
2	3.50	1.35	0.078	4.0

Top Notch Weir: None
Outflow Rating Curve: None

Stage (ft)	Elevation (ft)	Storage (cu. ft)	Storage (ac-ft)	Discharge (cfs)	Percolation (cfs)	Surf Area (sq. ft)
0.00	0.00	0.	0.000	0.000	0.00	4225.
0.01	0.01	42.	0.001	0.005	0.00	4233.
0.03	0.03	127.	0.003	0.007	0.00	4248.
0.04	0.04	170.	0.004	0.008	0.00	4256.
0.05	0.05	212.	0.005	0.010	0.00	4264.
0.07	0.07	298.	0.007	0.011	0.00	4280.
0.08	0.08	341.	0.008	0.012	0.00	4288.
0.09	0.09	383.	0.009	0.013	0.00	4295.
0.10	0.10	426.	0.010	0.014	0.00	4303.
0.20	0.20	861.	0.020	0.019	0.00	4382.
0.30	0.30	1303.	0.030	0.023	0.00	4462.
0.40	0.40	1753.	0.040	0.027	0.00	4543.
0.50	0.50	2212.	0.051	0.030	0.00	4624.
0.60	0.60	2678.	0.061	0.033	0.00	4706.
0.70	0.70	3153.	0.072	0.036	0.00	4789.
0.80	0.80	3636.	0.083	0.038	0.00	4872.
0.90	0.90	4127.	0.095	0.040	0.00	4956.
1.00	1.00	4627.	0.106	0.042	0.00	5041.
1.10	1.10	5135.	0.118	0.045	0.00	5127.
1.20	1.20	5652.	0.130	0.047	0.00	5213.
1.30	1.30	6178.	0.142	0.048	0.00	5300.
1.40	1.40	6712.	0.154	0.050	0.00	5388.
1.50	1.50	7256.	0.167	0.052	0.00	5476.
1.60	1.60	7808.	0.179	0.054	0.00	5565.
1.70	1.70	8369.	0.192	0.055	0.00	5655.
1.80	1.80	8939.	0.205	0.057	0.00	5746.
1.90	1.90	9518.	0.218	0.058	0.00	5837.
2.00	2.00	10106.	0.232	0.060	0.00	5929.
2.10	2.10	10704.	0.246	0.061	0.00	6022.
2.20	2.20	11310.	0.260	0.063	0.00	6115.
2.30	2.30	11927.	0.274	0.064	0.00	6209.
2.40	2.40	12552.	0.288	0.066	0.00	6304.
2.50	2.50	13188.	0.303	0.067	0.00	6400.
2.60	2.60	13832.	0.318	0.068	0.00	6496.

2.70	2.70	14487.	0.333	0.070	0.00	6593.
2.80	2.80	15151.	0.348	0.071	0.00	6691.
2.90	2.90	15825.	0.363	0.072	0.00	6790.
3.00	3.00	16509.	0.379	0.073	0.00	6889.
3.10	3.10	17203.	0.395	0.075	0.00	6989.
3.20	3.20	17907.	0.411	0.076	0.00	7090.
3.30	3.30	18621.	0.427	0.077	0.00	7191.
3.40	3.40	19345.	0.444	0.078	0.00	7293.
3.50	3.50	20080.	0.461	0.079	0.00	7396.
3.51	3.51	20154.	0.463	0.080	0.00	7406.
3.53	3.53	20302.	0.466	0.081	0.00	7427.
3.54	3.54	20376.	0.468	0.083	0.00	7437.
3.56	3.56	20525.	0.471	0.086	0.00	7458.
3.57	3.57	20600.	0.473	0.089	0.00	7468.
3.58	3.58	20674.	0.475	0.094	0.00	7479.
3.60	3.60	20824.	0.478	0.096	0.00	7500.
3.61	3.61	20899.	0.480	0.097	0.00	7510.
3.63	3.63	21050.	0.483	0.098	0.00	7531.
3.73	3.73	21808.	0.501	0.105	0.00	7635.
3.83	3.83	22577.	0.518	0.111	0.00	7740.
3.93	3.93	23356.	0.536	0.116	0.00	7846.
4.03	4.03	24146.	0.554	0.121	0.00	7953.
4.13	4.13	24947.	0.573	0.125	0.00	8060.
4.23	4.23	25758.	0.591	0.129	0.00	8169.
4.33	4.33	26581.	0.610	0.133	0.00	8277.
4.43	4.43	27414.	0.629	0.137	0.00	8387.
4.53	4.53	28258.	0.649	0.140	0.00	8497.
4.63	4.63	29113.	0.668	0.144	0.00	8608.
4.73	4.73	29980.	0.688	0.147	0.00	8720.
4.83	4.83	30857.	0.708	0.150	0.00	8832.
4.93	4.93	31746.	0.729	0.153	0.00	8945.
5.03	5.03	32646.	0.749	0.156	0.00	9059.
5.13	5.13	33558.	0.770	0.159	0.00	9174.
5.23	5.23	34481.	0.792	0.162	0.00	9289.
5.33	5.33	35416.	0.813	0.165	0.00	9405.
5.43	5.43	36362.	0.835	0.167	0.00	9522.
5.53	5.53	37320.	0.857	0.170	0.00	9639.
5.63	5.63	38290.	0.879	0.173	0.00	9757.
5.73	5.73	39272.	0.902	0.175	0.00	9876.
5.83	5.83	40265.	0.924	0.178	0.00	9996.
5.93	5.93	41271.	0.947	0.180	0.00	10116.
6.00	6.00	41982.	0.964	0.182	0.00	10201.
6.10	6.10	43008.	0.987	0.646	0.00	10323.
6.20	6.20	44047.	1.011	1.490	0.00	10445.
6.30	6.30	45097.	1.035	2.590	0.00	10568.
6.40	6.40	46160.	1.060	3.890	0.00	10692.
6.50	6.50	47236.	1.084	5.360	0.00	10816.
6.60	6.60	48323.	1.109	6.790	0.00	10941.
6.70	6.70	49424.	1.135	7.320	0.00	11067.
6.80	6.80	50537.	1.160	7.810	0.00	11194.
6.90	6.90	51663.	1.186	8.280	0.00	11321.
7.00	7.00	52801.	1.212	8.710	0.00	11449.
7.10	7.10	53952.	1.239	9.130	0.00	11578.
7.20	7.20	55117.	1.265	9.530	0.00	11707.
7.30	7.30	56294.	1.292	9.910	0.00	11837.
7.40	7.40	57484.	1.320	10.280	0.00	11968.
7.50	7.50	58688.	1.347	10.640	0.00	12100.
7.60	7.60	59904.	1.375	10.980	0.00	12232.
7.70	7.70	61134.	1.403	11.310	0.00	12365.
7.80	7.80	62377.	1.432	11.640	0.00	12499.
7.90	7.90	63634.	1.461	11.950	0.00	12634.

Hyd Inflow Outflow Peak Storage
Target Calc Stage Elev (Cu-Ft) (Ac-Ft)

1	3.63	*******	0.25	6.01	6.01	42134.	0.967
2	1.24	0.44	0.16	5.31	5.31	35214.	0.808
3	0.94	*******	0.15	4.86	4.86	31098.	0.714
4	1.03	*******	0.18	5.79	5.79	39883.	0.916
5	1.22	*******	0.14	4.55	4.55	28443.	0.653
6	0.88	*******	0.11	3.86	3.86	22799.	0.523
7	0.94	*******	0.08	3.11	3.11	17243.	0.396
8	1.14	*******	0.07	3.07	3.07	16962.	0.389

Route Time Series through Facility
Inflow Time Series File:ballinger-develop.tsf
Outflow Time Series File:Ballinger-rdout

Inflow/Outflow Analysis
Peak Inflow Discharge: 3.63 CFS at 6:30 on Jan 9 in Year 8
Peak Outflow Discharge: 0.251 CFS at 12:00 on Jan 9 in Year 8
Peak Reservoir Stage: 6.01 Ft
Peak Reservoir Elev: 6.01 Ft
Peak Reservoir Storage: 42134. Cu-Ft
: 0.967 Ac-Ft

Flow Duration from Time Series File:ballinger-rdout.tsf

Cutoff CFS	Count	Frequency %	CDF %	Exceedence_Probability %	
0.003	153504	62.583	62.583	37.417	0.374E+00
0.007	9209	3.754	66.338	33.662	0.337E+00
0.012	8600	3.506	69.844	30.156	0.302E+00
0.017	10056	4.100	73.944	26.056	0.261E+00
0.022	10510	4.285	78.229	21.771	0.218E+00
0.027	8538	3.481	81.709	18.291	0.183E+00
0.032	8878	3.620	85.329	14.671	0.147E+00
0.037	7340	2.992	88.322	11.678	0.117E+00
0.042	7507	3.061	91.382	8.618	0.862E-01
0.047	4258	1.736	93.118	6.882	0.688E-01
0.052	4438	1.809	94.927	5.073	0.507E-01
0.057	3182	1.297	96.225	3.775	0.378E-01
0.062	2671	1.089	97.314	2.686	0.269E-01
0.067	2217	0.904	98.218	1.782	0.178E-01
0.072	1467	0.598	98.816	1.184	0.118E-01
0.077	1152	0.470	99.285	0.715	0.715E-02
0.082	571	0.233	99.518	0.482	0.482E-02
0.087	40	0.016	99.534	0.466	0.466E-02
0.092	18	0.007	99.542	0.458	0.458E-02
0.097	40	0.016	99.558	0.442	0.442E-02
0.102	137	0.056	99.614	0.386	0.386E-02
0.106	91	0.037	99.651	0.349	0.349E-02
0.111	94	0.038	99.689	0.311	0.311E-02
0.116	77	0.031	99.721	0.279	0.279E-02
0.121	61	0.025	99.746	0.254	0.254E-02
0.126	83	0.034	99.779	0.221	0.221E-02
0.131	77	0.031	99.811	0.189	0.189E-02
0.136	93	0.038	99.849	0.151	0.151E-02
0.141	84	0.034	99.883	0.117	0.117E-02
0.146	46	0.019	99.902	0.098	0.983E-03
0.151	55	0.022	99.924	0.076	0.758E-03
0.156	53	0.022	99.946	0.054	0.542E-03
0.161	47	0.019	99.965	0.035	0.351E-03
0.166	34	0.014	99.979	0.021	0.212E-03
0.171	20	0.008	99.987	0.013	0.130E-03
0.176	24	0.010	99.997	0.003	0.326E-04

Route Time Series through Facility
  Inflow Time Series File:ballinger-develop.tsf
 Outflow Time Series File:Ballinger-rdout

Inflow/Outflow Analysis

Peak Inflow Discharge:	3.63 CFS	at 6:30 on Jan 9 in Year 8
Peak Outflow Discharge:	0.251 CFS	at 12:00 on Jan 9 in Year 8
Peak Reservoir Stage:	6.01 Ft	
Peak Reservoir Elev:	6.01 Ft	
Peak Reservoir Storage:	42134. Cu-Ft	
:	0.967 Ac-Ft	

Flow Duration from Time Series File:ballinger-rdout.tsf

Cutoff CFS	Count	Frequency %	CDF %	Exceedence_Probability %	
0.003	153504	62.583	62.583	37.417	0.374E+00
0.007	9209	3.754	66.338	33.662	0.337E+00
0.012	8600	3.506	69.844	30.156	0.302E+00
0.017	10056	4.100	73.944	26.056	0.261E+00
0.022	10510	4.285	78.229	21.771	0.218E+00
0.027	8538	3.481	81.709	18.291	0.183E+00
0.032	8878	3.620	85.329	14.671	0.147E+00
0.037	7340	2.992	88.322	11.678	0.117E+00
0.042	7507	3.061	91.382	8.618	0.862E-01
0.047	4258	1.736	93.118	6.882	0.688E-01
0.052	4438	1.809	94.927	5.073	0.507E-01
0.057	3182	1.297	96.225	3.775	0.378E-01
0.062	2671	1.089	97.314	2.686	0.269E-01
0.067	2217	0.904	98.218	1.782	0.178E-01
0.072	1467	0.598	98.816	1.184	0.118E-01
0.077	1152	0.470	99.285	0.715	0.715E-02
0.082	571	0.233	99.518	0.482	0.482E-02
0.087	40	0.016	99.534	0.466	0.466E-02
0.092	18	0.007	99.542	0.458	0.458E-02
0.097	40	0.016	99.558	0.442	0.442E-02
0.102	137	0.056	99.614	0.386	0.386E-02
0.106	91	0.037	99.651	0.349	0.349E-02
0.111	94	0.038	99.689	0.311	0.311E-02
0.116	77	0.031	99.721	0.279	0.279E-02
0.121	61	0.025	99.746	0.254	0.254E-02
0.126	83	0.034	99.779	0.221	0.221E-02
0.131	77	0.031	99.811	0.189	0.189E-02
0.136	93	0.038	99.849	0.151	0.151E-02
0.141	84	0.034	99.883	0.117	0.117E-02
0.146	46	0.019	99.902	0.098	0.983E-03
0.151	55	0.022	99.924	0.076	0.758E-03
0.156	53	0.022	99.946	0.054	0.542E-03
0.161	47	0.019	99.965	0.035	0.351E-03
0.166	34	0.014	99.979	0.021	0.212E-03
0.171	20	0.008	99.987	0.013	0.130E-03
0.176	24	0.010	99.997	0.003	0.326E-04

Maximum negative excursion = -0.374 cfs (84.9%)
occurring at 0.440 cfs on the Base Data:ballinger-predevel.tsf
and at 0.814 cfs on the New Data:echo-rdout.tsf
Duration Comparison Anaylsis
   Base File: ballinger-predevel.tsf
    New File: ballinger-rdout.tsf
Cutoff Units: Discharge in CFS

	-----Fraction of Time-----			---------Check of Tolerance-------			
Cutoff	Base	New	%Change	Probability	Base	New	%Change
0.086	0.53E-02	0.47E-02	-12.1	0.53E-02	0.086	0.079	-8.1

0.124	0.19E-02	0.23E-02	21.7	0.19E-02	0.124	0.131	5.7
0.163	0.82E-03	0.31E-03	-62.7	0.82E-03	0.163	0.150	-7.7
0.201	0.23E-03	0.00E+00	-100.0	0.23E-03	0.201	0.165	-17.8
0.239	0.29E-04	0.00E+00	-100.0	0.29E-04	0.239	0.176	-26.4
0.278	0.82E-05	0.00E+00	-100.0	0.82E-05	0.278	0.177	-36.4
0.316	0.41E-05	0.00E+00	-100.0	0.41E-05	0.316	0.177	-44.1
0.354	0.41E-05	0.00E+00	-100.0	0.41E-05	0.354	0.177	-50.1
0.393	0.41E-05	0.00E+00	-100.0	0.41E-05	0.393	0.177	-55.0
0.431	0.41E-05	0.00E+00	-100.0	0.41E-05	0.431	0.177	-59.0

Maximum positive excursion = 0.008 cfs (6.8%)
occurring at 0.113 cfs on the Base Data:ballinger-predevel.tsf
and at 0.121 cfs on the New Data:ballinger-rdout.tsf

Maximum negative excursion = 0.264 cfs (-59.9%)
occurring at 0.441 cfs on the Base Data:ballinger-predevel.tsf
and at 0.177 cfs on the New Data:ballinger-rdout.tsf

Retention/Detention Facility – Lake Ballinger

Type of Facility: Detention Pipe
Tank Diameter: 10.00 ft
Tank Length: 540.00 ft
Effective Storage Depth: 9.00 ft
Stage 0 Elevation: 100.00 ft
Storage Volume: 40204. cu. ft
Riser Head: 9.00 ft
Riser Diameter: 18.00 inches
Number of orifices: 2

Orifice #	Height (ft)	Diameter (in)	Full Head Discharge (CFS)	Pipe Diameter (in)
1	0.00	1.20	0.117	
2	4.25	1.00	0.059	4.0

Top Notch Weir: None
Outflow Rating Curve: None

Stage (ft)	Elevation (ft)	Storage (cu. ft)	Storage (ac-ft)	Discharge (cfs)	Percolation (cfs)
0.00	100.00	0.	0.000	0.000	0.00
0.01	100.01	33.	0.001	0.004	0.00
0.03	100.03	98.	0.002	0.006	0.00
0.04	100.04	131.	0.003	0.008	0.00
0.05	100.05	164.	0.004	0.009	0.00
0.06	100.06	197.	0.005	0.010	0.00
0.08	100.08	264.	0.006	0.011	0.00
0.09	100.09	297.	0.007	0.012	0.00
0.10	100.10	331.	0.008	0.012	0.00
0.25	100.25	853.	0.020	0.020	0.00
0.41	100.41	1439.	0.033	0.025	0.00
0.56	100.56	2015.	0.046	0.029	0.00
0.71	100.71	2614.	0.060	0.033	0.00
0.86	100.86	3235.	0.074	0.036	0.00
1.02	101.02	3918.	0.090	0.039	0.00
1.17	101.17	4577.	0.105	0.042	0.00
1.32	101.32	5253.	0.121	0.045	0.00
1.47	101.47	5944.	0.136	0.047	0.00
1.63	101.63	6697.	0.154	0.050	0.00
1.78	101.78	7417.	0.170	0.052	0.00
1.93	101.93	8149.	0.187	0.054	0.00
2.08	102.08	8891.	0.204	0.056	0.00
2.24	102.24	9695.	0.223	0.058	0.00
2.39	102.39	10457.	0.240	0.060	0.00
2.54	102.54	11228.	0.258	0.062	0.00
2.69	102.69	12006.	0.276	0.064	0.00
2.85	102.85	12844.	0.295	0.066	0.00
3.00	103.00	13635.	0.313	0.068	0.00
3.15	103.15	14431.	0.331	0.069	0.00
3.30	103.30	15231.	0.350	0.071	0.00
3.46	103.46	16088.	0.369	0.073	0.00
3.61	103.61	16895.	0.388	0.074	0.00
3.76	103.76	17703.	0.406	0.076	0.00
3.91	103.91	18513.	0.425	0.077	0.00
4.07	104.07	19376.	0.445	0.079	0.00
4.22	104.22	20186.	0.463	0.080	0.00
4.25	104.25	20348.	0.467	0.081	0.00
4.26	104.26	20402.	0.468	0.081	0.00
4.27	104.27	20456.	0.470	0.082	0.00

4.28	104.28	20510.	0.471	0.083	0.00
4.29	104.29	20564.	0.472	0.084	0.00
4.30	104.30	20618.	0.473	0.086	0.00
4.31	104.31	20671.	0.475	0.088	0.00
4.32	104.32	20725.	0.476	0.089	0.00
4.33	104.33	20779.	0.477	0.089	0.00
4.34	104.34	20833.	0.478	0.090	0.00
4.50	104.50	21694.	0.498	0.096	0.00
4.65	104.65	22499.	0.516	0.101	0.00
4.80	104.80	23300.	0.535	0.106	0.00
4.95	104.95	24097.	0.553	0.110	0.00
5.11	105.11	24943.	0.573	0.113	0.00
5.26	105.26	25730.	0.591	0.117	0.00
5.41	105.41	26510.	0.609	0.120	0.00
5.56	105.56	27284.	0.626	0.123	0.00
5.72	105.72	28100.	0.645	0.126	0.00
5.87	105.87	28856.	0.662	0.129	0.00
6.02	106.02	29602.	0.680	0.132	0.00
6.17	106.17	30337.	0.696	0.135	0.00
6.33	106.33	31109.	0.714	0.137	0.00
6.48	106.48	31819.	0.730	0.140	0.00
6.63	106.63	32515.	0.746	0.142	0.00
6.78	106.78	33196.	0.762	0.145	0.00
6.94	106.94	33905.	0.778	0.147	0.00
7.09	107.09	34551.	0.793	0.150	0.00
7.24	107.24	35178.	0.808	0.152	0.00
7.39	107.39	35785.	0.821	0.154	0.00
7.55	107.55	36406.	0.836	0.157	0.00
7.70	107.70	36964.	0.849	0.159	0.00
7.85	107.85	37495.	0.861	0.161	0.00
8.00	108.00	37997.	0.872	0.163	0.00
8.16	108.16	38496.	0.884	0.165	0.00
8.31	108.31	38927.	0.894	0.167	0.00
8.46	108.46	39316.	0.903	0.169	0.00
8.61	108.61	39656.	0.910	0.171	0.00
8.77	108.77	39955.	0.917	0.173	0.00
8.92	108.92	40153.	0.922	0.175	0.00
9.00	109.00	40204.	0.923	0.176	0.00
9.10	109.10	40204.	0.923	0.640	0.00
9.20	109.20	40204.	0.923	1.490	0.00
9.30	109.30	40204.	0.923	2.580	0.00
9.40	109.40	40204.	0.923	3.880	0.00
9.50	109.50	40204.	0.923	5.350	0.00
9.60	109.60	40204.	0.923	6.780	0.00
9.70	109.70	40204.	0.923	7.300	0.00
9.80	109.80	40204.	0.923	7.800	0.00
9.90	109.90	40204.	0.923	8.260	0.00
10.00	110.00	40204.	0.923	8.700	0.00
10.10	110.10	40204.	0.923	9.110	0.00
10.20	110.20	40204.	0.923	9.510	0.00
10.30	110.30	40204.	0.923	9.890	0.00
10.40	110.40	40204.	0.923	10.260	0.00
10.50	110.50	40204.	0.923	10.620	0.00
10.60	110.60	40204.	0.923	10.960	0.00
10.70	110.70	40205.	0.923	11.290	0.00
10.80	110.80	40205.	0.923	11.610	0.00

Hyd	Inflow	Outflow		Peak		Storage	
		Target	Calc	Stage	Elev	(Cu-Ft)	(Ac-Ft)
1	3.63	*******	0.86	9.13	109.13	40204.	0.923
2	2.73	0.44	0.13	5.87	105.87	28840.	0.662
3	1.94	*******	0.15	7.36	107.36	35650.	0.818
4	1.52	*******	0.10	4.74	104.74	22990.	0.528
5	1.42	*******	0.33	9.03	109.03	40204.	0.923

6	1.60	*******	0.14	6.39	106.39	31386.	0.721
7	0.99	*******	0.07	3.68	103.68	17267.	0.396
8	1.14	*******	0.07	3.64	103.64	17031.	0.391

Route Time Series through Facility
Inflow Time Series File:ballinger-develop.tsf
Outflow Time Series File:Ballinger-tank-rdout

Inflow/Outflow Analysis
Peak Inflow Discharge: 3.63 CFS at 6:30 on Jan 9 in Year 8
Peak Outflow Discharge: 0.858 CFS at 10:00 on Jan 9 in Year 8
Peak Reservoir Stage: 9.13 Ft
Peak Reservoir Elev: 109.13 Ft
Peak Reservoir Storage: 40204. Cu-Ft
: 0.923 Ac-Ft

Flow Duration from Time Series File:ballinger-tank-rdout.tsf

Cutoff CFS	Count	Frequency %	CDF %	Exceedence_Probability %	
0.005	157252	64.111	64.111	35.889	0.359E+00
0.014	17288	7.048	71.159	28.841	0.288E+00
0.023	16913	6.895	78.055	21.945	0.219E+00
0.032	16540	6.743	84.798	15.202	0.152E+00
0.041	14512	5.917	90.715	9.285	0.929E-01
0.050	8843	3.605	94.320	5.680	0.568E-01
0.059	6248	2.547	96.867	3.133	0.313E-01
0.068	3671	1.497	98.364	1.636	0.164E-01
0.078	2237	0.912	99.276	0.724	0.724E-02
0.087	523	0.213	99.489	0.511	0.511E-02
0.096	250	0.102	99.591	0.409	0.409E-02
0.105	206	0.084	99.675	0.325	0.325E-02
0.114	183	0.075	99.750	0.250	0.250E-02
0.123	171	0.070	99.819	0.181	0.181E-02
0.132	171	0.070	99.889	0.111	0.111E-02
0.141	99	0.040	99.929	0.071	0.705E-03
0.150	86	0.035	99.965	0.035	0.355E-03
0.159	42	0.017	99.982	0.018	0.183E-03
0.169	28	0.011	99.993	0.007	0.693E-04
0.178	13	0.005	99.998	0.002	0.163E-04
0.187	0	0.000	99.998	0.002	0.163E-04
0.196	0	0.000	99.998	0.002	0.163E-04
0.205	0	0.000	99.998	0.002	0.163E-04
0.214	0	0.000	99.998	0.002	0.163E-04
0.223	0	0.000	99.998	0.002	0.163E-04
0.232	1	0.000	99.999	0.001	0.122E-04
0.241	0	0.000	99.999	0.001	0.122E-04
0.251	0	0.000	99.999	0.001	0.122E-04
0.260	0	0.000	99.999	0.001	0.122E-04
0.269	1	0.000	99.999	0.001	0.815E-05
0.278	0	0.000	99.999	0.001	0.815E-05
0.287	1	0.000	100.000	0.000	0.408E-05
0.296	0	0.000	100.000	0.000	0.408E-05
0.305	0	0.000	100.000	0.000	0.408E-05
0.314	0	0.000	100.000	0.000	0.408E-05
0.323	0	0.000	100.000	0.000	0.408E-05

Western Washington Hydrology Model
PROJECT REPORT

Project Name: Planter Box Flow Control Sizing (Stormwater Targets-2005 KCSWDM)

Site Address:
City :
Report Date : 8/18/2007
Gage : Seatac
Data Start : 1948/10/01
Data End : 1998/09/30
Precip Scale: 0.83

PREDEVELOPED LAND USE – Historic Conditions as defined by the City

Name : Typical 55 by 100 basin (5500 SF,
Bypass: No

GroundWater: No

Pervious Land Use	Acres
C, Forest, Flat	0.0945
C, Lawn, Flat	0.0189

Impervious Land Use	Acres
ROADS FLAT	0.0126

Element Flows To:

Surface	Interflow	Groundwater

Name : Basin 1
Bypass: No

GroundWater: No

Pervious Land Use	Acres
C, Lawn, Flat	0.009

Impervious Land Use	Acres
ROADS FLAT	0.117

Element Flows To:

Surface	Interflow	Groundwater
Sand Filter 1,		

Name : Sand Filter 1
Bottom Length: 50ft.
Bottom Width : 4ft.
Depth : 4.01ft.
Side slope 1: 0 To 1
Side slope 2: 0 To 1
Side slope 3: 0 To 1
Side slope 4: 0 To 1
Filtration On
Hydraulic conductivity : 2
Depth of filter medium : 3
Discharge Structure
Riser Height: 4 ft.
Riser Diameter: 100 in.
Orifice 1 Diameter: 0.5 in. **Elevation:** 1 ft.

Element Flows To:
Outlet 1 **Outlet 2**

Planter Boxes designed 50% of the available space in the amenity zone to not historic peak flows for the 2 and 10 yr event.

ANALYSIS RESULTS

Flow Frequency Return Periods for Predeveloped. POC #1

Return Period	Flow(cfs)
2 year	0.002936
5 year	0.003823
10 year	0.004452
25 year	0.005397
50 year	0.005964
100 year	0.006664

Flow Frequency Return Periods for Mitigated. POC #1

Return Period	Flow(cfs)
2 year	0.006419
5 year	0.008173
10 year	0.008581
25 year	0.008769
50 year	0.008816
100 year	0.008835

Planter Boxes Capture Durations Flow and Meet Flow Control Requirements

POC #1

Flow(CFS)	Predev	Dev	Percentage	Pass/Fail
0.0015	869	6	0.0	Pass
0.0015	790	6	0.0	Pass
0.0016	713	6	0.0	Pass
0.0016	655	6	0.0	Pass
0.0017	601	6	0.0	Pass

0.0017	542	6	1.0	Pass
0.0017	483	6	1.0	Pass
0.0018	447	6	1.0	Pass
0.0018	402	6	1.0	Pass
0.0019	375	6	1.0	Pass
0.0019	346	6	1.0	Pass
0.0020	314	5	1.0	Pass
0.0020	294	5	1.0	Pass
0.0021	268	5	1.0	Pass
0.0021	242	5	2.0	Pass
0.0022	220	5	2.0	Pass
0.0022	200	5	2.0	Pass
0.0022	188	5	2.0	Pass
0.0023	174	5	2.0	Pass
0.0023	164	5	3.0	Pass
0.0024	152	5	3.0	Pass
0.0024	144	5	3.0	Pass
0.0025	133	4	3.0	Pass
0.0025	124	4	3.0	Pass
0.0026	118	4	3.0	Pass
0.0026	109	4	3.0	Pass
0.0027	104	4	3.0	Pass
0.0027	95	4	4.0	Pass
0.0027	89	3	3.0	Pass
0.0028	81	3	3.0	Pass
0.0028	75	3	4.0	Pass
0.0029	71	3	4.0	Pass
0.0029	64	3	4.0	Pass
0.0030	56	3	5.0	Pass
0.0030	54	3	5.0	Pass
0.0031	54	3	5.0	Pass
0.0031	51	3	5.0	Pass
0.0032	49	3	6.0	Pass
0.0032	47	3	6.0	Pass
0.0032	43	2	4.0	Pass
0.0033	38	2	5.0	Pass
0.0033	37	2	5.0	Pass
0.0034	36	2	5.0	Pass
0.0034	31	2	6.0	Pass
0.0035	30	2	6.0	Pass
0.0035	28	2	7.0	Pass
0.0036	26	2	7.0	Pass
0.0036	25	2	8.0	Pass
0.0037	23	2	8.0	Pass
0.0037	20	2	10.0	Pass
0.0037	18	2	11.0	Pass
0.0038	15	2	13.0	Pass
0.0038	14	2	14.0	Pass
0.0039	14	2	14.0	Pass
0.0039	14	2	14.0	Pass
0.0040	12	2	16.0	Pass
0.0040	12	1	8.0	Pass
0.0041	12	1	8.0	Pass
0.0041	12	1	8.0	Pass
0.0042	11	0	0.0	Pass
0.0042	10	0	0.0	Pass
0.0042	10	0	0.0	Pass

0.0043	10	0	0.0	Pass
0.0043	10	0	0.0	Pass
0.0044	10	0	0.0	Pass
0.0044	10	0	0.0	Pass
0.0045	9	0	0.0	Pass
0.0045	9	0	0.0	Pass
0.0046	9	0	0.0	Pass
0.0046	9	0	0.0	Pass
0.0047	8	0	0.0	Pass
0.0047	7	0	0.0	Pass
0.0048	7	0	0.0	Pass
0.0048	7	0	0.0	Pass
0.0048	7	0	0.0	Pass
0.0049	7	0	0.0	Pass
0.0049	7	0	0.0	Pass
0.0050	7	0	0.0	Pass
0.0050	5	0	0.0	Pass
0.0051	5	0	0.0	Pass
0.0051	5	0	0.0	Pass
0.0052	5	0	0.0	Pass
0.0052	5	0	0.0	Pass
0.0053	5	0	0.0	Pass
0.0053	5	0	0.0	Pass
0.0053	5	0	0.0	Pass
0.0054	5	0	0.0	Pass
0.0054	5	0	0.0	Pass
0.0055	5	0	0.0	Pass
0.0055	5	0	0.0	Pass
0.0056	5	0	0.0	Pass
0.0056	5	0	0.0	Pass
0.0057	5	0	0.0	Pass
0.0057	4	0	0.0	Pass
0.0058	4	0	0.0	Pass
0.0058	3	0	0.0	Pass
0.0058	3	0	0.0	Pass
0.0059	3	0	0.0	Pass
0.0059	3	0	0.0	Pass
0.0060	3	0	0.0	Pass

Water Quality BMP Flow and Volume for POC 1.
On-line facility volume: 0.001 acre-feet
On-line facility target flow: 0.01 **cfs.**
Adjusted for 15 min: 0.0144 **cfs.**
Off-line facility target flow: 0.0048 **cfs.**
Adjusted for 15 min: 0.0054 **cfs.**

APPENDIX D

Water Quality Sizing and Modeling

Water Quality Appendix D

Appendix D Table of Contents

Basic Water Quality Facility Sizing

According to the 1998 and 2005 KCSWDM, the goal of the water quality design flow is to treat 95-percent of the average annual runoff volume. KCSWDM uses single event SBUH modeling to estimate the Water Quality Design Flow by calculating 64-percent of the two-year, 24-hour precipitation. Results from the SBUH model were compared to Ecology continuous model results to create a range of water quality sizing volumes.

Although the 1998 and 2005 KCSWDM use SBUH to calculate water quality design flow, Shoreline requested a comparison of SBUH results with Western Washington Hydrology Model (WWHM) results. Using WWHM, water quality facilities can be sized two ways. One way is to match the volume require to capture 95-percent of the total volume from 1948-1998 rainfall events. The other method is to size a facility to filter at least 95-percent total runoff volume from 1948-1998. In general, both methods, using WWHM, provide similar results.

For both the WWMH and the SBUH Volume Methods, the length required was calculated knowing the porosity of the soil depth, ponding depth, width and volume required.   Table 9 in the Report has a summary of the different sizing methods, calculated lengths, and dimensions of the LID element required to meet Basic Water Quality Measures as defined in 1998 and 2005 KCSWDM. In general, the soil porosity was calculated at 0.4, per the Puget Sound LID Manual. Width was constrained to four feet, the size of the amenity zone. Depth was limited to four feet and ponding depth varies from one-foot to 0.5 feet, depending on the LID feature. The length of the feature was iterated until the facility filter 95-percent of rainfall runoff volume. See the percent filter number in figures below for the volume filtered. For a description of the WWHM volume method and the SBUH Volume Method calculations, see below.

WWHM Facility Sizing Method

WWHM was used to size the water quality elements for the typical water quality catchment area (4,300 SF, 0.1 acres). The typical catchment area for bioretention swales in the median was the whole roadway width (8600 SF, 0.2 Acres), assuming that the whole road is reverse-crowned. The sand filter option was modified to closely resemble the proposed stormwater planter boxes, tree box filters, and bioretention swales by adjusting the depth, orifice size, orifice height, and hydraulic conductivity. Width and depth of the proposed planter box and tree box filters are confined to fit in the amenity zone. The length was modified until the facility filtered or captured water quality design flow, or 95-percent total runoff volume. A perforated under drain was assumed to have a diameter of 0.5 inches and located one-foot from the bottom of the facility. For example, Figure 1 shows that 10 linear feet of stormwater planter boxes along the amenity zone capture and filter 95-percent of the total runoff volume.

WWHM WQ Volume Method

WWHM calculates the water quality volume required to capture 95-percent of the average annual volume over the years 1948-1998. Using the calculated water quality volume, LID features were sized to capture this volume using dimensions described above in Water Quality Sizing.

SBUH WQ Volume Method

KCSWDM uses single event SBUH model to estimate the Water Quality Design Flow by calculating 64-percent of the two-year, 24-hour precipitation. Using the calculated water quality volume, LID features were sized to capture this volume using dimensions described above in Water Quality Sizing.

Conventional Stormfilters

Contech estimated the number of stormfilter cartridges need to provide basic water quality, given the pervious and impervious areas provided by SvR for each sub-basin.

Enhance Basic and Lake Sensitive Water Quality

LID features alone according to both the 1998 KCSWDM and the 2005 KCSWDM do not meet requirements for Enhance Basin or Lake Sensitive Water Quality Treatment. However, LID features coupled with a stormfilter or sand filter vault meet the requirements.

WWHM Facility Sizing Method

Water Quality Current Requirements – 1998 KCSWDM

To create a baseline for sizing water quality, a typical catchment area was assumed to be 24 feet wide (half of the pollution-generating-impervious-surface – 40-foot concrete slab) by 100 feet long about 0.055 acres. Pre-developed conditions were modeled as 100-percent road (impervious), 0.055 acres and mitigated was modeled as 100-percent road, 0.055 acres.

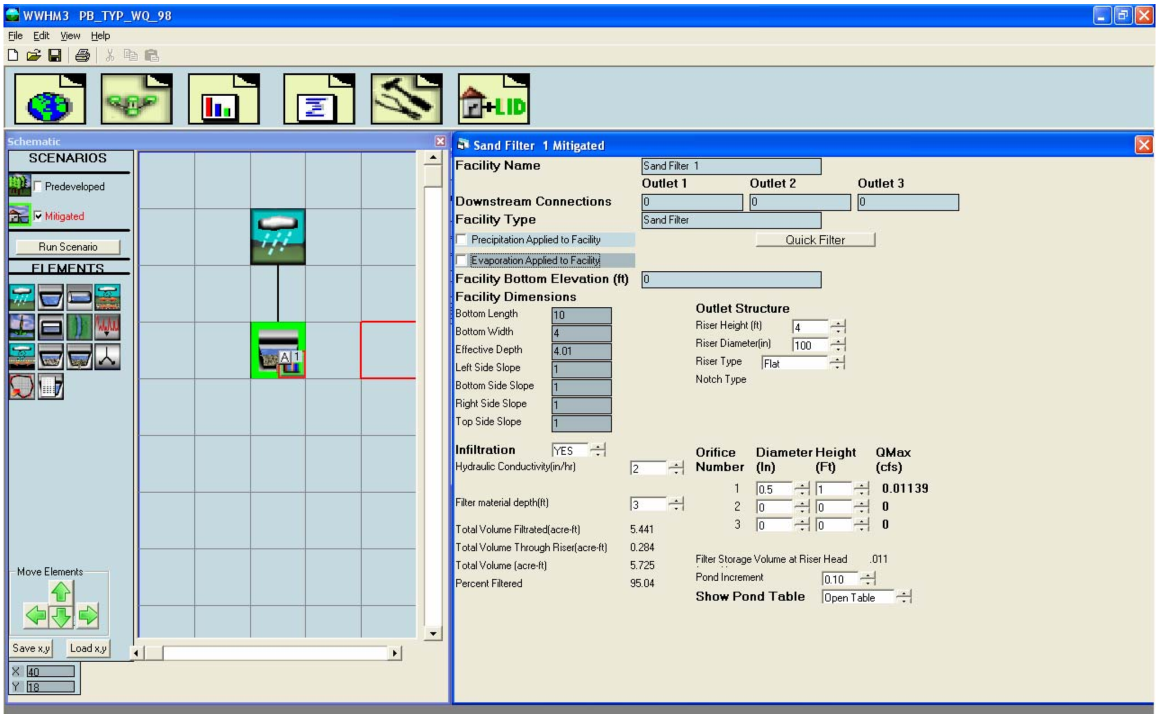


Figure 1: Current Requirement Water Quality Sizing if Base Course Replaced Using Planter Box in Amenity Zone, Modeled to Filter 95% of Total Volume Match Existing Conditions.

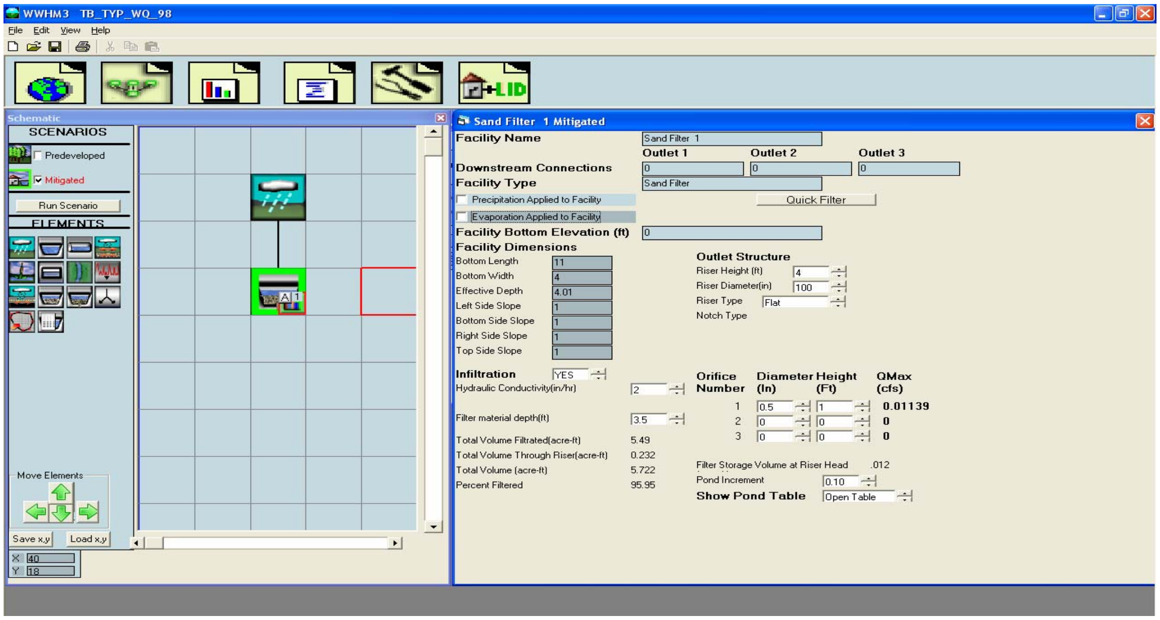


Figure 2: Current Requirement Water Quality Sizing if Base Course Replaced Using Tree Box Filter in Amenity Zone, Modeled to Filter 95% of Total Volume Match Existing Conditions.

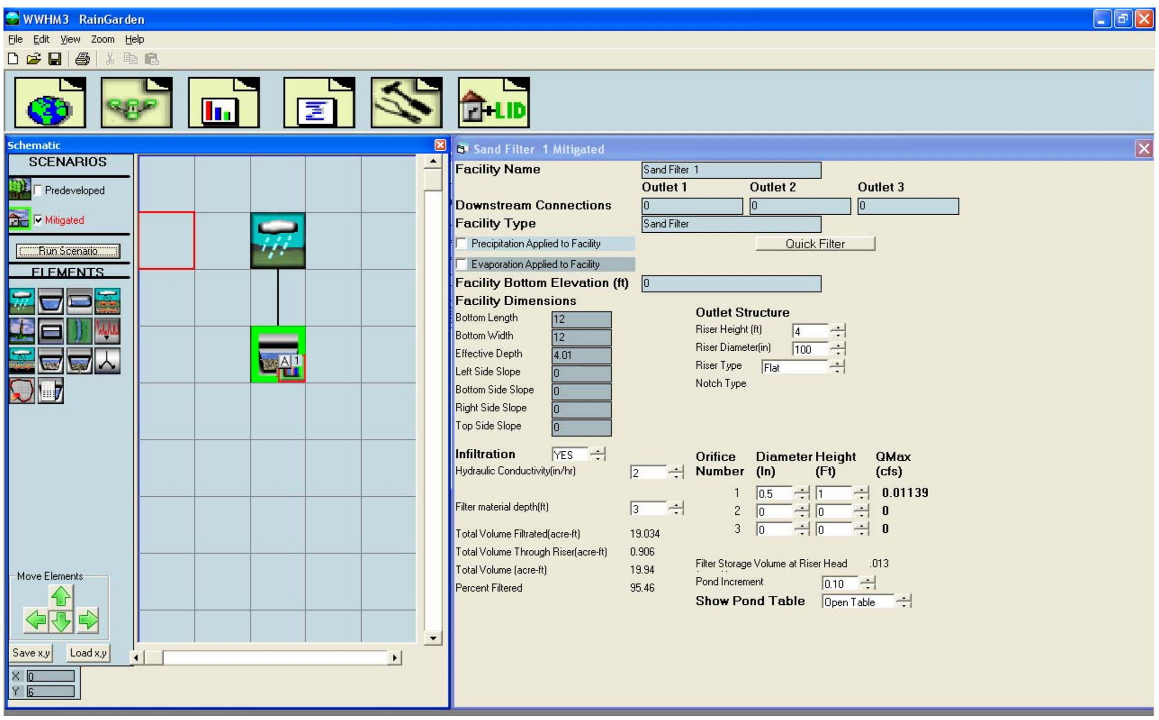


Figure 3: Current Requirement Water Quality Sizing if Base Course Replaced Using Bioretention Swale in the Median or Side Streets, Modeled to Filter 95% of Total Volume Match Existing Conditions. (Catchment area 0.2 acres whole PGIS roadway)

Target Requirements – 2005 KCSWDM

To create a baseline for sizing water quality, a typical catchment area was assumed to be 43 feet wide (half of the pollution-generating-impervious-surface, roadway width) by 100 feet long (approximately 0.1 acres). This method of sizing stormwater facilities enables Shoreline to easily scale from the typical section to a drainage basin or project area. Pre-developed conditions were modeled as Historic, i.e. 0.075 acre Forested, 0.015 acre Lawn, and 0.01 acre Road per direction from Shoreline. Mitigated conditions were modeled as 0.093 acres Road and 0.007 acres.

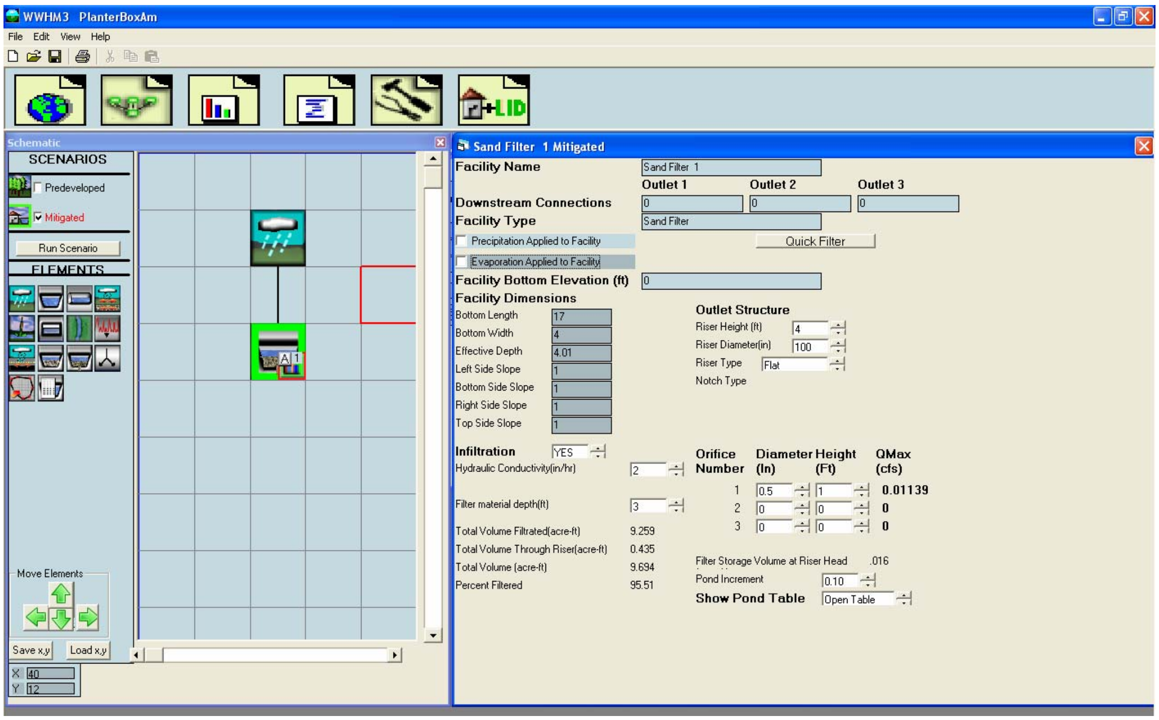


Figure 4: Target Water Quality Sizing Planter Boxes in Amenity Zone, Modeled to Filter 95% of Total Volume Match Historic Conditions.

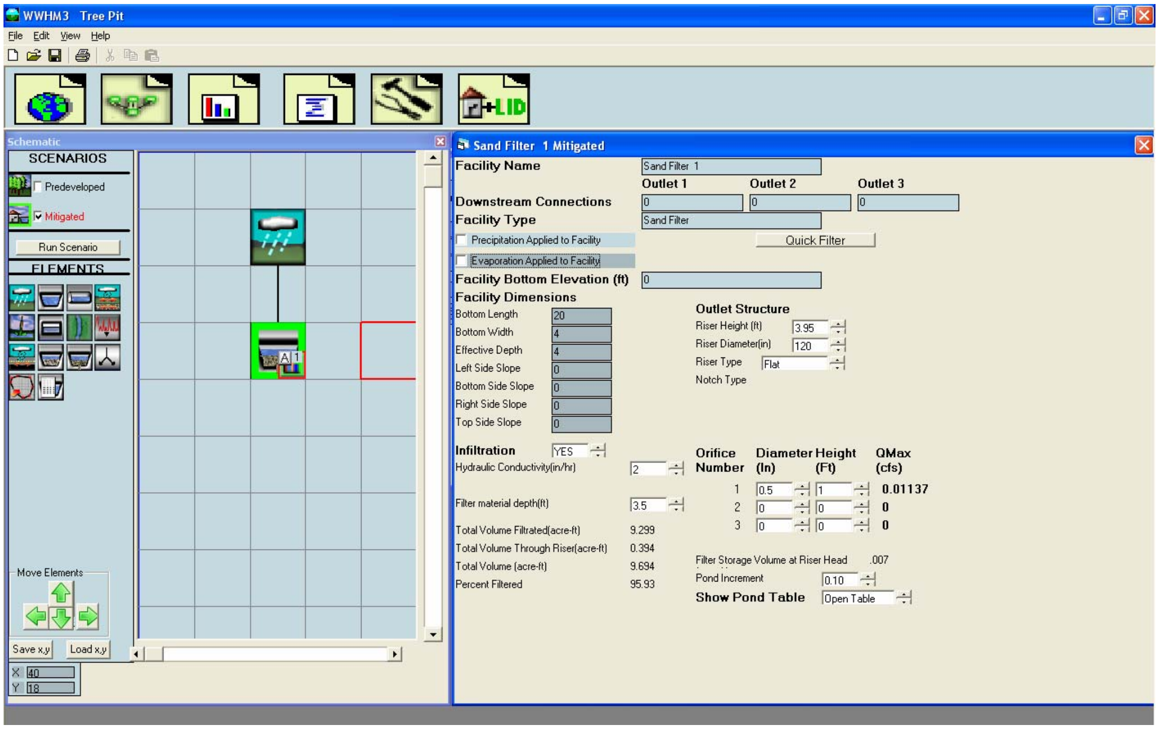


Figure 5: Target Water Quality Sizing Tree Box Filters in Amenity Zone, Modeled to Filter 95% of Total Volume Match Historic Conditions.

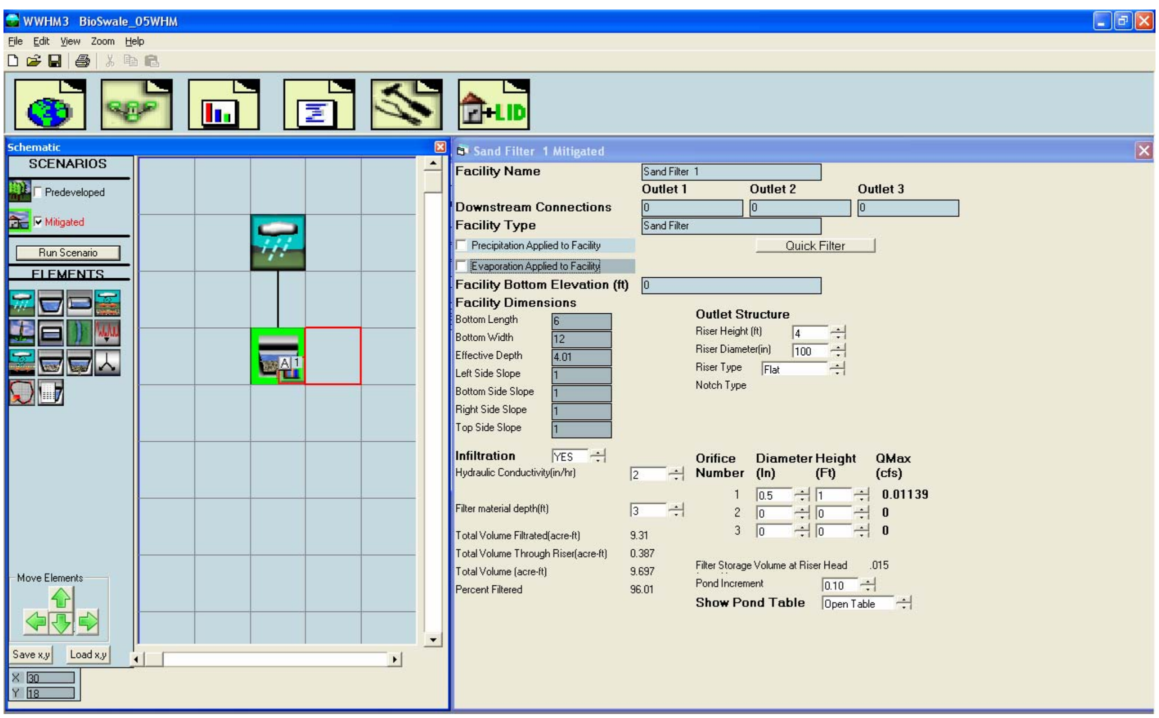


Figure 6: Target Water Quality Sizing Bioretention Swales in Median and Side Streets, Modeled to Filter 95% of Total Volume Match Historic Conditions.

WWHM Volume Method

WWHM volume method uses typical water quality catchment area (4,300SF).

Current Regulations – 1998 KCSWDM

See above description of typical catchment area for WWHM Facility modeling.

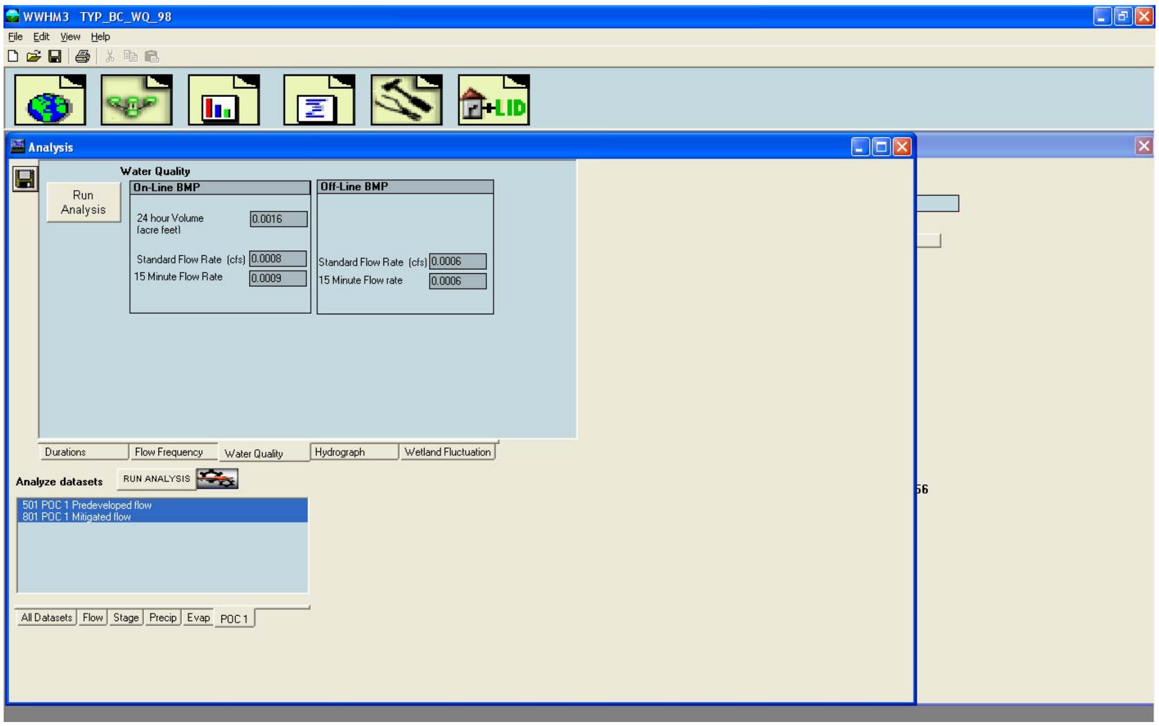


Figure 7: Typical Section of Replaced PGIS, 24 feet by 100 feet.

Converting Water Quality Volume to LID Feature Size

0.0016	Water Quality acre-feet
69.696	Water Quality Cubic Feet

Estimated Facility Size Based on WWHM Water Quality Volume (95% average annual)

9	LF Planter Box
11	LF Tree Box Filter
4	LF Bioretention Swale Median/Side Street

Target Requirements – 2005 KCSWDM

See above description of typical catchment area for WWHM Facility modeling

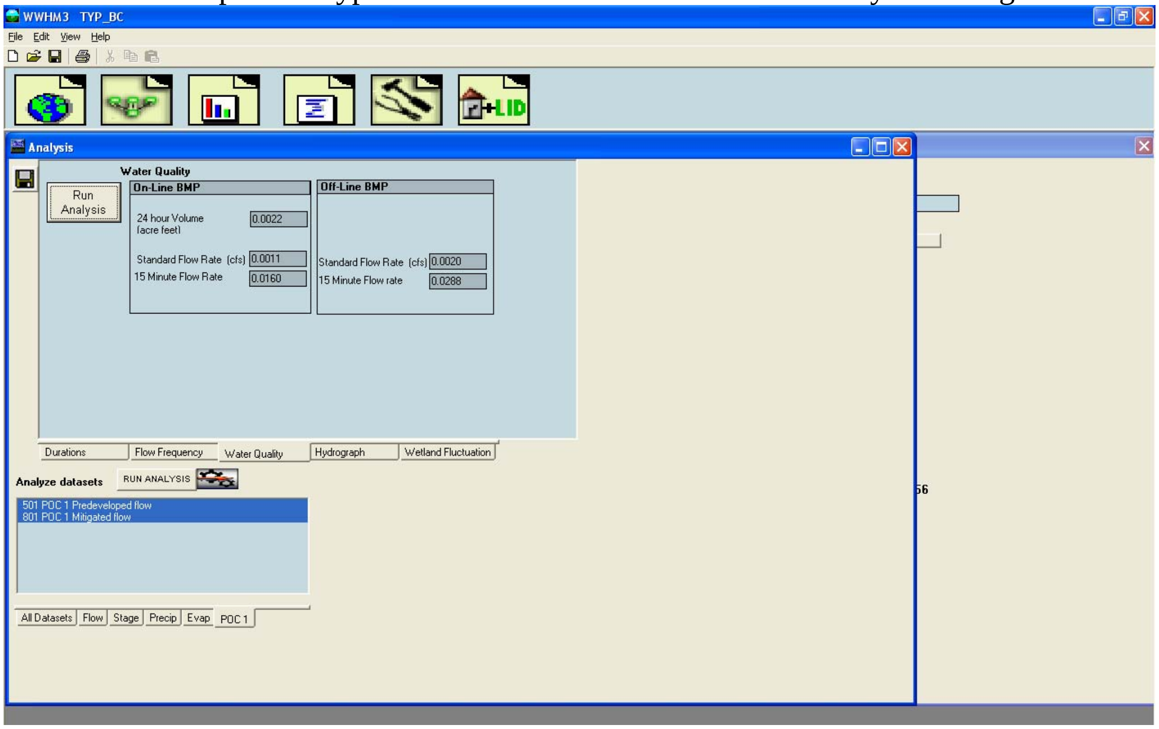


Figure 8: Typical Section of Replaced PGIS, 43 feet by 100 feet.

Converting Water Quality Volume to LID Feature Size

0.0022	acre-feet	Water Quality acre-feet
108.9	Cubic Feet	Water Quality Cubic Feet

Estimated Facility Size Based on WWHM Water Quality Volume (95% average annual)

15	LF Planter Box
18	LF Tree Box Filter
6	LF Bioretention Swale Median/Side Street

SBUH WQ Volume Method

Current Regulations – 1998 KCSWDM

See above description of typical catchment area for WWHM Facility modeling. See Spreadsheet 1 for more information on SBUH Method.

Converting Water Quality Volume to LID Feature Size

204	CF	Estimated Facility Size Based on SBUH 64% of the two-year, 24-hour precipitation

23	LF of Planter Box in Amenity Zone
27	LF of Tree Box Filter in Amenity Zone
8	LF of Bioretention Swale in Median/Side Street

Target Requirements – 2005 KCSWDM

See above description of typical catchment area for WWHM Facility modeling. See Spreadsheet 2 for more information on SBUH Method.

Converting Water Quality Volume to LID Feature Size

366	CF	Estimated Facility Size Based on SBUH 64% of the two-year, 24-hour precipitation

42	LF of Planter Box in Amenity Zone
48	LF of Tree Box Filter in Amenity Zone
14	LF of Bioretention Swale in Median/Side Street

Conventional Stormfilters

Contech estimated the number of stormfilter cartridges need to provide basic water quality given the pervious and impervious areas.

	Boeing Creek	McAleer Creek Drainage Basin (Level 2 Flow Control)		Total
		Echo Lake	Lake Ballinger	
Number of Stormfilters Cartridges for Basic Water Quality	23	92	20	138

Figure 9: Stormfilter in Pre-cast Vault (Image from Contech)

Figure 10: Stormfilters in Catch Basin Insert (Image from Contech)

Enhance Basic and Lake Sensitive Water Quality

Wetvaults were sized based on methods described in the 2005 KCSWDM Section 6.4.2.1. It is estimated using the method in the 2005 KCSWDM that a vault would need to capture 450 CF of water for a typical stormwater catchment area. (4,300 SF). It is estimated based on the numbers provided by Contech that one stormfilter will be required for a typical water quality catchment area. Stormfilter filter media can be altered to meet the requirement for Enhance Basic or Lake Sensitive Water Quality. However, stormfilters and wetvaults alone do not meet the requirement for Enhanced Basic or Lake Sensitive and must be part of a two-train system coupled together or with LID features.

SvR DESIGN COMPANY

City of Shoreline
Aurora Corridor
Planter Box Length
SvR Project No. 06052
Date: 5/18/2007
By: GP

Spreadsheet 1
Typical Water Quliaty Catchment Area - Stormwater Requirments 1998 KCSWD
Santa Barbara Urban Hydrograph Method (SBUH)
Note: SCS Type 1A or Seattle Modified

Estimated Water Quality Design Volume

Vol. (cf) =	**204**

Rainfall Distribution:	SCS Type 1A						
Storm Event	2 year	Pt =	1.83 inches	2 year		Rainfall Peak =	0.023 cfs
				2 year		Allow. Discharge	0.008 cfs
Pervious Area	0.0000 acre	CN =	86	Sp =	1.63		
Impervious Area	0.0550 acre	CN =	98	Si =	0.20		
		Tc =	10 minutes				
Total Area	0.0550 acre (2400 SF)	dt =	10 minutes	w =	0.33		

Time Increment	Time (minutes)	Rainfall Distribution 1 (fraction)	Incremental Rainfall (inches)	Accumulated Rainfall (inches)	Pervious Accumulated Runoff (inches)	Pervious Area Increment Runoff (inches)	Impervious Accumulated Runoff (inches)	Impervious Area Incr. Runoff (inches)	Total Runoff (inches)	Instant Flowrate (cfs)	Design Flowrate (cfs)	64% Design Flow rate uality Design Flow Rate
1	2	3	4	5	6	7	8	9	10	11	12.000	
0	0	0.0000	0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.000	0.000
1	10	0.0040	0.0073	0.007	0.000	0.000	0.000	0.000	0.000	0.00	0.000	0.000
2	20	0.0040	0.0073	0.015	0.000	0.000	0.000	0.000	0.000	0.00	0.000	0.000
3	30	0.0040	0.0073	0.022	0.000	0.000	0.000	0.000	0.000	0.00	0.000	0.000
4	40	0.0040	0.0073	0.029	0.000	0.000	0.000	0.000	0.000	0.00	0.000	0.000
5	50	0.0040	0.0073	0.037	0.000	0.000	0.000	0.000	0.000	0.00	0.000	0.000
6	60	0.0040	0.0073	0.044	0.000	0.000	0.000	0.000	0.000	0.00	0.000	0.000
7	70	0.0040	0.0073	0.051	0.000	0.000	0.001	0.000	0.000	0.00	0.000	0.000
8	80	0.0040	0.0073	0.059	0.000	0.000	0.001	0.001	0.001	0.00	0.000	0.000
9	90	0.0040	0.0073	0.066	0.000	0.000	0.003	0.001	0.001	0.00	0.000	0.000
10	100	0.0040	0.0073	0.073	0.000	0.000	0.004	0.002	0.002	0.00	0.000	0.000
11	110	0.0050	0.0092	0.082	0.000	0.000	0.007	0.003	0.003	0.00	0.001	0.000
12	120	0.0050	0.0092	0.092	0.000	0.000	0.010	0.003	0.003	0.00	0.001	0.001
13	130	0.0050	0.0092	0.101	0.000	0.000	0.014	0.003	0.003	0.00	0.001	0.001
14	140	0.0050	0.0092	0.110	0.000	0.000	0.017	0.004	0.004	0.00	0.001	0.001
15	150	0.0050	0.0092	0.119	0.000	0.000	0.022	0.004	0.004	0.00	0.001	0.001
16	160	0.0050	0.0092	0.128	0.000	0.000	0.026	0.005	0.005	0.00	0.001	0.001
17	170	0.0060	0.0110	0.139	0.000	0.000	0.032	0.006	0.006	0.00	0.002	0.001
18	180	0.0060	0.0110	0.150	0.000	0.000	0.038	0.006	0.006	0.00	0.002	0.001
19	190	0.0060	0.0110	0.161	0.000	0.000	0.045	0.006	0.006	0.00	0.002	0.001
20	200	0.0060	0.0110	0.172	0.000	0.000	0.051	0.007	0.007	0.00	0.002	0.001
21	210	0.0060	0.0110	0.183	0.000	0.000	0.058	0.007	0.007	0.00	0.002	0.001
22	220	0.0060	0.0110	0.194	0.000	0.000	0.066	0.007	0.007	0.00	0.002	0.001
23	230	0.0070	0.0128	0.207	0.000	0.000	0.074	0.009	0.009	0.00	0.003	0.002
24	240	0.0070	0.0128	0.220	0.000	0.000	0.083	0.009	0.009	0.00	0.003	0.002
25	250	0.0070	0.0128	0.232	0.000	0.000	0.093	0.009	0.009	0.00	0.003	0.002
26	260	0.0070	0.0128	0.245	0.000	0.000	0.102	0.010	0.010	0.00	0.003	0.002
27	270	0.0070	0.0128	0.258	0.000	0.000	0.112	0.010	0.010	0.00	0.003	0.002
28	280	0.0070	0.0128	0.271	0.000	0.000	0.122	0.010	0.010	0.00	0.003	0.002
29	290	0.0082	0.0150	0.286	0.000	0.000	0.134	0.012	0.012	0.00	0.003	0.002
30	300	0.0082	0.0150	0.301	0.000	0.000	0.146	0.012	0.012	0.00	0.004	0.002
31	310	0.0082	0.0150	0.316	0.000	0.000	0.158	0.012	0.012	0.00	0.004	0.003
32	320	0.0082	0.0150	0.331	0.000	0.000	0.170	0.012	0.012	0.00	0.004	0.003
33	330	0.0082	0.0150	0.346	0.000	0.000	0.183	0.013	0.013	0.00	0.004	0.003
34	340	0.0082	0.0150	0.361	0.001	0.000	0.195	0.013	0.013	0.00	0.004	0.003
35	350	0.0095	0.0174	0.378	0.002	0.001	0.210	0.015	0.015	0.00	0.004	0.003
36	360	0.0095	0.0174	0.396	0.003	0.001	0.225	0.015	0.015	0.00	0.005	0.003
37	370	0.0095	0.0174	0.413	0.004	0.002	0.240	0.015	0.015	0.01	0.005	0.003
38	380	0.0095	0.0174	0.430	0.006	0.002	0.256	0.015	0.015	0.01	0.005	0.003
39	390	0.0095	0.0174	0.448	0.009	0.002	0.271	0.015	0.015	0.01	0.005	0.003
40	400	0.0095	0.0174	0.465	0.011	0.002	0.287	0.015	0.015	0.01	0.005	0.003
41	410	0.0133	0.0243	0.490	0.015	0.004	0.308	0.022	0.022	0.01	0.006	0.004
42	420	0.0133	0.0243	0.514	0.020	0.005	0.330	0.022	0.022	0.01	0.007	0.004
43	430	0.0133	0.0243	0.538	0.025	0.005	0.353	0.022	0.022	0.01	0.007	0.005
44	440	0.0180	0.0329	0.571	0.032	0.008	0.383	0.030	0.030	0.01	0.008	0.005
45	450	0.0180	0.0329	0.604	0.041	0.008	0.413	0.031	0.031	0.01	0.009	0.006
46	460	0.0340	0.0622	0.666	0.059	0.018	0.472	0.058	0.058	0.02	0.013	0.008
47	**470**	**0.0540**	**0.0988**	**0.765**	**0.093**	**0.034**	**0.565**	**0.093**	**0.093**	**0.03**	**0.021**	0.014
48	480	0.0270	0.0494	0.815	0.113	0.019	0.612	0.047	0.047	0.02	0.023	0.014
49	490	0.0180	0.0329	0.847	0.127	0.014	0.644	0.032	0.032	0.01	0.016	0.010
50	500	0.0134	0.0245	0.872	0.137	0.011	0.667	0.024	0.024	0.01	0.012	0.007
51	510	0.0134	0.0245	0.897	0.148	0.011	0.691	0.024	0.024	0.01	0.009	0.006
52	520	0.0134	0.0245	0.921	0.159	0.011	0.715	0.024	0.024	0.01	0.008	0.005
53	530	0.0088	0.0161	0.937	0.167	0.008	0.730	0.016	0.016	0.01	0.007	0.005
54	540	0.0088	0.0161	0.953	0.175	0.008	0.746	0.016	0.016	0.01	0.006	0.004
55	550	0.0088	0.0161	0.969	0.182	0.008	0.761	0.016	0.016	0.01	0.005	0.003
56	560	0.0088	0.0161	0.985	0.190	0.008	0.777	0.016	0.016	0.01	0.005	0.003
57	570	0.0088	0.0161	1.002	0.198	0.008	0.792	0.016	0.016	0.01	0.005	0.003
58	580	0.0088	0.0161	1.018	0.206	0.008	0.808	0.016	0.016	0.01	0.005	0.003
59	590	0.0088	0.0161	1.034	0.215	0.008	0.824	0.016	0.016	0.01	0.005	0.003

60	600	0.0088	0.0161	1.050	0.223	0.008	0.839	0.016	0.016	0.01	0.005	0.003
61	610	0.0088	0.0161	1.066	0.231	0.008	0.855	0.016	0.016	0.01	0.005	0.003
62	620	0.0088	0.0161	1.082	0.240	0.009	0.871	0.016	0.016	0.01	0.005	0.003
63	630	0.0088	0.0161	1.098	0.249	0.009	0.886	0.016	0.016	0.01	0.005	0.003
64	640	0.0088	0.0161	1.114	0.257	0.009	0.902	0.016	0.016	0.01	0.005	0.003
65	650	0.0072	0.0132	1.127	0.265	0.007	0.915	0.013	0.013	0.00	0.005	0.003
66	660	0.0072	0.0132	1.141	0.272	0.007	0.928	0.013	0.013	0.00	0.004	0.003
67	670	0.0072	0.0132	1.154	0.279	0.007	0.941	0.013	0.013	0.00	0.004	0.003
68	680	0.0072	0.0132	1.167	0.287	0.007	0.953	0.013	0.013	0.00	0.004	0.003
69	690	0.0072	0.0132	1.180	0.294	0.007	0.966	0.013	0.013	0.00	0.004	0.003
70	700	0.0072	0.0132	1.193	0.302	0.008	0.979	0.013	0.013	0.00	0.004	0.003
71	710	0.0072	0.0132	1.207	0.309	0.008	0.992	0.013	0.013	0.00	0.004	0.003
72	720	0.0072	0.0132	1.220	0.317	0.008	1.005	0.013	0.013	0.00	0.004	0.003
73	730	0.0072	0.0132	1.233	0.325	0.008	1.018	0.013	0.013	0.00	0.004	0.003
74	740	0.0072	0.0132	1.246	0.332	0.008	1.031	0.013	0.013	0.00	0.004	0.003
75	750	0.0072	0.0132	1.259	0.340	0.008	1.044	0.013	0.013	0.00	0.004	0.003
76	760	0.0072	0.0132	1.272	0.348	0.008	1.057	0.013	0.013	0.00	0.004	0.003
77	770	0.0057	0.0104	1.283	0.354	0.006	1.067	0.010	0.010	0.00	0.004	0.003
78	780	0.0057	0.0104	1.293	0.361	0.006	1.077	0.010	0.010	0.00	0.004	0.002
79	790	0.0057	0.0104	1.304	0.367	0.006	1.087	0.010	0.010	0.00	0.003	0.002
80	800	0.0057	0.0104	1.314	0.373	0.006	1.097	0.010	0.010	0.00	0.003	0.002
81	810	0.0057	0.0104	1.325	0.380	0.006	1.108	0.010	0.010	0.00	0.003	0.002
82	820	0.0057	0.0104	1.335	0.386	0.006	1.118	0.010	0.010	0.00	0.003	0.002
83	830	0.0057	0.0104	1.345	0.393	0.006	1.128	0.010	0.010	0.00	0.003	0.002
84	840	0.0057	0.0104	1.356	0.399	0.007	1.138	0.010	0.010	0.00	0.003	0.002
85	850	0.0057	0.0104	1.366	0.406	0.007	1.149	0.010	0.010	0.00	0.003	0.002
86	860	0.0057	0.0104	1.377	0.412	0.007	1.159	0.010	0.010	0.00	0.003	0.002
87	870	0.0057	0.0104	1.387	0.419	0.007	1.169	0.010	0.010	0.00	0.003	0.002
88	880	0.0057	0.0104	1.398	0.426	0.007	1.179	0.010	0.010	0.00	0.003	0.002
89	890	0.0050	0.0092	1.407	0.431	0.006	1.188	0.009	0.009	0.00	0.003	0.002
90	900	0.0050	0.0092	1.416	0.437	0.006	1.197	0.009	0.009	0.00	0.003	0.002
91	910	0.0050	0.0092	1.425	0.443	0.006	1.206	0.009	0.009	0.00	0.003	0.002
92	920	0.0050	0.0092	1.434	0.449	0.006	1.215	0.009	0.009	0.00	0.003	0.002
93	930	0.0050	0.0092	1.443	0.455	0.006	1.224	0.009	0.009	0.00	0.003	0.002
94	940	0.0050	0.0092	1.452	0.461	0.006	1.233	0.009	0.009	0.00	0.003	0.002
95	950	0.0050	0.0092	1.462	0.467	0.006	1.242	0.009	0.009	0.00	0.003	0.002
96	960	0.0050	0.0092	1.471	0.473	0.006	1.251	0.009	0.009	0.00	0.003	0.002
97	970	0.0050	0.0092	1.480	0.479	0.006	1.260	0.009	0.009	0.00	0.003	0.002
98	980	0.0050	0.0092	1.489	0.485	0.006	1.269	0.009	0.009	0.00	0.003	0.002
99	990	0.0050	0.0092	1.498	0.491	0.006	1.278	0.009	0.009	0.00	0.003	0.002
100	1000	0.0050	0.0092	1.507	0.497	0.006	1.287	0.009	0.009	0.00	0.003	0.002
101	1010	0.0040	0.0073	1.515	0.502	0.005	1.295	0.007	0.007	0.00	0.003	0.002
102	1020	0.0040	0.0073	1.522	0.507	0.005	1.302	0.007	0.007	0.00	0.003	0.002
103	1030	0.0040	0.0073	1.529	0.512	0.005	1.309	0.007	0.007	0.00	0.002	0.002
104	1040	0.0040	0.0073	1.537	0.517	0.005	1.316	0.007	0.007	0.00	0.002	0.002
105	1050	0.0040	0.0073	1.544	0.522	0.005	1.323	0.007	0.007	0.00	0.002	0.002
106	1060	0.0040	0.0073	1.551	0.526	0.005	1.331	0.007	0.007	0.00	0.002	0.002
107	1070	0.0040	0.0073	1.559	0.531	0.005	1.338	0.007	0.007	0.00	0.002	0.002
108	1080	0.0040	0.0073	1.566	0.536	0.005	1.345	0.007	0.007	0.00	0.002	0.002
109	1090	0.0040	0.0073	1.573	0.541	0.005	1.352	0.007	0.007	0.00	0.002	0.002
110	1100	0.0040	0.0073	1.581	0.546	0.005	1.360	0.007	0.007	0.00	0.002	0.002
111	1110	0.0040	0.0073	1.588	0.551	0.005	1.367	0.007	0.007	0.00	0.002	0.002
112	1120	0.0040	0.0073	1.595	0.556	0.005	1.374	0.007	0.007	0.00	0.002	0.002
113	1130	0.0040	0.0073	1.603	0.561	0.005	1.381	0.007	0.007	0.00	0.002	0.002
114	1140	0.0040	0.0073	1.610	0.566	0.005	1.388	0.007	0.007	0.00	0.002	0.002
115	1150	0.0040	0.0073	1.617	0.571	0.005	1.396	0.007	0.007	0.00	0.002	0.002
116	1160	0.0040	0.0073	1.624	0.576	0.005	1.403	0.007	0.007	0.00	0.002	0.002
117	1170	0.0040	0.0073	1.632	0.582	0.005	1.410	0.007	0.007	0.00	0.002	0.002
118	1180	0.0040	0.0073	1.639	0.587	0.005	1.417	0.007	0.007	0.00	0.002	0.002
119	1190	0.0040	0.0073	1.646	0.592	0.005	1.425	0.007	0.007	0.00	0.002	0.002
120	1200	0.0040	0.0073	1.654	0.597	0.005	1.432	0.007	0.007	0.00	0.002	0.002
121	1210	0.0040	0.0073	1.661	0.602	0.005	1.439	0.007	0.007	0.00	0.002	0.002
122	1220	0.0040	0.0073	1.668	0.607	0.005	1.446	0.007	0.007	0.00	0.002	0.002
123	1230	0.0040	0.0073	1.676	0.612	0.005	1.453	0.007	0.007	0.00	0.002	0.002
124	1240	0.0040	0.0073	1.683	0.617	0.005	1.461	0.007	0.007	0.00	0.002	0.002
125	1250	0.0040	0.0073	1.690	0.622	0.005	1.468	0.007	0.007	0.00	0.002	0.002
126	1260	0.0040	0.0073	1.698	0.628	0.005	1.475	0.007	0.007	0.00	0.002	0.002
127	1270	0.0040	0.0073	1.705	0.633	0.005	1.482	0.007	0.007	0.00	0.002	0.002
128	1280	0.0040	0.0073	1.712	0.638	0.005	1.490	0.007	0.007	0.00	0.002	0.002
129	1290	0.0040	0.0073	1.720	0.643	0.005	1.497	0.007	0.007	0.00	0.002	0.002
130	1300	0.0040	0.0073	1.727	0.648	0.005	1.504	0.007	0.007	0.00	0.002	0.002
131	1310	0.0040	0.0073	1.734	0.654	0.005	1.511	0.007	0.007	0.00	0.002	0.002
132	1320	0.0040	0.0073	1.742	0.659	0.005	1.519	0.007	0.007	0.00	0.002	0.002
133	1330	0.0040	0.0073	1.749	0.664	0.005	1.526	0.007	0.007	0.00	0.002	0.002
134	1340	0.0040	0.0073	1.756	0.669	0.005	1.533	0.007	0.007	0.00	0.002	0.002
135	1350	0.0040	0.0073	1.764	0.674	0.005	1.540	0.007	0.007	0.00	0.002	0.002
136	1360	0.0040	0.0073	1.771	0.680	0.005	1.548	0.007	0.007	0.00	0.002	0.002
137	1370	0.0040	0.0073	1.778	0.685	0.005	1.555	0.007	0.007	0.00	0.002	0.002
138	1380	0.0040	0.0073	1.786	0.690	0.005	1.562	0.007	0.007	0.00	0.002	0.002
139	1390	0.0040	0.0073	1.793	0.696	0.005	1.569	0.007	0.007	0.00	0.002	0.002
140	1400	0.0040	0.0073	1.800	0.701	0.005	1.576	0.007	0.007	0.00	0.002	0.002
141	1410	0.0040	0.0073	1.807	0.706	0.005	1.584	0.007	0.007	0.00	0.002	0.002
142	1420	0.0040	0.0073	1.815	0.711	0.005	1.591	0.007	0.007	0.00	0.002	0.002
143	1430	0.0040	0.0073	1.822	0.717	0.005	1.598	0.007	0.007	0.00	0.002	0.002
144	1440	0.0040	0.0073	1.829	0.722	0.005	1.605	0.007	0.007	0.00	0.002	0.002
TOTAL		1.000	1.829	150.282	44.314	0.722	123.356	1.605	1.605	0.53	0.532	0.340

Per. Area	0 acres	Per. CN 86	Tp (min.)= 470	Qp (cfs) =	0.023	0.014
Imp. Area	0.055 acres	Imp. CN 98	Tc (min.) = 10	**Vol. (cf) =**	**319**	**204**

S v R DESIGN COMPANY

City of Shoreline
Aurora Corridor
Planter Box Length
SvR Project No. 06052
Date: 5/18/2007
By: GP

Spreadsheet 2
Typical Water Quliaty Catchment Area - Stormwater Targets 2005 KCSWD
Santa Barbara Urban Hydrograph Method (SBUH)
Note: SCS Type 1A or Seattle Modified

Estimated Water Quality Design Volume

Vol. (cf) =	**366**

Rainfall Distribution:	SCS Type 1A							
Storm Event	2 year	Pt =	1.83 inches	2 year		Rainfall	Peak =	0.041 cfs
				2 year		Allow. Discharge		0.015 cfs
Pervious Area	0.0000 acre	CN =	86	Sp =	1.63			
Impervious Area	0.0987 acre	CN =	98	Si =	0.20			
		Tc =	10 minutes					
Total Area	0.0987 acre (4300 SF)	dt =	10 minutes	w =	0.33			

Time Increment	Time (minutes)	Rainfall Distribution 1 (fraction)	Incremental Rainfall (inches)	Accumulated Rainfall (inches)	Pervious Accumulated Runoff (inches)	Pervious Area Increment Runoff (inches)	Impervious Accumulated Runoff (inches)	Impervious Area Incr. Runoff (inches)	Total Runoff (inches)	Instant Flowrate (cfs)	Design Flowrate (cfs)	64% Design Flow rate uality Design Flow Rate
1	2	3	4	5	6	7	8	9	10	11	12.000	
0	0	0.0000	0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.000	0.000
1	10	0.0040	0.0073	0.007	0.000	0.000	0.000	0.000	0.000	0.00	0.000	0.000
2	20	0.0040	0.0073	0.015	0.000	0.000	0.000	0.000	0.000	0.00	0.000	0.000
3	30	0.0040	0.0073	0.022	0.000	0.000	0.000	0.000	0.000	0.00	0.000	0.000
4	40	0.0040	0.0073	0.029	0.000	0.000	0.000	0.000	0.000	0.00	0.000	0.000
5	50	0.0040	0.0073	0.037	0.000	0.000	0.000	0.000	0.000	0.00	0.000	0.000
6	60	0.0040	0.0073	0.044	0.000	0.000	0.000	0.000	0.000	0.00	0.000	0.000
7	70	0.0040	0.0073	0.051	0.000	0.000	0.001	0.000	0.000	0.00	0.000	0.000
8	80	0.0040	0.0073	0.059	0.000	0.000	0.001	0.001	0.001	0.00	0.000	0.000
9	90	0.0040	0.0073	0.066	0.000	0.000	0.003	0.001	0.001	0.00	0.001	0.000
10	100	0.0040	0.0073	0.073	0.000	0.000	0.004	0.002	0.002	0.00	0.001	0.001
11	110	0.0050	0.0092	0.082	0.000	0.000	0.007	0.003	0.003	0.00	0.001	0.001
12	120	0.0050	0.0092	0.092	0.000	0.000	0.010	0.003	0.003	0.00	0.001	0.001
13	130	0.0050	0.0092	0.101	0.000	0.000	0.014	0.003	0.003	0.00	0.002	0.001
14	140	0.0050	0.0092	0.110	0.000	0.000	0.017	0.004	0.004	0.00	0.002	0.001
15	150	0.0050	0.0092	0.119	0.000	0.000	0.022	0.004	0.004	0.00	0.002	0.001
16	160	0.0050	0.0092	0.128	0.000	0.000	0.026	0.005	0.005	0.00	0.003	0.002
17	170	0.0060	0.0110	0.139	0.000	0.000	0.032	0.006	0.006	0.00	0.003	0.002
18	180	0.0060	0.0110	0.150	0.000	0.000	0.038	0.006	0.006	0.00	0.003	0.002
19	190	0.0060	0.0110	0.161	0.000	0.000	0.045	0.006	0.006	0.00	0.004	0.002
20	200	0.0060	0.0110	0.172	0.000	0.000	0.051	0.007	0.007	0.00	0.004	0.002
21	210	0.0060	0.0110	0.183	0.000	0.000	0.058	0.007	0.007	0.00	0.004	0.003
22	220	0.0060	0.0110	0.194	0.000	0.000	0.066	0.007	0.007	0.00	0.004	0.003
23	230	0.0070	0.0128	0.207	0.000	0.000	0.074	0.009	0.009	0.01	0.005	0.003
24	240	0.0070	0.0128	0.220	0.000	0.000	0.083	0.009	0.009	0.01	0.005	0.003
25	250	0.0070	0.0128	0.232	0.000	0.000	0.093	0.009	0.009	0.01	0.005	0.003
26	260	0.0070	0.0128	0.245	0.000	0.000	0.102	0.010	0.010	0.01	0.006	0.004
27	270	0.0070	0.0128	0.258	0.000	0.000	0.112	0.010	0.010	0.01	0.006	0.004
28	280	0.0070	0.0128	0.271	0.000	0.000	0.122	0.010	0.010	0.01	0.006	0.004
29	290	0.0082	0.0150	0.286	0.000	0.000	0.134	0.012	0.012	0.01	0.006	0.004
30	300	0.0082	0.0150	0.301	0.000	0.000	0.146	0.012	0.012	0.01	0.007	0.004
31	310	0.0082	0.0150	0.316	0.000	0.000	0.158	0.012	0.012	0.01	0.007	0.005
32	320	0.0082	0.0150	0.331	0.000	0.000	0.170	0.012	0.012	0.01	0.007	0.005
33	330	0.0082	0.0150	0.346	0.000	0.000	0.183	0.013	0.013	0.01	0.007	0.005
34	340	0.0082	0.0150	0.361	0.001	0.000	0.195	0.013	0.013	0.01	0.007	0.005
35	350	0.0095	0.0174	0.378	0.002	0.001	0.210	0.015	0.015	0.01	0.008	0.005
36	360	0.0095	0.0174	0.396	0.003	0.001	0.225	0.015	0.015	0.01	0.009	0.005
37	370	0.0095	0.0174	0.413	0.004	0.002	0.240	0.015	0.015	0.01	0.009	0.006
38	380	0.0095	0.0174	0.430	0.006	0.002	0.256	0.015	0.015	0.01	0.009	0.006
39	390	0.0095	0.0174	0.448	0.009	0.002	0.271	0.015	0.015	0.01	0.009	0.006
40	400	0.0095	0.0174	0.465	0.011	0.002	0.287	0.015	0.015	0.01	0.009	0.006
41	410	0.0133	0.0243	0.490	0.015	0.004	0.308	0.022	0.022	0.01	0.010	0.007
42	420	0.0133	0.0243	0.514	0.020	0.005	0.330	0.022	0.022	0.01	0.012	0.008
43	430	0.0133	0.0243	0.538	0.025	0.005	0.353	0.022	0.022	0.01	0.013	0.008
44	440	0.0180	0.0329	0.571	0.032	0.008	0.383	0.030	0.030	0.02	0.015	0.009
45	450	0.0180	0.0329	0.604	0.041	0.008	0.413	0.031	0.031	0.02	0.017	0.011
46	460	0.0340	0.0622	0.666	0.059	0.018	0.472	0.058	0.058	0.03	0.023	0.015
47	**470**	**0.0540**	**0.0988**	**0.765**	**0.093**	**0.034**	**0.565**	**0.093**	**0.093**	**0.06**	**0.038**	0.024
48	480	0.0270	0.0494	0.815	0.113	0.019	0.612	0.047	0.047	0.03	0.041	0.026
49	490	0.0180	0.0329	0.847	0.127	0.014	0.644	0.032	0.032	0.02	0.029	0.019
50	500	0.0134	0.0245	0.872	0.137	0.011	0.667	0.024	0.024	0.01	0.021	0.013
51	510	0.0134	0.0245	0.897	0.148	0.011	0.691	0.024	0.024	0.01	0.016	0.010
52	520	0.0134	0.0245	0.921	0.159	0.011	0.715	0.024	0.024	0.01	0.015	0.009
53	530	0.0088	0.0161	0.937	0.167	0.008	0.730	0.016	0.016	0.01	0.013	0.008
54	540	0.0088	0.0161	0.953	0.175	0.008	0.746	0.016	0.016	0.01	0.010	0.007
55	550	0.0088	0.0161	0.969	0.182	0.008	0.761	0.016	0.016	0.01	0.010	0.006
56	560	0.0088	0.0161	0.985	0.190	0.008	0.777	0.016	0.016	0.01	0.009	0.006
57	570	0.0088	0.0161	1.002	0.198	0.008	0.792	0.016	0.016	0.01	0.009	0.006
58	580	0.0088	0.0161	1.018	0.206	0.008	0.808	0.016	0.016	0.01	0.009	0.006
59	590	0.0088	0.0161	1.034	0.215	0.008	0.824	0.016	0.016	0.01	0.009	0.006

60	600	0.0088	0.0161	1.050	0.223	0.008	0.839	0.016	0.016	0.01	0.009	0.006
61	610	0.0088	0.0161	1.066	0.231	0.008	0.855	0.016	0.016	0.01	0.009	0.006
62	620	0.0088	0.0161	1.082	0.240	0.009	0.871	0.016	0.016	0.01	0.009	0.006
63	630	0.0088	0.0161	1.098	0.249	0.009	0.886	0.016	0.016	0.01	0.009	0.006
64	640	0.0088	0.0161	1.114	0.257	0.009	0.902	0.016	0.016	0.01	0.009	0.006
65	650	0.0072	0.0132	1.127	0.265	0.007	0.915	0.013	0.013	0.01	0.009	0.006
66	660	0.0072	0.0132	1.141	0.272	0.007	0.928	0.013	0.013	0.01	0.008	0.005
67	670	0.0072	0.0132	1.154	0.279	0.007	0.941	0.013	0.013	0.01	0.008	0.005
68	680	0.0072	0.0132	1.167	0.287	0.007	0.953	0.013	0.013	0.01	0.008	0.005
69	690	0.0072	0.0132	1.180	0.294	0.007	0.966	0.013	0.013	0.01	0.008	0.005
70	700	0.0072	0.0132	1.193	0.302	0.008	0.979	0.013	0.013	0.01	0.008	0.005
71	710	0.0072	0.0132	1.207	0.309	0.008	0.992	0.013	0.013	0.01	0.008	0.005
72	720	0.0072	0.0132	1.220	0.317	0.008	1.005	0.013	0.013	0.01	0.008	0.005
73	730	0.0072	0.0132	1.233	0.325	0.008	1.018	0.013	0.013	0.01	0.008	0.005
74	740	0.0072	0.0132	1.246	0.332	0.008	1.031	0.013	0.013	0.01	0.008	0.005
75	750	0.0072	0.0132	1.259	0.340	0.008	1.044	0.013	0.013	0.01	0.008	0.005
76	760	0.0072	0.0132	1.272	0.348	0.008	1.057	0.013	0.013	0.01	0.008	0.005
77	770	0.0057	0.0104	1.283	0.354	0.006	1.067	0.010	0.010	0.01	0.007	0.005
78	780	0.0057	0.0104	1.293	0.361	0.006	1.077	0.010	0.010	0.01	0.006	0.004
79	790	0.0057	0.0104	1.304	0.367	0.006	1.087	0.010	0.010	0.01	0.006	0.004
80	800	0.0057	0.0104	1.314	0.373	0.006	1.097	0.010	0.010	0.01	0.006	0.004
81	810	0.0057	0.0104	1.325	0.380	0.006	1.108	0.010	0.010	0.01	0.006	0.004
82	820	0.0057	0.0104	1.335	0.386	0.006	1.118	0.010	0.010	0.01	0.006	0.004
83	830	0.0057	0.0104	1.345	0.393	0.006	1.128	0.010	0.010	0.01	0.006	0.004
84	840	0.0057	0.0104	1.356	0.399	0.007	1.138	0.010	0.010	0.01	0.006	0.004
85	850	0.0057	0.0104	1.366	0.406	0.007	1.149	0.010	0.010	0.01	0.006	0.004
86	860	0.0057	0.0104	1.377	0.412	0.007	1.159	0.010	0.010	0.01	0.006	0.004
87	870	0.0057	0.0104	1.387	0.419	0.007	1.169	0.010	0.010	0.01	0.006	0.004
88	880	0.0057	0.0104	1.398	0.426	0.007	1.179	0.010	0.010	0.01	0.006	0.004
89	890	0.0050	0.0092	1.407	0.431	0.006	1.188	0.009	0.009	0.01	0.006	0.004
90	900	0.0050	0.0092	1.416	0.437	0.006	1.197	0.009	0.009	0.01	0.006	0.004
91	910	0.0050	0.0092	1.425	0.443	0.006	1.206	0.009	0.009	0.01	0.005	0.003
92	920	0.0050	0.0092	1.434	0.449	0.006	1.215	0.009	0.009	0.01	0.005	0.003
93	930	0.0050	0.0092	1.443	0.455	0.006	1.224	0.009	0.009	0.01	0.005	0.003
94	940	0.0050	0.0092	1.452	0.461	0.006	1.233	0.009	0.009	0.01	0.005	0.003
95	950	0.0050	0.0092	1.462	0.467	0.006	1.242	0.009	0.009	0.01	0.005	0.003
96	960	0.0050	0.0092	1.471	0.473	0.006	1.251	0.009	0.009	0.01	0.005	0.003
97	970	0.0050	0.0092	1.480	0.479	0.006	1.260	0.009	0.009	0.01	0.005	0.003
98	980	0.0050	0.0092	1.489	0.485	0.006	1.269	0.009	0.009	0.01	0.005	0.003
99	990	0.0050	0.0092	1.498	0.491	0.006	1.278	0.009	0.009	0.01	0.005	0.003
100	1000	0.0050	0.0092	1.507	0.497	0.006	1.287	0.009	0.009	0.01	0.005	0.003
101	1010	0.0040	0.0073	1.515	0.502	0.005	1.295	0.007	0.007	0.00	0.005	0.003
102	1020	0.0040	0.0073	1.522	0.507	0.005	1.302	0.007	0.007	0.00	0.005	0.003
103	1030	0.0040	0.0073	1.529	0.512	0.005	1.309	0.007	0.007	0.00	0.004	0.003
104	1040	0.0040	0.0073	1.537	0.517	0.005	1.316	0.007	0.007	0.00	0.004	0.003
105	1050	0.0040	0.0073	1.544	0.522	0.005	1.323	0.007	0.007	0.00	0.004	0.003
106	1060	0.0040	0.0073	1.551	0.526	0.005	1.331	0.007	0.007	0.00	0.004	0.003
107	1070	0.0040	0.0073	1.559	0.531	0.005	1.338	0.007	0.007	0.00	0.004	0.003
108	1080	0.0040	0.0073	1.566	0.536	0.005	1.345	0.007	0.007	0.00	0.004	0.003
109	1090	0.0040	0.0073	1.573	0.541	0.005	1.352	0.007	0.007	0.00	0.004	0.003
110	1100	0.0040	0.0073	1.581	0.546	0.005	1.360	0.007	0.007	0.00	0.004	0.003
111	1110	0.0040	0.0073	1.588	0.551	0.005	1.367	0.007	0.007	0.00	0.004	0.003
112	1120	0.0040	0.0073	1.595	0.556	0.005	1.374	0.007	0.007	0.00	0.004	0.003
113	1130	0.0040	0.0073	1.603	0.561	0.005	1.381	0.007	0.007	0.00	0.004	0.003
114	1140	0.0040	0.0073	1.610	0.566	0.005	1.388	0.007	0.007	0.00	0.004	0.003
115	1150	0.0040	0.0073	1.617	0.571	0.005	1.396	0.007	0.007	0.00	0.004	0.003
116	1160	0.0040	0.0073	1.624	0.576	0.005	1.403	0.007	0.007	0.00	0.004	0.003
117	1170	0.0040	0.0073	1.632	0.582	0.005	1.410	0.007	0.007	0.00	0.004	0.003
118	1180	0.0040	0.0073	1.639	0.587	0.005	1.417	0.007	0.007	0.00	0.004	0.003
119	1190	0.0040	0.0073	1.646	0.592	0.005	1.425	0.007	0.007	0.00	0.004	0.003
120	1200	0.0040	0.0073	1.654	0.597	0.005	1.432	0.007	0.007	0.00	0.004	0.003
121	1210	0.0040	0.0073	1.661	0.602	0.005	1.439	0.007	0.007	0.00	0.004	0.003
122	1220	0.0040	0.0073	1.668	0.607	0.005	1.446	0.007	0.007	0.00	0.004	0.003
123	1230	0.0040	0.0073	1.676	0.612	0.005	1.453	0.007	0.007	0.00	0.004	0.003
124	1240	0.0040	0.0073	1.683	0.617	0.005	1.461	0.007	0.007	0.00	0.004	0.003
125	1250	0.0040	0.0073	1.690	0.622	0.005	1.468	0.007	0.007	0.00	0.004	0.003
126	1260	0.0040	0.0073	1.698	0.628	0.005	1.475	0.007	0.007	0.00	0.004	0.003
127	1270	0.0040	0.0073	1.705	0.633	0.005	1.482	0.007	0.007	0.00	0.004	0.003
128	1280	0.0040	0.0073	1.712	0.638	0.005	1.490	0.007	0.007	0.00	0.004	0.003
129	1290	0.0040	0.0073	1.720	0.643	0.005	1.497	0.007	0.007	0.00	0.004	0.003
130	1300	0.0040	0.0073	1.727	0.648	0.005	1.504	0.007	0.007	0.00	0.004	0.003
131	1310	0.0040	0.0073	1.734	0.654	0.005	1.511	0.007	0.007	0.00	0.004	0.003
132	1320	0.0040	0.0073	1.742	0.659	0.005	1.519	0.007	0.007	0.00	0.004	0.003
133	1330	0.0040	0.0073	1.749	0.664	0.005	1.526	0.007	0.007	0.00	0.004	0.003
134	1340	0.0040	0.0073	1.756	0.669	0.005	1.533	0.007	0.007	0.00	0.004	0.003
135	1350	0.0040	0.0073	1.764	0.674	0.005	1.540	0.007	0.007	0.00	0.004	0.003
136	1360	0.0040	0.0073	1.771	0.680	0.005	1.548	0.007	0.007	0.00	0.004	0.003
137	1370	0.0040	0.0073	1.778	0.685	0.005	1.555	0.007	0.007	0.00	0.004	0.003
138	1380	0.0040	0.0073	1.786	0.690	0.005	1.562	0.007	0.007	0.00	0.004	0.003
139	1390	0.0040	0.0073	1.793	0.696	0.005	1.569	0.007	0.007	0.00	0.004	0.003
140	1400	0.0040	0.0073	1.800	0.701	0.005	1.576	0.007	0.007	0.00	0.004	0.003
141	1410	0.0040	0.0073	1.807	0.706	0.005	1.584	0.007	0.007	0.00	0.004	0.003
142	1420	0.0040	0.0073	1.815	0.711	0.005	1.591	0.007	0.007	0.00	0.004	0.003
143	1430	0.0040	0.0073	1.822	0.717	0.005	1.598	0.007	0.007	0.00	0.004	0.003
144	1440	0.0040	0.0073	1.829	0.722	0.005	1.605	0.007	0.007	0.00	0.004	0.003
TOTAL		1.000	1.829	150.282	44.314	0.722	123.356	1.605	1.605	0.96	0.954	0.611

Per. Area	0 acres	Per. CN 86	Tp (min.)= 470	Qp (cfs) = 0.041	0.026
Imp. Area	0.0987 acres	Imp. CN 98	Tc (min.) = 10	**Vol. (cf) = 573**	**366**