City of Snohomish

Stormwater Comprehensive Plan Update

SNOHOMISH

OCTOBER 2013

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City of Snohomish

Stormwater Comprehensive Plan Update

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ABBREVIATIONS AND ACRONYMS

BMP	Best Management Practice
BPCP	Bacterial Pollution Control Plan
CESCL	Certified Erosion Sediment Control Lead
City	City of Snohomish
cfs	cubic feet per second
CIP	Capital Improvement Program
CMP	Corrugated Metal Pipe
CSO	Combined Sewer Overflow
Ecology	Washington State Department of Ecology
Ecology Manual	2005 Stormwater Management Manual for Western Washington
GIS	Geographic Information System
GMA	Growth Management Act
HMA	Hot Mix Asphalt
HSPF	Hydrologic Simulation Program-Fortran
IDDE	Illicit Discharge and Detection and Elimination
JCPA	Joint Comprehensive Planning Area
LID	Low Impact Development
MS4	Municipal Separate Storm Sewer Systems
NA	Not Applicable
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service (formerly SCS)
O&M	Operation and Maintenance
QAPP	Quality Assurance Project Program
SBUH	Santa Barbara Unit Hydrograph
SCS	Soil Conservation Service
SEPA	State Environmental Policy Act
SWMP	Stormwater Management Program
TMDL	Total Maximum Daily Load
UGA	Urban Growth Area
USDA	U.S. Department of Agriculture
WAC	Washington Administrative Code
WDFW	Washington State Department of Fish & Wildlife
WWHM	Western Washington Hydrology Model
WWTF	Wastewater Treatment Facility

1.0 INTRODUCTION

In 2001, a Stormwater Management Plan was prepared for the City of Snohomish, Washington (City). Since that time, new areas have been annexed, capital projects have been constructed, the City has developed and implemented a NPDES Phase II Program, and the City has updated their stormwater utility funding program. The City has also adopted the 2005 Washington State Department of Ecology Stormwater Management Manual for Western Washington (Ecology Manual), made updates to the City of Snohomish Comprehensive Plan, and prepared a Combined Sewer Overflow Reduction Plan Update.

In April 2012, the City of Snohomish authorized the development of a Stormwater Comprehensive Plan Update. This Stormwater Comprehensive Plan (Plan) for the City of Snohomish is an update to the June 2001 report prepared by RW Beck entitled, "Final Stormwater Management Plan," (2001 Plan).

The purpose of this plan is to guide the City's Stormwater Utility programs in a manner consistent with applicable local, state, and federal regulations. The plan includes:

- Identification of proposed solutions to flooding and water quality issues.
- Actions necessary to comply with applicable federal, state, and local requirements, in particular, the Western Washington Phase II Municipal Stormwater Permit (Phase II Permit).

The Plan update includes an evaluation of the study area; a review of drainage basin boundaries and characteristics; public outreach to seek input on known surface water, drainage, and water quality concerns; development of approaches to resolve stormwater problems; review of operation and maintenance practices; and Capital Improvement Program (CIP) development for proposed stormwater improvements. In 2010, the City updated their funding program (FCS 2010); therefore, financial analysis was not completed for this Plan. The recommended CIP will utilize available funding through the City's stormwater utility.

This report is organized into eight sections:

1. Introduction to the stormwater program, the purpose of the Plan, and the general methods employed to develop the Plan.
2. Presentation of planning data relevant to the stormwater program and the goals and objectives of the Plan.
3. Description of the existing conditions within the study area.
4. Description of the hydrologic analysis completed for the Plan update.
5. Stormwater management program and activities required to comply with the Phase II Permit and defined program goals.
6. Citywide and site-specific stormwater problems and proposed solutions.
7. Discussion of opportunities for separating stormwater from combined (storm and sewer) systems.
8. Recommendations for implementation of the stormwater management program activities and projects.

The plan appendices provide improvement summary forms for proposed projects, estimated project costs, a SEPA checklist for the plan, and calculations.

2.0 PLANNING DATA

2.1 GOALS AND OBJECTIVES

The general objectives of this report are to prepare a plan that will serve as a guide for the continued improvement of the stormwater system for the City of Snohomish, to manage surface water runoff to protect people and property, and meet water quality and resource protection goals.

2.2 SCOPE OF WORK

Project goals and objectives will be met by completing the following tasks:

Data Collection and Review

- Review of the 2001 Plan and current regulations.
- Review of available mapping and recent and relevant documents (see Section 2.4).

Existing Study Area Definition

- Update planning data per the recent updates to the City Comprehensive Plan, including:
  - Land use and zoning, and
  - Climatic and topographic information.
- Evaluation of an expanded study area to include the North Planning Area and additional drainage basin contributions from newly annexed areas.
- Revise drainage basin delineations based on best-available GIS technology.
- Evaluate the existing and future conditions of the drainage basins.
- Revise hydrologic and hydraulic modeling for selected project areas.
- Incorporate City-staff knowledge of conveyance and flooding issues, water quality issues, operations and maintenance issues, and infrastructure improvements or changes.
- Complete site visits to evaluate known stormwater-related issues for incorporation into the existing conditions and stormwater inventory.
- Conduct a public meeting to identify the public's concerns with respect to the current stormwater facility.

Programmatic Recommendations

- Update programmatic recommendations including operation and maintenance (O&M) issues.
- Evaluate soils within the study area to determine the planning-level feasibility for Low Impact Development projects. Develop a map tool for use by the City, land owners and developers.

Identify and Develop Alternative Solutions to Stormwater Problems

- Identify problems and recommend improvements for control and mitigation of surface water quantity and quality issues.

- Coordinate with the City current stormwater problem areas and potential future problem areas due to growth or regulatory change. Provide alternative analysis and recommendations for more complex problems.
- Compile a list of stormwater-related problems, opportunities, and recommended alternatives. Develop a program of prioritized capital improvements for the construction of facilities included in the comprehensive plan.
- Review sensitive areas, wetlands and steep slopes for the potential effect on or by future development and stormwater impacts.
- Evaluate potential environmental impacts created by the list of capital improvements and draft a checklist in accordance with State Environmental Policy Act (SEPA) requirements.

2.3 PUBLIC INVOLVEMENT

Public participation is an important part of this Plan. The public's opinions and concerns were gathered at a public meeting held on November 27, 2012. The objective of the meeting was to inform local property owners about the Plan update and to provide the public the opportunity to provide input to the Plan by helping identify stormwater problem areas. The following problem areas, identified by City staff were presented at the Public Meeting:

- 87th Avenue SE (Sinclair Avenue);
- Swifty Creek (at Second Street);
- Maple Avenue (Unopened Fairview Street);
- Park Avenue/Blackmans Lake;
- 16th Street and Holly Vista Drive;
- Third Street and Avenue D; and
- Cypress Avenue.

No new areas were identified by the public during the meeting. The problem areas listed above and others later added are described in Sections 6.0 and 7.0.

2.4 PREVIOUS STUDIES AND REPORTS

The following documents were referenced during the preparation of this report:

- June 2001 Stormwater Comprehensive Plan (RW Beck), Volumes 1 and 2;
- June 2001 Stormwater Comprehensive Plan (RW Beck), HSPF Model support files;
- October 2004 Environmental Report (Tetra Tech/KCM);
- May 2005 CSO Reduction Plan Update (Tetra Tech/KCM);
- 2010 Rate Study (FCS);
- January 2009 Annexation History Map (City of Snohomish);
- December 2010 Comprehensive Plan (City of Snohomish);
- 2011 Illicit Discharge Detection and Elimination Program Manual (City of Snohomish);
- December 2011 Land Use Designations Map (City of Snohomish);

- 2012 Stormwater Management Program (City of Snohomish);
- 2012 GIS Stormwater Inventory Data (Gray & Osborne, Inc.);
- February 2012 Stormwater System Map (Gray & Osborne, Inc.); and
- June 2012 GIS Stormwater Network Data from Snohomish County.

3.0 EXISTING CONDITIONS

3.1 STUDY AREA

The original study area from the 2001 Plan included the incorporated city limits of Snohomish as well as adjoining unincorporated areas of Snohomish County. There were two study areas for 2001 Plan. The first larger study area is the Joint Comprehensive Planning Area (JCPA). The second study area is the Urban Growth Area (UGA).

The study area was expanded for this Plan to include the following:

- The North Planning Area, north of US Highway 2, and contributing areas.
- Additional areas to the west of the original study area that contribute flow to the Upper Cemetery Creek and Lower Cemetery Creek basins.
- Additional areas to the east of the original study area that contribute flow to the Pilchuck basin.

The drainage basin characterization and land use are described in Section 3.4.

3.2 DRAINAGE BASINS

The entire study area is approximately 4,869 acres, consisting of the eight drainage basins described below. Each drainage basin ultimately flows into either the Pilchuck River or the Snohomish River. See Figure 1, Basin Map, for drainage basin delineations.

The drainage basin area tributary to the UGA is approximately 4,314 acres and includes Cemetery Creek, the South Fork of Bunk Foss Creek, Swifty Creek, and Blackmans Lake drainage basins. These water bodies ultimately discharge to the Pilchuck River or the Snohomish River. Figure 1 shows the major drainage basin delineations. Following is a brief description of the drainage basins within the study area.

3.2.1 Upper Cemetery Creek

The Upper Cemetery Creek basin is in the northwest corner of the study area, and consists of 875 acres contributing to Cemetery Creek upstream (north) of State Route 9. This basin was modified slightly from the 2001 RW Beck plan to reflect contributory areas based on updated topographic information and the storm drain network within the US Highway 2 right-of-way. The basin is comprised mostly of single family and rural residential area.

One stormwater problem area (C-1) has been identified in this basin and is discussed in Section 6.0 Conveyance System Problem Identification and Solution Development. See Figure 1 for problem area locations.

3.2.2 Lower Cemetery Creek

The Lower Cemetery Creek basin is the westernmost basin, and consists of approximately 1,015 acres contributing to Cemetery Creek downstream (south) of State Route 9 until it discharges to the Snohomish River. This basin was modified slightly from the 2001 RW Beck plan to reflect contributory areas based

on updated topographic information. The basin is comprised mostly of single family and rural residential area.

One stormwater problem area (C-11) has been identified in this basin and is discussed in Section 6.0 Conveyance System Problem Identification and Solution Development. See Figure 1 for problem area locations.

3.2.3 Blackmans Lake Basin

The Blackmans Lake basin is in the north-central portion of the study area, and consists of approximately 465 acres, including Blackmans Lake. The lake is approximately 57 acres with a mean volume of 800 acre-feet. In general, the basin is bordered on the west by State Route 9, on the north by US Highway 2, and on the east by Pine Avenue. The basin is mostly undeveloped or rural residential. There is some medium-density residential development near the lake. The lake discharges to Swifty Creek on the south side, west of Avenue A. The Blackmans Lake Phase I Restoration Study (KCM 1993), characterizes the water quality of the lake and identifies a management strategy for the lake and the tributary area that is intended to improve and protect its water quality.

Two stormwater problem areas (C-4 and C-12) have been identified in this basin and are discussed in Section 6.0 Conveyance System Problem Identification and Solution Development. See Figure 1 for problem area locations.

3.2.4 Swifty Creek Basin

The Swifty Creek drainage basin is in the south-central portion of the study area, and consists of approximately 330 acres contributing to Swifty Creek, from the outlet to Blackmans Lake to the Snohomish River, near the downtown Snohomish Historic District Boundary.

Because Swifty Creek is the outlet to Blackmans Lake, this basin technically includes the entire tributary area to Blackmans Lake (approximately 465 acres, including Blackmans Lake), for a total of approximately 795 acres. The Swifty Creek basin is almost completely developed and, as shown in Table 3-1, several land use categories are represented in this basin. The basin is generally bordered to the west by Avenue D, to the north by Blackmans Lake, to the east by Pine Avenue, and to the south by the commercial downtown area.

Local nomenclature identifies Swifty Creek as the outlet from Blackmans Lake that flows south in an open channel to the junior high school campus (Freshman Campus), where it enters a 36-inch concrete pipe. There are several roadway culvert crossings between Blackmans Lake and the Freshman Campus. Capacity problems were reported in the 2001 Plan, which have been resolved since that time.

Once the creek enters the 36-inch pipe, it flows east-southeast across the playfield and changes to a 30-inch-diameter pipe before entering a diversion manhole on the east side of the campus. The diversion manhole has a weir constructed inside, which diverts all low flows east to the Pilchuck River. During high flows, excess flows continue south in the original Swifty Creek channel toward the downtown area. The pipe that conveys flows to the Pilchuck River runs east along Sixth Street. The original Swifty Creek system continues south in a 30-inch concrete pipe that discharges to an open channel just south of 5th Street. The open channel continues south, with culvert crossings at Fourth Street and Cedar Avenue to an open channel behind AA Rentals on the north side of Second Street. The open channel discharges to a 24-inch pipe that conveys flows under the downtown area to the Snohomish River.

One stormwater problem area (C-2) has been identified in this basin and is discussed in Section 6.0 Conveyance System Problem Identification and Solution Development. See Figure 1 for problem area location.

3.2.5 Bunk Foss Basin

The Bunk Foss basin is in the northeast corner of the study area, and consists of approximately 1,025 acres contributing to Bunk Foss Creek. Bunk Foss Creek is a right bank tributary of the Pilchuck River and gains flow from Clarks Fork, Fields Fork, and an unnamed tributary before draining into the Pilchuck River.

This basin was expanded significantly from the 2001 report to include the area outside of the UGA that drains to Bunk Foss Creek; the prior report provided information for only Clarks Fork, the southern fork of Bunk Foss Creek. Over one third of the basin includes a portion of the north planning area outside of the UGA boundary.

Clarks Fork drains approximately 200 acres located in the northeast portion of the study area. A portion of this basin is currently undeveloped. The developed portion is mostly low density or rural residential. The tributary drainage area extends as far south as 16th Street and is bordered by Pine Avenue on the west and Terrace Avenue on the east. Further to the north, near Highway 2, the basin widens to the east and west.

The main stem of Bunk Foss Creek collects flow from the land adjacent and to the south of Highway 2 as well as West Fields Fork and East Fields Fork, which are north of Highway 2. The main stem crosses Highway 9 south of Highway 2 within the Highway 2-Highway 9 interchange, then passes under 52nd Street SE on the south side of Highway 2. The confluence of Clarks Fork and the main stem is on the south side of Highway 2. Downstream of the confluence, the creek enters a 72-inch corrugated metal pipe (CMP) culvert passing under Highway 2. Bunk Foss Creek crosses under Old Machias Road, near the confluence with the unnamed tributary, and then crosses back to the south side of Highway 2 through a roadway culvert. The creek then crosses beneath South Machais Road and continues in a southeast direction prior to its confluence with the Pilchuck River.

The North Planning area is largely comprised of the Bunk Foss Creek drainage area outside of the City Limits and UGA. No stormwater problem areas have been identified in this basin.

3.2.6 Pilchuck River Basin

The Pilchuck River basin is the easternmost basin within the study area, and consists of approximately 466 acres flowing to the Pilchuck River.

There are three outfall locations to the Pilchuck River, which are shown on Figure 3. These are located along the Pilchuck River at Sixth Street, Seventh Street, and Grove Street. Stormwater also discharges to the Pilchuck River through open channels located at Fourth Street. Runoff from a portion of the area enters the river by surface and subsurface flow with no specific discharge point.

Five stormwater problem areas (C-3, C-5, C-6, C-9, and C-10) have been identified in this basin and are discussed in Section 6.0 Conveyance System Problem Identification and Solution Development. See Figure 1 for problem area locations.

3.2.7 Snohomish River Basin

The Snohomish River basin is the southernmost basin within the study area, and consists of approximately 445 acres flowing to the Snohomish River.

The southernmost portions of the study area drain to the Snohomish River. The basin area includes the land between First Street and the river as well as the area south of the river to the Airport Way-Highway 9 intersection. Runoff from most of this area enters the river by surface and subsurface flow, with no specific discharge point. However, there is a 20-inch stormwater overflow outfall located at the intersection of First Street and Lincoln Avenue. The outfall pipeline extends southwest and enters the Snohomish River approximately 600 to 800 feet downriver from the railroad bridge, near the confluence of the Pilchuck and Snohomish Rivers.

No specific problems have been identified in this basin. The area is within the 100-year floodplain and, with the exception of the airport and mill, a significant portion of the area is undeveloped and/or is currently being used as agricultural land. It is difficult to anticipate problems that will result from future development in this area because it is not known exactly how the area will develop. However, because the area is in the floodplain, development would likely require filling and subsequently, compensatory mitigation (excavation) to support a no-net rise of the 100-year flood plain, according to development standards. Future development will require site-specific planning for surface water management. For these reasons, no specific recommendations for managing surface water in the area south of the Snohomish River were identified as part of this planning process.

One stormwater problem area (C-8) has been identified in this basin and is discussed in Section 6.0 Conveyance System Problem Identification and Solution Development. See Figure 1 for problem area locations.

3.2.8 Combined Sewer Area

The Combined Sewer Area comprises most of the downtown Snohomish area, with stormwater flows joining the sanitary system, and flowing to the wastewater treatment plant west of downtown, or to one of the two Combined Sewer Overflows (CSOs) along the Snohomish River. This area consists of approximately 248 acres (see Figure 4).

Most of the downtown commercial area and the residential area northwest of the downtown commercial area are within the combined sewer area. Runoff from this area discharges to the sanitary sewer system. Since stormwater runoff from this area is collected in the sanitary sewer system, these flows are managed by that system.

See Section 7.0 for a more in depth description of the Combined Sewer Area, including recent proposed upgrades for separation of stormwater from wastewater.

Stormwater problem area (C-7) has been identified in this basin and is discussed in Section 6.0 Conveyance System Problem Identification and Solution Development. Also, a proposed CSO separation project (C-13) has been identified in the area and is described in Section 7.0 Separated Storm Drainage System for the Combined Sewer Area. The proposed CSO separation project will benefit the Combined Sewer Area as well as the Snohomish River Basin. See Figure 1 for problem area locations.

3.2.9 North Planning Area

The North Planning Area includes parcels in three drainage basins: Upper Cemetery Creek and Bunk Foss. This area consists of the expected future expansion north of the UGA, north of US Highway 2, and is approximately 556 acres.

3.3 SOILS

Soil information was gathered from the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Web Soil Survey website, as well as the Soil Survey Report for Snohomish County Area, Washington (USDA Soil Conservation Service July 1983).

Area soils are primarily of the Tokul group – Tokul gravelly loam and Tokul silt loam that formed in glacial till and volcanic ash. These soils are moderately deep and moderately well drained and have moderate permeability. The slopes range from 0 to 25 percent and they are typically underlain by a hardpan at a depth of less than 3 feet.

Soil mapping for the study area is presented on Figure 2: Soil Type Suitability for Low Impact Development (see Section 5.0). Tokul silt loam and Tokul gravelly loam are classified within hydrologic group C, having moderately high runoff potential and low infiltration rates when thoroughly wetted. Based on the predominant soil type, hydrologic modeling is based on hydrologic soil group C.

For purposes of this study, the mapping specifically categorizes the soils into three groups based upon their hydrologic properties: glacial till, glacial outwash, and wetland soils. The study area is predominated by till soils that cover 77 percent of the land area.

3.4 EXISTING LAND USE DESIGNATIONS

The land use designation information, within the UGA, was provided by the City Land Use Map (City of Snohomish 2011b). The land use designation, outside the UGA was provided by Snohomish County's General Policy Plan (Snohomish County 2012). The land use designations in the study area are commercial, residential, open areas, industrial, and the north planning area. The study area is comprised of areas within each basin boundary and is represented on Figure 1.

The basins that are described in Section 3.2 are divided into different land use designations. The impervious percentages for residential and commercial land use designations that were developed in the 2001 Plan (RW Beck 2001) were adopted for this current Plan. The effective impervious percentages used for hydrologic modeling purposes for low-density residential, medium-density residential, high-density residential, and multifamily residential are 4, 10, 25, and 50 percent, respectively.

Also in the 2001 Plan, the commercial land use designation was divided into three categories: 20, 50, and 80 percent effective impervious areas (RW Beck 2001). The commercial land use designation provided by the 2011 City Land Use Map and Snohomish County's General Policy Plan did not divide the commercial land use into three categories to identify the effective impervious areas. For hydrologic modeling, the impervious area within the commercial land use designation was verified by interpretation of the aerial photograph.

The delineated north planning area, discussed in Section 3.2.9, is outside of the UGA and was provided by Snohomish County's General Policy Plan (Snohomish County 2012). The north planning area is both

a delineated area and a land use designation. For hydrologic modeling, the impervious area within the north planning area land use designation was verified by interpretation of the aerial photograph.

The pervious areas of the watershed were assumed to be in good condition with grass cover on more than 75 percent of the area. The impervious and pervious percentages for each land use designation were used in the hydrologic analysis of the problem areas identified by the City. The total drainage basin areas, land use areas, and existing land use designations are presented in Table 3-1.

Table 3-1 Existing Land Use Designations (Acres)

Land Use	Upper Cemetery Creek	Lower Cemetery Creek	Blackmans Lake	Swifty Creek	Combined Sewer Area	Pilchuck River	Bunk Foss	Snohomish River	Total
Commercial Area									
COMM (Commercial)	24.1	34.1	6.5	53.0	7.7	9.1	0.0	16.7	151.1
BUSINESS PARK	246.8	2.2	11.9	14.0	0.0	0.0	0.0	0.0	274.9
HISTORIC BUSINESS	0.0	0.0	0.0	0.0	24.5	0.0	0.0	5.3	29.8
Total Commercial Area	**270.9**	**36.4**	**18.3**	**67.0**	**32.2**	**9.1**	**0.0**	**22.0**	455.8
Residential Area									
SINGLE FAMILY RES	151.6	197.3	276.5	101.8	109.0	150.5	181.3	12.6	1180.5
HD-RES (High Density Residential)	0.0	0.0	0.0	1.0	0.4	2.5	0.0	13.6	17.5
MD-RES (Medium Density Residential)	24.2	0.0	1.4	41.4	14.6	45.0	0.6	0.0	127.2
LD-RES (Low Density Residential)	196.9	592.8	2.5	33.6	0.0	6.2	296.2	0.0	1128.1
Total Residential Area	**372.7**	**790.1**	**280.4**	**177.8**	**124.0**	**204.1**	**478.0**	**26.2**	2453.3
Open Area									
CITY/ROW	62.2	46.7	56.4	71.4	88.5	61.8	36.2	32.0	455.1
URBAN HORTICULTURE	0.0	0.0	0.0	0.0	0.0	8.8	0.0	20.3	29.1
RIVERWAY COMM FARMLAND	0.0	0.3	0.0	0.0	0.0	69.3	134.3	23.8	227.7
PARKS/OPEN SPACE	0.0	2.3	43.2	9.6	2.1	80.7	0.0	13.1	151.0
Total Open Area	**62.2**	**49.3**	**99.6**	**80.9**	**90.5**	**220.6**	**170.5**	**89.2**	**862.8**
Industrial Area									
MIXED USE	0.0	0.0	0.0	4.4	1.4	27.2	0.0	3.5	36.4
AIRPORT INDUSTRY	0.0	0.0	0.0	0.0	0.0	0.0	0.0	144.5	144.5
INDUSTRY	0.0	138.9	0.0	0.3	0.0	5.0	0.2	159.5	303.9
Total Industrial Area	**0.0**	**138.9**	**0.0**	**4.7**	**1.4**	**32.2**	**0.2**	**307.4**	484.8
Blackmans Lake	**0.0**	**0.0**	**57.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**57.0**
TOTAL AREA WITHIN UGA BOUNDARY	**705.8**	**1014.7**	**455.3**	**330.3**	**248.1**	**466.0**	**648.7**	**444.8**	**4313.7**
North Planning Area	**169.4**	**0.0**	**9.9**	**0.0**	**0.0**	**0.0**	**376.2**	**0.0**	**555.5**
TOTAL STUDY AREA	**875.2**	**1014.7**	**465.3**	**330.3**	**248.1**	**466.0**	**1024.9**	**444.8**	**4869.2**

The distribution of existing land use designations are summarized by percentage in Table 3-2.

Table 3-2 Existing Land Use Designation Summary

Land Use Designations	Distribution
Commercial	**11%**
Residential (total)	**57%**
Single Family	27.5%
High-density Residential	0.5%
Medium-density Residential	3.0%
Low-density Residential	26%
Open Area	**20%**
Industrial Area	**11%**
Blackmans Lake	**1%**
Total (within UGA Boundary)	**100%**

The North Planning Area is under evaluation and was not included in Table 3-2: Existing Land Use Designation Summary.

3.5 FISH HABITAT

There are three major streams in the City of Snohomish UGA: Bunk Foss Creek, Cemetery Creek, and Swifty Creek. The streams are all Class 2 streams. They are not large enough to be considered "Shorelines of the State" but they all provide some salmonid habitat. In addition, WDFW stocks Blackmans Lake with trout (Steward 2004).

Several previous studies of these stream courses have been performed within the City of Snohomish UGA. The City completed critical areas mapping in 1991 as required by the Growth Management Act (GMA) of 1990. In addition, RW Beck inventoried streams within the City of Snohomish to evaluate fisheries resources and to identify problems associated with those resources. The inventory focused on field observations of the three major streams within the City of Snohomish and is limited to the portions of these streams within the 2001 Urban Growth Boundary (RW Beck 2001). Subsequently, Steward and Associates prepared an Endangered Species Act Response Plan for the City of Snohomish in 2004 (Steward and Associates 2004).

All three streams display varying effects from past and present development. Clearing of riparian vegetation has resulted in a loss of cover for fish, increased erosion, and loss of shade, which results in increased summertime stream temperatures. Portions of some drainages have been channelized or "ditched." Culverts have been installed for road crossings of streams. Fish migration barriers consist primarily of culverts. Most of these barriers are partial and serve to block fish migration only under certain stream flow conditions (RW Beck 2001). Bunk Foss Creek and Cemetery Creek are still used to some extent by salmonids for rearing and spawning. Swifty Creek however has fish passage barriers that have eliminated salmon migration from the Snohomish and Pilchuck Rivers (Steward 2004).

In addition to the three major streams, two rivers flow through or are adjacent to the City of Snohomish UGA. The Snohomish River in the vicinity of the city supports several salmonid species, including Chinook salmon (federally listed threatened), coho salmon, chum salmon, pink salmon, sockeye salmon, bull trout/Dolly Varden (federally listed threatened), and steelhead (federally listed threatened). Of these

species, summer Chinook salmon are documented to spawn in this portion of the river (WDFW 2010).

The Pilchuck River in the vicinity of the City supports several salmonid species, including Chinook salmon (federally listed threatened), coho salmon, chum salmon, pink salmon, sockeye salmon, bull trout/Dolly Varden (federally listed threatened), steelhead (federally listed threatened), whitefish, and rainbow and cutthroat trout (Steward and Associates 2004).

A further description of the Snohomish and Pilchuck Rivers' physical properties and surrounding land use patterns can be found in the City of Snohomish Master Program Draft Shoreline Inventory and Characterization (ESA 2010). Additional information on the Pilchuck River can be found in Habitat Conditions and Chinook Use in the Pilchuck River (Savery and Hook 2003).

3.6 EXISTING WILDLIFE HABITAT

The Washington Department of Fish and Wildlife (WDFW) maintains a list and mapping of priority habitats and species throughout the state. Priority habitats are those that have a high value to many fish and wildlife species and may be limited or vulnerable. Priority species are those requiring protection or management to ensure their survival. Priority wildlife habitats mapped in the City's UGA include wetlands, riparian zones, and urban natural open space. The wetlands, open water areas, and shoreline trees provide foraging and nesting habitats for priority species such as waterfowl, bald eagle, bats, great blue heron, and pileated woodpecker.

Portions of the study area have been extensively developed with both residential and commercial land uses. Within these areas, vegetation has often been cleared or replaced by ornamental plants and landscaping.

Mammals that are likely to occur in the study area habitats include raccoons, coyotes, opossums, various rodents, cottontail rabbit, and black-tailed deer. In addition, a variety of songbirds, waterfowl, reptiles, and amphibians are expected to use these habitats.

3.7 WETLANDS

Wetlands within the City are primarily classified as fresh water, non-tidal ("palustrine") wetlands. The majority of these palustrine wetlands are emergent wetlands currently in use as pasture or open fallow land. Forested and/or scrub-shrub wetlands were also identified along stream corridors throughout the study area. Forested wetlands are associated with Cemetery Creek and its tributaries, as well as Bunk Foss Creek. The largest wetland within the study area is Blackmans Lake and associated forested, scrub-shrub, and emergent wetlands surrounding the lake. Blackmans Lake is considered a lacustrine, open water wetland. Other open water wetlands found in the study area are limited to farm ponds, most of which are manmade. Palustrine wetland habitat was verified within those areas of Snohomish, which are located within the floodplain of the Snohomish River. Floodplain wetlands identified are largely cultivated, emergent wetlands, or scrub-shrub wetlands occurring near the existing sewage treatment lagoon.

Of particular note is a large wetland complex is located adjacent to the City's wastewater treatment plant. This wetland includes palustrine emergent, scrub-shrub, and forested vegetation communities. The wetland covers approximately 18 acres (ESA 2010). Cemetery Creek meanders through this wetland system and discharges to the Snohomish River at a point just north and west of the city limits. This

wetland is believed to be part of a historical meander of the Snohomish River that was cut off when the river was channelized. Tides now create large off-channel pools in the wetland that may provide salmonid juvenile rearing and adult holding habitat (Steward and Associates 2004).

3.8 BLACKMANS LAKE

Lakes are typically defined as bodies of open fresh water greater than 20 acres in size. Based on this definition, Blackmans Lake is the only lake within the study area. Blackmans Lake has a surface area of approximately 57 acres and a total watershed area of 465 acres, which includes the lake. It is surrounded by single family residential development and some wetland areas. The lake's maximum depth is 29 feet. Blackmans Lake Creek and Grassy Bottom Creek enter the north side of the lake. Swifty Creek is the outlet stream from Blackmans Lake and discharges to the Snohomish River near Cady Park (ESA 2010).

A narrow, blind channel known as Champagne Lane extends from the northeastern side of the lake. This channel is maintained by local homeowners (ESA 2010).

The average storage volume of Blackmans Lake is 800 acre-feet. With approximately 150 acre-feet of available storage, the lake provides enough detention storage to control peak flows in Swifty Creek (RW Beck 2001).

A further description of Blackmans Lake's physical properties and surrounding land use patterns can be found in the City of Snohomish Master Program Draft Shoreline Inventory and Characterization (ESA 2010).

4.0 HYDROLOGIC ANALYSIS

Hydrologic modeling for existing and future land use conditions was conducted for the 2001 Plan. This modeling was reviewed and used to the extent practical while evaluating existing and proposed stormwater infrastructure for this updated plan.

The 2001 hydrologic modeling was performed using U.S. EPA's Hydrologic Simulation Program-Fortran (HSPF) model. HSPF is a sophisticated computer modeling program that simulates land surface and instream hydrologic processes. The model is used to transform a long time-series of observed rainfall and evaporation data into a time-series of runoff using a continuous accounting of soil moisture levels.

Depending on the application and purpose, the HSPF model can provide an advantage over more traditional event-based models. Event-based models simulate flow for individual storms only; while HSPF can estimate flow over a period of record, including evaluating specific historic storms. The 2001 hydrologic modeling involved four basic steps:

- Definition of drainage basin and subbasin characteristics.
- Calibration with recorded flow data.
- Simulation of runoff for current and future land use conditions.
- Frequency analysis of simulated runoff data to provide design inflow hydrographs to the storm drainage system.

Definition of the drainage basin area for the 2001 Plan included a smaller study area than the current Plan. Several new areas have been annexed since 2001 and a larger area to the North is included in the Basin areas for this Plan. Comparing basin size between 2001 and 2013 (Table 4-1), the current plan includes a larger portion of the drainage areas for the basins to the north and west of the City for the Upper Cemetery Creek Basin and the Bunk Foss Basin. Other small differences in basin size occurs for several basins because the 2013 basin delineation is based on more recent data and employed modeling techniques using GIS.

Table 4-1 Comparison of Drainage Basin Area from 2001 to 2013

Drainage Basin	2001 Area (acres)	2013 Area (acres)
Upper Cemetery Creek	558	875
Lower Cemetery Creek	1,024	1,015
Blackmans Lake	448	465
Swifty Creek	357	330
Combined Sewer Area	238	248
Pilchuck River	456	466
Bunk Foss	514	1,025
Snohomish River	501	445
Total	**4,096**	**4,869**

Drainage basin characteristics for this Plan are based on existing land use designations as described in Section 3.4. The percentage of impervious area based on land use that was developed for the 2001 modeling was adopted for this Plan.

Model characteristics and inputs were reviewed and coordinated with City staff to identify known changes and improvements since 2001. Focus areas included stormwater system improvements, new or worsened capacity problems, and new or worsened water quality problems. Several capacity issues were identified and are described in Section 6.0. One water quality problem in the Combined Sewer Area was identified and is described in Section 7.0.

In general, capacity issues are mainly related to undersized or non-existent stormwater infrastructure. Upgrades of these facilities require specific design methods outlined in the Engineering Design and Construction Standards (City of Snohomish 2004). Conveyance design requires evaluation using event-based storms; where pipes shall be sized to convey the 25-year 24-hour storm and be evaluated for flooding and erosion concerns that may occur during the 100-year 24-hour storm. Therefore, modeling with HSPF was not required. The stormwater quality problem was for the Combined Sewer (Combined Utility) Area, which is almost completely developed. A simple hydrologic model using the Department of Ecology Western Washington Hydrology Model (WWHM) was used to estimate the wetpool volume to evaluate the feasibility of converting the former wastewater lagoon into a stormwater quality treatment facility. Stormwater calculations are provided in Appendix D.

The 2001 HSPF modeling evaluated watersheds and streams with culverts and other infrastructure. The model was calibrated using known data for both existing and future land use conditions. The model estimated peak flows for existing and future conditions, including evaluation of the 2-, 10-, 20-, and 100-year peak flows.

Table 4-2 provides a summary of existing and future flows calculated in 2001 for several locations throughout the City. The difference between existing and future peak flows was compared for the 100-year peak flow to examine the potential increase in flow at a particular location. By dividing the future 100-year peak flow by the existing 100-year peak flow a ratio of increase could be readily evaluated. For example, Cemetery Creek at Bickford Road, south of Skipley Road had an existing and future 100-year peak flow of 10.8 cfs and 11.2 cfs respectively. The ratio of 11.2 divided by 10.8 is 1.04, or 1.0; which correlates to a minor increase from existing to future conditions. Evaluating the Cemetery Creek crossing at Weaver Road yields a ratio of 2.5, which notes a significant increase. Table 4-2 is highlighted in yellow for moderate increases in flow between existing and future conditions (ratios of 1.5 to 2.0), and highlighted in blue for significant increases between existing and future conditions (ratios greater than 2.0).

These locations were reviewed with City staff to determine if project improvements are required for this Plan. Several projects listed in this table have been completed and many had no current flooding or conveyance concerns. Both completed projects and those without present day problems were flagged for continued monitoring. Monitoring is discussed in Section 5. Three projects that were identified in the 2001 Plan remain and new projects have been identified (C-4, C-5b, and C-12).

From a programmatic perspective, as the watersheds develop, it will be important to make sure that development standards are met for flow control; which would help alleviate future peak flows within the creek systems shown in Table 4-2.

Table 4-2 Comparison of Existing and Future Peak Flows (2001 Plan)

Conveyance System Improvement ID from 2001 Plan	Drainage Basin	Location Description	Return Period (Years)								Ratio of Future vs. Existing 100-Year Flow	Comments	Recommended Action
			2-Year Flow (cfs)		10-Year Flow (cfs)		20-Year Flow (cfs)		100 -Year Flow (cfs)				
			Existing	Future	Existing	Future	Existing	Future	Existing	Future			
CS-13	Cemetery Creek	Bickford Road South of Skipley Road	5.81	8.11	8.34	9.98	9.17	10.4	10.8	11.2	1.0	Beaver activity within the culvert was causing local flooding (RW Beck 2001). Property owner modified inlet to culvert to alleviate flooding. No flooding has been reported since then. The new installation should be evaluated for hydraulic capacity.	Monitor
CS-11	Cemetery Creek	Weaver Road	17.2	37.9	25.9	58	29	67	35.5	90.4	2.5	Culvert has been replaced.	Monitor
CS-10	Cemetery Creek Anderson's Fork	Weaver Road	4.34	5.56	6.71	9.09	7.69	10.6	10.1	14.2	1.4	Culvert is under capacity for the 10-year event under existing land use conditions (RW Beck 2001). This culvert replacement is low priority until significant development occurs in the upstream tributary area.	Monitor
	Cemetery Creek	72nd Street SE	23.7	50.5	35.7	78.7	39.9	91.2	48.7	124	2.5	No flooding problems have been reported.	Monitor
	Cemetery Creek East Branch	62nd Place SE Between Bickford Ave and SR 9	5.46	7.85	9.31	13	11.1	15.6	16.2	22.8	1.4	No flooding problems have been reported.	Monitor
	Cemetery Creek East Branch	72nd Street SE	9.66	21.1	15.5	33.4	18	39	24.4	53.8	2.2	No flooding problems have been reported.	Monitor
	Cemetery Creek	HWY 9 BPA Wetland Outflow	52.2	83.5	73.3	120	81.8	134	102	169	1.7	No flooding problems have been reported.	Monitor
	Cemetery Creek	89th Avenue SE	55	86.2	77.7	124	86.7	139	108	174	1.6	No flooding problems have been reported.	Monitor
	Cemetery Creek	Harkins Fork at 85th Avenue	14.7	14.7	24.3	24.3	28.8	28.8	41.2	41.2	1.0	No flooding problems have been reported.	Monitor
	Cemetery Creek	At River View Road	72.1	96.7	104	136	114	149	137	176	1.3	No flooding problems have been reported.	Monitor
	Bunk Foss Main Stem	52nd St SE	15.1	15.1	23.6	23.6	27.1	27.1	35.6	35.6	1.0	No flooding problems have been reported.	Monitor
CS-9	Bunk Foss	South Fork - at mouth	14.2	20.1	22	35	25.3	41.5	33.5	58.4	1.7	Culvert is at capacity for the 2-year event; however, no problems have been reported.	Monitor
CS-7	Bunk Foss Main Stem	US HWY 2	29.2	35	45.4	57.9	51.7	67.8	66.4	93	1.4	Obstruction in Bunk Foss Creek Culver under US Highway 2 due to beaver activity (RW Beck 2001). No recent problems have been reported.	Monitor
CS-8	Blackman Lake North Tributary	64th Street SE	8.95	16.6	14.1	29.6	16.3	35.6	21.8	51.6	2.4	Culvert is at capacity for 5-year event under existing land use conditions. Replace culvert with a 48-inch concrete culvert.	Monitor
*CS-5	Blackman Lake East Tributary	Park Street	8.76	13.4	15.2	24.1	18.4	29.2	27.5	42.7	1.6	Flooding at 1830 Park Avenue due to inadequate conveyance capacity (RW Beck 2001). Also, reports of flooding at driveway on the west side of Park Avenue between 18th Street and 19th Street. 2001 Plan recommends to relocate existing catch basin (CB) and low berm to direct runoff to CB.	New Project C-4
	Blackman Lake	Lake Outlet	10.6	11.7	15	16.5	16.4	18.1	19.2	21.3	1.1	See project C-12: Blackmans Lake Outlet Control Project	New Project C-12
	Swifty Creek	10th St	19.2	21.1	26.9	29.6	29.8	32.9	36.5	40.5	1.1	No flooding problems have been reported.	Monitor
CS-1	Swifty Creek	Middle School Flooding Area	45.8	48.5	70.1	74	80.9	85.4	109	115	1.1	Project has been completed.	Monitor
	Swifty Creek	Portion Diverted to Pilchuck	42.6	42.8	47.8	48.6	48.9	50.2	50.4	53.3	1.1	No flooding problems have been reported.	Monitor
	Swifty Creek	Overflow to Old Channel D/S of Middle School	3.13	5.2	21.5	25.3	33.5	36.4	68.7	65.8	1.0	No flooding problems have been reported.	Monitor
	Swifty Creek	Tributary 2nd St Detention	11.4	13	31.8	36.2	45.4	50.6	96.3	100	1.0	No flooding problems have been reported.	Monitor
*CS-6	Pilchuck River	North Maple Avenue	8.2	8.19	13.6	13.6	16.3	16.3	23.8	23.8	1.0	Flooding on private property along west side of Terrace Avenue, debris clogs culvert inlet.	New Project C-5b
CS-3	Pilchuck River	South Maple Avenue	14.1	14.1	23.3	23.3	27.9	27.9	40.8	40.8	1.0	No flooding problems reported.	Monitor
CS-2	Snohomish River Basin	Avenue D between Sixth Street and railroad ROW										Project has been completed.	Monitor
CS-4	Snohomish River Basin	Southwest Corner of Avenue D and First Street										Flooding and erosion on southwest corner of Avenue D and First Street. The existing 12-inch culvert should be replaced with a 24-inch concrete culvert. The water quality runoff to the ditch discharging to the culvert was improved through the installation of a water quality vault. Project is complete.	Monitor
CS-12	Cemetery Creek	87th Avenue SE and Fobes Road										Considerable sediment buildup on the downstream end of the culvert under Fobes Road (RW Beck 2001). No other flooding problems have been reported.	Monitor

Notes:
* The location identified by the 2001 Plan was also identified as a problem area for the 2013 Plan. See Section 6.0 for descriptions of New Projects.
Ratio between existing and future 100-year flow greater than 1.5
Ratio between existing and future 100-year flow greater than 2.0

5.0 PROGRAMMATIC EVALUATION AND RECOMMENDATIONS

This section describes the City's stormwater management program and the evaluation of programmatic alternatives evaluated for this Plan.

5.1 NPDES PHASE II PERMIT

The City of Snohomish is regulated under the National Pollutant Discharge Elimination System (NPDES) Western Washington Phase II Municipal Stormwater Permit.

The NPDES Permit is a federal permit that regulates stormwater and wastewater discharges to waters of the State. While it is a federal permit, the regulatory authority was passed on to the Washington State Department of Ecology (Ecology). In response, Ecology developed and issued the Western Washington Phase II Municipal Stormwater Permit (Permit). The Permit was issued by Ecology in January 2007 and was modified in June 2009. Ecology reissued the Permit unmodified on August 1, 2012 at legislative direction to be effective through July 31, 2013. After an extensive public process, Ecology also reissued the updated 2013 to 2018 permit on August 1, 2012. The Permit for western Washington covers approximately 80 cities and portions of five counties with an effective date of September 1, 2012. The updated 2013-2018 permit will become effective on August 1, 2013.

5.2 STORMWATER MANAGEMENT PROGRAM

All municipalities affected by the Permit are required to create and implement a Stormwater Management Program (SWMP). The Permit requires the SWMP be designed to reduce the discharge of pollutants from the regulated small Municipal Separate Storm Sewer Systems (MS4) to the maximum extent practicable and to protect water quality. The SWMP is to be developed and implemented in accordance with the schedules set forth by the Permit. Each Permittee is required to prepare written documentation of the SWMP. The SWMP shall include an ongoing program for gathering, tracking, maintaining, and using information to evaluate SWMP development, implementation and permit compliance and to set priorities.

According to the Permit, the SWMP shall address the following five minimum program elements, plus a sixth element triggered by the Total Maximum Daily Load (TMDL) status for the Snohomish River:

1) Public Education and Outreach.
2) Public Involvement and Participation.
3) Illicit Discharge Detection and Elimination.
4) Controlling Runoff from New Development, Redevelopment and Construction Sites.
5) Municipal Operations and Maintenance Program.
6) Compliance with TMDL Requirements.

Elements addressed in the SWMP are described in the following subsections.

5.2.1 Public Education and Outreach

The SWMP includes an education program aimed at residents, businesses, industries, elected officials, policy makers, and planning staff. The goal of the education program is to reduce or eliminate behaviors and practices that cause or contribute to adverse stormwater impacts.

The City of Snohomish SWMP is updated annually and submitted with the City's Annual Report to Ecology. The City of Snohomish posts this document on the City of Snohomish web site, www.ci.snohomish.wa.us, so it can be viewed by the public. The SWMP includes directions to the public for providing comments and input to the SWMP.

The City's education and outreach program is summarized by year as follows (City of Snohomish 2012):

- 2009: The City began implementing a public education and outreach program in partnership with Snohomish County. It is the City's goal to provide a public education and outreach program that will be prioritized to target the recommended target audiences and subject areas. The City has been working with Snohomish County to explore regional public education and outreach activities and methods of measuring the understanding and adoption of targeted behaviors among the target audiences.
- 2010: The City implemented three public education and outreach programs in partnership with Snohomish County: 1) Pet Waste Management; 2) Natural Yard Care; and 3) Septic System Operation and Maintenance.
- 2011: Education efforts included flyers for carpet cleaners and pressure washers, and education on car washes including outreach for youth fundraising carwashes and general citizen car washing.
- 2012: The City and Streamside Landowners expanded its education and outreach program to include targeted activities directed to painters and food service related businesses. Also in 2012, the City held a second round of natural yard care workshops for its citizens and provided stormwater outreach to properties abutting streams.
- 2013: According to the City's Business Education Plan, education activities intended for landscapers, contractors, and distribution of spill kits to automotive, gas, and convenience businesses are planned for 2013. These activities include distributing educational materials to landscapers on proper techniques to minimize effects on water quality.

General public education opportunities are provided by the City at various public events. The City has provided a booth to increase awareness on how the public can reduce bacterial pollution. At the booth, the City distributes materials about stormwater, wastewater, drinking water, parks and pet waste disposal instructions. A pet waste station and pooper scooper information are included. The booth is managed by a City of Snohomish representative to answer questions. If the representative does not know a response, they are trained to acquire the name and phone number of the person and will have the appropriate City staff person contact the individual to answer any questions they may have. The events include but are not limited to:

- Farmers Market
- Kla Ha Ya Days weekend
- National Night Out
- Snohomish Community Day

Engineers, contractors, developers, review staff and land use planners have also been included in education and outreach program. The City has been assessing the current understanding of stormwater BMPs and stormwater impacts among various City departments and staff members involved in the review and inspection of land development or redevelopment projects. In areas where understanding was below a desired level, the City has provided its staff with information to increase their knowledge. In an effort to reach developers and contractors, the City has added stormwater informational sheets to all new construction and development permit application packages.

5.2.2 Public Involvement and Participation

The City actively pursues public involvement and participation in the development of stormwater management programs, stewardship programs, environmental activities, rate structure development, and other similar activities. Examples of this are an advisory committee that was established to guide initial development of the City's stormwater utility and first stormwater rate structure; development of parks, trails, and open spaces; and volunteer programs for planting of native trees and shrubs in environmentally critical and sensitive areas. The City continues to examine ways to expand existing public involvement opportunities and create new ones.

The City uses its public hearing process to provide an opportunity for the public to make comment on the City's SWMP. The SWMP is posted on the City's website with a request for public comment on the development and update of the SWMP. This process will occur yearly during the permit cycle.

The City has created a surface water web page on its website with links to the SWMP, annual report, educational information, public involvement opportunities, and Quality Assurance Project Plan (QAPP).

5.2.3 Illicit Discharge Detection and Elimination

The City has developed and implemented an ongoing program which includes the compilation of an Illicit Discharge and Detection and Elimination (IDDE) Program Manual (City of Snohomish 2011a). The City had previously developed an IDDE program to meet the requirements of the Permit. The Manual documents the steps necessary to inspect, prevent, educate and document IDDE related issues throughout the City. City staff presently responds to spills, illegal dumps, and actively searches out illicit connections.

Using grant money supplied by Ecology in 2009, the City purchased CCTV equipment to inspect for illicit connections and aid with mapping efforts. Grant money from the 2010 Ecology grant program was used in late 2009 to upgrade the City's CCTV software to make this tool as effective as possible.

IDDE training was provided by Snohomish County in March of 2009 for select City staff. This training was then passed on to all municipal field staff in August 2009. Follow up training was for 30 Public Works employees was conducted in 2011 and will continue every two years.

The City purchased a cargo trailer dedicated solely for IDDE spill response. The outside of the trailer has educational poster-like information pointing out the hazards of illegal discharges.

The City has implemented the 2011 IDDE Manual when removing the source of an illicit discharge. The Manual outlines procedures and presents a flow chart for notification of appropriate authorities and property owners when removing the source of an illicit discharge. Appropriate language has been included in the City's stormwater ordinance which gives the City authority to remove illicit discharges, provides escalating enforcement, and provides for legal actions if the discharge is not eliminated. This ordinance was adopted on July 21, 2009.

More information on IDDE is available in the SWMP (City of Snohomish 2012) and in the IDDE Manual (City of Snohomish 2011a).

5.2.4 Controlling Runoff from New Development, Redevelopment, and Construction Sites

The City of Snohomish adopted the 2005 Ecology Manual and Appendix 1 of the Municipal Stormwater Permit: Minimum Technical Requirements as standards for all new construction and redevelopment within the City's jurisdiction, through the adoption of Ordinance No. 2173 on July 21, 2009.

The Design and Construction Standards and Specifications Section 2: Erosion and Sedimentation Control (City of Snohomish 2004) include design criteria, standard plans, and specifications for temporary erosion and sediment control during construction.

The City of Snohomish currently has a plan review process in place for all sites disturbing a land area of one acre or more, including projects less than one acre which are part of a larger common plan of development or sale as required under the 2005 Ecology Manual.

The 2005 Ecology Manual includes the minimum requirements for water quality and flow control for new construction and redevelopment sites.

The City currently has Certified Erosion Sediment Control Leads (CESCL) on staff to inspect development sites during construction.

5.2.5 Municipal Operation and Maintenance Program

The Permit requires owners to develop and implement an operations and maintenance (O&M) program that includes a training component and has the ultimate goal of preventing or reducing pollutant runoff from municipal operations. The pollution prevention and O&M programs are described in this subsection. The SWMP (City of Snohomish 2012) provides more detailed information.

Maintenance Standards and Inspection

One component of the O&M program is to develop maintenance standards that are as protective, or more protective, of facility function than those specified in Chapter 4 of Volume V of the 2005 Ecology Manual. The purpose of the maintenance standard is to determine if a facility requires maintenance. The 2005 Ecology Manual contains maintenance standards that satisfy this requirement. The City formalized adoption of the 2005 Ecology Manual on July 21, 2009 through the adoption of Ordinance No. 2173.

The City conducts facility inspections annually (except for catch basins) as required by the Permit. A database and other tracking mechanisms have been developed and are used by City inspection personnel to record and analyze data collected while performing inspections of the facilities. Inspection records are used to document findings and determine whether a reduced inspection schedule can be justified in the future.

The City has developed a list of treatment and flow control facilities to inspect when the 10-year 24-hour rainfall threshold is reached. The City conducts these inspections when required and records the results of inspections and any associated facility repairs as needed. If widespread damage or maintenance needs are encountered following this type of storm event, all stormwater treatment and flow control facilities that may be affected are inspected. Repairs or appropriate maintenance actions are completed in accordance with maintenance standards established above, based on the results of the inspections.

In accordance with the Permit, inspection and cleaning of all catch basins and inlets owned or operated by the City was finished in 2010. This work was accomplished using the Maintenance/Technical Ace Crew (M/TAC) established with Ecology grant funding, secured in cooperation with Snohomish County and the

Cities of Snohomish, Lake Stevens, and Granite Falls. Using City labor as matching grant funds, this work was completed at *zero out-of-pocket cost* to the City. Continued maintenance will occur as the need arises.

Unless there are circumstances beyond the City's control, when an inspection identifies an exceedence of the maintenance standard, maintenance is performed:

- Within 1 year for wetpool facilities and retention / detention ponds.
- Within 6 months for typical maintenance.
- Within 9 months for maintenance requiring re-vegetation.
- Within 2 years for maintenance that requires capital construction of less than $25,000.

Circumstances beyond the permittees control includes denial or delay of access by property owners, denial or delay of necessary permit approvals, and unexpected reallocations of maintenance staff to perform emergency work. If an exceedence of the required timeframe occurs, the City documents the circumstances and how they were beyond their control.

Streets, parking lots, roads and highways

The Permit requires owners to establish and implement practices to reduce stormwater impacts associated with runoff from streets, parking lots, roads or highways owned or maintained by the Permit Holder. Stormwater Pollution Prevention Plans (SWPPP's) have been developed specifically for each department within Public Works and appropriate practices have been deployed.

The following activities are addressed:

- **Pipe cleaning**: A City-owned vactor truck is used for cleaning stormwater system pipes. Pipes that were heavily impacted with sediment and debris were cleaned through the M/TAC process. Moderately impacted pipes were documented and a schedule was put in place for later cleaning.
- **Ditch maintenance and cleaning of culverts that convey stormwater in ditch systems**: The City has a ditch maintenance program that includes cleaning of culverts that convey stormwater in ditch systems. Some ditches commingle road runoff and waters of the state and require a Hydraulic Project Approval (HPA) from Washington Department of Fish and Wildlife prior to conducting maintenance activities. In 2009, the City applied for and received a five-year HPA which allows the City to perform these tasks on a regular basis.
- **Street cleaning:** Snohomish County performs street cleaning weekly through an interlocal agreement. County staff is trained to avoid areas of contaminants such as oil, antifreeze and other similar fluids so sweepings do not become contaminated. County staff notifies City staff of these areas so City staff can place absorbent material and remove contaminants for disposal.
- **Road repair and resurfacing, including pavement grinding**: The City contracts with either Snohomish County or private contractors to perform road repair and resurfacing, including pavement grinding. Those performing the work are required to implement the BMPs necessary to minimize stormwater impacts.
- **Snow and ice control**: The City provides snow and ice control as deemed necessary by the City's police department when unsafe road conditions exist. Snow is plowed on primary travel routes. Washed sand is placed on primary travel routes and known problem areas. Once road conditions return to normal, the City coordinates with Snohomish County who mobilizes sweeper trucks to remove the sand.
- **Utility installation**: The City owns and operates the storm, sewer and water utilities. Qualified staff members perform repairs and maintenance of the utility systems, and contractors are hired to install utilities. The City has developed department-specific SWPPP's to ensure City staff and

contractors follow all appropriate BMPs required to protect the stormwater system. Some installations are done privately as part of development and redevelopment activities. The City requires the use of appropriate BMPs during construction of utilities at development sites.

- **Pavement striping maintenance**: Nearly all pavement striping maintenance in the City is hired out and performed annually by Snohomish County, while minor pavement striping maintenance of parking stalls and some stop bars is performed by City staff. Procedures will be updated as needed to integrate appropriate BMPs.
- **Maintaining roadside areas, including vegetation management**: The City Street Department conducts maintenance of roadside areas including vegetation management. Vegetation management practices are utilized to correct impeded visibility within the ROW or to clear blocked ROW. Presently all vegetation is cut by boom mower during the roadside maintenance process. The City is reviewing current practices and will consider modifying them to leave a grass buffer between the roadway and drainage ditch to control sediment from entering the ditch. A department-specific SWPPP has been developed which addresses these concerns.
- **Dust control**: On City-owned gravel roadways and parking lots, the City annually applies a tree-sap based product to control dust. On construction sites, dust control is occasionally implemented using appropriate BMPs which are employed by a contractor and observed by a City Inspector. The City regularly evaluates its dust control procedures to ensure the best practices and methods are being used and BMPs are in place.

City-owned/maintained land

Establishment and implementation of policies and procedures to reduce pollutants in discharges from land owned or maintained by the City is required by the Permit. Examples of such land include parks, open space, road ROW, maintenance yards, and stormwater treatment and flow control facilities. Department specific SWPPPs have been developed and implemented to address these issues. The City has also developed and implemented a SWPPP for the municipally owned maintenance yard. The SWPPPs address the following:

- **Application of fertilizer, pesticides, and herbicides** including the development of nutrient management and integrated pest management plans. Several City staff members are licensed to apply pesticides and herbicides. They receive regular training and recertification. The City adopted an Integrated Pest Management Plan in December 2009.
- **Sediment and erosion control**. The City has five CESCL certified maintenance workers. The City Public Works Inspector, Building and Fire Official, Operations Managers and two Project Engineers are also CESCL certified.
- **Landscape maintenance and vegetation disposal**. Training in the area of appropriate practices for landscape maintenance and vegetation disposal is being considered. Staff members will be trained to implement procedures while performing landscape maintenance that will greatly reduce or eliminate pollutant discharges into stormwater.
- **Trash management**. The City of Snohomish contracts with a private hauler for the collection of solid waste and recyclable materials. The City will review its current contract and will look for language that obligates the contractor to reduce pollutants in discharges during the collection process. The City will consider placing requirements in future solid waste contracts to further reduce pollutants generated during the collection process.
- **Building exterior cleaning and maintenance**. The City of Snohomish is aware of the impacts to water quality that can be caused by building exterior cleaning and maintenance. Training has been conducted for the staff members that provide exterior cleaning and maintenance at City facilities. These staff members have been informed of BMPs available to reduce stormwater

impacts. On-going training will be provided as needed to ensure that proper BMP's are being used.

- **Heavy equipment maintenance or storage yards, and material storage facilities**. In accordance with the Permit, the City has developed and implemented SWPPPs for heavy equipment maintenance and storage yards, and material storage facilities owned or operated by the City in areas subject to the Permit. Copies are available from the Public Works Department.

Employee Training Program

The Permit requires owners to develop and implement an on-going training program for employees whose construction, operations or maintenance job functions may impact stormwater quality. The training program shall address the importance of protecting water quality, the requirements of the Permit, operation and maintenance standards, inspection procedures, selecting appropriate BMPs, ways to perform their job activities to prevent or minimize impacts to water quality, and procedures for reporting water quality concerns, including potential illicit discharges. The City has conducted numerous trainings to date and will continue with its ongoing training program. City staff will seek opportunities to train with other jurisdictions to reduce costs and benefit from the knowledge and skills of other jurisdictions. The City routinely documents and maintains records of training provided.

Record Keeping

The City presently maintains a record of all repair and maintenance activities conducted by its staff in accordance with the Permit. Efforts were undertaken in 2012 to incorporate these records into an electronic format that can be imported to the GIS system. Currently the City is in the process of labeling its catch basins and pipes so that maintenance documentation can be incorporated more easily into GIS.

5.2.6 Compliance with TMDL Requirements

In accordance with the Permit, the City conducts monitoring to determine the effectiveness of the SWMP to control stormwater-related problems that are directly addressed by actions in the SWMP. This component of the monitoring program was designed to answer the following types of questions:

- How effective is a targeted action or narrow suite of actions?
- Is the SWMP achieving a targeted environmental outcome?

A Stormwater Management Program Effectiveness Monitoring Plan was prepared in accordance with Permit requirements (Gray and Osborne, 2010).

Total Maximum Daily Loads (TMDLs) apply to the Snohomish River; therefore, the City is required to comply with TMDL requirements. In 2008, the City of Snohomish began the required water quality monitoring in accordance with the Quality Assurance Project Plan (QAPP) that the City prepared and Ecology approved. Monthly collection and analysis of water quality sampling at the locations identified by the QAPP is ongoing.

The Bacterial Pollution Control Plan (BPCP) (City of Snohomish 2010) was prepared to comply with TMDL permit requirements and addresses topics including but not limited to pet waste ordinance, water pollution control enforcement, educational programs directed at reducing bacterial pollution, investigation and implementation of methods that prevent stormwater bacterial pollution through treatment, reducing runoff volumes, and preventing additional sources of stormwater in association with new development, implementation of activities in the Snohomish Watershed Management Plan

5.3 LOW IMPACT DEVELOPMENT FEASIBILITY

Low Impact Development (LID) is a design approach to manage stormwater runoff as close to its source as possible and helps to protect and restore water quality. LID Best Management Practices (BMPs) are used to reduce runoff flow rates by supporting infiltration and providing water quality benefits by filtering pollutants. BMPs used for LID may include porous pavement, rain gardens, bioretention facilities, vegetated rooftops, infiltration trenches, dispersion systems, and rainwater harvesting. These types of LID solutions are described in Volume V, Section 5.3.1 of the 2005 Ecology Manual. Applications, limitations and design guidelines are also provided. The 2012 Low Impact Development Technical Guidance Manual for Puget Sound provides additional information related to LID BMPs.

To determine if LID applications can be used for a project or area, the site soils need to be evaluated. The NRCS has made available soil surveys which provide detailed soil reports including engineering properties, such as typical soil types, soil gradation, and infiltration rates. For future development and redevelopment within the City of Snohomish, an LID feasibility map was prepared for the areas within each basin, see Figure 2. Soil information based on the NRCS Survey for Snohomish County (see Section 3.3) was referenced. Soil types listed from the soil survey were evaluated for their overall suitability for LID implementation. For this evaluation, suitability was based on the four hydrologic soil groups that have been established by NRCS.

Soils are classified into hydrologic soil groups to indicate the minimum rate of infiltration obtained for bare soil after prolonged wetting. The infiltration rate is controlled by the surface conditions and is the rate at which water enters the soils surface. There are four hydrologic soil group, which are A, B, C and D. The four groups are defined as follows:

- Group A soils have low runoff potential and high infiltration rates even when thoroughly wetted. The infiltration rates for these soils are greater than 0.3 inches per hour. These soils consist of well to excessively drained sands or gravels.
- Group B soils have moderate infiltration rates when thoroughly wetted. Infiltration rates for these soils are 0.15 to 0.3 inches per hour. These soils consist of moderately well to well drained soils with moderately fine to moderately coarse textures with moderately slow to moderately rapid permeability.
- Group C soils have low infiltration rates and consist of soil with a layer that impedes downward movement of water. Group C soils have an infiltration rate of 0.05 to 0.15 inches per hour and consist of soils with moderately fine to fine texture.
- Group D soils have high runoff potential and very low infiltration rates. The infiltration rate is approximately 0 to 0.05 inches per hour. Soils in this group could be due to a high water table that creates a drainage problem. These soils consist of clay soils with high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at the surface, and shallow soils over nearly impervious material.

The texture and structure of the soil as well as vegetation impact the rate of which the infiltration occurs. Soil groups A through D range in infiltration rates. Gravel and sandy material allow for the most infiltration. These soil types have large pore sizes which allow water to move quicker between the soils. Vegetation also increases the infiltration by making the soil more porous. Clay soils have the lowest infiltration rates due to its small pores and impermeable properties. The infiltration is slow or fully prevented and the water is forced to runoff.

An important design element for an LID practice is the depth from the base of the LID measure to seasonal groundwater, because LID promotes infiltration of stormwater. If there is a high groundwater table, surface water will not be allowed to infiltrate regardless of soil conditions.

Figure 2: Soil Type Suitability for Low Impact Development was developed as an initial screening tool to evaluate soil type and typical infiltration rates to help determine if soils in a particular area might be suitable for LID. In general, the higher the infiltration rate, the more suitable the soil is for LID. This map should be used for planning purposes; guidance on how to determine infiltration rates for design purposes can be found in the LID Technical Guidance Manual (Puget Sound Partnership 2012). LID design guidance and field investigation requirements for development and redevelopment are also provided in the 2005 Ecology Manual.

6.0 PROBLEM IDENTIFICATION AND SOLUTION DEVELOPMENT

6.1 GENERAL

This section describes conveyance system related surface water problems in the study area, the methodology used to identify them, and the alternative solutions.

Conveyance system problems include occurrences such as flooding, channel erosion, and damaged or substandard storm drainage systems. System problems such as flooding and channel erosion may be the result of:

- Uncontrolled runoff from developed areas.
- Inadequate channel or pipe capacities or material failures in existing storm drainage systems.
- The loss of flood reducing storage capacity in natural depressions and riparian areas.

The locations of the conveyance system problems identified for this Plan are shown in Figure 1: Basin Map.

6.2 PROBLEM IDENTIFICATION METHODOLOGY

Developing a comprehensive summary of stormwater problems in the study area involved a combination of conducting a public meeting, several meetings with City staff, field observations, and technical analysis. Detailed descriptions of the information sources used and technical investigations performed are described in the following paragraphs.

6.2.1 Public Input

The public meeting held to solicit input from the public related to drainage problems was advertised in a notice posted in the Everett Herald on two occasions, each one and two weeks prior to the public meeting, on the City's website, and in the City Manager's newsletter. The meeting was also advertised by posting flyers at City Hall, City Engineering Office, and the City Library.

The notice and flyers described the stormwater comprehensive plan update and requested individuals to attend a public meeting, November 27th, 2012, to help identify existing drainage problems. Problem identification input forms were available at the public meeting for the participants to use to help identify problems. Several maps were also presented at the Public meeting illustrating known existing problems and potential solutions.

6.2.2 Input from City Staff

Both the City engineering staff and the maintenance personnel provided input on problems. City staff provided input on the type, size and condition of existing systems; knowledge of historical flooding; and feedback on practical and cost-effective solutions.

6.3 STORMWATER PROBLEM AREAS

6.3.1 Area C-1: 87th Avenue SE (Sinclair Avenue)

During heavy rainfall events water ponds on the right of way and private property at the northeast corner of the intersection. Surface water runoff from 87th Avenue SE and properties located north of 50th Street and along the east side of 87th Avenue drains into the 87th Avenue frontage ditch. The ditch slopes north to south and terminates at the northeast corner of the intersection. Water from the ditch enters a 12-inch culvert and empties into a ditch on the west side of 87th Avenue. The east end of the culvert is approximately 6 inches higher than the west end. From the west end of the culvert, the ditch extends westward approximately 30 to 50 feet before turning south. The ditch meanders south and terminates in a small basin located at the northwest corner on 87th Avenue SE and Bickford Avenue. From this location storm water flows south along Bickford Avenue through a series of culverts and ditches (see Figure C-1).

As reported by City staff, it appears that stormwater runoff from two commercial properties located west of 87th Avenue SE is trenched to the existing west side ditch paralleling 87th Avenue SE. The trench terminates at the west end of the 87th Avenue culvert. It is not known if the existing west side ditch was intended or checked to see if it could accommodate the runoff from the two commercial properties.

6.3.2 Area C-2: Swifty Creek (at Second Street)

Swifty Creek begins at the outlet from Blackmans Lake and flows through a series of open channels, culverts, and pipelines to a diversion structure at Maple Avenue and Sixth Street (Freshman Campus). The diversion structure diverts low flows and a majority of high flows to the Pilchuck River, via a pipeline. The diversion structure does allow some overflows into Swifty Creek. From the diversion structure, Swifty Creek flows through a combination of open channels, pipelines, and culverts before discharging into the Snohomish River.

The downstream-most segment of Swifty Creek is conveyed within a series of storm drain pipes. The 24-inch diameter pipeline begins approximately 150 feet north of Second Street, behind the AA Rental property (between Union and Cedar Avenues) and ends at the Snohomish River. The pipeline is approximately 1,300 feet long and the majority of the pipeline is located under private property. Due to poor pipe condition and/or partial pipe blockage, flow in the pipeline backs up creating a deep backwater pond at the pipeline entrance. Backwater conditions occur during wet and dry conditions, indicating groundwater infiltration into the open sections of Swifty Creek.

The City has made several attempts to inspect the pipeline via closed circuit televising. The first attempt started at a manhole located approximately in the middle of the pipeline and on private property, near Pearl Street. Due to rock and debris within the pipeline, the City was unable to video the pipeline in the northern direction. The second attempt was made from a manhole located downstream of First Avenue, near the Snohomish River. The manhole was located on City property. The City was able to video the pipeline to the north, until reaching the manhole near Pearl Street. At this point the video camera was unable to proceed because of the rock and debris in the pipeline. The video of this section indicated fractures in the pipe. Since the majority of the pipeline access manholes are located on private property and adequate space for vehicles and cleaning equipment is not available, the City is not able to maintain sections of the pipeline. In areas where the City has adequate access, periodic removal of large woody debris and tires has occurred near the pipeline entrance. Since a majority of the pipeline is located under private property, including buildings, inspection, maintenance, repair or replacement of damaged pipe sections is not feasible (see Figure C-2).

6.3.3 Area C-3: Maple Avenue (Unopened Fairview Street)

A small ditch approximately 100 feet long receives stormwater runoff from the upper Suncrest Drive, via a pipeline, and the adjacent hillside to the north. The ditch is located on the north side of the unopened Fairview Street. The street intersects with Maple Avenue and is approximately 270 feet long. The street slopes toward Maple Avenue, with a slope of about 16 percent. The street surface is gravel and rock. The lower portion of the street provides access to a single family residence while the upper section provides access for the City to maintain the ditch and storm drain system.

Stormwater in the ditch enters a driveway culvert and flows through a series of small ponds and connecting culverts on private property before entering a final pipe section that connects to the existing storm drain manhole in Maple Avenue. During high stormwater runoff events, water flow in the ditch backs up and overflows the ditch at the upstream end of the driveway culvert. It appears that the private pond/culvert system is inadequate to accommodate all of the ditch flow during large storm events. The ditch overflow sheet flows down the gravel and rock street surface, eroding the street surface and depositing gravel, rock, and fine particle material on the sidewalk and Maple Avenue (see Figure C-3).

6.3.4 Area C-4: Park Avenue/Blackmans Lake

Stormwater runoff from Park Avenue and adjacent properties empty into the roadside ditches along Park Avenue. The west side ditch, north of 19th Street, enters a culvert crossing 19th Street at Park Avenue. The culvert ends at a catch basin located at the southwest corner of Park Avenue and 19th Street. From the catch basin a 12 inch storm drain pipeline continues south within Park Avenue right of way for approximately 175 feet and terminates at a manhole. A 36 inch pipeline extends from the manhole and ends at Blackmans Lake (see Figure C-4).

During large storm events, stormwater flow from the roadside ditch exceeds the capacity of the 12 inch pipeline. As a result, stormwater backs up in the catch basin and exits the grated top. The released stormwater sheet flows in a southwesterly direction and onto private property. On at least one occasion, stormwater entered a garage.

6.3.5 Area C-5: Two problems: 16th Street and Holly Vista Drive

Area 5a: 16th Street. There is currently no storm drainage system along 16th Street, from Pine Avenue to Terrace Avenue. During large storm events, stormwater ponds within the right of way and approaches private properties (see Figure C-5a).

Area C-5b: Holly Vista Drive. Originally, stormwater collection and conveyance along Holly Vista Drive was provided by open ditches. Over time, a number of the ditches were filled by private homeowners. Currently, there is no storm drainage system along Holly Vista Drive. Several open ditch sections remain but there is no outlet for the ditch sections. Stormwater runoff is via sheet flow from the northeast to the southwest direction. Runoff crosses Holly Vista Drive and sheet flows across residential properties located along the west side of Holly Vista Drive (see Figure C-5b).

6.3.6 Area C-6: Cypress Avenue

Extending north from Fourth Street, Cypress Avenue ends at a private roadway for several homes. Three shallow catch basins located near the north end of Cypress Avenue drain to a catch basin in the private roadway. From the private catch basin stormwater is routed to the west towards an adjacent private property. The route of the storm drain pipeline from the private catch basin is unknown but the City believes it eventually connects into the storm drain main located along Pine Avenue (see Figure C-6).

During heavy or prolonged storm events the catch basin in the private roadway clogs with debris and causes the catch basins in Cypress Avenue to overflow. The overflow runoff flows onto private property. City maintenance crews clean the private catch basin to relieve the overflow problem in the City catch basins on Cypress Avenue.

6.3.7 Area C-7: Third Street and Avenue D

The gutter catch basin located at the northeast corner of Third Street and Avenue D does not drain properly due to the poor condition of the storm drain pipe from the catch basin. Stormwater runoff backs up in the catch basin and ponds in the roadway intersection. Age and tree roots from a nearby tree has compromised the integrity of the storm drain pipe (see Figure C-7).

6.3.8 Area C-8: Grove Street

There is no stormwater collection system along Grove Street. The south side of Grove Street has concrete curb, but the north side does not. Stormwater flows more readily along the south side gutter to the catch basins located on Lincoln Avenue. Stormwater ponding occurs in areas along the street edge and in the right of way near private property. One area in particular is the property located at the southwest corner of Grove Street and Lincoln Avenue. Water ponds behind the recessed driveway curb and approaches the private property during storm events (see Figure C-8).

6.3.9 Area C-9: Baird and Victor Avenues

There is no stormwater collection system along Victor and Baird Avenues. Water ponds within the paved streets. Several properties along both avenues are at or below street grade and during large rain events runoff from the roads flow towards these properties (see Figure C-9).

6.3.10 Area C-10: Short and Long Streets

There is no stormwater collection system along Short and Long Streets. The streets and surrounding area is basically flat and does not promote natural or positive drainage. Water ponds along the streets and the right of way areas. Another factor impacting drainage along Short Street is Short Street is not paved. Small to moderate potholes form in the gravel street and trap stormwater (see Figure C-10).

6.3.11 Area C-11: Bonneville Avenue

There are two areas of water ponding along Bonneville Avenue near Bickford Avenue. Both ponding areas are in driveways at the entrance to Bonneville Avenue. One driveway is for a private residence and the other is for a commercial property (see Figure C-11).

6.3.12 Area C-12: Blackmans Lake Outlet Control Project

Properties adjacent to Blackmans Lake have experienced flooding problems due to the variations of the lake water level. Silt accumulation and vegetation growth in the outlet channel (Swifty Creek) has restricted the discharge from the lake which results in rising water levels during storm events. The outlet channel is located at the south end of the lake. Discharge water from the lake also flows through a series of culverts which have decreased in capacity due to sediment accumulation. There is also a series of culverts which have decreased in capacity due to sediment accumulation causing backwater to occur.

6.4 HYDROLOGIC AND HYDRAULIC ANALYSIS

Overall hydrologic and hydraulic computer analysis for the planning area is described in Chapter 4. This section describes stormwater modeling conducted for several problem areas. Solutions for smaller problem areas were estimated. The specific problem areas that underwent hydrologic and hydraulic modeling are listed below (see Appendix D for calculations):

- Area C-1: 87th Avenue SE (Sinclair Avenue)
- Area C-3: Maple Avenue (Unopened Fairview Street)
- Area C-4: Park Avenue/Blackmans Lake
- Area C-5: 16th Street and Holly Vista Drive

The majority of the stormwater problems in the City are conveyance related and result in ponding or flooding of stormwater that have led to concerns of public safety, flooding of private property, water quality, and the need for additional operation and maintenance to inspect, maintain/unplug, and repair City infrastructure.

There are several stormwater conveyance pipes within the storm drainage system that have been identified for upgrades. The larger basin map shown on Figure 1 identifies the 12 projects that have been identified by City staff and the public. Conveyance related issues were evaluated in a similar manner.

The existing land use designations from the 2011 City Land Use Map (City of Snohomish 2010) and the 2012 land use designations from the Snohomish County's comprehensive plan (Snohomish County 2012) were used in ARCGIS to identify the land use designation for each problem area. Single family residential land use was assumed to be multifamily, 50% pervious and 50% impervious (Taylor, 1993). The areas analyzed were mostly developed and may fall under high density residential land use. The pervious portions were assumed to be in good condition with grass cover on more than 75% of the area, resulting in a curve number of 86. The right-of-way area was assumed to be paved, with a curve number of 98.

The Engineering Design and Construction Standards (City of Snohomish 2004) requires new conveyance elements to be sized for 25-year, 24-hour storm and checked for 100-year storm to verify that excessive erosion or flooding does not occur. New stormwater conveyance pipes were sized by computing the peak flow resulting from 24-hour duration, 25- and 100-year recurrence interval storms, using the Santa Barbara Unit Hydrograph (SBUH) method.

The land use areas estimated in ARCGIS were separated into pervious and impervious areas for input into SBUH spreadsheet. A Type 1A unit hydrograph was used, appropriate for Western Washington. The precipitation for the 2-, 25- and 100-year storm events was determined by using NOAA Atlas 2 isopluvial maps. Time of concentration was estimated using methodology defined in TR-55 (USDA NRCS Technical Release 55).

Bentley Systems, Inc. FlowMaster, 2008 software was used to size new pipes, based on the peak 25-year 24-hour storm. The pipes were graded so that they can gravity drain to the connection point. Slopes were based on the existing topography as provided by the available data in GIS. Systems were checked using the 100-year peak flow to evaluate the proposed solution for flooding or erosion.

Modeling was conducted for the Blackmans Lake Outlet Control Project and is described in the document entitled, "Blackmans Lake Level Evaluation; Summary of Outlet Analysis", (Tetra Tech 2008).

6.5 PROBLEM AREA IMPROVEMENT RECOMMENDATIONS

Recommended improvements are described in the following subsections. Projects were evaluated and compared based on several categories, including potential impacts to wetlands, challenges with easement

acquisition, potential impacts to fish/wildlife habitat and water quality, constructability, operation and maintenance, perception of public acceptance, ability to obtain permits. A project summary sheet including overall score and estimated costs is included in Appendix A. Construction costs were estimated and are presented in Appendix B. Table 6-1: Proposed Drainage Improvements includes a summary for each project.

6.5.1 Area C-1: 87th Avenue SE (Sinclair Avenue)

In order to alleviate the ponding problem at the northeast corner of 87th Avenue SE and 50th Street, approximately 400 linear feet of 12- to 16-inch diameter storm drain pipeline would be installed from the outlet end of the culvert crossing 87th Avenue SE to the storm drain conveyance system along Bickford Avenue. The pipeline can be installed along the west shoulder of 87th Avenue SE. Eliminating the runoff from businesses located west of 87th Avenue SE from accessing the culvert crossing 87th Avenue SE is needed to control flooding within the ROW and to nearby private property. The access ditch would be redirected and runoff from the west properties would utilize an existing ditch that empties into the Bickford Avenue drainage system (see Figure C-1). This recommended improvement would restore the public stormwater system that historically flowed to Bickford Avenue.

6.5.2 Area C-2: Swifty Creek (at Second Street)

The repair or replacement of the existing 24-inch Swifty Creek storm drain pipeline from Second Street to a manhole located south of the intersection of First Street and Union Avenue is not feasible because a majority of the pipeline is on private property. A new pipeline within city right of way and an acquired easement could be constructed. The easement would need to be secured for approximately the first 180 to 200 linear feet of pipeline to cross one private property adjacent to Second Street. The remaining 800 linear feet or so of pipeline would be constructed along Glen and Union Avenues and crossing First and Second Streets. The lower end of the new pipeline would connect into an existing 60-inch manhole, where the existing 24-inch pipeline extends to the Snohomish River. The existing 24-inch pipeline would be plugged at the Swifty Creek end and at the existing 60-inch manhole. Approximately 4 new manholes would be installed at horizontal bends along the pipeline route (see Figure C-2). Additional catch basins would be installed along Union Avenue, between First and Second Streets, which would empty into the proposed storm drain pipeline. The additional catch basins would improve drainage along Union Avenue. Also, existing catch basins along Glen Avenue would be removed from the combined sewer system and connected into the new pipeline.

6.5.3 Area C-3: Maple Avenue (Unopened Fairview Street)

The largest contributor to the ditch overloading and subsequent overflow along the unopened section of Fairview Street is the storm drain system from the Suncrest Drive neighborhood. To remove this runoff load from the ditch, a new 12-inch storm drain pipeline would be installed to bypass the ditch and empty directly into the storm main located in Maple Avenue. The pipeline, approximately 280 linear feet, would originate at the existing receiving manhole for the Suncrest Avenue neighborhood runoff and discharge into the Maple Avenue storm main, via a new manhole. The new pipeline would be installed within the unopened gravel Fairview Street right of way (see Figure C-3).

6.5.4 Area C-4: Park Avenue/Blackmans Lake

The existing 12-inch storm drain pipeline, from the catch basin located at the southwest corner of Park Avenue and 19th Street to the Blackmans Lake inlet manhole, would be replaced with a 24-inch pipeline. The replacement pipeline would be approximately 180 feet in length. The existing catch basin and manhole would be replaced if they were determined to be undersized (see Figure C-4).

6.5.5 Area C-5: Two projects: 16th Street and Holly Vista Drive

Area C-5a: 16th Street. A stormwater collection and conveyance system would be installed along 16th Street, from Terrace Avenue to Pine Avenue. The system would consist of approximately 6 to 8 properly

located catch basins along both sides of the roadway and a 12-inch storm drain pipeline (approximately 285 feet in length) that would receive stormwater from the catch basins. The pipeline would empty into the Pine Avenue roadway ditch (see Figure C-5a).

Area C-5b: Holly Vista Drive. The drainage improvements associated with Holly Vista Drive can be divided into three sections:

- Holly Vista Drive (north of 16th Street) and 16th Street (between Terrace Avenue and Holly Vista Drive),
- Holly Vista Drive (south of 16th Street), and
- Unopened Terrace Avenue (from 15th Street/Suncrest Drive to 16th Street)

Improvements along Holly Vista Drive north and 16th Street would involve constructing a 12- to 18-inch storm drain pipeline along the west shoulder of Holly Vista Drive. This pipeline section would be approximately 550 feet in length. The pipeline would turn west on 16th street and extend approximately 75 feet to an existing manhole at Terrace Avenue. Approximately 9 to 12 catch basins and 2 to 3 storm manholes would be installed. Stormwater collected in the new system would flow through a series of existing ditches and pipes to the proposed stormwater improvements for the unopened Terrace Avenue.

The Holly Vista Drive south improvement section would involve constructing a 12- to 18-inch storm drain pipeline along the west shoulder of Holly Vista Drive for approximately 180 feet to the cul-de-sac at the south end of Holly Vista Drive. From the cul-de-sac, the pipeline would extend southwest through a platted utility easement approximately 170 feet, to an existing storm drain manhole located on Suncrest Drive. The 170-foot pipe section would be installed within an existing city easement. Approximately 4 to 6 catch basins and 2 to 3 storm drain manholes would be installed.

The improvements along the unopened section of Terrace Avenue would involve installing approximately 430 linear feet of 12- to 18-inch storm drain pipeline from an existing manhole on 16th Street to an existing storm manhole on Suncrest Drive. Prior to reaching the manhole on Suncrest Drive the storm drain pipeline would enter an approximate 8-foot diameter by 100-foot long pipe detention vault and exit the vault to the manhole. The detention vault would be needed to control the additional flow from the Holly Vista Drive area to the existing stormwater drainage system downstream of the manhole and prevent overloading of the existing system. Stormwater from this area would enter the drainage system improvements for Area C-3 (Maple Avenue Washout Area) and empty into the 12 inch stormwater main located on Maple Avenue. The Suncrest drive manhole would be same manhole utilized by the storm drain pipeline for the Holly Vista Drive south section. Also, the existing storm drain outlet for Terrace Avenue to an existing ditch extending along the unopened Terrace Avenue road section would be removed. Terrace Avenue drainage would flow through the new storm drain pipeline. The unopened Terrace Avenue section is cleared and covered with grass and weeds (see Figure C-5b).

6.5.6 Area C-6: Cypress Avenue

Three existing shallow catch basins on the north end of Cypress Avenue drain to a common catch basin located in a private road. The private catch basin is not properly maintained and plugs periodically. The proper operation of the Cypress Avenue catch basins is dependent on the private catch basin.

On the south end of Cypress Avenue, six shallow catch basins drain into the existing CSO pipeline that extends north/south along Cypress Avenue. To improve drainage and eliminate the maintenance issues associated with the three north end catch basins, replacing the catch basins with larger and deeper ones and installing new pipelines are proposed. The catch basin flows would be redirected and connected into the five catch basin system that drains into the CSO pipeline. The proposed solution is presented on Figure C-6.

The improvements would drain additional water into the CSO system. Two other options were considered that would not place additional stormwater flows into the CSO system but they were not feasible. One option was to reroute the flow from the three north catch basins, via a pipeline, to the existing storm main located at Fourth Street and Pine Avenue. Due to the shallow depth of the Pine Avenue storm main (approximately 4 feet) and Pine Avenue being approximately 12 to 18 inches higher than Cypress Avenue, a proper slope or grade would not be achievable for the new pipeline. The second option was to create a new stormwater outfall to the Pilchuck River at the east end of Fourth Street and reroute the flow from the north catch basins to the outfall. This option was not selected based on the following environmental constraints: the slope from the end of Fourth Street down to the river is very steep and potentially unstable; wetland impacts along the toe of the slope may occur by extending an outfall to the river; and the river is regulated under the Endangered Species Act.

6.5.7 Area C-7: Third Street and Avenue D

Age and tree roots have impacted the flow through a storm drain pipe that services the northeast gutter catch basin at the intersection of Avenue D and Third Street. The existing pipe section would be replaced with a 12-inch pipe. The pipe would be cased inside of a steel casing pipe. The casing pipe would protect the carrier pipe from tree roots (see Figure C-7).

6.5.8 Area C-8: Grove Street

A stormwater collection and conveyance system would be installed along Grove Street, from Lincoln Avenue to Pine Avenue. The system would consist of approximately 6 to 8 properly located catch basins along both sides of the roadway and a 12- to 15-inch storm drain pipeline (approximately 300 feet in length) that would receive stormwater from the catch basins. The pipeline would empty into the Lincoln Avenue storm main, via a new manhole (see Figure C-8).

6.5.9 Area C-9: Baird and Victor Avenues

A stormwater collection and conveyance system would be installed along Baird and Victor Avenues, from Seventh Street to Eighth Street. The combined system would consist of approximately 16 to 18 properly located catch basins along both sides of the roadways, 12- to 15-inch storm drain pipelines (approximately 800 feet in length), and two manholes at the connection location of the new storm pipelines to the existing 30 inch storm main located in Seventh Street (see Figure C-9).

6.5.10 Area C-10: Short and Long Streets

A stormwater collection and conveyance system would be installed along Short and Long Streets, from Mill Avenue. The combined system would consist of approximately 18 to 20 properly located catch basins along both sides of the roadways, 12- to 15-inch storm drain pipelines (approximately 900 feet in length), and two connections at existing catch basins in Mill Avenue. Since Short Street is not paved the final lift of the trench backfill would consist of 4 inches of crushed surfacing base course material. The street may be paved at a future under the City's paving program or as part of the Transportation Benefit District. (see Figure C-10).

6.5.11 Area C-11: Bonneville Avenue

A catch basin would be installed at the driveway low point within the road right of way. Water collected by the catch basins would empty into the existing storm main located across the street via a 12" to 15" inch pipe (see Figure C-11).

6.5.12 Area C-12: Blackmans Lake Outlet Control Project

The Blackmans Lake Level Evaluation; Summary of Outlet Analysis (Tetra Tech 2008) describes the analysis that was completed to develop the proposed improvements to resolve the flooding issue. The

improvements consist of the installation of a weir to control the lake level, channel improvements including sediment removal, culvert replacement and culvert sediment removal. Estimated project cost is $528,000 (Tetra Tech 2008). Design of the improvements is currently underway.

Table 6-1 Proposed Drainage Improvements

Project	Location	Problem	Proposed Improvement	Estimated Cost	Overall Score [1]
C-1	87th Avenue SE (Sinclair Avenue)	Flooding at intersection of 50th Street and Sinclair Ave. Flood water approaches private property.	Construct new storm drain pipeline along 87th Avenue from 50th Street to Bickford Avenue.	$78,000	20
C-2	Swifty Creek (at Second Street)	Damaged/obstructed existing storm drain pipeline located in private property. Safety and flooding is of concern for adjacent properties.	Construct a new pipeline within City right of way along Glen and Union Avenues, from Second St. to First St.	$468,000	51
C-3	Maple Avenue (Unopened Fairview Street)	Undersized ditch on private property overflows down the gravel surfaced Fairview Drive and causes erosion and sedimentation. Safety, flooding of private property, and maintenance concerns.	Construct a 12-inch storm drain pipeline from the ditch to the existing storm main located in Maple Avenue.	$60,000	15
C-4	Park Avenue/ Blackmans Lake	Undersized storm drainage pipeline backs up and causes flooding of private property.	Replace the existing 12” storm drain pipeline with a 24” pipeline.	$62,000	15
C-5a	16th Street	There is no drainage system on this section of 16th Street. Flooding of private property is of concern.	Construct catch basins and 12” storm drain lines; connect to the roadside ditch along Pine Ave.	$122,000	17
C-5b	Holly Vista Drive	There is no drainage system along Holly Vista Drive. Flooding of private property is of concern.	Construct catch basins and 12” storm drain lines; connect to existing storm manhole on Suncrest Dr. Provide detention system due to limited downstream conveyance capacity.	$394,000	19
C-6	Cypress Avenue	The north end of Cypress Ave. drains to a private catch basin that plugs and requires maintenance. Flooding of private property is of concern.	Reroute storm flows south to existing storm main that connects to a CSO pipeline on Cypress Ave.	$77,000	17
C-7	Third Street and Avenue D	Stormwater ponds at this intersection because a pipe is damaged/obstructed by tree roots.	Replace with steel-cased pipe.	$14,000	15
C-8	Grove Street	There is no drainage system along Grove Street. Flooding of private property is of concern.	Construct catch basins and a 12” to 15” storm pipeline; connect to the existing storm main located on Lincoln Avenue.	$89,000	15
C-9	Baird and Victor Avenues	There is no drainage system along Baird and Victor Avenues. Flooding of private property is of concern.	Construct catch basins and a 12” to 15” storm pipeline that would tie into the existing storm main on 7th Street.	$234,000	15
C-10	Short and Long Streets	There is no drainage system along Short and Long Streets. Short Street is not paved and has several potholes. Flooding of private property and maintenance concerns.	Construct catch basins and a 12” to 15” storm pipeline; connect to existing storm main on Mill Avenue	$224,000	15
C-11	Bonneville Avenue	Water ponds in residential and commercial business driveways. Flooding concerns on private property.	Install new catch basin and connect to existing storm main across the street.	$10,000	18
C-12	Blackmans Lake Outfall Control Project	Sediments and/or vegetation partially blocking Lake outlet system (channel and culverts) and causing flooding of lakeside homes during storm events.	Remove the sediments and vegetation and replace old or damaged culverts.	$528,000	NA

[1] See Appendix A

7.0 SEPARATED STORM DRAINAGE SYSTEM FOR THE COMBINED SEWER AREA

7.1 GENERAL

The combined-sewer area in the City of Snohomish is located in the downtown historic district, in the south-southwest portion of the City. All sanitary sewer (sewer) pipelines in the combined-sewer area receive and convey sewer and stormwater flows. Contributors of stormwater flow include roof drains, plumbing drains, and storm drains (catch basins and inlets) along roadways. The combined-sewer area is approximately 248 (see Table 3-1) acres and is roughly bordered by First Street to the south, State trail on the southeast, Glen Avenue to the east, Fifth to Sixth Streets along the north, and State Route 9 to the west (see Figure 3).

The combined-sewer area is divided into two sub-basins, the gravity basin and the pump station basin (see Figure 4).

The sewer lines in the gravity basin empty into a sewer main located in Second Street, which extends west along Second Street, and terminates at the wastewater treatment plant. A combined-sewer overflow is associated with this basin. The overflow consists of a manhole and an 18" overflow pipe from the manhole to the Snohomish River. The manhole is located at Second Street and Avenue H. If the flow capacity of the sewer main is exceeded during large storm events, flow backs up into the manhole. Once the water level in the manhole reaches the overflow pipe invert, flow is diverted through the overflow pipe to the Snohomish River. This combined sewer overflow location is labeled CSO #1 on Figure 3.

A combined-sewer overflow is also associated with the pump station basin. The overflow consists of a manhole and a 24-inch diameter overflow pipe from the manhole to the Snohomish River. The overflow concept is similar to the gravity basin overflow. The manhole is located at Avenue E and First Street. This combined sewer overflow location is labeled CSO #2 on Figure 3.

In 2010-2011, improvements to the two combined-sewer sub-basins were constructed under the CSO Reduction Project. The improvements included:

- A new sanitary sewer/stormwater pump station was constructed to replace the original pump station, Pump Station No. 1, for the pump station basin. The new pump station is located at the City Shop site on First Street.
- New combined sewer main along Second Street, from Avenue H to the Wastewater Treatment Facility (WWTF).
- New sewer and storm water forcemain from the new pump station to the WWTF.
- A 30 inch stormwater main installed along Second Street, from Avenue H to the WWTF entrance. This pipeline was installed to accommodate stormwater flows for future CSO separation projects.

This project was constructed to provide additional combined-sewer flow capacity, increase pumping capacity, reduce CSO events, and provide a dedicated stormwater main to the treatment plant located on the west side of State Route 9. The future CSO separation projects would utilize the former wastewater lagoon at the WWTF as a stormwater quality treatment basin.

7.2 OPPORTUNITIES FOR CSO SEPARATION

As part of this stormwater comprehensive plan update project, the City requested that a potential CSO separation project be evaluated. The evaluation area is from Second Street to Fifth Street and Avenue E to Avenue L. The project would address disconnecting existing catch basins from sewer pipelines and reconnecting them to a new stormwater pipeline. The new stormwater pipelines would empty into the 30" storm main on Second Street. The project would also extend the 30" storm main to the former wastewater lagoon at the WWTF (See Figure C-12). The former wastewater lagoon is approximately 30 acres in size and would be converted to a stormwater quality treatment pond.

The lagoon has been closed to receiving wastewater and has been revegetated. Currently, thick vegetation covers the surface of the lagoon. A low point in the existing dike system around the lagoon, located in the southwest corner, allows high flows from the Snohomish River to enter the lagoon during flood events and allows water within the pond to discharge back to the river.

7.2.1 Water Quality Treatment Facility Options

There are two possible water quality treatment facility designs that could be implemented, including a stormwater wetpond or a stormwater treatment wetland. Design criteria for these two types of facilities are included in the Ecology Manual, Volume V: Runoff Treatment BMPs, Chapter 10 – Wetpool Facilities (Ecology 2005).

A wetpond is a constructed stormwater pond that retains a permanent pool of water at least during the wet season. The volume of the wetpool is related to the effectiveness of the pond in settling particulate pollutants. Peak flow control (detention) can be provided in the "live storage" area above the permanent pool.

There are two types of wetponds, basic and large. For the basic wetpond, the designed wetpool volume shall be equal to or greater than the total volume of runoff from the water quality design storm (the 6-month, 24-hour storm event). Alternatively, the design volume can be calculated based on the 91st percentile, 24-hour runoff volume indicated by an Ecology-approved continuous runoff model such as WWHM, HSPF, or MGS Flood. Large wetponds are designed for higher levels of pollutant removal. A large wetpond requires a wetpool volume at least 1.5 times larger than the total volume of runoff from the 6-month, 24-hour storm.

Wetpond design criteria includes the following:

- Two cells (with the first cell 25% to 35% of the wetpool volume).
- A berm or baffle separating the two cells.
- Access road and ramp to the first cell for cleaning and maintenance.
- Energy dissipation at the pond inlet.
- Large length to width ratio (wetpool flow length at least 3 times the width).
- Maximized flow length between the inlet and outlet to enhance treatment.
- Minimum depth of the first cell of 4 feet.
- Outlet control structure and emergency spillway.

A stormwater treatment wetland is a shallow man-made pond that is designed to treat stormwater through the biological process associated with emergent aquatic plants. Stormwater treatment wetlands are used to capture and transform pollutants, just as wetponds are, and over time pollutants will concentrate in the

sediment. Therefore, the facility would require maintenance including occasional harvesting of vegetation and sediment dredging from the facility.

A stormwater wetland design occupies about the same surface area as a wetpond, but has the potential to be better integrated aesthetically into a site because of the abundance of emergent aquatic vegetation. The most critical factor for a successful design is the provision of an adequate supply of water for most of the year. Careful planning is needed to be sure sufficient water will be retained to sustain good wetland plant growth. Since water depths are shallower than in wetponds, water loss by evaporation is an important concern. Stormwater wetlands are appropriate for areas with higher winter groundwater levels.

Stormwater treatment wetland design criteria include the following:

- Two cells (with the first cell 33% of the wetpool volume).
- A berm separating the two cells.
- Access road and ramp to the first cell for cleaning and maintenance.
- Energy Dissipation at the inlet to the first cell.
- The second cell or "wetland cell" shall have an average depth of about 1.5 feet and a maximum depth of 2.5 feet.
- Wetland cell can be uniformly graded or graded with a more natural sinuosity.
- The surface area of the stormwater treatment wetland shall be the same as the top area of a wetpond sized for the same site conditions.
- Minimum depth of the first cell of 4 feet.
- Outlet control structure and emergency spillway.

The selection of a wetpond (basic or large) versus a stormwater treatment wetland should be based on a site specific evaluation. Considerations for this facility should include the water quality of the inflowing stormwater. Another key consideration is the amount of operation and maintenance involved. A stormwater treatment wetland will rely on plant health more than a wetpond and periodically the plants will need to be removed and replanted.

Whether a stormwater treatment wetland or a wetpond is preferred, the existing pond facility should undergo a physical survey and inspection. The existing pond embankments and overflow from the pond should be observed to make sure the facility has adequate slope stability and erosion protection.

Another consideration during planning and design of the facility is to evaluate permit considerations related to the former wastewater lagoon. It is understood that the lagoon was closed several years ago. Documentation associated with closure should be reviewed to determine if there are any restrictions on redeveloping the pond into a stormwater treatment facility. Because the pond is presently open to the river for flood storage, use of the pond for treating stormwater from smaller rain events appears feasible.

7.2.2 Water Quality Treatment Design Storm

A preliminary hydrologic evaluation was completed to estimate the water quality design volume for a basic wetpond. Supporting documents and calculations are provided in Appendix D. The area from the Combined Sewer Overflow drainage area (approximately 248 acres) was modeled using WWHM. Land use characteristics used in modeling are described in Section 3.4. Based on existing zoning, the wetpool design volume was estimated to be approximately 23 acre-feet. It is assumed that the pond would be designed as an on-line pond with stormwater routed directly to the facility. Flows higher than the design storm event would be allowed to overtop through the existing spillway and discharge to the river. The 15-minute design flow rate for an on-line facility is 32.2 cfs. A design option could be to use a piped

high-flow bypass, which would result in a 15-minute design flow rate of 18.3 cfs. A high-flow bypass would add additional cost and is likely not necessary; thus, was not included.

Based on the BMPs employed by the City and Snohomish County within the study area, it is assumed that the water quality of the separated stormwater would be adequately treated in a basic wetpond, approximately 23 acres.

Future changes in zoning and land use were evaluated to determine the wetpond volume needed for a complete build-out of the 248 acre Combined Sewer Area. Assuming 100 percent impervious area, the wetpond volume would increase to 30 acre-feet.

If deemed necessary during the design phase, an influent water quality evaluation would help determine if a basic or large wetpond or treatment wetland is preferred. A large wetpond would require a wetpool size of 45 acre-feet (based on the future zoning assumption of 100% impervious area). The proposed facility design will need to allow room for sediment storage and freeboard. Per Ecology requirements, the first cell requires 1 foot of sediment storage. Freeboard will vary based on the design, but a minimum of 1 foot of freeboard should be considered during design.

The existing pond was observed during a recent site visit and it appears that the pond is approximately 30 acres in plan with a depth of approximately nine feet deep. Based on the size available, it appears that a stormwater wetpond or treatment wetland would fit within the existing foot print. The first cell may require excavation into the existing pond bottom to achieve the minimum required depth based on Ecology requirements.

Inlet and outlet control structures will be required depending on the design. An evaluation of the existing vegetation and vegetation needed for optimal stormwater treatment is also recommended.

Section 3.7 also describes known wetlands in the vicinity of the WWTF, which should be considered in the planning and design of retrofits to the existing pond.

7.2.3 Flow Conveyance to the Water Quality Treatment Facility

Stormwater runoff will be conveyed to the lagoon in the Second Street 30 inch stormwater main. Peak flows in excess of the water quality design flows conveyed to the lagoon will be allowed to bypass and overflow to the river. A high flow bypass is allowed for water quality treatment facilities in accordance with Ecology guidelines. Possible locations of a high flow bypass could include the existing 18-inch Avenue H outfall (CSO #1) or an overflow near the WWTF lagoon location.

Runoff from the First Street trunk will flow via gravity to a pump station at First Street and Avenue E. This flow will be pumped to the Second Street trunk. Peak flows in the First Street trunk that exceed the water quality treatment design flow rate (6-month, 24-hour storm) will be discharged directly to the river via the existing 24-inch outfall at Avenue E.

The major work items for the project would include:

- Extend the 30 inch storm main in Second Street east to Avenue E and west from the WWTF entrance to the old wastewater lagoon.
- Disconnect the Avenue F stormwater pipeline from the CSO pipeline on Second Street and reconnect it to the new 30 inch stormwater main.

- Extend a new 12 inch stormwater pipeline along Avenues E, G, H, I, and L from Fifth Street to the 30 inch stormwater main on Second Street and Avenue J from 7th Street to the 30 inch storm main.
- Install new 12 inch storm pipelines on Fifth Street and Riverview Lane and connect them to the new storm main along Avenue J.
- Disconnect the existing catch basins in the separation area and reconnect them to the new 12 inch stormwater pipelines.
- Install manholes at the connection points of the 12 inch stormwater pipelines to the 30 inch storm main along Second Street.
- Install new catch basins where needed to improve drainage.

7.2.4 Estimated Capital Costs

A preliminary cost estimate was developed for the major work items listed above and as shown on Figure C-13. The cost summary table is located in Appendix B. The estimated project cost, including construction, sales tax, engineering design, permitting, survey, contingency, and construction services, is $2.7 million.

Eliminating other stormwater sources to the existing sewer system, such as roof drains, could be added to this project in the future. Due to the uncertainty of the amount of roof drains and their locations, this work was not included in the preliminary cost estimate for this CSO separation project. Further evaluation would is recommended to quantify the number and location of roof drains that could be targeted for CSO separation.

8.0 RECOMMENDED PLAN

This section describes the City's evaluation process, the selected priority of stormwater improvement projects, and how the CIP will be funded over time.

Part of the evaluation process included preparation of a State Environmental Policy Act (SEPA) checklist which describes potential environmental impacts and considerations for the implementation phase. The SEPA checklist is presented in Appendix C.

8.1 STORMWATER UTILITY FUND

In October 2010, FCS Group prepared a Financial and Rate Forecast Update for the Water, Storm, and Wastewater Utilities (FCS Group 2010). Upgrades to the stormwater system identified in this plan will be funded through the stormwater utility and potential project related grants. The rate forecast was not updated for this plan.

The 2010 financial rate forecast for stormwater included the following assumptions:

- Study period: 2011 to 2016;
- Customer growth: 0.6%;
- Construction cost inflation: 4.0%;
- New revenue debt service: 30 years, 5.0% interest rate;
- Operating fund target: 60 days of O&M;
- Capital fund target: $300,000;
- Capital program of $3.2 million dollars (2011 dollars);
- New debt service of $85,000 in 2013, increasing to $170,000 in 2016.

The 2010 study concluded that stormwater rate increases were required to fund the $3.2 million in forecasted projects (see Table 8-1). Rate increases of 8.25% were adopted for years 2011 and 2012 and 5.1% for years 2013 to 2016. Over the timeframe of 2011 to 2016, average residential bi-monthly bills were estimated to range from $20.61 to $27.22 (see Table 8-2). Table 8-3 shows the distribution of funds for the stormwater utility based on the 2011 stormwater utility capital program.

Table 8-1 2011 Stormwater Utility Capital Program

Storm Utility Capital Program (2011$)							
Storm	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Total**
Stormwater (SW) Overlay Coordination Program	$ -	$ -	$ -	$ 200,000	$ -	$ -	**$ 200,000**
SW Comprehensive Plan	-	-	250,000	-	-	-	**250,000**
SW Decant Facility - Property and Construction	-	225,000	-	-	-	-	**225,000**
Annual SW Misc. Repairs	-	-	100,000	100,000	100,000	100,000	**400,000**
Phase II CSO - Design	-	-	-	400,000	-	-	**400,000**
Phase II CSO - Constuction	-	-	-	-	-	1,100,000	**1,100,000**
Stoneridge Outfall Replace	120,000	-	-	-	-	-	**120,000**
Blackman's Lake Outlet Control	123,000	377,000	-	-	-	-	**500,000**
Total Storm	**$ 243,000**	**$ 602,000**	**$ 350,000**	**$ 700,000**	**$ 100,000**	**$ 1,200,000**	**$ 3,195,000**

(Reference: FCS Group 2010)

Table 8-2 Stormwater: Operating

Revenue Requirements	2011	2012	2013	2014	2015	2016
Revenues						
Rate Revenues Under Existing Rates	$ 770,000	$ 774,330	$ 778,660	$ 782,990	$ 787,320	$ 791,650
Non-Rate Revenues	112,000	3,802	3,384	3,484	3,600	3,721
Total Revenues	**$ 882,000**	**$ 778,132**	**$ 782,045**	**$ 786,474**	**$ 790,920**	**$ 795,371**
Expenses						
Cash O&M Expenses	$ 770,948	$ 686,283	$ 706,493	$ 729,996	$ 754,508	$ 780,089
Existing Debt Service	-	-	-	-	-	-
New Debt Service	-	-	84,854	84,854	84,854	169,709
Additions to meet Min. Op. Fund Balance	-	-	-	-	-	-
Rate Funded System Replacement	100,000	100,000	140,000	180,000	180,000	180,000
Total Expenses	**$ 870,948**	**$ 786,283**	**$ 931,348**	**$ 994,851**	**$ 1,019,362**	**$ 1,129,798**
Net Surplus (Deficiency)	**$ 11,052**	**$ (8,151)**	**$ (149,303)**	**$ (208,376)**	**$ (228,442)**	**$ (334,427)**
% of Rate Revenue	0.00%	1.36%	19.52%	27.05%	29.56%	42.89%
Annual Rate Adjustment	**8.25%**	**8.25%**	**5.10%**	**5.10%**	**5.10%**	**5.10%**
Rate Revenues After Rate Increase	$ 833,525	$ 907,365	$ 958,973	$ 1,013,486	$ 1,071,064	$ 1,131,879
Additional Taxes from Rate Increase	$ 1,143	$ 2,395	$ 2,705	$ 3,457	$ 4,256	$ 5,103
Net Cash Flow After Rate Increase	**73,434**	**122,489**	**28,305**	**18,662**	**51,046**	**699**
Coverage After Rate Increases	n/a	n/a	2.98	3.67	3.86	2.14
Average Residential Bi-Monthly Bill	$ 20.61	$ 22.31	$ 23.45	$ 24.64	$ 25.90	$ 27.22
Bi-Monthly Difference	1.57	1.70	1.14	1.20	1.26	1.32

(Reference: FCS Group 2010)

Table 8-3 Stormwater: Funding

Fund Balance	2011	2012	2013	2014	2015	2016
Operating:						
Beginning Balance	**$ 532,805**	**$ 126,731**	**$ 112,814**	**$ 116,136**	**$ 119,999**	**$ 124,029**
Net Cash Flow after Rate Increase	73,434	122,489	28,305	18,662	51,046	699
Transfer of Surplus to Capital Fund	(479,508)	(136,407)	(24,983)	(14,798)	(47,017)	-
Ending Balance	$ 126,731	$ 112,814	$ 116,136	$ 119,999	$ 124,029	$ 124,727
Min.Operating 60 Day Target	*$ 126,731*	*$ 112,814*	*$ 116,136*	*$ 119,999*	*$ 124,029*	*$ 128,234*
Days	60	60	60	60	60	58
Capital						
Beginning Balance	**$ -**	**$ 336,508**	**$ (43,070)**	**$ 943,353**	**$ 379,047**	**$ 437,435**
Transfers from Replacement Fund (473)	100,000	100,000	140,000	180,000	116,986	244,905
Grants/Developer Donations /Other	**-**	**-**	**-**	**-**	**-**	**-**
Net Debt Proceeds Available for Projects	-	-	1,200,000	-	-	1,200,000
Interest Earnings	-	10,095	-	28,301	11,371	13,123
Transfer of Surplus from Operating Fund	479,508	136,407	24,983	14,798	47,017	-
Capital Expenditures	(243,000)	(626,080)	(378,560)	(787,405)	(116,986)	(1,459,983)
Ending Balance	**336,508**	**(43,070)**	**943,353**	**379,047**	**437,435**	**435,479**
REPLACEMENT FUND (473)						
Beginning Balance	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 63,014**
System Replacement	100,000	100,000	140,000	180,000	180,000	180,000
Capital Facilities Fee Revenue	-	-	-	-	-	-
Interest Earnings	-	-	-	-	-	1,890
Transfers to Capital Fund	(100,000)	(100,000)	(140,000)	(180,000)	(116,986)	(244,905)
Ending Balance	**$ -**	**$ -**	**$ -**	**$ -**	**$ 63,014**	**$ -**
Ending Capital Balances	$ 336,508	$ (43,070)	$ 943,353	$ 379,047	$ 500,449	$ 435,479
Minimum Capital Contingency Target	*$ 300,000*	*$ 300,000*	*$ 300,000*	*$ 300,000*	*$ 300,000*	*$ 300,000*

(Reference: FCS Group 2010)

8.2 PROGRAMMATIC RECOMMENDATIONS

The Stormwater Management Program, including O&M, as described in Section 5 is recommended for continued implementation. Funding for this program is included in the Operating budget of the 2010 financial study (FCS Group 2010).

8.3 RECOMMENDED CAPITAL IMPROVEMENTS

Table 8-4 shows the 14 capital projects evaluated during the development of this plan. Total project costs include design, permitting, investigations, construction cost, sales tax, and 20% contingency. The estimated costs for all 14 projects is approximately $5.1 million.

The proposed CIP is shown in Table 8-4 and includes a project implentation schedule of approximately seven years. In addition to project implementation, the following steps are recommended:

1. Annually meet with all with City Public Works Operations staff to:
    a. Identify changes in the risk related to the problems addressed by the current CIP project list.
    b. Identify ongoing or new stormwater problems that should be considered for addition to the project list.
2. Annually review the data contained in Table 6-1 and Appendix A, and add updated information that is collected regarding each problem and solution.
3. Store information collected during the two prior steps in a paper or electronic file that can be revisited on an annual basis, and used to formally update the CIP and programmatic elements of the plan.
4. Review Sections 5, 6, and 7 when the plan is updated every 6 years or sooner as needed. Use the information collected in prior steps to justify adding, removing, or modifying projects.

Table 8-4 CIP Project Implementation Schedule

City Priority	Project	Location	Total Cost (2012 dollars)	2014	2015	2016	2017	2018	2019	2020 (+)
1	C-12	Blackmans Lake Outfall Control Project	$528,000	$100,000	$428,000					
1	C-13	CSO Separation	$2,700,000	$120,000	$400,000	$1,100,000	$1,080,000			
1	C-4	Park Avenue/ Blackmans Lake	$62,000	$62,000						
2	C-1	87th Avenue SE (Sinclair Avenue)	$78,000		$78,000					
3	C-5b	Holly Vista Drive	$394,000					$80,000*	$314,000*	
4	C-5a	16th Street	$122,000					$25,000*	$97,000*	
5	C-3	Maple Avenue (Unopened Fairview Street)	$60,000					$60,000		
6	C-6	Cypress Avenue	$77,000						$77,000	
7	C-11	Bonneville Avenue	$10,000		$10,000					
8	C-10	Short and Long Streets	$224,000							$224,000
9	C-9	Baird and Victor Avenues	$234,000							$234,000
10	C-8	Grove Street	$89,000							$89,000
11	C-2	Swifty Creek (at Second Street)	$468,000							$468,000
12	C-7	Third Street and Avenue D	$14,000	$14,000						
	Total Annual Expenditures (Inflation: 0% per year)		$5,060,000	$296,000	$916,000	$1,100,000	$1,080,000	$165,000	$488,000	$1,015,000

[1] See Appendix

*Design 2018; Construct 2019

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Bunk Foss
Area: 1024.92 acres

Upper Cemetery Creek
Area: 875.21 acres

Blackmans Lake
Area: 465.26 acres

Lower Cemetery Creek
Area: 1019.54 acres

Pilchuck Area (Hug River)
Area: 464.63 acres

Swifty Creek
Area: 330.43 acres

Combined Sewer Area
Area: 2.07 acres

Combined Sewer Area
Area: 243.25 acres

Combined Sewer Area
Area: 2.76 acres

Snohomish
Area: 444.78 acres

C-1 C-2 C-3 C-4 C-5 C-6 C-7 C-8 C-9 C-10 C-11 C-12 C-13

State Route 9
US Highway 2
Bunk Foss Creek
West Fields Fork
East Fields Fork
Clarks Fork (South Fork)
Blackmans Lake
Anderson Fork
Marshs Fork
Cemetery Creek
Harkins Fork
Swifty Creek
Snohomish River
Pilchuck River

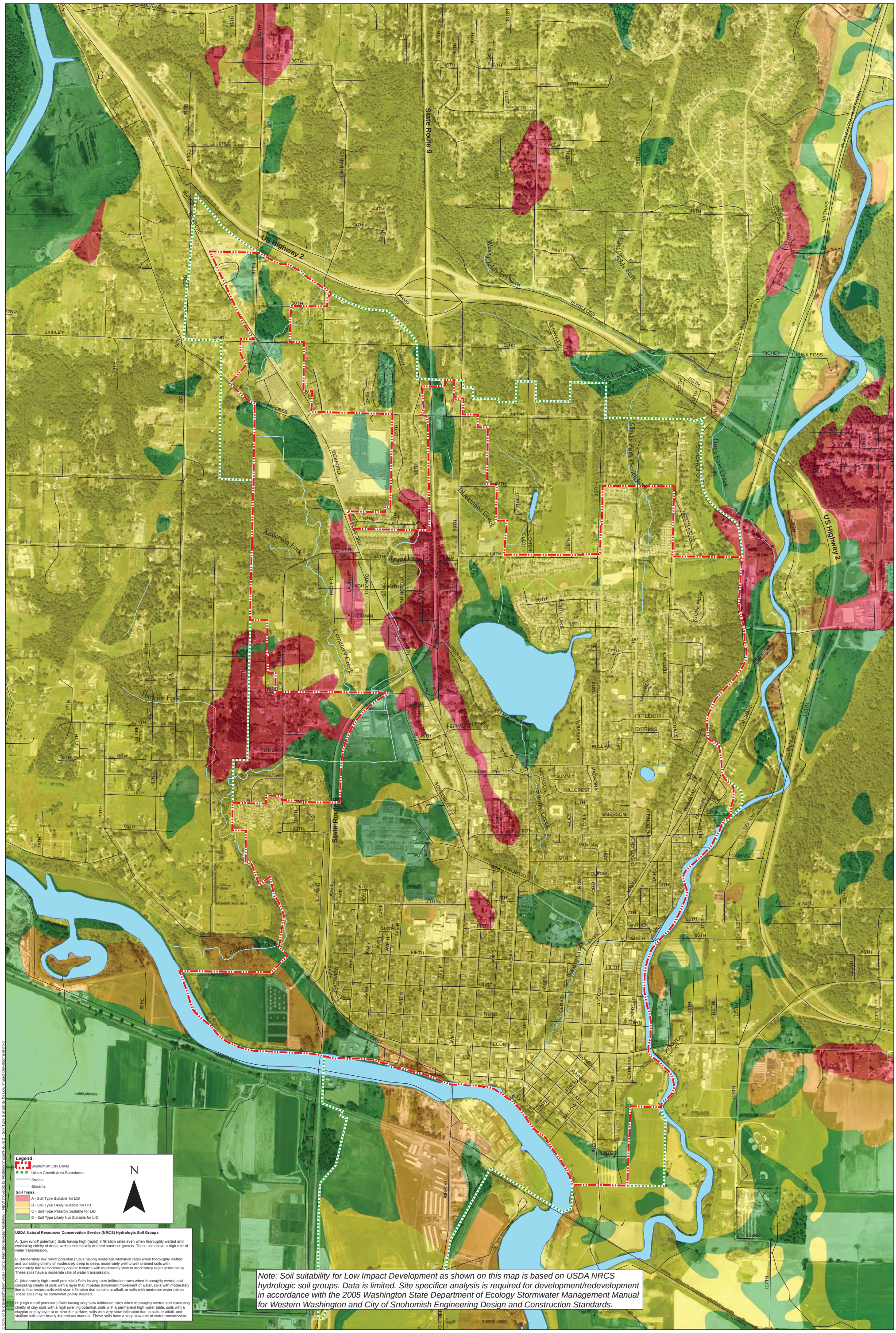
Legend
- C-# SCP Project #
- CSO Area Sewer
- Streets
- Streams
- CSO Separation Area
- Snohomish City Limits
- Urban Growth Area Boundary
- Lakes and Rivers

N

3,200 1,600 0 3,200
Feet

Job No. 33763575

Figure 1
Basin Map
Stormwater Comprehensive Plan
City of Snohomish



O:\City of Snohomish\Stormwater Comp Plan\Stormwater Modeling - NEW mxwrd\GIS Modeling\maps\Figure 2 - Soil Type Suitability for Low Impact Development.mxd

Job No. 33763575

Figure 2

Soil Type Suitability for Low Impact Development

Stormwater Comprehensive Plan
City of Snohomish

Bunk Foss Basin

Bunk Foss
Area: 1024.92 acres

Upper Cemetery Creek Basin

Upper Cemetery Creek
Area: 875.21 acres

Blackmans Lake Basin

Blackmans Lake
Area: 465.26 acres

Lower Cemetery Creek Basin

Lower Cemetery Creek
Area: 1019.54 acres

Swifty Creek Basin

Swifty Creek
Area: 330.43 acres

Pilchuck River Basin

Pilchuck Area (Hug River)
Area: 464.63 acres

Combined Sewer Area Basin

Combined Sewer Area
Area: 243.25 acres

Combined Sewer Area
Area: 2.07 acres

Combined Sewer Area
Area: 2.76 acres

Snohomish
Area: 444.78 acres

Legend

- CSO Outfall
- CSO Storm Catch Basins
- CSO Sewer Manholes
- Catch Basins (private)
- Drainage Basins
- Snohomish City Limits
- Urban Growth Area Boundary
- CSO Area Sewer
- Swale/Ditch
- Culvert
- Enclosed Pipe

Stormwater Drainage Network

- 4"
- 6"
- 8"
- 12"
- 15"
- 18"
- 24"
- 36"
- 48"
- Lakes and Rivers

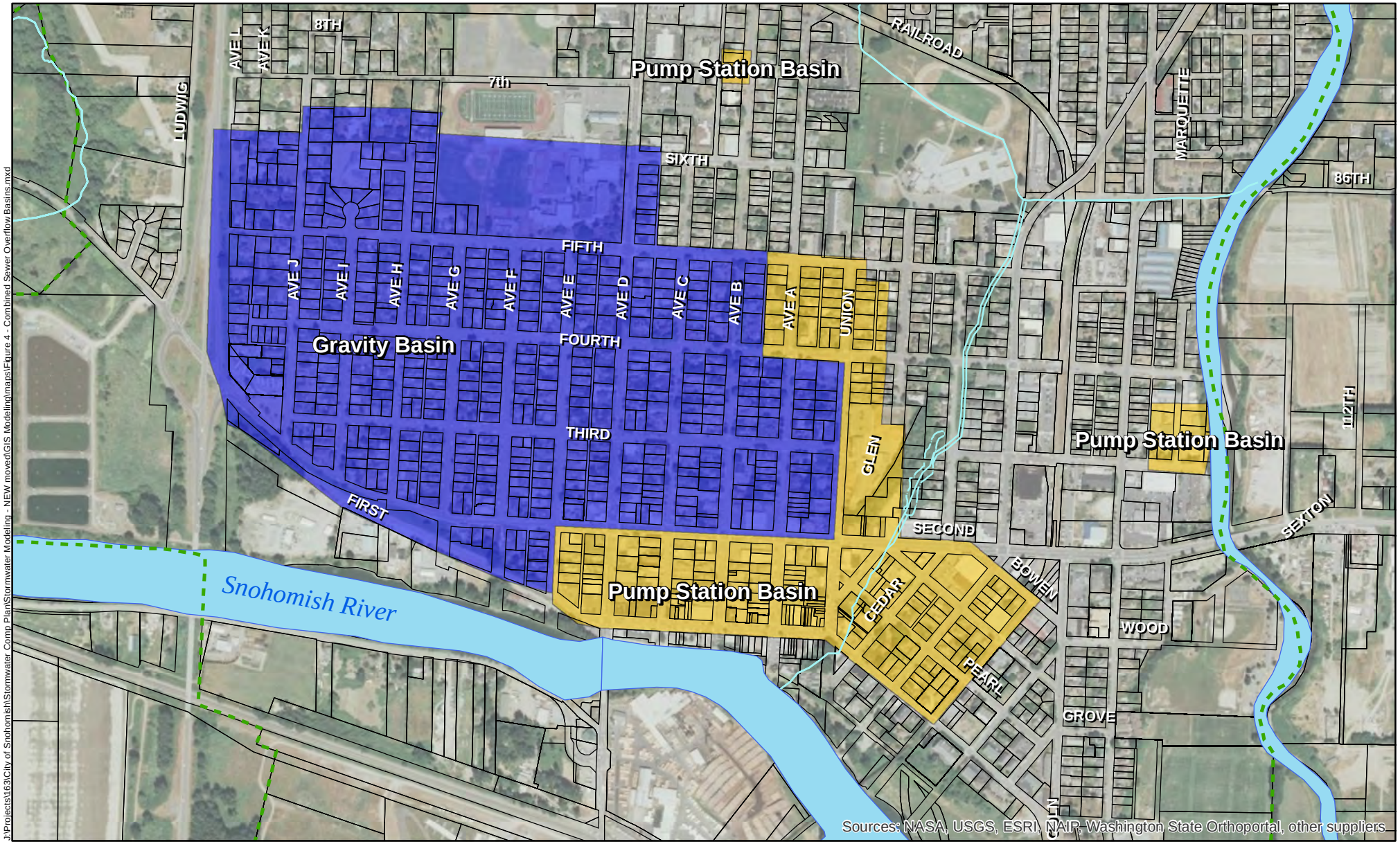
O:\City of Snohomish\Stormwater Comp Plan\Stormwater Modeling - NEW moved\GIS Models\maps\Figure 3 - Stormwater System Map.mxd

3,200 1,600 0 3,200
Feet

NORTH

Job No. 33763575

Figure 3
Stormwater System Map
Stormwater Comprehensive Plan
City of Snohomish



J:\Projects\163\City of Snohomish\Stormwater Comp Plan\Stormwater Modeling - NEW moved\GIS Modeling\maps\Figure 4 - Combined Sewer Overflow Basins.mxd

NORTH

800 400 0 800

Feet

Figure 4

Combined Sewer Overflow Basins

Stormwater Comprehensive Plan

City of Snohomish

Job No. 33763575

URS

Problem: Stormwater runoff ponds at the NE corner of 50th St. and 87th Ave. and approaches private property.

50th St

87th Ave SE

Bickford Ave

1

2

3

Legend

- # Bubble Name
- Existing Drainage Point
- New Catch Basin
- 10 ft Index Contours
- 1 ft Contours
- Wetland

Existing Drainage

- Existing Ditch
- Existing Culvert

Stormlines

- Flow Direction Arrow
- New Stormline

Bubble Name	Bubble Description
1	Install 15" storm drain pipeline with catch basins.
2	Separate private and public runoff.
3	Existing ditch on private property.

80 40 0 80 160 240 320 Feet

Path: J:\Projects\t63\City of Snohomish\Stormwater Comp Plan\Stormwater Modeling - NEW moved\GIS Modeling\maps\Figure C-1 - 87th Ave SE (Sinclair Drainage Area).mxd

SNOHOMISH

Job No. 33763575

URS

Figure C-1

87th Avenue S.E. (Sinclair Avenue)

Stormwater Comprehensive Plan

City of Snohomish

Problem - Swifty Creek drains through a 24" storm drain pipeline beginning just north of 2nd Street between Union and Cedar Avenues, and terminating at the Snohomish River. A large section of this pipeline crosses private property. Due to poor pipe condition and/or partial pipe blockage, Swifty Creek backs up and causes deep backwater in the open creek sections.

Avenue B
Avenue A
Union Avenue
Swifty Creek
Cedar Avenue
Second Street
Glen Ave
Pearl Street
Rainier Street
First Street

1
2
3
4
5

Legend

- # Bubble Name
- 25' Index Contour lines
- 5' Contour lines

Drainage points

- New Manhole
- Existing Manhole
- New Catch Basin

Stormlines

- Existing Stormline
- Flow Direction Arrow
- New Stormline

Bubble Name	Bubble Description
1	New inlet location
2	Pipe section from inlet to proposed manhole at Second Street, including manholes, will require an easement
3	New 24" storm drain pipeline
4	Connect new storm drain to existing manhole
5	Approximate location of existing 24" storm drain pipeline for Swifty Creek

Path: J:\Projects\63\City of Snohomish\Stormwater Comp Plan\Stormwater Modeling - NEW moved\GIS Modeling\maps\Figure C-2 - Swifty Creek at Second Street.mxd

SNOHOMISH

Job No. 33763575

URS

0 80 160 320 480 640 800 Feet

Figure C-2
Swifty Creek (at Second Street)
Stormwater Comprehensive Plan
City of Snohomish

Problem: Stormwater in upper ditch exceeds culvert/pond system and overflows ditch. Due to the steep grade of the unopened Fairview Street, gravel roadway overflow water erodes roadway and deposits gravel and fines on sidewalk and Maple Avenue.

Unopened Fairview Street

Maple Avenue

170 160 150 120 110 100 90

Legend

- # Bubble Name
- 10 ft Contours

Drainage points

- New Drainage Point
- Existing Drainage Point

Stormlines

- Existing Stormline
- Flow Direction Arrow
- New Stormline

Bubble Name	Bubble Description
1	Existing manhole with outlet pipe to ditch
2	Existing Ditch
3	Ditch overflow location
4	Existing Culvert
5	Series of small ponds and culverts that drain to existing manhole
6	Existing storm drain manhole
7	New 12" storm drain
8	New manhole at existing storm pipeline. New storm drain to connect to manhole.
9	Existing 12" storm main
10	Existing storm drain pipeline from Suncrest Drive

30 15 0 30 60 90 120 Feet

Path: J:\Projects\t63\City of Snohomish\Stormwater Comp Plan\Stormwater Modeling - NEW moved\GIS Modeling\maps\Figure C-3 - Maple Avenue - Unopened Fairview Street.mxd

SNOHOMISH

URS

Job No. 33763575

Figure C-3

Maple Avenue (unopened Fairview Street)

Stormwater Comprehensive Plan

City of Snohomish

Problem: Existing 12" storm drain line is too small; therefore, water backs up and the ditch overflows at the SW corner of Park Avenue and 19th Street. The overflow water flows to the SW and enters private properties.

Legend

- # Bubble Name

Drainage points

- New Drainage Point
- Existing Drainage Point
- Existing Type 1 Catch Basin
- 25' Index Contours
- 5' Contours

Stormlines

- Existing Storm Drain Line
- Flow Direction Arrow
- New Storm Drain Line

North Lake Ave.
Park Ave.
19th St.
North Shore Pl.
Blackmans Lake

Bubble Name	Bubble Description
1	Existing Ditch
2	Existing Culvert
3	Replace existing 12" storm drain line with a 24" line.
4	Connect to existing manhole/replace if necessary.
5	Existing 24" storm line to Blackmans Lake.
6	Existing Type 1 catch basin. Upsize to Type 2 catch basin.
7	Remove existing drainage point

60 30 0 60 120 180 240 Feet

Path: J:\Projects\163\City of Snohomish\Stormwater Comp Plan\Stormwater Modeling - NEW moved\GIS Modeling\maps\Figure C-4 - Park Ave-Blackman Drainage Area.mxd

SNOHOMISH URS

Job No. 33763575

Figure C-4

Park Avenue/Blackmans Lake

Stormwater Comprehensive Plan
City of Snohomish

Problem: No stormwater collection system exists along 16th St. As a result, stormwater runoff approaches private property along the street.

Pine Avenue

Lakeview Place

Terrace Avenue

16th Street

16th Street

Legend

- # Bubble Name

Drainage points

- New Drainage Point
- Existing Drainage Point

Stormlines

- Existing Stormline
- Flow Direction Arrow
- New Stormline
- 10 ft Contours

Bubble Name	Bubble Description
1	Existing Ditch
2	Existing Culvert
3	New 12" storm drain line
4	New catch basins
5	New storm drain line to empty into existing ditch
6	See Figure C-5b for upstream continuation of drainage improvements

80 40 0 80 160 240 Feet

Path: J:\Projects\t163\City of Snohomish\Stormwater Comp Plan\Stormwater Modeling - NEW moved\GIS Modeling\maps\Figure C-5a - Sixteenth Street Drainage Area.mxd

Job No. 33763575

Figure C-5a

16th Street Drainage

Stormwater Comprehensive Plan

City of Snohomish

Problem: No existing drainage system along Holly Vista Drive

Legend

- # Bubble Name
- 10 ft Contours

Drainage points

- New Drainage Point
- Existing Drainage Point

Stormlines

- Existing Stormline
- Flow Direction Arrow
- New Stormline
- Existing Culvert
- Existing Ditch

Terrace Avenue
16th St.
16th Street
15th Street
Holly Vista Drive

Bubble Name	Bubble Description
1	Remove existing catch basin and influent/effluent pipes.
2	Connect new 12" storm line to existing manhole.
3	New 12" storm line
4	Connect new 12" storm lines from north and northeast to existing manhole
5	New catch basins (typical)
6	New 12" storm line installed in an existing public utility easement.
7	New storm drain manhole
8	See Figure C-5a for continuation downstream of drainage improvements.
9	Existing ditch
10	Existing pipe
11	Pipe Inlet
12	New 8' Ø x 100' long pipe detention vault
13	New culvert

75 37.5 0 75 150 Feet

SNOHOMISH

Job No. 33763575

URS

Figure C-5b

Holly Vista Drive

Stormwater Comprehensive Plan
City of Snohomish

Problem: Without City maintenance of a private catch basin that receives runoff from Cypress Avenue, catch basins on Cypress Avenue overflow and stormwater enters private property.

Legend

- # Bubble Name
- 10 ft Contour lines

Drainage points

- New Drainage Point
- Existing Drainage Point

Stormlines

- Existing Stormline
- Flow Direction Arrow
- New Stormline
- Existing CSO line

Bubble Name	Bubble Description
1	Private Driveway
2	Private catch basin receives stormwater from Cypress Avenue. City maintains catch basin to prevent overflow of Cypress Avenue catch basins.
3	Replace catch basins with Type I catch basins.
4	Plug existing 12" stormline
5	Replace existing stormline with new 12" stormline
6	Install new 12" stormline
7	Existing CSO line
8	Disconnect existing CB pipeline at CSO manhole and install new CB pipe deeper in MH.

Pine Avenue

Cypress Avenue

Fourth Street

Pilchuck River

60 30 0 60 120 180 240 Feet

Path: J:\Projects\163\City of Snohomish\Stormwater Comp Plan\Stormwater Modeling - NEW moved\GIS Modeling\maps\Figure C-6 - Cypress Ave Drainage Area.mxd

SNOHOMISH

Job No. 33763575

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Figure C-6

Cypress Avenue

Stormwater Comprehensive Plan

City of Snohomish

Problem: Stormline connecting the two catch basins located in the northeast corner of Third Street and Avenue D plugs or stormwater flow is restricted due to tree root impacts. This results in stormwater ponding at this location.

Legend

- # Bubble Name

Drainage points

- New Drainage Point
- Existing Drainage Point

Stormlines

- Existing Stormline
- Flow Direction Arrow
- New Stormline

Third Street

Avenue D

1

2

Bubble Name	Bubble Description
1	Existing Storm drain main
2	Replace existing storm drain pipeline impacted by tree roots with new pipeline. Install new pipeline in steel casing pipe to prevent future root intrusion.

Path: J:\Projects\163\City of Snohomish\Stormwater Comp Plan\Stormwater Modeling - NEW moved\GIS Modeling\maps\Figure C-7 - Third Street and Ave D Drainage Area.mxd

40 20 0 40 80 120 160 Feet

SNOHOMISH

Job No. 33763575

URS

Figure C-7

Third Street and Avenue D

Stormwater Comprehensive Plan

City of Snohomish

Problem: No stormwater collection system exists along Grove Street. Water ponds within the right-of-way area.

Legend

- # Bubble Name

Drainage points

- New Drainage Point
- Existing Drainage Point

Stormlines

- Existing Stormline
- Flow Direction Arrow
- New Stormline
- Stormlines, 4" - 15" diameter
- Stormlines, 16" - 24" diameter

Bubble Name	Bubble Description
1	New catch basin
2	New 12" storm drain line
3	Connect new storm line to existing storm main with new manhole

Grove Street

Lincoln Avenue

Pine Avenue

Alder S

Path: J:\Projects\163\City of Snohomish\Stormwater Comp Plan\Stormwater Modeling - NEW moved\GIS Modeling\maps\Figure C-8 - Grove Street Drainage Area.mxd

40 20 0 40 80 120 160 200 Feet

SNOHOMISH

URS

Job No. 33763575

Figure C-8

Grove Street

Stormwater Comprehensive Plan

City of Snohomish

Problem: No stormwater collection system exists along Baird and Victor Avenues. As a result, stormwater ponds along the streets.

Legend

- # Bubble Name
- 10 ft Contours

Drainage points

- New Catch Basins
- Existing Drainage Point

Stormlines

- Existing Stormline
- Flow Direction Arrow
- New Stormline
- Existing Culvert
- Existing Ditch

Bubble Name	Bubble Description
1	New catch basin (typ)
2	New 12" storm drain line
3	Connect new storm lines to existing 30" storm main with new manholes
4	Existing 30" storm main

Maple Avenue
8th Street
Baird Avenue
Mill Avenue
Taylor Street
Victor Ave
7th Street

75 37.5 0 75 150 Feet

\\Seaocean\GIS\City of Snohomish\Stormwater Comp Plan\Stormwater Modeling\GIS Modeling

Job No. 33763575

Figure C-9
Baird and Victor Avenues
Stormwater Comprehensive Plan
City of Snohomish

Problem: No stormwater collection system exists along Short and Long Streets. Short Street is not paved and potholes are problematic. Stormwater ponds in the streets and within the right-of-way.

Legend

- # Bubble Name

Drainage points

- New Catch Basins
- Existing Drainage Point

Stormlines

- Existing Stormline
- Flow Direction Arrow
- New Stormline

Bubble Name	Bubble Description
1	Existing 12" storm main
2	New 12" storm drain line
3	Connect new storm lines into existing catch basins

Short Street

Long Street

Mill Avenue

40 20 0 40 80 120 160 200 Feet

Job No. 33763575

URS

SNOHOMISH

Figure C-10

Short and Long Streets

Stormwater Comprehensive Plan

City of Snohomish

Path: J:\Projects\163\City of Snohomish\Stormwater Comp Plan\Stormwater Modeling - NEW moved\GIS Modeling\maps\Figure C-10 - Short and Long Streets Drainage Area.mxd

Bubble Name	Bubble Description
1	New catch basin
2	New 12" storm drain line
3	Connect to existing catch basin

Path: J:\Projects\163\City of Snohomish\Stormwater Comp Plan\Stormwater Modeling - NEW moved\GIS Modeling\maps\Figure C-11 - Bonneville Avenue Drainage Area.mxd

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Figure C-11

Bonneville Avenue

Stormwater Comprehensive Plan

City of Snohomish

Problem: Properties adjacent to Blackmans Lake have experienced flooding problems due to rising water levels during storm events. Silt accumulation and vegetation growth in the lake's outlet channel (Swifty Creek) and culverts have restricted the discharge from the lake.

Legend

- # — Bubble Name

Drainage points

- Existing Drainage Point
- New Weir

Stormlines

- Existing Storm Drain Line
- Flow Direction Arrow
- New Channel

Blackmans Lake

Ferguson Park Road

Avenue A

13th Street

Bubble Name	Bubble Description
1	Swifty Creek
2	Replace existing culverts.
3	Construct new channel.
4	Remove sediment and vegetation from creek.
5	Remove sediment from existing culvert.
6	Construct weir in creek.

60 30 0 60 120 180 240 Feet

Path: J:\Projects\163\City of Snohomish\Stormwater Comp Plan\Stormwater Modeling - NEW moved\GIS Modeling\maps\Figure C-12 - Blackmans Lake Outlet Control Project.mxd

SNOHOMISH URS

Job No. 33763575

Figure C-12

Blackmans Lake Outlet Control Project

Stormwater Comprehensive Plan

City of Snohomish

Problem: Existing storm sewer connects to sanitary sewer system.

Legend

- # Bubble Name

Drainage points

- Existing CSO Storm Catch Basin
- New Catch Basin
- New Manhole
- Existing Catch Basin

Stormlines

- Existing Stormline
- Flow Direction Arrow
- New Stormline

Combined Sewer Overflow Basins

- Gravity Basin
- Pump Station Basin

Bubble Name	Bubble Description
1	Existing 30" unused trunck storm main
2	New 12" storm main; connect to 30" main
3	New 30" storm trunk main
4	Existing storm main connected to CSO system
5	Disconnect Avenue F storm main from CSO system and reconnect to 30" storm main
6	Pond inlet protection
7	First wetpool cell, approximately 9 acre-feet
8	Dividing berm, approximately 640' long
9	Pond outlet structure
10	Ramp/Access Improvements

Proposed Stormwater Quality Pond
(Former wastewater lagoon)

Approx. 30 acres

Low spot in levee

Existing Wastewater Treatment Plant

CSO Separation Area (Approx. 85 acres)

7th Street
Fifth Street
Fourth Street
Third Street
Second Street

Avenue K
Avenue L
Riverview Lane
Avenue J
Avenue I
Avenue H
Avenue G
Avenue F
Avenue E
SR9

Snohomish River

400 200 0 400 800 1,200 1,600
Feet

Job No. 33763575

Figure C-13
CSO Separation Area
Stormwater Comprehensive Plan
City of Snohomish

Path: J:\Projects\163\City of Snohomish\Stormwater Comp Plan\Stormwater Modeling - NEW moved\GIS Modeling\maps\Figure C-13 - CSO Separation Area.mxd

APPENDIX A

IMPROVEMENT/PROJECT SUMMARY SHEETS

Improvement/Project Summary

Project:	Area C-1: 87th Avenue S.E. (Sinclair Ave.)	
Stakeholders:	Local Property Owners & City of Snohomish	
Location/Address:	Intersection of 50th Street & 87th Ave. SE (Sinclair)	
Date:	August 2013	
Problem Description:	**Photo/Map/Sketch:**	
Localized flooding occurs at the northeast corner of the intersection during large storm events. Flood waters approach private property.		
City Actions and/or Analysis Process and Results:		
The City of Snohomish maintenance staff answers complaints from local residences about stormwater backing up and ponding and routinely makes field observations. Drainage systems to and from the problem area were field verified to determine the preferred option for reducing or eliminating the ponding problem.		
Recommended Improvement:		
Construct a new storm drain pipeline along 87th Avenue SE from the ponded area near 50th Street to the receiving drainage system near Bickford Avenue.		
Cost Estimate (see Appendix B for cost breakdown)		
Total (design, permitting, construction, tax, contingency):	**$78,000**	
Challenges, Impacts or Enhancements (Rate from 1 to 10, high scores indicate challenges/impacts on project completion. Total < 35 preferred.)		
Wetlands:	0	No apparent impact to wetlands.
Easement Acquisition:	0	Easements are not required.
Fish/Wildlife Habitat including Water Quality:	5	Fish/Wildlife habitat will not be impacted.
Construction:	5	Construction requires partial closure of 87th Ave. SE.
O&M:	5	New pipeline to require periodic maintenance.
Public Acceptance (based on cost, safety and property damage):	3	Community likely in favor of project.
Permitting:	2	Only construction permits required.
Overall Score	**20**	

Improvement/Project Summary

Project:	C-2: Swifty Creek	
Stakeholders:	Local Community and City of Snohomish	
Location/Address:	First St. to Second St. Along Glen and Union Ave.	
Date:	August 2013	
Problem Description:	**Photo/Map/Sketch:**	
Due to damage and/or blockage in the existing storm drainage pipeline from the open channel of Swifty Creek to the final outlet system at Snohomish River, stormwater backs up in the open channel section of Swifty Creek. Water in Swifty Creek becomes deep and stagnate. Safety and flooding is of concern for adjacent properties.		
City Actions and/or Analysis Process and Results:		
Deep, stagnate water is observed in the creek after rain events and during the dry season. City personnel attribute this to localized groundwater flowing into the creek and blockage in the existing pipeline. The existing pipe extends under several private properties which makes cleaning, repairing, or replacing damaged pipe unfeasible.		
Recommended Improvement:		
Construct a new pipeline that would be placed within City owned right-of-way along Glen and Union Avenues, from Second St. to First St. A small section of pipeline, at the upstream end of the proposed new pipeline, will require an easement.		
Cost Estimate (see Appendix B for cost breakdown)		
Total (design, permitting, construction, tax, contingency):	**$468,000**	
Challenges, Impacts or Enhancements (Rate from 1 to 10, high scores indicate challenges/impacts on project completion. Total < 35 preferred.)		
Wetlands:	5	Potential impacts to wetlands within creek.
Easement Acquisition:	10	Easement acquisition is required.
Fish/Wildlife Habitat Including Water Quality:	7	Swifty Creek is a non-fish bearing creek but a HPA may be required.
Construction:	8	Construction within downtown roadways requiring closures and detours.
O&M:	7	Pipeline and manhole maintenance necessary.
Public Acceptance (based on cost, safety and property damage):	7	Community acceptance may be difficult due to project cost.
Permitting:	7	Construction and environmental permits required.
Overall Score	**51**	

Improvement/Project Summary

Project:	C-3: Maple Avenue	
Stakeholders:	Local Property Owners & City of Snohomish	
Location/Address:	Maple Ave. & Fairview St. (unopened section)	
Date:	August 2013	
Problem Description:	**Photo/Map/Sketch:**	
A ditch receiving stormwater runoff from Suncrest Dr. overflows during large storm events. The ditch enters a private culvert and open pond drainage system that is too small to accommodate the stormwater flow. Water that overflows the ditch flows down the unopened gravel section of Fairview Dr. to Maple Ave. and causes erosion in the gravel drive way. Eroded gravel/sand materials are deposited on the sidewalk and on Maple Ave.		
City Actions and/or Analysis Process and Results:		
City maintenance staff has periodically repaired the gravel surfacing on the unopened Fairview Drive and cleaned debris from the sidewalk and street (Maple Ave.).		
Recommended Improvement:		
Construct new 12-inch storm drain pipeline from ditch to existing Maple Ave storm main.		
Cost Estimate (see Appendix B for cost breakdown)		
Total (design, permitting, construction, tax, contingency):	**$60,000**	
Challenges, Impacts or Enhancements (Rate from 1 to 10, high scores indicate challenges/impacts on project completion. Total < 35 preferred.)		
Wetlands:	0	No impact to wetlands.
Easement Acquisition:	0	Easements are not required.
Fish/Wildlife Habitat including Water Quality:	0	Fish/wildlife habitat will not be impacted.
Construction:	5	Maple Dr. partially closed during construction.
O&M:	5	New pipeline to require periodic maintenance.
Public Acceptance (based on cost, safety and property damage):	3	Community likely in favor of project.
Permitting:	2	Only construction permits are anticipated to be required.
Overall Score	**15**	

Improvement/Project Summary

Project:	C-4: Park Avenue/Blackmans Lake	
Stakeholders:	Local Property Owners & City of Snohomish	
Location/Address:	Park Ave. & 19th St.	
Date:	August 2013	
Problem Description:	**Photo/Map/Sketch:**	
Stormwater flow from the Park Ave. ditch enters a 12" pipeline that empties into a down-gradient manhole that directs flow to an outfall pipe to Blackmans Lake. The 12" pipe is too small to accommodate large storm flows. As a result, stormwater backs up within an adjacent catch basin and surface flows onto private property.		
City Actions and/or Analysis Process and Results:		
The City Public Works Department has received several calls from citizens complaining about the stormwater entering their property caused by back water in the catch basin.		
Recommended Improvement:		
Replace the existing 12" storm drain pipeline with a 24" pipeline that will accommodate the larger storm flows (under existing and long term conditions).		
Cost Estimate (see Appendix B for cost breakdown)		
Total (design, permitting, construction, tax, contingency):	**$62,000**	
Challenges, Impacts or Enhancements (Rate from 1 to 10, high scores indicate challenges/impacts on project completion. Total < 35 preferred.)		
Wetlands:	0	No impact to wetlands.
Easement Acquisition:	0	Easements are not required.
Fish/Wildlife Habitat including Water Quality:	0	Fish/wildlife habitat will not be adversely impacted.
Construction:	5	One block of Park Ave. will be partially closed during construction.
O&M:	5	New pipeline to require periodic maintenance.
Public Acceptance (based on cost, safety and property damage):	3	Community likely in favor of project due to reduction in property damage.
Permitting:	2	Only construction permits anticipated to be required.
Overall Score	**15**	

Improvement/Project Summary

Project:	C-5a: 16th Street	
Stakeholders:	Local Property Owners & City of Snohomish	
Location/Address:	16th St. between Pine Ave. and Terrace Ave.	
Date:	August 2013	
Problem Description:	**Photo/Map/Sketch:**	
There is no drainage system along this section of 16th St. Stormwater runoff approaches private properties along 16th St.		
City Actions and/or Analysis Process and Results:		
The City Public Works Department has received calls from citizens complaining about the stormwater accumulation along 16th St.		
Recommended Improvement:		
Construct a stromwater collection and conveyance system along 16th St. The system would consist of catch basins and a storm drain main that would connect to the roadside ditch along Pine Ave.		
Cost Estimate (see Appendix B for cost breakdown)		
Total (design, permitting, construction, tax, contingency):	**$122,000**	
Challenges, Impacts or Enhancements (Rate from 1 to 10, high scores indicate challenges/impacts on project completion. Total < 35 preferred.)		
Wetlands:	0	No impact to wetlands.
Easement Acquisition:	0	Easements are not required.
Fish/Wildlife Habitat including Water Quality:	0	Fish/wildlife habitat will not be impacted.
Construction:	5	16th St. will be partially closed during construction.
O&M:	7	Periodic pipeline and catch basin maintenance required.
Public Acceptance (based on cost, safety and property damage):	3	Community likely in favor of project.
Permitting:	2	Only construction permits required.
Overall Score	**17**	

Improvement/Project Summary

Project:	C-5b: Holly Vista Drive	
Stakeholders:	Local Property Owners & City of Snohomish	
Location/Address:	Holly Vista Dr.	
Date:	August 2013	
Problem Description:	**Photo/Map/Sketch:**	
There is no drainage system along Holly Vista Dr. Stormwater runoff sheet flows across the roadway and onto private property.		
City Actions and/or Analysis Process and Results:		
The City Public Works Department has received calls from citizens with complaints about the stormwater flooding their property.		
Recommended Improvement:		
Construct a stromwater collection and conveyance system along Holly Vista Dr. The system would consist of catch basins and a storm drain main that would connect to an existing storm manhole located on Suncrest Dr. A detention pipe is anticipated to be needed to control flooding downstream.		
Cost Estimate (see Appendix B for cost breakdown)		
Total (design, permitting, construction, tax, contingency):	**$394,000**	
Challenges, Impacts or Enhancements (Rate from 1 to 10, high scores indicate challenges/impacts on project completion. Total < 35 preferred.)		
Wetlands:	0	No impact to wetlands.
Easement Acquisition:	0	Easements are not required.
Fish/Wildlife Habitat including Water Quality:	0	Fish/wildlife habitat will not be impacted.
Construction:	5	Holly Vista Dr. will be partially closed during construction.
O&M:	7	Periodic pipeline, catch basin, and detention pipe maintenance required.
Public Acceptance (based on cost, safety and property damage):	5	Community likely in favor of project.
Permitting:	2	Only construction permits anticipated to be required.
Overall Score	**19**	

Improvement/Project Summary

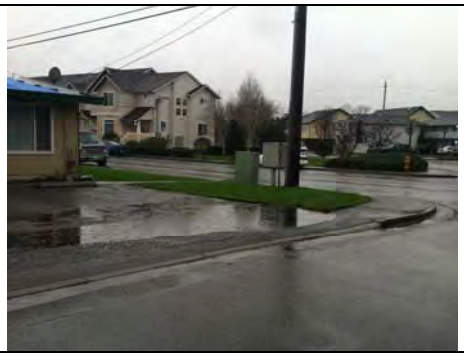
Project:	C-6: Cypress Avenue	
Stakeholders:	Local Property Owners & City of Snohomish	
Location/Address:	Cypress Ave. (from 4th St. north to end)	
Date:	August 2013	
Problem Description:	**Photo/Map/Sketch:**	
Four catch basins on the north end of Cypress Ave. drain to a private catch basin. The private catch basin plugs periodically and during large storm events the Cypress Ave. catch basin overflows and water flows onto private properties.		
City Actions and/or Analysis Process and Results:		
City maintenance staff periodically cleans the private catch basin to help prevent the upstream city catch basins from backing up onto private property. At times during storm events, the City staff needs to unclog/maintain the private catch basin during storm events.		
Recommended Improvement:		
Disconnect from the existing private catch basin and connect the four city catch basins to the existing storm main that connects to the CSO pipeline along Cypress Ave.		
Cost Estimate (see Appendix B for cost breakdown)		
Total (design, permitting, construction, tax, contingency):	**$77,000**	
Challenges, Impacts or Enhancements (Rate from 1 to 10, high scores indicate challenges/impacts on project completion. Total < 35 preferred.)		
Wetlands:	0	No impact to wetlands.
Easement Acquisition:	0	Easements are not required.
Fish/Wildlife Habitat including Water Quality:	0	Fish/wildlife habitat will not be impacted.
Construction:	5	Construction requires partial closure of Cypress Ave.
O&M:	7	Periodic pipeline and catch basin maintenance required.
Public Acceptance (based on cost, safety and property damage):	3	Community likely in favor of project.
Permitting:	2	Only construction permits required.
Overall Score	**17**	

URS

Improvement/Project Summary

Project:	C-7: Avenue D and Third Street	
Stakeholders:	Local Property Owners & City of Snohomish	
Location/Address:	Intersection of Avenue D and Third Street	
Date:	August 2013	
Problem Description:	**Photo/Map/Sketch:**	
The gutter catch basin located at the northeast corner of the intersection does not drain efficiently due to damage to the catch basin outlet pipe. As a result, water ponds at this intersection corner during large storm events. The outlet pipe is damaged because of tree roots from a nearby tree.		
City Actions and/or Analysis Process and Results:		
City maintenance staff periodically cleans the outfall pipe and tries to cut the roots from the inside of the pipe.		
Recommended Improvement:		
Replace the existing outfall pipe with a new one and install the new pipe inside a steel casing pipe. The casing pipe will prevent tree roots from accessing the carrier pipe.		
Cost Estimate (see Appendix B for cost breakdown)		
Total (design, permitting, construction, tax, contingency):	**$14,000**	
Challenges, Impacts or Enhancements (Rate from 1 to 10, high scores indicate challenges/impacts on project completion. Total < 35 preferred.)		
Wetlands:	0	No impact to wetlands.
Easement Acquisition:	0	Easements are not required.
Fish/Wildlife Habitat including Water Quality:	0	Fish/wildlife habitat will not be impacted.
Construction:	5	Construction requires partial closure of Avenue D and 3rd Street.
O&M:	5	Periodic pipe maintenance required.
Public Acceptance (based on cost, safety and property damage):	3	Community likely in favor of project.
Permitting:	2	Only construction permits anticipated to be required.
Overall Score	**15**	

Improvement/Project Summary

Project:	C-8: Grove Street	
Stakeholders:	Local Property Owners & City of Snohomish	
Location/Address:	Grove Street Between Lincoln Avenue and Pine Avenue	
Date:	August 2013	
Problem Description:	**Photo/Map/Sketch:**	
There is not a stormwater collection system along Grove Street. Stormwater sheet flows and ponds in areas along the street and the right-of-way.		
City Actions and/or Analysis Process and Results:		
City maintenance staff periodically answers complaints from local residences about stormwater ponding along the street and in their driveway.		
Recommended Improvement:		
Install a new stormwater collection system consisting of catch basins and a 15" storm pipeline that would tie into the existing storm main located on Lincoln Avenue.		
Cost Estimate (see Appendix B for cost breakdown)		
Total (design, permitting, construction, tax, contingency):	**$89,000**	
Challenges, Impacts or Enhancements (Rate from 1 to 10, high scores indicate challenges/impacts on project completion. Total < 35 preferred.)		
Wetlands:	0	No impact to wetlands.
Easement Acquisition:	0	Easements are not required.
Fish/Wildlife Habitat including Water Quality:	0	Fish/wildlife habitat will not be impacted.
Construction:	5	Construction requires partial closure of Grove Street.
O&M:	5	Periodic pipe maintenance required.
Public Acceptance (based on cost, safety and property damage):	3	Community likely in favor of project.
Permitting:	2	Only construction permits anticipated to be required.
Overall Score	**15**	

Improvement/Project Summary

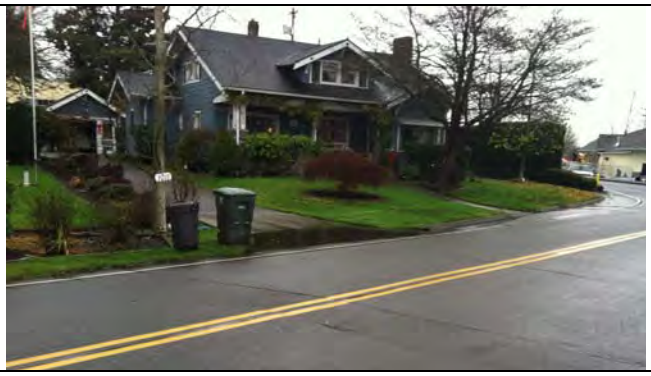
Project:	C-9: Baird and Victor Avenues	
Stakeholders:	Local Property Owners & City of Snohomish	
Location/Address:	Baird and Victor Avenues between 7th and 8th Streets	
Date:	August 2013	
Problem Description:	**Photo/Map/Sketch:**	
There is not a stormwater collection system along Baird and Victor Avenues. Stormwater sheet flows and ponds in areas along the street and the right-of-way.		
City Actions and/or Analysis Process and Results:		
City maintenance staff periodically respond to complaints from local residences about stormwater ponding along the street and in their driveways.		
Recommended Improvement:		
Install a new stormwater collection system consisting of catch basins and a 12" to 15" storm pipeline that would tie into the existing storm main located on 7th Street.		
Cost Estimate (see Appendix B for cost breakdown)		
Total (design, permitting, construction, tax, contingency):	**$234,000**	
Challenges, Impacts or Enhancements (Rate from 1 to 10, high scores indicate challenges/impacts on project completion. Total < 35 preferred.)		
Wetlands:	0	No impact to wetlands.
Easement Acquisition:	0	Easements are not required.
Fish/Wildlife Habitat including Water Quality:	0	Fish/wildlife habitat will not be impacted.
Construction:	5	Construction requires partial closure of Grove Street.
O&M:	5	Periodic pipe maintenance required.
Public Acceptance (based on cost, safety and property damage):	3	Community likely in favor of project.
Permitting:	2	Only construction permits anticipated to be required.
Overall Score	**15**	

Improvement/Project Summary

Project:	C-10: Short and Long Streets
Stakeholders:	Local Property Owners & City of Snohomish
Location/Address:	Short and Long Streets at Mill Avenue
Date:	August 2013
Problem Description:	**Photo/Map/Sketch:**
There is not a stormwater collection system along Short and Long Streets. Stormwater sheet flows and ponds in areas along the street and the right-of-way. Also, Short Street is not paved and small to medium size potholes form frequently.	
City Actions and/or Analysis Process and Results:	
City maintenance staff periodically answers complaints from local residences about stormwater ponding along the street and in their driveways. Also, City staff periodically needs to maintain Short Street to fill in the potholes.	
Recommended Improvement:	
Install a new stormwater collection system consisting of catch basins and a 12" storm pipeline that would tie into the existing storm main located on Mill Avenue.	
Cost Estimate (see Appendix B for cost breakdown)	
Total (design, permitting, construction, tax, contingency):	**$224,000**
Challenges, Impacts or Enhancements (Rate from 1 to 10, high scores indicate challenges/impacts on project completion. Total < 35 preferred.)	
Wetlands:	0 No impact to wetlands.
Easement Acquisition:	0 Easements are not required.
Fish/Wildlife Habitat including Water Quality:	0 Fish/wildlife habitat will not be impacted.
Construction:	5 Construction requires partial closure of Grove Street.
O&M:	5 Periodic pipe maintenance required.
Public Acceptance (based on cost, safety and property damage):	3 Community likely in favor of project.
Permitting:	2 Only construction permits anticipated to be required.
Overall Score	**15**

URS

Improvement/Project Summary

Project:	C-11: Bonneville Avenue	
Stakeholders:	Local Community and City of Snohomish	
Location/Address:	Bonneville Avenue near Bickford Avenue	
Date:	August 2013	
Problem Description:	**Photo/Map/Sketch:**	
Water is ponding in the driveways to a residential house and commercial business.		
City Actions and/or Analysis Process and Results:		
City maintenance staff receives complaints of localized flooding/ponding water from the land owners.		
Recommended Improvement:		
Install a new catch basin at each driveway to drain the water from the driveways to the existing storm main located across the street.		
Total (design, permitting, construction, tax, contingency):		
Total (design, permitting, construction, tax, contingency):	**$10,000**	
Challenges, Impacts or Enhancements (Rate from 1 to 10, high scores indicate challenges/impacts on project completion. Total < 35 preferred.)		
Wetlands:	0	No potential impacts to wetlands.
Easement Acquisition:	0	No easement acquisition is required.
Fish/Wildlife Habitat including Water Quality:	0	Fish/Wildlife habitat will not be impacted.
Construction:	5	Construction will require partial road closure.
O&M:	5	Pipeline and catch basins to require periodic maintenance.
Public Acceptance:	3	Community likely in favor of project.
Permitting:	5	Only construction permits anticipated to be required.
Overall Score	**18**	

Improvement/Project Summary

Project:	C-12: Blackmans Lake Outlet
Stakeholders:	Local Community and City of Snohomish
Location/Address:	
Date:	August 2013
Problem Description:	**Photo/Map/Sketch:**
Lake floods during large storm events due to constrictions at Blackmans Lake outlet and along Swifty Creek. Rising waters have caused flooding problems for properties along the lake.	See Figure C-12
City Actions and/or Analysis Process and Results:	
City is currently addressing this problem under a separate project.	
Recommended Improvement:	
See Figure C-12.	
Cost Estimate (City provided cost)	
Total:	**$528,000**
Challenges, Impacts or Enhancements (Rate from 1 to 10, high scores indicate challenges/impacts on project completion. Total < 35 preferred.)	
Wetlands:	
Easement Acquisition:	
Fish/Wildlife Habitat including Water Quality:	
Construction:	
O&M:	
Public Acceptance:	
Permitting:	
Overall Score	

Improvement/Project Summary

Project:	C-13: CSO Separation
Stakeholders:	Local Community and City of Snohomish
Location/Address:	Downtown Area Between Avenues F and L and First and Fifth Streets
Date:	August 2013
Problem Description:	**Photo/Map/Sketch:**
Existing stormwater system in this area discharges into the sanitary sewer system and impacts the sewer treatment process and creates overflows to the Snohomish River during large storm events.	See Figure C-13
City Actions and/or Analysis Process and Results:	
Separating sewer from stormwater would benefit water quality within the Snohomish River and reduce the amount of water requiring treatment. A stormwater quality pond located within the former (closed) wastewater lagoon would provide treatment of stormwater prior to discharge to the river.	
Recommended Improvement:	
See Section 7 and Figure C-13	
Cost Estimate (see Appendix B for cost breakdown)	
Total (design, permitting, construction, tax, contingency):	**$2,700,000**
Challenges, Impacts or Enhancements (Rate from 1 to 10, high scores indicate challenges/impacts on project completion. Total < 35 preferred.)	
Wetlands:	
Easement Acquisition:	
Fish/Wildlife Habitat including Water Quality:	
Construction:	
O&M:	
Public Acceptance:	
Permitting:	
Overall Score	**NA**

APPENDIX B

PROJECT COST ESTIMATES

UNIT RATES FOR PROJECT COST ESTIMATES

ITEM	UNITS	UNIT PRICE (2012)
Preparation		
Mobilization	LS	**10% of Subtotal**
Contingency	LS	**20% of Subtotal**
Sales Tax	LS	**8.8% of Subtotal**
Engineering, Permitting, Legal, Admin., Survey	LS	**20% of Total**
Construction Services	LS	**5% of Total**
Road Paving and Repair Materials		
3" Asphalt Pavement Sawcut	LF	**$1.00**
Asphalt and Concrete Removal & Disposal	TON	**$95.00**
Crushed Surfacing or Base Course (in place)	TON	**$30.00**
Gravel Base (in place)	TON	**$20.00**
Temporary Patch (cold mix)	SY	**$20.00**
3" Asphalt Concrete Pavement Trench Patch	TON	**$150.00**
Concrete Sidewalk Replacement	SF	**$20.00**
Concrete Curb & Gutter Replacement	LF	**$30.00**
Pipe Trench Excavation & Backfill		
Tree Revoval, incl. Stump (up to 24" diam.)	EA	**$600.00**
Shrub, Bush, & Brush Removal (by hand)	ACRE	**$3,600.00**
Pipe Trench Excavation	CY	**$10.00**
Pipe Bedding (in place)	CY	**$45.00**
Trench Backfill (in place with native material)	CY	**$15.00**
Ditch Excavation	LF	**$20.00**
Culvert Trench, Backfill, & Compaction	CY	**$38.00**
Drainage Structures		
12" Storm Sewer Pipe (material only)	LF	**$30.00**
15" Storm Sewer Pipe (material only)	LF	**$35.00**
18" Storm Sewer Pipe (material only)	LF	**$40.00**
12" Culvert Pipe (material only)	LF	**$30.00**
24" Storm Sewer Pipe (material only)	LF	**$60.00**
Catch Basin, Type I (in place)	EA	**$1,500.00**
Catch Basin, Type II, 48" (in place)	EA	**$2,500.00**
Manhole 48" (in place)	EA	**$4,000.00**
Reconnect to Existing Catch Basin or Manhole	EA	**$500.00**
New Ditch/Swale Construction	LF	**$20.00**
Ground Repair		
Hydroseeding	SY	**$3.00**
Sod	SY	**$8.00**
Miscellaneous		
Traffic Control (based on road classification and traffic volumes)	LF	**$10.00 to $25.00**
Trench Safety	SF	**$1.00**

Note: Unit rates derived from previous bids, RS Means, and best engineering estimate.

Project C-1

87th Avenue S.E. (Sinclair Avenue) (at 50th Street)

Item	Item Description	Unit	Unit Rate	Quantity	Cost
Construction Cost					
1	Tree Removal	EA	$600.00	8	$4,800.00
2	Pipe Trench Excavation	CY	$10.00	223	$2,230.00
3	Pipe Bedding	CY	$45.00	77	$3,465.00
4	Trench Backfill	CY	$15.00	134	$2,010.00
5	15" Storm Sewer Pipe	LF	$35.00	400	$14,000.00
6	Hydroseeding	SY	$3.00	223	$669.00
7	Traffic Control	LF	$20.00	400	$8,000.00
8	Trench Safety	SF	$1.00	2000	$2,000.00
9	Catch Basin, Type I	EA	$1,500.00	3	$4,500.00
Subtotal					**$41,674.00**
10	Mobilization	LS	10%	1	$4,167.40
11	Contingency	LS	20%	1	$8,334.80
12	Sales Tax	LS	8.80%	1	$3,667.31
Total Construction Cost					**$57,843.51**
13	Engineering	LS	20%	1	$11,568.70
14	Permitting, Legal Admin., Survey	LS	10%	1	$5,784.35
15	Construction Services	LS	5%	1	$2,892.18

Total Project Cost	**$78,088.74**

USE **$78,000.00**

Assumptions:

1. Trench width = 3' and depth = 5'

Project C-2

Swifty Creek (at Second Street)

Item	Item Description	Unit	Unit Rate	Quantity	Cost
Construction Cost					
1	3" Asphalt Concrete Pavement Sawcut	LF	$1.00	1,850	$1,850.00
2	Asphalt & Concrete Removal and Disposal	TON	$95.00	100	$9,500.00
3	Trench Excavation	CY	$10.00	1,340	$13,400.00
4	Pipe Bedding	CY	$45.00	550	$24,750.00
5	Trench Backfill	CY	$15.00	420	$6,300.00
6	Gravel Base	TON	$20.00	125	$2,500.00
7	Crushed Surfacing Top Course	TON	$30.00	125	$3,750.00
8	Temporary Patch (cold mix)	SY	$20.00	338	$6,760.00
9	3" Asphalt Concrete Pavement Trench Patch	TON	$150.00	100	$15,000.00
10	Concrete Sidewalk Replacement	SF	$20.00	60	$1,200.00
11	Concrete Curb and/or Gutter Replacement	LF	$30.00	30	$900.00
12	12" Storm Sewer Pipe	LF	$30.00	160	$4,800.00
13	24" Storm Sewer Pipe	LF	$60.00	1,150	$69,000.00
14	Manhole	EA	$4,000.00	7	$28,000.00
15	Catch Basin, Type I	EA	$1,500.00	4	$6,000.00
16	Reconnect to Existing Manhole	EA	$500.00	1	$500.00
17	Connect Exist. CB to New Manhole	EA	$500.00	5	$2,500.00
18	Traffic Control	LF	$25.00	1,000	$25,000.00
19	Trench Safety	SF	$1.00	10,500	$10,500.00
Subtotal					**$232,210.00**
20	Mobilization	LS	10%	1	$23,221.00
21	Contingency	LS	20%	1	$46,442.00
22	Sales Tax	LS	8.80%	1	$20,434.48
Total Construction Cost					**$322,307.48**
23	Engineering	LS	20%	1	$64,461.50
24	Permitting, Legal Admin., Survey	LS	10%	1	$32,230.75
25	Construction Services	LS	5%	1	$16,115.37
26	Easement Acquisition	LS	10%	1	$32,230.75

Total Project Cost	**$467,345.85**

USE **$468,000.00**

Assumptions:

1. Trench width = 4' and depth = 8'
2. Existing pavement cut, removal, and patch to be 1 foot wider than trench on each side.
3. Crushed surfacing material under trench pavement patch to be 6" thick.

Project C-3

Maple Avenue (at unopened Fairview Street)

Item	Item Description	Unit	Unit Rate	Quantity	Cost
Construction Cost					
1	3" Asphalt Concrete Pavement Sawcut	LF	$1.00	60	$60.00
2	Asphalt & Concrete Removal and Disposal	TON	$95.00	4	$380.00
3	Pipe Trench Excavation	CY	$10.00	160	$1,600.00
4	Pipe Bedding	CY	$45.00	95	$4,275.00
5	Trench Backfill	CY	$15.00	32	$480.00
6	Gravel Base	TON	$20.00	3	$60.00
7	Crushed Surfacing Top Course	TON	$30.00	53	$1,590.00
8	Temporary Patch (cold mix)	SY	$20.00	14	$280.00
9	3" Asphalt Concrete Pavement Trench Patch	TON	$150.00	3	$450.00
10	Concrete Sidewalk Replacement	SF	$20.00	36	$720.00
11	Concrete Curb and/or Gutter Replacement	LF	$30.00	8	$240.00
12	12" Storm Sewer Pipe	LF	$30.00	285	$8,550.00
13	Manhole	EA	$4,000.00	1	$4,000.00
14	Reconnect to Existing Manhole	EA	$500.00	1	$500.00
15	Traffic Control	LF	$25.00	285	$7,125.00
16	Trench Safety	SF	$1.00	1,425	$1,425.00
Subtotal					**$31,735.00**
17	Mobilization	LS	10%	1	$3,173.50
18	Contingency	LS	20%	1	$6,347.00
19	Sales Tax	LS	8.80%	1	$2,792.68
Total Construction Cost					**$44,048.18**
20	Engineering	LS	20%	1	$8,809.64
21	Permitting, Legal Admin., Survey	LS	10%	1	$4,404.82
22	Construction Services	LS	5%	1	$2,202.41

Total Project Cost	**$59,465.04**

USE **$60,000.00**

Assumptions:

1. Trench width = 3' and depth = 5'
2. Existing pavement cut, removal, and patch to be 1 foot wider than trench on each side.
3. Crushed surfacing material under trench pavement patch to be 6" thick.

Project C-4

Park Avenue (at Blackmans Lake)

Item	Item Description	Unit	Unit Rate	Quantity	Cost
Construction Cost					
1	Shrub, Bush, & Brush Removal	HRS.	$60.00	48.0	$2,880.00
2	Asphalt & Concrete Removal and Disposal	TON	$95.00	15	$1,425.00
3	Pipe Trench Excavation	CY	$10.00	112	$1,120.00
4	Pipe Bedding	CY	$45.00	39	$1,755.00
5	Trench Backfill	CY	$15.00	45	$675.00
6	Crushed Surfacing Top Course	TON	$30.00	11	$330.00
7	3" Asphalt Concrete Sidewalk Replacement	TON	$150.00	15	$2,250.00
8	24" Storm Sewer Pipe	LF	$60.00	200	$12,000.00
9	Reconnect to Existing Manhole or Catch basin	EA	$500.00	2	$1,000.00
10	Sod	SY	$8.00	134	$1,072.00
11	Traffic Control	LF	$25.00	200	$5,000.00
12	Trench Safety	SF	$1.00	1,000	$1,000.00
13	Catch Basin, Type II	EA	$2,500.00	1	$2,500.00
Subtotal					**$33,007.00**
14	Mobilization	LS	10%	1	$3,300.70
15	Contingency	LS	20%	1	$6,601.40
16	Sales Tax	LS	8.80%	1	$2,904.62
Total Construction Cost					**$45,813.72**
17	Engineering	LS	20%	1	$9,162.74
18	Permitting, Legal Admin., Survey	LS	10%	1	$4,581.37
19	Construction Services	LS	5%	1	$2,290.69

Total Project Cost	**$61,848.52**

USE **$62,000.00**

Assumptions:

1. Trench width = 4' and depth = 5'
2. Crushed surfacing material under asphalt sidewalk to be 3" thick.

Project C-5a
16th Street

Item	Item Description	Unit	Unit Rate	Quantity	Cost
Construction Cost					
1	3" Asphalt Concrete Pavement Sawcut	LF	$1.00	240	$240.00
2	Asphalt & Concrete Removal and Disposal	TON	$95.00	11	$1,045.00
3	Pipe Trench Excavation	CY	$10.00	420	$4,200.00
4	Pipe Bedding	CY	$45.00	170	$7,650.00
5	Trench Backfill	CY	$15.00	237	$3,555.00
6	Gravel Base	TON	$20.00	9	$180.00
7	Crushed Surfacing Top Course	TON	$30.00	13	$390.00
8	3" Asphalt Concrete Pavement Trench Patch	TON	$150.00	9	$1,350.00
9	12" Storm Sewer Pipe	LF	$30.00	750	$22,500.00
10	Catch Basin, Type I	EA	$1,500.00	6	$9,000.00
11	Hydroseeding	SY	$3.00	350	$1,050.00
12	Traffic Control	LF	$15.00	650	$9,750.00
13	Trench Safety	SF	$1.00	3,750	$3,750.00
Subtotal					**$64,660.00**
14	Mobilization	LS	10%	1	$6,466.00
15	Contingency	LS	20%	1	$12,932.00
16	Sales Tax	LS	8.80%	1	$5,690.08
Total Construction Cost					**$89,748.08**
17	Engineering	LS	20%	1	$17,949.62
18	Permitting, Legal Admin., Survey	LS	10%	1	$8,974.81
19	Construction Services	LS	5%	1	$4,487.40

Total Project Cost	**$121,159.91**

USE **$122,000.00**

Assumptions:

1. Trench width = 3' and depth = 5'
2. Existing pavement cut, removal, and patch to be 1 foot wider than trench on each side.
3. Crushed surfacing material under trench pavement patch to be 6" thick.

Project C-5b

Holly Vista Drive

Item	Item Description	Unit	Unit Rate	Quantity	Cost
Construction Cost					
1	3" Asphalt Concrete Pavement Sawcut	LF	$1.00	740	$740.00
2	Asphalt & Concrete Removal and Disposal	TON	$95.00	34	$3,230.00
3	Pipe Trench Excavation	CY	$10.00	950	$9,500.00
4	Pipe Bedding	CY	$45.00	330	$14,850.00
5	Trench Backfill	CY	$15.00	570	$8,550.00
7	Gravel Base	TON	$20.00	30	$600.00
8	Crushed Surfacing Top Course	TON	$30.00	30	$900.00
9	3" Asphalt Concrete Pavement Trench Patch	TON	$150.00	27	$4,050.00
10	12" Storm Sewer Pipe	LF	$30.00	1,710	$51,300.00
11	12" Culvert Pipe	LF	$30.00	40	$1,200.00
12	Catch Basin, Type I	EA	$1,500.00	13	$19,500.00
13	Manhole	EA	$4,000.00	4	$16,000.00
14	Reconnect ot Existing Catch Basin/Manhole	EA	$500.00	2	$1,000.00
15	8' diam. X 100' L Detention Pipe	LF	$500.00	100	$50,000.00
16	Hydroseeding	SY	$3.00	240	$720.00
17	Sod	SY	$8.00	370	$2,960.00
18	Traffic Control	LF	$15.00	1,100	$16,500.00
19	Trench Safety	SF	$1.00	8,550	$8,550.00
Subtotal					**$210,150.00**
20	Mobilization	LS	10%	1	$21,015.00
21	Contingency	LS	20%	1	$42,030.00
22	Sales Tax	LS	8.80%	1	$18,493.20
Total Construction Cost					**$291,688.20**
23	Engineering	LS	20%	1	$58,337.64
24	Permitting, Legal Admin., Survey	LS	10%	1	$29,168.82
25	Construction Services	LS	5%	1	$14,584.41

Total Project Cost	**$393,779.07**

USE **$394,000.00**

Assumptions:

1. Trench width = 3' and depth = 5'
2. Existing pavement cut, removal, and patch to be 1 foot wider than trench on each side.
3. Crushed surfacing material under trench pavement patch to be 6" thick.

Project C-6

Cypress Avenue

Item	Item Description	Unit	Unit Rate	Quantity	Cost
Construction Cost					
1	3" Asphalt Concrete Pavement Sawcut	LF	$1.00	620	$620.00
2	Asphalt & Concrete Removal and Disposal	TON	$95.00	28	$2,660.00
3	Trench Excavation	CY	$10.00	173	$1,730.00
4	Pipe Bedding	CY	$45.00	70	$3,150.00
5	Trench Backfill	CY	$15.00	70	$1,050.00
6	Gravel Base	TON	$20.00	26	$520.00
7	Crushed Surfacing Top Course	TON	$30.00	26	$780.00
8	3" Asphalt Concrete Pavement Trench Patch	TON	$150.00	28	$4,200.00
9	12" Storm Sewer Pipe	LF	$30.00	310	$9,300.00
10	Catch Basin, Type I	EA	$1,500.00	6	$9,000.00
11	Reconnect to Existing Catch Basin/Manhole	EA	$500.00	1	$500.00
12	Traffic Control	LF	$15.00	400	$6,000.00
13	Trench Safety	SF	$1.00	1,550	$1,550.00
Subtotal					**$41,060.00**
14	Mobilization	LS	10%	1	$4,106.00
15	Contingency	LS	20%	1	$8,212.00
16	Sales Tax	LS	8.80%	1	$3,613.28
Total Construction Cost					**$56,991.28**
17	Engineering	LS	20%	1	$11,398.26
18	Permitting, Legal Admin., Survey	LS	10%	1	$5,699.13
19	Construction Services	LS	5%	1	$2,849.56

Total Project Cost	**$76,938.23**

USE **$77,000.00**

Assumptions:

1. Trench width = 3' and depth = 5'
2. Existing pavement cut, removal, and patch to be 1 foot wider than trench on each side.
3. Crushed surfacing material under trench pavement patch to be 6" thick.

Project C-7

Third Street and Avenue D

Item	Item Description	Unit	Unit Rate	Quantity	Cost
Construction Cost					
1	3" Asphalt Concrete Pavement Sawcut	LF	$1.00	60	$60.00
2	Asphalt & Concrete Removal and Disposal	TON	$95.00	2	$190.00
3	Pipe Trench Excavation	CY	$10.00	17	$170.00
4	Pipe Bedding	CY	$45.00	7	$315.00
5	Trench Backfill	CY	$15.00	7	$105.00
6	Gravel Base	TON	$20.00	3	$60.00
7	Crushed Surfacing Top Course	TON	$30.00	3	$90.00
8	3" Asphalt Concrete Pavement	TON	$150.00	2	$300.00
9	12" Storm Sewer Pipe	LF	$30.00	30	$900.00
10	16" Steel Casing Pipe	LF	$75.00	30	$2,250.00
11	Reconnect to Existing Catch Basin/Manhole	EA	$500.00	2	$1,000.00
12	Traffic Control	LF	$25.00	60	$1,500.00
13	Trench Safety	SF	$1.00	90	$90.00
Subtotal					**$7,030.00**
14	Mobilization	LS	10%	1	$703.00
15	Contingency	LS	20%	1	$1,406.00
16	Sales Tax	LS	8.80%	1	$618.64
Total Construction Cost					**$9,757.64**
17	Engineering	LS	20%	1	$1,951.53
18	Permitting, Legal Admin., Survey	LS	10%	1	$975.76
19	Construction Services	LS	5%	1	$487.88

Total Project Cost	**$13,172.81**

USE **$14,000.00**

Assumptions:

1. Trench width = 3' and depth = 5'
2. Existing pavement cut, removal, and patch to be 1 foot wider than trench on each side.
3. Crushed surfacing material under trench pavement patch to be 6" thick.

Project C-8
Grove Street

Item	Item Description	Unit	Unit Rate	Quantity	Cost
Construction Cost					
1	3" Asphalt Concrete Pavement Sawcut	LF	$1.00	710	$710.00
2	Asphalt & Concrete Removal and Disposal	TON	$95.00	32	$3,040.00
3	Pipe Trench Excavation	CY	$10.00	200	$2,000.00
4	Pipe Bedding	CY	$45.00	80	$3,600.00
5	Trench Backfill	CY	$15.00	80	$1,200.00
6	Gravel Base	TON	$20.00	30	$600.00
7	Crushed Surfacing Top Course	TON	$30.00	30	$900.00
8	3" Asphalt Concrete Pavement Trench Patch	TON	$150.00	33	$4,950.00
9	12" Storm Sewer Pipe	LF	$30.00	355	$10,650.00
10	Catch Basin, Type I	EA	$1,500.00	6	$9,000.00
11	Manhole, 48"	EA	$4,000.00	1	$4,000.00
12	Connect to Existing Storm Main	EA	$500.00	1	$500.00
13	Traffic Control	LF	$15.00	300	$4,500.00
14	Trench Safety	SF	$1.00	1,775	$1,775.00
Subtotal					**$47,425.00**
15	Mobilization	LS	10%	1	$4,742.50
16	Contingency	LS	20%	1	$9,485.00
17	Sales Tax	LS	8.80%	1	$4,173.40
Total Construction Cost					**$65,825.90**
18	Engineering	LS	20%	1	$13,165.18
19	Permitting, Legal Admin., Survey	LS	10%	1	$6,582.59
20	Construction Services	LS	5%	1	$3,291.30

Total Project Cost	**$88,864.97**

USE **$89,000.00**

Assumptions:

1. Trench width = 3' and depth = 5'
2. Existing pavement cut, removal, and patch to be 1 foot wider than trench on each side.
3. Crushed surfacing material under trench pavement patch to be 6" thick.

Project C-9

Baird and Victor Avenues

Item	Item Description	Unit	Unit Rate	Quantity	Cost
Construction Cost					
1	3" Asphalt Concrete Pavement Sawcut	LF	$1.00	440	$440.00
2	Asphalt & Concrete Removal and Disposal	TON	$95.00	20	$1,900.00
3	Pipe Trench Excavation	CY	$10.00	640	$6,400.00
4	Pipe Bedding	CY	$45.00	255	$11,475.00
5	Trench Backfill	CY	$15.00	255	$3,825.00
6	Gravel Base	TON	$20.00	95	$1,900.00
7	Crushed Surfacing Top Course	TON	$30.00	95	$2,850.00
8	3" Asphalt Concrete Pavement Trench Patch	TON	$150.00	20	$3,000.00
9	12" Storm Sewer Pipe	LF	$30.00	1,145	$34,350.00
10	Catch Basin, Type I	EA	$1,500.00	20	$30,000.00
11	Manhole, 48"	EA	$4,000.00	2	$8,000.00
12	Connect to Existing Storm Main	EA	$500.00	2	$1,000.00
13	Traffic Control	LF	$15.00	925	$13,875.00
14	Trench Safety	SF	$1.00	5,725	$5,725.00
Subtotal					**$124,740.00**
15	Mobilization	LS	10%	1	$12,474.00
16	Contingency	LS	20%	1	$24,948.00
17	Sales Tax	LS	8.80%	1	$10,977.12
Total Construction Cost					**$173,139.12**
18	Engineering	LS	20%	1	$34,627.82
19	Permitting, Legal Admin., Survey	LS	10%	1	$17,313.91
20	Construction Services	LS	5%	1	$8,656.96

Total Project Cost	**$233,737.81**

USE **$234,000.00**

Assumptions:

1. Trench width = 3' and depth = 5'
2. Existing pavement cut, removal, and patch to be 1 foot wider than trench on each side.
3. Crushed surfacing material under trench pavement patch to be 6" thick.

Project C-10

Short and Long Streets

Item	Item Description	Unit	Unit Rate	Quantity	Cost
Construction Cost					
1	3" Asphalt Concrete Pavement Sawcut	LF	$1.00	1,110	$1,110.00
2	Asphalt & Concrete Removal and Disposal	TON	$95.00	50	$4,750.00
3	Pipe Trench Excavation	CY	$10.00	575	$5,750.00
4	Pipe Bedding	CY	$45.00	228	$10,260.00
5	Trench Backfill	CY	$15.00	228	$3,420.00
6	Gravel Base	TON	$20.00	85	$1,700.00
7	Crushed Surfacing Top Course	TON	$30.00	125	$3,750.00
8	3" Asphalt Concrete Pavement Trench Patch	TON	$150.00	50	$7,500.00
9	12" Storm Sewer Pipe	LF	$30.00	1,030	$30,900.00
10	Catch Basin, Type I	EA	$1,500.00	19	$28,500.00
11	Connect to Existing Catch Basins	EA	$500.00	2	$1,000.00
12	Traffic Control	LF	$15.00	1,030	$15,450.00
13	Trench Safety	SF	$1.00	5,150	$5,150.00
Subtotal					**$119,240.00**
14	Mobilization	LS	10%	1	$11,924.00
15	Contingency	LS	20%	1	$23,848.00
16	Sales Tax	LS	8.80%	1	$10,493.12
Total Construction Cost					**$165,505.12**
17	Engineering	LS	20%	1	$33,101.02
18	Permitting, Legal Admin., Survey	LS	10%	1	$16,550.51
19	Construction Services	LS	5%	1	$8,275.26

Total Project Cost	**$223,431.91**

USE **$224,000.00**

Assumptions:

1. Trench width = 3' and depth = 5'
2. Existing pavement cut, removal, and patch to be 1 foot wider than trench on each side.
3. Crushed surfacing material under trench pavement patch to be 6" thick.

Project C-11

Bonneville Avenue

Item	Item Description	Unit	Unit Rate	Quantity	Cost
Construction Cost					
1	3" Asphalt Concrete Pavement Sawcut	LF	$1.00	60	$60.00
2	Asphalt & Concrete Removal and Disposal	TON	$95.00	3	$285.00
3	Pipe Trench Excavation	CY	$10.00	20	$200.00
4	Pipe Bedding	CY	$45.00	7	$315.00
5	Trench Backfill	CY	$15.00	7	$105.00
6	Gravel Base	TON	$20.00	3	$60.00
7	Crushed Surfacing Top Course	TON	$30.00	3	$90.00
8	3" Asphalt Concrete Pavement Trench Patch	TON	$150.00	3	$450.00
9	12" Storm Sewer Pipe	LF	$30.00	30	$900.00
10	Catch Basin, Type I	EA	$1,500.00	1	$1,500.00
11	Connect to Existing Catch Basin or Manhole	EA	$500.00	1	$500.00
12	Traffic Control	LF	$15.00	30	$450.00
13	Trench Safety	SF	$1.00	150	$150.00
Subtotal					**$5,065.00**
14	Mobilization	LS	10%	1	$506.50
15	Contingency	LS	20%	1	$1,013.00
16	Sales Tax	LS	8.80%	1	$445.72
Total Construction Cost					**$7,030.22**
17	Engineering	LS	20%	1	$1,406.04
18	Permitting, Legal Admin., Survey	LS	10%	1	$703.02
19	Construction Services	LS	5%	1	$351.51

Total Project Cost	**$9,490.80**

USE **$10,000.00**

Assumptions:

1. Trench width = 3' and depth = 5'
2. Existing pavement cut, removal, and patch to be 1 foot wider than trench on each side.
3. Crushed surfacing material under trench pavement patch to be 6" thick.

Project C-12 Conducted under separate project by city. No cost estimate to provide.

Project: C-13 CSO Separation (west end of downtown)

Area: **Second Street (from Avenue E to WWTP)**
Avenue E (from Second St to Fifth St)
Avenue F (storm/sewer separation at Second St)
Avenue G (from Second St to Fifth St)
Avenue H (from Second St to Fifth St)
Avenue I (from Second St to Fifth St)
Avenue J (from Second St to Fifth St)
Fifth St (from Avenue H to Avenue J)
Riverview Lane to Fourth St
Avenue L (from Second St to Fifth St)
Stormwater Detention Pond

Item	Item Description	Unit	Unit Rate	Quantity	Cost
CSO Area Construction Cost					
1	3" Asphalt Concrete Pavement Sawcut	LF	$1.00	22,730	$22,730.00
2	Asphalt & Concrete Removal and Disposal	TON	$95.00	875	$83,125.00
3	Pipe Trench Excavation	CY	$10.00	7,156	$71,560.00
4	Pipe Bedding	CY	$45.00	1,158	$52,110.00
5	Trench Backfill	CY	$15.00	4,640	$69,600.00
6	Crushed Surfacing Top Course	TON	$30.00	846	$25,380.00
7	3" Asphalt Concrete Pavement Trench Patch	TON	$150.00	875	$131,250.00
8	30" Storm Sewer Pipe	LF	$45.00	2,360	$106,200.00
9	12" Storm Sewer Pipe	LF	$30.00	9,850	$295,500.00
10	Catch Basin, Type I	EA	$1,500.00	16	$24,000.00
11	Manhole	EA	$4,000.00	13	$52,000.00
12	Connect Exist. 30" Storm Pipe to New Manholes	EA	$500.00	5	$2,500.00
13	Reconnect Exist. Catch Basins to 30" Storm Pipe	EA	$500.00	2	$1,000.00
14	Disconnect Exist. CSO Storm Line and Reconnect to New 30" Storm	EA	$5,000.00	2	$10,000.00
15	Reconnect Exist. Catch Basins to New 12" Storm	EA	$3,000.00	27	$81,000.00
16	Traffic Control	LF	$15.00	10,150	$152,250.00
17	Trench Safety	SF	$1.00	45,600	$45,600.00
18	Top Soil	CY	$50.00	37	$1,850.00
19	Hydroseed	SF	$1.00	1,950	$1,950.00
Stormwater Pond Upgrade Construction Cost					
20	Inlet Protection				
	24" Minus Riprap (Heavy Loose)	TON	$50.00	53	$2,650.00
	Gravel Filter	CY	$50.00	10	$500.00
21	First Wetpool Cell				
	Excavation (Keyway for Berm)	CY	$10.00	790	$7,900.00
	Excavation (First Cell)	CY	$10.00	3,630	$36,300.00
	Fill (Berm)	CY	$40.00	1,580	$63,200.00
22	Outlet Structure				
	Manhole or Weir Structure & Emergency Retrofit	LS	$75,000.00	1	$75,000.00
	Erosion Protection (Similar to Inlet Protection)	LS	$3,200.00	1	$3,200.00
23	Revegetation (Hydro-Seeding)				
	First Cell	AC	$10,000.00	2.3	$22,500.00
	Berm (Assume 20' Wide By 640' Long)	AC	$10,000.00	0.3	$3,000.00
	Disturbed Areas (Assume 15% of 30 Acre Pond)	AC	$10,000.00	5	$45,000.00
24	Access Ramps Into Pond				
	New Ramp and Improvements to Existing Ramp	LS	$10,000.00	1	$10,000.00
Subtotal					**$1,498,855.00**
25	Mobilization	LS	10%	1	$149,885.50
26	Contingency	LS	20%	1	$299,771.00
27	Sales Tax	LS	8.80%	1	$131,899.24
Total Construction Cost					**$2,080,410.74**
28	Engineering	LS	15%	1	$312,061.61
29	Permitting, Legal Admin., Survey	LS	10%	1	$208,041.07
30	Construction Services	LS	5%	1	$104,020.54

Total Project Cost	**$2,704,533.96**

USE **$2,700,000.00**

Assumptions:

1. Trench width = 2' and depth = 5.5'
2. Existing pavement cut and removal to be 1 foot wider than tench on each side
3. Crushed surfacing top course material under pavement to be 6 " thick
4. Unit rates derived from pervious bids, RS Means, and best engineering estimate

APPENDIX C

SEPA CHECKLIST

CITY OF SNOHOMISH

Founded 1859, Incorporated 1890

116 UNION AVENUE • SNOHOMISH, WASHINGTON 98290 • TEL (360) 568-3115 FAX (360) 568-1375

STATE ENVIRONMENTAL POLICY ACT (SEPA) CHECKLIST

PURPOSE OF CHECKLIST

The State Environmental Policy Act (SEPA), Chapter 43.21C RCW, requires all governmental agencies to consider the environmental impacts of a proposal before making decisions. An environmental impact statement (EIS) must be prepared for all proposals with probable significant adverse impacts on the quality of the environment. The purpose of this checklist is to provide information to help you and the agency identify impacts from your proposal (and to reduce or avoid impacts from the proposal, if it can be done) and to help the agency decide whether an EIS is required.

INSTRUCTIONS FOR APPLICANTS

This environmental checklist asks you to describe some basic information about your proposal. Governmental agencies use this checklist to determine whether the environmental impacts of your proposal are significant, requiring preparation of an EIS. Answer the questions briefly, with the most precise information known, or give the best description you can.

You must answer each question accurately and carefully, to the best of your knowledge. In most cases, you should be able to answer the questions from your own observations and project plans without the need to hire experts. If you really do not know the answer, or if a question does not apply to your proposal, write "do not know" or "does not apply." Complete answers to the questions now may avoid unnecessary delays later.

Some questions ask about governmental regulations, such as zoning, shoreline, and landmark designations. Answer these questions if you can. If you have problems, the governmental agencies can assist you.

The checklist questions apply to all parts of your proposal, even if you plan to do them over a period of time or on different parcels of land. Attach any additional information that will help describe your proposal or its environmental effects. The agency to which you submit this checklist may ask you to explain your answers or provide additional information reasonably related to determining if there may be significant adverse impact.

USE OF CHECKLIST FOR NONPROJECT PROPOSALS

Complete this checklist for nonproject proposals, even though questions may be answered "does not apply." IN ADDITION, complete the SUPPLEMENTAL SHEET FOR NONPROJECT ACTIONS (part D).

For nonproject actions, the references in the checklist to the words "project," "applicant," and "property or site" should be read as "proposal," "proposer," and "affected geographic area," respectively.

last revision: 073009

ADMINISTRATION
COMMENTS ONLY

CITY OF SNOHOMISH
ENVIRONMENTAL CHECKLIST

FILE NO. DATE RECEIVED:

I. BACKGROUND

A. Name of proposed project, if applicable:

City of Snohomish Stormwater Comprehensive Plan Update

B. Name, address and telephone number of property owner(s):

Max Selin, Project Engineer
City of Snohomish
116 Union Avenue
Snohomish, WA 98290
360-282-3196

C. Name, address and telephone number of representative(s) [contractor, architect, etc.]:

Carla Talich, Senior Civil Engineer
URS Corporation
1501 4th Avenue, Suite 1400
Seattle, WA 98101
206-438-2125

D. Date checklist prepared:

August 2013

E. Agency requesting checklist:

Washington State Department of Ecology

F. Proposed timing or schedule (including phasing, if applicable):

The Stormwater Comprehensive Plan Update ("Plan") is expected to be finalized in fall 2013. The Plan will be implemented over a several year period (6-10 years), with periodic updates. Activities associated with the Plan are anticipated to occur during this timeframe.

G. Do you have any plans for future additions, expansion, or further activity related to or connected with this proposal? If yes, explain.

This SEPA review for the Plan update is a "non-project action." There are specific actions described in the Plan for future additions and expansions to provide acceptable levels of service; these will be reviewed under separate project and site-specific SEPA processes.

H. List any environmental information you know about that has been prepared, or will be prepared, directly related to this proposal.

May 2005 CSO Reduction Plan Update, Tetra Tech/KCM
October 2004 Environmental Report, Tetra Tech/KCM

ADMINISTRATION COMMENTS ONLY

I. Do you know whether applications are pending for governmental approvals of other proposals directly affecting the property covered by your proposal? If yes, explain.

No.

J. List any government approvals or permits that will be needed for your proposal, if known.

The Plan is subject to approval by the Washington State Department of Ecology and the City of Snohomish. Individual projects recommended in the plan may require city, state or federal permits on a case-by-case basis.

K. Give a brief, complete description of your proposal, including the proposed uses and the size of the project and site. (There are several questions later in this checklist which ask you to describe certain aspects of your proposal. You do not need to repeat those answers on this page.)

The original study area from the 2001 Plan included the Incorporated City Limits of Snohomish as well as adjoining unincorporated areas of Snohomish County. This Plan update has been prepared to address the following additional areas:

- ***The North Planning Area, north of US Highway 2, and contributing areas;***
- ***Additional areas to the west of the original study area that contribute flow to the Upper Cemetery Creek and Lower Cemetery Creek basins; and***
- ***Additional areas to the east of the original study area that contribute flow to the Pilchuck basin.***

Twelve stormwater projects (C-1 to C-12) and one Combined Sewer Separation project (C-13) are included in the Plan. The Plan has been prepared to meet the rules and regulations of the Washington State Department of Ecology regarding storm drainage facilities. The plan is also written to be consistent with requirements of the State Growth Management Act and the City of Snohomish Comprehensive Plan.

L. Location of the proposal including street address (if any) and legal description (including section, township and range). Give sufficient information for a person to understand the precise location of your proposed project. If a proposal would occur over a range of area, provide the range or boundaries of the site(s). (You are not required to duplicate maps or detailed plans submitted with any permit applications related to this checklist.)

The City of Snohomish is located in Snohomish County. The study area for the Plan is approximately 4,869 acres (see Figure 1), consisting of the following drainage basins:

- ***Upper Cemetery Creek basin, located in the northwest corner of the study area (875 acres);***
- ***Lower Cemetery Creek basin, located in the westernmost portion of the study area (1,015 acres);***
- ***Blackmans Lake basin, located in the north-central portion of the study area (465 acres);***
- ***Swifty Creek basin, located in the south-central portion of the study area (330 acres);***
- ***Pilchuck River basin, located in the westernmost portion of the study area (466 acres);***
- ***Bunk Foss basin, located in the northeast corner of the study area (1,025 acres);***
- ***Snohomish River basin, located in the southernmost portion of the study area (445 acres);***
- ***Combined Sewer Area, located in the southernmost portion of the study area (248 acres);***

ADMINISTRATION COMMENTS ONLY

The Plan study area is located within Sections 1, 2, 11-14, 23, and 24 of Township 28N, Range 5E; Sections 5-8 and 17-19 of Township 28N, Range 6E; Sections 25, 26, 35, and 36 of Township 29N, Range 5E; and Sections 29-32 of Township 29N, Range 6E.

II. ENVIRONMENTAL ELEMENTS

A. EARTH

1. General description of the site (circle one): flat; rolling hilly; steep slopes; mountainous; other (explain):

The Plan study area includes varied terrain.

2. What is the steepest slope on the site (approximate percent slope)?

Based on the U.S. Department of Agriculture Natural Resources Conservation Service, slopes in the Plan study area range from 0 to 25 percent.

3. What general types of soils are found on the site? (For example: clay; sand; gravel; peat; muck.)

Plan study area soils are primarily Tokul gravelly loam and Tokul silt loam; these soils are moderately deep and well-drained with moderate permeability.

4. Are there surface indications or history of unstable soils in the immediate vicinity? If so, describe.

Soils in the vicinity of specific construction projects would be evaluated during the design of each project.

5. Describe the purpose, type, and approximate quantities of any filling or grading proposed. Indicate source of fill.

Requirements for filling and grading will be evaluated during the design of each project. Filling and grading will comply with applicable City of Snohomish requirements. If necessary, sources of fill would be determined by the contractor hired.

6. Could erosion occur as a result of clearing, construction, or use? If so, generally describe.

Erosion and sediment transport could occur during clearing and earth moving activities associated with projects included in the Plan. Such activities will be the subject of subsequent project-specific SEPA review.

7. About what percent of the site will be covered with impervious surfaces after project construction (for example: asphalt or buildings)?

This will be evaluated as the projects are designed; however an increase in impervious surfaces is not anticipated.

8. Proposed measures to reduce or control erosion, or other impacts to the earth, if any?

Appropriate Best Management Practices (BMPs) will be installed to help prevent and control runoff and erosion of exposed soils during construction. Low impact development techniques may be applied during the design phase of each project to reduce runoff flow rates and filter pollutants. In addition, a temporary erosion and sediment control plan will be prepared for each Plan-specific project consistent with applicable City of Snohomish requirements.

ADMINISTRATION
COMMENTS ONLY

B. AIR

1. What type of emissions to the air would result from the proposal (i.e., dust, automobile, odors, industrial wood smoke) during construction and when the project is completed? If any, generally describe and give approximate quantities, if known.

Short-term emissions from construction and construction equipment would likely occur during construction of specific projects identified in the Plan.

2. Are there any off-site sources of emissions or odor that may affect your proposal? If so, generally describe.

No.

3. Proposed measures to reduce or control emissions or other impacts to air, if any:

Emission and dust control methods will be used as necessary, including but not limited to: use of proper mufflers, use of air emissions control equipment devices, and wetting disturbed areas to control dust.

C. WATER

1. Surface:

a. Is there any surface water body on or in the immediate vicinity of the site (including year-round and seasonal streams, saltwater, lakes, ponds, wetlands)? If yes, describe type and provide names. If appropriate, state what stream or river it flows into.

Surface water bodies in the Plan study area include Cemetery Creek, Blackmans Lake, Swifty Creek, Bunk Foss Creek, the Pilchuck River, and the Snohomish River. These creeks ultimately flow into either the Pilchuck (which discharges to the Snohomish River) or Snohomish Rivers (which discharges into Puget Sound).

b. Will the project require any work over, in or adjacent to (within 200 feet) the described waters? If yes, please describe and attach available plans.

Construction of specific projects identified in the Plan would occur near Swifty Creek, Blackmans Lake, and several small unnamed ditches.

c. Estimate the amount of fill and dredge material that would be placed in or removed from surface of water or wetlands, and indicate the area of the site that would be affected. Indicate the source of fill material.

To be determined during design of specific projects identified in the Plan.

d. Will the proposal require surface water withdrawals or diversions? Give general description, purpose and approximate quantities if known.

To be determined during design of specific projects identified in the Plan.

e. Does the proposal lie within any 100-year flood plain? If so, note location on the site plan.

ADMINISTRATION
COMMENTS ONLY

It appears that Plan projects C-6 and C-13 are within the 100-year floodplain; no other Plan-specific projects are within the 100-year floodplain.

f. Does the proposal involve any discharges of waste material to surface waters? If so, describe the type of waste and anticipated volume of discharge.

None of the work associated with specific projects identified in the Plan is anticipated to discharge waste materials to surface waters.

2. Ground:

a. Will ground water be withdrawn, or will water be discharged to ground water? Give general description, purpose and approximate quantities, if known.

No.

b. Describe waste material that will be discharged into the ground from septic tanks or other sources, if any (for example: domestic sewage; industrial, containing the following chemicals...; agricultural; etc.). Describe the general size of the system, the number of such systems, the number of houses to be served (if applicable), or the number of animals or humans the system(s) are expected to serve.

Most of the downtown Snohomish area (about 248 acres) is within a Combined Sewer Area. Runoff from this area discharges to the sanitary sewer system. Since stormwater runoff from this area is collected in the sanitary sewer system, these flows are managed by that system. Partial separation of stormwater from the wastewater in this area is contained in the Plan.

3. Water Runoff (including storm water):

a. Describe the source of runoff (including storm water) and method of collection and disposal, if any (including quantities, if known). Where will this water flow? Will this water flow into other waters? If so, describe.

During construction of Plan-specific projects, stormwater runoff from any disturbed areas would be routed through erosion and sediment control facilities to minimize impacts to surface water bodies, including Swifty Creek, Blackmans Lake, and unnamed ditches near proposed project sites. Implementation of projects identified in the Plan would help improve conveyance of stormwater runoff.

b. Could waste materials enter ground or surface waters? If so, generally describe.

To be determined during design of specific projects identified in the Plan; however it is unlikely that waste materials would enter ground or surface waters.

4. Proposed measures to reduce or control surface, ground, and runoff water impacts, if any.

The projects identified in the Plan are designed to improve conveyance of stormwater runoff, reducing flooding, downstream erosion, sedimentation, and impacts to private property.

Appropriate BMPs will be installed to help prevent and control runoff during construction. In addition, a temporary erosion and sediment control plan will be prepared for each Plan-specific project consistent with applicable City of Snohomish requirements.

ADMINISTRATION
COMMENTS ONLY

D. PLANTS

a. Underline types of vegetation found on the site:

deciduous tree:
alder, maple, aspen,
other:

evergreen tree:
fir, cedar, pine,
other: madrona

shrubs

grass

wet soil plants:
cattail, buttercup,
bulrush, skunk cabbage,
other:

water plants:
water lily, eelgrass, milfoil,
other:

pasture

crop or grain

other types of vegetation:

No detailed survey of the Plan-specific project areas has been done. However, there is a wide range of vegetation in the Plan study area, including most listed above.

2. What kind and amount of vegetation will be removed or altered?

Vegetation removal and alteration associated with Plan-specific projects would be limited in scope as the majority of the project work would occur in the roadway or previously disturbed areas.

3. List threatened or endangered species known to be on or near the site.

None known. A query of the Washington Natural Heritage Program database confirmed that no special status plant species are known in the Plan area.

4. Proposed landscaping, use of native plants, or other measures to preserve or enhance vegetation on the site, if any:

To be determined during design of specific projects identified in the Plan. Any required landscaping would conform to City of Snohomish requirements.

E. ANIMALS/WILDLIFE

1. Underline any birds and animals that have been observed on or near the site or are known to be on or near the site:

birds:
heron, eagle, songbirds,
other: crow, seagull, starling, robin, waterfowl, bats, pileated woodpecker

mammals:
deer, bear, elk, beavers,
other: raccoon, squirrel, opossum, coyote, rodent, cottontail rabbit

fish:

ADMINISTRATION COMMENTS ONLY

bass, salmon, trout, herring, shellfish,
other: steelhead

2. List any threatened or endangered species known to be on or near the site.

Threatened or endangered species known within the Plan study area include: Chinook salmon, bull trout/Dolly Varden, and steelhead. This would be evaluated in further detail for each Plan-specific project.

3. Is the site part of a migrational route? If so, explain.

Yes, the Plan study area is part of the Pacific Flyway.

4. Proposed measures to preserve or enhance wildlife, if any:

Wildlife mitigation measures will be developed during design of specific projects identified in the Plan.

F. ENERGY AND NATURAL RESOURCES

1. What kinds of energy (electric, natural gas, oil, wood stove, solar) will be used to meet the completed projects energy needs? Describe whether it will be used for heating, manufacturing, etc.

Electricity would be used for pumps. Gasoline and diesel fuel would be used for construction equipment.

2. Would your project affect the potential use of solar energy by adjacent properties? If so, generally describe.

No.

3. What kinds of energy conservation features are included in the plans of this proposal? List other proposed measures to reduce or control energy impacts, if any:

Energy efficient pumps and equipment will be used when feasible.

G. ENVIRONMENTAL HEALTH

1. Are there any environmental health hazards, including exposure to toxic chemicals, risk of fire and explosion, spill, or hazardous waste, that could occur as a result of this proposal? If so, describe.

There are no anticipated environment health hazards associated with the Plan or Plan-specific actions – work would occur in previously disturbed areas.

a. Describe special emergency services that might be required.

None are anticipated.

b. Proposed measures to reduce or control environmental health hazards, if any:

None proposed.

ADMINISTRATION
COMMENTS ONLY

2. Noise

a. What types of noise exist in the area which may affect your project (for example: traffic, equipment, operation, other)?

None.

b. What types and levels of noise would be created by or associated with the project on a short-term or a long-term basis (for example: traffic, construction, operation, other)? Indicate what hours noise would come from the site.

Short-term noise during construction from construction-related activities. Noise is not anticipated during operations of Plan-specific projects.

c. Proposed measures to reduce or control noise impacts, if any:

Noise associated with construction activities will meet federal, state, and local noise regulations.

H. LAND AND SHORELINE USE

1. What is the current use of the site and adjacent properties?

The designated land uses in the Plan study area are commercial, residential, open disturbed spaces, industrial, and the north planning area. Most of the Plan-specific projects are within residential areas.

2. Has the site been used for agriculture? If so, describe.

Portions of the Plan study area are or have been in use for agriculture; none of the Plan-specific projects occur on agricultural lands.

3. Describe any structures on the site.

The Plan study area contains many residential, commercial, industrial, and recreational structures.

4. Will any structures be demolished? If so, what?

No structures would be demolished.

5. What is the current zoning classification of the site?

The majority of the Plan study area is zoned as Single Family Residential. Plan-specific projects would take place on land zoned as Single Family Residential, Business Park, Pilchuck District, Mixed Use, Historic Business, and High Density Residential.

6. What is the current Comprehensive Plan designation of the site?

The majority of the Plan study area is designated as Single Family Residential. Plan-specific projects would take place on land designated as Single Family Residential, Business Park, Mixed Use Commercial, Commercial, Historic Business Commercial, and Industry.

ADMINISTRATION COMMENTS ONLY

7. If applicable, what is the current Shoreline Master Program designation of the site?

The City's current Shoreline Master Program has designations of Urban, Suburban, and Rural in the Plan study area. None of the Plan-specific projects are located within the shoreline jurisdiction.

The City is currently updating their Shoreline Master Program; draft designations in the Plan study area include Aquatic, Rural Conservancy, Shoreline Residential, Urban Conservancy, and Downtown Riverfront. It appears that two Plan-specific projects (projects C-4 and C-12) may be located within the draft Shoreline Residential environment around Blackmans Lake; this will be evaluated during design of this specific project.

8. Has any part of the site been classified as an "environmentally sensitive" area? If so, specify.

The Plan study area contains lands mapped as flood hazard areas, earthquake hazard areas, steep slopes, wetlands, and fish and wildlife habitat areas. It appears that two Plan-specific projects (projects C-4 and C-12) may be located within a Class 2 wetland buffer associated with Blackmans Lake – this will be verified during design.

9. Approximately how many people would reside or work in the completed project?

Per the U.S. Census, the Plan study area had a population of approximately 9,100 people in 2010. The population of the City of Snohomish is anticipated to increase to approximately 14,600 people by 2040 (Source: PSRC 2012).

10. Approximately how many people would the completed project displace?

None.

11. Proposed measures to avoid or reduce displacement impacts, if any:

Not applicable.

12. Proposed measures to ensure the proposal is compatible with existing and projected land uses and plans, if any:

The Plan is required to comply with the City's adopted Comprehensive Plan.

I. HOUSING

1. Approximately how many units would be provided, if any? Indicate whether high-, middle- or low-income housing.

None.

2. Approximately how many units, if any would be eliminated? Indicate whether high-, middle- of low-income housing.

None.

3. Proposed measures to reduce or control housing impacts, if any:

Not Applicable.

ADMINISTRATION COMMENTS ONLY

J. AESTHETICS

1. What is the tallest height of any proposed structure(s), not including antennas; what is the principal exterior building material(s) proposed?

Not applicable.

2. What views in the immediate vicinity would be altered or obstructed?

None.

3. Proposed measures to reduce or control aesthetic impacts, if any:

Landscaping, if necessary, in accordance with City of Snohomish requirements would be included for Plan-specific projects.

K. LIGHT AND GLARE

1. What type of light or glare will the proposal produce? What time of day would it mainly occur?

None.

2. Could light or glare from the finished project be a safety hazard or interfere with views?

No.

3. What existing off-site sources of light or glare may affect your proposal?

None.

4. Proposed measure(s) to reduce or control light and glare impacts, if any:

Not applicable.

L. RECREATION

1. What designated and informal recreational opportunities are in the immediate vicinity?

The Plan study area contains several parks, open space areas, and a County trail (the Centennial Trail).

2. Would the proposed project displace any existing recreational uses? If so, describe.

No.

3. Proposed measures to reduce or control impacts on recreation, including recreational opportunities to be provided by the project or application, if any:

Not applicable.

ADMINISTRATION COMMENTS ONLY

M. HISTORIC AND CULTURAL PRESERVATION

1. Are there any places or objects listed on, or proposed for, national, state or local preservation registers known to be on or next to the site? If so, generally describe.

None known.

2. Generally describe any landmarks or evidence of historic, archaeological, scientific, or cultural importance known to be on or next to the site:

Three Plan-specific projects, C-2, C-7, and C-13, are located within the Historic District.

3. Proposed measure to reduce or control impacts, if any:

Mitigation of impacts, if any, on historic and cultural sites will be considered during the design of Plan-specific projects C-2, C-7, and C-13.

N. TRANSPORTATION

1. Identify public streets and highways serving the site, and describe proposed access to the existing street system. Show on site plans, if any.

The Plan study area includes multiple arterials and surface streets. Plan-specific projects are located near the following streets: First Street, Second Street, Third Street, 16th Street, 19th Street, 50th Street SE, 87th Avenue SE, Avenue D, Cypress Avenue, Maple Avenue, Holly Vista Drive, and Park Avenue.

2. Is the site currently served by public transportation? If not, what is the approximate distance to the nearest transit stop?

The Plan study area is served by Community Transit routes 270, 275, 277, and 424.

3. How many parking spaces would the completed project have? How many would the project eliminate?

Not applicable.

4. Will the proposal require any new roads or streets, or improvements to existing roads or streets, not including driveways? If so, generally describe (indicate whether private or public).

Upgrades/modifications to existing storm drainage facilities would occur along road rights-of-way. Some Plan-specific projects are located along unimproved rights-of-way; however these rights-of-way would not be improved by project activities.

5. Will the project use (or occur in the immediate vicinity of) water, rail, or air transportation? If so, generally describe.

No.

6. How many vehicular trips per day would be generated by the completed project? If known, indicate when peak volumes would occur.

Infrequent, short visits to storm drainage facilities for inspection and maintenance may be necessary.

7. Proposed measures to reduce or control transportation impacts, if any:

ADMINISTRATION COMMENTS ONLY

None.

O. PUBLIC SERVICES

1. Would the project result in an increased need for public services (for example: fire protection, police protection, health care, schools, other)? If so, generally describe.

No.

2. Proposed measures to reduce or control impacts on public services, it any:

Not applicable.

P. UTILITIES

1. Underline utilities currently available at the site: electricity, natural gas, water, refuse service, telephone, sanitary sewer, septic system, other (describe):

The above utilities are available in the Plan study area.

2. Describe the utilities that are proposed for the project, the utility providing the service, and the general construction activities on the site or in the immediate vicinity that might be needed.

The Plan proposes improvements to the city stormwater system to serve future needs of the City.

III. SIGNATURE

I hereby certify under penalty of perjury of the Laws of the State of Washington that the above answers are true and complete to the best of my knowledge. I understand that the lead agency is relying on them to make its decision.

_____
Signature

_____ _____ _____
Type or Print Name Title Submittal Date

ADMINISTRATION ONLY

Administrative Review By: _____

Title: _____ Date: _____

ADMINISTRATION
COMMENTS ONLY

CITY OF SNOHOMISH
ENVIRONMENTAL CHECKLIST
NON-PROJECT ACTIONS

FILE NO.: **DATE RECEIVED:**

Because these questions are very general, it may be helpful to read them in conjunction with the list of the elements of the environment. When answering these questions, be aware of the extent the proposal, or the types of activities likely to result from the proposal, would affect the item at a greater intensity or at a faster rate than if the proposal were not implemented. Respond briefly and in general terms.

IV. SUPPLEMENTAL QUESTIONS FOR NON-PROJECT ACTIONS

ADMINISTRATION COMMENTS ONLY

A. How would the proposal be likely to increase discharge to water; emissions to air; production, storage, or release of toxic or hazardous substances; or production of noise?

The Plan foresees implementation of the 12 Plan-specific stormwater conveyance projects (C-1 through C-12) and one combined sewer separation project (C-13). While there may be increases in noise and emissions to air associated with construction activities to implement Plan-specific projects, there should be no long-term increases.

Proposed measures to avoid or reduce such increases are:

Proper construction practices will avoid or reduce temporary impacts.

B. How would the proposal be likely to affect plants, animals, fish, or marine life?

Construction associated with Plan-specific projects would likely temporarily affect vegetation in non-roadway areas and ditches; areas disturbed for construction may be more susceptible to erosion and stormwater runoff. These impacts would be temporary. Long-term impacts are not anticipated. Impacts to animals, fish, or marine life are not anticipated.

Proposed measures to protect or conserve plants, animals, fish, or marine life are:

The use of Best Management Practices will be required during construction. A Temporary Erosion and Sediment Control Plan for each Plan-specific project developed in compliance with City of Snohomish regulations will also minimize impacts.

C. How would the proposal be likely to deplete energy or natural resources?

Implementation of the Plan and Plan-specific projects are not anticipated to increase the use of energy or natural resources.

Proposed measures to protect or conserve energy and natural resources are:

Not applicable.

ADMINISTRATION
COMMENTS ONLY

D. How would the proposal be likely to use or affect environmentally sensitive areas or areas designated (or eligible or under study) for governmental protection (such as parks, wilderness, wild and scenic rivers, threatened or endangered species habitat, historic or cultural sites, wetlands, floodplains, or prime farmlands)?

It appears that one Plan-specific project (project C-4) may be located within a Class 2 wetland buffer associated with Blackmans Lake – this will be verified during design of this project. For Plan project C-4, an approximately 180-foot existing 12-inch storm drain pipeline would be replaced with a 24-in pipeline. In addition, the existing catch basin and manhole may be replaced if determined to be undersized or in substandard condition.

Proposed measures to protect such resources or to avoid or reduce impacts are:

All local and state regulations concerning sensitive or protected areas, including wetlands, will be followed during implementation of Plan project C-4.

E. How would the proposal be likely to affect land and shoreline use, including whether it would allow or encourage land or shoreline uses incompatible with existing plans?

Improvements included in the Plan should not change or alter land uses in the Plan study area.

Proposed measures to avoid or reduce shoreline and land use impacts are:

Not applicable.

F. How would the proposal be likely to increase demands on transportation or public services and utilities?

The Plan and Plan-specific projects are aimed at improving the conveyance of stormwater; this in itself will not increase the demand for public services. Increases in demands on transportation or public services and utilities will be addressed through zoning and the City's Comprehensive Plan.

Proposed measures to reduce or respond to such demand(s) are:

In the future, additional stormwater facilities, transmission and distribution system improvements could occur to address future demands for such facilities.

G. Identify, if possible, whether the proposal may conflict with local, state, or federal laws or requirements for the protection of the environment:

The Plan is being prepared to meet the rules and regulations of the Washington State Department of Ecology regarding storm drainage facilities. In addition, the Plan will be approved by the City of Snohomish. Plan-specific projects will be evaluated for effects on the environment and, if needed, additional SEPA compliance will be conducted.

APPENDIX D

CALCULATIONS

Calculation Title	Project Number(s)	Location
Stormwater Conveyance – 87th Avenue SE (Sinclair Avenue)	C-1	87th Avenue SE (Sinclair Avenue)
Stormwater Conveyance – Blackmans Lake	C-4	Park Avenue/ Blackmans Lake
Stormwater Conveyance – 16th Street / Terrace and Maple Ave	C-3	Maple Avenue (Unopened Fairview Street)
	C-5b	Holly Vista Drive
Detention Facility – 16th and Terrace	C-5b	Holly Vista Drive
Water Quality Analysis – Combined Sewer Area	C-13	CSO Separation Area
Evaluate Conversion of Former Wastewater Lagoon to Water Quality Pond	C-13	CSO Separation Area

APPENDIX D

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Stormwater Conveyance – 16th Street / Terrace and Maple Ave	C-3	Maple Avenue (Unopened Fairview Street)
	C-5b	Holly Vista Drive
Detention Facility – 16th and Terrace	C-5b	Holly Vista Drive
Water Quality Analysis – Combined Sewer Area	C-13	CSO Separation Area
Evaluate Conversion of Former Wastewater Lagoon to Water Quality Pond	C-13	CSO Separation Area

Stormwater Conveyance – 87th Avenue SE (Sinclair Avenue)

URS CALCULATION COVER SHEET Quality

Project Name:	Stormwater Comprehensive Plan Update	**Project Number:**	33763575
Project Location:	City of Snohomish	**Client Name:**	City of Snohomish
PM Name:	Carla Talich	**PIC Name:**	Kevin Weed

IDENTIFYING INFORMATION

(This section is to be completed by the Originator.)

Calculation Medium: ☐ Electronic File Name: K:\City of Snohomish\Stormwater Comp Plan\Stormwater Modeling - NEW moved\Sinclair

(Select as appropriate) ☒ Hard-copy Unique Identification:

Number of pages *(including cover sheet)*: 16

Discipline: Hydraulics

Title of Calculation: Stormwater Conveyance - 87th Avenue SE (Sinclair Avenue)

Calculation Originator: Gina Franco

Calculation Contributors: Tobey Clarkin

Calculation Checker: Carla Talich

DESCRIPTION & PURPOSE

Determine the land use and area that contributes to locations identified by the city that need to be upgraded from a ditch to a pipe. Find the peak flows in these areas and size a pipe to convey the 25year peak flow.

BASIS / REFERENCE / ASSUMPTIONS

Assumptions are stated on calculation write up.

ISSUE / REVISION RECORD

Checker comments, if any, provided on: ☒ hard-copy ☐ electronic file ☐ Form 3-5 (MM)

No.	Description	P	S	F	Originator Initials	Date	Checker Initials	Date
0	Initial Issue	☒	☐	☐	gmf	12/9/12	cgt	12/9/12
1	Updated calculation	☐	☐	☒	gmf	7/3/13	cgt	7/9/13
2		☐	☐	☐	[ ]	[ ]	[ ]	[ ]
3		☐	☐	☐	[ ]	[ ]	[ ]	[ ]

Note: For a given Revision No. Check off either P (Preliminary), S (Superseding) or F (Final). If there are no revisions to the Initial Issue check off F (Final). Comments may be provided on the hard-copy calculations, electronic file or on Form 3-5 (MM).

APPROVAL and DISTRIBUTION

☐ The calculations associated with this Cover Sheet have been checked.

Gina Franco — Originator Signature — 7/3/13 — Date

Carla Talich — Checker Signature — 7/9/13 — Date

Carla Talich — Project Manager Signature — 7/29/13. — Date

Distribution:

Project Central File – Quality file folder

Project Statement:
There are currently ditches that connect stormwater conveyance pipes within the storm system in the City of Snohomish. On the west side of Sinclair Avenue, the City plans to replace the ditch and install stormwater conveyance pipe in the right of way to convey the 25-year storm event per the Engineering Design and Construction Standards (City of Snohomish, 2004). See attached calculations for a map with location identified.

Land Use and Contributing Area:
The future land use and contributing areas were calculated using 2011 City Land Use Map (City of Snohomish, 2010) and 2007 LiDAR data in ARCGIS. The commercial land use designation was assumed to be 50% impervious. The business park land use designation was assumed to be 90% impervious. The land use designations were verified by interpretation of the aerial photography. The pervious and impervious area for each designated land use is presented in Table 1. The pervious portions were assumed to be in good condition with grass cover on more than 75% of the area, resulting in a curve number of 86. The right-of-way area was assumed to be paved, with a curve number of 98.

Table 1: Impervious and Pervious Areas

Land Use Designation	Total Area (ac)	Impervious Area (ac)	Pervious Area (ac)
Commercial Area (COM)	2.47	1.23	1.24
Business Park (BP)	8.47	7.62	0.85
ROW	0.77	0.77	0.00
Total	11.71	9.62	2.09

The contributing areas to the Sinclair Ave. pipe are outlined in the attached maps. The drainage area contributing to the proposed pipe along Sinclair Ave. is subject to additional field reconnaissance and survey during design to adequately delineate the drainage basin. The northern portion of the delineated drainage area appears to be flowing north to the low area along Sinclair Ave. and Stevens Pass Hwy. The drainage infrastructure in that area is undefined, therefore one conservatively large drainage area was considered. Option A, the delineated drainage area assumes all water flows south along Sinclair Ave. Option B assumed that the north portion of the delineated drainage area is conveyed north to the low area at Sinclair Ave. and Stevens Pass Hwy and only a small portion of the drainage area flows south along Sinclair Ave. This option resulted in a much smaller drainage area (approximately 3.2 acres) and was not evaluated further

The land use area was calculated in ARCGIS. They were separated into pervious and impervious areas for input into the Santa Barbara Urban Hydrograph (SBUH) spreadsheet, a Type 1A unit hydrograph method. The precipitation for the 25-year storm event was determined by using NOAA Atlas 2 isopluvial maps. See attached calculations.

Pipe Sizing:
The City's Design and Construction Standards (City of Snohomish, 2004) that new conveyance elements are to be sized for 25-year, 24-hour storm and checked for 100-year storm to verify if

flooding occurs. The new stormwater conveyance pipes were sized by computing the peak flow resulting from 24-hour duration, 25-year recurrence interval storm, using the SBUH method.

The size of the storm drain pipe was based on the peak flows calculated using the SBUH method.
Bentley Systems, Inc. FlowMaster, 2008 software was used to size the pipes. The pipe was graded so that it can gravity drain to the connection point. It is anticipated that a minimum of three feet of cover over the pipes; therefore, polyvinyl chloride (PVC) was feasible. A 1% slope was checked using the peak flows from the 25-year storm event. It was determined that for Option A, a 15-inch PVC pipe can be used. Verification of drainage connection points and flow for the northern portion of the drainage area is recommended to be checked during the design phase.

Results:
Based on the calculations described above, it is recommended that a 15-inch diameter PVC pipe be used. Results and calculations for each location are attached.

References:
City of Snohomish, Washington. Comprehensive Plan. December 2010.

City of Snohomish, Washington. 2004. Design and Construction Standards. March 2004.

Taylor, Brian L. 1993. The Influence of Wetland and Watershed Morphological Characteristeics on Wetland Hydrology and Relationships to Wetland Vegetation Communities. 1993.

Path: O:\City of Snohomish\Stormwater Comp Plan\Stormwater Modeling - NEW moved\GIS Modeling\maps\Sinclair Ave and 50th St SE drainage.mxd

Sinclair Avenue and 50th St. SE

URS

300 150 0 300
Feet

Stormwater Comprehensive Plan
City of Snohomish

Sinclair ave, 25 yr flow Op.A, PVC, S=1%

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Diameter

Input Data

Roughness Coefficient	0.010	
Channel Slope	0.01000	ft/ft
Normal Depth	1.23	ft
Diameter	1.23	ft
Discharge	7.98	ft³/s

Results

Diameter	1.23	ft
Normal Depth	1.23	ft
Flow Area	1.18	ft²
Wetted Perimeter	3.85	ft
Hydraulic Radius	0.31	ft
Top Width	0.00	ft
Critical Depth	1.11	ft
Percent Full	100.0	%
Critical Slope	0.00876	ft/ft
Velocity	6.76	ft/s
Velocity Head	0.71	ft
Specific Energy	1.94	ft
Froude Number	0.00	
Maximum Discharge	8.58	ft³/s
Discharge Full	7.98	ft³/s
Slope Full	0.01000	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%

Sinclair ave, 25 yr flow Op.A, PVC, S=1%

GVF Output Data

Normal Depth Over Rise	100.00	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.23	ft
Critical Depth	1.11	ft
Channel Slope	0.01000	ft/ft
Critical Slope	0.00876	ft/ft

Sinclair ave,100 yr flow Op.A, PVC, S=1%

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Diameter

Input Data

Roughness Coefficient	0.010	
Channel Slope	0.01000	ft/ft
Normal Depth	1.33	ft
Diameter	1.33	ft
Discharge	9.90	ft³/s

Results

Diameter	1.33	ft
Normal Depth	1.33	ft
Flow Area	1.39	ft²
Wetted Perimeter	4.18	ft
Hydraulic Radius	0.33	ft
Top Width	0.00	ft
Critical Depth	1.21	ft
Percent Full	100.0	%
Critical Slope	0.00874	ft/ft
Velocity	7.13	ft/s
Velocity Head	0.79	ft
Specific Energy	2.12	ft
Froude Number	0.00	
Maximum Discharge	10.65	ft³/s
Discharge Full	9.90	ft³/s
Slope Full	0.01000	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%

Sinclair ave,100 yr flow Op.A, PVC, S=1%

GVF Output Data

Normal Depth Over Rise	100.00	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.33	ft
Critical Depth	1.21	ft
Channel Slope	0.01000	ft/ft
Critical Slope	0.00874	ft/ft

City of Snohomish
Stormwater Comprehensive Plan
Time of Concentration
Option A-Sinclair Tc

Calculate Time of Concentration (Tc)

Tc = Sum(Tt)

Where:

Tt = travel time (min) = $\frac{L}{(60xV)}$ (for shallow concentrated flow or channel flow)

Tt = travel time (min)= $\frac{0.42(n_s L)^{0.8}}{(P_2)^{0.5}(s_o)^{0.4}}$ (for sheet flow)

Where:

V = avg. velocity (ft/s) = $V = k(s_o)^{0.5}$

k = time of concentration velocity factor (ft/s) (see Attachment __)

L = flow length (ft)

n_s = sheet flow Manning's effective roughness coefficient (see Attachment __)

P_2 = 2-year, 24-hour rainfall (in), (see Attachment __)

s_o = slope of hydraulic grade line (land slope, ft/ft)

	L (ft)	$k_{s/c}$	V (fps)	n_s	P_2	s_o (ft/ft)	Tt (min)
a - sheet	100	NA	NA	0.011	1.8	0.01	2.1
b - shallow	255	27	5.2	NA	NA	0.04	0.8
c - culvert	508	42	8.1	NA	NA	0.04	1.0
d - channel	519	17	3.5	NA	NA	0.04	2.5
e - culvert	235	42	13.7	NA	NA	0.11	0.3
Total (Tc)							6.8

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

Project: City of Snohomish - Stormwater Comp Plan
Basin: Sinclair Ave - OPTION A
Storm Event: 25-YEAR, 24-HOUR
Given:

Area	=	11.71	acres				
Pt	=	3.05	inches				
dt	=	10	min.				
Tc	=	6.8	min.				
PERVIOUS AREA				IMPERVIOUS AREA (Roads)			
Area	=	2.09	acres	Area	=	9.62	acres
CN	=	86		CN	=	98	
S	=	1.63		S	=	0.20	
0.2S	=	0.33		0.2S	=	0.04	

SUMMARY	
T_{pk}(hrs)=	7.83
T_c (min)=	6.8
Q_{pk}(cfs)=	7.98
Vol(cf)=	111,004

Compute: Runoff Hydrograph

Column (3) = SCS Type IA Rainfall Distribution
Column (4) = Col. (3) x Pt
Column (5) = Accumulated Sum of Col. (4)
Column (6) = [If P <= 0.2S] = 0; Note, use PERVIOUS Area "S" value.
[If P > 0.2S] = (Col.(5) - 0.2S)^2/(Col.(5) + 0.8S); Using the PERVIOUS Area "S" value.
Column (7) = Col.(6) of Present Time Step - Col.(6) of Previous Time Step
Column (8) = Same method as for Col.(6), except use the IMPERVIOUS Area "S" value.
Column (9) = Col.(8) of the present time step - Col.(8) of the previous time step.
Column (10) = ((PERVIOUS area / Total area) x Col.(7)) + ((IMPERVIOUS area / Total area) x Col.(9))
Column (11) = (60.5 x Col.(10) x Total Area) / 10 (dt = 10 minutes)
Routing Constant, w = dt / (2Tc + dt) = 0.4237
Column (12) = Col.(12) of Previous Time Step + (w x [Col.(11) of Previous Time Step
+ Col.(11) of Present Time Step - (2 x Col.(12) of Previous Time Step)])

					Pervious Area		Impervious Area				
(1) Time Increment	(2) Time	(3) Rainfall distri-bution	(4) Incre-mental Rainfall	(5) Accumu-lated Rainfall	(6) Accumu-lated Runoff	(7) Incre-mental Runoff	(8) Accumu-lated Runoff	(9) Incre-mental Runoff	(10) Total Runoff	(11) Instant hydro-graph	(12) design hydro-graph	
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs	
1	10	0.0040	0.0122	0.0122	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
2	20	0.0040	0.0122	0.0244	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
3	30	0.0040	0.0122	0.0366	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
4	40	0.0040	0.0122	0.0488	0.0000	0.0000	0.0003	0.0003	0.0002	0.0	0.01	
5	50	0.0040	0.0122	0.0610	0.0000	0.0000	0.0018	0.0015	0.0012	0.1	0.05	
6	60	0.0040	0.0122	0.0732	0.0000	0.0000	0.0044	0.0026	0.0022	0.2	0.11	
7	70	0.0040	0.0122	0.0854	0.0000	0.0000	0.0080	0.0036	0.0029	0.2	0.17	
8	80	0.0040	0.0122	0.0976	0.0000	0.0000	0.0124	0.0044	0.0036	0.3	0.22	
9	90	0.0040	0.0122	0.1098	0.0000	0.0000	0.0174	0.0051	0.0042	0.3	0.27	
10	100	0.0040	0.0122	0.1220	0.0000	0.0000	0.0231	0.0057	0.0047	0.3	0.31	
11	110	0.0050	0.0153	0.1373	0.0000	0.0000	0.0309	0.0078	0.0064	0.5	0.38	
12	120	0.0050	0.0153	0.1525	0.0000	0.0000	0.0395	0.0086	0.0070	0.5	0.46	
13	130	0.0050	0.0153	0.1678	0.0000	0.0000	0.0487	0.0092	0.0075	0.5	0.51	
14	140	0.0050	0.0153	0.1830	0.0000	0.0000	0.0584	0.0097	0.0080	0.6	0.54	
15	150	0.0050	0.0153	0.1983	0.0000	0.0000	0.0686	0.0102	0.0084	0.6	0.57	
16	160	0.0050	0.0153	0.2135	0.0000	0.0000	0.0791	0.0106	0.0087	0.6	0.60	
17	170	0.0060	0.0183	0.2318	0.0000	0.0000	0.0923	0.0132	0.0108	0.8	0.68	
18	180	0.0060	0.0183	0.2501	0.0000	0.0000	0.1060	0.0136	0.0112	0.8	0.76	
19	190	0.0060	0.0183	0.2684	0.0000	0.0000	0.1200	0.0140	0.0115	0.8	0.80	
20	200	0.0060	0.0183	0.2867	0.0000	0.0000	0.1344	0.0144	0.0118	0.8	0.82	
21	210	0.0060	0.0183	0.3050	0.0000	0.0000	0.1490	0.0147	0.0121	0.9	0.84	
22	220	0.0060	0.0183	0.3233	0.0000	0.0000	0.1640	0.0150	0.0123	0.9	0.86	
23	230	0.0070	0.0214	0.3447	0.0002	0.0002	0.1818	0.0178	0.0146	1.0	0.94	
24	240	0.0070	0.0214	0.3660	0.0010	0.0008	0.1998	0.0180	0.0150	1.1	1.03	
25	250	0.0070	0.0214	0.3874	0.0023	0.0013	0.2181	0.0183	0.0153	1.1	1.06	
26	260	0.0070	0.0214	0.4087	0.0040	0.0018	0.2366	0.0185	0.0155	1.1	1.09	
27	270	0.0070	0.0214	0.4301	0.0063	0.0023	0.2553	0.0187	0.0158	1.1	1.11	
28	280	0.0070	0.0214	0.4514	0.0090	0.0027	0.2743	0.0189	0.0160	1.1	1.12	
29	290	0.0082	0.0250	0.4764	0.0128	0.0038	0.2966	0.0224	0.0190	1.3	1.22	
30	300	0.0082	0.0250	0.5014	0.0171	0.0044	0.3192	0.0226	0.0193	1.4	1.34	
31	310	0.0082	0.0250	0.5264	0.0221	0.0049	0.3419	0.0227	0.0196	1.4	1.37	
32	320	0.0082	0.0250	0.5514	0.0275	0.0055	0.3648	0.0229	0.0198	1.4	1.39	
33	330	0.0082	0.0250	0.5765	0.0335	0.0060	0.3879	0.0230	0.0200	1.4	1.41	
34	340	0.0082	0.0250	0.6015	0.0400	0.0065	0.4110	0.0232	0.0202	1.4	1.42	
35	350	0.0095	0.0290	0.6304	0.0481	0.0081	0.4380	0.0270	0.0236	1.7	1.53	
36	360	0.0095	0.0290	0.6594	0.0568	0.0087	0.4651	0.0271	0.0238	1.7	1.66	
37	370	0.0095	0.0290	0.6884	0.0661	0.0093	0.4924	0.0273	0.0241	1.7	1.69	
38	380	0.0095	0.0290	0.7174	0.0760	0.0099	0.5198	0.0274	0.0242	1.7	1.71	
39	390	0.0095	0.0290	0.7463	0.0864	0.0104	0.5472	0.0275	0.0244	1.7	1.72	
40	400	0.0095	0.0290	0.7753	0.0973	0.0109	0.5748	0.0276	0.0246	1.7	1.73	
41	410	0.0134	0.0409	0.8162	0.1136	0.0163	0.6138	0.0390	0.0350	2.5	2.05	
42	420	0.0134	0.0409	0.8570	0.1308	0.0172	0.6530	0.0392	0.0352	2.5	2.42	
43	430	0.0134	0.0409	0.8979	0.1489	0.0181	0.6923	0.0393	0.0355	2.5	2.49	
44	440	0.0180	0.0549	0.9528	0.1745	0.0256	0.7452	0.0530	0.0481	3.4	2.89	
45	450	0.0180	0.0549	1.0077	0.2014	0.0270	0.7984	0.0532	0.0485	3.4	3.34	
46	460	0.0340	0.1037	1.1114	0.2558	0.0544	0.8992	0.1008	0.0925	6.6	4.74	
47	470	0.0540	0.1647	1.2761	0.3504	0.0946	1.0602	0.1610	0.1491	10.6	7.98	Q peak
48	480	0.0270	0.0824	1.3585	0.4010	0.0505	1.1409	0.0808	0.0754	5.3	7.96	
49	490	0.0180	0.0549	1.4134	0.4357	0.0348	1.1949	0.0539	0.0505	3.6	4.99	
50	500	0.0134	0.0409	1.4542	0.4621	0.0264	1.2351	0.0402	0.0377	2.7	3.41	
51	510	0.0134	0.0409	1.4951	0.4889	0.0268	1.2753	0.0402	0.0378	2.7	2.79	
52	520	0.0134	0.0409	1.5360	0.5162	0.0272	1.3156	0.0403	0.0379	2.7	2.70	
53	530	0.0088	0.0268	1.5628	0.5343	0.0181	1.3421	0.0265	0.0250	1.8	2.30	
54	540	0.0088	0.0268	1.5897	0.5525	0.0183	1.3685	0.0265	0.0250	1.8	1.85	
55	550	0.0088	0.0268	1.6165	0.5709	0.0184	1.3950	0.0265	0.0250	1.8	1.78	
56	560	0.0088	0.0268	1.6433	0.5895	0.0186	1.4215	0.0265	0.0251	1.8	1.78	
57	570	0.0088	0.0268	1.6702	0.6082	0.0187	1.4480	0.0265	0.0251	1.8	1.78	
58	580	0.0088	0.0268	1.6970	0.6271	0.0189	1.4745	0.0265	0.0251	1.8	1.78	
59	590	0.0088	0.0268	1.7239	0.6461	0.0190	1.5010	0.0265	0.0252	1.8	1.78	
60	600	0.0088	0.0268	1.7507	0.6652	0.0191	1.5276	0.0265	0.0252	1.8	1.78	
61	610	0.0088	0.0268	1.7775	0.6845	0.0193	1.5541	0.0265	0.0252	1.8	1.79	
62	620	0.0088	0.0268	1.8044	0.7039	0.0194	1.5806	0.0265	0.0253	1.8	1.79	
63	630	0.0088	0.0268	1.8312	0.7234	0.0195	1.6072	0.0266	0.0253	1.8	1.79	
64	640	0.0088	0.0268	1.8581	0.7431	0.0197	1.6338	0.0266	0.0253	1.8	1.79	
65	650	0.0072	0.0220	1.8800	0.7593	0.0162	1.6555	0.0217	0.0207	1.5	1.66	

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

					Pervious Area		Impervious Area				
(1) Time Increment	(2) Time	(3) Rainfall distri-bution	(4) Incre-mental	(5) Accumu-lated	(6) Accumu-lated	(7) Incre-mental	(8) Accumu-lated	(9) Incre-mental	(10) Total Runoff	(11) Instant hydro-graph	(12) design hydro-graph
	min.	% of Pt	Rainfall in.	Rainfall in.	Runoff in.	Runoff in.	Runoff in.	Runoff in.	in.	cfs	cfs
66	660	0.0072	0.0220	1.9020	0.7755	0.0163	1.6772	0.0217	0.0208	1.5	1.50
67	670	0.0072	0.0220	1.9239	0.7919	0.0163	1.6990	0.0217	0.0208	1.5	1.48
68	680	0.0072	0.0220	1.9459	0.8083	0.0164	1.7207	0.0218	0.0208	1.5	1.47
69	690	0.0072	0.0220	1.9679	0.8247	0.0165	1.7425	0.0218	0.0208	1.5	1.47
70	700	0.0072	0.0220	1.9898	0.8413	0.0166	1.7643	0.0218	0.0208	1.5	1.48
71	710	0.0072	0.0220	2.0118	0.8579	0.0166	1.7860	0.0218	0.0208	1.5	1.48
72	720	0.0072	0.0220	2.0337	0.8746	0.0167	1.8078	0.0218	0.0209	1.5	1.48
73	730	0.0072	0.0220	2.0557	0.8914	0.0168	1.8296	0.0218	0.0209	1.5	1.48
74	740	0.0072	0.0220	2.0777	0.9082	0.0168	1.8513	0.0218	0.0209	1.5	1.48
75	750	0.0072	0.0220	2.0996	0.9251	0.0169	1.8731	0.0218	0.0209	1.5	1.48
76	760	0.0072	0.0220	2.1216	0.9421	0.0170	1.8949	0.0218	0.0209	1.5	1.48
77	770	0.0057	0.0174	2.1390	0.9556	0.0135	1.9122	0.0172	0.0166	1.2	1.35
78	780	0.0057	0.0174	2.1564	0.9691	0.0135	1.9294	0.0172	0.0166	1.2	1.20
79	790	0.0057	0.0174	2.1737	0.9826	0.0136	1.9467	0.0173	0.0166	1.2	1.18
80	800	0.0057	0.0174	2.1911	0.9962	0.0136	1.9639	0.0173	0.0166	1.2	1.18
81	810	0.0057	0.0174	2.2085	1.0098	0.0136	1.9812	0.0173	0.0166	1.2	1.18
82	820	0.0057	0.0174	2.2259	1.0235	0.0137	1.9984	0.0173	0.0166	1.2	1.18
83	830	0.0057	0.0174	2.2433	1.0372	0.0137	2.0157	0.0173	0.0166	1.2	1.18
84	840	0.0057	0.0174	2.2607	1.0510	0.0137	2.0329	0.0173	0.0166	1.2	1.18
85	850	0.0057	0.0174	2.2780	1.0647	0.0138	2.0502	0.0173	0.0166	1.2	1.18
86	860	0.0057	0.0174	2.2954	1.0785	0.0138	2.0675	0.0173	0.0166	1.2	1.18
87	870	0.0057	0.0174	2.3128	1.0924	0.0138	2.0847	0.0173	0.0167	1.2	1.18
88	880	0.0057	0.0174	2.3302	1.1063	0.0139	2.1020	0.0173	0.0167	1.2	1.18
89	890	0.0050	0.0153	2.3455	1.1185	0.0122	2.1172	0.0151	0.0146	1.0	1.12
90	900	0.0050	0.0153	2.3607	1.1307	0.0122	2.1323	0.0151	0.0146	1.0	1.05
91	910	0.0050	0.0153	2.3760	1.1429	0.0123	2.1475	0.0152	0.0146	1.0	1.04
92	920	0.0050	0.0153	2.3912	1.1552	0.0123	2.1626	0.0152	0.0146	1.0	1.04
93	930	0.0050	0.0153	2.4065	1.1675	0.0123	2.1778	0.0152	0.0146	1.0	1.04
94	940	0.0050	0.0153	2.4217	1.1798	0.0123	2.1929	0.0152	0.0146	1.0	1.04
95	950	0.0050	0.0153	2.4370	1.1922	0.0123	2.2081	0.0152	0.0147	1.0	1.04
96	960	0.0050	0.0153	2.4522	1.2045	0.0124	2.2232	0.0152	0.0147	1.0	1.04
97	970	0.0050	0.0153	2.4675	1.2169	0.0124	2.2384	0.0152	0.0147	1.0	1.04
98	980	0.0050	0.0153	2.4827	1.2294	0.0124	2.2535	0.0152	0.0147	1.0	1.04
99	990	0.0050	0.0153	2.4980	1.2418	0.0124	2.2687	0.0152	0.0147	1.0	1.04
100	1000	0.0050	0.0153	2.5132	1.2543	0.0125	2.2839	0.0152	0.0147	1.0	1.04
101	1010	0.0040	0.0122	2.5254	1.2642	0.0100	2.2960	0.0121	0.0117	0.8	0.95
102	1020	0.0040	0.0122	2.5376	1.2743	0.0100	2.3081	0.0121	0.0117	0.8	0.85
103	1030	0.0040	0.0122	2.5498	1.2843	0.0100	2.3203	0.0121	0.0118	0.8	0.84
104	1040	0.0040	0.0122	2.5620	1.2943	0.0100	2.3324	0.0121	0.0118	0.8	0.83
105	1050	0.0040	0.0122	2.5742	1.3043	0.0100	2.3445	0.0121	0.0118	0.8	0.83
106	1060	0.0040	0.0122	2.5864	1.3144	0.0101	2.3566	0.0121	0.0118	0.8	0.83
107	1070	0.0040	0.0122	2.5986	1.3245	0.0101	2.3688	0.0121	0.0118	0.8	0.83
108	1080	0.0040	0.0122	2.6108	1.3345	0.0101	2.3809	0.0121	0.0118	0.8	0.83
109	1090	0.0040	0.0122	2.6230	1.3446	0.0101	2.3931	0.0121	0.0118	0.8	0.83
110	1100	0.0040	0.0122	2.6352	1.3547	0.0101	2.4052	0.0121	0.0118	0.8	0.83
111	1110	0.0040	0.0122	2.6474	1.3649	0.0101	2.4173	0.0121	0.0118	0.8	0.83
112	1120	0.0040	0.0122	2.6596	1.3750	0.0101	2.4295	0.0121	0.0118	0.8	0.83
113	1130	0.0040	0.0122	2.6718	1.3851	0.0101	2.4416	0.0121	0.0118	0.8	0.83
114	1140	0.0040	0.0122	2.6840	1.3953	0.0102	2.4537	0.0121	0.0118	0.8	0.83
115	1150	0.0040	0.0122	2.6962	1.4055	0.0102	2.4659	0.0121	0.0118	0.8	0.83
116	1160	0.0040	0.0122	2.7084	1.4157	0.0102	2.4780	0.0121	0.0118	0.8	0.84
117	1170	0.0040	0.0122	2.7206	1.4259	0.0102	2.4901	0.0121	0.0118	0.8	0.84
118	1180	0.0040	0.0122	2.7328	1.4361	0.0102	2.5023	0.0121	0.0118	0.8	0.84
119	1190	0.0040	0.0122	2.7450	1.4463	0.0102	2.5144	0.0121	0.0118	0.8	0.84
120	1200	0.0040	0.0122	2.7572	1.4565	0.0102	2.5266	0.0121	0.0118	0.8	0.84
121	1210	0.0040	0.0122	2.7694	1.4668	0.0102	2.5387	0.0121	0.0118	0.8	0.84
122	1220	0.0040	0.0122	2.7816	1.4770	0.0103	2.5508	0.0121	0.0118	0.8	0.84
123	1230	0.0040	0.0122	2.7938	1.4873	0.0103	2.5630	0.0121	0.0118	0.8	0.84
124	1240	0.0040	0.0122	2.8060	1.4976	0.0103	2.5751	0.0121	0.0118	0.8	0.84
125	1250	0.0040	0.0122	2.8182	1.5079	0.0103	2.5873	0.0121	0.0118	0.8	0.84
126	1260	0.0040	0.0122	2.8304	1.5182	0.0103	2.5994	0.0121	0.0118	0.8	0.84
127	1270	0.0040	0.0122	2.8426	1.5285	0.0103	2.6116	0.0121	0.0118	0.8	0.84
128	1280	0.0040	0.0122	2.8548	1.5388	0.0103	2.6237	0.0121	0.0118	0.8	0.84
129	1290	0.0040	0.0122	2.8670	1.5491	0.0103	2.6358	0.0121	0.0118	0.8	0.84
130	1300	0.0040	0.0122	2.8792	1.5595	0.0103	2.6480	0.0121	0.0118	0.8	0.84
131	1310	0.0040	0.0122	2.8914	1.5698	0.0104	2.6601	0.0121	0.0118	0.8	0.84
132	1320	0.0040	0.0122	2.9036	1.5802	0.0104	2.6723	0.0121	0.0118	0.8	0.84
133	1330	0.0040	0.0122	2.9158	1.5906	0.0104	2.6844	0.0121	0.0118	0.8	0.84
134	1340	0.0040	0.0122	2.9280	1.6010	0.0104	2.6966	0.0121	0.0118	0.8	0.84
135	1350	0.0040	0.0122	2.9402	1.6114	0.0104	2.7087	0.0121	0.0118	0.8	0.84
136	1360	0.0040	0.0122	2.9524	1.6218	0.0104	2.7209	0.0121	0.0118	0.8	0.84
137	1370	0.0040	0.0122	2.9646	1.6322	0.0104	2.7330	0.0121	0.0118	0.8	0.84
138	1380	0.0040	0.0122	2.9768	1.6426	0.0104	2.7452	0.0121	0.0118	0.8	0.84
139	1390	0.0040	0.0122	2.9890	1.6531	0.0104	2.7573	0.0121	0.0118	0.8	0.84
140	1400	0.0040	0.0122	3.0012	1.6635	0.0104	2.7695	0.0121	0.0118	0.8	0.84
141	1410	0.0040	0.0122	3.0134	1.6740	0.0105	2.7816	0.0121	0.0118	0.8	0.84
142	1420	0.0040	0.0122	3.0256	1.6844	0.0105	2.7938	0.0121	0.0118	0.8	0.84
143	1430	0.0040	0.0122	3.0378	1.6949	0.0105	2.8059	0.0122	0.0119	0.8	0.84
144	1440	0.0040	0.0122	3.0500	1.7054	0.0105	2.8181	0.0122	0.0119	0.8	0.84

Total Volume of Runoff[1] = 111,004 cu. ft.

Notes:

1. Total Runoff Volume is found by summing column (12) and multiplying by the time step, dt as follows:

   V = SumQ x dt
   V(cu.ft.) = SumQ(cu.ft/s) x dt(min.) x (60 s/min.)

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

Project: City of Snohomish - Stormwater Comp Plan
Basin: Sinclair Ave - OPTION A
Storm Event: 100-YEAR, 24-HOUR
Given:

Area = 11.71 acres
Pt = 3.70 inches
dt = 10 min.
Tc = 6.8 min.

PERVIOUS AREA			IMPERVIOUS AREA (Roads)		
Area	=	2.09 acres	Area	=	9.62 acres
CN	=	86	CN	=	98
S	=	1.63	S	=	0.20
0.2S	=	0.33	0.2S	=	0.04

SUMMARY	
T_{pk}(hrs)=	7.83
T_c (min)=	6.8
Q_{pk}(cfs)=	9.89
Vol(cf)=	137,881

Compute: Runoff Hydrograph

Column (3) = SCS Type IA Rainfall Distribution
Column (4) = Col. (3) x Pt
Column (5) = Accumulated Sum of Col. (4)
Column (6) = [If P <= 0.2S] = 0; Note, use PERVIOUS Area "S" value.
[If P > 0.2S] = (Col.(5) - 0.2S)^2/(Col.(5) + 0.8S); Using the PERVIOUS Area "S" value.
Column (7) = Col.(6) of Present Time Step - Col.(6) of Previous Time Step
Column (8) = Same method as for Col.(6), except use the IMPERVIOUS Area "S" value.
Column (9) = Col.(8) of the present time step - Col.(8) of the previous time step.
Column (10) = ((PERVIOUS area / Total area) x Col.(7)) + ((IMPERVIOUS area / Total area) x Col.(9))
Column (11) = (60.5 x Col.(10) x Total Area) / 10 (dt = 10 minutes)
Routing Constant, w = dt / (2Tc + dt) = 0.4237
Column (12) = Col.(12) of Previous Time Step + (w x [Col.(11) of Previous Time Step
+ Col.(11) of Present Time Step - (2 x Col.(12) of Previous Time Step)])

					Pervious Area		Impervious Area				
(1) Time Increment	(2) Time	(3) Rainfall distri-bution	(4) Incre-mental Rainfall	(5) Accumu-lated Rainfall	(6) Accumu-lated Runoff	(7) Incre-mental Runoff	(8) Accumu-lated Runoff	(9) Incre-mental Runoff	(10) Total Runoff	(11) Instant hydro-graph	(12) design hydro-graph	
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs	
1	10	0.0040	0.0148	0.0148	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
2	20	0.0040	0.0148	0.0296	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
3	30	0.0040	0.0148	0.0444	0.0000	0.0000	0.0001	0.0001	0.0001	0.0	0.00	
4	40	0.0040	0.0148	0.0592	0.0000	0.0000	0.0015	0.0015	0.0012	0.1	0.04	
5	50	0.0040	0.0148	0.0740	0.0000	0.0000	0.0046	0.0031	0.0026	0.2	0.12	
6	60	0.0040	0.0148	0.0888	0.0000	0.0000	0.0091	0.0045	0.0037	0.3	0.21	
7	70	0.0040	0.0148	0.1036	0.0000	0.0000	0.0148	0.0056	0.0046	0.3	0.28	
8	80	0.0040	0.0148	0.1184	0.0000	0.0000	0.0214	0.0066	0.0054	0.4	0.34	
9	90	0.0040	0.0148	0.1332	0.0000	0.0000	0.0288	0.0074	0.0061	0.4	0.40	
10	100	0.0040	0.0148	0.1480	0.0000	0.0000	0.0369	0.0081	0.0067	0.5	0.44	
11	110	0.0050	0.0185	0.1665	0.0000	0.0000	0.0479	0.0110	0.0090	0.6	0.54	
12	120	0.0050	0.0185	0.1850	0.0000	0.0000	0.0597	0.0118	0.0097	0.7	0.64	
13	130	0.0050	0.0185	0.2035	0.0000	0.0000	0.0722	0.0125	0.0102	0.7	0.70	
14	140	0.0050	0.0185	0.2220	0.0000	0.0000	0.0852	0.0130	0.0107	0.8	0.74	
15	150	0.0050	0.0185	0.2405	0.0000	0.0000	0.0988	0.0135	0.0111	0.8	0.77	
16	160	0.0050	0.0185	0.2590	0.0000	0.0000	0.1127	0.0140	0.0115	0.8	0.80	
17	170	0.0060	0.0222	0.2812	0.0000	0.0000	0.1300	0.0173	0.0142	1.0	0.89	
18	180	0.0060	0.0222	0.3034	0.0000	0.0000	0.1478	0.0177	0.0146	1.0	1.00	
19	190	0.0060	0.0222	0.3256	0.0000	0.0000	0.1659	0.0181	0.0149	1.1	1.04	
20	200	0.0060	0.0222	0.3478	0.0003	0.0003	0.1844	0.0185	0.0153	1.1	1.06	
21	210	0.0060	0.0222	0.3700	0.0012	0.0009	0.2032	0.0188	0.0156	1.1	1.09	
22	220	0.0060	0.0222	0.3922	0.0026	0.0014	0.2223	0.0191	0.0159	1.1	1.11	
23	230	0.0070	0.0259	0.4181	0.0050	0.0024	0.2448	0.0226	0.0190	1.3	1.22	
24	240	0.0070	0.0259	0.4440	0.0080	0.0031	0.2677	0.0228	0.0193	1.4	1.33	
25	250	0.0070	0.0259	0.4699	0.0118	0.0037	0.2908	0.0231	0.0196	1.4	1.37	
26	260	0.0070	0.0259	0.4958	0.0161	0.0044	0.3141	0.0233	0.0199	1.4	1.40	
27	270	0.0070	0.0259	0.5217	0.0211	0.0050	0.3376	0.0235	0.0202	1.4	1.42	
28	280	0.0070	0.0259	0.5476	0.0266	0.0056	0.3613	0.0237	0.0204	1.4	1.44	
29	290	0.0082	0.0303	0.5779	0.0339	0.0072	0.3892	0.0279	0.0242	1.7	1.56	
30	300	0.0082	0.0303	0.6083	0.0418	0.0080	0.4174	0.0281	0.0245	1.7	1.70	
31	310	0.0082	0.0303	0.6386	0.0505	0.0087	0.4457	0.0283	0.0248	1.8	1.74	
32	320	0.0082	0.0303	0.6690	0.0598	0.0093	0.4741	0.0284	0.0250	1.8	1.76	
33	330	0.0082	0.0303	0.6993	0.0698	0.0100	0.5027	0.0286	0.0253	1.8	1.78	
34	340	0.0082	0.0303	0.7296	0.0803	0.0106	0.5314	0.0287	0.0255	1.8	1.79	
35	350	0.0095	0.0352	0.7648	0.0933	0.0130	0.5648	0.0334	0.0297	2.1	1.93	
36	360	0.0095	0.0352	0.7999	0.1070	0.0137	0.5983	0.0335	0.0300	2.1	2.09	
37	370	0.0095	0.0352	0.8351	0.1215	0.0144	0.6319	0.0336	0.0302	2.1	2.12	
38	380	0.0095	0.0352	0.8702	0.1365	0.0151	0.6656	0.0337	0.0304	2.2	2.14	
39	390	0.0095	0.0352	0.9054	0.1523	0.0157	0.6995	0.0338	0.0306	2.2	2.16	
40	400	0.0095	0.0352	0.9405	0.1686	0.0163	0.7334	0.0339	0.0308	2.2	2.17	
41	410	0.0134	0.0496	0.9901	0.1926	0.0240	0.7813	0.0480	0.0437	3.1	2.57	
42	420	0.0134	0.0496	1.0397	0.2177	0.0251	0.8294	0.0481	0.0440	3.1	3.02	
43	430	0.0134	0.0496	1.0893	0.2439	0.0261	0.8776	0.0482	0.0443	3.1	3.11	
44	440	0.0180	0.0666	1.1559	0.2804	0.0366	0.9426	0.0649	0.0599	4.2	3.60	
45	450	0.0180	0.0666	1.2225	0.3186	0.0382	1.0076	0.0651	0.0603	4.3	4.16	
46	460	0.0340	0.1258	1.3483	0.3946	0.0760	1.1309	0.1233	0.1149	8.1	5.89	
47	470	0.0540	0.1998	1.5481	0.5243	0.1297	1.3275	0.1966	0.1846	13.1	9.89	Q peak
48	480	0.0270	0.0999	1.6480	0.5927	0.0684	1.4261	0.0986	0.0932	6.6	9.85	
49	490	0.0180	0.0666	1.7146	0.6395	0.0468	1.4919	0.0658	0.0624	4.4	6.17	
50	500	0.0134	0.0496	1.7642	0.6749	0.0354	1.5409	0.0490	0.0466	3.3	4.21	
51	510	0.0134	0.0496	1.8137	0.7107	0.0358	1.5899	0.0490	0.0467	3.3	3.44	
52	520	0.0134	0.0496	1.8633	0.7470	0.0363	1.6390	0.0491	0.0468	3.3	3.33	
53	530	0.0088	0.0326	1.8959	0.7710	0.0240	1.6712	0.0322	0.0308	2.2	2.84	
54	540	0.0088	0.0326	1.9284	0.7952	0.0242	1.7035	0.0322	0.0308	2.2	2.28	
55	550	0.0088	0.0326	1.9610	0.8196	0.0244	1.7357	0.0323	0.0308	2.2	2.20	
56	560	0.0088	0.0326	1.9936	0.8441	0.0245	1.7680	0.0323	0.0309	2.2	2.19	
57	570	0.0088	0.0326	2.0261	0.8688	0.0247	1.8002	0.0323	0.0309	2.2	2.19	
58	580	0.0088	0.0326	2.0587	0.8937	0.0248	1.8325	0.0323	0.0310	2.2	2.19	
59	590	0.0088	0.0326	2.0912	0.9187	0.0250	1.8648	0.0323	0.0310	2.2	2.19	
60	600	0.0088	0.0326	2.1238	0.9438	0.0251	1.8971	0.0323	0.0310	2.2	2.20	
61	610	0.0088	0.0326	2.1564	0.9691	0.0253	1.9294	0.0323	0.0311	2.2	2.20	
62	620	0.0088	0.0326	2.1889	0.9945	0.0254	1.9617	0.0323	0.0311	2.2	2.20	
63	630	0.0088	0.0326	2.2215	1.0200	0.0255	1.9940	0.0323	0.0311	2.2	2.20	
64	640	0.0088	0.0326	2.2540	1.0457	0.0257	2.0264	0.0323	0.0311	2.2	2.20	
65	650	0.0072	0.0266	2.2807	1.0668	0.0211	2.0528	0.0265	0.0255	1.8	2.04	

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

(1) Time Increment	(2) Time min.	(3) Rainfall distri-bution % of Pt	(4) Incre-mental Rainfall in.	(5) Accumu-lated Rainfall in.	Pervious Area (6) Accumu-lated Runoff in.	Pervious Area (7) Incre-mental Runoff in.	Impervious Area (8) Accumu-lated Runoff in.	Impervious Area (9) Incre-mental Runoff in.	(10) Total Runoff in.	(11) Instant hydro-graph cfs	(12) design hydro-graph cfs
66	660	0.0072	0.0266	2.3073	1.0880	0.0212	2.0793	0.0265	0.0255	1.8	1.84
67	670	0.0072	0.0266	2.3340	1.1093	0.0213	2.1057	0.0265	0.0255	1.8	1.81
68	680	0.0072	0.0266	2.3606	1.1306	0.0213	2.1322	0.0265	0.0255	1.8	1.81
69	690	0.0072	0.0266	2.3872	1.1520	0.0214	2.1587	0.0265	0.0256	1.8	1.81
70	700	0.0072	0.0266	2.4139	1.1735	0.0215	2.1851	0.0265	0.0256	1.8	1.81
71	710	0.0072	0.0266	2.4405	1.1951	0.0216	2.2116	0.0265	0.0256	1.8	1.81
72	720	0.0072	0.0266	2.4672	1.2167	0.0216	2.2381	0.0265	0.0256	1.8	1.81
73	730	0.0072	0.0266	2.4938	1.2384	0.0217	2.2646	0.0265	0.0256	1.8	1.81
74	740	0.0072	0.0266	2.5204	1.2602	0.0218	2.2911	0.0265	0.0256	1.8	1.82
75	750	0.0072	0.0266	2.5471	1.2820	0.0218	2.3175	0.0265	0.0257	1.8	1.82
76	760	0.0072	0.0266	2.5737	1.3039	0.0219	2.3440	0.0265	0.0257	1.8	1.82
77	770	0.0057	0.0211	2.5948	1.3213	0.0174	2.3650	0.0210	0.0203	1.4	1.66
78	780	0.0057	0.0211	2.6159	1.3388	0.0174	2.3860	0.0210	0.0203	1.4	1.47
79	790	0.0057	0.0211	2.6370	1.3562	0.0175	2.4070	0.0210	0.0204	1.4	1.45
80	800	0.0057	0.0211	2.6581	1.3737	0.0175	2.4279	0.0210	0.0204	1.4	1.44
81	810	0.0057	0.0211	2.6792	1.3913	0.0175	2.4489	0.0210	0.0204	1.4	1.44
82	820	0.0057	0.0211	2.7003	1.4089	0.0176	2.4699	0.0210	0.0204	1.4	1.44
83	830	0.0057	0.0211	2.7214	1.4265	0.0176	2.4909	0.0210	0.0204	1.4	1.44
84	840	0.0057	0.0211	2.7424	1.4441	0.0177	2.5119	0.0210	0.0204	1.4	1.44
85	850	0.0057	0.0211	2.7635	1.4618	0.0177	2.5329	0.0210	0.0204	1.4	1.44
86	860	0.0057	0.0211	2.7846	1.4796	0.0177	2.5539	0.0210	0.0204	1.4	1.45
87	870	0.0057	0.0211	2.8057	1.4973	0.0178	2.5748	0.0210	0.0204	1.4	1.45
88	880	0.0057	0.0211	2.8268	1.5151	0.0178	2.5958	0.0210	0.0204	1.4	1.45
89	890	0.0050	0.0185	2.8453	1.5308	0.0156	2.6142	0.0184	0.0179	1.3	1.37
90	900	0.0050	0.0185	2.8638	1.5464	0.0157	2.6327	0.0184	0.0179	1.3	1.29
91	910	0.0050	0.0185	2.8823	1.5621	0.0157	2.6511	0.0184	0.0179	1.3	1.27
92	920	0.0050	0.0185	2.9008	1.5778	0.0157	2.6695	0.0184	0.0179	1.3	1.27
93	930	0.0050	0.0185	2.9193	1.5936	0.0157	2.6879	0.0184	0.0179	1.3	1.27
94	940	0.0050	0.0185	2.9378	1.6093	0.0158	2.7063	0.0184	0.0179	1.3	1.27
95	950	0.0050	0.0185	2.9563	1.6251	0.0158	2.7248	0.0184	0.0179	1.3	1.27
96	960	0.0050	0.0185	2.9748	1.6409	0.0158	2.7432	0.0184	0.0180	1.3	1.27
97	970	0.0050	0.0185	2.9933	1.6567	0.0158	2.7616	0.0184	0.0180	1.3	1.27
98	980	0.0050	0.0185	3.0118	1.6726	0.0159	2.7800	0.0184	0.0180	1.3	1.27
99	990	0.0050	0.0185	3.0303	1.6885	0.0159	2.7984	0.0184	0.0180	1.3	1.27
100	1000	0.0050	0.0185	3.0488	1.7044	0.0159	2.8169	0.0184	0.0180	1.3	1.27
101	1010	0.0040	0.0148	3.0636	1.7171	0.0127	2.8316	0.0147	0.0144	1.0	1.17
102	1020	0.0040	0.0148	3.0784	1.7299	0.0127	2.8464	0.0147	0.0144	1.0	1.04
103	1030	0.0040	0.0148	3.0932	1.7426	0.0128	2.8611	0.0147	0.0144	1.0	1.02
104	1040	0.0040	0.0148	3.1080	1.7554	0.0128	2.8758	0.0147	0.0144	1.0	1.02
105	1050	0.0040	0.0148	3.1228	1.7682	0.0128	2.8906	0.0147	0.0144	1.0	1.02
106	1060	0.0040	0.0148	3.1376	1.7810	0.0128	2.9053	0.0147	0.0144	1.0	1.02
107	1070	0.0040	0.0148	3.1524	1.7938	0.0128	2.9201	0.0147	0.0144	1.0	1.02
108	1080	0.0040	0.0148	3.1672	1.8066	0.0128	2.9348	0.0147	0.0144	1.0	1.02
109	1090	0.0040	0.0148	3.1820	1.8195	0.0128	2.9496	0.0147	0.0144	1.0	1.02
110	1100	0.0040	0.0148	3.1968	1.8323	0.0129	2.9643	0.0147	0.0144	1.0	1.02
111	1110	0.0040	0.0148	3.2116	1.8452	0.0129	2.9790	0.0147	0.0144	1.0	1.02
112	1120	0.0040	0.0148	3.2264	1.8581	0.0129	2.9938	0.0147	0.0144	1.0	1.02
113	1130	0.0040	0.0148	3.2412	1.8710	0.0129	3.0085	0.0147	0.0144	1.0	1.02
114	1140	0.0040	0.0148	3.2560	1.8839	0.0129	3.0233	0.0147	0.0144	1.0	1.02
115	1150	0.0040	0.0148	3.2708	1.8968	0.0129	3.0380	0.0147	0.0144	1.0	1.02
116	1160	0.0040	0.0148	3.2856	1.9097	0.0129	3.0528	0.0147	0.0144	1.0	1.02
117	1170	0.0040	0.0148	3.3004	1.9227	0.0129	3.0675	0.0147	0.0144	1.0	1.02
118	1180	0.0040	0.0148	3.3152	1.9356	0.0130	3.0823	0.0147	0.0144	1.0	1.02
119	1190	0.0040	0.0148	3.3300	1.9486	0.0130	3.0970	0.0147	0.0144	1.0	1.02
120	1200	0.0040	0.0148	3.3448	1.9616	0.0130	3.1118	0.0147	0.0144	1.0	1.02
121	1210	0.0040	0.0148	3.3596	1.9746	0.0130	3.1265	0.0148	0.0144	1.0	1.02
122	1220	0.0040	0.0148	3.3744	1.9876	0.0130	3.1413	0.0148	0.0144	1.0	1.02
123	1230	0.0040	0.0148	3.3892	2.0006	0.0130	3.1560	0.0148	0.0144	1.0	1.02
124	1240	0.0040	0.0148	3.4040	2.0136	0.0130	3.1708	0.0148	0.0144	1.0	1.02
125	1250	0.0040	0.0148	3.4188	2.0266	0.0130	3.1855	0.0148	0.0144	1.0	1.02
126	1260	0.0040	0.0148	3.4336	2.0397	0.0130	3.2003	0.0148	0.0144	1.0	1.02
127	1270	0.0040	0.0148	3.4484	2.0527	0.0131	3.2150	0.0148	0.0144	1.0	1.02
128	1280	0.0040	0.0148	3.4632	2.0658	0.0131	3.2298	0.0148	0.0145	1.0	1.02
129	1290	0.0040	0.0148	3.4780	2.0789	0.0131	3.2445	0.0148	0.0145	1.0	1.02
130	1300	0.0040	0.0148	3.4928	2.0920	0.0131	3.2593	0.0148	0.0145	1.0	1.02
131	1310	0.0040	0.0148	3.5076	2.1051	0.0131	3.2740	0.0148	0.0145	1.0	1.02
132	1320	0.0040	0.0148	3.5224	2.1182	0.0131	3.2888	0.0148	0.0145	1.0	1.02
133	1330	0.0040	0.0148	3.5372	2.1313	0.0131	3.3036	0.0148	0.0145	1.0	1.02
134	1340	0.0040	0.0148	3.5520	2.1444	0.0131	3.3183	0.0148	0.0145	1.0	1.02
135	1350	0.0040	0.0148	3.5668	2.1576	0.0131	3.3331	0.0148	0.0145	1.0	1.02
136	1360	0.0040	0.0148	3.5816	2.1707	0.0132	3.3478	0.0148	0.0145	1.0	1.02
137	1370	0.0040	0.0148	3.5964	2.1839	0.0132	3.3626	0.0148	0.0145	1.0	1.03
138	1380	0.0040	0.0148	3.6112	2.1971	0.0132	3.3773	0.0148	0.0145	1.0	1.03
139	1390	0.0040	0.0148	3.6260	2.2102	0.0132	3.3921	0.0148	0.0145	1.0	1.03
140	1400	0.0040	0.0148	3.6408	2.2234	0.0132	3.4069	0.0148	0.0145	1.0	1.03
141	1410	0.0040	0.0148	3.6556	2.2366	0.0132	3.4216	0.0148	0.0145	1.0	1.03
142	1420	0.0040	0.0148	3.6704	2.2498	0.0132	3.4364	0.0148	0.0145	1.0	1.03
143	1430	0.0040	0.0148	3.6852	2.2631	0.0132	3.4511	0.0148	0.0145	1.0	1.03
144	1440	0.0040	0.0148	3.7000	2.2763	0.0132	3.4659	0.0148	0.0145	1.0	1.03

Total Volume of Runoff[1] = 137,881 cu. ft.

Notes:

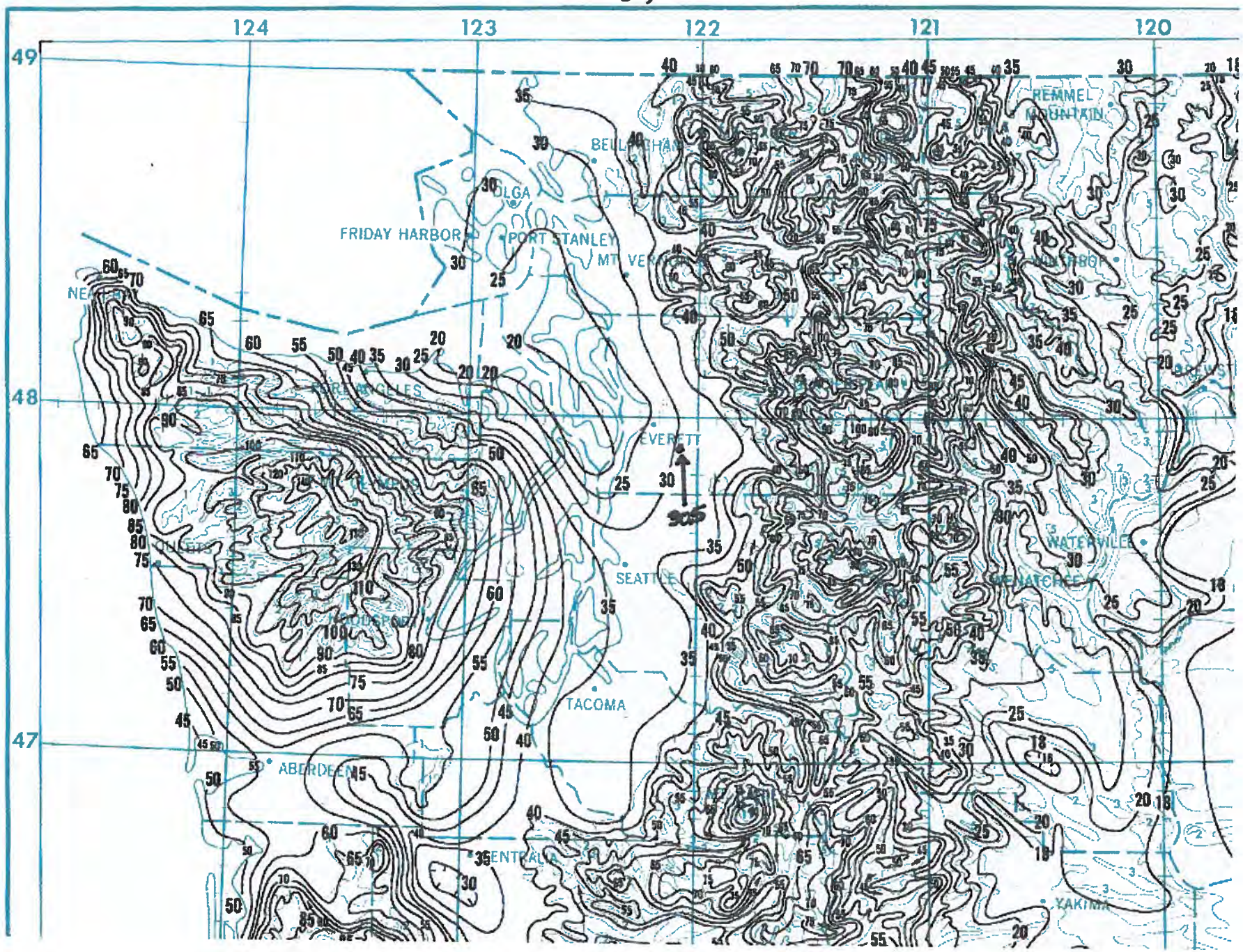
1. Total Runoff Volume is found by summing column (12) and multiplying by the time step, dt as follows:

   V = SumQ x dt
   V(cu.ft.) = SumQ(cu.ft/s) x dt(min.) x (60 s/min.)

Table 4.4.1 Values of "n" and "k" for use in computing Time of Concentration

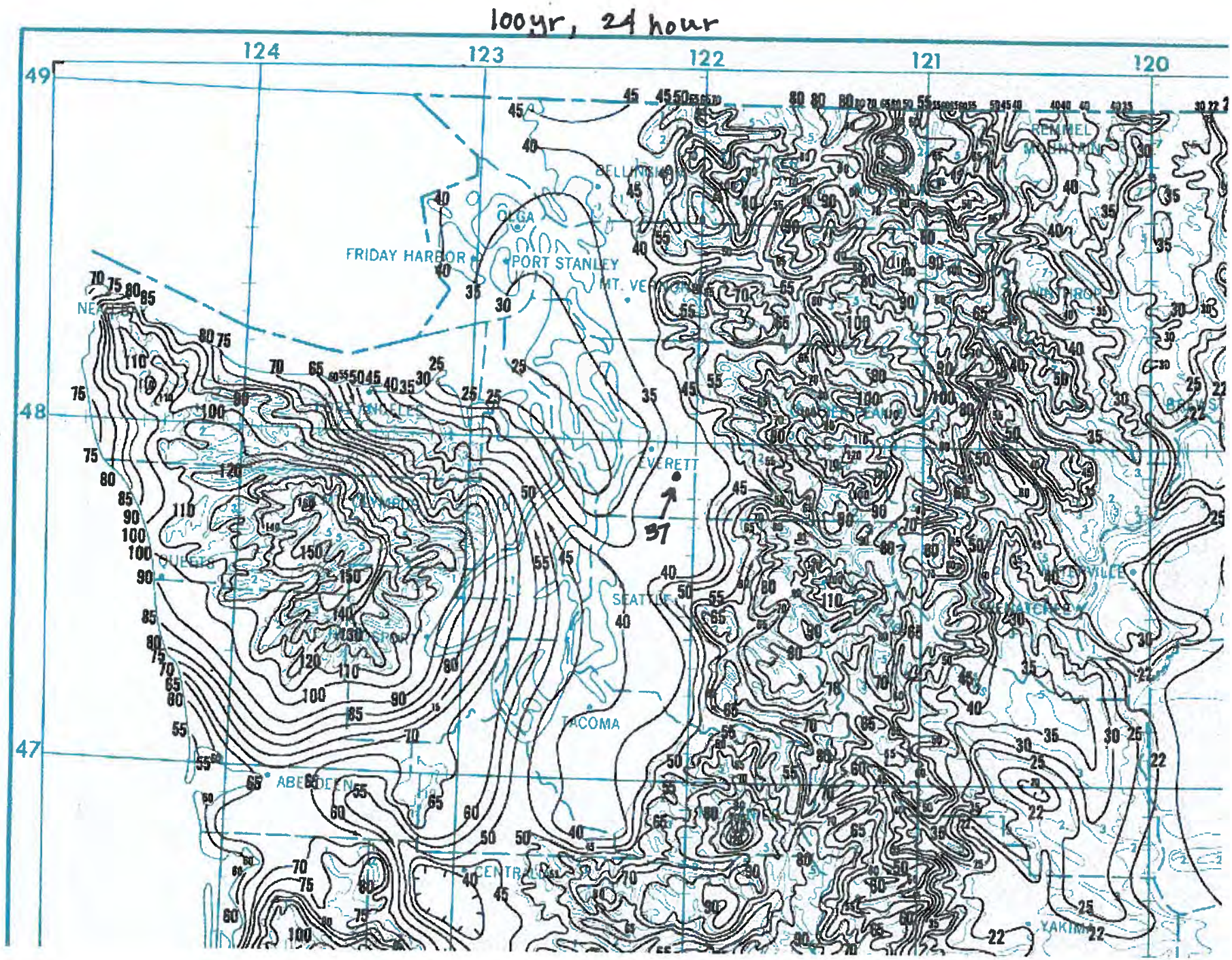
FOR SHEET FLOW	**n_s**
Smooth surfaces (concrete, asphalt, gravel, or bare hard soil)	0.011
Fallow fields of loose soil surface (no vegetal residue)	0.05
Cultivated soil with crop residue (slope < 0.20 ft/ft)	0.06
Cultivated soil with crop residue (slope > 0.20 ft/ft)	0.17
Short prairie grass and lawns	0.15
Dense grass	0.24
Bermuda grass	0.41
Range, natural	0.13
Woods or forest, poor cover	0.40
Woods or forest, good cover	0.80
FOR SHALLOW, CONCENTRATED FLOW	**k_s**
Forest with heavy ground litter and meadows (n = 0.10)	3
Brushy ground with some trees (n =0.06)	5
Fallow or minimum tillage cultivation (n = 0.04)	8
High grass (n = 0.035)	9
Short grass, pasture and lawns (n = 0.030)	11
Newly-bare ground (n = 0.025)	13
Paved and gravel areas (n = 0.012)	27
CHANNEL FLOW (INTERMITTENT, R = 0.2)	**k_c**
Forested swale with heavy ground litter (n=0.10)	5
Forested drainage course/ravine with defined channel bed (n=0.050)	10
Rock-lined waterway (n=0.035)	15
Grassed waterway (n=0.030)	17
Earth-lined waterway (n=0.025)	20
CMP pipe (n=0.024)	21
Concrete pipe (n=0.012)	42
Other waterways and pipes	0.508/n
CHANNEL FLOW (CONTINUOUS STREAM, R =0.4)	**k_c**
Meandering stream with some pools (n=0.040)	20
Rock-lined stream (n=0.035)	23
Grassed stream (n=0.030)	27
Other streams, man-made channels and pipe	0.807/n

25yr, 24hour



http://www.wrcc.dri.edu/pcpnfreq/wa25y24h.gif

10/3/2012


100yr, 24 hour
124
123
122
121
120
49
48
47
FRIDAY HARBOR
PORT STANLEY
OLGA
EVERETT
SEATTLE
TACOMA
ABERDEEN
YAKIMA
37

Stormwater Conveyance – Blackmans Lake

URS CALCULATION COVER SHEET

Quality

Project Name:	Stormwater Comprehensive Plan Update	**Project Number:**	33763575
Project Location:	City of Snohomish	**Client Name:**	City of Snohomish
PM Name:	Carla Talich	**PIC Name:**	Kevin Weed

IDENTIFYING INFORMATION

(This section is to be completed by the Originator.)

Calculation Medium: ☐ Electronic — File Name: K:\City of Snohomish\Stormwater Comp Plan\Stormwater Modeling - NEW moved\Blackmans Lake

(Select as appropriate) ☒ Hard-copy — Unique Identification:

Number of pages *(including cover sheet)*: 49

Discipline: Hydraulics

Title of Calculation: Stormwater Conveyance - Blackmans Lake

Calculation Originator: Gina Franco

Calculation Contributors: Tobey Clarkin

Calculation Checker: Carla Talich

DESCRIPTION & PURPOSE

Determine the land use and area that contributes to locations identified by the city that need to be upgraded from a ditch to a pipe. Find the peak flows in these areas and size a pipe to convey the 25year peak flow.

BASIS / REFERENCE / ASSUMPTIONS

Assumptions are stated on calculation write up.

ISSUE / REVISION RECORD

Checker comments, if any, provided on: ☒ hard-copy ☐ electronic file ☐ Form 3-5 (MM)

No.	Description	P	S	F	Originator Initials	Date	Checker Initials	Date
0	Initial Issue	☒	☐	☐	gmf	12/9/12	cgt	12/9/12
1	Updated calculation	☐	☐	☒	gmf	7-3-13	cgt	
2		☐	☐	☐	[ ]	[ ]	[ ]	[ ]
3		☐	☐	☐	[ ]	[ ]	[ ]	[ ]

Note: For a given Revision No. Check off either P (Preliminary), S (Superseding) or F (Final). If there are no revisions to the Initial Issue check off F (Final). Comments may be provided on the hard-copy calculations, electronic file or on Form 3-5 (MM).

APPROVAL and DISTRIBUTION

☐ The calculations associated with this Cover Sheet have been checked.

Gina Franco — Originator Signature — 7/3/13 — Date

Carla Talich — Checker Signature — 7/9/13 — Date

Carla Talich — Project Manager Signature — 7/9/13 — Date

Distribution:

Project Central File – Quality file folder

Project Statement:
There are currently stormwater conveyance pipes within the storm system in the City of Snohomish (City) that have been identified as areas that flood. One particular pipe that overflows is upstream of the inlet into Blackmans Lake. The City plans to upsize the pipe to be able to convey a minimum 25-year storm event per the Design and Construction Standards (City of Snohomish, 2004). See attached calculations for a map with location identified.

Land Use and Contributing Area:
The future land use and contributing areas were calculated using 2011 City Land Use Map (City of Snohomish, 2010) and 2007 LiDAR data in ARCGIS. To be conservative, the single family residential land use was assumed to be multifamily (50% pervious and 50% impervious) (Taylor, 1993). The area is mostly developed and may fall under high density residential land use. Further refinement of land use may be conducted during the design phase.

The contributing areas to Blackmans Lake inlet pipe is the flow from the detention pond upstream of Blackmans Lake inlet and the area to the east and south of the Blackmans Lake inlet. Therefore the areas were added together to determine the total contributing areas to the Blackmans Lake.

The existing land uses within the contributing areas were verified by interpretation of the aerial photograph. The existing single family residential land use in the contributing area to the detention pond was assumed to be 20 percent of the zoned single family land use. The other 80 percent was assumed currently to be forest. The existing single family residential land use in the contributing area to the east and south of the Blackmans Lake inlet was assumed to be 80 percent of the zoned single family land use. The other 20 percent was assumed currently to be park. The right of way future land use in both contributing areas was verified to be the same area for existing.

The pervious portions were assumed to be in good condition with grass cover on more than 75 percent of the area, resulting in a curve number of 86. The right-of-way area was assumed to be paved, with a curve number of 98. The existing land use and contribution areas were scaled from the aerial map with the future land use areas delineated.

The land use areas calculated in ARCGIS were separated into pervious and impervious areas for input into the Santa Barbara Urban Hydrograph (SBUH) spreadsheet, a Type 1A unit hydrograph method. The precipitation for the 25- and 100-year storm events was determined by using NOAA Atlas 2 isopluvial maps. See attached calculations.

Pipe Sizing:
The new stormwater conveyance pipes were sized by computing the peak flow resulting from 24-hour duration, 25- and 100-year recurrence interval storms, using the SBUH method. The Design and Construction Standards (City of Snohomish, 2004) states that new conveyance elements are to be sized for 25-year, 24-hour storm and checked for 100-year storm to verify possible flooding.

The size of the pipes was based on the peak flows calculated using the SBUH method.

Bentley Systems, Inc. FlowMaster, 2008 software was used to size the pipes. The pipes were graded so that they can gravity drain to the connection point. Slopes ranging from 5 percent to 6.8 percent were checked using the peak flows from the 25- and the 100-year storm events. The slopes used were based on the existing topography and the existing pipes that were analyzed. The pipe sizing conclusions can be seen in Table 1.

Table 1: Flow and Pipe Size Summary from Detention Pond

	Flow from Detention Pond				
	Existing Condition Flow (cfs)	Required Concrete Pipe Size (in)	Existing Pipe Size (in)	Future Development Flow (cfs)	Required PVC Pipe Size (in)
25-year flow (cfs)	7.77	12	12	24.64	18
100-year flow (cfs)	11.96	15		31.61	21

Table 2: Flow and Pipe Size Summary from Combined Flow to Blackmans Lake

	Combined Flow to Blackmans Lake Inlet				
	Existing Condition Flow (cfs)	Required PVC Pipe Size (in)	Existing Pipe Size (in)	Future Development Flow (cfs)	Required PVC Pipe Size (in)
25-year flow (cfs)	45.43	21	24	51.57	21
100-year flow (cfs)	59.60	24		65.82	24

Results:
Results and calculations for each area are attached.

The minimum pipe size to convey the existing 25-year flow from the detention pond is a 12-inch pipe. Due to the known flooding issues along Park Avenue between 19th Street and 18th Street, it is recommended that the pipe conveying the flow from the detention pond to Blackmans Lake be sized for the future development 100-year peak flow, 18-inch to 24-inch pipe. The pipe would be placed in along the side of the road and out of the drive path. The City's Design and

Construction Standards allow PVC (SDR35) in the right-of-way and is a reasonable pipe material to be used (City of Snohomish, 2004).

For the fully developed, detention facilities would be required in accordance with the SMMWW. The soil in the area is hydrologic soil group C and there is minimal infiltration, therefore limited LID options will be available for use. With detention used for future development, a 24-inch pipe sized for the 100-year flow for the existing land use conditions is anticipated to be adequately sized for the flow from the detention pond to Blackmans Lake.

References:

City of Snohomish, Washington. Comprehensive Plan. December 2010.

City of Snohomish, Washington. 2004. Design and Construction Standards. March 2004.

Taylor, Brian L. 1993. The Influence of Wetland and Watershed Morphological Characteristeics on Wetland Hydrology and Relationships to Wetland Vegetation Communities. 1993.

large blue #s on this dwg are object ID #s

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NORTH

Job No. 33763575

URS

400 200 0 400

Feet

Detention Pond Upstream of Blackmans Lake

Stormwater Comprehensive Plan
City of Snohomish

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NORTH

400 200 0 400

Feet

Job No. 33763575

URS

Blackmans Lake

Stormwater Comprehensive Plan

City of Snohomish

Detention Pond to Blackmans Lake (along Park Ave.)

Future Zoning

Parks	4.13	ac		
SFRES	48.89	ac		
Right-of-Way	2.02	ac		

SFRES: 50% pervious and 50% impervious

SFRES - pervious	48.89	x	0.5 =	24.445
SFRES - impervious	48.89	x	0.5 =	24.445

Pervious	Impervious
4.13	2.02
24.45	24.445
28.58	26.47

From SBUH

Q25 =	24.64	cfs
Q100 =	31.61	cfs

Existing land use

Parks	4.13	ac	
SFRES	9.778	ac	assume 20% of future zoning is single family
Forest	39.112	ac	assume 80% of future zoning single family is forest
Right-of-Way	2.02	ac	

SFRES: 50% pervious and 50% impervious

SFRES - pervious	9.778	x	0.5 =	4.889
SFRES - impervious	9.778	x	0.5 =	4.889

Pervious	Impervious
4.13	2.02
4.89	4.889
39.112	
48.13	6.91

From SBUH

Q25 =	17.77	cfs
Q100 =	11.96	cfs

Discharge to Blackmans Lake

Future Zoning

Parks	4.13 ac	
SFRES	48.89 ac	contribution from detention pond
Right-of-Way	2.02 ac	

Parks	2.09 ac	
SFRES	42.37 ac	contribution from east of Park Ave and south of inlet
Right-of-Way	9.15 ac	

SFRES: 50% pervious and 50% impervious

SFRES - pervious	91.26	x	0.5 =	45.63
SFRES - impervious	91.26	x	0.5 =	45.63

Pervious	Impervious
4.13	2.02
2.09	9.15
45.63	45.63
51.85	56.80

From SBUH

Q25 =	51.57	cfs
Q100 =	65.82	cfs

Existing land use

Parks	4.13 ac	contribution from detention pond
SFRES	9.78 ac	assume 20% of future zoning is single family
Forest	39.11 ac	assume 80% of future zoning single family is forest
Right-of-Way	2.02 ac	

Parks	10.56 ac	contribution from east of Park Ave and south of inlet
SFRES	33.90 ac	assume 80% of future zoning is single family
Right-of-Way	9.15 ac	

SFRES: 50% pervious and 50% impervious

SFRES - pervious	43.67	x	0.5 =	21.837
SFRES - impervious	43.67	x	0.5 =	21.837

Pervious	Impervious
4.13	2.02
10.56	9.15
21.84	21.837
39.112	
75.64	33.01

From SBUH

Q25 =	45.43	cfs
Q100 =	59.6	cfs

Existing Det Pond, 25 yr flow, Conc., S=5%

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Diameter

Input Data

Roughness Coefficient	0.013	
Channel Slope	0.05000	ft/ft
Normal Depth	0.99	ft
Diameter	0.99	ft
Discharge	7.77	ft³/s

Results

Diameter	0.99	ft
Normal Depth	0.99	ft
Flow Area	0.77	ft²
Wetted Perimeter	3.11	ft
Hydraulic Radius	0.25	ft
Top Width	0.00	ft
Critical Depth	0.98	ft
Percent Full	100.0	%
Critical Slope	0.04531	ft/ft
Velocity	10.08	ft/s
Velocity Head	1.58	ft
Specific Energy	2.57	ft
Froude Number	0.00	
Maximum Discharge	8.36	ft³/s
Discharge Full	7.77	ft³/s
Slope Full	0.05000	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%

Existing Det Pond, 25 yr flow, Conc., S=5%

GVF Output Data

Normal Depth Over Rise	100.00	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.99	ft
Critical Depth	0.98	ft
Channel Slope	0.05000	ft/ft
Critical Slope	0.04531	ft/ft

Existing Det Pond, 100 yr flow, Conc., S=5%

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Diameter

Input Data

Roughness Coefficient	0.013	
Channel Slope	0.05000	ft/ft
Normal Depth	1.16	ft
Diameter	1.16	ft
Discharge	11.96	ft^3/s

Results

Diameter	1.16	ft
Normal Depth	1.16	ft
Flow Area	1.07	ft^2
Wetted Perimeter	3.66	ft
Hydraulic Radius	0.29	ft
Top Width	0.00	ft
Critical Depth	1.15	ft
Percent Full	100.0	%
Critical Slope	0.04550	ft/ft
Velocity	11.23	ft/s
Velocity Head	1.96	ft
Specific Energy	3.12	ft
Froude Number	0.00	
Maximum Discharge	12.87	ft^3/s
Discharge Full	11.96	ft^3/s
Slope Full	0.05000	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%

Existing Det Pond, 100 yr flow, Conc., S=5%

GVF Output Data

Normal Depth Over Rise	100.00	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.16	ft
Critical Depth	1.15	ft
Channel Slope	0.05000	ft/ft
Critical Slope	0.04550	ft/ft

City of Snohomish
Stormwater Comprehensive Plan
Time of Concentration
Blackmans - Existing-Det Pond

Calculate Time of Concentration (Tc)

Tc = Sum(Tt)

Where:

Tt = travel time (min) = $\frac{L}{(60xV)}$ (for shallow concentrated flow or channel flow)

Tt = travel time (min)= $\frac{0.42(n_s L)^{0.8}}{(P_2)^{0.5}(s_o)^{0.4}}$ (for sheet flow)

Where:

V = avg. velocity (ft/s) = $V = k(s_o)^{0.5}$

k = time of concentration velocity factor (ft/s)

L = flow length (ft)

n_s = sheet flow Manning's effective roughness coefficient

P_2 = 2-year, 24-hour rainfall (in)

s_o = slope of hydraulic grade line (land slope, ft/ft)

	L (ft)	$k_{s/c}$	V (fps)	n_s	P_2	s_o (ft/ft)	Tt (min)
a - sheet	100	NA	NA	0.4	1.8	0.040	21.7
b - channel	2600	17	3.4	NA	NA	0.040	12.7
Total (Tc)							34.4

Minimum Allowable Tc = 6.0 minutes

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

Project: City of Snohomish - Stormwater Comp Plan
Basin: Detention Pond Upstream of Blackmans Lake - Existing
Storm Event: 25-YEAR, 24-HOUR
Given:

Area = 55.04 acres
Pt = 3.05 inches
dt = 10 min.
Tc = 34.4 min.

PERVIOUS AREA			IMPERVIOUS AREA (Roads)		
Area	=	48.13 acres	Area	=	6.91 acres
CN	=	73	CN	=	98
S	=	3.70	S	=	0.20
0.2S	=	0.74	0.2S	=	0.04

SUMMARY	
T_{pk}(hrs)=	7.83
T_c (min)=	34.4
Q_{pk}(cfs)=	7.77
Vol(cf)=	220,310

Compute: Runoff Hydrograph

Column (3) = SCS Type IA Rainfall Distribution
Column (4) = Col. (3) x Pt
Column (5) = Accumulated Sum of Col. (4)
Column (6) = [If P <= 0.2S] = 0; Note, use PERVIOUS Area "S" value.
[If P > 0.2S] = (Col.(5) - 0.2S)^2/(Col.(5) + 0.8S); Using the PERVIOUS Area "S" value.
Column (7) = Col.(6) of Present Time Step - Col.(6) of Previous Time Step
Column (8) = Same method as for Col.(6), except use the IMPERVIOUS Area "S" value.
Column (9) = Col.(8) of the present time step - Col.(8) of the previous time step.
Column (10) = ((PERVIOUS area / Total area) x Col.(7)) + ((IMPERVIOUS area / Total area) x Col.(9))
Column (11) = (60.5 x Col.(10) x Total Area) / 10 (dt = 10 minutes)
Routing Constant, w = dt / (2Tc + dt) = 0.1269
Column (12) = Col.(12) of Previous Time Step + (w x [Col.(11) of Previous Time Step
+ Col.(11) of Present Time Step - (2 x Col.(12) of Previous Time Step)])

					Pervious Area		Impervious Area					
(1) Time Increment	(2) Time	(3) Rainfall distri-bution	(4) Incre-mental Rainfall	(5) Accumu-lated Rainfall	(6) Accumu-lated Runoff	(7) Incre-mental Runoff	(8) Accumu-lated Runoff	(9) Incre-mental Runoff	(10) Total Runoff	(11) Instant hydro-graph	(12) design hydro-graph	
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs	
1	10	0.0040	0.0122	0.0122	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
2	20	0.0040	0.0122	0.0244	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
3	30	0.0040	0.0122	0.0366	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
4	40	0.0040	0.0122	0.0488	0.0000	0.0000	0.0003	0.0003	0.0000	0.0	0.00	
5	50	0.0040	0.0122	0.0610	0.0000	0.0000	0.0018	0.0015	0.0002	0.1	0.01	
6	60	0.0040	0.0122	0.0732	0.0000	0.0000	0.0044	0.0026	0.0003	0.1	0.03	
7	70	0.0040	0.0122	0.0854	0.0000	0.0000	0.0080	0.0036	0.0004	0.1	0.06	
8	80	0.0040	0.0122	0.0976	0.0000	0.0000	0.0124	0.0044	0.0005	0.2	0.08	
9	90	0.0040	0.0122	0.1098	0.0000	0.0000	0.0174	0.0051	0.0006	0.2	0.11	
10	100	0.0040	0.0122	0.1220	0.0000	0.0000	0.0231	0.0057	0.0007	0.2	0.14	
11	110	0.0050	0.0153	0.1373	0.0000	0.0000	0.0309	0.0078	0.0010	0.3	0.18	
12	120	0.0050	0.0153	0.1525	0.0000	0.0000	0.0395	0.0086	0.0011	0.4	0.22	
13	130	0.0050	0.0153	0.1678	0.0000	0.0000	0.0487	0.0092	0.0012	0.4	0.26	
14	140	0.0050	0.0153	0.1830	0.0000	0.0000	0.0584	0.0097	0.0012	0.4	0.29	
15	150	0.0050	0.0153	0.1983	0.0000	0.0000	0.0686	0.0102	0.0013	0.4	0.32	
16	160	0.0050	0.0153	0.2135	0.0000	0.0000	0.0791	0.0106	0.0013	0.4	0.35	
17	170	0.0060	0.0183	0.2318	0.0000	0.0000	0.0923	0.0132	0.0017	0.6	0.39	
18	180	0.0060	0.0183	0.2501	0.0000	0.0000	0.1060	0.0136	0.0017	0.6	0.43	
19	190	0.0060	0.0183	0.2684	0.0000	0.0000	0.1200	0.0140	0.0018	0.6	0.47	
20	200	0.0060	0.0183	0.2867	0.0000	0.0000	0.1344	0.0144	0.0018	0.6	0.50	
21	210	0.0060	0.0183	0.3050	0.0000	0.0000	0.1490	0.0147	0.0018	0.6	0.53	
22	220	0.0060	0.0183	0.3233	0.0000	0.0000	0.1640	0.0150	0.0019	0.6	0.55	
23	230	0.0070	0.0214	0.3447	0.0000	0.0000	0.1818	0.0178	0.0022	0.7	0.58	
24	240	0.0070	0.0214	0.3660	0.0000	0.0000	0.1998	0.0180	0.0023	0.8	0.63	
25	250	0.0070	0.0214	0.3874	0.0000	0.0000	0.2181	0.0183	0.0023	0.8	0.66	
26	260	0.0070	0.0214	0.4087	0.0000	0.0000	0.2366	0.0185	0.0023	0.8	0.69	
27	270	0.0070	0.0214	0.4301	0.0000	0.0000	0.2553	0.0187	0.0024	0.8	0.71	
28	280	0.0070	0.0214	0.4514	0.0000	0.0000	0.2743	0.0189	0.0024	0.8	0.73	
29	290	0.0082	0.0250	0.4764	0.0000	0.0000	0.2966	0.0224	0.0028	0.9	0.76	
30	300	0.0082	0.0250	0.5014	0.0000	0.0000	0.3192	0.0226	0.0028	0.9	0.81	
31	310	0.0082	0.0250	0.5264	0.0000	0.0000	0.3419	0.0227	0.0029	1.0	0.84	
32	320	0.0082	0.0250	0.5514	0.0000	0.0000	0.3648	0.0229	0.0029	1.0	0.87	
33	330	0.0082	0.0250	0.5765	0.0000	0.0000	0.3879	0.0230	0.0029	1.0	0.89	
34	340	0.0082	0.0250	0.6015	0.0000	0.0000	0.4110	0.0232	0.0029	1.0	0.91	
35	350	0.0095	0.0290	0.6304	0.0000	0.0000	0.4380	0.0270	0.0034	1.1	0.95	
36	360	0.0095	0.0290	0.6594	0.0000	0.0000	0.4651	0.0271	0.0034	1.1	0.99	
37	370	0.0095	0.0290	0.6884	0.0000	0.0000	0.4924	0.0273	0.0034	1.1	1.03	
38	380	0.0095	0.0290	0.7174	0.0000	0.0000	0.5198	0.0274	0.0034	1.1	1.06	
39	390	0.0095	0.0290	0.7463	0.0000	0.0000	0.5472	0.0275	0.0035	1.2	1.08	
40	400	0.0095	0.0290	0.7753	0.0003	0.0003	0.5748	0.0276	0.0037	1.2	1.11	
41	410	0.0134	0.0409	0.8162	0.0015	0.0012	0.6138	0.0390	0.0060	2.0	1.24	
42	420	0.0134	0.0409	0.8570	0.0036	0.0021	0.6530	0.0392	0.0067	2.2	1.46	
43	430	0.0134	0.0409	0.8979	0.0065	0.0029	0.6923	0.0393	0.0075	2.5	1.69	
44	440	0.0180	0.0549	0.9528	0.0116	0.0051	0.7452	0.0530	0.0111	3.7	2.05	
45	450	0.0180	0.0549	1.0077	0.0181	0.0065	0.7984	0.0532	0.0124	4.1	2.52	
46	460	0.0340	0.1037	1.1114	0.0339	0.0158	0.8992	0.1008	0.0265	8.8	3.52	
47	470	0.0540	0.1647	1.2761	0.0679	0.0340	1.0602	0.1610	0.0499	16.6	5.86	
48	480	0.0270	0.0824	1.3585	0.0887	0.0207	1.1409	0.0808	0.0283	9.4	7.68	
49	490	0.0180	0.0549	1.4134	0.1038	0.0151	1.1949	0.0539	0.0200	6.7	7.77	Q peak
50	500	0.0134	0.0409	1.4542	0.1157	0.0119	1.2351	0.0402	0.0154	5.1	7.29	
51	510	0.0134	0.0409	1.4951	0.1281	0.0124	1.2753	0.0402	0.0159	5.3	6.77	
52	520	0.0134	0.0409	1.5360	0.1411	0.0129	1.3156	0.0403	0.0164	5.5	6.41	
53	530	0.0088	0.0268	1.5628	0.1498	0.0088	1.3421	0.0265	0.0110	3.7	5.94	
54	540	0.0088	0.0268	1.5897	0.1588	0.0090	1.3685	0.0265	0.0112	3.7	5.37	
55	550	0.0088	0.0268	1.6165	0.1680	0.0092	1.3950	0.0265	0.0114	3.8	4.96	
56	560	0.0088	0.0268	1.6433	0.1774	0.0094	1.4215	0.0265	0.0115	3.8	4.67	
57	570	0.0088	0.0268	1.6702	0.1870	0.0096	1.4480	0.0265	0.0117	3.9	4.47	
58	580	0.0088	0.0268	1.6970	0.1968	0.0098	1.4745	0.0265	0.0119	4.0	4.33	
59	590	0.0088	0.0268	1.7239	0.2068	0.0100	1.5010	0.0265	0.0121	4.0	4.25	
60	600	0.0088	0.0268	1.7507	0.2170	0.0102	1.5276	0.0265	0.0122	4.1	4.20	
61	610	0.0088	0.0268	1.7775	0.2274	0.0104	1.5541	0.0265	0.0124	4.1	4.17	
62	620	0.0088	0.0268	1.8044	0.2380	0.0106	1.5806	0.0265	0.0126	4.2	4.17	
63	630	0.0088	0.0268	1.8312	0.2487	0.0107	1.6072	0.0266	0.0127	4.2	4.18	
64	640	0.0088	0.0268	1.8581	0.2596	0.0109	1.6338	0.0266	0.0129	4.3	4.20	
65	650	0.0072	0.0220	1.8800	0.2687	0.0091	1.6555	0.0217	0.0107	3.6	4.13	

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

					Pervious Area		Impervious Area				
(1) Time Increment	(2) Time	(3) Rainfall distri- bution	(4) Incre- mental Rainfall	(5) Accumu- lated Rainfall	(6) Accumu- lated Runoff	(7) Incre- mental Runoff	(8) Accumu- lated Runoff	(9) Incre- mental Runoff	(10) Total Runoff	(11) Instant hydro- graph	(12) design hydro- graph
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs
66	660	0.0072	0.0220	1.9020	0.2779	0.0092	1.6772	0.0217	0.0108	3.6	3.99
67	670	0.0072	0.0220	1.9239	0.2872	0.0093	1.6990	0.0217	0.0109	3.6	3.89
68	680	0.0072	0.0220	1.9459	0.2966	0.0094	1.7207	0.0218	0.0110	3.7	3.83
69	690	0.0072	0.0220	1.9679	0.3061	0.0095	1.7425	0.0218	0.0111	3.7	3.79
70	700	0.0072	0.0220	1.9898	0.3158	0.0096	1.7643	0.0218	0.0112	3.7	3.76
71	710	0.0072	0.0220	2.0118	0.3255	0.0097	1.7860	0.0218	0.0113	3.7	3.76
72	720	0.0072	0.0220	2.0337	0.3354	0.0099	1.8078	0.0218	0.0114	3.8	3.76
73	730	0.0072	0.0220	2.0557	0.3453	0.0100	1.8296	0.0218	0.0114	3.8	3.77
74	740	0.0072	0.0220	2.0777	0.3554	0.0101	1.8513	0.0218	0.0115	3.8	3.78
75	750	0.0072	0.0220	2.0996	0.3656	0.0102	1.8731	0.0218	0.0116	3.9	3.80
76	760	0.0072	0.0220	2.1216	0.3759	0.0103	1.8949	0.0218	0.0117	3.9	3.82
77	770	0.0057	0.0174	2.1390	0.3841	0.0082	1.9122	0.0172	0.0093	3.1	3.74
78	780	0.0057	0.0174	2.1564	0.3923	0.0083	1.9294	0.0172	0.0094	3.1	3.58
79	790	0.0057	0.0174	2.1737	0.4006	0.0083	1.9467	0.0173	0.0094	3.1	3.47
80	800	0.0057	0.0174	2.1911	0.4090	0.0084	1.9639	0.0173	0.0095	3.2	3.39
81	810	0.0057	0.0174	2.2085	0.4175	0.0084	1.9812	0.0173	0.0096	3.2	3.34
82	820	0.0057	0.0174	2.2259	0.4260	0.0085	1.9984	0.0173	0.0096	3.2	3.30
83	830	0.0057	0.0174	2.2433	0.4346	0.0086	2.0157	0.0173	0.0097	3.2	3.28
84	840	0.0057	0.0174	2.2607	0.4432	0.0086	2.0329	0.0173	0.0097	3.2	3.26
85	850	0.0057	0.0174	2.2780	0.4519	0.0087	2.0502	0.0173	0.0098	3.3	3.26
86	860	0.0057	0.0174	2.2954	0.4606	0.0087	2.0675	0.0173	0.0098	3.3	3.26
87	870	0.0057	0.0174	2.3128	0.4694	0.0088	2.0847	0.0173	0.0099	3.3	3.26
88	880	0.0057	0.0174	2.3302	0.4783	0.0089	2.1020	0.0173	0.0099	3.3	3.27
89	890	0.0050	0.0153	2.3455	0.4861	0.0078	2.1172	0.0151	0.0087	2.9	3.23
90	900	0.0050	0.0153	2.3607	0.4939	0.0079	2.1323	0.0151	0.0088	2.9	3.15
91	910	0.0050	0.0153	2.3760	0.5018	0.0079	2.1475	0.0152	0.0088	2.9	3.09
92	920	0.0050	0.0153	2.3912	0.5098	0.0079	2.1626	0.0152	0.0088	2.9	3.05
93	930	0.0050	0.0153	2.4065	0.5178	0.0080	2.1778	0.0152	0.0089	3.0	3.03
94	940	0.0050	0.0153	2.4217	0.5258	0.0080	2.1929	0.0152	0.0089	3.0	3.01
95	950	0.0050	0.0153	2.4370	0.5338	0.0081	2.2081	0.0152	0.0090	3.0	3.00
96	960	0.0050	0.0153	2.4522	0.5420	0.0081	2.2232	0.0152	0.0090	3.0	3.00
97	970	0.0050	0.0153	2.4675	0.5501	0.0081	2.2384	0.0152	0.0090	3.0	3.00
98	980	0.0050	0.0153	2.4827	0.5583	0.0082	2.2535	0.0152	0.0091	3.0	3.00
99	990	0.0050	0.0153	2.4980	0.5665	0.0082	2.2687	0.0152	0.0091	3.0	3.01
100	1000	0.0050	0.0153	2.5132	0.5748	0.0083	2.2839	0.0152	0.0091	3.0	3.01
101	1010	0.0040	0.0122	2.5254	0.5814	0.0066	2.2960	0.0121	0.0073	2.4	2.94
102	1020	0.0040	0.0122	2.5376	0.5881	0.0067	2.3081	0.0121	0.0073	2.4	2.82
103	1030	0.0040	0.0122	2.5498	0.5948	0.0067	2.3203	0.0121	0.0074	2.5	2.72
104	1040	0.0040	0.0122	2.5620	0.6015	0.0067	2.3324	0.0121	0.0074	2.5	2.66
105	1050	0.0040	0.0122	2.5742	0.6082	0.0067	2.3445	0.0121	0.0074	2.5	2.61
106	1060	0.0040	0.0122	2.5864	0.6150	0.0068	2.3566	0.0121	0.0074	2.5	2.57
107	1070	0.0040	0.0122	2.5986	0.6218	0.0068	2.3688	0.0121	0.0075	2.5	2.55
108	1080	0.0040	0.0122	2.6108	0.6286	0.0068	2.3809	0.0121	0.0075	2.5	2.53
109	1090	0.0040	0.0122	2.6230	0.6354	0.0068	2.3931	0.0121	0.0075	2.5	2.52
110	1100	0.0040	0.0122	2.6352	0.6423	0.0069	2.4052	0.0121	0.0075	2.5	2.52
111	1110	0.0040	0.0122	2.6474	0.6491	0.0069	2.4173	0.0121	0.0075	2.5	2.51
112	1120	0.0040	0.0122	2.6596	0.6560	0.0069	2.4295	0.0121	0.0076	2.5	2.51
113	1130	0.0040	0.0122	2.6718	0.6630	0.0069	2.4416	0.0121	0.0076	2.5	2.52
114	1140	0.0040	0.0122	2.6840	0.6699	0.0069	2.4537	0.0121	0.0076	2.5	2.52
115	1150	0.0040	0.0122	2.6962	0.6769	0.0070	2.4659	0.0121	0.0076	2.5	2.52
116	1160	0.0040	0.0122	2.7084	0.6839	0.0070	2.4780	0.0121	0.0076	2.5	2.53
117	1170	0.0040	0.0122	2.7206	0.6909	0.0070	2.4901	0.0121	0.0077	2.6	2.53
118	1180	0.0040	0.0122	2.7328	0.6979	0.0070	2.5023	0.0121	0.0077	2.6	2.54
119	1190	0.0040	0.0122	2.7450	0.7050	0.0071	2.5144	0.0121	0.0077	2.6	2.54
120	1200	0.0040	0.0122	2.7572	0.7121	0.0071	2.5266	0.0121	0.0077	2.6	2.55
121	1210	0.0040	0.0122	2.7694	0.7192	0.0071	2.5387	0.0121	0.0077	2.6	2.56
122	1220	0.0040	0.0122	2.7816	0.7263	0.0071	2.5508	0.0121	0.0078	2.6	2.56
123	1230	0.0040	0.0122	2.7938	0.7334	0.0071	2.5630	0.0121	0.0078	2.6	2.57
124	1240	0.0040	0.0122	2.8060	0.7406	0.0072	2.5751	0.0121	0.0078	2.6	2.57
125	1250	0.0040	0.0122	2.8182	0.7478	0.0072	2.5873	0.0121	0.0078	2.6	2.58
126	1260	0.0040	0.0122	2.8304	0.7550	0.0072	2.5994	0.0121	0.0078	2.6	2.59
127	1270	0.0040	0.0122	2.8426	0.7622	0.0072	2.6116	0.0121	0.0078	2.6	2.59
128	1280	0.0040	0.0122	2.8548	0.7695	0.0073	2.6237	0.0121	0.0079	2.6	2.60
129	1290	0.0040	0.0122	2.8670	0.7768	0.0073	2.6358	0.0121	0.0079	2.6	2.60
130	1300	0.0040	0.0122	2.8792	0.7840	0.0073	2.6480	0.0121	0.0079	2.6	2.61
131	1310	0.0040	0.0122	2.8914	0.7914	0.0073	2.6601	0.0121	0.0079	2.6	2.62
132	1320	0.0040	0.0122	2.9036	0.7987	0.0073	2.6723	0.0121	0.0079	2.6	2.62
133	1330	0.0040	0.0122	2.9158	0.8060	0.0074	2.6844	0.0121	0.0080	2.6	2.63
134	1340	0.0040	0.0122	2.9280	0.8134	0.0074	2.6966	0.0121	0.0080	2.7	2.63
135	1350	0.0040	0.0122	2.9402	0.8208	0.0074	2.7087	0.0121	0.0080	2.7	2.64
136	1360	0.0040	0.0122	2.9524	0.8282	0.0074	2.7209	0.0121	0.0080	2.7	2.65
137	1370	0.0040	0.0122	2.9646	0.8357	0.0074	2.7330	0.0121	0.0080	2.7	2.65
138	1380	0.0040	0.0122	2.9768	0.8431	0.0075	2.7452	0.0121	0.0080	2.7	2.66
139	1390	0.0040	0.0122	2.9890	0.8506	0.0075	2.7573	0.0121	0.0081	2.7	2.66
140	1400	0.0040	0.0122	3.0012	0.8581	0.0075	2.7695	0.0121	0.0081	2.7	2.67
141	1410	0.0040	0.0122	3.0134	0.8656	0.0075	2.7816	0.0121	0.0081	2.7	2.68
142	1420	0.0040	0.0122	3.0256	0.8731	0.0075	2.7938	0.0121	0.0081	2.7	2.68
143	1430	0.0040	0.0122	3.0378	0.8807	0.0075	2.8059	0.0122	0.0081	2.7	2.69
144	1440	0.0040	0.0122	3.0500	0.8882	0.0076	2.8181	0.0122	0.0081	2.7	2.69

Total Volume of Runoff[1] = 220,310 cu. ft.

Notes:

1. Total Runoff Volume is found by summing column (12) and multiplying by the time step, dt as follows:

   V = SumQ x dt
   V(cu.ft.) = SumQ(cu.ft/s) x dt(min.) x (60 s/min.)

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

Project: City of Snohomish - Stormwater Comp Plan
Basin: Detention Pond Upstream of Blackmans Lake - Existing
Storm Event: 100-YEAR, 24-HOUR
Given:

Area	=	55.04	acres				
Pt	=	3.70	inches				
dt	=	10	min.				
Tc	=	34.4	min.				
PERVIOUS AREA				IMPERVIOUS AREA (Roads)			
Area	=	48.13	acres	Area	=	6.91	acres
CN	=	73		CN	=	98	
S	=	3.70		S	=	0.20	
0.2S	=	0.74		0.2S	=	0.04	

SUMMARY	
T_{pk}(hrs)=	7.83
T_c (min)=	34.4
Q_{pk}(cfs)=	11.96
Vol(cf)=	309,478

Compute: Runoff Hydrograph

Column (3) = SCS Type IA Rainfall Distribution
Column (4) = Col. (3) x Pt
Column (5) = Accumulated Sum of Col. (4)
Column (6) = [If P <= 0.2S] = 0; Note, use PERVIOUS Area "S" value.
[If P > 0.2S] = (Col.(5) - 0.2S)^2/(Col.(5) + 0.8S); Using the PERVIOUS Area "S" value.
Column (7) = Col.(6) of Present Time Step - Col.(6) of Previous Time Step
Column (8) = Same method as for Col.(6), except use the IMPERVIOUS Area "S" value.
Column (9) = Col.(8) of the present time step - Col.(8) of the previous time step.
Column (10) = ((PERVIOUS area / Total area) x Col.(7)) + ((IMPERVIOUS area / Total area) x Col.(9))
Column (11) = (60.5 x Col.(10) x Total Area) / 10 (dt = 10 minutes)
Routing Constant, w = dt / (2Tc + dt) = 0.1269
Column (12) = Col.(12) of Previous Time Step + (w x [Col.(11) of Previous Time Step
+ Col.(11) of Present Time Step - (2 x Col.(12) of Previous Time Step)])

					Pervious Area		Impervious Area					
(1) Time Increment	(2) Time	(3) Rainfall distri-bution	(4) Incre-mental Rainfall	(5) Accumu-lated Rainfall	(6) Accumu-lated Runoff	(7) Incre-mental Runoff	(8) Accumu-lated Runoff	(9) Incre-mental Runoff	(10) Total Runoff	(11) Instant hydro-graph	(12) design hydro-graph	
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs	
1	10	0.0040	0.0148	0.0148	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
2	20	0.0040	0.0148	0.0296	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
3	30	0.0040	0.0148	0.0444	0.0000	0.0000	0.0001	0.0001	0.0000	0.0	0.00	
4	40	0.0040	0.0148	0.0592	0.0000	0.0000	0.0015	0.0015	0.0002	0.1	0.01	
5	50	0.0040	0.0148	0.0740	0.0000	0.0000	0.0046	0.0031	0.0004	0.1	0.03	
6	60	0.0040	0.0148	0.0888	0.0000	0.0000	0.0091	0.0045	0.0006	0.2	0.06	
7	70	0.0040	0.0148	0.1036	0.0000	0.0000	0.0148	0.0056	0.0007	0.2	0.10	
8	80	0.0040	0.0148	0.1184	0.0000	0.0000	0.0214	0.0066	0.0008	0.3	0.14	
9	90	0.0040	0.0148	0.1332	0.0000	0.0000	0.0288	0.0074	0.0009	0.3	0.18	
10	100	0.0040	0.0148	0.1480	0.0000	0.0000	0.0369	0.0081	0.0010	0.3	0.22	
11	110	0.0050	0.0185	0.1665	0.0000	0.0000	0.0479	0.0110	0.0014	0.5	0.26	
12	120	0.0050	0.0185	0.1850	0.0000	0.0000	0.0597	0.0118	0.0015	0.5	0.32	
13	130	0.0050	0.0185	0.2035	0.0000	0.0000	0.0722	0.0125	0.0016	0.5	0.37	
14	140	0.0050	0.0185	0.2220	0.0000	0.0000	0.0852	0.0130	0.0016	0.5	0.41	
15	150	0.0050	0.0185	0.2405	0.0000	0.0000	0.0988	0.0135	0.0017	0.6	0.45	
16	160	0.0050	0.0185	0.2590	0.0000	0.0000	0.1127	0.0140	0.0018	0.6	0.48	
17	170	0.0060	0.0222	0.2812	0.0000	0.0000	0.1300	0.0173	0.0022	0.7	0.52	
18	180	0.0060	0.0222	0.3034	0.0000	0.0000	0.1478	0.0177	0.0022	0.7	0.58	
19	190	0.0060	0.0222	0.3256	0.0000	0.0000	0.1659	0.0181	0.0023	0.8	0.62	
20	200	0.0060	0.0222	0.3478	0.0000	0.0000	0.1844	0.0185	0.0023	0.8	0.66	
21	210	0.0060	0.0222	0.3700	0.0000	0.0000	0.2032	0.0188	0.0024	0.8	0.69	
22	220	0.0060	0.0222	0.3922	0.0000	0.0000	0.2223	0.0191	0.0024	0.8	0.71	
23	230	0.0070	0.0259	0.4181	0.0000	0.0000	0.2448	0.0226	0.0028	0.9	0.75	
24	240	0.0070	0.0259	0.4440	0.0000	0.0000	0.2677	0.0228	0.0029	1.0	0.80	
25	250	0.0070	0.0259	0.4699	0.0000	0.0000	0.2908	0.0231	0.0029	1.0	0.84	
26	260	0.0070	0.0259	0.4958	0.0000	0.0000	0.3141	0.0233	0.0029	1.0	0.88	
27	270	0.0070	0.0259	0.5217	0.0000	0.0000	0.3376	0.0235	0.0030	1.0	0.90	
28	280	0.0070	0.0259	0.5476	0.0000	0.0000	0.3613	0.0237	0.0030	1.0	0.92	
29	290	0.0082	0.0303	0.5779	0.0000	0.0000	0.3892	0.0279	0.0035	1.2	0.96	
30	300	0.0082	0.0303	0.6083	0.0000	0.0000	0.4174	0.0281	0.0035	1.2	1.02	
31	310	0.0082	0.0303	0.6386	0.0000	0.0000	0.4457	0.0283	0.0036	1.2	1.06	
32	320	0.0082	0.0303	0.6690	0.0000	0.0000	0.4741	0.0284	0.0036	1.2	1.09	
33	330	0.0082	0.0303	0.6993	0.0000	0.0000	0.5027	0.0286	0.0036	1.2	1.12	
34	340	0.0082	0.0303	0.7296	0.0000	0.0000	0.5314	0.0287	0.0036	1.2	1.14	
35	350	0.0095	0.0352	0.7648	0.0002	0.0002	0.5648	0.0334	0.0043	1.4	1.18	
36	360	0.0095	0.0352	0.7999	0.0010	0.0008	0.5983	0.0335	0.0049	1.6	1.27	
37	370	0.0095	0.0352	0.8351	0.0024	0.0014	0.6319	0.0336	0.0055	1.8	1.39	
38	380	0.0095	0.0352	0.8702	0.0044	0.0021	0.6656	0.0337	0.0060	2.0	1.52	
39	390	0.0095	0.0352	0.9054	0.0071	0.0027	0.6995	0.0338	0.0066	2.2	1.67	
40	400	0.0095	0.0352	0.9405	0.0103	0.0032	0.7334	0.0339	0.0071	2.4	1.82	
41	410	0.0134	0.0496	0.9901	0.0159	0.0055	0.7813	0.0480	0.0109	3.6	2.12	
42	420	0.0134	0.0496	1.0397	0.0225	0.0066	0.8294	0.0481	0.0118	3.9	2.54	
43	430	0.0134	0.0496	1.0893	0.0302	0.0077	0.8776	0.0482	0.0128	4.3	2.93	
44	440	0.0180	0.0666	1.1559	0.0421	0.0119	0.9426	0.0649	0.0186	6.2	3.51	
45	450	0.0180	0.0666	1.2225	0.0557	0.0136	1.0076	0.0651	0.0201	6.7	4.26	
46	460	0.0340	0.1258	1.3483	0.0860	0.0302	1.1309	0.1233	0.0419	14.0	5.80	
47	470	0.0540	0.1998	1.5481	0.1450	0.0590	1.3275	0.1966	0.0763	25.4	9.32	
48	480	0.0270	0.0999	1.6480	0.1791	0.0341	1.4261	0.0986	0.0422	14.0	11.96	Q peak
49	490	0.0180	0.0666	1.7146	0.2033	0.0243	1.4919	0.0658	0.0295	9.8	11.95	
50	500	0.0134	0.0496	1.7642	0.2222	0.0189	1.5409	0.0490	0.0226	7.5	11.12	
51	510	0.0134	0.0496	1.8137	0.2417	0.0195	1.5899	0.0490	0.0232	7.7	10.24	
52	520	0.0134	0.0496	1.8633	0.2618	0.0201	1.6390	0.0491	0.0237	7.9	9.62	
53	530	0.0088	0.0326	1.8959	0.2753	0.0135	1.6712	0.0322	0.0159	5.3	8.85	
54	540	0.0088	0.0326	1.9284	0.2891	0.0138	1.7035	0.0322	0.0161	5.4	7.96	
55	550	0.0088	0.0326	1.9610	0.3032	0.0140	1.7357	0.0323	0.0163	5.4	7.31	
56	560	0.0088	0.0326	1.9936	0.3174	0.0143	1.7680	0.0323	0.0165	5.5	6.84	
57	570	0.0088	0.0326	2.0261	0.3320	0.0145	1.8002	0.0323	0.0167	5.6	6.51	
58	580	0.0088	0.0326	2.0587	0.3467	0.0148	1.8325	0.0323	0.0170	5.6	6.28	
59	590	0.0088	0.0326	2.0912	0.3617	0.0150	1.8648	0.0323	0.0172	5.7	6.13	
60	600	0.0088	0.0326	2.1238	0.3769	0.0152	1.8971	0.0323	0.0174	5.8	6.03	
61	610	0.0088	0.0326	2.1564	0.3923	0.0154	1.9294	0.0323	0.0175	5.8	5.98	
62	620	0.0088	0.0326	2.1889	0.4080	0.0156	1.9617	0.0323	0.0177	5.9	5.95	
63	630	0.0088	0.0326	2.2215	0.4238	0.0159	1.9940	0.0323	0.0179	6.0	5.95	
64	640	0.0088	0.0326	2.2540	0.4399	0.0161	2.0264	0.0323	0.0181	6.0	5.96	
65	650	0.0072	0.0266	2.2807	0.4532	0.0133	2.0528	0.0265	0.0149	5.0	5.84	

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

					Pervious Area		Impervious Area				
(1) Time Increment	(2) Time	(3) Rainfall distri- bution	(4) Incre- mental Rainfall	(5) Accumu- lated Rainfall	(6) Accumu- lated Runoff	(7) Incre- mental Runoff	(8) Accumu- lated Runoff	(9) Incre- mental Runoff	(10) Total Runoff	(11) Instant hydro- graph	(12) design hydro- graph
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs
66	660	0.0072	0.0266	2.3073	0.4666	0.0134	2.0793	0.0265	0.0151	5.0	5.63
67	670	0.0072	0.0266	2.3340	0.4802	0.0136	2.1057	0.0265	0.0152	5.1	5.48
68	680	0.0072	0.0266	2.3606	0.4939	0.0137	2.1322	0.0265	0.0153	5.1	5.38
69	690	0.0072	0.0266	2.3872	0.5077	0.0138	2.1587	0.0265	0.0154	5.1	5.31
70	700	0.0072	0.0266	2.4139	0.5217	0.0140	2.1851	0.0265	0.0155	5.2	5.27
71	710	0.0072	0.0266	2.4405	0.5357	0.0141	2.2116	0.0265	0.0156	5.2	5.25
72	720	0.0072	0.0266	2.4672	0.5499	0.0142	2.2381	0.0265	0.0157	5.2	5.24
73	730	0.0072	0.0266	2.4938	0.5643	0.0143	2.2646	0.0265	0.0158	5.3	5.25
74	740	0.0072	0.0266	2.5204	0.5787	0.0144	2.2911	0.0265	0.0160	5.3	5.26
75	750	0.0072	0.0266	2.5471	0.5933	0.0146	2.3175	0.0265	0.0161	5.3	5.28
76	760	0.0072	0.0266	2.5737	0.6079	0.0147	2.3440	0.0265	0.0162	5.4	5.30
77	770	0.0057	0.0211	2.5948	0.6196	0.0117	2.3650	0.0210	0.0129	4.3	5.18
78	780	0.0057	0.0211	2.6159	0.6314	0.0118	2.3860	0.0210	0.0129	4.3	4.96
79	790	0.0057	0.0211	2.6370	0.6433	0.0118	2.4070	0.0210	0.0130	4.3	4.79
80	800	0.0057	0.0211	2.6581	0.6552	0.0119	2.4279	0.0210	0.0130	4.3	4.68
81	810	0.0057	0.0211	2.6792	0.6672	0.0120	2.4489	0.0210	0.0131	4.4	4.60
82	820	0.0057	0.0211	2.7003	0.6792	0.0120	2.4699	0.0210	0.0132	4.4	4.54
83	830	0.0057	0.0211	2.7214	0.6913	0.0121	2.4909	0.0210	0.0132	4.4	4.50
84	840	0.0057	0.0211	2.7424	0.7035	0.0122	2.5119	0.0210	0.0133	4.4	4.48
85	850	0.0057	0.0211	2.7635	0.7157	0.0122	2.5329	0.0210	0.0133	4.4	4.47
86	860	0.0057	0.0211	2.7846	0.7281	0.0123	2.5539	0.0210	0.0134	4.5	4.46
87	870	0.0057	0.0211	2.8057	0.7404	0.0124	2.5748	0.0210	0.0135	4.5	4.47
88	880	0.0057	0.0211	2.8268	0.7529	0.0124	2.5958	0.0210	0.0135	4.5	4.47
89	890	0.0050	0.0185	2.8453	0.7638	0.0110	2.6142	0.0184	0.0119	4.0	4.41
90	900	0.0050	0.0185	2.8638	0.7748	0.0110	2.6327	0.0184	0.0119	4.0	4.30
91	910	0.0050	0.0185	2.8823	0.7859	0.0111	2.6511	0.0184	0.0120	4.0	4.22
92	920	0.0050	0.0185	2.9008	0.7970	0.0111	2.6695	0.0184	0.0120	4.0	4.16
93	930	0.0050	0.0185	2.9193	0.8082	0.0112	2.6879	0.0184	0.0121	4.0	4.12
94	940	0.0050	0.0185	2.9378	0.8194	0.0112	2.7063	0.0184	0.0121	4.0	4.10
95	950	0.0050	0.0185	2.9563	0.8306	0.0112	2.7248	0.0184	0.0121	4.0	4.08
96	960	0.0050	0.0185	2.9748	0.8419	0.0113	2.7432	0.0184	0.0122	4.1	4.08
97	970	0.0050	0.0185	2.9933	0.8532	0.0113	2.7616	0.0184	0.0122	4.1	4.07
98	980	0.0050	0.0185	3.0118	0.8646	0.0114	2.7800	0.0184	0.0123	4.1	4.07
99	990	0.0050	0.0185	3.0303	0.8760	0.0114	2.7984	0.0184	0.0123	4.1	4.08
100	1000	0.0050	0.0185	3.0488	0.8875	0.0115	2.8169	0.0184	0.0123	4.1	4.08
101	1010	0.0040	0.0148	3.0636	0.8967	0.0092	2.8316	0.0147	0.0099	3.3	3.99
102	1020	0.0040	0.0148	3.0784	0.9059	0.0092	2.8464	0.0147	0.0099	3.3	3.81
103	1030	0.0040	0.0148	3.0932	0.9152	0.0093	2.8611	0.0147	0.0099	3.3	3.68
104	1040	0.0040	0.0148	3.1080	0.9245	0.0093	2.8758	0.0147	0.0100	3.3	3.59
105	1050	0.0040	0.0148	3.1228	0.9338	0.0093	2.8906	0.0147	0.0100	3.3	3.52
106	1060	0.0040	0.0148	3.1376	0.9431	0.0093	2.9053	0.0147	0.0100	3.3	3.47
107	1070	0.0040	0.0148	3.1524	0.9525	0.0094	2.9201	0.0147	0.0100	3.3	3.44
108	1080	0.0040	0.0148	3.1672	0.9619	0.0094	2.9348	0.0147	0.0101	3.4	3.42
109	1090	0.0040	0.0148	3.1820	0.9713	0.0094	2.9496	0.0147	0.0101	3.4	3.40
110	1100	0.0040	0.0148	3.1968	0.9808	0.0094	2.9643	0.0147	0.0101	3.4	3.39
111	1110	0.0040	0.0148	3.2116	0.9902	0.0095	2.9790	0.0147	0.0101	3.4	3.39
112	1120	0.0040	0.0148	3.2264	0.9997	0.0095	2.9938	0.0147	0.0102	3.4	3.38
113	1130	0.0040	0.0148	3.2412	1.0092	0.0095	3.0085	0.0147	0.0102	3.4	3.38
114	1140	0.0040	0.0148	3.2560	1.0188	0.0095	3.0233	0.0147	0.0102	3.4	3.39
115	1150	0.0040	0.0148	3.2708	1.0284	0.0096	3.0380	0.0147	0.0102	3.4	3.39
116	1160	0.0040	0.0148	3.2856	1.0379	0.0096	3.0528	0.0147	0.0102	3.4	3.39
117	1170	0.0040	0.0148	3.3004	1.0476	0.0096	3.0675	0.0147	0.0103	3.4	3.40
118	1180	0.0040	0.0148	3.3152	1.0572	0.0096	3.0823	0.0147	0.0103	3.4	3.40
119	1190	0.0040	0.0148	3.3300	1.0669	0.0097	3.0970	0.0147	0.0103	3.4	3.41
120	1200	0.0040	0.0148	3.3448	1.0766	0.0097	3.1118	0.0147	0.0103	3.4	3.42
121	1210	0.0040	0.0148	3.3596	1.0863	0.0097	3.1265	0.0148	0.0103	3.4	3.42
122	1220	0.0040	0.0148	3.3744	1.0960	0.0097	3.1413	0.0148	0.0104	3.5	3.43
123	1230	0.0040	0.0148	3.3892	1.1058	0.0098	3.1560	0.0148	0.0104	3.5	3.44
124	1240	0.0040	0.0148	3.4040	1.1156	0.0098	3.1708	0.0148	0.0104	3.5	3.44
125	1250	0.0040	0.0148	3.4188	1.1254	0.0098	3.1855	0.0148	0.0104	3.5	3.45
126	1260	0.0040	0.0148	3.4336	1.1352	0.0098	3.2003	0.0148	0.0105	3.5	3.46
127	1270	0.0040	0.0148	3.4484	1.1451	0.0099	3.2150	0.0148	0.0105	3.5	3.46
128	1280	0.0040	0.0148	3.4632	1.1550	0.0099	3.2298	0.0148	0.0105	3.5	3.47
129	1290	0.0040	0.0148	3.4780	1.1649	0.0099	3.2445	0.0148	0.0105	3.5	3.48
130	1300	0.0040	0.0148	3.4928	1.1748	0.0099	3.2593	0.0148	0.0105	3.5	3.48
131	1310	0.0040	0.0148	3.5076	1.1847	0.0099	3.2740	0.0148	0.0106	3.5	3.49
132	1320	0.0040	0.0148	3.5224	1.1947	0.0100	3.2888	0.0148	0.0106	3.5	3.50
133	1330	0.0040	0.0148	3.5372	1.2047	0.0100	3.3036	0.0148	0.0106	3.5	3.50
134	1340	0.0040	0.0148	3.5520	1.2147	0.0100	3.3183	0.0148	0.0106	3.5	3.51
135	1350	0.0040	0.0148	3.5668	1.2247	0.0100	3.3331	0.0148	0.0106	3.5	3.52
136	1360	0.0040	0.0148	3.5816	1.2348	0.0101	3.3478	0.0148	0.0106	3.5	3.52
137	1370	0.0040	0.0148	3.5964	1.2449	0.0101	3.3626	0.0148	0.0107	3.6	3.53
138	1380	0.0040	0.0148	3.6112	1.2550	0.0101	3.3773	0.0148	0.0107	3.6	3.54
139	1390	0.0040	0.0148	3.6260	1.2651	0.0101	3.3921	0.0148	0.0107	3.6	3.54
140	1400	0.0040	0.0148	3.6408	1.2752	0.0101	3.4069	0.0148	0.0107	3.6	3.55
141	1410	0.0040	0.0148	3.6556	1.2854	0.0102	3.4216	0.0148	0.0107	3.6	3.55
142	1420	0.0040	0.0148	3.6704	1.2956	0.0102	3.4364	0.0148	0.0108	3.6	3.56
143	1430	0.0040	0.0148	3.6852	1.3058	0.0102	3.4511	0.0148	0.0108	3.6	3.57
144	1440	0.0040	0.0148	3.7000	1.3160	0.0102	3.4659	0.0148	0.0108	3.6	3.57

Total Volume of Runoff[1] = 309,478 cu. ft.

Notes:

1. Total Runoff Volume is found by summing column (12) and multiplying by the time step, dt as follows:

   V = SumQ x dt
   V(cu.ft.) = SumQ(cu.ft/s) x dt(min.) x (60 s/min.)

Future Det Pond, 25 yr flow, PVC, S=5%

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Diameter

Input Data

Roughness Coefficient	0.010	
Channel Slope	0.05000	ft/ft
Normal Depth	1.38	ft
Diameter	1.38	ft
Discharge	24.64	ft^3/s

Results

Diameter	1.38	ft
Normal Depth	1.38	ft
Flow Area	1.50	ft^2
Wetted Perimeter	4.35	ft
Hydraulic Radius	0.35	ft
Top Width	0.00	ft
Critical Depth	1.38	ft
Percent Full	100.0	%
Critical Slope	0.04733	ft/ft
Velocity	16.38	ft/s
Velocity Head	4.17	ft
Specific Energy	5.55	ft
Froude Number	0.00	
Maximum Discharge	26.50	ft^3/s
Discharge Full	24.64	ft^3/s
Slope Full	0.05002	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%

Future Det Pond, 25 yr flow, PVC, S=5%

GVF Output Data

Normal Depth Over Rise	100.00	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.38	ft
Critical Depth	1.38	ft
Channel Slope	0.05000	ft/ft
Critical Slope	0.04733	ft/ft

Future Det Pond, 100 yr flow, PVC, S=5%

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Diameter

Input Data

Roughness Coefficient	0.010	
Channel Slope	0.05000	ft/ft
Normal Depth	1.52	ft
Diameter	1.52	ft
Discharge	31.61	ft^3/s

Results

Diameter	1.52	ft
Normal Depth	1.52	ft
Flow Area	1.81	ft^2
Wetted Perimeter	4.77	ft
Hydraulic Radius	0.38	ft
Top Width	0.00	ft
Critical Depth	1.51	ft
Percent Full	100.0	%
Critical Slope	0.04739	ft/ft
Velocity	17.43	ft/s
Velocity Head	4.72	ft
Specific Energy	6.24	ft
Froude Number	0.00	
Maximum Discharge	34.00	ft^3/s
Discharge Full	31.61	ft^3/s
Slope Full	0.05000	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%

Future Det Pond, 100 yr flow, PVC, S=5%

GVF Output Data

Normal Depth Over Rise	100.00	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.52	ft
Critical Depth	1.51	ft
Channel Slope	0.05000	ft/ft
Critical Slope	0.04739	ft/ft

City of Snohomish
Stormwater Comprehensive Plan
Time of Concentration
Blackmans - Future-Det Pond

Calculate Time of Concentration (Tc)

Tc = Sum(Tt)

Where:

Tt = travel time (min) = $\frac{L}{(60xV)}$ (for shallow concentrated flow or channel flow)

Tt = travel time (min)= $\frac{0.42(n_s L)^{0.8}}{(P_2)^{0.5}(s_o)^{0.4}}$ (for sheet flow)

Where:

V = avg. velocity (ft/s) = $V = k(s_o)^{0.5}$

k = time of concentration velocity factor (ft/s)

L = flow length (ft)

n_s = sheet flow Manning's effective roughness coefficient

P_2 = 2-year, 24-hour rainfall (in)

s_o = slope of hydraulic grade line (land slope, ft/ft)

	L (ft)	$k_{s/c}$	V (fps)	n_s	P_2	s_o (ft/ft)	Tt (min)
a - sheet	100	NA	NA	0.24	1.8	0.030	16.2
b - channel	2600	42	5.9	NA	NA	0.02	7.3
Total (Tc)							23.5

Minimum Allowable Tc = 6.0 minutes

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

Project: City of Snohomish - Stormwater Comp Plan
Basin: Detention Pond Upstream of Blackmans Lake - Future
Storm Event: 25-YEAR, 24-HOUR
Given:

Area = 55.04 acres
Pt = 3.05 inches
dt = 10 min.
Tc = 23.5 min.

PERVIOUS AREA			IMPERVIOUS AREA (Roads)		
Area	=	28.58 acres	Area	=	26.47 acres
CN	=	86	CN	=	98
S	=	1.63	S	=	0.20
0.2S	=	0.33	0.2S	=	0.04

SUMMARY	
T_{pk}(hrs)=	7.83
T_c (min)=	23.5
Q_{pk}(cfs)=	24.64
Vol(cf)=	442,327

Compute: Runoff Hydrograph

Column (3) = SCS Type IA Rainfall Distribution
Column (4) = Col. (3) x Pt
Column (5) = Accumulated Sum of Col. (4)
Column (6) = [If P <= 0.2S] = 0; Note, use PERVIOUS Area "S" value.
[If P > 0.2S] = (Col.(5) - 0.2S)^2/(Col.(5) + 0.8S); Using the PERVIOUS Area "S" value.
Column (7) = Col.(6) of Present Time Step - Col.(6) of Previous Time Step
Column (8) = Same method as for Col.(6), except use the IMPERVIOUS Area "S" value.
Column (9) = Col.(8) of the present time step - Col.(8) of the previous time step.
Column (10) = ((PERVIOUS area / Total area) x Col.(7)) + ((IMPERVIOUS area / Total area) x Col.(9))
Column (11) = (60.5 x Col.(10) x Total Area) / 10 (dt = 10 minutes)
Routing Constant, w = dt / (2Tc + dt) = 0.1754
Column (12) = Col.(12) of Previous Time Step + (w x [Col.(11) of Previous Time Step
+ Col.(11) of Present Time Step - (2 x Col.(12) of Previous Time Step)])

					Pervious Area		Impervious Area					
(1) Time Increment	(2) Time	(3) Rainfall distri-bution	(4) Incre-mental Rainfall	(5) Accumu-lated Rainfall	(6) Accumu-lated Runoff	(7) Incre-mental Runoff	(8) Accumu-lated Runoff	(9) Incre-mental Runoff	(10) Total Runoff	(11) Instant hydro-graph	(12) design hydro-graph	
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs	
1	10	0.0040	0.0122	0.0122	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
2	20	0.0040	0.0122	0.0244	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
3	30	0.0040	0.0122	0.0366	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
4	40	0.0040	0.0122	0.0488	0.0000	0.0000	0.0003	0.0003	0.0001	0.0	0.01	
5	50	0.0040	0.0122	0.0610	0.0000	0.0000	0.0018	0.0015	0.0007	0.2	0.06	
6	60	0.0040	0.0122	0.0732	0.0000	0.0000	0.0044	0.0026	0.0013	0.4	0.15	
7	70	0.0040	0.0122	0.0854	0.0000	0.0000	0.0080	0.0036	0.0017	0.6	0.27	
8	80	0.0040	0.0122	0.0976	0.0000	0.0000	0.0124	0.0044	0.0021	0.7	0.40	
9	90	0.0040	0.0122	0.1098	0.0000	0.0000	0.0174	0.0051	0.0024	0.8	0.52	
10	100	0.0040	0.0122	0.1220	0.0000	0.0000	0.0231	0.0057	0.0027	0.9	0.64	
11	110	0.0050	0.0153	0.1373	0.0000	0.0000	0.0309	0.0078	0.0038	1.3	0.80	
12	120	0.0050	0.0153	0.1525	0.0000	0.0000	0.0395	0.0086	0.0041	1.4	0.98	
13	130	0.0050	0.0153	0.1678	0.0000	0.0000	0.0487	0.0092	0.0044	1.5	1.13	
14	140	0.0050	0.0153	0.1830	0.0000	0.0000	0.0584	0.0097	0.0047	1.6	1.27	
15	150	0.0050	0.0153	0.1983	0.0000	0.0000	0.0686	0.0102	0.0049	1.6	1.38	
16	160	0.0050	0.0153	0.2135	0.0000	0.0000	0.0791	0.0106	0.0051	1.7	1.48	
17	170	0.0060	0.0183	0.2318	0.0000	0.0000	0.0923	0.0132	0.0063	2.1	1.63	
18	180	0.0060	0.0183	0.2501	0.0000	0.0000	0.1060	0.0136	0.0066	2.2	1.81	
19	190	0.0060	0.0183	0.2684	0.0000	0.0000	0.1200	0.0140	0.0067	2.2	1.95	
20	200	0.0060	0.0183	0.2867	0.0000	0.0000	0.1344	0.0144	0.0069	2.3	2.06	
21	210	0.0060	0.0183	0.3050	0.0000	0.0000	0.1490	0.0147	0.0071	2.4	2.16	
22	220	0.0060	0.0183	0.3233	0.0000	0.0000	0.1640	0.0150	0.0072	2.4	2.23	
23	230	0.0070	0.0214	0.3447	0.0002	0.0002	0.1818	0.0178	0.0087	2.9	2.37	
24	240	0.0070	0.0214	0.3660	0.0010	0.0008	0.1998	0.0180	0.0091	3.0	2.58	
25	250	0.0070	0.0214	0.3874	0.0023	0.0013	0.2181	0.0183	0.0095	3.2	2.76	
26	260	0.0070	0.0214	0.4087	0.0040	0.0018	0.2366	0.0185	0.0098	3.3	2.92	
27	270	0.0070	0.0214	0.4301	0.0063	0.0023	0.2553	0.0187	0.0102	3.4	3.06	
28	280	0.0070	0.0214	0.4514	0.0090	0.0027	0.2743	0.0189	0.0105	3.5	3.20	
29	290	0.0082	0.0250	0.4764	0.0128	0.0038	0.2966	0.0224	0.0127	4.2	3.43	
30	300	0.0082	0.0250	0.5014	0.0171	0.0044	0.3192	0.0226	0.0131	4.4	3.73	
31	310	0.0082	0.0250	0.5264	0.0221	0.0049	0.3419	0.0227	0.0135	4.5	3.98	
32	320	0.0082	0.0250	0.5514	0.0275	0.0055	0.3648	0.0229	0.0138	4.6	4.18	
33	330	0.0082	0.0250	0.5765	0.0335	0.0060	0.3879	0.0230	0.0142	4.7	4.35	
34	340	0.0082	0.0250	0.6015	0.0400	0.0065	0.4110	0.0232	0.0145	4.8	4.50	
35	350	0.0095	0.0290	0.6304	0.0481	0.0081	0.4380	0.0270	0.0172	5.7	4.77	
36	360	0.0095	0.0290	0.6594	0.0568	0.0087	0.4651	0.0271	0.0176	5.9	5.13	
37	370	0.0095	0.0290	0.6884	0.0661	0.0093	0.4924	0.0273	0.0179	6.0	5.40	
38	380	0.0095	0.0290	0.7174	0.0760	0.0099	0.5198	0.0274	0.0183	6.1	5.62	
39	390	0.0095	0.0290	0.7463	0.0864	0.0104	0.5472	0.0275	0.0186	6.2	5.81	
40	400	0.0095	0.0290	0.7753	0.0973	0.0109	0.5748	0.0276	0.0189	6.3	5.96	
41	410	0.0134	0.0409	0.8162	0.1136	0.0163	0.6138	0.0390	0.0272	9.1	6.57	
42	420	0.0134	0.0409	0.8570	0.1308	0.0172	0.6530	0.0392	0.0278	9.2	7.47	
43	430	0.0134	0.0409	0.8979	0.1489	0.0181	0.6923	0.0393	0.0283	9.4	8.12	
44	440	0.0180	0.0549	0.9528	0.1745	0.0256	0.7452	0.0530	0.0387	12.9	9.19	
45	450	0.0180	0.0549	1.0077	0.2014	0.0270	0.7984	0.0532	0.0396	13.2	10.54	
46	460	0.0340	0.1037	1.1114	0.2558	0.0544	0.8992	0.1008	0.0767	25.5	13.63	
47	470	0.0540	0.1647	1.2761	0.3504	0.0946	1.0602	0.1610	0.1265	42.1	20.72	
48	480	0.0270	0.0824	1.3585	0.4010	0.0505	1.1409	0.0808	0.0651	21.7	24.64	Q peak
49	490	0.0180	0.0549	1.4134	0.4357	0.0348	1.1949	0.0539	0.0440	14.6	22.37	
50	500	0.0134	0.0409	1.4542	0.4621	0.0264	1.2351	0.0402	0.0330	11.0	19.02	
51	510	0.0134	0.0409	1.4951	0.4889	0.0268	1.2753	0.0402	0.0333	11.1	16.22	
52	520	0.0134	0.0409	1.5360	0.5162	0.0272	1.3156	0.0403	0.0335	11.2	14.43	
53	530	0.0088	0.0268	1.5628	0.5343	0.0181	1.3421	0.0265	0.0221	7.4	12.62	
54	540	0.0088	0.0268	1.5897	0.5525	0.0183	1.3685	0.0265	0.0222	7.4	10.78	
55	550	0.0088	0.0268	1.6165	0.5709	0.0184	1.3950	0.0265	0.0223	7.4	9.60	
56	560	0.0088	0.0268	1.6433	0.5895	0.0186	1.4215	0.0265	0.0224	7.5	8.84	
57	570	0.0088	0.0268	1.6702	0.6082	0.0187	1.4480	0.0265	0.0225	7.5	8.36	
58	580	0.0088	0.0268	1.6970	0.6271	0.0189	1.4745	0.0265	0.0225	7.5	8.05	
59	590	0.0088	0.0268	1.7239	0.6461	0.0190	1.5010	0.0265	0.0226	7.5	7.87	
60	600	0.0088	0.0268	1.7507	0.6652	0.0191	1.5276	0.0265	0.0227	7.6	7.75	
61	610	0.0088	0.0268	1.7775	0.6845	0.0193	1.5541	0.0265	0.0228	7.6	7.69	
62	620	0.0088	0.0268	1.8044	0.7039	0.0194	1.5806	0.0265	0.0228	7.6	7.66	
63	630	0.0088	0.0268	1.8312	0.7234	0.0195	1.6072	0.0266	0.0229	7.6	7.64	
64	640	0.0088	0.0268	1.8581	0.7431	0.0197	1.6338	0.0266	0.0230	7.7	7.64	
65	650	0.0072	0.0220	1.8800	0.7593	0.0162	1.6555	0.0217	0.0188	6.3	7.40	

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

(1) Time Increment	(2) Time	(3) Rainfall distri- bution	(4) Incre- mental Rainfall	(5) Accumu- lated Rainfall	Pervious Area (6) Accumu- lated Runoff	(7) Incre- mental Runoff	Impervious Area (8) Accumu- lated Runoff	(9) Incre- mental Runoff	(10) Total Runoff	(11) Instant hydro- graph	(12) design hydro- graph
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs
66	660	0.0072	0.0220	1.9020	0.7755	0.0163	1.6772	0.0217	0.0189	6.3	7.01
67	670	0.0072	0.0220	1.9239	0.7919	0.0163	1.6990	0.0217	0.0189	6.3	6.76
68	680	0.0072	0.0220	1.9459	0.8083	0.0164	1.7207	0.0218	0.0190	6.3	6.60
69	690	0.0072	0.0220	1.9679	0.8247	0.0165	1.7425	0.0218	0.0190	6.3	6.51
70	700	0.0072	0.0220	1.9898	0.8413	0.0166	1.7643	0.0218	0.0191	6.3	6.45
71	710	0.0072	0.0220	2.0118	0.8579	0.0166	1.7860	0.0218	0.0191	6.4	6.41
72	720	0.0072	0.0220	2.0337	0.8746	0.0167	1.8078	0.0218	0.0191	6.4	6.40
73	730	0.0072	0.0220	2.0557	0.8914	0.0168	1.8296	0.0218	0.0192	6.4	6.39
74	740	0.0072	0.0220	2.0777	0.9082	0.0168	1.8513	0.0218	0.0192	6.4	6.39
75	750	0.0072	0.0220	2.0996	0.9251	0.0169	1.8731	0.0218	0.0192	6.4	6.39
76	760	0.0072	0.0220	2.1216	0.9421	0.0170	1.8949	0.0218	0.0193	6.4	6.40
77	770	0.0057	0.0174	2.1390	0.9556	0.0135	1.9122	0.0172	0.0153	5.1	6.18
78	780	0.0057	0.0174	2.1564	0.9691	0.0135	1.9294	0.0172	0.0153	5.1	5.80
79	790	0.0057	0.0174	2.1737	0.9826	0.0136	1.9467	0.0173	0.0153	5.1	5.55
80	800	0.0057	0.0174	2.1911	0.9962	0.0136	1.9639	0.0173	0.0154	5.1	5.40
81	810	0.0057	0.0174	2.2085	1.0098	0.0136	1.9812	0.0173	0.0154	5.1	5.30
82	820	0.0057	0.0174	2.2259	1.0235	0.0137	1.9984	0.0173	0.0154	5.1	5.24
83	830	0.0057	0.0174	2.2433	1.0372	0.0137	2.0157	0.0173	0.0154	5.1	5.20
84	840	0.0057	0.0174	2.2607	1.0510	0.0137	2.0329	0.0173	0.0154	5.1	5.18
85	850	0.0057	0.0174	2.2780	1.0647	0.0138	2.0502	0.0173	0.0155	5.1	5.16
86	860	0.0057	0.0174	2.2954	1.0785	0.0138	2.0675	0.0173	0.0155	5.2	5.16
87	870	0.0057	0.0174	2.3128	1.0924	0.0138	2.0847	0.0173	0.0155	5.2	5.16
88	880	0.0057	0.0174	2.3302	1.1063	0.0139	2.1020	0.0173	0.0155	5.2	5.16
89	890	0.0050	0.0153	2.3455	1.1185	0.0122	2.1172	0.0151	0.0136	4.5	5.05
90	900	0.0050	0.0153	2.3607	1.1307	0.0122	2.1323	0.0151	0.0136	4.5	4.87
91	910	0.0050	0.0153	2.3760	1.1429	0.0123	2.1475	0.0152	0.0136	4.5	4.75
92	920	0.0050	0.0153	2.3912	1.1552	0.0123	2.1626	0.0152	0.0137	4.5	4.68
93	930	0.0050	0.0153	2.4065	1.1675	0.0123	2.1778	0.0152	0.0137	4.6	4.64
94	940	0.0050	0.0153	2.4217	1.1798	0.0123	2.1929	0.0152	0.0137	4.6	4.61
95	950	0.0050	0.0153	2.4370	1.1922	0.0123	2.2081	0.0152	0.0137	4.6	4.59
96	960	0.0050	0.0153	2.4522	1.2045	0.0124	2.2232	0.0152	0.0137	4.6	4.58
97	970	0.0050	0.0153	2.4675	1.2169	0.0124	2.2384	0.0152	0.0137	4.6	4.58
98	980	0.0050	0.0153	2.4827	1.2294	0.0124	2.2535	0.0152	0.0137	4.6	4.57
99	990	0.0050	0.0153	2.4980	1.2418	0.0124	2.2687	0.0152	0.0137	4.6	4.58
100	1000	0.0050	0.0153	2.5132	1.2543	0.0125	2.2839	0.0152	0.0138	4.6	4.58
101	1010	0.0040	0.0122	2.5254	1.2642	0.0100	2.2960	0.0121	0.0110	3.7	4.42
102	1020	0.0040	0.0122	2.5376	1.2743	0.0100	2.3081	0.0121	0.0110	3.7	4.16
103	1030	0.0040	0.0122	2.5498	1.2843	0.0100	2.3203	0.0121	0.0110	3.7	3.99
104	1040	0.0040	0.0122	2.5620	1.2943	0.0100	2.3324	0.0121	0.0110	3.7	3.88
105	1050	0.0040	0.0122	2.5742	1.3043	0.0100	2.3445	0.0121	0.0110	3.7	3.81
106	1060	0.0040	0.0122	2.5864	1.3144	0.0101	2.3566	0.0121	0.0111	3.7	3.76
107	1070	0.0040	0.0122	2.5986	1.3245	0.0101	2.3688	0.0121	0.0111	3.7	3.73
108	1080	0.0040	0.0122	2.6108	1.3345	0.0101	2.3809	0.0121	0.0111	3.7	3.72
109	1090	0.0040	0.0122	2.6230	1.3446	0.0101	2.3931	0.0121	0.0111	3.7	3.71
110	1100	0.0040	0.0122	2.6352	1.3547	0.0101	2.4052	0.0121	0.0111	3.7	3.70
111	1110	0.0040	0.0122	2.6474	1.3649	0.0101	2.4173	0.0121	0.0111	3.7	3.70
112	1120	0.0040	0.0122	2.6596	1.3750	0.0101	2.4295	0.0121	0.0111	3.7	3.70
113	1130	0.0040	0.0122	2.6718	1.3851	0.0101	2.4416	0.0121	0.0111	3.7	3.70
114	1140	0.0040	0.0122	2.6840	1.3953	0.0102	2.4537	0.0121	0.0111	3.7	3.70
115	1150	0.0040	0.0122	2.6962	1.4055	0.0102	2.4659	0.0121	0.0111	3.7	3.70
116	1160	0.0040	0.0122	2.7084	1.4157	0.0102	2.4780	0.0121	0.0111	3.7	3.70
117	1170	0.0040	0.0122	2.7206	1.4259	0.0102	2.4901	0.0121	0.0111	3.7	3.70
118	1180	0.0040	0.0122	2.7328	1.4361	0.0102	2.5023	0.0121	0.0111	3.7	3.70
119	1190	0.0040	0.0122	2.7450	1.4463	0.0102	2.5144	0.0121	0.0111	3.7	3.71
120	1200	0.0040	0.0122	2.7572	1.4565	0.0102	2.5266	0.0121	0.0111	3.7	3.71
121	1210	0.0040	0.0122	2.7694	1.4668	0.0102	2.5387	0.0121	0.0112	3.7	3.71
122	1220	0.0040	0.0122	2.7816	1.4770	0.0103	2.5508	0.0121	0.0112	3.7	3.71
123	1230	0.0040	0.0122	2.7938	1.4873	0.0103	2.5630	0.0121	0.0112	3.7	3.71
124	1240	0.0040	0.0122	2.8060	1.4976	0.0103	2.5751	0.0121	0.0112	3.7	3.72
125	1250	0.0040	0.0122	2.8182	1.5079	0.0103	2.5873	0.0121	0.0112	3.7	3.72
126	1260	0.0040	0.0122	2.8304	1.5182	0.0103	2.5994	0.0121	0.0112	3.7	3.72
127	1270	0.0040	0.0122	2.8426	1.5285	0.0103	2.6116	0.0121	0.0112	3.7	3.72
128	1280	0.0040	0.0122	2.8548	1.5388	0.0103	2.6237	0.0121	0.0112	3.7	3.72
129	1290	0.0040	0.0122	2.8670	1.5491	0.0103	2.6358	0.0121	0.0112	3.7	3.73
130	1300	0.0040	0.0122	2.8792	1.5595	0.0103	2.6480	0.0121	0.0112	3.7	3.73
131	1310	0.0040	0.0122	2.8914	1.5698	0.0104	2.6601	0.0121	0.0112	3.7	3.73
132	1320	0.0040	0.0122	2.9036	1.5802	0.0104	2.6723	0.0121	0.0112	3.7	3.73
133	1330	0.0040	0.0122	2.9158	1.5906	0.0104	2.6844	0.0121	0.0112	3.7	3.73
134	1340	0.0040	0.0122	2.9280	1.6010	0.0104	2.6966	0.0121	0.0112	3.7	3.74
135	1350	0.0040	0.0122	2.9402	1.6114	0.0104	2.7087	0.0121	0.0112	3.7	3.74
136	1360	0.0040	0.0122	2.9524	1.6218	0.0104	2.7209	0.0121	0.0112	3.7	3.74
137	1370	0.0040	0.0122	2.9646	1.6322	0.0104	2.7330	0.0121	0.0113	3.7	3.74
138	1380	0.0040	0.0122	2.9768	1.6426	0.0104	2.7452	0.0121	0.0113	3.7	3.74
139	1390	0.0040	0.0122	2.9890	1.6531	0.0104	2.7573	0.0121	0.0113	3.7	3.75
140	1400	0.0040	0.0122	3.0012	1.6635	0.0104	2.7695	0.0121	0.0113	3.8	3.75
141	1410	0.0040	0.0122	3.0134	1.6740	0.0105	2.7816	0.0121	0.0113	3.8	3.75
142	1420	0.0040	0.0122	3.0256	1.6844	0.0105	2.7938	0.0121	0.0113	3.8	3.75
143	1430	0.0040	0.0122	3.0378	1.6949	0.0105	2.8059	0.0122	0.0113	3.8	3.75
144	1440	0.0040	0.0122	3.0500	1.7054	0.0105	2.8181	0.0122	0.0113	3.8	3.75

Total Volume of Runoff[1] = 442,327 cu. ft.

Notes:

1. Total Runoff Volume is found by summing column (12) and multiplying by the time step, dt as follows:

   V = SumQ x dt
   V(cu.ft.) = SumQ(cu.ft/s) x dt(min.) x (60 s/min.)

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

Project: City of Snohomish - Stormwater Comp Plan
Basin: Detention Pond Upstream of Blackmans Lake - Future
Storm Event: 100-YEAR, 24-HOUR
Given:

Area = 55.04 acres
Pt = 3.70 inches
dt = 10 min.
Tc = 23.5 min.

PERVIOUS AREA			IMPERVIOUS AREA (Roads)		
Area	=	28.58 acres	Area	=	26.47 acres
CN	=	86	CN	=	98
S	=	1.63	S	=	0.20
0.2S	=	0.33	0.2S	=	0.04

SUMMARY	
T_{pk}(hrs)=	7.83
T_c (min)=	23.5
Q_{pk}(cfs)=	31.61
Vol(cf)=	562,521

Compute: Runoff Hydrograph

Column (3) = SCS Type IA Rainfall Distribution
Column (4) = Col. (3) x Pt
Column (5) = Accumulated Sum of Col. (4)
Column (6) = [If P <= 0.2S] = 0; Note, use PERVIOUS Area "S" value.
[If P > 0.2S] = (Col.(5) - 0.2S)^2/(Col.(5) + 0.8S); Using the PERVIOUS Area "S" value.
Column (7) = Col.(6) of Present Time Step - Col.(6) of Previous Time Step
Column (8) = Same method as for Col.(6), except use the IMPERVIOUS Area "S" value.
Column (9) = Col.(8) of the present time step - Col.(8) of the previous time step.
Column (10) = ((PERVIOUS area / Total area) x Col.(7)) + ((IMPERVIOUS area / Total area) x Col.(9))
Column (11) = (60.5 x Col.(10) x Total Area) / 10 (dt = 10 minutes)
Routing Constant, w = dt / (2Tc + dt) = 0.1754
Column (12) = Col.(12) of Previous Time Step + (w x [Col.(11) of Previous Time Step
+ Col.(11) of Present Time Step - (2 x Col.(12) of Previous Time Step)])

					Pervious Area		Impervious Area					
(1) Time Increment	(2) Time	(3) Rainfall distri-bution	(4) Incre-mental Rainfall	(5) Accumu-lated Rainfall	(6) Accumu-lated Runoff	(7) Incre-mental Runoff	(8) Accumu-lated Runoff	(9) Incre-mental Runoff	(10) Total Runoff	(11) Instant hydro-graph	(12) design hydro-graph	
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs	
1	10	0.0040	0.0148	0.0148	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
2	20	0.0040	0.0148	0.0296	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
3	30	0.0040	0.0148	0.0444	0.0000	0.0000	0.0001	0.0001	0.0000	0.0	0.00	
4	40	0.0040	0.0148	0.0592	0.0000	0.0000	0.0015	0.0015	0.0007	0.2	0.04	
5	50	0.0040	0.0148	0.0740	0.0000	0.0000	0.0046	0.0031	0.0015	0.5	0.16	
6	60	0.0040	0.0148	0.0888	0.0000	0.0000	0.0091	0.0045	0.0022	0.7	0.32	
7	70	0.0040	0.0148	0.1036	0.0000	0.0000	0.0148	0.0056	0.0027	0.9	0.49	
8	80	0.0040	0.0148	0.1184	0.0000	0.0000	0.0214	0.0066	0.0032	1.1	0.66	
9	90	0.0040	0.0148	0.1332	0.0000	0.0000	0.0288	0.0074	0.0036	1.2	0.82	
10	100	0.0040	0.0148	0.1480	0.0000	0.0000	0.0369	0.0081	0.0039	1.3	0.97	
11	110	0.0050	0.0185	0.1665	0.0000	0.0000	0.0479	0.0110	0.0053	1.8	1.17	
12	120	0.0050	0.0185	0.1850	0.0000	0.0000	0.0597	0.0118	0.0057	1.9	1.40	
13	130	0.0050	0.0185	0.2035	0.0000	0.0000	0.0722	0.0125	0.0060	2.0	1.59	
14	140	0.0050	0.0185	0.2220	0.0000	0.0000	0.0852	0.0130	0.0063	2.1	1.75	
15	150	0.0050	0.0185	0.2405	0.0000	0.0000	0.0988	0.0135	0.0065	2.2	1.88	
16	160	0.0050	0.0185	0.2590	0.0000	0.0000	0.1127	0.0140	0.0067	2.2	1.99	
17	170	0.0060	0.0222	0.2812	0.0000	0.0000	0.1300	0.0173	0.0083	2.8	2.17	
18	180	0.0060	0.0222	0.3034	0.0000	0.0000	0.1478	0.0177	0.0085	2.8	2.39	
19	190	0.0060	0.0222	0.3256	0.0000	0.0000	0.1659	0.0181	0.0087	2.9	2.56	
20	200	0.0060	0.0222	0.3478	0.0003	0.0003	0.1844	0.0185	0.0091	3.0	2.70	
21	210	0.0060	0.0222	0.3700	0.0012	0.0009	0.2032	0.0188	0.0095	3.2	2.84	
22	220	0.0060	0.0222	0.3922	0.0026	0.0014	0.2223	0.0191	0.0099	3.3	2.98	
23	230	0.0070	0.0259	0.4181	0.0050	0.0024	0.2448	0.0226	0.0121	4.0	3.22	
24	240	0.0070	0.0259	0.4440	0.0080	0.0031	0.2677	0.0228	0.0126	4.2	3.53	
25	250	0.0070	0.0259	0.4699	0.0118	0.0037	0.2908	0.0231	0.0130	4.3	3.79	
26	260	0.0070	0.0259	0.4958	0.0161	0.0044	0.3141	0.0233	0.0135	4.5	4.01	
27	270	0.0070	0.0259	0.5217	0.0211	0.0050	0.3376	0.0235	0.0139	4.6	4.20	
28	280	0.0070	0.0259	0.5476	0.0266	0.0056	0.3613	0.0237	0.0143	4.8	4.37	
29	290	0.0082	0.0303	0.5779	0.0339	0.0072	0.3892	0.0279	0.0172	5.7	4.68	
30	300	0.0082	0.0303	0.6083	0.0418	0.0080	0.4174	0.0281	0.0177	5.9	5.07	
31	310	0.0082	0.0303	0.6386	0.0505	0.0087	0.4457	0.0283	0.0181	6.0	5.38	
32	320	0.0082	0.0303	0.6690	0.0598	0.0093	0.4741	0.0284	0.0185	6.2	5.63	
33	330	0.0082	0.0303	0.6993	0.0698	0.0100	0.5027	0.0286	0.0189	6.3	5.84	
34	340	0.0082	0.0303	0.7296	0.0803	0.0106	0.5314	0.0287	0.0193	6.4	6.02	
35	350	0.0095	0.0352	0.7648	0.0933	0.0130	0.5648	0.0334	0.0228	7.6	6.37	
36	360	0.0095	0.0352	0.7999	0.1070	0.0137	0.5983	0.0335	0.0232	7.7	6.82	
37	370	0.0095	0.0352	0.8351	0.1215	0.0144	0.6319	0.0336	0.0237	7.9	7.17	
38	380	0.0095	0.0352	0.8702	0.1365	0.0151	0.6656	0.0337	0.0241	8.0	7.44	
39	390	0.0095	0.0352	0.9054	0.1523	0.0157	0.6995	0.0338	0.0244	8.1	7.66	
40	400	0.0095	0.0352	0.9405	0.1686	0.0163	0.7334	0.0339	0.0248	8.3	7.85	
41	410	0.0134	0.0496	0.9901	0.1926	0.0240	0.7813	0.0480	0.0355	11.8	8.62	
42	420	0.0134	0.0496	1.0397	0.2177	0.0251	0.8294	0.0481	0.0362	12.0	9.78	
43	430	0.0134	0.0496	1.0893	0.2439	0.0261	0.8776	0.0482	0.0367	12.2	10.61	
44	440	0.0180	0.0666	1.1559	0.2804	0.0366	0.9426	0.0649	0.0502	16.7	11.97	
45	450	0.0180	0.0666	1.2225	0.3186	0.0382	1.0076	0.0651	0.0511	17.0	13.69	
46	460	0.0340	0.1258	1.3483	0.3946	0.0760	1.1309	0.1233	0.0987	32.9	17.64	
47	470	0.0540	0.1998	1.5481	0.5243	0.1297	1.3275	0.1966	0.1619	53.9	26.67	
48	480	0.0270	0.0999	1.6480	0.5927	0.0684	1.4261	0.0986	0.0829	27.6	31.61	Q peak
49	490	0.0180	0.0666	1.7146	0.6395	0.0468	1.4919	0.0658	0.0559	18.6	28.63	
50	500	0.0134	0.0496	1.7642	0.6749	0.0354	1.5409	0.0490	0.0419	14.0	24.30	
51	510	0.0134	0.0496	1.8137	0.7107	0.0358	1.5899	0.0490	0.0422	14.0	20.69	
52	520	0.0134	0.0496	1.8633	0.7470	0.0363	1.6390	0.0491	0.0424	14.1	18.37	
53	530	0.0088	0.0326	1.8959	0.7710	0.0240	1.6712	0.0322	0.0280	9.3	16.04	
54	540	0.0088	0.0326	1.9284	0.7952	0.0242	1.7035	0.0322	0.0281	9.3	13.69	
55	550	0.0088	0.0326	1.9610	0.8196	0.0244	1.7357	0.0323	0.0282	9.4	12.17	
56	560	0.0088	0.0326	1.9936	0.8441	0.0245	1.7680	0.0323	0.0283	9.4	11.19	
57	570	0.0088	0.0326	2.0261	0.8688	0.0247	1.8002	0.0323	0.0283	9.4	10.57	
58	580	0.0088	0.0326	2.0587	0.8937	0.0248	1.8325	0.0323	0.0284	9.5	10.18	
59	590	0.0088	0.0326	2.0912	0.9187	0.0250	1.8648	0.0323	0.0285	9.5	9.93	
60	600	0.0088	0.0326	2.1238	0.9438	0.0251	1.8971	0.0323	0.0286	9.5	9.78	
61	610	0.0088	0.0326	2.1564	0.9691	0.0253	1.9294	0.0323	0.0287	9.5	9.69	
62	620	0.0088	0.0326	2.1889	0.9945	0.0254	1.9617	0.0323	0.0287	9.6	9.64	
63	630	0.0088	0.0326	2.2215	1.0200	0.0255	1.9940	0.0323	0.0288	9.6	9.62	
64	640	0.0088	0.0326	2.2540	1.0457	0.0257	2.0264	0.0323	0.0289	9.6	9.62	
65	650	0.0072	0.0266	2.2807	1.0668	0.0211	2.0528	0.0265	0.0237	7.9	9.31	

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

					Pervious Area		Impervious Area				
(1) Time Increment	(2) Time	(3) Rainfall distri-bution	(4) Incre-mental Rainfall	(5) Accumu-lated Rainfall	(6) Accumu-lated Runoff	(7) Incre-mental Runoff	(8) Accumu-lated Runoff	(9) Incre-mental Runoff	(10) Total Runoff	(11) Instant hydro-graph	(12) design hydro-graph
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs
66	660	0.0072	0.0266	2.3073	1.0880	0.0212	2.0793	0.0265	0.0237	7.9	8.81
67	670	0.0072	0.0266	2.3340	1.1093	0.0213	2.1057	0.0265	0.0238	7.9	8.49
68	680	0.0072	0.0266	2.3606	1.1306	0.0213	2.1322	0.0265	0.0238	7.9	8.29
69	690	0.0072	0.0266	2.3872	1.1520	0.0214	2.1587	0.0265	0.0238	7.9	8.17
70	700	0.0072	0.0266	2.4139	1.1735	0.0215	2.1851	0.0265	0.0239	8.0	8.09
71	710	0.0072	0.0266	2.4405	1.1951	0.0216	2.2116	0.0265	0.0239	8.0	8.04
72	720	0.0072	0.0266	2.4672	1.2167	0.0216	2.2381	0.0265	0.0240	8.0	8.02
73	730	0.0072	0.0266	2.4938	1.2384	0.0217	2.2646	0.0265	0.0240	8.0	8.01
74	740	0.0072	0.0266	2.5204	1.2602	0.0218	2.2911	0.0265	0.0240	8.0	8.00
75	750	0.0072	0.0266	2.5471	1.2820	0.0218	2.3175	0.0265	0.0241	8.0	8.01
76	760	0.0072	0.0266	2.5737	1.3039	0.0219	2.3440	0.0265	0.0241	8.0	8.01
77	770	0.0057	0.0211	2.5948	1.3213	0.0174	2.3650	0.0210	0.0191	6.4	7.73
78	780	0.0057	0.0211	2.6159	1.3388	0.0174	2.3860	0.0210	0.0191	6.4	7.25
79	790	0.0057	0.0211	2.6370	1.3562	0.0175	2.4070	0.0210	0.0192	6.4	6.94
80	800	0.0057	0.0211	2.6581	1.3737	0.0175	2.4279	0.0210	0.0192	6.4	6.75
81	810	0.0057	0.0211	2.6792	1.3913	0.0175	2.4489	0.0210	0.0192	6.4	6.62
82	820	0.0057	0.0211	2.7003	1.4089	0.0176	2.4699	0.0210	0.0192	6.4	6.54
83	830	0.0057	0.0211	2.7214	1.4265	0.0176	2.4909	0.0210	0.0192	6.4	6.49
84	840	0.0057	0.0211	2.7424	1.4441	0.0177	2.5119	0.0210	0.0193	6.4	6.46
85	850	0.0057	0.0211	2.7635	1.4618	0.0177	2.5329	0.0210	0.0193	6.4	6.45
86	860	0.0057	0.0211	2.7846	1.4796	0.0177	2.5539	0.0210	0.0193	6.4	6.44
87	870	0.0057	0.0211	2.8057	1.4973	0.0178	2.5748	0.0210	0.0193	6.4	6.43
88	880	0.0057	0.0211	2.8268	1.5151	0.0178	2.5958	0.0210	0.0193	6.4	6.43
89	890	0.0050	0.0185	2.8453	1.5308	0.0156	2.6142	0.0184	0.0170	5.7	6.30
90	900	0.0050	0.0185	2.8638	1.5464	0.0157	2.6327	0.0184	0.0170	5.7	6.07
91	910	0.0050	0.0185	2.8823	1.5621	0.0157	2.6511	0.0184	0.0170	5.7	5.93
92	920	0.0050	0.0185	2.9008	1.5778	0.0157	2.6695	0.0184	0.0170	5.7	5.83
93	930	0.0050	0.0185	2.9193	1.5936	0.0157	2.6879	0.0184	0.0170	5.7	5.78
94	940	0.0050	0.0185	2.9378	1.6093	0.0158	2.7063	0.0184	0.0170	5.7	5.74
95	950	0.0050	0.0185	2.9563	1.6251	0.0158	2.7248	0.0184	0.0171	5.7	5.72
96	960	0.0050	0.0185	2.9748	1.6409	0.0158	2.7432	0.0184	0.0171	5.7	5.70
97	970	0.0050	0.0185	2.9933	1.6567	0.0158	2.7616	0.0184	0.0171	5.7	5.70
98	980	0.0050	0.0185	3.0118	1.6726	0.0159	2.7800	0.0184	0.0171	5.7	5.69
99	990	0.0050	0.0185	3.0303	1.6885	0.0159	2.7984	0.0184	0.0171	5.7	5.69
100	1000	0.0050	0.0185	3.0488	1.7044	0.0159	2.8169	0.0184	0.0171	5.7	5.69
101	1010	0.0040	0.0148	3.0636	1.7171	0.0127	2.8316	0.0147	0.0137	4.6	5.50
102	1020	0.0040	0.0148	3.0784	1.7299	0.0127	2.8464	0.0147	0.0137	4.6	5.17
103	1030	0.0040	0.0148	3.0932	1.7426	0.0128	2.8611	0.0147	0.0137	4.6	4.96
104	1040	0.0040	0.0148	3.1080	1.7554	0.0128	2.8758	0.0147	0.0137	4.6	4.82
105	1050	0.0040	0.0148	3.1228	1.7682	0.0128	2.8906	0.0147	0.0137	4.6	4.73
106	1060	0.0040	0.0148	3.1376	1.7810	0.0128	2.9053	0.0147	0.0137	4.6	4.68
107	1070	0.0040	0.0148	3.1524	1.7938	0.0128	2.9201	0.0147	0.0137	4.6	4.64
108	1080	0.0040	0.0148	3.1672	1.8066	0.0128	2.9348	0.0147	0.0138	4.6	4.62
109	1090	0.0040	0.0148	3.1820	1.8195	0.0128	2.9496	0.0147	0.0138	4.6	4.61
110	1100	0.0040	0.0148	3.1968	1.8323	0.0129	2.9643	0.0147	0.0138	4.6	4.60
111	1110	0.0040	0.0148	3.2116	1.8452	0.0129	2.9790	0.0147	0.0138	4.6	4.59
112	1120	0.0040	0.0148	3.2264	1.8581	0.0129	2.9938	0.0147	0.0138	4.6	4.59
113	1130	0.0040	0.0148	3.2412	1.8710	0.0129	3.0085	0.0147	0.0138	4.6	4.59
114	1140	0.0040	0.0148	3.2560	1.8839	0.0129	3.0233	0.0147	0.0138	4.6	4.59
115	1150	0.0040	0.0148	3.2708	1.8968	0.0129	3.0380	0.0147	0.0138	4.6	4.59
116	1160	0.0040	0.0148	3.2856	1.9097	0.0129	3.0528	0.0147	0.0138	4.6	4.59
117	1170	0.0040	0.0148	3.3004	1.9227	0.0129	3.0675	0.0147	0.0138	4.6	4.59
118	1180	0.0040	0.0148	3.3152	1.9356	0.0130	3.0823	0.0147	0.0138	4.6	4.60
119	1190	0.0040	0.0148	3.3300	1.9486	0.0130	3.0970	0.0147	0.0138	4.6	4.60
120	1200	0.0040	0.0148	3.3448	1.9616	0.0130	3.1118	0.0147	0.0138	4.6	4.60
121	1210	0.0040	0.0148	3.3596	1.9746	0.0130	3.1265	0.0148	0.0138	4.6	4.60
122	1220	0.0040	0.0148	3.3744	1.9876	0.0130	3.1413	0.0148	0.0138	4.6	4.60
123	1230	0.0040	0.0148	3.3892	2.0006	0.0130	3.1560	0.0148	0.0138	4.6	4.61
124	1240	0.0040	0.0148	3.4040	2.0136	0.0130	3.1708	0.0148	0.0139	4.6	4.61
125	1250	0.0040	0.0148	3.4188	2.0266	0.0130	3.1855	0.0148	0.0139	4.6	4.61
126	1260	0.0040	0.0148	3.4336	2.0397	0.0130	3.2003	0.0148	0.0139	4.6	4.61
127	1270	0.0040	0.0148	3.4484	2.0527	0.0131	3.2150	0.0148	0.0139	4.6	4.61
128	1280	0.0040	0.0148	3.4632	2.0658	0.0131	3.2298	0.0148	0.0139	4.6	4.62
129	1290	0.0040	0.0148	3.4780	2.0789	0.0131	3.2445	0.0148	0.0139	4.6	4.62
130	1300	0.0040	0.0148	3.4928	2.0920	0.0131	3.2593	0.0148	0.0139	4.6	4.62
131	1310	0.0040	0.0148	3.5076	2.1051	0.0131	3.2740	0.0148	0.0139	4.6	4.62
132	1320	0.0040	0.0148	3.5224	2.1182	0.0131	3.2888	0.0148	0.0139	4.6	4.62
133	1330	0.0040	0.0148	3.5372	2.1313	0.0131	3.3036	0.0148	0.0139	4.6	4.63
134	1340	0.0040	0.0148	3.5520	2.1444	0.0131	3.3183	0.0148	0.0139	4.6	4.63
135	1350	0.0040	0.0148	3.5668	2.1576	0.0131	3.3331	0.0148	0.0139	4.6	4.63
136	1360	0.0040	0.0148	3.5816	2.1707	0.0132	3.3478	0.0148	0.0139	4.6	4.63
137	1370	0.0040	0.0148	3.5964	2.1839	0.0132	3.3626	0.0148	0.0139	4.6	4.63
138	1380	0.0040	0.0148	3.6112	2.1971	0.0132	3.3773	0.0148	0.0139	4.6	4.64
139	1390	0.0040	0.0148	3.6260	2.2102	0.0132	3.3921	0.0148	0.0139	4.6	4.64
140	1400	0.0040	0.0148	3.6408	2.2234	0.0132	3.4069	0.0148	0.0139	4.6	4.64
141	1410	0.0040	0.0148	3.6556	2.2366	0.0132	3.4216	0.0148	0.0139	4.6	4.64
142	1420	0.0040	0.0148	3.6704	2.2498	0.0132	3.4364	0.0148	0.0140	4.6	4.64
143	1430	0.0040	0.0148	3.6852	2.2631	0.0132	3.4511	0.0148	0.0140	4.6	4.64
144	1440	0.0040	0.0148	3.7000	2.2763	0.0132	3.4659	0.0148	0.0140	4.6	4.65

Total Volume of Runoff[1] = 562,521 cu. ft.

Notes:

1. Total Runoff Volume is found by summing column (12) and multiplying by the time step, dt as follows:

   V = SumQ x dt
   V(cu.ft.) = SumQ(cu.ft/s) x dt(min.) x (60 s/min.)

Existing Blackmans, 25 yr flow, PVC, S=6.8%

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Diameter

Input Data

Roughness Coefficient	0.010	
Channel Slope	0.06800	ft/ft
Normal Depth	1.64	ft
Diameter	1.64	ft
Discharge	45.43	ft^3/s

Results

Diameter	1.64	ft
Normal Depth	1.64	ft
Flow Area	2.12	ft^2
Wetted Perimeter	5.16	ft
Hydraulic Radius	0.41	ft
Top Width	0.00	ft
Critical Depth	1.64	ft
Percent Full	100.0	%
Critical Slope	0.06547	ft/ft
Velocity	21.42	ft/s
Velocity Head	7.13	ft
Specific Energy	8.77	ft
Froude Number	0.00	
Maximum Discharge	48.86	ft^3/s
Discharge Full	45.42	ft^3/s
Slope Full	0.06804	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%

Existing Blackmans, 25 yr flow, PVC, S=6.8%

GVF Output Data

Normal Depth Over Rise	100.00	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.64	ft
Critical Depth	1.64	ft
Channel Slope	0.06800	ft/ft
Critical Slope	0.06547	ft/ft

Existing Blackmans, 100 yr flow, PVC, S=6.8%

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Diameter

Input Data

Roughness Coefficient	0.010	
Channel Slope	0.06800	ft/ft
Normal Depth	1.82	ft
Diameter	1.82	ft
Discharge	59.60	ft³/s

Results

Diameter	1.82	ft
Normal Depth	1.82	ft
Flow Area	2.60	ft²
Wetted Perimeter	5.72	ft
Hydraulic Radius	0.45	ft
Top Width	0.00	ft
Critical Depth	1.82	ft
Percent Full	100.0	%
Critical Slope	0.06550	ft/ft
Velocity	22.92	ft/s
Velocity Head	8.16	ft
Specific Energy	9.98	ft
Froude Number	0.00	
Maximum Discharge	64.12	ft³/s
Discharge Full	59.61	ft³/s
Slope Full	0.06799	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%

Existing Blackmans, 100 yr flow, PVC, S=6.8%

GVF Output Data

Normal Depth Over Rise	100.00	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.82	ft
Critical Depth	1.82	ft
Channel Slope	0.06800	ft/ft
Critical Slope	0.06550	ft/ft

City of Snohomish
Stormwater Comprehensive Plan
Time of Concentration
Blackmans - Existing-Lake

Calculate Time of Concentration (Tc)

Tc = Sum(Tt)

Where:

Tt = travel time (min) = $\frac{L}{(60xV)}$ (for shallow concentrated flow or channel flow)

Tt = travel time (min)= $\frac{0.42(n_s L)^{0.8}}{(P_2)^{0.5}(s_o)^{0.4}}$ (for sheet flow)

Where:

V = avg. velocity (ft/s) = $V = k(s_o)^{0.5}$

k = time of concentration velocity factor (ft/s)

L = flow length (ft)

n_s = sheet flow Manning's effective roughness coefficient

P_2 = 2-year, 24-hour rainfall (in)

s_o = slope of hydraulic grade line (land slope, ft/ft)

	L (ft)	$k_{s/c}$	V (fps)	n_s	P_2	s_o (ft/ft)	Tt (min)
a - sheet	100	NA	NA	0.24	1.8	0.030	16.2
b - channel	195	17	2.9	NA	NA	0.030	1.1
c - channel	2445	42	10.3	NA	NA	0.06	4.0
Total (Tc)							21.2

Minimum Allowable Tc = 6.0 minutes

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

Project: City of Snohomish - Stormwater Comp Plan
Basin: Blackmans Lake - Existing
Storm Event: 25-YEAR, 24-HOUR
Given:

Area = 108.65 acres
Pt = 3.05 inches
dt = 10 min.
Tc = 21.2 min.

PERVIOUS AREA			IMPERVIOUS AREA (Roads)		
Area	=	75.64 acres	Area	=	33.01 acres
CN	=	86	CN	=	98
S	=	1.63	S	=	0.20
0.2S	=	0.33	0.2S	=	0.04

SUMMARY	
T_{pk}(hrs)=	7.83
T_c (min)=	21.2
Q_{pk}(cfs)=	45.43
Vol(cf)=	796,753

Compute: Runoff Hydrograph

Column (3) = SCS Type IA Rainfall Distribution
Column (4) = Col. (3) x Pt
Column (5) = Accumulated Sum of Col. (4)
Column (6) = [If P <= 0.2S] = 0; Note, use PERVIOUS Area "S" value.
[If P > 0.2S] = (Col.(5) - 0.2S)^2/(Col.(5) + 0.8S); Using the PERVIOUS Area "S" value.
Column (7) = Col.(6) of Present Time Step - Col.(6) of Previous Time Step
Column (8) = Same method as for Col.(6), except use the IMPERVIOUS Area "S" value.
Column (9) = Col.(8) of the present time step - Col.(8) of the previous time step.
Column (10) = ((PERVIOUS area / Total area) x Col.(7)) + ((IMPERVIOUS area / Total area) x Col.(9))
Column (11) = (60.5 x Col.(10) x Total Area) / 10 (dt = 10 minutes)
Routing Constant, w = dt / (2Tc + dt) = 0.1908
Column (12) = Col.(12) of Previous Time Step + (w x [Col.(11) of Previous Time Step
+ Col.(11) of Present Time Step - (2 x Col.(12) of Previous Time Step)])

					Pervious Area		Impervious Area					
(1) Time Increment	(2) Time	(3) Rainfall distri-bution	(4) Incre-mental Rainfall	(5) Accumu-lated Rainfall	(6) Accumu-lated Runoff	(7) Incre-mental Runoff	(8) Accumu-lated Runoff	(9) Incre-mental Runoff	(10) Total Runoff	(11) Instant hydro-graph	(12) design hydro-graph	
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs	
1	10	0.0040	0.0122	0.0122	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
2	20	0.0040	0.0122	0.0244	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
3	30	0.0040	0.0122	0.0366	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
4	40	0.0040	0.0122	0.0488	0.0000	0.0000	0.0003	0.0003	0.0001	0.1	0.01	
5	50	0.0040	0.0122	0.0610	0.0000	0.0000	0.0018	0.0015	0.0005	0.3	0.08	
6	60	0.0040	0.0122	0.0732	0.0000	0.0000	0.0044	0.0026	0.0008	0.5	0.20	
7	70	0.0040	0.0122	0.0854	0.0000	0.0000	0.0080	0.0036	0.0011	0.7	0.36	
8	80	0.0040	0.0122	0.0976	0.0000	0.0000	0.0124	0.0044	0.0013	0.9	0.53	
9	90	0.0040	0.0122	0.1098	0.0000	0.0000	0.0174	0.0051	0.0015	1.0	0.68	
10	100	0.0040	0.0122	0.1220	0.0000	0.0000	0.0231	0.0057	0.0017	1.1	0.83	
11	110	0.0050	0.0153	0.1373	0.0000	0.0000	0.0309	0.0078	0.0024	1.6	1.03	
12	120	0.0050	0.0153	0.1525	0.0000	0.0000	0.0395	0.0086	0.0026	1.7	1.26	
13	130	0.0050	0.0153	0.1678	0.0000	0.0000	0.0487	0.0092	0.0028	1.8	1.46	
14	140	0.0050	0.0153	0.1830	0.0000	0.0000	0.0584	0.0097	0.0029	1.9	1.62	
15	150	0.0050	0.0153	0.1983	0.0000	0.0000	0.0686	0.0102	0.0031	2.0	1.76	
16	160	0.0050	0.0153	0.2135	0.0000	0.0000	0.0791	0.0106	0.0032	2.1	1.88	
17	170	0.0060	0.0183	0.2318	0.0000	0.0000	0.0923	0.0132	0.0040	2.6	2.07	
18	180	0.0060	0.0183	0.2501	0.0000	0.0000	0.1060	0.0136	0.0041	2.7	2.30	
19	190	0.0060	0.0183	0.2684	0.0000	0.0000	0.1200	0.0140	0.0043	2.8	2.48	
20	200	0.0060	0.0183	0.2867	0.0000	0.0000	0.1344	0.0144	0.0044	2.9	2.61	
21	210	0.0060	0.0183	0.3050	0.0000	0.0000	0.1490	0.0147	0.0045	2.9	2.72	
22	220	0.0060	0.0183	0.3233	0.0000	0.0000	0.1640	0.0150	0.0045	3.0	2.81	
23	230	0.0070	0.0214	0.3447	0.0002	0.0002	0.1818	0.0178	0.0055	3.6	3.01	
24	240	0.0070	0.0214	0.3660	0.0010	0.0008	0.1998	0.0180	0.0060	4.0	3.31	
25	250	0.0070	0.0214	0.3874	0.0023	0.0013	0.2181	0.0183	0.0064	4.2	3.61	
26	260	0.0070	0.0214	0.4087	0.0040	0.0018	0.2366	0.0185	0.0069	4.5	3.90	
27	270	0.0070	0.0214	0.4301	0.0063	0.0023	0.2553	0.0187	0.0073	4.8	4.19	
28	280	0.0070	0.0214	0.4514	0.0090	0.0027	0.2743	0.0189	0.0076	5.0	4.46	
29	290	0.0082	0.0250	0.4764	0.0128	0.0038	0.2966	0.0224	0.0094	6.2	4.90	
30	300	0.0082	0.0250	0.5014	0.0171	0.0044	0.3192	0.0226	0.0099	6.5	5.45	
31	310	0.0082	0.0250	0.5264	0.0221	0.0049	0.3419	0.0227	0.0103	6.8	5.90	
32	320	0.0082	0.0250	0.5514	0.0275	0.0055	0.3648	0.0229	0.0108	7.1	6.30	
33	330	0.0082	0.0250	0.5765	0.0335	0.0060	0.3879	0.0230	0.0112	7.3	6.64	
34	340	0.0082	0.0250	0.6015	0.0400	0.0065	0.4110	0.0232	0.0116	7.6	6.96	
35	350	0.0095	0.0290	0.6304	0.0481	0.0081	0.4380	0.0270	0.0138	9.1	7.49	
36	360	0.0095	0.0290	0.6594	0.0568	0.0087	0.4651	0.0271	0.0143	9.4	8.16	
37	370	0.0095	0.0290	0.6884	0.0661	0.0093	0.4924	0.0273	0.0148	9.7	8.69	
38	380	0.0095	0.0290	0.7174	0.0760	0.0099	0.5198	0.0274	0.0152	10.0	9.13	
39	390	0.0095	0.0290	0.7463	0.0864	0.0104	0.5472	0.0275	0.0156	10.3	9.51	
40	400	0.0095	0.0290	0.7753	0.0973	0.0109	0.5748	0.0276	0.0160	10.5	9.84	
41	410	0.0134	0.0409	0.8162	0.1136	0.0163	0.6138	0.0390	0.0232	15.2	11.00	
42	420	0.0134	0.0409	0.8570	0.1308	0.0172	0.6530	0.0392	0.0239	15.7	12.70	
43	430	0.0134	0.0409	0.8979	0.1489	0.0181	0.6923	0.0393	0.0245	16.1	13.92	
44	440	0.0180	0.0549	0.9528	0.1745	0.0256	0.7452	0.0530	0.0339	22.3	15.94	
45	450	0.0180	0.0549	1.0077	0.2014	0.0270	0.7984	0.0532	0.0349	23.0	18.49	
46	460	0.0340	0.1037	1.1114	0.2558	0.0544	0.8992	0.1008	0.0685	45.0	24.41	
47	470	0.0540	0.1647	1.2761	0.3504	0.0946	1.0602	0.1610	0.1147	75.4	38.08	
48	480	0.0270	0.0824	1.3585	0.4010	0.0505	1.1409	0.0808	0.0597	39.3	45.43	Q peak
49	490	0.0180	0.0549	1.4134	0.4357	0.0348	1.1949	0.0539	0.0406	26.7	40.68	
50	500	0.0134	0.0409	1.4542	0.4621	0.0264	1.2351	0.0402	0.0306	20.1	34.08	
51	510	0.0134	0.0409	1.4951	0.4889	0.0268	1.2753	0.0402	0.0309	20.3	28.79	
52	520	0.0134	0.0409	1.5360	0.5162	0.0272	1.3156	0.0403	0.0312	20.5	25.59	
53	530	0.0088	0.0268	1.5628	0.5343	0.0181	1.3421	0.0265	0.0206	13.6	22.32	
54	540	0.0088	0.0268	1.5897	0.5525	0.0183	1.3685	0.0265	0.0208	13.6	18.99	
55	550	0.0088	0.0268	1.6165	0.5709	0.0184	1.3950	0.0265	0.0209	13.7	16.97	
56	560	0.0088	0.0268	1.6433	0.5895	0.0186	1.4215	0.0265	0.0210	13.8	15.74	
57	570	0.0088	0.0268	1.6702	0.6082	0.0187	1.4480	0.0265	0.0211	13.9	15.01	
58	580	0.0088	0.0268	1.6970	0.6271	0.0189	1.4745	0.0265	0.0212	13.9	14.58	
59	590	0.0088	0.0268	1.7239	0.6461	0.0190	1.5010	0.0265	0.0213	14.0	14.34	
60	600	0.0088	0.0268	1.7507	0.6652	0.0191	1.5276	0.0265	0.0214	14.1	14.22	
61	610	0.0088	0.0268	1.7775	0.6845	0.0193	1.5541	0.0265	0.0215	14.1	14.17	
62	620	0.0088	0.0268	1.8044	0.7039	0.0194	1.5806	0.0265	0.0216	14.2	14.16	
63	630	0.0088	0.0268	1.8312	0.7234	0.0195	1.6072	0.0266	0.0217	14.2	14.18	
64	640	0.0088	0.0268	1.8581	0.7431	0.0197	1.6338	0.0266	0.0218	14.3	14.22	
65	650	0.0072	0.0220	1.8800	0.7593	0.0162	1.6555	0.0217	0.0179	11.7	13.76	

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

					Pervious Area		Impervious Area				
(1) Time Increment	(2) Time	(3) Rainfall distri- bution	(4) Incre- mental Rainfall	(5) Accumu- lated Rainfall	(6) Accumu- lated Runoff	(7) Incre- mental Runoff	(8) Accumu- lated Runoff	(9) Incre- mental Runoff	(10) Total Runoff	(11) Instant hydro- graph	(12) design hydro- graph
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs
66	660	0.0072	0.0220	1.9020	0.7755	0.0163	1.6772	0.0217	0.0179	11.8	13.00
67	670	0.0072	0.0220	1.9239	0.7919	0.0163	1.6990	0.0217	0.0180	11.8	12.54
68	680	0.0072	0.0220	1.9459	0.8083	0.0164	1.7207	0.0218	0.0180	11.9	12.27
69	690	0.0072	0.0220	1.9679	0.8247	0.0165	1.7425	0.0218	0.0181	11.9	12.12
70	700	0.0072	0.0220	1.9898	0.8413	0.0166	1.7643	0.0218	0.0181	11.9	12.04
71	710	0.0072	0.0220	2.0118	0.8579	0.0166	1.7860	0.0218	0.0182	12.0	12.00
72	720	0.0072	0.0220	2.0337	0.8746	0.0167	1.8078	0.0218	0.0182	12.0	11.99
73	730	0.0072	0.0220	2.0557	0.8914	0.0168	1.8296	0.0218	0.0183	12.0	11.99
74	740	0.0072	0.0220	2.0777	0.9082	0.0168	1.8513	0.0218	0.0183	12.1	12.01
75	750	0.0072	0.0220	2.0996	0.9251	0.0169	1.8731	0.0218	0.0184	12.1	12.03
76	760	0.0072	0.0220	2.1216	0.9421	0.0170	1.8949	0.0218	0.0184	12.1	12.06
77	770	0.0057	0.0174	2.1390	0.9556	0.0135	1.9122	0.0172	0.0146	9.6	11.60
78	780	0.0057	0.0174	2.1564	0.9691	0.0135	1.9294	0.0172	0.0146	9.6	10.84
79	790	0.0057	0.0174	2.1737	0.9826	0.0136	1.9467	0.0173	0.0147	9.6	10.38
80	800	0.0057	0.0174	2.1911	0.9962	0.0136	1.9639	0.0173	0.0147	9.7	10.11
81	810	0.0057	0.0174	2.2085	1.0098	0.0136	1.9812	0.0173	0.0147	9.7	9.94
82	820	0.0057	0.0174	2.2259	1.0235	0.0137	1.9984	0.0173	0.0148	9.7	9.85
83	830	0.0057	0.0174	2.2433	1.0372	0.0137	2.0157	0.0173	0.0148	9.7	9.79
84	840	0.0057	0.0174	2.2607	1.0510	0.0137	2.0329	0.0173	0.0148	9.7	9.77
85	850	0.0057	0.0174	2.2780	1.0647	0.0138	2.0502	0.0173	0.0148	9.8	9.76
86	860	0.0057	0.0174	2.2954	1.0785	0.0138	2.0675	0.0173	0.0149	9.8	9.76
87	870	0.0057	0.0174	2.3128	1.0924	0.0138	2.0847	0.0173	0.0149	9.8	9.76
88	880	0.0057	0.0174	2.3302	1.1063	0.0139	2.1020	0.0173	0.0149	9.8	9.77
89	890	0.0050	0.0153	2.3455	1.1185	0.0122	2.1172	0.0151	0.0131	8.6	9.56
90	900	0.0050	0.0153	2.3607	1.1307	0.0122	2.1323	0.0151	0.0131	8.6	9.20
91	910	0.0050	0.0153	2.3760	1.1429	0.0123	2.1475	0.0152	0.0131	8.6	8.98
92	920	0.0050	0.0153	2.3912	1.1552	0.0123	2.1626	0.0152	0.0131	8.6	8.85
93	930	0.0050	0.0153	2.4065	1.1675	0.0123	2.1778	0.0152	0.0132	8.7	8.77
94	940	0.0050	0.0153	2.4217	1.1798	0.0123	2.1929	0.0152	0.0132	8.7	8.73
95	950	0.0050	0.0153	2.4370	1.1922	0.0123	2.2081	0.0152	0.0132	8.7	8.71
96	960	0.0050	0.0153	2.4522	1.2045	0.0124	2.2232	0.0152	0.0132	8.7	8.70
97	970	0.0050	0.0153	2.4675	1.2169	0.0124	2.2384	0.0152	0.0132	8.7	8.70
98	980	0.0050	0.0153	2.4827	1.2294	0.0124	2.2535	0.0152	0.0133	8.7	8.70
99	990	0.0050	0.0153	2.4980	1.2418	0.0124	2.2687	0.0152	0.0133	8.7	8.71
100	1000	0.0050	0.0153	2.5132	1.2543	0.0125	2.2839	0.0152	0.0133	8.7	8.71
101	1010	0.0040	0.0122	2.5254	1.2642	0.0100	2.2960	0.0121	0.0106	7.0	8.39
102	1020	0.0040	0.0122	2.5376	1.2743	0.0100	2.3081	0.0121	0.0106	7.0	7.86
103	1030	0.0040	0.0122	2.5498	1.2843	0.0100	2.3203	0.0121	0.0107	7.0	7.53
104	1040	0.0040	0.0122	2.5620	1.2943	0.0100	2.3324	0.0121	0.0107	7.0	7.33
105	1050	0.0040	0.0122	2.5742	1.3043	0.0100	2.3445	0.0121	0.0107	7.0	7.21
106	1060	0.0040	0.0122	2.5864	1.3144	0.0101	2.3566	0.0121	0.0107	7.0	7.14
107	1070	0.0040	0.0122	2.5986	1.3245	0.0101	2.3688	0.0121	0.0107	7.0	7.10
108	1080	0.0040	0.0122	2.6108	1.3345	0.0101	2.3809	0.0121	0.0107	7.0	7.07
109	1090	0.0040	0.0122	2.6230	1.3446	0.0101	2.3931	0.0121	0.0107	7.0	7.06
110	1100	0.0040	0.0122	2.6352	1.3547	0.0101	2.4052	0.0121	0.0107	7.0	7.05
111	1110	0.0040	0.0122	2.6474	1.3649	0.0101	2.4173	0.0121	0.0107	7.1	7.05
112	1120	0.0040	0.0122	2.6596	1.3750	0.0101	2.4295	0.0121	0.0107	7.1	7.06
113	1130	0.0040	0.0122	2.6718	1.3851	0.0101	2.4416	0.0121	0.0108	7.1	7.06
114	1140	0.0040	0.0122	2.6840	1.3953	0.0102	2.4537	0.0121	0.0108	7.1	7.06
115	1150	0.0040	0.0122	2.6962	1.4055	0.0102	2.4659	0.0121	0.0108	7.1	7.07
116	1160	0.0040	0.0122	2.7084	1.4157	0.0102	2.4780	0.0121	0.0108	7.1	7.07
117	1170	0.0040	0.0122	2.7206	1.4259	0.0102	2.4901	0.0121	0.0108	7.1	7.08
118	1180	0.0040	0.0122	2.7328	1.4361	0.0102	2.5023	0.0121	0.0108	7.1	7.08
119	1190	0.0040	0.0122	2.7450	1.4463	0.0102	2.5144	0.0121	0.0108	7.1	7.09
120	1200	0.0040	0.0122	2.7572	1.4565	0.0102	2.5266	0.0121	0.0108	7.1	7.10
121	1210	0.0040	0.0122	2.7694	1.4668	0.0102	2.5387	0.0121	0.0108	7.1	7.10
122	1220	0.0040	0.0122	2.7816	1.4770	0.0103	2.5508	0.0121	0.0108	7.1	7.11
123	1230	0.0040	0.0122	2.7938	1.4873	0.0103	2.5630	0.0121	0.0108	7.1	7.11
124	1240	0.0040	0.0122	2.8060	1.4976	0.0103	2.5751	0.0121	0.0108	7.1	7.12
125	1250	0.0040	0.0122	2.8182	1.5079	0.0103	2.5873	0.0121	0.0109	7.1	7.12
126	1260	0.0040	0.0122	2.8304	1.5182	0.0103	2.5994	0.0121	0.0109	7.1	7.13
127	1270	0.0040	0.0122	2.8426	1.5285	0.0103	2.6116	0.0121	0.0109	7.1	7.13
128	1280	0.0040	0.0122	2.8548	1.5388	0.0103	2.6237	0.0121	0.0109	7.1	7.14
129	1290	0.0040	0.0122	2.8670	1.5491	0.0103	2.6358	0.0121	0.0109	7.2	7.14
130	1300	0.0040	0.0122	2.8792	1.5595	0.0103	2.6480	0.0121	0.0109	7.2	7.15
131	1310	0.0040	0.0122	2.8914	1.5698	0.0104	2.6601	0.0121	0.0109	7.2	7.15
132	1320	0.0040	0.0122	2.9036	1.5802	0.0104	2.6723	0.0121	0.0109	7.2	7.16
133	1330	0.0040	0.0122	2.9158	1.5906	0.0104	2.6844	0.0121	0.0109	7.2	7.16
134	1340	0.0040	0.0122	2.9280	1.6010	0.0104	2.6966	0.0121	0.0109	7.2	7.17
135	1350	0.0040	0.0122	2.9402	1.6114	0.0104	2.7087	0.0121	0.0109	7.2	7.17
136	1360	0.0040	0.0122	2.9524	1.6218	0.0104	2.7209	0.0121	0.0109	7.2	7.18
137	1370	0.0040	0.0122	2.9646	1.6322	0.0104	2.7330	0.0121	0.0109	7.2	7.18
138	1380	0.0040	0.0122	2.9768	1.6426	0.0104	2.7452	0.0121	0.0110	7.2	7.19
139	1390	0.0040	0.0122	2.9890	1.6531	0.0104	2.7573	0.0121	0.0110	7.2	7.19
140	1400	0.0040	0.0122	3.0012	1.6635	0.0104	2.7695	0.0121	0.0110	7.2	7.20
141	1410	0.0040	0.0122	3.0134	1.6740	0.0105	2.7816	0.0121	0.0110	7.2	7.20
142	1420	0.0040	0.0122	3.0256	1.6844	0.0105	2.7938	0.0121	0.0110	7.2	7.21
143	1430	0.0040	0.0122	3.0378	1.6949	0.0105	2.8059	0.0122	0.0110	7.2	7.21
144	1440	0.0040	0.0122	3.0500	1.7054	0.0105	2.8181	0.0122	0.0110	7.2	7.22

Total Volume of Runoff[1] = 796,753 cu. ft.

Notes:

1. Total Runoff Volume is found by summing column (12) and multiplying by the time step, dt as follows:

   V = SumQ x dt
   V(cu.ft.) = SumQ(cu.ft/s) x dt(min.) x (60 s/min.)

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

Project: City of Snohomish - Stormwater Comp Plan
Basin: Blackmans Lake - Existing
Storm Event: 100-YEAR, 24-HOUR
Given:

Area = 108.65 acres
Pt = 3.70 inches
dt = 10 min.
Tc = 21.2 min.

PERVIOUS AREA			IMPERVIOUS AREA (Roads)		
Area	=	75.64 acres	Area	=	33.01 acres
CN	=	86	CN	=	98
S	=	1.63	S	=	0.20
0.2S	=	0.33	0.2S	=	0.04

SUMMARY	
T_{pk}(hrs)=	7.83
T_c (min)=	21.2
Q_{pk}(cfs)=	59.60
Vol(cf)=	1,028,870

Compute: Runoff Hydrograph

Column (3) = SCS Type IA Rainfall Distribution
Column (4) = Col. (3) x Pt
Column (5) = Accumulated Sum of Col. (4)
Column (6) = [If P <= 0.2S] = 0; Note, use PERVIOUS Area "S" value.
[If P > 0.2S] = (Col.(5) - 0.2S)^2/(Col.(5) + 0.8S); Using the PERVIOUS Area "S" value.
Column (7) = Col.(6) of Present Time Step - Col.(6) of Previous Time Step
Column (8) = Same method as for Col.(6), except use the IMPERVIOUS Area "S" value.
Column (9) = Col.(8) of the present time step - Col.(8) of the previous time step.
Column (10) = ((PERVIOUS area / Total area) x Col.(7)) + ((IMPERVIOUS area / Total area) x Col.(9))
Column (11) = (60.5 x Col.(10) x Total Area) / 10 (dt = 10 minutes)
Routing Constant, w = dt / (2Tc + dt) = 0.1908
Column (12) = Col.(12) of Previous Time Step + (w x [Col.(11) of Previous Time Step
+ Col.(11) of Present Time Step - (2 x Col.(12) of Previous Time Step)])

					Pervious Area		Impervious Area					
(1) Time Increment	(2) Time	(3) Rainfall distri-bution	(4) Incre-mental Rainfall	(5) Accumu-lated Rainfall	(6) Accumu-lated Runoff	(7) Incre-mental Runoff	(8) Accumu-lated Runoff	(9) Incre-mental Runoff	(10) Total Runoff	(11) Instant hydro-graph	(12) design hydro-graph	
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs	
1	10	0.0040	0.0148	0.0148	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
2	20	0.0040	0.0148	0.0296	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
3	30	0.0040	0.0148	0.0444	0.0000	0.0000	0.0001	0.0001	0.0000	0.0	0.00	
4	40	0.0040	0.0148	0.0592	0.0000	0.0000	0.0015	0.0015	0.0004	0.3	0.06	
5	50	0.0040	0.0148	0.0740	0.0000	0.0000	0.0046	0.0031	0.0009	0.6	0.21	
6	60	0.0040	0.0148	0.0888	0.0000	0.0000	0.0091	0.0045	0.0014	0.9	0.42	
7	70	0.0040	0.0148	0.1036	0.0000	0.0000	0.0148	0.0056	0.0017	1.1	0.65	
8	80	0.0040	0.0148	0.1184	0.0000	0.0000	0.0214	0.0066	0.0020	1.3	0.87	
9	90	0.0040	0.0148	0.1332	0.0000	0.0000	0.0288	0.0074	0.0023	1.5	1.07	
10	100	0.0040	0.0148	0.1480	0.0000	0.0000	0.0369	0.0081	0.0025	1.6	1.25	
11	110	0.0050	0.0185	0.1665	0.0000	0.0000	0.0479	0.0110	0.0033	2.2	1.50	
12	120	0.0050	0.0185	0.1850	0.0000	0.0000	0.0597	0.0118	0.0036	2.4	1.80	
13	130	0.0050	0.0185	0.2035	0.0000	0.0000	0.0722	0.0125	0.0038	2.5	2.04	
14	140	0.0050	0.0185	0.2220	0.0000	0.0000	0.0852	0.0130	0.0040	2.6	2.23	
15	150	0.0050	0.0185	0.2405	0.0000	0.0000	0.0988	0.0135	0.0041	2.7	2.39	
16	160	0.0050	0.0185	0.2590	0.0000	0.0000	0.1127	0.0140	0.0042	2.8	2.53	
17	170	0.0060	0.0222	0.2812	0.0000	0.0000	0.1300	0.0173	0.0052	3.4	2.75	
18	180	0.0060	0.0222	0.3034	0.0000	0.0000	0.1478	0.0177	0.0054	3.5	3.04	
19	190	0.0060	0.0222	0.3256	0.0000	0.0000	0.1659	0.0181	0.0055	3.6	3.25	
20	200	0.0060	0.0222	0.3478	0.0003	0.0003	0.1844	0.0185	0.0058	3.8	3.43	
21	210	0.0060	0.0222	0.3700	0.0012	0.0009	0.2032	0.0188	0.0063	4.2	3.65	
22	220	0.0060	0.0222	0.3922	0.0026	0.0014	0.2223	0.0191	0.0068	4.5	3.90	
23	230	0.0070	0.0259	0.4181	0.0050	0.0024	0.2448	0.0226	0.0085	5.6	4.33	
24	240	0.0070	0.0259	0.4440	0.0080	0.0031	0.2677	0.0228	0.0091	6.0	4.88	
25	250	0.0070	0.0259	0.4699	0.0118	0.0037	0.2908	0.0231	0.0096	6.3	5.36	
26	260	0.0070	0.0259	0.4958	0.0161	0.0044	0.3141	0.0233	0.0101	6.7	5.79	
27	270	0.0070	0.0259	0.5217	0.0211	0.0050	0.3376	0.0235	0.0106	7.0	6.18	
28	280	0.0070	0.0259	0.5476	0.0266	0.0056	0.3613	0.0237	0.0111	7.3	6.54	
29	290	0.0082	0.0303	0.5779	0.0339	0.0072	0.3892	0.0279	0.0135	8.9	7.13	
30	300	0.0082	0.0303	0.6083	0.0418	0.0080	0.4174	0.0281	0.0141	9.3	7.87	
31	310	0.0082	0.0303	0.6386	0.0505	0.0087	0.4457	0.0283	0.0146	9.6	8.47	
32	320	0.0082	0.0303	0.6690	0.0598	0.0093	0.4741	0.0284	0.0151	9.9	8.97	
33	330	0.0082	0.0303	0.6993	0.0698	0.0100	0.5027	0.0286	0.0156	10.3	9.40	
34	340	0.0082	0.0303	0.7296	0.0803	0.0106	0.5314	0.0287	0.0161	10.6	9.79	
35	350	0.0095	0.0352	0.7648	0.0933	0.0130	0.5648	0.0334	0.0192	12.6	10.48	
36	360	0.0095	0.0352	0.7999	0.1070	0.0137	0.5983	0.0335	0.0197	13.0	11.36	
37	370	0.0095	0.0352	0.8351	0.1215	0.0144	0.6319	0.0336	0.0203	13.3	12.04	
38	380	0.0095	0.0352	0.8702	0.1365	0.0151	0.6656	0.0337	0.0208	13.6	12.59	
39	390	0.0095	0.0352	0.9054	0.1523	0.0157	0.6995	0.0338	0.0212	14.0	13.05	
40	400	0.0095	0.0352	0.9405	0.1686	0.0163	0.7334	0.0339	0.0217	14.2	13.45	
41	410	0.0134	0.0496	0.9901	0.1926	0.0240	0.7813	0.0480	0.0313	20.6	14.96	
42	420	0.0134	0.0496	1.0397	0.2177	0.0251	0.8294	0.0481	0.0321	21.1	17.20	
43	430	0.0134	0.0496	1.0893	0.2439	0.0261	0.8776	0.0482	0.0328	21.6	18.78	
44	440	0.0180	0.0666	1.1559	0.2804	0.0366	0.9426	0.0649	0.0452	29.7	21.40	
45	450	0.0180	0.0666	1.2225	0.3186	0.0382	1.0076	0.0651	0.0463	30.5	24.71	
46	460	0.0340	0.1258	1.3483	0.3946	0.0760	1.1309	0.1233	0.0904	59.4	32.43	
47	470	0.0540	0.1998	1.5481	0.5243	0.1297	1.3275	0.1966	0.1500	98.6	50.21	
48	480	0.0270	0.0999	1.6480	0.5927	0.0684	1.4261	0.0986	0.0776	51.0	59.60	Q peak
49	490	0.0180	0.0666	1.7146	0.6395	0.0468	1.4919	0.0658	0.0525	34.5	53.17	
50	500	0.0134	0.0496	1.7642	0.6749	0.0354	1.5409	0.0490	0.0395	26.0	44.43	
51	510	0.0134	0.0496	1.8137	0.7107	0.0358	1.5899	0.0490	0.0398	26.2	37.43	
52	520	0.0134	0.0496	1.8633	0.7470	0.0363	1.6390	0.0491	0.0402	26.4	33.18	
53	530	0.0088	0.0326	1.8959	0.7710	0.0240	1.6712	0.0322	0.0265	17.4	28.88	
54	540	0.0088	0.0326	1.9284	0.7952	0.0242	1.7035	0.0322	0.0267	17.5	24.53	
55	550	0.0088	0.0326	1.9610	0.8196	0.0244	1.7357	0.0323	0.0268	17.6	21.87	
56	560	0.0088	0.0326	1.9936	0.8441	0.0245	1.7680	0.0323	0.0269	17.7	20.25	
57	570	0.0088	0.0326	2.0261	0.8688	0.0247	1.8002	0.0323	0.0270	17.7	19.28	
58	580	0.0088	0.0326	2.0587	0.8937	0.0248	1.8325	0.0323	0.0271	17.8	18.71	
59	590	0.0088	0.0326	2.0912	0.9187	0.0250	1.8648	0.0323	0.0272	17.9	18.38	
60	600	0.0088	0.0326	2.1238	0.9438	0.0251	1.8971	0.0323	0.0273	18.0	18.21	
61	610	0.0088	0.0326	2.1564	0.9691	0.0253	1.9294	0.0323	0.0274	18.0	18.12	
62	620	0.0088	0.0326	2.1889	0.9945	0.0254	1.9617	0.0323	0.0275	18.1	18.10	
63	630	0.0088	0.0326	2.2215	1.0200	0.0255	1.9940	0.0323	0.0276	18.1	18.10	
64	640	0.0088	0.0326	2.2540	1.0457	0.0257	2.0264	0.0323	0.0277	18.2	18.13	
65	650	0.0072	0.0266	2.2807	1.0668	0.0211	2.0528	0.0265	0.0227	14.9	17.54	

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

					Pervious Area		Impervious Area				
(1) Time Increment	(2) Time	(3) Rainfall distri-bution	(4) Incre-mental Rainfall	(5) Accumu-lated Rainfall	(6) Accumu-lated Runoff	(7) Incre-mental Runoff	(8) Accumu-lated Runoff	(9) Incre-mental Runoff	(10) Total Runoff	(11) Instant hydro-graph	(12) design hydro-graph
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs
66	660	0.0072	0.0266	2.3073	1.0880	0.0212	2.0793	0.0265	0.0228	15.0	16.55
67	670	0.0072	0.0266	2.3340	1.1093	0.0213	2.1057	0.0265	0.0228	15.0	15.96
68	680	0.0072	0.0266	2.3606	1.1306	0.0213	2.1322	0.0265	0.0229	15.1	15.60
69	690	0.0072	0.0266	2.3872	1.1520	0.0214	2.1587	0.0265	0.0230	15.1	15.40
70	700	0.0072	0.0266	2.4139	1.1735	0.0215	2.1851	0.0265	0.0230	15.1	15.29
71	710	0.0072	0.0266	2.4405	1.1951	0.0216	2.2116	0.0265	0.0231	15.2	15.23
72	720	0.0072	0.0266	2.4672	1.2167	0.0216	2.2381	0.0265	0.0231	15.2	15.21
73	730	0.0072	0.0266	2.4938	1.2384	0.0217	2.2646	0.0265	0.0232	15.2	15.21
74	740	0.0072	0.0266	2.5204	1.2602	0.0218	2.2911	0.0265	0.0232	15.3	15.22
75	750	0.0072	0.0266	2.5471	1.2820	0.0218	2.3175	0.0265	0.0233	15.3	15.24
76	760	0.0072	0.0266	2.5737	1.3039	0.0219	2.3440	0.0265	0.0233	15.3	15.26
77	770	0.0057	0.0211	2.5948	1.3213	0.0174	2.3650	0.0210	0.0185	12.1	14.68
78	780	0.0057	0.0211	2.6159	1.3388	0.0174	2.3860	0.0210	0.0185	12.2	13.72
79	790	0.0057	0.0211	2.6370	1.3562	0.0175	2.4070	0.0210	0.0185	12.2	13.13
80	800	0.0057	0.0211	2.6581	1.3737	0.0175	2.4279	0.0210	0.0186	12.2	12.77
81	810	0.0057	0.0211	2.6792	1.3913	0.0175	2.4489	0.0210	0.0186	12.2	12.56
82	820	0.0057	0.0211	2.7003	1.4089	0.0176	2.4699	0.0210	0.0186	12.2	12.43
83	830	0.0057	0.0211	2.7214	1.4265	0.0176	2.4909	0.0210	0.0186	12.3	12.36
84	840	0.0057	0.0211	2.7424	1.4441	0.0177	2.5119	0.0210	0.0187	12.3	12.32
85	850	0.0057	0.0211	2.7635	1.4618	0.0177	2.5329	0.0210	0.0187	12.3	12.31
86	860	0.0057	0.0211	2.7846	1.4796	0.0177	2.5539	0.0210	0.0187	12.3	12.30
87	870	0.0057	0.0211	2.8057	1.4973	0.0178	2.5748	0.0210	0.0187	12.3	12.31
88	880	0.0057	0.0211	2.8268	1.5151	0.0178	2.5958	0.0210	0.0188	12.3	12.31
89	890	0.0050	0.0185	2.8453	1.5308	0.0156	2.6142	0.0184	0.0165	10.8	12.04
90	900	0.0050	0.0185	2.8638	1.5464	0.0157	2.6327	0.0184	0.0165	10.8	11.58
91	910	0.0050	0.0185	2.8823	1.5621	0.0157	2.6511	0.0184	0.0165	10.9	11.30
92	920	0.0050	0.0185	2.9008	1.5778	0.0157	2.6695	0.0184	0.0165	10.9	11.13
93	930	0.0050	0.0185	2.9193	1.5936	0.0157	2.6879	0.0184	0.0166	10.9	11.03
94	940	0.0050	0.0185	2.9378	1.6093	0.0158	2.7063	0.0184	0.0166	10.9	10.98
95	950	0.0050	0.0185	2.9563	1.6251	0.0158	2.7248	0.0184	0.0166	10.9	10.95
96	960	0.0050	0.0185	2.9748	1.6409	0.0158	2.7432	0.0184	0.0166	10.9	10.93
97	970	0.0050	0.0185	2.9933	1.6567	0.0158	2.7616	0.0184	0.0166	10.9	10.93
98	980	0.0050	0.0185	3.0118	1.6726	0.0159	2.7800	0.0184	0.0166	10.9	10.93
99	990	0.0050	0.0185	3.0303	1.6885	0.0159	2.7984	0.0184	0.0167	10.9	10.93
100	1000	0.0050	0.0185	3.0488	1.7044	0.0159	2.8169	0.0184	0.0167	11.0	10.94
101	1010	0.0040	0.0148	3.0636	1.7171	0.0127	2.8316	0.0147	0.0133	8.8	10.53
102	1020	0.0040	0.0148	3.0784	1.7299	0.0127	2.8464	0.0147	0.0134	8.8	9.86
103	1030	0.0040	0.0148	3.0932	1.7426	0.0128	2.8611	0.0147	0.0134	8.8	9.45
104	1040	0.0040	0.0148	3.1080	1.7554	0.0128	2.8758	0.0147	0.0134	8.8	9.20
105	1050	0.0040	0.0148	3.1228	1.7682	0.0128	2.8906	0.0147	0.0134	8.8	9.04
106	1060	0.0040	0.0148	3.1376	1.7810	0.0128	2.9053	0.0147	0.0134	8.8	8.95
107	1070	0.0040	0.0148	3.1524	1.7938	0.0128	2.9201	0.0147	0.0134	8.8	8.90
108	1080	0.0040	0.0148	3.1672	1.8066	0.0128	2.9348	0.0147	0.0134	8.8	8.86
109	1090	0.0040	0.0148	3.1820	1.8195	0.0128	2.9496	0.0147	0.0134	8.8	8.85
110	1100	0.0040	0.0148	3.1968	1.8323	0.0129	2.9643	0.0147	0.0134	8.8	8.84
111	1110	0.0040	0.0148	3.2116	1.8452	0.0129	2.9790	0.0147	0.0134	8.8	8.84
112	1120	0.0040	0.0148	3.2264	1.8581	0.0129	2.9938	0.0147	0.0134	8.8	8.84
113	1130	0.0040	0.0148	3.2412	1.8710	0.0129	3.0085	0.0147	0.0135	8.8	8.84
114	1140	0.0040	0.0148	3.2560	1.8839	0.0129	3.0233	0.0147	0.0135	8.9	8.84
115	1150	0.0040	0.0148	3.2708	1.8968	0.0129	3.0380	0.0147	0.0135	8.9	8.85
116	1160	0.0040	0.0148	3.2856	1.9097	0.0129	3.0528	0.0147	0.0135	8.9	8.85
117	1170	0.0040	0.0148	3.3004	1.9227	0.0129	3.0675	0.0147	0.0135	8.9	8.86
118	1180	0.0040	0.0148	3.3152	1.9356	0.0130	3.0823	0.0147	0.0135	8.9	8.86
119	1190	0.0040	0.0148	3.3300	1.9486	0.0130	3.0970	0.0147	0.0135	8.9	8.87
120	1200	0.0040	0.0148	3.3448	1.9616	0.0130	3.1118	0.0147	0.0135	8.9	8.87
121	1210	0.0040	0.0148	3.3596	1.9746	0.0130	3.1265	0.0148	0.0135	8.9	8.88
122	1220	0.0040	0.0148	3.3744	1.9876	0.0130	3.1413	0.0148	0.0135	8.9	8.88
123	1230	0.0040	0.0148	3.3892	2.0006	0.0130	3.1560	0.0148	0.0135	8.9	8.89
124	1240	0.0040	0.0148	3.4040	2.0136	0.0130	3.1708	0.0148	0.0135	8.9	8.89
125	1250	0.0040	0.0148	3.4188	2.0266	0.0130	3.1855	0.0148	0.0136	8.9	8.90
126	1260	0.0040	0.0148	3.4336	2.0397	0.0130	3.2003	0.0148	0.0136	8.9	8.91
127	1270	0.0040	0.0148	3.4484	2.0527	0.0131	3.2150	0.0148	0.0136	8.9	8.91
128	1280	0.0040	0.0148	3.4632	2.0658	0.0131	3.2298	0.0148	0.0136	8.9	8.92
129	1290	0.0040	0.0148	3.4780	2.0789	0.0131	3.2445	0.0148	0.0136	8.9	8.92
130	1300	0.0040	0.0148	3.4928	2.0920	0.0131	3.2593	0.0148	0.0136	8.9	8.93
131	1310	0.0040	0.0148	3.5076	2.1051	0.0131	3.2740	0.0148	0.0136	8.9	8.93
132	1320	0.0040	0.0148	3.5224	2.1182	0.0131	3.2888	0.0148	0.0136	8.9	8.94
133	1330	0.0040	0.0148	3.5372	2.1313	0.0131	3.3036	0.0148	0.0136	9.0	8.94
134	1340	0.0040	0.0148	3.5520	2.1444	0.0131	3.3183	0.0148	0.0136	9.0	8.95
135	1350	0.0040	0.0148	3.5668	2.1576	0.0131	3.3331	0.0148	0.0136	9.0	8.95
136	1360	0.0040	0.0148	3.5816	2.1707	0.0132	3.3478	0.0148	0.0136	9.0	8.95
137	1370	0.0040	0.0148	3.5964	2.1839	0.0132	3.3626	0.0148	0.0136	9.0	8.96
138	1380	0.0040	0.0148	3.6112	2.1971	0.0132	3.3773	0.0148	0.0137	9.0	8.96
139	1390	0.0040	0.0148	3.6260	2.2102	0.0132	3.3921	0.0148	0.0137	9.0	8.97
140	1400	0.0040	0.0148	3.6408	2.2234	0.0132	3.4069	0.0148	0.0137	9.0	8.97
141	1410	0.0040	0.0148	3.6556	2.2366	0.0132	3.4216	0.0148	0.0137	9.0	8.98
142	1420	0.0040	0.0148	3.6704	2.2498	0.0132	3.4364	0.0148	0.0137	9.0	8.98
143	1430	0.0040	0.0148	3.6852	2.2631	0.0132	3.4511	0.0148	0.0137	9.0	8.99
144	1440	0.0040	0.0148	3.7000	2.2763	0.0132	3.4659	0.0148	0.0137	9.0	8.99

Total Volume of Runoff[1] = 1,028,870 cu. ft.

Notes:

1. Total Runoff Volume is found by summing column (12) and multiplying by the time step, dt as follows:

   V = SumQ x dt
   V(cu.ft.) = SumQ(cu.ft/s) x dt(min.) x (60 s/min.)

Future-Blackmans, 25 yr flow, PVC, S=6.8%

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Diameter

Input Data

Roughness Coefficient	0.010	
Channel Slope	0.06800	ft/ft
Normal Depth	1.72	ft
Diameter	1.72	ft
Discharge	51.57	ft³/s

Results

Diameter	1.72	ft
Normal Depth	1.72	ft
Flow Area	2.33	ft²
Wetted Perimeter	5.41	ft
Hydraulic Radius	0.43	ft
Top Width	0.00	ft
Critical Depth	1.72	ft
Percent Full	100.0	%
Critical Slope	0.06549	ft/ft
Velocity	22.11	ft/s
Velocity Head	7.60	ft
Specific Energy	9.32	ft
Froude Number	0.00	
Maximum Discharge	55.47	ft³/s
Discharge Full	51.56	ft³/s
Slope Full	0.06802	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%

Future-Blackmans, 25 yr flow, PVC, S=6.8%

GVF Output Data

Normal Depth Over Rise	100.00	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.72	ft
Critical Depth	1.72	ft
Channel Slope	0.06800	ft/ft
Critical Slope	0.06549	ft/ft

Future-Blackmans, 100 yr flow, PVC, S=6.8%

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Diameter

Input Data

Roughness Coefficient	0.010	
Channel Slope	0.06800	ft/ft
Normal Depth	1.89	ft
Diameter	1.89	ft
Discharge	65.82	ft^3/s

Results

Diameter	1.89	ft
Normal Depth	1.89	ft
Flow Area	2.80	ft^2
Wetted Perimeter	5.93	ft
Hydraulic Radius	0.47	ft
Top Width	0.00	ft
Critical Depth	1.89	ft
Percent Full	100.0	%
Critical Slope	0.06552	ft/ft
Velocity	23.49	ft/s
Velocity Head	8.58	ft
Specific Energy	10.46	ft
Froude Number	0.00	
Maximum Discharge	70.82	ft^3/s
Discharge Full	65.83	ft^3/s
Slope Full	0.06797	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%

Future-Blackmans, 100 yr flow, PVC, S=6.8%

GVF Output Data

Normal Depth Over Rise	100.00	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.89	ft
Critical Depth	1.89	ft
Channel Slope	0.06800	ft/ft
Critical Slope	0.06552	ft/ft

City of Snohomish
Stormwater Comprehensive Plan
Time of Concentration
Blackmans - Future-Lake

Calculate Time of Concentration (Tc)

Tc = Sum(Tt)

Where:

Tt = travel time (min) = $\frac{L}{(60xV)}$ (for shallow concentrated flow or channel flow)

Tt = travel time (min)= $\frac{0.42(n_s L)^{0.8}}{(P_2)^{0.5}(s_o)^{0.4}}$ (for sheet flow)

Where:

V = avg. velocity (ft/s) = $V = k(s_o)^{0.5}$

k = time of concentration velocity factor (ft/s)

L = flow length (ft)

n_s = sheet flow Manning's effective roughness coefficient

P_2 = 2-year, 24-hour rainfall (in)

s_o = slope of hydraulic grade line (land slope, ft/ft)

	L (ft)	$k_{s/c}$	V (fps)	n_s	P_2	s_o (ft/ft)	Tt (min)
a - sheet	100	NA	NA	0.24	1.8	0.030	16.2
b - channel	195	17	2.9	NA	NA	0.030	1.1
c - channel	2445	42	10.3	NA	NA	0.06	4.0
Total (Tc)							21.2

Minimum Allowable Tc = 6.0 minutes

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

Project: City of Snohomish - Stormwater Comp Plan
Basin: Blackmans Lake - Future
Storm Event: 25-YEAR, 24-HOUR
Given:

Area = 108.65 acres
Pt = 3.05 inches
dt = 10 min.
Tc = 21.2 min.

PERVIOUS AREA			IMPERVIOUS AREA (Roads)		
Area	=	51.85 acres	Area	=	56.80 acres
CN	=	86	CN	=	98
S	=	1.63	S	=	0.20
0.2S	=	0.33	0.2S	=	0.04

SUMMARY	
T_{pk}(hrs)=	7.83
T_c (min)=	21.2
Q_{pk}(cfs)=	51.57
Vol(cf)=	892,533

Compute: Runoff Hydrograph

Column (3) = SCS Type IA Rainfall Distribution
Column (4) = Col. (3) x Pt
Column (5) = Accumulated Sum of Col. (4)
Column (6) = [If P <= 0.2S] = 0; Note, use PERVIOUS Area "S" value.
[If P > 0.2S] = (Col.(5) - 0.2S)^2/(Col.(5) + 0.8S); Using the PERVIOUS Area "S" value.
Column (7) = Col.(6) of Present Time Step - Col.(6) of Previous Time Step
Column (8) = Same method as for Col.(6), except use the IMPERVIOUS Area "S" value.
Column (9) = Col.(8) of the present time step - Col.(8) of the previous time step.
Column (10) = ((PERVIOUS area / Total area) x Col.(7)) + ((IMPERVIOUS area / Total area) x Col.(9))
Column (11) = (60.5 x Col.(10) x Total Area) / 10 (dt = 10 minutes)
Routing Constant, w = dt / (2Tc + dt) = 0.1908
Column (12) = Col.(12) of Previous Time Step + (w x [Col.(11) of Previous Time Step
+ Col.(11) of Present Time Step - (2 x Col.(12) of Previous Time Step)])

					Pervious Area		Impervious Area					
(1) Time Increment	(2) Time	(3) Rainfall distri-bution	(4) Incre-mental Rainfall	(5) Accumu-lated Rainfall	(6) Accumu-lated Runoff	(7) Incre-mental Runoff	(8) Accumu-lated Runoff	(9) Incre-mental Runoff	(10) Total Runoff	(11) Instant hydro-graph	(12) design hydro-graph	
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs	
1	10	0.0040	0.0122	0.0122	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
2	20	0.0040	0.0122	0.0244	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
3	30	0.0040	0.0122	0.0366	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
4	40	0.0040	0.0122	0.0488	0.0000	0.0000	0.0003	0.0003	0.0002	0.1	0.02	
5	50	0.0040	0.0122	0.0610	0.0000	0.0000	0.0018	0.0015	0.0008	0.5	0.13	
6	60	0.0040	0.0122	0.0732	0.0000	0.0000	0.0044	0.0026	0.0014	0.9	0.35	
7	70	0.0040	0.0122	0.0854	0.0000	0.0000	0.0080	0.0036	0.0019	1.2	0.62	
8	80	0.0040	0.0122	0.0976	0.0000	0.0000	0.0124	0.0044	0.0023	1.5	0.90	
9	90	0.0040	0.0122	0.1098	0.0000	0.0000	0.0174	0.0051	0.0026	1.7	1.18	
10	100	0.0040	0.0122	0.1220	0.0000	0.0000	0.0231	0.0057	0.0030	2.0	1.43	
11	110	0.0050	0.0153	0.1373	0.0000	0.0000	0.0309	0.0078	0.0041	2.7	1.77	
12	120	0.0050	0.0153	0.1525	0.0000	0.0000	0.0395	0.0086	0.0045	2.9	2.17	
13	130	0.0050	0.0153	0.1678	0.0000	0.0000	0.0487	0.0092	0.0048	3.2	2.51	
14	140	0.0050	0.0153	0.1830	0.0000	0.0000	0.0584	0.0097	0.0051	3.3	2.79	
15	150	0.0050	0.0153	0.1983	0.0000	0.0000	0.0686	0.0102	0.0053	3.5	3.03	
16	160	0.0050	0.0153	0.2135	0.0000	0.0000	0.0791	0.0106	0.0055	3.6	3.23	
17	170	0.0060	0.0183	0.2318	0.0000	0.0000	0.0923	0.0132	0.0069	4.5	3.56	
18	180	0.0060	0.0183	0.2501	0.0000	0.0000	0.1060	0.0136	0.0071	4.7	3.96	
19	190	0.0060	0.0183	0.2684	0.0000	0.0000	0.1200	0.0140	0.0073	4.8	4.26	
20	200	0.0060	0.0183	0.2867	0.0000	0.0000	0.1344	0.0144	0.0075	4.9	4.50	
21	210	0.0060	0.0183	0.3050	0.0000	0.0000	0.1490	0.0147	0.0077	5.0	4.69	
22	220	0.0060	0.0183	0.3233	0.0000	0.0000	0.1640	0.0150	0.0078	5.1	4.84	
23	230	0.0070	0.0214	0.3447	0.0002	0.0002	0.1818	0.0178	0.0094	6.2	5.15	
24	240	0.0070	0.0214	0.3660	0.0010	0.0008	0.1998	0.0180	0.0098	6.4	5.59	
25	250	0.0070	0.0214	0.3874	0.0023	0.0013	0.2181	0.0183	0.0102	6.7	5.96	
26	260	0.0070	0.0214	0.4087	0.0040	0.0018	0.2366	0.0185	0.0105	6.9	6.28	
27	270	0.0070	0.0214	0.4301	0.0063	0.0023	0.2553	0.0187	0.0109	7.1	6.57	
28	280	0.0070	0.0214	0.4514	0.0090	0.0027	0.2743	0.0189	0.0112	7.4	6.83	
29	290	0.0082	0.0250	0.4764	0.0128	0.0038	0.2966	0.0224	0.0135	8.9	7.32	
30	300	0.0082	0.0250	0.5014	0.0171	0.0044	0.3192	0.0226	0.0139	9.1	7.96	
31	310	0.0082	0.0250	0.5264	0.0221	0.0049	0.3419	0.0227	0.0142	9.4	8.45	
32	320	0.0082	0.0250	0.5514	0.0275	0.0055	0.3648	0.0229	0.0146	9.6	8.84	
33	330	0.0082	0.0250	0.5765	0.0335	0.0060	0.3879	0.0230	0.0149	9.8	9.16	
34	340	0.0082	0.0250	0.6015	0.0400	0.0065	0.4110	0.0232	0.0152	10.0	9.44	
35	350	0.0095	0.0290	0.6304	0.0481	0.0081	0.4380	0.0270	0.0180	11.8	10.00	
36	360	0.0095	0.0290	0.6594	0.0568	0.0087	0.4651	0.0271	0.0183	12.1	10.74	
37	370	0.0095	0.0290	0.6884	0.0661	0.0093	0.4924	0.0273	0.0187	12.3	11.29	
38	380	0.0095	0.0290	0.7174	0.0760	0.0099	0.5198	0.0274	0.0190	12.5	11.71	
39	390	0.0095	0.0290	0.7463	0.0864	0.0104	0.5472	0.0275	0.0193	12.7	12.05	
40	400	0.0095	0.0290	0.7753	0.0973	0.0109	0.5748	0.0276	0.0196	12.9	12.34	
41	410	0.0134	0.0409	0.8162	0.1136	0.0163	0.6138	0.0390	0.0282	18.5	13.62	
42	420	0.0134	0.0409	0.8570	0.1308	0.0172	0.6530	0.0392	0.0287	18.9	15.55	
43	430	0.0134	0.0409	0.8979	0.1489	0.0181	0.6923	0.0393	0.0292	19.2	16.87	
44	440	0.0180	0.0549	0.9528	0.1745	0.0256	0.7452	0.0530	0.0399	26.2	19.10	
45	450	0.0180	0.0549	1.0077	0.2014	0.0270	0.7984	0.0532	0.0407	26.7	21.91	
46	460	0.0340	0.1037	1.1114	0.2558	0.0544	0.8992	0.1008	0.0787	51.7	28.52	
47	470	0.0540	0.1647	1.2761	0.3504	0.0946	1.0602	0.1610	0.1293	85.0	43.72	
48	480	0.0270	0.0824	1.3585	0.4010	0.0505	1.1409	0.0808	0.0664	43.6	51.57	Q peak
49	490	0.0180	0.0549	1.4134	0.4357	0.0348	1.1949	0.0539	0.0448	29.4	45.83	
50	500	0.0134	0.0409	1.4542	0.4621	0.0264	1.2351	0.0402	0.0336	22.1	38.17	
51	510	0.0134	0.0409	1.4951	0.4889	0.0268	1.2753	0.0402	0.0338	22.2	32.07	
52	520	0.0134	0.0409	1.5360	0.5162	0.0272	1.3156	0.0403	0.0340	22.4	28.34	
53	530	0.0088	0.0268	1.5628	0.5343	0.0181	1.3421	0.0265	0.0225	14.8	24.61	
54	540	0.0088	0.0268	1.5897	0.5525	0.0183	1.3685	0.0265	0.0226	14.8	20.87	
55	550	0.0088	0.0268	1.6165	0.5709	0.0184	1.3950	0.0265	0.0226	14.9	18.57	
56	560	0.0088	0.0268	1.6433	0.5895	0.0186	1.4215	0.0265	0.0227	14.9	17.17	
57	570	0.0088	0.0268	1.6702	0.6082	0.0187	1.4480	0.0265	0.0228	15.0	16.32	
58	580	0.0088	0.0268	1.6970	0.6271	0.0189	1.4745	0.0265	0.0229	15.0	15.82	
59	590	0.0088	0.0268	1.7239	0.6461	0.0190	1.5010	0.0265	0.0229	15.1	15.53	
60	600	0.0088	0.0268	1.7507	0.6652	0.0191	1.5276	0.0265	0.0230	15.1	15.36	
61	610	0.0088	0.0268	1.7775	0.6845	0.0193	1.5541	0.0265	0.0231	15.2	15.28	
62	620	0.0088	0.0268	1.8044	0.7039	0.0194	1.5806	0.0265	0.0231	15.2	15.24	
63	630	0.0088	0.0268	1.8312	0.7234	0.0195	1.6072	0.0266	0.0232	15.3	15.24	
64	640	0.0088	0.0268	1.8581	0.7431	0.0197	1.6338	0.0266	0.0233	15.3	15.25	
65	650	0.0072	0.0220	1.8800	0.7593	0.0162	1.6555	0.0217	0.0191	12.5	14.74	

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

					Pervious Area		Impervious Area				
(1) Time Increment	(2) Time	(3) Rainfall distri- bution	(4) Incre- mental Rainfall	(5) Accumu- lated Rainfall	(6) Accumu- lated Runoff	(7) Incre- mental Runoff	(8) Accumu- lated Runoff	(9) Incre- mental Runoff	(10) Total Runoff	(11) Instant hydro- graph	(12) design hydro- graph
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs
66	660	0.0072	0.0220	1.9020	0.7755	0.0163	1.6772	0.0217	0.0191	12.6	13.91
67	670	0.0072	0.0220	1.9239	0.7919	0.0163	1.6990	0.0217	0.0192	12.6	13.40
68	680	0.0072	0.0220	1.9459	0.8083	0.0164	1.7207	0.0218	0.0192	12.6	13.10
69	690	0.0072	0.0220	1.9679	0.8247	0.0165	1.7425	0.0218	0.0192	12.6	12.92
70	700	0.0072	0.0220	1.9898	0.8413	0.0166	1.7643	0.0218	0.0193	12.7	12.82
71	710	0.0072	0.0220	2.0118	0.8579	0.0166	1.7860	0.0218	0.0193	12.7	12.77
72	720	0.0072	0.0220	2.0337	0.8746	0.0167	1.8078	0.0218	0.0193	12.7	12.74
73	730	0.0072	0.0220	2.0557	0.8914	0.0168	1.8296	0.0218	0.0194	12.7	12.74
74	740	0.0072	0.0220	2.0777	0.9082	0.0168	1.8513	0.0218	0.0194	12.8	12.74
75	750	0.0072	0.0220	2.0996	0.9251	0.0169	1.8731	0.0218	0.0195	12.8	12.76
76	760	0.0072	0.0220	2.1216	0.9421	0.0170	1.8949	0.0218	0.0195	12.8	12.77
77	770	0.0057	0.0174	2.1390	0.9556	0.0135	1.9122	0.0172	0.0154	10.2	12.28
78	780	0.0057	0.0174	2.1564	0.9691	0.0135	1.9294	0.0172	0.0155	10.2	11.47
79	790	0.0057	0.0174	2.1737	0.9826	0.0136	1.9467	0.0173	0.0155	10.2	10.98
80	800	0.0057	0.0174	2.1911	0.9962	0.0136	1.9639	0.0173	0.0155	10.2	10.67
81	810	0.0057	0.0174	2.2085	1.0098	0.0136	1.9812	0.0173	0.0155	10.2	10.49
82	820	0.0057	0.0174	2.2259	1.0235	0.0137	1.9984	0.0173	0.0155	10.2	10.39
83	830	0.0057	0.0174	2.2433	1.0372	0.0137	2.0157	0.0173	0.0156	10.2	10.32
84	840	0.0057	0.0174	2.2607	1.0510	0.0137	2.0329	0.0173	0.0156	10.2	10.29
85	850	0.0057	0.0174	2.2780	1.0647	0.0138	2.0502	0.0173	0.0156	10.3	10.27
86	860	0.0057	0.0174	2.2954	1.0785	0.0138	2.0675	0.0173	0.0156	10.3	10.27
87	870	0.0057	0.0174	2.3128	1.0924	0.0138	2.0847	0.0173	0.0156	10.3	10.27
88	880	0.0057	0.0174	2.3302	1.1063	0.0139	2.1020	0.0173	0.0156	10.3	10.27
89	890	0.0050	0.0153	2.3455	1.1185	0.0122	2.1172	0.0151	0.0137	9.0	10.04
90	900	0.0050	0.0153	2.3607	1.1307	0.0122	2.1323	0.0151	0.0138	9.0	9.66
91	910	0.0050	0.0153	2.3760	1.1429	0.0123	2.1475	0.0152	0.0138	9.0	9.42
92	920	0.0050	0.0153	2.3912	1.1552	0.0123	2.1626	0.0152	0.0138	9.1	9.28
93	930	0.0050	0.0153	2.4065	1.1675	0.0123	2.1778	0.0152	0.0138	9.1	9.20
94	940	0.0050	0.0153	2.4217	1.1798	0.0123	2.1929	0.0152	0.0138	9.1	9.15
95	950	0.0050	0.0153	2.4370	1.1922	0.0123	2.2081	0.0152	0.0138	9.1	9.12
96	960	0.0050	0.0153	2.4522	1.2045	0.0124	2.2232	0.0152	0.0138	9.1	9.11
97	970	0.0050	0.0153	2.4675	1.2169	0.0124	2.2384	0.0152	0.0138	9.1	9.10
98	980	0.0050	0.0153	2.4827	1.2294	0.0124	2.2535	0.0152	0.0139	9.1	9.10
99	990	0.0050	0.0153	2.4980	1.2418	0.0124	2.2687	0.0152	0.0139	9.1	9.10
100	1000	0.0050	0.0153	2.5132	1.2543	0.0125	2.2839	0.0152	0.0139	9.1	9.11
101	1010	0.0040	0.0122	2.5254	1.2642	0.0100	2.2960	0.0121	0.0111	7.3	8.77
102	1020	0.0040	0.0122	2.5376	1.2743	0.0100	2.3081	0.0121	0.0111	7.3	8.21
103	1030	0.0040	0.0122	2.5498	1.2843	0.0100	2.3203	0.0121	0.0111	7.3	7.86
104	1040	0.0040	0.0122	2.5620	1.2943	0.0100	2.3324	0.0121	0.0111	7.3	7.65
105	1050	0.0040	0.0122	2.5742	1.3043	0.0100	2.3445	0.0121	0.0111	7.3	7.52
106	1060	0.0040	0.0122	2.5864	1.3144	0.0101	2.3566	0.0121	0.0111	7.3	7.45
107	1070	0.0040	0.0122	2.5986	1.3245	0.0101	2.3688	0.0121	0.0111	7.3	7.40
108	1080	0.0040	0.0122	2.6108	1.3345	0.0101	2.3809	0.0121	0.0112	7.3	7.37
109	1090	0.0040	0.0122	2.6230	1.3446	0.0101	2.3931	0.0121	0.0112	7.3	7.36
110	1100	0.0040	0.0122	2.6352	1.3547	0.0101	2.4052	0.0121	0.0112	7.3	7.35
111	1110	0.0040	0.0122	2.6474	1.3649	0.0101	2.4173	0.0121	0.0112	7.3	7.35
112	1120	0.0040	0.0122	2.6596	1.3750	0.0101	2.4295	0.0121	0.0112	7.3	7.35
113	1130	0.0040	0.0122	2.6718	1.3851	0.0101	2.4416	0.0121	0.0112	7.4	7.35
114	1140	0.0040	0.0122	2.6840	1.3953	0.0102	2.4537	0.0121	0.0112	7.4	7.35
115	1150	0.0040	0.0122	2.6962	1.4055	0.0102	2.4659	0.0121	0.0112	7.4	7.35
116	1160	0.0040	0.0122	2.7084	1.4157	0.0102	2.4780	0.0121	0.0112	7.4	7.36
117	1170	0.0040	0.0122	2.7206	1.4259	0.0102	2.4901	0.0121	0.0112	7.4	7.36
118	1180	0.0040	0.0122	2.7328	1.4361	0.0102	2.5023	0.0121	0.0112	7.4	7.37
119	1190	0.0040	0.0122	2.7450	1.4463	0.0102	2.5144	0.0121	0.0112	7.4	7.37
120	1200	0.0040	0.0122	2.7572	1.4565	0.0102	2.5266	0.0121	0.0112	7.4	7.37
121	1210	0.0040	0.0122	2.7694	1.4668	0.0102	2.5387	0.0121	0.0112	7.4	7.38
122	1220	0.0040	0.0122	2.7816	1.4770	0.0103	2.5508	0.0121	0.0112	7.4	7.38
123	1230	0.0040	0.0122	2.7938	1.4873	0.0103	2.5630	0.0121	0.0112	7.4	7.38
124	1240	0.0040	0.0122	2.8060	1.4976	0.0103	2.5751	0.0121	0.0113	7.4	7.39
125	1250	0.0040	0.0122	2.8182	1.5079	0.0103	2.5873	0.0121	0.0113	7.4	7.39
126	1260	0.0040	0.0122	2.8304	1.5182	0.0103	2.5994	0.0121	0.0113	7.4	7.40
127	1270	0.0040	0.0122	2.8426	1.5285	0.0103	2.6116	0.0121	0.0113	7.4	7.40
128	1280	0.0040	0.0122	2.8548	1.5388	0.0103	2.6237	0.0121	0.0113	7.4	7.40
129	1290	0.0040	0.0122	2.8670	1.5491	0.0103	2.6358	0.0121	0.0113	7.4	7.41
130	1300	0.0040	0.0122	2.8792	1.5595	0.0103	2.6480	0.0121	0.0113	7.4	7.41
131	1310	0.0040	0.0122	2.8914	1.5698	0.0104	2.6601	0.0121	0.0113	7.4	7.41
132	1320	0.0040	0.0122	2.9036	1.5802	0.0104	2.6723	0.0121	0.0113	7.4	7.42
133	1330	0.0040	0.0122	2.9158	1.5906	0.0104	2.6844	0.0121	0.0113	7.4	7.42
134	1340	0.0040	0.0122	2.9280	1.6010	0.0104	2.6966	0.0121	0.0113	7.4	7.43
135	1350	0.0040	0.0122	2.9402	1.6114	0.0104	2.7087	0.0121	0.0113	7.4	7.43
136	1360	0.0040	0.0122	2.9524	1.6218	0.0104	2.7209	0.0121	0.0113	7.4	7.43
137	1370	0.0040	0.0122	2.9646	1.6322	0.0104	2.7330	0.0121	0.0113	7.4	7.44
138	1380	0.0040	0.0122	2.9768	1.6426	0.0104	2.7452	0.0121	0.0113	7.4	7.44
139	1390	0.0040	0.0122	2.9890	1.6531	0.0104	2.7573	0.0121	0.0113	7.4	7.44
140	1400	0.0040	0.0122	3.0012	1.6635	0.0104	2.7695	0.0121	0.0113	7.5	7.45
141	1410	0.0040	0.0122	3.0134	1.6740	0.0105	2.7816	0.0121	0.0113	7.5	7.45
142	1420	0.0040	0.0122	3.0256	1.6844	0.0105	2.7938	0.0121	0.0113	7.5	7.45
143	1430	0.0040	0.0122	3.0378	1.6949	0.0105	2.8059	0.0122	0.0114	7.5	7.46
144	1440	0.0040	0.0122	3.0500	1.7054	0.0105	2.8181	0.0122	0.0114	7.5	7.46

Total Volume of Runoff[1] = 892,533 cu. ft.

Notes:

1. Total Runoff Volume is found by summing column (12) and multiplying by the time step, dt as follows:

   V = SumQ x dt
   V(cu.ft.) = SumQ(cu.ft/s) x dt(min.) x (60 s/min.)

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

Project: City of Snohomish - Stormwater Comp Plan
Basin: Blackmans Lake - Future
Storm Event: 100-YEAR, 24-HOUR
Given:

Area = 108.65 acres
Pt = 3.70 inches
dt = 10 min.
Tc = 21.2 min.

PERVIOUS AREA			IMPERVIOUS AREA (Roads)		
Area	=	51.85 acres	Area	=	56.80 acres
CN	=	86	CN	=	98
S	=	1.63	S	=	0.20
0.2S	=	0.33	0.2S	=	0.04

SUMMARY	
T_{pk}(hrs)=	7.83
T_c (min)=	21.2
Q_{pk}(cfs)=	65.82
Vol(cf)=	1,131,318

Compute: Runoff Hydrograph

Column (3) = SCS Type IA Rainfall Distribution
Column (4) = Col. (3) x Pt
Column (5) = Accumulated Sum of Col. (4)
Column (6) = [If P <= 0.2S] = 0; Note, use PERVIOUS Area "S" value.
[If P > 0.2S] = (Col.(5) - 0.2S)^2/(Col.(5) + 0.8S); Using the PERVIOUS Area "S" value.
Column (7) = Col.(6) of Present Time Step - Col.(6) of Previous Time Step
Column (8) = Same method as for Col.(6), except use the IMPERVIOUS Area "S" value.
Column (9) = Col.(8) of the present time step - Col.(8) of the previous time step.
Column (10) = ((PERVIOUS area / Total area) x Col.(7)) + ((IMPERVIOUS area / Total area) x Col.(9))
Column (11) = (60.5 x Col.(10) x Total Area) / 10 (dt = 10 minutes)
Routing Constant, w = dt / (2Tc + dt) = 0.1908
Column (12) = Col.(12) of Previous Time Step + (w x [Col.(11) of Previous Time Step
+ Col.(11) of Present Time Step - (2 x Col.(12) of Previous Time Step)])

					Pervious Area		Impervious Area					
(1) Time Increment	(2) Time	(3) Rainfall distri-bution	(4) Incre-mental Rainfall	(5) Accumu-lated Rainfall	(6) Accumu-lated Runoff	(7) Incre-mental Runoff	(8) Accumu-lated Runoff	(9) Incre-mental Runoff	(10) Total Runoff	(11) Instant hydro-graph	(12) design hydro-graph	
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs	
1	10	0.0040	0.0148	0.0148	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
2	20	0.0040	0.0148	0.0296	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
3	30	0.0040	0.0148	0.0444	0.0000	0.0000	0.0001	0.0001	0.0000	0.0	0.00	
4	40	0.0040	0.0148	0.0592	0.0000	0.0000	0.0015	0.0015	0.0008	0.5	0.10	
5	50	0.0040	0.0148	0.0740	0.0000	0.0000	0.0046	0.0031	0.0016	1.1	0.36	
6	60	0.0040	0.0148	0.0888	0.0000	0.0000	0.0091	0.0045	0.0023	1.5	0.72	
7	70	0.0040	0.0148	0.1036	0.0000	0.0000	0.0148	0.0056	0.0029	1.9	1.11	
8	80	0.0040	0.0148	0.1184	0.0000	0.0000	0.0214	0.0066	0.0035	2.3	1.49	
9	90	0.0040	0.0148	0.1332	0.0000	0.0000	0.0288	0.0074	0.0039	2.5	1.84	
10	100	0.0040	0.0148	0.1480	0.0000	0.0000	0.0369	0.0081	0.0042	2.8	2.16	
11	110	0.0050	0.0185	0.1665	0.0000	0.0000	0.0479	0.0110	0.0057	3.8	2.59	
12	120	0.0050	0.0185	0.1850	0.0000	0.0000	0.0597	0.0118	0.0062	4.1	3.09	
13	130	0.0050	0.0185	0.2035	0.0000	0.0000	0.0722	0.0125	0.0065	4.3	3.50	
14	140	0.0050	0.0185	0.2220	0.0000	0.0000	0.0852	0.0130	0.0068	4.5	3.84	
15	150	0.0050	0.0185	0.2405	0.0000	0.0000	0.0988	0.0135	0.0071	4.7	4.12	
16	160	0.0050	0.0185	0.2590	0.0000	0.0000	0.1127	0.0140	0.0073	4.8	4.35	
17	170	0.0060	0.0222	0.2812	0.0000	0.0000	0.1300	0.0173	0.0090	5.9	4.74	
18	180	0.0060	0.0222	0.3034	0.0000	0.0000	0.1478	0.0177	0.0093	6.1	5.23	
19	190	0.0060	0.0222	0.3256	0.0000	0.0000	0.1659	0.0181	0.0095	6.2	5.59	
20	200	0.0060	0.0222	0.3478	0.0003	0.0003	0.1844	0.0185	0.0098	6.5	5.88	
21	210	0.0060	0.0222	0.3700	0.0012	0.0009	0.2032	0.0188	0.0103	6.7	6.15	
22	220	0.0060	0.0222	0.3922	0.0026	0.0014	0.2223	0.0191	0.0107	7.0	6.43	
23	230	0.0070	0.0259	0.4181	0.0050	0.0024	0.2448	0.0226	0.0129	8.5	6.93	
24	240	0.0070	0.0259	0.4440	0.0080	0.0031	0.2677	0.0228	0.0134	8.8	7.59	
25	250	0.0070	0.0259	0.4699	0.0118	0.0037	0.2908	0.0231	0.0138	9.1	8.11	
26	260	0.0070	0.0259	0.4958	0.0161	0.0044	0.3141	0.0233	0.0143	9.4	8.54	
27	270	0.0070	0.0259	0.5217	0.0211	0.0050	0.3376	0.0235	0.0147	9.6	8.91	
28	280	0.0070	0.0259	0.5476	0.0266	0.0056	0.3613	0.0237	0.0150	9.9	9.24	
29	290	0.0082	0.0303	0.5779	0.0339	0.0072	0.3892	0.0279	0.0181	11.9	9.86	
30	300	0.0082	0.0303	0.6083	0.0418	0.0080	0.4174	0.0281	0.0185	12.2	10.68	
31	310	0.0082	0.0303	0.6386	0.0505	0.0087	0.4457	0.0283	0.0189	12.4	11.30	
32	320	0.0082	0.0303	0.6690	0.0598	0.0093	0.4741	0.0284	0.0193	12.7	11.79	
33	330	0.0082	0.0303	0.6993	0.0698	0.0100	0.5027	0.0286	0.0197	12.9	12.18	
34	340	0.0082	0.0303	0.7296	0.0803	0.0106	0.5314	0.0287	0.0200	13.2	12.52	
35	350	0.0095	0.0352	0.7648	0.0933	0.0130	0.5648	0.0334	0.0236	15.5	13.22	
36	360	0.0095	0.0352	0.7999	0.1070	0.0137	0.5983	0.0335	0.0241	15.8	14.16	
37	370	0.0095	0.0352	0.8351	0.1215	0.0144	0.6319	0.0336	0.0245	16.1	14.84	
38	380	0.0095	0.0352	0.8702	0.1365	0.0151	0.6656	0.0337	0.0248	16.3	15.36	
39	390	0.0095	0.0352	0.9054	0.1523	0.0157	0.6995	0.0338	0.0252	16.6	15.77	
40	400	0.0095	0.0352	0.9405	0.1686	0.0163	0.7334	0.0339	0.0255	16.8	16.11	
41	410	0.0134	0.0496	0.9901	0.1926	0.0240	0.7813	0.0480	0.0365	24.0	17.75	
42	420	0.0134	0.0496	1.0397	0.2177	0.0251	0.8294	0.0481	0.0371	24.4	20.22	
43	430	0.0134	0.0496	1.0893	0.2439	0.0261	0.8776	0.0482	0.0377	24.8	21.88	
44	440	0.0180	0.0666	1.1559	0.2804	0.0366	0.9426	0.0649	0.0514	33.8	24.70	
45	450	0.0180	0.0666	1.2225	0.3186	0.0382	1.0076	0.0651	0.0522	34.3	28.27	
46	460	0.0340	0.1258	1.3483	0.3946	0.0760	1.1309	0.1233	0.1007	66.2	36.67	
47	470	0.0540	0.1998	1.5481	0.5243	0.1297	1.3275	0.1966	0.1647	108.2	55.97	
48	480	0.0270	0.0999	1.6480	0.5927	0.0684	1.4261	0.0986	0.0842	55.3	65.82	Q peak
49	490	0.0180	0.0666	1.7146	0.6395	0.0468	1.4919	0.0658	0.0567	37.3	58.37	
50	500	0.0134	0.0496	1.7642	0.6749	0.0354	1.5409	0.0490	0.0425	27.9	48.54	
51	510	0.0134	0.0496	1.8137	0.7107	0.0358	1.5899	0.0490	0.0427	28.1	40.71	
52	520	0.0134	0.0496	1.8633	0.7470	0.0363	1.6390	0.0491	0.0430	28.2	35.92	
53	530	0.0088	0.0326	1.8959	0.7710	0.0240	1.6712	0.0322	0.0283	18.6	31.15	
54	540	0.0088	0.0326	1.9284	0.7952	0.0242	1.7035	0.0322	0.0284	18.7	26.38	
55	550	0.0088	0.0326	1.9610	0.8196	0.0244	1.7357	0.0323	0.0285	18.7	23.45	
56	560	0.0088	0.0326	1.9936	0.8441	0.0245	1.7680	0.0323	0.0286	18.8	21.66	
57	570	0.0088	0.0326	2.0261	0.8688	0.0247	1.8002	0.0323	0.0287	18.8	20.57	
58	580	0.0088	0.0326	2.0587	0.8937	0.0248	1.8325	0.0323	0.0287	18.9	19.92	
59	590	0.0088	0.0326	2.0912	0.9187	0.0250	1.8648	0.0323	0.0288	18.9	19.53	
60	600	0.0088	0.0326	2.1238	0.9438	0.0251	1.8971	0.0323	0.0289	19.0	19.32	
61	610	0.0088	0.0326	2.1564	0.9691	0.0253	1.9294	0.0323	0.0290	19.0	19.20	
62	620	0.0088	0.0326	2.1889	0.9945	0.0254	1.9617	0.0323	0.0290	19.1	19.14	
63	630	0.0088	0.0326	2.2215	1.0200	0.0255	1.9940	0.0323	0.0291	19.1	19.13	
64	640	0.0088	0.0326	2.2540	1.0457	0.0257	2.0264	0.0323	0.0292	19.2	19.13	
65	650	0.0072	0.0266	2.2807	1.0668	0.0211	2.0528	0.0265	0.0239	15.7	18.48	

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

					Pervious Area		Impervious Area				
(1) Time Increment	(2) Time	(3) Rainfall distri-bution	(4) Incre-mental Rainfall	(5) Accumu-lated Rainfall	(6) Accumu-lated Runoff	(7) Incre-mental Runoff	(8) Accumu-lated Runoff	(9) Incre-mental Runoff	(10) Total Runoff	(11) Instant hydro-graph	(12) design hydro-graph
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs
66	660	0.0072	0.0266	2.3073	1.0880	0.0212	2.0793	0.0265	0.0239	15.7	17.43
67	670	0.0072	0.0266	2.3340	1.1093	0.0213	2.1057	0.0265	0.0240	15.8	16.79
68	680	0.0072	0.0266	2.3606	1.1306	0.0213	2.1322	0.0265	0.0240	15.8	16.40
69	690	0.0072	0.0266	2.3872	1.1520	0.0214	2.1587	0.0265	0.0241	15.8	16.17
70	700	0.0072	0.0266	2.4139	1.1735	0.0215	2.1851	0.0265	0.0241	15.8	16.04
71	710	0.0072	0.0266	2.4405	1.1951	0.0216	2.2116	0.0265	0.0241	15.9	15.97
72	720	0.0072	0.0266	2.4672	1.2167	0.0216	2.2381	0.0265	0.0242	15.9	15.93
73	730	0.0072	0.0266	2.4938	1.2384	0.0217	2.2646	0.0265	0.0242	15.9	15.92
74	740	0.0072	0.0266	2.5204	1.2602	0.0218	2.2911	0.0265	0.0242	15.9	15.92
75	750	0.0072	0.0266	2.5471	1.2820	0.0218	2.3175	0.0265	0.0243	16.0	15.93
76	760	0.0072	0.0266	2.5737	1.3039	0.0219	2.3440	0.0265	0.0243	16.0	15.94
77	770	0.0057	0.0211	2.5948	1.3213	0.0174	2.3650	0.0210	0.0193	12.7	15.32
78	780	0.0057	0.0211	2.6159	1.3388	0.0174	2.3860	0.0210	0.0193	12.7	14.31
79	790	0.0057	0.0211	2.6370	1.3562	0.0175	2.4070	0.0210	0.0193	12.7	13.69
80	800	0.0057	0.0211	2.6581	1.3737	0.0175	2.4279	0.0210	0.0193	12.7	13.31
81	810	0.0057	0.0211	2.6792	1.3913	0.0175	2.4489	0.0210	0.0193	12.7	13.08
82	820	0.0057	0.0211	2.7003	1.4089	0.0176	2.4699	0.0210	0.0194	12.7	12.94
83	830	0.0057	0.0211	2.7214	1.4265	0.0176	2.4909	0.0210	0.0194	12.7	12.86
84	840	0.0057	0.0211	2.7424	1.4441	0.0177	2.5119	0.0210	0.0194	12.7	12.82
85	850	0.0057	0.0211	2.7635	1.4618	0.0177	2.5329	0.0210	0.0194	12.8	12.79
86	860	0.0057	0.0211	2.7846	1.4796	0.0177	2.5539	0.0210	0.0194	12.8	12.78
87	870	0.0057	0.0211	2.8057	1.4973	0.0178	2.5748	0.0210	0.0194	12.8	12.78
88	880	0.0057	0.0211	2.8268	1.5151	0.0178	2.5958	0.0210	0.0195	12.8	12.78
89	890	0.0050	0.0185	2.8453	1.5308	0.0156	2.6142	0.0184	0.0171	11.2	12.49
90	900	0.0050	0.0185	2.8638	1.5464	0.0157	2.6327	0.0184	0.0171	11.2	12.01
91	910	0.0050	0.0185	2.8823	1.5621	0.0157	2.6511	0.0184	0.0171	11.2	11.72
92	920	0.0050	0.0185	2.9008	1.5778	0.0157	2.6695	0.0184	0.0171	11.3	11.54
93	930	0.0050	0.0185	2.9193	1.5936	0.0157	2.6879	0.0184	0.0171	11.3	11.44
94	940	0.0050	0.0185	2.9378	1.6093	0.0158	2.7063	0.0184	0.0172	11.3	11.37
95	950	0.0050	0.0185	2.9563	1.6251	0.0158	2.7248	0.0184	0.0172	11.3	11.34
96	960	0.0050	0.0185	2.9748	1.6409	0.0158	2.7432	0.0184	0.0172	11.3	11.32
97	970	0.0050	0.0185	2.9933	1.6567	0.0158	2.7616	0.0184	0.0172	11.3	11.31
98	980	0.0050	0.0185	3.0118	1.6726	0.0159	2.7800	0.0184	0.0172	11.3	11.30
99	990	0.0050	0.0185	3.0303	1.6885	0.0159	2.7984	0.0184	0.0172	11.3	11.31
100	1000	0.0050	0.0185	3.0488	1.7044	0.0159	2.8169	0.0184	0.0172	11.3	11.31
101	1010	0.0040	0.0148	3.0636	1.7171	0.0127	2.8316	0.0147	0.0138	9.1	10.88
102	1020	0.0040	0.0148	3.0784	1.7299	0.0127	2.8464	0.0147	0.0138	9.1	10.19
103	1030	0.0040	0.0148	3.0932	1.7426	0.0128	2.8611	0.0147	0.0138	9.1	9.76
104	1040	0.0040	0.0148	3.1080	1.7554	0.0128	2.8758	0.0147	0.0138	9.1	9.50
105	1050	0.0040	0.0148	3.1228	1.7682	0.0128	2.8906	0.0147	0.0138	9.1	9.34
106	1060	0.0040	0.0148	3.1376	1.7810	0.0128	2.9053	0.0147	0.0138	9.1	9.24
107	1070	0.0040	0.0148	3.1524	1.7938	0.0128	2.9201	0.0147	0.0138	9.1	9.18
108	1080	0.0040	0.0148	3.1672	1.8066	0.0128	2.9348	0.0147	0.0138	9.1	9.15
109	1090	0.0040	0.0148	3.1820	1.8195	0.0128	2.9496	0.0147	0.0138	9.1	9.13
110	1100	0.0040	0.0148	3.1968	1.8323	0.0129	2.9643	0.0147	0.0138	9.1	9.11
111	1110	0.0040	0.0148	3.2116	1.8452	0.0129	2.9790	0.0147	0.0138	9.1	9.11
112	1120	0.0040	0.0148	3.2264	1.8581	0.0129	2.9938	0.0147	0.0139	9.1	9.11
113	1130	0.0040	0.0148	3.2412	1.8710	0.0129	3.0085	0.0147	0.0139	9.1	9.11
114	1140	0.0040	0.0148	3.2560	1.8839	0.0129	3.0233	0.0147	0.0139	9.1	9.11
115	1150	0.0040	0.0148	3.2708	1.8968	0.0129	3.0380	0.0147	0.0139	9.1	9.11
116	1160	0.0040	0.0148	3.2856	1.9097	0.0129	3.0528	0.0147	0.0139	9.1	9.12
117	1170	0.0040	0.0148	3.3004	1.9227	0.0129	3.0675	0.0147	0.0139	9.1	9.12
118	1180	0.0040	0.0148	3.3152	1.9356	0.0130	3.0823	0.0147	0.0139	9.1	9.12
119	1190	0.0040	0.0148	3.3300	1.9486	0.0130	3.0970	0.0147	0.0139	9.1	9.13
120	1200	0.0040	0.0148	3.3448	1.9616	0.0130	3.1118	0.0147	0.0139	9.1	9.13
121	1210	0.0040	0.0148	3.3596	1.9746	0.0130	3.1265	0.0148	0.0139	9.1	9.14
122	1220	0.0040	0.0148	3.3744	1.9876	0.0130	3.1413	0.0148	0.0139	9.1	9.14
123	1230	0.0040	0.0148	3.3892	2.0006	0.0130	3.1560	0.0148	0.0139	9.2	9.14
124	1240	0.0040	0.0148	3.4040	2.0136	0.0130	3.1708	0.0148	0.0139	9.2	9.15
125	1250	0.0040	0.0148	3.4188	2.0266	0.0130	3.1855	0.0148	0.0139	9.2	9.15
126	1260	0.0040	0.0148	3.4336	2.0397	0.0130	3.2003	0.0148	0.0139	9.2	9.15
127	1270	0.0040	0.0148	3.4484	2.0527	0.0131	3.2150	0.0148	0.0139	9.2	9.16
128	1280	0.0040	0.0148	3.4632	2.0658	0.0131	3.2298	0.0148	0.0139	9.2	9.16
129	1290	0.0040	0.0148	3.4780	2.0789	0.0131	3.2445	0.0148	0.0140	9.2	9.16
130	1300	0.0040	0.0148	3.4928	2.0920	0.0131	3.2593	0.0148	0.0140	9.2	9.17
131	1310	0.0040	0.0148	3.5076	2.1051	0.0131	3.2740	0.0148	0.0140	9.2	9.17
132	1320	0.0040	0.0148	3.5224	2.1182	0.0131	3.2888	0.0148	0.0140	9.2	9.18
133	1330	0.0040	0.0148	3.5372	2.1313	0.0131	3.3036	0.0148	0.0140	9.2	9.18
134	1340	0.0040	0.0148	3.5520	2.1444	0.0131	3.3183	0.0148	0.0140	9.2	9.18
135	1350	0.0040	0.0148	3.5668	2.1576	0.0131	3.3331	0.0148	0.0140	9.2	9.19
136	1360	0.0040	0.0148	3.5816	2.1707	0.0132	3.3478	0.0148	0.0140	9.2	9.19
137	1370	0.0040	0.0148	3.5964	2.1839	0.0132	3.3626	0.0148	0.0140	9.2	9.19
138	1380	0.0040	0.0148	3.6112	2.1971	0.0132	3.3773	0.0148	0.0140	9.2	9.20
139	1390	0.0040	0.0148	3.6260	2.2102	0.0132	3.3921	0.0148	0.0140	9.2	9.20
140	1400	0.0040	0.0148	3.6408	2.2234	0.0132	3.4069	0.0148	0.0140	9.2	9.20
141	1410	0.0040	0.0148	3.6556	2.2366	0.0132	3.4216	0.0148	0.0140	9.2	9.21
142	1420	0.0040	0.0148	3.6704	2.2498	0.0132	3.4364	0.0148	0.0140	9.2	9.21
143	1430	0.0040	0.0148	3.6852	2.2631	0.0132	3.4511	0.0148	0.0140	9.2	9.21
144	1440	0.0040	0.0148	3.7000	2.2763	0.0132	3.4659	0.0148	0.0140	9.2	9.21

Total Volume of Runoff[1] = 1,131,318 cu. ft.

Notes:

1. Total Runoff Volume is found by summing column (12) and multiplying by the time step, dt as follows:

   V = SumQ x dt
   V(cu.ft.) = SumQ(cu.ft/s) x dt(min.) x (60 s/min.)

Table 2.2
Runoff Curve Numbers for Selected Agricultural, Suburban, and Urban Areas

(Sources: TR 55, 1986, and Stormwater Management Manual, 1992. See Section 2.1.1 for explanation)

Cover type and hydrologic condition.	CNs for hydrologic soil group A	B	C	D
Curve Numbers for Pre-Development Conditions				
Pasture, grassland, or range-continuous forage for grazing:				
Fair condition (ground cover 50% to 75% and not heavily grazed).	49	69	79	84
Good condition (ground cover >75% and lightly or only occasionally grazed)	39	61	74	80
Woods:				
Fair (Woods are grazed but not burned, and some forest litter covers the soil).	36	60	73	79
Good (Woods are protected from grazing, and litter and brush adequately cover the soil).	30	55	70	77
Curve Numbers for Post-Development Conditions				
Open space (lawns, parks, golf courses, cemeteries, landscaping, etc.)[1]				
Fair condition (grass cover on 50% - 75% of the area).	77	85	90	92
Good condition (grass cover on >75% of the area)	68	80	86	90
Impervious areas:				
Open water bodies: lakes, wetlands, ponds etc.	100	100	100	100
Paved parking lots, roofs[2], driveways, etc. (excluding right-of-way)	98	98	98	98
Permeable Pavement (See Appendix C to decide which condition below to use)				
Landscaped area	77	85	90	92
50% landscaped area/50% impervious	87	91	94	96
100% impervious area	98	98	98	98
Paved	98	98	98	98
Gravel (including right-of-way)	76	85	89	91
Dirt (including right-of-way)	72	82	87	89
Pasture, grassland, or range-continuous forage for grazing:				
Poor condition (ground cover <50% or heavily grazed with no mulch).	68	79	86	89
Fair condition (ground cover 50% to 75% and not heavily grazed).	49	69	79	84
Good condition (ground cover >75% and lightly or only occasionally grazed)	39	61	74	80
Woods:				
Poor (Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning).	45	66	77	83
Fair (Woods are grazed but not burned, and some forest litter covers the soil).	36	60	73	79
Good (Woods are protected from grazing, and litter and brush adequately cover the soil).	30	55	70	77

Single family residential[3]: Dwelling Unit/Gross Acre	Should only be used for subdivisions > 50 acres	Average Percent impervious area[3,4]	
1.0 DU/GA		15	Separate curve number shall be selected for pervious & impervious portions of the site or basin
1.5 DU/GA		20	
2.0 DU/GA		25	
2.5 DU/GA		30	
3.0 DU/GA		34	
3.5 DU/GA		38	
4.0 DU/GA		42	
4.5 DU/GA		46	
5.0 DU/GA		48	
5.5 DU/GA		50	
6.0 DU/GA		52	
6.5 DU/GA		54	
7.0 DU/GA		56	
7.5 DU/GA		58	

PUD's, condos, apartments, commercial businesses, industrial areas & & subdivisions < 50 acres	%impervious must be computed	Separate curve numbers shall be selected for pervious and impervious portions of the site

For a more detailed and complete description of land use curve numbers refer to chapter two (2) of the Soil Conservation Service's Technical Release No. 55 , (210-VI-TR-55, Second Ed., June 1986).

[1] Composite CN's may be computed for other combinations of open space cover type.

[2] Where roof runoff and driveway runoff are infiltrated or dispersed according to the requirements in Chapter 3, the average percent impervious area may be adjusted in accordance with the procedure described under "Flow Credit for Roof Downspout Infiltration" (Section 3.1.1), and "Flow Credit for Roof Downspout Dispersion" (Section 3.1.2).

[3] Assumes roof and driveway runoff is directed into street/storm system.

[4] All the remaining pervious area (lawn) are considered to be in good condition for these curve numbers.

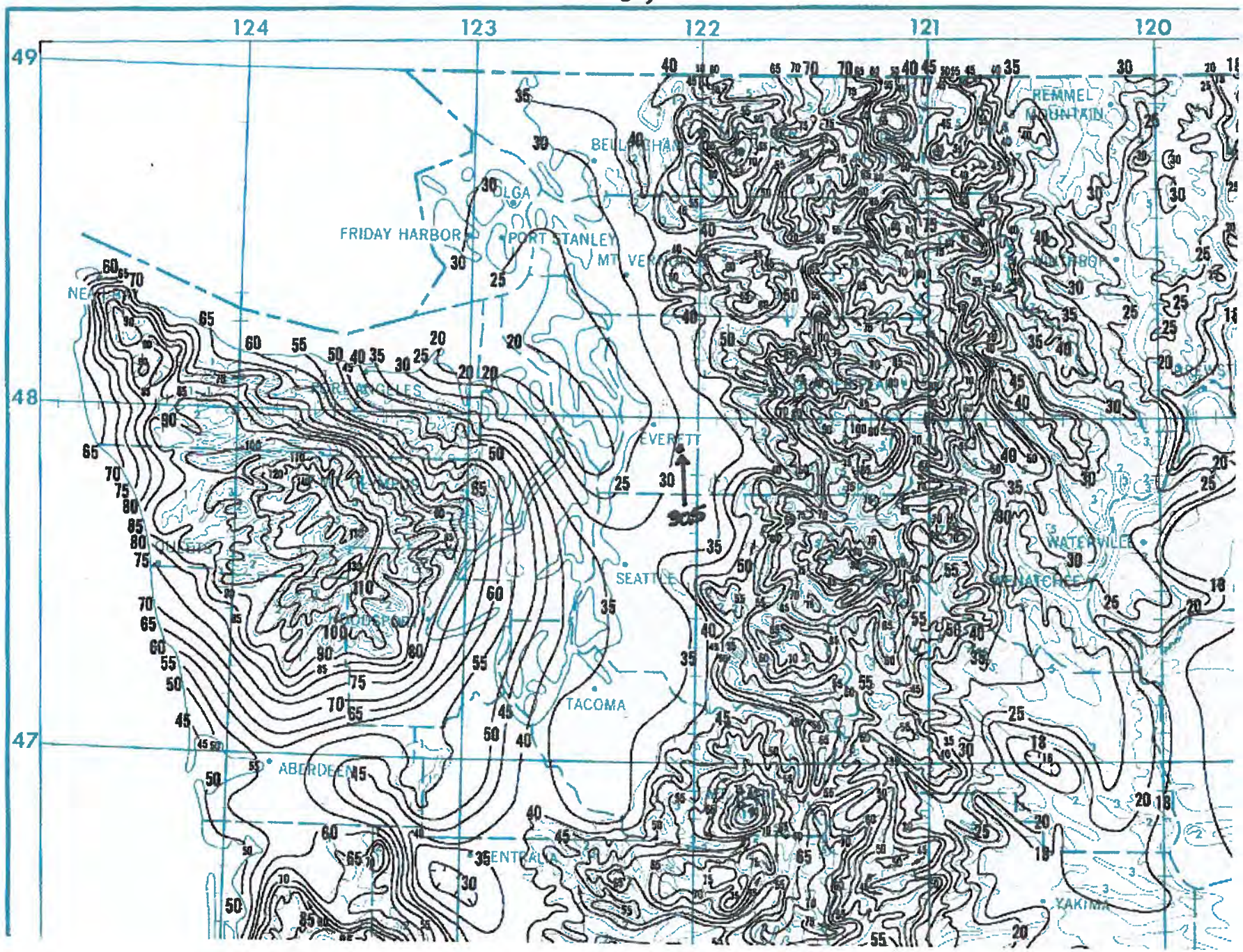
Use for SFRES

Right of Way

Table 4.4.1 Values of "n" and "k" for use in computing Time of Concentration

FOR SHEET FLOW	**n_s**
Smooth surfaces (concrete, asphalt, gravel, or bare hard soil)	0.011
Fallow fields of loose soil surface (no vegetal residue)	0.05
Cultivated soil with crop residue (slope < 0.20 ft/ft)	0.06
Cultivated soil with crop residue (slope > 0.20 ft/ft)	0.17
Short prairie grass and lawns	0.15
Dense grass	0.24
Bermuda grass	0.41
Range, natural	0.13
Woods or forest, poor cover	0.40
Woods or forest, good cover	0.80
FOR SHALLOW, CONCENTRATED FLOW	**k_s**
Forest with heavy ground litter and meadows (n = 0.10)	3
Brushy ground with some trees (n =0.06)	5
Fallow or minimum tillage cultivation (n = 0.04)	8
High grass (n = 0.035)	9
Short grass, pasture and lawns (n = 0.030)	11
Newly-bare ground (n = 0.025)	13
Paved and gravel areas (n = 0.012)	27
CHANNEL FLOW (INTERMITTENT, R = 0.2)	**k_c**
Forested swale with heavy ground litter (n=0.10)	5
Forested drainage course/ravine with defined channel bed (n=0.050)	10
Rock-lined waterway (n=0.035)	15
Grassed waterway (n=0.030)	17
Earth-lined waterway (n=0.025)	20
CMP pipe (n=0.024)	21
Concrete pipe (n=0.012)	42
Other waterways and pipes	0.508/n
CHANNEL FLOW (CONTINUOUS STREAM, R =0.4)	**k_c**
Meandering stream with some pools (n=0.040)	20
Rock-lined stream (n=0.035)	23
Grassed stream (n=0.030)	27
Other streams, man-made channels and pipe	0.807/n

25yr, 24hour



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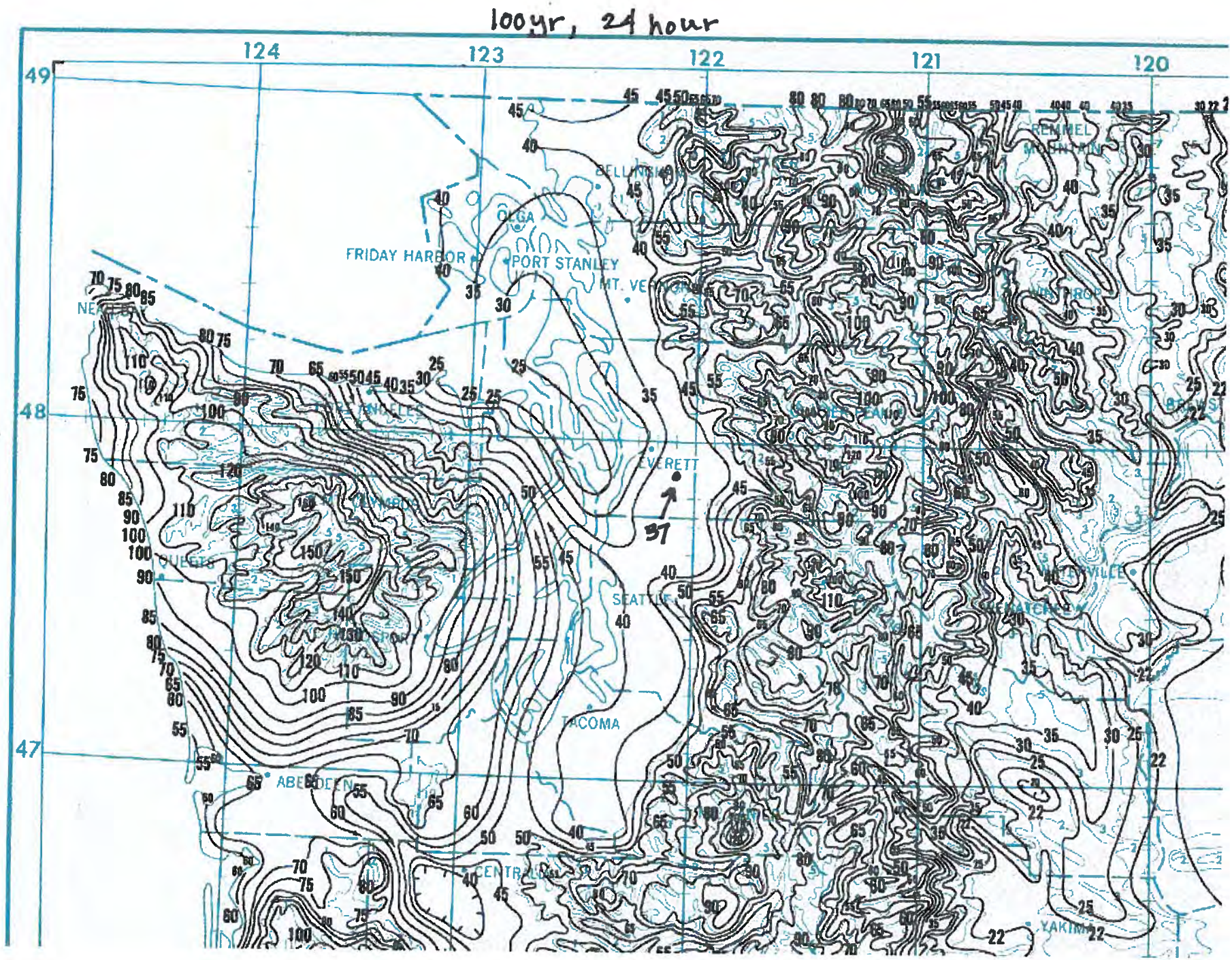

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10/3/2012

Stormwater Conveyance – 16th Street / Terrace and Maple Ave

URS CALCULATION COVER SHEET Quality

Project Name:	Stormwater Comprehensive Plan Update	**Project Number:**	33763575
Project Location:	City of Snohomish	**Client Name:**	City of Snohomish
PM Name:	Carla Talich	**PIC Name:**	Kevin Weed

IDENTIFYING INFORMATION

(This section is to be completed by the Originator.)

Calculation Medium: ☐ Electronic File Name: K:\City of Snohomish\Stormwater Comp Plan\Stormwater Modeling - NEW moved\16th&Terrace - Maple Ave Calcs

(Select as appropriate) ☒ Hard-copy Unique Identification:

Number of pages *(including cover sheet)*: 30

Discipline: Hydraulics

Title of Calculation: Stormwater Conveyance - 16th Street / Terrace and Maple Ave

Calculation Originator: Gina Franco

Calculation Contributors: Tobey Clarkin

Calculation Checker: Carla Talich

DESCRIPTION & PURPOSE

Determine the land use and area that contributes to locations identified by the city that need to be upgraded from a ditch to a pipe. Find the peak flows in these areas and size a pipe to convey the 25year peak flow.

BASIS / REFERENCE / ASSUMPTIONS

Assumptions are stated on calculation write up.

ISSUE / REVISION RECORD

Checker comments, if any, provided on: ☒ hard-copy ☐ electronic file ☐ Form 3-5 (MM)

No.	Description	P	S	F	Originator Initials	Date	Checker Initials	Date
0	Initial issue	☒	☐	☐	gmf	12/9/12	cgt	12/9/12
1	Updated calculation based on comments from the City	☐	☐	☒	gmf	7/2/13	cgt	
2		☐	☐	☐	[ ]	[ ]	[ ]	[ ]
3		☐	☐	☐	[ ]	[ ]	[ ]	[ ]

Note: For a given Revision No. Check off either P (Preliminary), S (Superseding) or F (Final). If there are no revisions to the Initial Issue check off F (Final). Comments may be provided on the hard-copy calculations, electronic file or on Form 3-5 (MM).

APPROVAL and DISTRIBUTION

☐ The calculations associated with this Cover Sheet have been checked.

gina franco — Originator Signature — 7/3/13 — Date

Carla Talich — Checker Signature — 7/9/13 — Date

Carla Talich — Project Manager Signature — 7/9/13. — Date

Distribution:

Project Central File – Quality file folder

Project Statement:
There are currently ditches that connect stormwater conveyance pipes within the storm system in the City of Snohomish. There are two locations, 16th/Terrace and Maple Avenue, where the City plans to replace the ditch and install stormwater conveyance pipe in the right-of-way. See attached calculations for a map with both locations identified.

Land Use and Contributing Area:
The existing land use and contributing areas were calculated using 2011 City Land Use Map (City of Snohomish, 2010) and 2007 LiDAR data in ARCGIS. The single family residential land use was assumed to be multifamily (50% pervious and 50% impervious). The area is mostly developed and may fall under high density residential land use. The medium density residential land use was assumed to be 90% pervious and 10% impervious (Taylor, 1993). Further refinement of land use may be conducted during the design phase. The pervious portions were assumed to be in good condition with grass cover on more than 75% of the area, resulting in a curve number of 86. The right-of-way area was assumed to be paved, with a curve number of 98.

The contributing areas to the 16th/Terrace pipe also contribute to the Maple Avenue pipe. The two areas were analyzed separately to determine time of concentration and peak flows. The peak flow from the 16th/Terrace and from Maple Avenue area were added together to check the capacity of the 12-inch pipe connection in Maple Avenue. The land use areas calculated in ARCGIS were separated into pervious and impervious areas for input into the Santa Barbara Urban Hydrograph (SBUH) spreadsheet. See attached calculations.

Pipe Sizing:
The new stormwater conveyance pipes were sized based on Section 4-2.2 of the Design and Construction Standards set forth by the City of Snohomish, by computing the peak flow resulting from the 24-hour duration, 25- and 100-year recurrence interval storms (City of Snohomish, 2004), using the SBUH method. A Type 1A unit hydrograph was used, as appropriate for western Washington. The precipitation for the 25- and 100-year storm events was determined by using NOAA Atlas 2 isopluvial maps.

A detention pipe system is to be located in Terrace Avenue between 15th Street and 16th Street; the sizing of a new detention pipe will be done as a separate calculation package.

The size of the pipes was based on the peak flows calculated using the SBUH method.
Bentley Systems, Inc. FlowMaster, 2008 software was used to size the pipes. The pipes were graded so that they can gravity drain to the connection point. There was a minimum of three feet of cover over the pipes; therefore, polyvinyl chloride (PVC) was feasible. Slopes ranging from 4% to 6% were checked using the peak flows from the 25- and the 100-year storm events. The slope at 16th/Terrace was determined using existing manhole rim elevations, see attached sketch. The slope at Maple Avenue was determined using the topography; see Figure C3 in the Stormwater Comprehensive Plan.

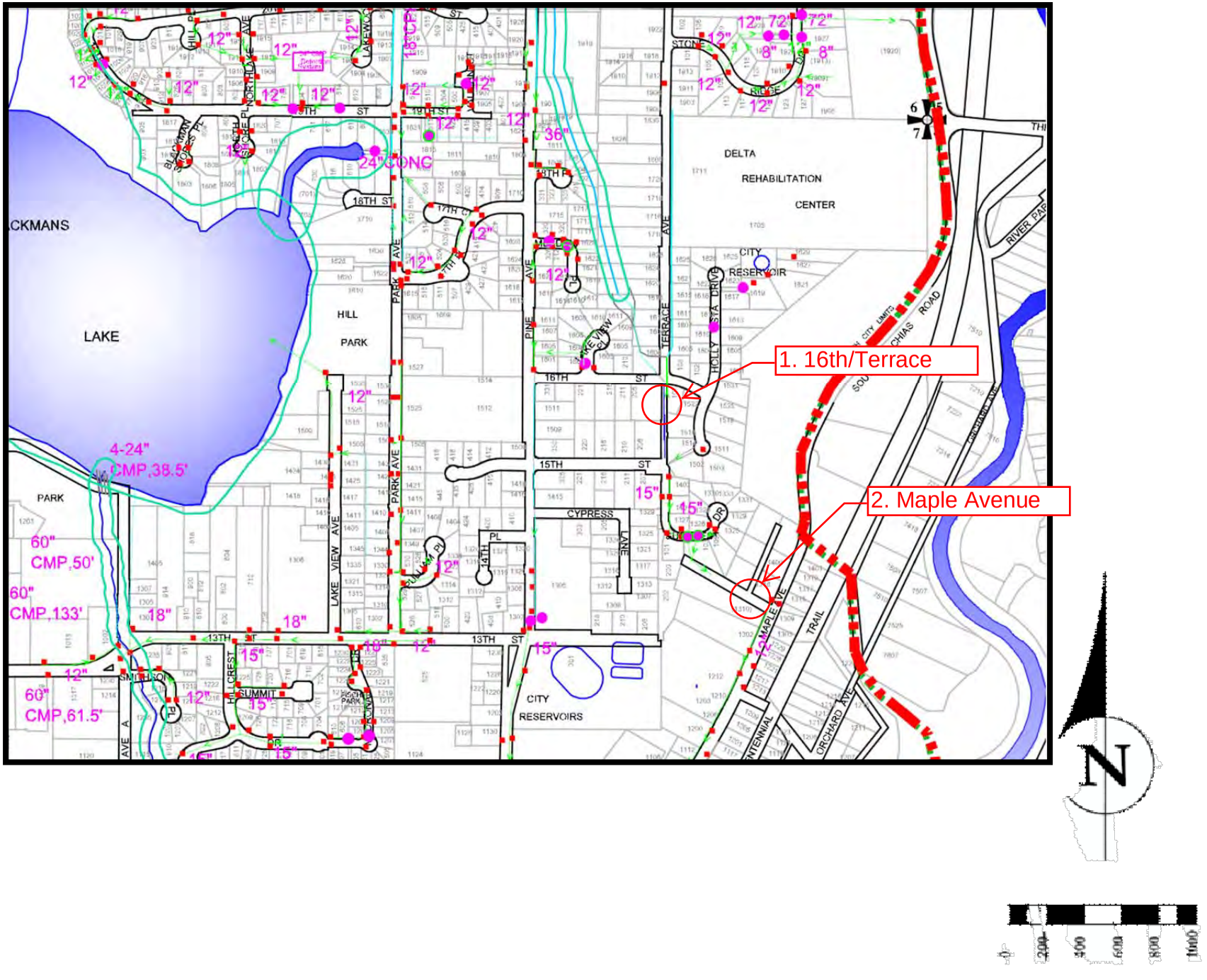
It was determined that a 12-inch PVC pipe would be adequate for the 25-year storm event and may surcharge at the 100-year storm event. The drainage in this area is contained within a manmade system and erosion is not likely to occur.

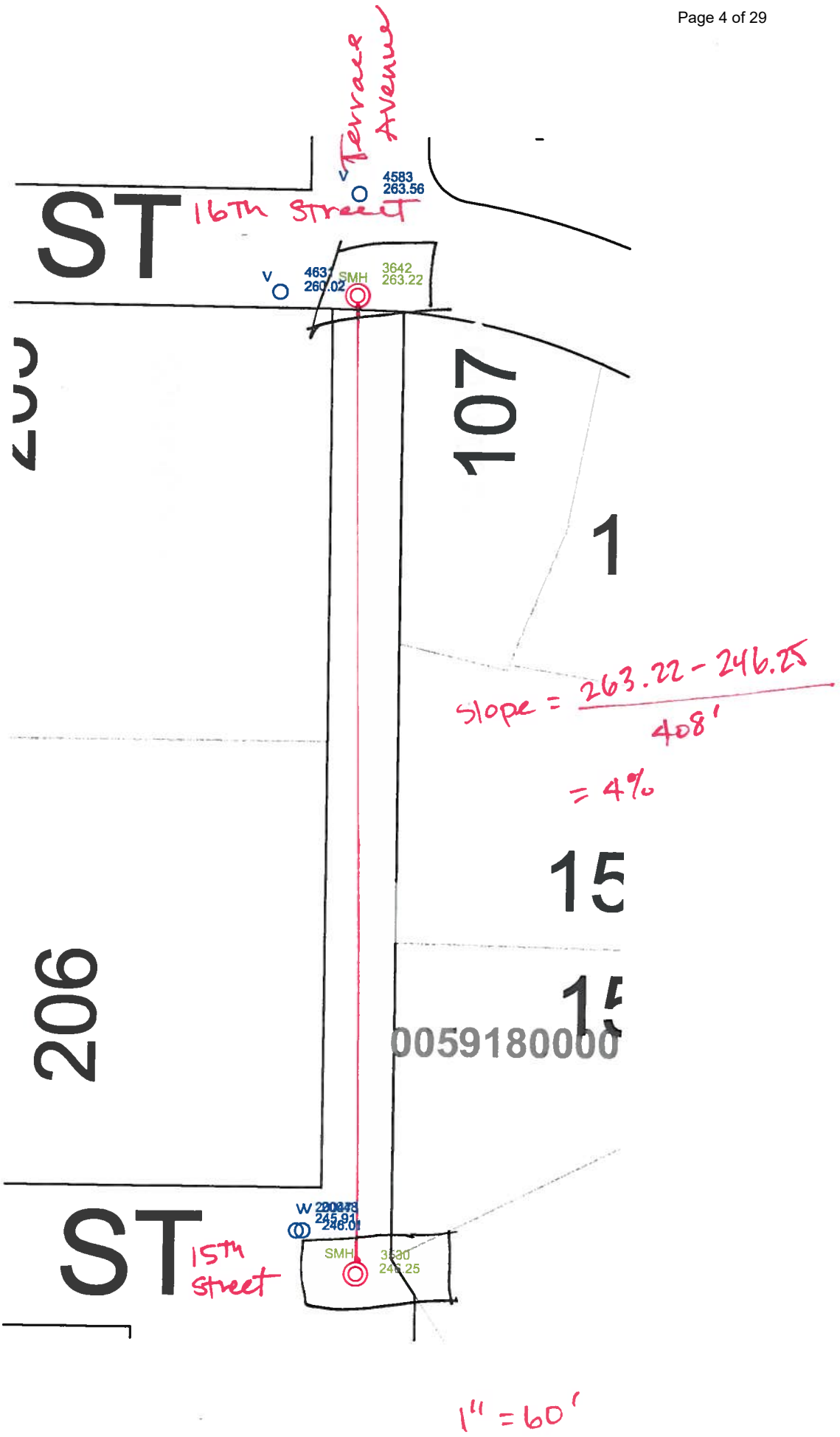
Results:
Based on the calculations described above, it is recommended that a 12-inch diameter PVC pipe used for both systems: 16th/Terrace and the Maple Avenue. Results and calculations are attached.

References:
City of Snohomish, Washington. Comprehensive Plan. December 2010.

City of Snohomish, Washington. 2004. Design and Construction Standards. March 2004.

Taylor, Brian L. 1993. The Influence of Wetland and Watershed Morphological Characteristeics on Wetland Hydrology and Relationships to Wetland Vegetation Communities. 1993.


1. 16th/Terrace
2. Maple Avenue
LAKE
HILL
PARK
DELTA
REHABILITATION
CENTER
CITY
RESERVOIR
CITY
RESERVOIRS
24" CONC
4-24"
CMP,38.5'
60"
CMP,50'
60"
CMP,133'
60"
CMP,61.5'
18TH ST
16TH ST
15TH ST
13TH ST
PARK AVE
LAKE VIEW AVE
PINE AVE
TERRACE AVE
HOLLY STA DRIVE
CYPRESS LANE
MAPLE AVE
TRAIL
ORCHARD AVE
RIVER PAR
N
0
200
400
600
800
1000


Terrace Avenue
ST
16TH Street
4583
263.56
4631
260.02
SMH
3642
263.22
107
1
slope = 263.22 - 246.25 / 408'
= 4%
15
206
0059180000
W
245.91
246.01
SMH
3630
246.25
ST
15TH Street
1" = 60'

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NORTH

400 200 0 400

Feet

Job No. 33763575

URS

16th/Terrace and Maple

Stormwater Comprehensive Plan

City of Snohomish

16th and Terrace Pipe Sizing

Existing land use

SFRES	14.24	ac
MDRES	9.61	ac
Right-of-Way	2.08	ac

SFRES: 50% pervious and 50% impervious

SFRES - pervious	14.24	x	0.5	=	7.12
SFRES - impervious	14.24	x	0.5	=	7.12

MDRES: 90% pervious and 10% impervious

MDRES - pervious	9.61	x	0.9	=	8.65
MDRES - impervious	9.61	x	0.1	=	0.961

Pervious	Impervious
7.12	7.12
8.65	0.961
15.77	2.08
	10.16

From SBUH

Q25	=	8.4
Q100	=	10.91

Maple Ave Pipe Sizing

Existing land use

SFRES	6.62	ac
Right-of-Way	1.46	ac

SFRES: 50% pervious and 50% impervious

SFRES - pervious	6.62	x	0.5 =	3.31
SFRES - impervious	6.62	x	0.5 =	3.31

Pervious	Impervious
3.31	3.31
	1.46
3.31	4.77

From SBUH

Q25	=	4.49
Q100	=	5.68

Flow from 16th & Terrace and Maple Ave Flow

Q25	=	12.89
Q100	=	16.59

16th/Terrace, 25 yr flow, PVC, S=4%

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Diameter

Input Data

Roughness Coefficient	0.010	
Channel Slope	0.04000	ft/ft
Normal Depth	0.96	ft
Diameter	0.96	ft
Discharge	8.40	ft³/s

The 25-yr flow was used to determine the diameter of pipe that would be able to contain the design flow per the City's Design Standards. The 25-yr flow will be contained in a 12" diameter pipe.

Results

Diameter	0.96	ft
Normal Depth	0.96	ft
Flow Area	0.73	ft²
Wetted Perimeter	3.03	ft
Hydraulic Radius	0.24	ft
Top Width	0.00	ft
Critical Depth	0.96	ft
Percent Full	100.0	%
Critical Slope	0.03706	ft/ft
Velocity	11.51	ft/s
Velocity Head	2.06	ft
Specific Energy	3.02	ft
Froude Number	0.00	
Maximum Discharge	9.04	ft³/s
Discharge Full	8.40	ft³/s
Slope Full	0.04000	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%

16th/Terrace, 25 yr flow, PVC, S=4%

GVF Output Data

Normal Depth Over Rise	100.00	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.96	ft
Critical Depth	0.96	ft
Channel Slope	0.04000	ft/ft
Critical Slope	0.03706	ft/ft

16th/Terrace, 100 yr flow, PVC, S=4%

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Diameter

Input Data

Roughness Coefficient	0.010	
Channel Slope	0.04000	ft/ft
Normal Depth	1.06	ft
Diameter	1.06	ft
Discharge	10.91	ft³/s

The 100-yr flow was used to determine if flooding would occur per the City's Design Standards. The 100-yr flow will mostly be contained in a 12" diameter pipe with some minor surcharge.

Results

Diameter	1.06	ft
Normal Depth	1.06	ft
Flow Area	0.89	ft²
Wetted Perimeter	3.34	ft
Hydraulic Radius	0.27	ft
Top Width	0.00	ft
Critical Depth	1.05	ft
Percent Full	100.0	%
Critical Slope	0.03714	ft/ft
Velocity	12.29	ft/s
Velocity Head	2.35	ft
Specific Energy	3.41	ft
Froude Number	0.00	
Maximum Discharge	11.74	ft³/s
Discharge Full	10.91	ft³/s
Slope Full	0.03999	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%

16th/Terrace, 100 yr flow, PVC, S=4%

GVF Output Data

Normal Depth Over Rise	100.00	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.06	ft
Critical Depth	1.05	ft
Channel Slope	0.04000	ft/ft
Critical Slope	0.03714	ft/ft

City of Snohomish
Stormwater Comprehensive Plan
Time of Concentration
16th-Terrace

Calculate Time of Concentration (Tc)

Tc = Sum(Tt)

Where:

Tt = travel time (min) = $\frac{L}{(60xV)}$ (for shallow concentrated flow or channel flow)

Tt = travel time (min)= $\frac{0.42(n_s L)^{0.8}}{(P_2)^{0.5}(s_o)^{0.4}}$ (for sheet flow)

Where:

V = avg. velocity (ft/s) = $V = k(s_o)^{0.5}$

k = time of concentration velocity factor (ft/s)

L = flow length (ft)

n_s = sheet flow Manning's effective roughness coefficient

P_2 = 2-year, 24-hour rainfall (in)

s_o = slope of hydraulic grade line (land slope, ft/ft)

	L (ft)	$k_{s/c}$	V (fps)	n_s	P_2	s_o (ft/ft)	Tt (min)
a - sheet	100	NA	NA	0.8	1.8	0.040	37.8
b - shallow	815	11	2.2	NA	NA	0.040	6.2
c - channel	1800	42	8.0	NA	NA	0.04	3.8
Total (Tc)							47.7

Minimum Allowable Tc = 6.0 minutes

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

Project: City of Snohomish - Stormwater Comp Plan
Basin: 16th / Terrace
Storm Event: 25-YEAR, 24-HOUR
Given:

Area	=	26.43	acres				
Pt	=	3.05	inches				
dt	=	10	min.				
Tc	=	47.7	min.				
PERVIOUS AREA				IMPERVIOUS AREA (Roads)			
Area	=	15.77	acres	Area	=	10.66	acres
CN	=	86		CN	=	98	
S	=	1.63		S	=	0.20	
0.2S	=	0.33		0.2S	=	0.04	

SUMMARY	
T_{pk}(hrs)=	7.83
T_c (min)=	47.7
Q_{pk}(cfs)=	8.40
Vol(cf)=	201,578

Compute: Runoff Hydrograph

Column (3) = SCS Type IA Rainfall Distribution
Column (4) = Col. (3) x Pt
Column (5) = Accumulated Sum of Col. (4)
Column (6) = [If P <= 0.2S] = 0; Note, use PERVIOUS Area "S" value.
[If P > 0.2S] = (Col.(5) - 0.2S)^2/(Col.(5) + 0.8S); Using the PERVIOUS Area "S" value.
Column (7) = Col.(6) of Present Time Step - Col.(6) of Previous Time Step
Column (8) = Same method as for Col.(6), except use the IMPERVIOUS Area "S" value.
Column (9) = Col.(8) of the present time step - Col.(8) of the previous time step.
Column (10) = ((PERVIOUS area / Total area) x Col.(7)) + ((IMPERVIOUS area / Total area) x Col.(9))
Column (11) = (60.5 x Col.(10) x Total Area) / 10 (dt = 10 minutes)
Routing Constant, w = dt / (2Tc + dt) = 0.0949
Column (12) = Col.(12) of Previous Time Step + (w x [Col.(11) of Previous Time Step
+ Col.(11) of Present Time Step - (2 x Col.(12) of Previous Time Step)])

					Pervious Area		Impervious Area				
(1) Time Increment	(2) Time	(3) Rainfall distribution	(4) Incremental Rainfall	(5) Accumulated Rainfall	(6) Accumulated Runoff	(7) Incremental Runoff	(8) Accumulated Runoff	(9) Incremental Runoff	(10) Total Runoff	(11) Instant hydrograph	(12) design hydrograph	
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs	
1	10	0.0040	0.0122	0.0122	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
2	20	0.0040	0.0122	0.0244	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
3	30	0.0040	0.0122	0.0366	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
4	40	0.0040	0.0122	0.0488	0.0000	0.0000	0.0003	0.0003	0.0001	0.0	0.00	
5	50	0.0040	0.0122	0.0610	0.0000	0.0000	0.0018	0.0015	0.0006	0.1	0.01	
6	60	0.0040	0.0122	0.0732	0.0000	0.0000	0.0044	0.0026	0.0011	0.2	0.04	
7	70	0.0040	0.0122	0.0854	0.0000	0.0000	0.0080	0.0036	0.0014	0.2	0.07	
8	80	0.0040	0.0122	0.0976	0.0000	0.0000	0.0124	0.0044	0.0018	0.3	0.10	
9	90	0.0040	0.0122	0.1098	0.0000	0.0000	0.0174	0.0051	0.0020	0.3	0.14	
10	100	0.0040	0.0122	0.1220	0.0000	0.0000	0.0231	0.0057	0.0023	0.4	0.18	
11	110	0.0050	0.0153	0.1373	0.0000	0.0000	0.0309	0.0078	0.0032	0.5	0.23	
12	120	0.0050	0.0153	0.1525	0.0000	0.0000	0.0395	0.0086	0.0035	0.6	0.29	
13	130	0.0050	0.0153	0.1678	0.0000	0.0000	0.0487	0.0092	0.0037	0.6	0.34	
14	140	0.0050	0.0153	0.1830	0.0000	0.0000	0.0584	0.0097	0.0039	0.6	0.39	
15	150	0.0050	0.0153	0.1983	0.0000	0.0000	0.0686	0.0102	0.0041	0.7	0.44	
16	160	0.0050	0.0153	0.2135	0.0000	0.0000	0.0791	0.0106	0.0043	0.7	0.48	
17	170	0.0060	0.0183	0.2318	0.0000	0.0000	0.0923	0.0132	0.0053	0.8	0.54	
18	180	0.0060	0.0183	0.2501	0.0000	0.0000	0.1060	0.0136	0.0055	0.9	0.60	
19	190	0.0060	0.0183	0.2684	0.0000	0.0000	0.1200	0.0140	0.0057	0.9	0.65	
20	200	0.0060	0.0183	0.2867	0.0000	0.0000	0.1344	0.0144	0.0058	0.9	0.70	
21	210	0.0060	0.0183	0.3050	0.0000	0.0000	0.1490	0.0147	0.0059	0.9	0.75	
22	220	0.0060	0.0183	0.3233	0.0000	0.0000	0.1640	0.0150	0.0060	1.0	0.79	
23	230	0.0070	0.0214	0.3447	0.0002	0.0002	0.1818	0.0178	0.0073	1.2	0.84	
24	240	0.0070	0.0214	0.3660	0.0010	0.0008	0.1998	0.0180	0.0077	1.2	0.91	
25	250	0.0070	0.0214	0.3874	0.0023	0.0013	0.2181	0.0183	0.0081	1.3	0.98	
26	260	0.0070	0.0214	0.4087	0.0040	0.0018	0.2366	0.0185	0.0085	1.4	1.04	
27	270	0.0070	0.0214	0.4301	0.0063	0.0023	0.2553	0.0187	0.0089	1.4	1.11	
28	280	0.0070	0.0214	0.4514	0.0090	0.0027	0.2743	0.0189	0.0093	1.5	1.18	
29	290	0.0082	0.0250	0.4764	0.0128	0.0038	0.2966	0.0224	0.0113	1.8	1.26	
30	300	0.0082	0.0250	0.5014	0.0171	0.0044	0.3192	0.0226	0.0117	1.9	1.37	
31	310	0.0082	0.0250	0.5264	0.0221	0.0049	0.3419	0.0227	0.0121	1.9	1.47	
32	320	0.0082	0.0250	0.5514	0.0275	0.0055	0.3648	0.0229	0.0125	2.0	1.57	
33	330	0.0082	0.0250	0.5765	0.0335	0.0060	0.3879	0.0230	0.0129	2.1	1.65	
34	340	0.0082	0.0250	0.6015	0.0400	0.0065	0.4110	0.0232	0.0132	2.1	1.74	
35	350	0.0095	0.0290	0.6304	0.0481	0.0081	0.4380	0.0270	0.0157	2.5	1.85	
36	360	0.0095	0.0290	0.6594	0.0568	0.0087	0.4651	0.0271	0.0161	2.6	1.98	
37	370	0.0095	0.0290	0.6884	0.0661	0.0093	0.4924	0.0273	0.0165	2.6	2.10	
38	380	0.0095	0.0290	0.7174	0.0760	0.0099	0.5198	0.0274	0.0169	2.7	2.21	
39	390	0.0095	0.0290	0.7463	0.0864	0.0104	0.5472	0.0275	0.0173	2.8	2.31	
40	400	0.0095	0.0290	0.7753	0.0973	0.0109	0.5748	0.0276	0.0176	2.8	2.40	
41	410	0.0134	0.0409	0.8162	0.1136	0.0163	0.6138	0.0390	0.0254	4.1	2.60	
42	420	0.0134	0.0409	0.8570	0.1308	0.0172	0.6530	0.0392	0.0261	4.2	2.89	
43	430	0.0134	0.0409	0.8979	0.1489	0.0181	0.6923	0.0393	0.0266	4.3	3.14	
44	440	0.0180	0.0549	0.9528	0.1745	0.0256	0.7452	0.0530	0.0366	5.9	3.50	
45	450	0.0180	0.0549	1.0077	0.2014	0.0270	0.7984	0.0532	0.0375	6.0	3.96	
46	460	0.0340	0.1037	1.1114	0.2558	0.0544	0.8992	0.1008	0.0731	11.7	4.89	
47	470	0.0540	0.1647	1.2761	0.3504	0.0946	1.0602	0.1610	0.1213	19.4	6.91	
48	480	0.0270	0.0824	1.3585	0.4010	0.0505	1.1409	0.0808	0.0627	10.0	8.39	
49	490	0.0180	0.0549	1.4134	0.4357	0.0348	1.1949	0.0539	0.0425	6.8	8.40	Q peak
50	500	0.0134	0.0409	1.4542	0.4621	0.0264	1.2351	0.0402	0.0320	5.1	7.93	
51	510	0.0134	0.0409	1.4951	0.4889	0.0268	1.2753	0.0402	0.0322	5.2	7.40	
52	520	0.0134	0.0409	1.5360	0.5162	0.0272	1.3156	0.0403	0.0325	5.2	6.98	
53	530	0.0088	0.0268	1.5628	0.5343	0.0181	1.3421	0.0265	0.0215	3.4	6.47	
54	540	0.0088	0.0268	1.5897	0.5525	0.0183	1.3685	0.0265	0.0216	3.4	5.90	
55	550	0.0088	0.0268	1.6165	0.5709	0.0184	1.3950	0.0265	0.0217	3.5	5.43	
56	560	0.0088	0.0268	1.6433	0.5895	0.0186	1.4215	0.0265	0.0218	3.5	5.06	
57	570	0.0088	0.0268	1.6702	0.6082	0.0187	1.4480	0.0265	0.0219	3.5	4.76	
58	580	0.0088	0.0268	1.6970	0.6271	0.0189	1.4745	0.0265	0.0219	3.5	4.52	
59	590	0.0088	0.0268	1.7239	0.6461	0.0190	1.5010	0.0265	0.0220	3.5	4.33	
60	600	0.0088	0.0268	1.7507	0.6652	0.0191	1.5276	0.0265	0.0221	3.5	4.18	
61	610	0.0088	0.0268	1.7775	0.6845	0.0193	1.5541	0.0265	0.0222	3.6	4.06	

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

					Pervious Area		Impervious Area				
(1) Time Increment	(2) Time	(3) Rainfall distri-bution	(4) Incre-mental Rainfall	(5) Accumu-lated Rainfall	(6) Accumu-lated Runoff	(7) Incre-mental Runoff	(8) Accumu-lated Runoff	(9) Incre-mental Runoff	(10) Total Runoff	(11) Instant hydro-graph	(12) design hydro-graph
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs
62	620	0.0088	0.0268	1.8044	0.7039	0.0194	1.5806	0.0265	0.0223	3.6	3.96
63	630	0.0088	0.0268	1.8312	0.7234	0.0195	1.6072	0.0266	0.0224	3.6	3.89
64	640	0.0088	0.0268	1.8581	0.7431	0.0197	1.6338	0.0266	0.0224	3.6	3.83
65	650	0.0072	0.0220	1.8800	0.7593	0.0162	1.6555	0.0217	0.0184	2.9	3.72
66	660	0.0072	0.0220	1.9020	0.7755	0.0163	1.6772	0.0217	0.0185	3.0	3.58
67	670	0.0072	0.0220	1.9239	0.7919	0.0163	1.6990	0.0217	0.0185	3.0	3.46
68	680	0.0072	0.0220	1.9459	0.8083	0.0164	1.7207	0.0218	0.0186	3.0	3.37
69	690	0.0072	0.0220	1.9679	0.8247	0.0165	1.7425	0.0218	0.0186	3.0	3.29
70	700	0.0072	0.0220	1.9898	0.8413	0.0166	1.7643	0.0218	0.0187	3.0	3.23
71	710	0.0072	0.0220	2.0118	0.8579	0.0166	1.7860	0.0218	0.0187	3.0	3.19
72	720	0.0072	0.0220	2.0337	0.8746	0.0167	1.8078	0.0218	0.0187	3.0	3.15
73	730	0.0072	0.0220	2.0557	0.8914	0.0168	1.8296	0.0218	0.0188	3.0	3.12
74	740	0.0072	0.0220	2.0777	0.9082	0.0168	1.8513	0.0218	0.0188	3.0	3.10
75	750	0.0072	0.0220	2.0996	0.9251	0.0169	1.8731	0.0218	0.0189	3.0	3.08
76	760	0.0072	0.0220	2.1216	0.9421	0.0170	1.8949	0.0218	0.0189	3.0	3.07
77	770	0.0057	0.0174	2.1390	0.9556	0.0135	1.9122	0.0172	0.0150	2.4	3.00
78	780	0.0057	0.0174	2.1564	0.9691	0.0135	1.9294	0.0172	0.0150	2.4	2.89
79	790	0.0057	0.0174	2.1737	0.9826	0.0136	1.9467	0.0173	0.0150	2.4	2.80
80	800	0.0057	0.0174	2.1911	0.9962	0.0136	1.9639	0.0173	0.0151	2.4	2.72
81	810	0.0057	0.0174	2.2085	1.0098	0.0136	1.9812	0.0173	0.0151	2.4	2.66
82	820	0.0057	0.0174	2.2259	1.0235	0.0137	1.9984	0.0173	0.0151	2.4	2.62
83	830	0.0057	0.0174	2.2433	1.0372	0.0137	2.0157	0.0173	0.0151	2.4	2.58
84	840	0.0057	0.0174	2.2607	1.0510	0.0137	2.0329	0.0173	0.0152	2.4	2.55
85	850	0.0057	0.0174	2.2780	1.0647	0.0138	2.0502	0.0173	0.0152	2.4	2.53
86	860	0.0057	0.0174	2.2954	1.0785	0.0138	2.0675	0.0173	0.0152	2.4	2.51
87	870	0.0057	0.0174	2.3128	1.0924	0.0138	2.0847	0.0173	0.0152	2.4	2.49
88	880	0.0057	0.0174	2.3302	1.1063	0.0139	2.1020	0.0173	0.0152	2.4	2.48
89	890	0.0050	0.0153	2.3455	1.1185	0.0122	2.1172	0.0151	0.0134	2.1	2.45
90	900	0.0050	0.0153	2.3607	1.1307	0.0122	2.1323	0.0151	0.0134	2.1	2.39
91	910	0.0050	0.0153	2.3760	1.1429	0.0123	2.1475	0.0152	0.0134	2.1	2.34
92	920	0.0050	0.0153	2.3912	1.1552	0.0123	2.1626	0.0152	0.0134	2.1	2.30
93	930	0.0050	0.0153	2.4065	1.1675	0.0123	2.1778	0.0152	0.0135	2.2	2.28
94	940	0.0050	0.0153	2.4217	1.1798	0.0123	2.1929	0.0152	0.0135	2.2	2.25
95	950	0.0050	0.0153	2.4370	1.1922	0.0123	2.2081	0.0152	0.0135	2.2	2.23
96	960	0.0050	0.0153	2.4522	1.2045	0.0124	2.2232	0.0152	0.0135	2.2	2.22
97	970	0.0050	0.0153	2.4675	1.2169	0.0124	2.2384	0.0152	0.0135	2.2	2.21
98	980	0.0050	0.0153	2.4827	1.2294	0.0124	2.2535	0.0152	0.0135	2.2	2.20
99	990	0.0050	0.0153	2.4980	1.2418	0.0124	2.2687	0.0152	0.0135	2.2	2.19
100	1000	0.0050	0.0153	2.5132	1.2543	0.0125	2.2839	0.0152	0.0136	2.2	2.19
101	1010	0.0040	0.0122	2.5254	1.2642	0.0100	2.2960	0.0121	0.0109	1.7	2.14
102	1020	0.0040	0.0122	2.5376	1.2743	0.0100	2.3081	0.0121	0.0109	1.7	2.07
103	1030	0.0040	0.0122	2.5498	1.2843	0.0100	2.3203	0.0121	0.0109	1.7	2.00
104	1040	0.0040	0.0122	2.5620	1.2943	0.0100	2.3324	0.0121	0.0109	1.7	1.95
105	1050	0.0040	0.0122	2.5742	1.3043	0.0100	2.3445	0.0121	0.0109	1.7	1.91
106	1060	0.0040	0.0122	2.5864	1.3144	0.0101	2.3566	0.0121	0.0109	1.7	1.88
107	1070	0.0040	0.0122	2.5986	1.3245	0.0101	2.3688	0.0121	0.0109	1.7	1.85
108	1080	0.0040	0.0122	2.6108	1.3345	0.0101	2.3809	0.0121	0.0109	1.7	1.83
109	1090	0.0040	0.0122	2.6230	1.3446	0.0101	2.3931	0.0121	0.0109	1.7	1.82
110	1100	0.0040	0.0122	2.6352	1.3547	0.0101	2.4052	0.0121	0.0109	1.7	1.80
111	1110	0.0040	0.0122	2.6474	1.3649	0.0101	2.4173	0.0121	0.0109	1.7	1.79
112	1120	0.0040	0.0122	2.6596	1.3750	0.0101	2.4295	0.0121	0.0109	1.7	1.78
113	1130	0.0040	0.0122	2.6718	1.3851	0.0101	2.4416	0.0121	0.0109	1.8	1.78
114	1140	0.0040	0.0122	2.6840	1.3953	0.0102	2.4537	0.0121	0.0110	1.8	1.77
115	1150	0.0040	0.0122	2.6962	1.4055	0.0102	2.4659	0.0121	0.0110	1.8	1.77
116	1160	0.0040	0.0122	2.7084	1.4157	0.0102	2.4780	0.0121	0.0110	1.8	1.77
117	1170	0.0040	0.0122	2.7206	1.4259	0.0102	2.4901	0.0121	0.0110	1.8	1.76
118	1180	0.0040	0.0122	2.7328	1.4361	0.0102	2.5023	0.0121	0.0110	1.8	1.76
119	1190	0.0040	0.0122	2.7450	1.4463	0.0102	2.5144	0.0121	0.0110	1.8	1.76
120	1200	0.0040	0.0122	2.7572	1.4565	0.0102	2.5266	0.0121	0.0110	1.8	1.76
121	1210	0.0040	0.0122	2.7694	1.4668	0.0102	2.5387	0.0121	0.0110	1.8	1.76
122	1220	0.0040	0.0122	2.7816	1.4770	0.0103	2.5508	0.0121	0.0110	1.8	1.76
123	1230	0.0040	0.0122	2.7938	1.4873	0.0103	2.5630	0.0121	0.0110	1.8	1.76
124	1240	0.0040	0.0122	2.8060	1.4976	0.0103	2.5751	0.0121	0.0110	1.8	1.76
125	1250	0.0040	0.0122	2.8182	1.5079	0.0103	2.5873	0.0121	0.0110	1.8	1.76
126	1260	0.0040	0.0122	2.8304	1.5182	0.0103	2.5994	0.0121	0.0110	1.8	1.76
127	1270	0.0040	0.0122	2.8426	1.5285	0.0103	2.6116	0.0121	0.0111	1.8	1.76
128	1280	0.0040	0.0122	2.8548	1.5388	0.0103	2.6237	0.0121	0.0111	1.8	1.76
129	1290	0.0040	0.0122	2.8670	1.5491	0.0103	2.6358	0.0121	0.0111	1.8	1.77
130	1300	0.0040	0.0122	2.8792	1.5595	0.0103	2.6480	0.0121	0.0111	1.8	1.77
131	1310	0.0040	0.0122	2.8914	1.5698	0.0104	2.6601	0.0121	0.0111	1.8	1.77
132	1320	0.0040	0.0122	2.9036	1.5802	0.0104	2.6723	0.0121	0.0111	1.8	1.77
133	1330	0.0040	0.0122	2.9158	1.5906	0.0104	2.6844	0.0121	0.0111	1.8	1.77
134	1340	0.0040	0.0122	2.9280	1.6010	0.0104	2.6966	0.0121	0.0111	1.8	1.77
135	1350	0.0040	0.0122	2.9402	1.6114	0.0104	2.7087	0.0121	0.0111	1.8	1.77
136	1360	0.0040	0.0122	2.9524	1.6218	0.0104	2.7209	0.0121	0.0111	1.8	1.77
137	1370	0.0040	0.0122	2.9646	1.6322	0.0104	2.7330	0.0121	0.0111	1.8	1.77
138	1380	0.0040	0.0122	2.9768	1.6426	0.0104	2.7452	0.0121	0.0111	1.8	1.77
139	1390	0.0040	0.0122	2.9890	1.6531	0.0104	2.7573	0.0121	0.0111	1.8	1.77
140	1400	0.0040	0.0122	3.0012	1.6635	0.0104	2.7695	0.0121	0.0111	1.8	1.78
141	1410	0.0040	0.0122	3.0134	1.6740	0.0105	2.7816	0.0121	0.0111	1.8	1.78
142	1420	0.0040	0.0122	3.0256	1.6844	0.0105	2.7938	0.0121	0.0111	1.8	1.78
143	1430	0.0040	0.0122	3.0378	1.6949	0.0105	2.8059	0.0122	0.0112	1.8	1.78
144	1440	0.0040	0.0122	3.0500	1.7054	0.0105	2.8181	0.0122	0.0112	1.8	1.78

Total Volume of Runoff[1] = 201,578 cu. ft.

Notes:

1. Total Runoff Volume is found by summing column (12) and multiplying by the time step, dt as follows:

   V = SumQ x dt
   V(cu.ft.) = SumQ(cu.ft/s) x dt(min.) x (60 s/min.)

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

Project: City of Snohomish - Stormwater Comp Plan
Basin: 16th / Terrace
Storm Event: 100-YEAR, 24-HOUR
Given:

Area = 26.43 acres
Pt = 3.70 inches
dt = 10 min.
Tc = 47.7 min.

PERVIOUS AREA			IMPERVIOUS AREA (Roads)		
Area	=	15.77 acres	Area	=	10.66 acres
CN	=	86	CN	=	98
S	=	1.63	S	=	0.20
0.2S	=	0.33	0.2S	=	0.04

SUMMARY	
T_{pk}(hrs)=	7.83
T_c (min)=	47.7
Q_{pk}(cfs)=	10.91
Vol(cf)=	258,096

Compute: Runoff Hydrograph

Column (3) = SCS Type IA Rainfall Distribution
Column (4) = Col. (3) x Pt
Column (5) = Accumulated Sum of Col. (4)
Column (6) = [If P <= 0.2S] = 0; Note, use PERVIOUS Area "S" value.
[If P > 0.2S] = (Col.(5) - 0.2S)^2/(Col.(5) + 0.8S); Using the PERVIOUS Area "S" value.
Column (7) = Col.(6) of Present Time Step - Col.(6) of Previous Time Step
Column (8) = Same method as for Col.(6), except use the IMPERVIOUS Area "S" value.
Column (9) = Col.(8) of the present time step - Col.(8) of the previous time step.
Column (10) = ((PERVIOUS area / Total area) x Col.(7)) + ((IMPERVIOUS area / Total area) x Col.(9))
Column (11) = (60.5 x Col.(10) x Total Area) / 10 (dt = 10 minutes)
Routing Constant, w = dt / (2Tc + dt) = 0.0949
Column (12) = Col.(12) of Previous Time Step + (w x [Col.(11) of Previous Time Step
+ Col.(11) of Present Time Step - (2 x Col.(12) of Previous Time Step)])

					Pervious Area		Impervious Area					
(1) Time Increment	(2) Time	(3) Rainfall distri-bution	(4) Incre-mental Rainfall	(5) Accumu-lated Rainfall	(6) Accumu-lated Runoff	(7) Incre-mental Runoff	(8) Accumu-lated Runoff	(9) Incre-mental Runoff	(10) Total Runoff	(11) Instant hydro-graph	(12) design hydro-graph	
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs	
1	10	0.0040	0.0148	0.0148	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
2	20	0.0040	0.0148	0.0296	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
3	30	0.0040	0.0148	0.0444	0.0000	0.0000	0.0001	0.0001	0.0000	0.0	0.00	
4	40	0.0040	0.0148	0.0592	0.0000	0.0000	0.0015	0.0015	0.0006	0.1	0.01	
5	50	0.0040	0.0148	0.0740	0.0000	0.0000	0.0046	0.0031	0.0013	0.2	0.04	
6	60	0.0040	0.0148	0.0888	0.0000	0.0000	0.0091	0.0045	0.0018	0.3	0.08	
7	70	0.0040	0.0148	0.1036	0.0000	0.0000	0.0148	0.0056	0.0023	0.4	0.12	
8	80	0.0040	0.0148	0.1184	0.0000	0.0000	0.0214	0.0066	0.0027	0.4	0.17	
9	90	0.0040	0.0148	0.1332	0.0000	0.0000	0.0288	0.0074	0.0030	0.5	0.23	
10	100	0.0040	0.0148	0.1480	0.0000	0.0000	0.0369	0.0081	0.0033	0.5	0.28	
11	110	0.0050	0.0185	0.1665	0.0000	0.0000	0.0479	0.0110	0.0044	0.7	0.34	
12	120	0.0050	0.0185	0.1850	0.0000	0.0000	0.0597	0.0118	0.0048	0.8	0.42	
13	130	0.0050	0.0185	0.2035	0.0000	0.0000	0.0722	0.0125	0.0050	0.8	0.49	
14	140	0.0050	0.0185	0.2220	0.0000	0.0000	0.0852	0.0130	0.0053	0.8	0.55	
15	150	0.0050	0.0185	0.2405	0.0000	0.0000	0.0988	0.0135	0.0055	0.9	0.61	
16	160	0.0050	0.0185	0.2590	0.0000	0.0000	0.1127	0.0140	0.0056	0.9	0.66	
17	170	0.0060	0.0222	0.2812	0.0000	0.0000	0.1300	0.0173	0.0070	1.1	0.73	
18	180	0.0060	0.0222	0.3034	0.0000	0.0000	0.1478	0.0177	0.0072	1.1	0.80	
19	190	0.0060	0.0222	0.3256	0.0000	0.0000	0.1659	0.0181	0.0073	1.2	0.87	
20	200	0.0060	0.0222	0.3478	0.0003	0.0003	0.1844	0.0185	0.0076	1.2	0.93	
21	210	0.0060	0.0222	0.3700	0.0012	0.0009	0.2032	0.0188	0.0081	1.3	0.99	
22	220	0.0060	0.0222	0.3922	0.0026	0.0014	0.2223	0.0191	0.0086	1.4	1.06	
23	230	0.0070	0.0259	0.4181	0.0050	0.0024	0.2448	0.0226	0.0105	1.7	1.15	
24	240	0.0070	0.0259	0.4440	0.0080	0.0031	0.2677	0.0228	0.0110	1.8	1.26	
25	250	0.0070	0.0259	0.4699	0.0118	0.0037	0.2908	0.0231	0.0115	1.8	1.36	
26	260	0.0070	0.0259	0.4958	0.0161	0.0044	0.3141	0.0233	0.0120	1.9	1.46	
27	270	0.0070	0.0259	0.5217	0.0211	0.0050	0.3376	0.0235	0.0124	2.0	1.55	
28	280	0.0070	0.0259	0.5476	0.0266	0.0056	0.3613	0.0237	0.0129	2.1	1.64	
29	290	0.0082	0.0303	0.5779	0.0339	0.0072	0.3892	0.0279	0.0156	2.5	1.76	
30	300	0.0082	0.0303	0.6083	0.0418	0.0080	0.4174	0.0281	0.0161	2.6	1.91	
31	310	0.0082	0.0303	0.6386	0.0505	0.0087	0.4457	0.0283	0.0166	2.7	2.04	
32	320	0.0082	0.0303	0.6690	0.0598	0.0093	0.4741	0.0284	0.0170	2.7	2.16	
33	330	0.0082	0.0303	0.6993	0.0698	0.0100	0.5027	0.0286	0.0175	2.8	2.28	
34	340	0.0082	0.0303	0.7296	0.0803	0.0106	0.5314	0.0287	0.0179	2.9	2.38	
35	350	0.0095	0.0352	0.7648	0.0933	0.0130	0.5648	0.0334	0.0212	3.4	2.52	
36	360	0.0095	0.0352	0.7999	0.1070	0.0137	0.5983	0.0335	0.0217	3.5	2.69	
37	370	0.0095	0.0352	0.8351	0.1215	0.0144	0.6319	0.0336	0.0222	3.5	2.85	
38	380	0.0095	0.0352	0.8702	0.1365	0.0151	0.6656	0.0337	0.0226	3.6	2.99	
39	390	0.0095	0.0352	0.9054	0.1523	0.0157	0.6995	0.0338	0.0230	3.7	3.11	
40	400	0.0095	0.0352	0.9405	0.1686	0.0163	0.7334	0.0339	0.0234	3.7	3.23	
41	410	0.0134	0.0496	0.9901	0.1926	0.0240	0.7813	0.0480	0.0337	5.4	3.48	
42	420	0.0134	0.0496	1.0397	0.2177	0.0251	0.8294	0.0481	0.0344	5.5	3.85	
43	430	0.0134	0.0496	1.0893	0.2439	0.0261	0.8776	0.0482	0.0350	5.6	4.17	
44	440	0.0180	0.0666	1.1559	0.2804	0.0366	0.9426	0.0649	0.0480	7.7	4.64	
45	450	0.0180	0.0666	1.2225	0.3186	0.0382	1.0076	0.0651	0.0490	7.8	5.23	
46	460	0.0340	0.1258	1.3483	0.3946	0.0760	1.1309	0.1233	0.0951	15.2	6.43	
47	470	0.0540	0.1998	1.5481	0.5243	0.1297	1.3275	0.1966	0.1567	25.1	9.03	
48	480	0.0270	0.0999	1.6480	0.5927	0.0684	1.4261	0.0986	0.0806	12.9	10.91	Q peak
49	490	0.0180	0.0666	1.7146	0.6395	0.0468	1.4919	0.0658	0.0544	8.7	10.89	
50	500	0.0134	0.0496	1.7642	0.6749	0.0354	1.5409	0.0490	0.0409	6.5	10.27	
51	510	0.0134	0.0496	1.8137	0.7107	0.0358	1.5899	0.0490	0.0412	6.6	9.57	
52	520	0.0134	0.0496	1.8633	0.7470	0.0363	1.6390	0.0491	0.0414	6.6	9.00	
53	530	0.0088	0.0326	1.8959	0.7710	0.0240	1.6712	0.0322	0.0273	4.4	8.34	
54	540	0.0088	0.0326	1.9284	0.7952	0.0242	1.7035	0.0322	0.0275	4.4	7.59	
55	550	0.0088	0.0326	1.9610	0.8196	0.0244	1.7357	0.0323	0.0276	4.4	6.98	
56	560	0.0088	0.0326	1.9936	0.8441	0.0245	1.7680	0.0323	0.0277	4.4	6.49	
57	570	0.0088	0.0326	2.0261	0.8688	0.0247	1.8002	0.0323	0.0278	4.4	6.10	
58	580	0.0088	0.0326	2.0587	0.8937	0.0248	1.8325	0.0323	0.0278	4.5	5.79	
59	590	0.0088	0.0326	2.0912	0.9187	0.0250	1.8648	0.0323	0.0279	4.5	5.54	
60	600	0.0088	0.0326	2.1238	0.9438	0.0251	1.8971	0.0323	0.0280	4.5	5.33	
61	610	0.0088	0.0326	2.1564	0.9691	0.0253	1.9294	0.0323	0.0281	4.5	5.17	
62	620	0.0088	0.0326	2.1889	0.9945	0.0254	1.9617	0.0323	0.0282	4.5	5.05	
63	630	0.0088	0.0326	2.2215	1.0200	0.0255	1.9940	0.0323	0.0283	4.5	4.95	
64	640	0.0088	0.0326	2.2540	1.0457	0.0257	2.0264	0.0323	0.0284	4.5	4.87	
65	650	0.0072	0.0266	2.2807	1.0668	0.0211	2.0528	0.0265	0.0233	3.7	4.73	

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

					Pervious Area		Impervious Area				
(1) Time Increment	(2) Time	(3) Rainfall distri- bution	(4) Incre- mental Rainfall	(5) Accumu- lated Rainfall	(6) Accumu- lated Runoff	(7) Incre- mental Runoff	(8) Accumu- lated Runoff	(9) Incre- mental Runoff	(10) Total Runoff	(11) Instant hydro- graph	(12) design hydro- graph
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs
66	660	0.0072	0.0266	2.3073	1.0880	0.0212	2.0793	0.0265	0.0233	3.7	4.54
67	670	0.0072	0.0266	2.3340	1.1093	0.0213	2.1057	0.0265	0.0234	3.7	4.38
68	680	0.0072	0.0266	2.3606	1.1306	0.0213	2.1322	0.0265	0.0234	3.7	4.26
69	690	0.0072	0.0266	2.3872	1.1520	0.0214	2.1587	0.0265	0.0235	3.8	4.16
70	700	0.0072	0.0266	2.4139	1.1735	0.0215	2.1851	0.0265	0.0235	3.8	4.09
71	710	0.0072	0.0266	2.4405	1.1951	0.0216	2.2116	0.0265	0.0235	3.8	4.02
72	720	0.0072	0.0266	2.4672	1.2167	0.0216	2.2381	0.0265	0.0236	3.8	3.98
73	730	0.0072	0.0266	2.4938	1.2384	0.0217	2.2646	0.0265	0.0236	3.8	3.94
74	740	0.0072	0.0266	2.5204	1.2602	0.0218	2.2911	0.0265	0.0237	3.8	3.91
75	750	0.0072	0.0266	2.5471	1.2820	0.0218	2.3175	0.0265	0.0237	3.8	3.89
76	760	0.0072	0.0266	2.5737	1.3039	0.0219	2.3440	0.0265	0.0238	3.8	3.87
77	770	0.0057	0.0211	2.5948	1.3213	0.0174	2.3650	0.0210	0.0188	3.0	3.78
78	780	0.0057	0.0211	2.6159	1.3388	0.0174	2.3860	0.0210	0.0189	3.0	3.64
79	790	0.0057	0.0211	2.6370	1.3562	0.0175	2.4070	0.0210	0.0189	3.0	3.52
80	800	0.0057	0.0211	2.6581	1.3737	0.0175	2.4279	0.0210	0.0189	3.0	3.42
81	810	0.0057	0.0211	2.6792	1.3913	0.0175	2.4489	0.0210	0.0189	3.0	3.35
82	820	0.0057	0.0211	2.7003	1.4089	0.0176	2.4699	0.0210	0.0190	3.0	3.29
83	830	0.0057	0.0211	2.7214	1.4265	0.0176	2.4909	0.0210	0.0190	3.0	3.24
84	840	0.0057	0.0211	2.7424	1.4441	0.0177	2.5119	0.0210	0.0190	3.0	3.20
85	850	0.0057	0.0211	2.7635	1.4618	0.0177	2.5329	0.0210	0.0190	3.0	3.17
86	860	0.0057	0.0211	2.7846	1.4796	0.0177	2.5539	0.0210	0.0190	3.0	3.15
87	870	0.0057	0.0211	2.8057	1.4973	0.0178	2.5748	0.0210	0.0191	3.0	3.13
88	880	0.0057	0.0211	2.8268	1.5151	0.0178	2.5958	0.0210	0.0191	3.1	3.11
89	890	0.0050	0.0185	2.8453	1.5308	0.0156	2.6142	0.0184	0.0168	2.7	3.07
90	900	0.0050	0.0185	2.8638	1.5464	0.0157	2.6327	0.0184	0.0168	2.7	2.99
91	910	0.0050	0.0185	2.8823	1.5621	0.0157	2.6511	0.0184	0.0168	2.7	2.93
92	920	0.0050	0.0185	2.9008	1.5778	0.0157	2.6695	0.0184	0.0168	2.7	2.89
93	930	0.0050	0.0185	2.9193	1.5936	0.0157	2.6879	0.0184	0.0168	2.7	2.85
94	940	0.0050	0.0185	2.9378	1.6093	0.0158	2.7063	0.0184	0.0168	2.7	2.82
95	950	0.0050	0.0185	2.9563	1.6251	0.0158	2.7248	0.0184	0.0168	2.7	2.80
96	960	0.0050	0.0185	2.9748	1.6409	0.0158	2.7432	0.0184	0.0169	2.7	2.78
97	970	0.0050	0.0185	2.9933	1.6567	0.0158	2.7616	0.0184	0.0169	2.7	2.76
98	980	0.0050	0.0185	3.0118	1.6726	0.0159	2.7800	0.0184	0.0169	2.7	2.75
99	990	0.0050	0.0185	3.0303	1.6885	0.0159	2.7984	0.0184	0.0169	2.7	2.74
100	1000	0.0050	0.0185	3.0488	1.7044	0.0159	2.8169	0.0184	0.0169	2.7	2.73
101	1010	0.0040	0.0148	3.0636	1.7171	0.0127	2.8316	0.0147	0.0135	2.2	2.68
102	1020	0.0040	0.0148	3.0784	1.7299	0.0127	2.8464	0.0147	0.0136	2.2	2.58
103	1030	0.0040	0.0148	3.0932	1.7426	0.0128	2.8611	0.0147	0.0136	2.2	2.50
104	1040	0.0040	0.0148	3.1080	1.7554	0.0128	2.8758	0.0147	0.0136	2.2	2.44
105	1050	0.0040	0.0148	3.1228	1.7682	0.0128	2.8906	0.0147	0.0136	2.2	2.39
106	1060	0.0040	0.0148	3.1376	1.7810	0.0128	2.9053	0.0147	0.0136	2.2	2.35
107	1070	0.0040	0.0148	3.1524	1.7938	0.0128	2.9201	0.0147	0.0136	2.2	2.31
108	1080	0.0040	0.0148	3.1672	1.8066	0.0128	2.9348	0.0147	0.0136	2.2	2.29
109	1090	0.0040	0.0148	3.1820	1.8195	0.0128	2.9496	0.0147	0.0136	2.2	2.27
110	1100	0.0040	0.0148	3.1968	1.8323	0.0129	2.9643	0.0147	0.0136	2.2	2.25
111	1110	0.0040	0.0148	3.2116	1.8452	0.0129	2.9790	0.0147	0.0136	2.2	2.24
112	1120	0.0040	0.0148	3.2264	1.8581	0.0129	2.9938	0.0147	0.0136	2.2	2.23
113	1130	0.0040	0.0148	3.2412	1.8710	0.0129	3.0085	0.0147	0.0136	2.2	2.22
114	1140	0.0040	0.0148	3.2560	1.8839	0.0129	3.0233	0.0147	0.0136	2.2	2.21
115	1150	0.0040	0.0148	3.2708	1.8968	0.0129	3.0380	0.0147	0.0137	2.2	2.20
116	1160	0.0040	0.0148	3.2856	1.9097	0.0129	3.0528	0.0147	0.0137	2.2	2.20
117	1170	0.0040	0.0148	3.3004	1.9227	0.0129	3.0675	0.0147	0.0137	2.2	2.20
118	1180	0.0040	0.0148	3.3152	1.9356	0.0130	3.0823	0.0147	0.0137	2.2	2.20
119	1190	0.0040	0.0148	3.3300	1.9486	0.0130	3.0970	0.0147	0.0137	2.2	2.19
120	1200	0.0040	0.0148	3.3448	1.9616	0.0130	3.1118	0.0147	0.0137	2.2	2.19
121	1210	0.0040	0.0148	3.3596	1.9746	0.0130	3.1265	0.0148	0.0137	2.2	2.19
122	1220	0.0040	0.0148	3.3744	1.9876	0.0130	3.1413	0.0148	0.0137	2.2	2.19
123	1230	0.0040	0.0148	3.3892	2.0006	0.0130	3.1560	0.0148	0.0137	2.2	2.19
124	1240	0.0040	0.0148	3.4040	2.0136	0.0130	3.1708	0.0148	0.0137	2.2	2.19
125	1250	0.0040	0.0148	3.4188	2.0266	0.0130	3.1855	0.0148	0.0137	2.2	2.19
126	1260	0.0040	0.0148	3.4336	2.0397	0.0130	3.2003	0.0148	0.0137	2.2	2.19
127	1270	0.0040	0.0148	3.4484	2.0527	0.0131	3.2150	0.0148	0.0137	2.2	2.19
128	1280	0.0040	0.0148	3.4632	2.0658	0.0131	3.2298	0.0148	0.0137	2.2	2.19
129	1290	0.0040	0.0148	3.4780	2.0789	0.0131	3.2445	0.0148	0.0138	2.2	2.20
130	1300	0.0040	0.0148	3.4928	2.0920	0.0131	3.2593	0.0148	0.0138	2.2	2.20
131	1310	0.0040	0.0148	3.5076	2.1051	0.0131	3.2740	0.0148	0.0138	2.2	2.20
132	1320	0.0040	0.0148	3.5224	2.1182	0.0131	3.2888	0.0148	0.0138	2.2	2.20
133	1330	0.0040	0.0148	3.5372	2.1313	0.0131	3.3036	0.0148	0.0138	2.2	2.20
134	1340	0.0040	0.0148	3.5520	2.1444	0.0131	3.3183	0.0148	0.0138	2.2	2.20
135	1350	0.0040	0.0148	3.5668	2.1576	0.0131	3.3331	0.0148	0.0138	2.2	2.20
136	1360	0.0040	0.0148	3.5816	2.1707	0.0132	3.3478	0.0148	0.0138	2.2	2.20
137	1370	0.0040	0.0148	3.5964	2.1839	0.0132	3.3626	0.0148	0.0138	2.2	2.20
138	1380	0.0040	0.0148	3.6112	2.1971	0.0132	3.3773	0.0148	0.0138	2.2	2.20
139	1390	0.0040	0.0148	3.6260	2.2102	0.0132	3.3921	0.0148	0.0138	2.2	2.20
140	1400	0.0040	0.0148	3.6408	2.2234	0.0132	3.4069	0.0148	0.0138	2.2	2.21
141	1410	0.0040	0.0148	3.6556	2.2366	0.0132	3.4216	0.0148	0.0138	2.2	2.21
142	1420	0.0040	0.0148	3.6704	2.2498	0.0132	3.4364	0.0148	0.0138	2.2	2.21
143	1430	0.0040	0.0148	3.6852	2.2631	0.0132	3.4511	0.0148	0.0138	2.2	2.21
144	1440	0.0040	0.0148	3.7000	2.2763	0.0132	3.4659	0.0148	0.0138	2.2	2.21

Total Volume of Runoff[1] = 258,096 cu. ft.

Notes:

1. Total Runoff Volume is found by summing column (12) and multiplying by the time step, dt as follows:

   V = SumQ x dt
   V(cu.ft.) = SumQ(cu.ft/s) x dt(min.) x (60 s/min.)

Existing Maple Ave, 25 yr flow, PVC

Project Description

Friction Method	Manning Formula
Solve For	Channel Slope

Input Data

Roughness Coefficient	0.010	
Normal Depth	1.00	ft
Diameter	1.00	ft
Discharge	12.89	ft³/s

The 25-yr flow was used to determine the slope of the pipe that would be able to contain the design flow in a 12-inch diameter pipe.

Results

Channel Slope	0.07746	ft/ft
Flow Area	0.79	ft²
Wetted Perimeter	3.14	ft
Hydraulic Radius	0.25	ft
Top Width	0.00	ft
Critical Depth	1.00	ft
Percent Full	100.0	%
Critical Slope	0.07443	ft/ft
Velocity	16.41	ft/s
Velocity Head	4.19	ft
Specific Energy	5.19	ft
Froude Number	0.00	
Maximum Discharge	13.87	ft³/s
Discharge Full	12.89	ft³/s
Slope Full	0.07746	ft/ft
Flow Type	SubCritical	

The minimum pipe slope for a 12-inch diameter pipe, is 7.7%. Based on the topography of the land (See Figure C3 of the report) the average slope is 18%.

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%
Normal Depth Over Rise	100.00	%
Downstream Velocity	Infinity	ft/s

Existing Maple Ave, 25 yr flow, PVC

GVF Output Data

Upstream Velocity	Infinity	ft/s
Normal Depth	1.00	ft
Critical Depth	1.00	ft
Channel Slope	0.07746	ft/ft
Critical Slope	0.07443	ft/ft

Maple Ave,100 yr flow, PVC

Project Description

Friction Method	Manning Formula
Solve For	Channel Slope

Input Data

Roughness Coefficient	0.010	
Normal Depth	1.00	ft
Diameter	1.00	ft
Discharge	16.59	ft^3/s

Results

Channel Slope	0.12831	ft/ft
Flow Area	0.79	ft^2
Wetted Perimeter	3.14	ft
Hydraulic Radius	0.25	ft
Top Width	0.00	ft
Critical Depth	1.00	ft
Percent Full	100.0	%
Critical Slope	0.12525	ft/ft
Velocity	21.12	ft/s
Velocity Head	6.93	ft
Specific Energy	7.93	ft
Froude Number	0.00	
Maximum Discharge	17.85	ft^3/s
Discharge Full	16.59	ft^3/s
Slope Full	0.12831	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%
Normal Depth Over Rise	100.00	%
Downstream Velocity	Infinity	ft/s

Maple Ave,100 yr flow, PVC

GVF Output Data

Upstream Velocity	Infinity	ft/s
Normal Depth	1.00	ft
Critical Depth	1.00	ft
Channel Slope	0.12831	ft/ft
Critical Slope	0.12525	ft/ft

City of Snohomish
Stormwater Comprehensive Plan
Time of Concentration
Maple Ave

Calculate Time of Concentration (Tc)

Tc = Sum(Tt)

Where:

Tt = travel time (min) = $\frac{L}{(60xV)}$ (for shallow concentrated flow or channel flow)

Tt = travel time (min)= $\frac{0.42(n_s L)^{0.8}}{(P_2)^{0.5}(s_o)^{0.4}}$ (for sheet flow)

Where:

V = avg. velocity (ft/s) = $V = k(s_o)^{0.5}$

k = time of concentration velocity factor (ft/s)

L = flow length (ft)

n_s = sheet flow Manning's effective roughness coefficient

P_2 = 2-year, 24-hour rainfall (in)

s_o = slope of hydraulic grade line (land slope, ft/ft)

	L (ft)	$k_{s/c}$	V (fps)	n_s	P_2	s_o (ft/ft)	Tt (min)
a - sheet	90	NA	NA	0.24	1.8	0.055	11.7
b - channel	1240	42	10.3	NA	NA	0.06	2.0
Total (Tc)							13.7

Minimum Allowable Tc = 6.0 minutes

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

Project: City of Snohomish - Stormwater Comp Plan
Basin: Maple Avenue
Storm Event: 25-YEAR, 24-HOUR
Given:

Area = 8.08 acres
Pt = 3.05 inches
dt = 10 min.
Tc = 13.7 min.

PERVIOUS AREA			IMPERVIOUS AREA (Roads)		
Area	=	3.31 acres	Area	=	4.77 acres
CN	=	86	CN	=	98
S	=	1.63	S	=	0.20
0.2S	=	0.33	0.2S	=	0.04

SUMMARY	
T_{pk}(hrs)=	7.83
T_c (min)=	13.7
Q_{pk}(cfs)=	4.49
Vol(cf)=	68,825

Compute: Runoff Hydrograph

Column (3) = SCS Type IA Rainfall Distribution
Column (4) = Col. (3) x Pt
Column (5) = Accumulated Sum of Col. (4)
Column (6) = [If P <= 0.2S] = 0; Note, use PERVIOUS Area "S" value.
[If P > 0.2S] = (Col.(5) - 0.2S)^2/(Col.(5) + 0.8S); Using the PERVIOUS Area "S" value.
Column (7) = Col.(6) of Present Time Step - Col.(6) of Previous Time Step
Column (8) = Same method as for Col.(6), except use the IMPERVIOUS Area "S" value.
Column (9) = Col.(8) of the present time step - Col.(8) of the previous time step.
Column (10) = ((PERVIOUS area / Total area) x Col.(7)) + ((IMPERVIOUS area / Total area) x Col.(9))
Column (11) = (60.5 x Col.(10) x Total Area) / 10 (dt = 10 minutes)
Routing Constant, w = dt / (2Tc + dt) = 0.2674
Column (12) = Col.(12) of Previous Time Step + (w x [Col.(11) of Previous Time Step
+ Col.(11) of Present Time Step - (2 x Col.(12) of Previous Time Step)])

					Pervious Area		Impervious Area					
(1) Time Increment	(2) Time	(3) Rainfall distri-bution	(4) Incre-mental Rainfall	(5) Accumu-lated Rainfall	(6) Accumu-lated Runoff	(7) Incre-mental Runoff	(8) Accumu-lated Runoff	(9) Incre-mental Runoff	(10) Total Runoff	(11) Instant hydro-graph	(12) design hydro-graph	
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs	
1	10	0.0040	0.0122	0.0122	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
2	20	0.0040	0.0122	0.0244	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
3	30	0.0040	0.0122	0.0366	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
4	40	0.0040	0.0122	0.0488	0.0000	0.0000	0.0003	0.0003	0.0002	0.0	0.00	
5	50	0.0040	0.0122	0.0610	0.0000	0.0000	0.0018	0.0015	0.0009	0.0	0.02	
6	60	0.0040	0.0122	0.0732	0.0000	0.0000	0.0044	0.0026	0.0015	0.1	0.04	
7	70	0.0040	0.0122	0.0854	0.0000	0.0000	0.0080	0.0036	0.0021	0.1	0.07	
8	80	0.0040	0.0122	0.0976	0.0000	0.0000	0.0124	0.0044	0.0026	0.1	0.09	
9	90	0.0040	0.0122	0.1098	0.0000	0.0000	0.0174	0.0051	0.0030	0.1	0.12	
10	100	0.0040	0.0122	0.1220	0.0000	0.0000	0.0231	0.0057	0.0034	0.2	0.14	
11	110	0.0050	0.0153	0.1373	0.0000	0.0000	0.0309	0.0078	0.0046	0.2	0.17	
12	120	0.0050	0.0153	0.1525	0.0000	0.0000	0.0395	0.0086	0.0051	0.2	0.20	
13	130	0.0050	0.0153	0.1678	0.0000	0.0000	0.0487	0.0092	0.0054	0.3	0.23	
14	140	0.0050	0.0153	0.1830	0.0000	0.0000	0.0584	0.0097	0.0057	0.3	0.25	
15	150	0.0050	0.0153	0.1983	0.0000	0.0000	0.0686	0.0102	0.0060	0.3	0.27	
16	160	0.0050	0.0153	0.2135	0.0000	0.0000	0.0791	0.0106	0.0062	0.3	0.29	
17	170	0.0060	0.0183	0.2318	0.0000	0.0000	0.0923	0.0132	0.0078	0.4	0.32	
18	180	0.0060	0.0183	0.2501	0.0000	0.0000	0.1060	0.0136	0.0080	0.4	0.35	
19	190	0.0060	0.0183	0.2684	0.0000	0.0000	0.1200	0.0140	0.0083	0.4	0.38	
20	200	0.0060	0.0183	0.2867	0.0000	0.0000	0.1344	0.0144	0.0085	0.4	0.40	
21	210	0.0060	0.0183	0.3050	0.0000	0.0000	0.1490	0.0147	0.0087	0.4	0.41	
22	220	0.0060	0.0183	0.3233	0.0000	0.0000	0.1640	0.0150	0.0088	0.4	0.42	
23	230	0.0070	0.0214	0.3447	0.0002	0.0002	0.1818	0.0178	0.0106	0.5	0.45	
24	240	0.0070	0.0214	0.3660	0.0010	0.0008	0.1998	0.0180	0.0110	0.5	0.49	
25	250	0.0070	0.0214	0.3874	0.0023	0.0013	0.2181	0.0183	0.0113	0.6	0.52	
26	260	0.0070	0.0214	0.4087	0.0040	0.0018	0.2366	0.0185	0.0117	0.6	0.54	
27	270	0.0070	0.0214	0.4301	0.0063	0.0023	0.2553	0.0187	0.0120	0.6	0.56	
28	280	0.0070	0.0214	0.4514	0.0090	0.0027	0.2743	0.0189	0.0123	0.6	0.58	
29	290	0.0082	0.0250	0.4764	0.0128	0.0038	0.2966	0.0224	0.0147	0.7	0.62	
30	300	0.0082	0.0250	0.5014	0.0171	0.0044	0.3192	0.0226	0.0151	0.7	0.68	
31	310	0.0082	0.0250	0.5264	0.0221	0.0049	0.3419	0.0227	0.0154	0.8	0.72	
32	320	0.0082	0.0250	0.5514	0.0275	0.0055	0.3648	0.0229	0.0158	0.8	0.74	
33	330	0.0082	0.0250	0.5765	0.0335	0.0060	0.3879	0.0230	0.0161	0.8	0.76	
34	340	0.0082	0.0250	0.6015	0.0400	0.0065	0.4110	0.0232	0.0163	0.8	0.78	
35	350	0.0095	0.0290	0.6304	0.0481	0.0081	0.4380	0.0270	0.0193	0.9	0.83	
36	360	0.0095	0.0290	0.6594	0.0568	0.0087	0.4651	0.0271	0.0196	1.0	0.89	
37	370	0.0095	0.0290	0.6884	0.0661	0.0093	0.4924	0.0273	0.0199	1.0	0.93	
38	380	0.0095	0.0290	0.7174	0.0760	0.0099	0.5198	0.0274	0.0202	1.0	0.96	
39	390	0.0095	0.0290	0.7463	0.0864	0.0104	0.5472	0.0275	0.0205	1.0	0.98	
40	400	0.0095	0.0290	0.7753	0.0973	0.0109	0.5748	0.0276	0.0208	1.0	0.99	
41	410	0.0134	0.0409	0.8162	0.1136	0.0163	0.6138	0.0390	0.0297	1.5	1.12	
42	420	0.0134	0.0409	0.8570	0.1308	0.0172	0.6530	0.0392	0.0302	1.5	1.30	
43	430	0.0134	0.0409	0.8979	0.1489	0.0181	0.6923	0.0393	0.0306	1.5	1.40	
44	440	0.0180	0.0549	0.9528	0.1745	0.0256	0.7452	0.0530	0.0417	2.0	1.60	
45	450	0.0180	0.0549	1.0077	0.2014	0.0270	0.7984	0.0532	0.0424	2.1	1.84	
46	460	0.0340	0.1037	1.1114	0.2558	0.0544	0.8992	0.1008	0.0818	4.0	2.48	
47	470	0.0540	0.1647	1.2761	0.3504	0.0946	1.0602	0.1610	0.1338	6.5	3.97	
48	480	0.0270	0.0824	1.3585	0.4010	0.0505	1.1409	0.0808	0.0684	3.3	4.49	Q peak
49	490	0.0180	0.0549	1.4134	0.4357	0.0348	1.1949	0.0539	0.0461	2.3	3.59	
50	500	0.0134	0.0409	1.4542	0.4621	0.0264	1.2351	0.0402	0.0345	1.7	2.72	
51	510	0.0134	0.0409	1.4951	0.4889	0.0268	1.2753	0.0402	0.0347	1.7	2.17	
52	520	0.0134	0.0409	1.5360	0.5162	0.0272	1.3156	0.0403	0.0349	1.7	1.92	
53	530	0.0088	0.0268	1.5628	0.5343	0.0181	1.3421	0.0265	0.0230	1.1	1.65	
54	540	0.0088	0.0268	1.5897	0.5525	0.0183	1.3685	0.0265	0.0231	1.1	1.37	
55	550	0.0088	0.0268	1.6165	0.5709	0.0184	1.3950	0.0265	0.0232	1.1	1.24	
56	560	0.0088	0.0268	1.6433	0.5895	0.0186	1.4215	0.0265	0.0232	1.1	1.19	
57	570	0.0088	0.0268	1.6702	0.6082	0.0187	1.4480	0.0265	0.0233	1.1	1.16	
58	580	0.0088	0.0268	1.6970	0.6271	0.0189	1.4745	0.0265	0.0234	1.1	1.15	
59	590	0.0088	0.0268	1.7239	0.6461	0.0190	1.5010	0.0265	0.0234	1.1	1.15	
60	600	0.0088	0.0268	1.7507	0.6652	0.0191	1.5276	0.0265	0.0235	1.1	1.15	
61	610	0.0088	0.0268	1.7775	0.6845	0.0193	1.5541	0.0265	0.0236	1.2	1.15	
62	620	0.0088	0.0268	1.8044	0.7039	0.0194	1.5806	0.0265	0.0236	1.2	1.15	
63	630	0.0088	0.0268	1.8312	0.7234	0.0195	1.6072	0.0266	0.0237	1.2	1.15	
64	640	0.0088	0.0268	1.8581	0.7431	0.0197	1.6338	0.0266	0.0237	1.2	1.16	
65	650	0.0072	0.0220	1.8800	0.7593	0.0162	1.6555	0.0217	0.0195	1.0	1.10	

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

					Pervious Area		Impervious Area				
(1) Time Increment	(2) Time	(3) Rainfall distri-bution	(4) Incre-mental Rainfall	(5) Accumu-lated Rainfall	(6) Accumu-lated Runoff	(7) Incre-mental Runoff	(8) Accumu-lated Runoff	(9) Incre-mental Runoff	(10) Total Runoff	(11) Instant hydro-graph	(12) design hydro-graph
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs
66	660	0.0072	0.0220	1.9020	0.7755	0.0163	1.6772	0.0217	0.0195	1.0	1.02
67	670	0.0072	0.0220	1.9239	0.7919	0.0163	1.6990	0.0217	0.0195	1.0	0.99
68	680	0.0072	0.0220	1.9459	0.8083	0.0164	1.7207	0.0218	0.0196	1.0	0.97
69	690	0.0072	0.0220	1.9679	0.8247	0.0165	1.7425	0.0218	0.0196	1.0	0.96
70	700	0.0072	0.0220	1.9898	0.8413	0.0166	1.7643	0.0218	0.0196	1.0	0.96
71	710	0.0072	0.0220	2.0118	0.8579	0.0166	1.7860	0.0218	0.0197	1.0	0.96
72	720	0.0072	0.0220	2.0337	0.8746	0.0167	1.8078	0.0218	0.0197	1.0	0.96
73	730	0.0072	0.0220	2.0557	0.8914	0.0168	1.8296	0.0218	0.0197	1.0	0.96
74	740	0.0072	0.0220	2.0777	0.9082	0.0168	1.8513	0.0218	0.0198	1.0	0.96
75	750	0.0072	0.0220	2.0996	0.9251	0.0169	1.8731	0.0218	0.0198	1.0	0.97
76	760	0.0072	0.0220	2.1216	0.9421	0.0170	1.8949	0.0218	0.0198	1.0	0.97
77	770	0.0057	0.0174	2.1390	0.9556	0.0135	1.9122	0.0172	0.0157	0.8	0.91
78	780	0.0057	0.0174	2.1564	0.9691	0.0135	1.9294	0.0172	0.0157	0.8	0.84
79	790	0.0057	0.0174	2.1737	0.9826	0.0136	1.9467	0.0173	0.0157	0.8	0.80
80	800	0.0057	0.0174	2.1911	0.9962	0.0136	1.9639	0.0173	0.0158	0.8	0.78
81	810	0.0057	0.0174	2.2085	1.0098	0.0136	1.9812	0.0173	0.0158	0.8	0.78
82	820	0.0057	0.0174	2.2259	1.0235	0.0137	1.9984	0.0173	0.0158	0.8	0.77
83	830	0.0057	0.0174	2.2433	1.0372	0.0137	2.0157	0.0173	0.0158	0.8	0.77
84	840	0.0057	0.0174	2.2607	1.0510	0.0137	2.0329	0.0173	0.0158	0.8	0.77
85	850	0.0057	0.0174	2.2780	1.0647	0.0138	2.0502	0.0173	0.0158	0.8	0.77
86	860	0.0057	0.0174	2.2954	1.0785	0.0138	2.0675	0.0173	0.0158	0.8	0.77
87	870	0.0057	0.0174	2.3128	1.0924	0.0138	2.0847	0.0173	0.0159	0.8	0.77
88	880	0.0057	0.0174	2.3302	1.1063	0.0139	2.1020	0.0173	0.0159	0.8	0.78
89	890	0.0050	0.0153	2.3455	1.1185	0.0122	2.1172	0.0151	0.0139	0.7	0.75
90	900	0.0050	0.0153	2.3607	1.1307	0.0122	2.1323	0.0151	0.0140	0.7	0.71
91	910	0.0050	0.0153	2.3760	1.1429	0.0123	2.1475	0.0152	0.0140	0.7	0.70
92	920	0.0050	0.0153	2.3912	1.1552	0.0123	2.1626	0.0152	0.0140	0.7	0.69
93	930	0.0050	0.0153	2.4065	1.1675	0.0123	2.1778	0.0152	0.0140	0.7	0.69
94	940	0.0050	0.0153	2.4217	1.1798	0.0123	2.1929	0.0152	0.0140	0.7	0.68
95	950	0.0050	0.0153	2.4370	1.1922	0.0123	2.2081	0.0152	0.0140	0.7	0.68
96	960	0.0050	0.0153	2.4522	1.2045	0.0124	2.2232	0.0152	0.0140	0.7	0.68
97	970	0.0050	0.0153	2.4675	1.2169	0.0124	2.2384	0.0152	0.0140	0.7	0.69
98	980	0.0050	0.0153	2.4827	1.2294	0.0124	2.2535	0.0152	0.0140	0.7	0.69
99	990	0.0050	0.0153	2.4980	1.2418	0.0124	2.2687	0.0152	0.0140	0.7	0.69
100	1000	0.0050	0.0153	2.5132	1.2543	0.0125	2.2839	0.0152	0.0141	0.7	0.69
101	1010	0.0040	0.0122	2.5254	1.2642	0.0100	2.2960	0.0121	0.0113	0.6	0.65
102	1020	0.0040	0.0122	2.5376	1.2743	0.0100	2.3081	0.0121	0.0113	0.6	0.60
103	1030	0.0040	0.0122	2.5498	1.2843	0.0100	2.3203	0.0121	0.0113	0.6	0.57
104	1040	0.0040	0.0122	2.5620	1.2943	0.0100	2.3324	0.0121	0.0113	0.6	0.56
105	1050	0.0040	0.0122	2.5742	1.3043	0.0100	2.3445	0.0121	0.0113	0.6	0.56
106	1060	0.0040	0.0122	2.5864	1.3144	0.0101	2.3566	0.0121	0.0113	0.6	0.55
107	1070	0.0040	0.0122	2.5986	1.3245	0.0101	2.3688	0.0121	0.0113	0.6	0.55
108	1080	0.0040	0.0122	2.6108	1.3345	0.0101	2.3809	0.0121	0.0113	0.6	0.55
109	1090	0.0040	0.0122	2.6230	1.3446	0.0101	2.3931	0.0121	0.0113	0.6	0.55
110	1100	0.0040	0.0122	2.6352	1.3547	0.0101	2.4052	0.0121	0.0113	0.6	0.55
111	1110	0.0040	0.0122	2.6474	1.3649	0.0101	2.4173	0.0121	0.0113	0.6	0.55
112	1120	0.0040	0.0122	2.6596	1.3750	0.0101	2.4295	0.0121	0.0113	0.6	0.55
113	1130	0.0040	0.0122	2.6718	1.3851	0.0101	2.4416	0.0121	0.0113	0.6	0.55
114	1140	0.0040	0.0122	2.6840	1.3953	0.0102	2.4537	0.0121	0.0113	0.6	0.55
115	1150	0.0040	0.0122	2.6962	1.4055	0.0102	2.4659	0.0121	0.0113	0.6	0.55
116	1160	0.0040	0.0122	2.7084	1.4157	0.0102	2.4780	0.0121	0.0113	0.6	0.55
117	1170	0.0040	0.0122	2.7206	1.4259	0.0102	2.4901	0.0121	0.0113	0.6	0.55
118	1180	0.0040	0.0122	2.7328	1.4361	0.0102	2.5023	0.0121	0.0113	0.6	0.55
119	1190	0.0040	0.0122	2.7450	1.4463	0.0102	2.5144	0.0121	0.0114	0.6	0.55
120	1200	0.0040	0.0122	2.7572	1.4565	0.0102	2.5266	0.0121	0.0114	0.6	0.55
121	1210	0.0040	0.0122	2.7694	1.4668	0.0102	2.5387	0.0121	0.0114	0.6	0.56
122	1220	0.0040	0.0122	2.7816	1.4770	0.0103	2.5508	0.0121	0.0114	0.6	0.56
123	1230	0.0040	0.0122	2.7938	1.4873	0.0103	2.5630	0.0121	0.0114	0.6	0.56
124	1240	0.0040	0.0122	2.8060	1.4976	0.0103	2.5751	0.0121	0.0114	0.6	0.56
125	1250	0.0040	0.0122	2.8182	1.5079	0.0103	2.5873	0.0121	0.0114	0.6	0.56
126	1260	0.0040	0.0122	2.8304	1.5182	0.0103	2.5994	0.0121	0.0114	0.6	0.56
127	1270	0.0040	0.0122	2.8426	1.5285	0.0103	2.6116	0.0121	0.0114	0.6	0.56
128	1280	0.0040	0.0122	2.8548	1.5388	0.0103	2.6237	0.0121	0.0114	0.6	0.56
129	1290	0.0040	0.0122	2.8670	1.5491	0.0103	2.6358	0.0121	0.0114	0.6	0.56
130	1300	0.0040	0.0122	2.8792	1.5595	0.0103	2.6480	0.0121	0.0114	0.6	0.56
131	1310	0.0040	0.0122	2.8914	1.5698	0.0104	2.6601	0.0121	0.0114	0.6	0.56
132	1320	0.0040	0.0122	2.9036	1.5802	0.0104	2.6723	0.0121	0.0114	0.6	0.56
133	1330	0.0040	0.0122	2.9158	1.5906	0.0104	2.6844	0.0121	0.0114	0.6	0.56
134	1340	0.0040	0.0122	2.9280	1.6010	0.0104	2.6966	0.0121	0.0114	0.6	0.56
135	1350	0.0040	0.0122	2.9402	1.6114	0.0104	2.7087	0.0121	0.0114	0.6	0.56
136	1360	0.0040	0.0122	2.9524	1.6218	0.0104	2.7209	0.0121	0.0114	0.6	0.56
137	1370	0.0040	0.0122	2.9646	1.6322	0.0104	2.7330	0.0121	0.0114	0.6	0.56
138	1380	0.0040	0.0122	2.9768	1.6426	0.0104	2.7452	0.0121	0.0114	0.6	0.56
139	1390	0.0040	0.0122	2.9890	1.6531	0.0104	2.7573	0.0121	0.0114	0.6	0.56
140	1400	0.0040	0.0122	3.0012	1.6635	0.0104	2.7695	0.0121	0.0115	0.6	0.56
141	1410	0.0040	0.0122	3.0134	1.6740	0.0105	2.7816	0.0121	0.0115	0.6	0.56
142	1420	0.0040	0.0122	3.0256	1.6844	0.0105	2.7938	0.0121	0.0115	0.6	0.56
143	1430	0.0040	0.0122	3.0378	1.6949	0.0105	2.8059	0.0122	0.0115	0.6	0.56
144	1440	0.0040	0.0122	3.0500	1.7054	0.0105	2.8181	0.0122	0.0115	0.6	0.56

Total Volume of Runoff[1] = 68,825 cu. ft.

Notes:

1. Total Runoff Volume is found by summing column (12) and multiplying by the time step, dt as follows:

   V = SumQ x dt
   V(cu.ft.) = SumQ(cu.ft/s) x dt(min.) x (60 s/min.)

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

Project: City of Snohomish - Stormwater Comp Plan
Basin: Maple Avenue
Storm Event: 100-YEAR, 24-HOUR
Given:

Area = 8.08 acres
Pt = 3.70 inches
dt = 10 min.
Tc = 13.7 min.

PERVIOUS AREA			IMPERVIOUS AREA (Roads)		
Area	=	3.31 acres	Area	=	4.77 acres
CN	=	86	CN	=	98
S	=	1.63	S	=	0.20
0.2S	=	0.33	0.2S	=	0.04

SUMMARY	
T_{pk}(hrs)=	7.83
T_c (min)=	13.7
Q_{pk}(cfs)=	5.68
Vol(cf)=	86,795

Compute: Runoff Hydrograph

Column (3) = SCS Type IA Rainfall Distribution
Column (4) = Col. (3) x Pt
Column (5) = Accumulated Sum of Col. (4)
Column (6) = [If P <= 0.2S] = 0; Note, use PERVIOUS Area "S" value.
[If P > 0.2S] = (Col.(5) - 0.2S)^2/(Col.(5) + 0.8S); Using the PERVIOUS Area "S" value.
Column (7) = Col.(6) of Present Time Step - Col.(6) of Previous Time Step
Column (8) = Same method as for Col.(6), except use the IMPERVIOUS Area "S" value.
Column (9) = Col.(8) of the present time step - Col.(8) of the previous time step.
Column (10) = ((PERVIOUS area / Total area) x Col.(7)) + ((IMPERVIOUS area / Total area) x Col.(9))
Column (11) = (60.5 x Col.(10) x Total Area) / 10 (dt = 10 minutes)
Routing Constant, w = dt / (2Tc + dt) = 0.2674
Column (12) = Col.(12) of Previous Time Step + (w x [Col.(11) of Previous Time Step
+ Col.(11) of Present Time Step - (2 x Col.(12) of Previous Time Step)])

					Pervious Area		Impervious Area					
(1) Time Increment	(2) Time	(3) Rainfall distri-bution	(4) Incre-mental Rainfall	(5) Accumu-lated Rainfall	(6) Accumu-lated Runoff	(7) Incre-mental Runoff	(8) Accumu-lated Runoff	(9) Incre-mental Runoff	(10) Total Runoff	(11) Instant hydro-graph	(12) design hydro-graph	
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs	
1	10	0.0040	0.0148	0.0148	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
2	20	0.0040	0.0148	0.0296	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
3	30	0.0040	0.0148	0.0444	0.0000	0.0000	0.0001	0.0001	0.0000	0.0	0.00	
4	40	0.0040	0.0148	0.0592	0.0000	0.0000	0.0015	0.0015	0.0009	0.0	0.01	
5	50	0.0040	0.0148	0.0740	0.0000	0.0000	0.0046	0.0031	0.0018	0.1	0.04	
6	60	0.0040	0.0148	0.0888	0.0000	0.0000	0.0091	0.0045	0.0027	0.1	0.08	
7	70	0.0040	0.0148	0.1036	0.0000	0.0000	0.0148	0.0056	0.0033	0.2	0.11	
8	80	0.0040	0.0148	0.1184	0.0000	0.0000	0.0214	0.0066	0.0039	0.2	0.15	
9	90	0.0040	0.0148	0.1332	0.0000	0.0000	0.0288	0.0074	0.0044	0.2	0.18	
10	100	0.0040	0.0148	0.1480	0.0000	0.0000	0.0369	0.0081	0.0048	0.2	0.20	
11	110	0.0050	0.0185	0.1665	0.0000	0.0000	0.0479	0.0110	0.0065	0.3	0.24	
12	120	0.0050	0.0185	0.1850	0.0000	0.0000	0.0597	0.0118	0.0070	0.3	0.29	
13	130	0.0050	0.0185	0.2035	0.0000	0.0000	0.0722	0.0125	0.0074	0.4	0.32	
14	140	0.0050	0.0185	0.2220	0.0000	0.0000	0.0852	0.0130	0.0077	0.4	0.35	
15	150	0.0050	0.0185	0.2405	0.0000	0.0000	0.0988	0.0135	0.0080	0.4	0.37	
16	160	0.0050	0.0185	0.2590	0.0000	0.0000	0.1127	0.0140	0.0083	0.4	0.38	
17	170	0.0060	0.0222	0.2812	0.0000	0.0000	0.1300	0.0173	0.0102	0.5	0.42	
18	180	0.0060	0.0222	0.3034	0.0000	0.0000	0.1478	0.0177	0.0105	0.5	0.47	
19	190	0.0060	0.0222	0.3256	0.0000	0.0000	0.1659	0.0181	0.0107	0.5	0.49	
20	200	0.0060	0.0222	0.3478	0.0003	0.0003	0.1844	0.0185	0.0110	0.5	0.51	
21	210	0.0060	0.0222	0.3700	0.0012	0.0009	0.2032	0.0188	0.0115	0.6	0.53	
22	220	0.0060	0.0222	0.3922	0.0026	0.0014	0.2223	0.0191	0.0119	0.6	0.55	
23	230	0.0070	0.0259	0.4181	0.0050	0.0024	0.2448	0.0226	0.0143	0.7	0.60	
24	240	0.0070	0.0259	0.4440	0.0080	0.0031	0.2677	0.0228	0.0147	0.7	0.66	
25	250	0.0070	0.0259	0.4699	0.0118	0.0037	0.2908	0.0231	0.0152	0.7	0.70	
26	260	0.0070	0.0259	0.4958	0.0161	0.0044	0.3141	0.0233	0.0156	0.8	0.73	
27	270	0.0070	0.0259	0.5217	0.0211	0.0050	0.3376	0.0235	0.0159	0.8	0.75	
28	280	0.0070	0.0259	0.5476	0.0266	0.0056	0.3613	0.0237	0.0163	0.8	0.77	
29	290	0.0082	0.0303	0.5779	0.0339	0.0072	0.3892	0.0279	0.0195	1.0	0.82	
30	300	0.0082	0.0303	0.6083	0.0418	0.0080	0.4174	0.0281	0.0199	1.0	0.90	
31	310	0.0082	0.0303	0.6386	0.0505	0.0087	0.4457	0.0283	0.0203	1.0	0.94	
32	320	0.0082	0.0303	0.6690	0.0598	0.0093	0.4741	0.0284	0.0206	1.0	0.97	
33	330	0.0082	0.0303	0.6993	0.0698	0.0100	0.5027	0.0286	0.0210	1.0	1.00	
34	340	0.0082	0.0303	0.7296	0.0803	0.0106	0.5314	0.0287	0.0213	1.0	1.02	
35	350	0.0095	0.0352	0.7648	0.0933	0.0130	0.5648	0.0334	0.0250	1.2	1.08	
36	360	0.0095	0.0352	0.7999	0.1070	0.0137	0.5983	0.0335	0.0254	1.2	1.16	
37	370	0.0095	0.0352	0.8351	0.1215	0.0144	0.6319	0.0336	0.0258	1.3	1.21	
38	380	0.0095	0.0352	0.8702	0.1365	0.0151	0.6656	0.0337	0.0261	1.3	1.24	
39	390	0.0095	0.0352	0.9054	0.1523	0.0157	0.6995	0.0338	0.0264	1.3	1.26	
40	400	0.0095	0.0352	0.9405	0.1686	0.0163	0.7334	0.0339	0.0267	1.3	1.28	
41	410	0.0134	0.0496	0.9901	0.1926	0.0240	0.7813	0.0480	0.0382	1.9	1.44	
42	420	0.0134	0.0496	1.0397	0.2177	0.0251	0.8294	0.0481	0.0387	1.9	1.68	
43	430	0.0134	0.0496	1.0893	0.2439	0.0261	0.8776	0.0482	0.0392	1.9	1.80	
44	440	0.0180	0.0666	1.1559	0.2804	0.0366	0.9426	0.0649	0.0533	2.6	2.04	
45	450	0.0180	0.0666	1.2225	0.3186	0.0382	1.0076	0.0651	0.0541	2.6	2.35	
46	460	0.0340	0.1258	1.3483	0.3946	0.0760	1.1309	0.1233	0.1039	5.1	3.16	
47	470	0.0540	0.1998	1.5481	0.5243	0.1297	1.3275	0.1966	0.1692	8.3	5.04	
48	480	0.0270	0.0999	1.6480	0.5927	0.0684	1.4261	0.0986	0.0862	4.2	5.68	Q peak
49	490	0.0180	0.0666	1.7146	0.6395	0.0468	1.4919	0.0658	0.0580	2.8	4.53	
50	500	0.0134	0.0496	1.7642	0.6749	0.0354	1.5409	0.0490	0.0434	2.1	3.43	
51	510	0.0134	0.0496	1.8137	0.7107	0.0358	1.5899	0.0490	0.0436	2.1	2.73	
52	520	0.0134	0.0496	1.8633	0.7470	0.0363	1.6390	0.0491	0.0438	2.1	2.42	
53	530	0.0088	0.0326	1.8959	0.7710	0.0240	1.6712	0.0322	0.0289	1.4	2.07	
54	540	0.0088	0.0326	1.9284	0.7952	0.0242	1.7035	0.0322	0.0290	1.4	1.72	
55	550	0.0088	0.0326	1.9610	0.8196	0.0244	1.7357	0.0323	0.0290	1.4	1.56	
56	560	0.0088	0.0326	1.9936	0.8441	0.0245	1.7680	0.0323	0.0291	1.4	1.48	
57	570	0.0088	0.0326	2.0261	0.8688	0.0247	1.8002	0.0323	0.0292	1.4	1.45	
58	580	0.0088	0.0326	2.0587	0.8937	0.0248	1.8325	0.0323	0.0292	1.4	1.44	
59	590	0.0088	0.0326	2.0912	0.9187	0.0250	1.8648	0.0323	0.0293	1.4	1.43	
60	600	0.0088	0.0326	2.1238	0.9438	0.0251	1.8971	0.0323	0.0294	1.4	1.43	
61	610	0.0088	0.0326	2.1564	0.9691	0.0253	1.9294	0.0323	0.0294	1.4	1.44	
62	620	0.0088	0.0326	2.1889	0.9945	0.0254	1.9617	0.0323	0.0295	1.4	1.44	
63	630	0.0088	0.0326	2.2215	1.0200	0.0255	1.9940	0.0323	0.0295	1.4	1.44	
64	640	0.0088	0.0326	2.2540	1.0457	0.0257	2.0264	0.0323	0.0296	1.4	1.44	
65	650	0.0072	0.0266	2.2807	1.0668	0.0211	2.0528	0.0265	0.0243	1.2	1.38	

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

					Pervious Area		Impervious Area				
(1) Time Increment	(2) Time	(3) Rainfall distri- bution	(4) Incre- mental Rainfall	(5) Accumu- lated Rainfall	(6) Accumu- lated Runoff	(7) Incre- mental Runoff	(8) Accumu- lated Runoff	(9) Incre- mental Runoff	(10) Total Runoff	(11) Instant hydro- graph	(12) design hydro- graph
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs
66	660	0.0072	0.0266	2.3073	1.0880	0.0212	2.0793	0.0265	0.0243	1.2	1.27
67	670	0.0072	0.0266	2.3340	1.1093	0.0213	2.1057	0.0265	0.0243	1.2	1.23
68	680	0.0072	0.0266	2.3606	1.1306	0.0213	2.1322	0.0265	0.0244	1.2	1.21
69	690	0.0072	0.0266	2.3872	1.1520	0.0214	2.1587	0.0265	0.0244	1.2	1.20
70	700	0.0072	0.0266	2.4139	1.1735	0.0215	2.1851	0.0265	0.0244	1.2	1.20
71	710	0.0072	0.0266	2.4405	1.1951	0.0216	2.2116	0.0265	0.0245	1.2	1.20
72	720	0.0072	0.0266	2.4672	1.2167	0.0216	2.2381	0.0265	0.0245	1.2	1.20
73	730	0.0072	0.0266	2.4938	1.2384	0.0217	2.2646	0.0265	0.0245	1.2	1.20
74	740	0.0072	0.0266	2.5204	1.2602	0.0218	2.2911	0.0265	0.0246	1.2	1.20
75	750	0.0072	0.0266	2.5471	1.2820	0.0218	2.3175	0.0265	0.0246	1.2	1.20
76	760	0.0072	0.0266	2.5737	1.3039	0.0219	2.3440	0.0265	0.0246	1.2	1.20
77	770	0.0057	0.0211	2.5948	1.3213	0.0174	2.3650	0.0210	0.0195	1.0	1.14
78	780	0.0057	0.0211	2.6159	1.3388	0.0174	2.3860	0.0210	0.0195	1.0	1.04
79	790	0.0057	0.0211	2.6370	1.3562	0.0175	2.4070	0.0210	0.0195	1.0	0.99
80	800	0.0057	0.0211	2.6581	1.3737	0.0175	2.4279	0.0210	0.0196	1.0	0.97
81	810	0.0057	0.0211	2.6792	1.3913	0.0175	2.4489	0.0210	0.0196	1.0	0.96
82	820	0.0057	0.0211	2.7003	1.4089	0.0176	2.4699	0.0210	0.0196	1.0	0.96
83	830	0.0057	0.0211	2.7214	1.4265	0.0176	2.4909	0.0210	0.0196	1.0	0.96
84	840	0.0057	0.0211	2.7424	1.4441	0.0177	2.5119	0.0210	0.0196	1.0	0.96
85	850	0.0057	0.0211	2.7635	1.4618	0.0177	2.5329	0.0210	0.0196	1.0	0.96
86	860	0.0057	0.0211	2.7846	1.4796	0.0177	2.5539	0.0210	0.0197	1.0	0.96
87	870	0.0057	0.0211	2.8057	1.4973	0.0178	2.5748	0.0210	0.0197	1.0	0.96
88	880	0.0057	0.0211	2.8268	1.5151	0.0178	2.5958	0.0210	0.0197	1.0	0.96
89	890	0.0050	0.0185	2.8453	1.5308	0.0156	2.6142	0.0184	0.0173	0.8	0.93
90	900	0.0050	0.0185	2.8638	1.5464	0.0157	2.6327	0.0184	0.0173	0.8	0.88
91	910	0.0050	0.0185	2.8823	1.5621	0.0157	2.6511	0.0184	0.0173	0.8	0.86
92	920	0.0050	0.0185	2.9008	1.5778	0.0157	2.6695	0.0184	0.0173	0.8	0.85
93	930	0.0050	0.0185	2.9193	1.5936	0.0157	2.6879	0.0184	0.0173	0.8	0.85
94	940	0.0050	0.0185	2.9378	1.6093	0.0158	2.7063	0.0184	0.0173	0.8	0.85
95	950	0.0050	0.0185	2.9563	1.6251	0.0158	2.7248	0.0184	0.0173	0.8	0.85
96	960	0.0050	0.0185	2.9748	1.6409	0.0158	2.7432	0.0184	0.0174	0.8	0.85
97	970	0.0050	0.0185	2.9933	1.6567	0.0158	2.7616	0.0184	0.0174	0.8	0.85
98	980	0.0050	0.0185	3.0118	1.6726	0.0159	2.7800	0.0184	0.0174	0.8	0.85
99	990	0.0050	0.0185	3.0303	1.6885	0.0159	2.7984	0.0184	0.0174	0.8	0.85
100	1000	0.0050	0.0185	3.0488	1.7044	0.0159	2.8169	0.0184	0.0174	0.9	0.85
101	1010	0.0040	0.0148	3.0636	1.7171	0.0127	2.8316	0.0147	0.0139	0.7	0.80
102	1020	0.0040	0.0148	3.0784	1.7299	0.0127	2.8464	0.0147	0.0139	0.7	0.74
103	1030	0.0040	0.0148	3.0932	1.7426	0.0128	2.8611	0.0147	0.0139	0.7	0.71
104	1040	0.0040	0.0148	3.1080	1.7554	0.0128	2.8758	0.0147	0.0139	0.7	0.69
105	1050	0.0040	0.0148	3.1228	1.7682	0.0128	2.8906	0.0147	0.0139	0.7	0.69
106	1060	0.0040	0.0148	3.1376	1.7810	0.0128	2.9053	0.0147	0.0139	0.7	0.68
107	1070	0.0040	0.0148	3.1524	1.7938	0.0128	2.9201	0.0147	0.0140	0.7	0.68
108	1080	0.0040	0.0148	3.1672	1.8066	0.0128	2.9348	0.0147	0.0140	0.7	0.68
109	1090	0.0040	0.0148	3.1820	1.8195	0.0128	2.9496	0.0147	0.0140	0.7	0.68
110	1100	0.0040	0.0148	3.1968	1.8323	0.0129	2.9643	0.0147	0.0140	0.7	0.68
111	1110	0.0040	0.0148	3.2116	1.8452	0.0129	2.9790	0.0147	0.0140	0.7	0.68
112	1120	0.0040	0.0148	3.2264	1.8581	0.0129	2.9938	0.0147	0.0140	0.7	0.68
113	1130	0.0040	0.0148	3.2412	1.8710	0.0129	3.0085	0.0147	0.0140	0.7	0.68
114	1140	0.0040	0.0148	3.2560	1.8839	0.0129	3.0233	0.0147	0.0140	0.7	0.68
115	1150	0.0040	0.0148	3.2708	1.8968	0.0129	3.0380	0.0147	0.0140	0.7	0.68
116	1160	0.0040	0.0148	3.2856	1.9097	0.0129	3.0528	0.0147	0.0140	0.7	0.68
117	1170	0.0040	0.0148	3.3004	1.9227	0.0129	3.0675	0.0147	0.0140	0.7	0.68
118	1180	0.0040	0.0148	3.3152	1.9356	0.0130	3.0823	0.0147	0.0140	0.7	0.68
119	1190	0.0040	0.0148	3.3300	1.9486	0.0130	3.0970	0.0147	0.0140	0.7	0.68
120	1200	0.0040	0.0148	3.3448	1.9616	0.0130	3.1118	0.0147	0.0140	0.7	0.69
121	1210	0.0040	0.0148	3.3596	1.9746	0.0130	3.1265	0.0148	0.0140	0.7	0.69
122	1220	0.0040	0.0148	3.3744	1.9876	0.0130	3.1413	0.0148	0.0140	0.7	0.69
123	1230	0.0040	0.0148	3.3892	2.0006	0.0130	3.1560	0.0148	0.0140	0.7	0.69
124	1240	0.0040	0.0148	3.4040	2.0136	0.0130	3.1708	0.0148	0.0140	0.7	0.69
125	1250	0.0040	0.0148	3.4188	2.0266	0.0130	3.1855	0.0148	0.0140	0.7	0.69
126	1260	0.0040	0.0148	3.4336	2.0397	0.0130	3.2003	0.0148	0.0141	0.7	0.69
127	1270	0.0040	0.0148	3.4484	2.0527	0.0131	3.2150	0.0148	0.0141	0.7	0.69
128	1280	0.0040	0.0148	3.4632	2.0658	0.0131	3.2298	0.0148	0.0141	0.7	0.69
129	1290	0.0040	0.0148	3.4780	2.0789	0.0131	3.2445	0.0148	0.0141	0.7	0.69
130	1300	0.0040	0.0148	3.4928	2.0920	0.0131	3.2593	0.0148	0.0141	0.7	0.69
131	1310	0.0040	0.0148	3.5076	2.1051	0.0131	3.2740	0.0148	0.0141	0.7	0.69
132	1320	0.0040	0.0148	3.5224	2.1182	0.0131	3.2888	0.0148	0.0141	0.7	0.69
133	1330	0.0040	0.0148	3.5372	2.1313	0.0131	3.3036	0.0148	0.0141	0.7	0.69
134	1340	0.0040	0.0148	3.5520	2.1444	0.0131	3.3183	0.0148	0.0141	0.7	0.69
135	1350	0.0040	0.0148	3.5668	2.1576	0.0131	3.3331	0.0148	0.0141	0.7	0.69
136	1360	0.0040	0.0148	3.5816	2.1707	0.0132	3.3478	0.0148	0.0141	0.7	0.69
137	1370	0.0040	0.0148	3.5964	2.1839	0.0132	3.3626	0.0148	0.0141	0.7	0.69
138	1380	0.0040	0.0148	3.6112	2.1971	0.0132	3.3773	0.0148	0.0141	0.7	0.69
139	1390	0.0040	0.0148	3.6260	2.2102	0.0132	3.3921	0.0148	0.0141	0.7	0.69
140	1400	0.0040	0.0148	3.6408	2.2234	0.0132	3.4069	0.0148	0.0141	0.7	0.69
141	1410	0.0040	0.0148	3.6556	2.2366	0.0132	3.4216	0.0148	0.0141	0.7	0.69
142	1420	0.0040	0.0148	3.6704	2.2498	0.0132	3.4364	0.0148	0.0141	0.7	0.69
143	1430	0.0040	0.0148	3.6852	2.2631	0.0132	3.4511	0.0148	0.0141	0.7	0.69
144	1440	0.0040	0.0148	3.7000	2.2763	0.0132	3.4659	0.0148	0.0141	0.7	0.69

Total Volume of Runoff[1] = 86,795 cu. ft.

Notes:

1. Total Runoff Volume is found by summing column (12) and multiplying by the time step, dt as follows:

   V = SumQ x dt
   V(cu.ft.) = SumQ(cu.ft/s) x dt(min.) x (60 s/min.)

Table 2.2
Runoff Curve Numbers for Selected Agricultural, Suburban, and Urban Areas

(Sources: TR 55, 1986, and Stormwater Management Manual, 1992. See Section 2.1.1 for explanation)

Cover type and hydrologic condition.	CNs for hydrologic soil group A	B	C	D
Curve Numbers for Pre-Development Conditions				
Pasture, grassland, or range-continuous forage for grazing:				
Fair condition (ground cover 50% to 75% and not heavily grazed).	49	69	79	84
Good condition (ground cover >75% and lightly or only occasionally grazed)	39	61	74	80
Woods:				
Fair (Woods are grazed but not burned, and some forest litter covers the soil).	36	60	73	79
Good (Woods are protected from grazing, and litter and brush adequately cover the soil).	30	55	70	77
Curve Numbers for Post-Development Conditions				
Open space (lawns, parks, golf courses, cemeteries, landscaping, etc.)[1]				
Fair condition (grass cover on 50% - 75% of the area).	77	85	90	92
Good condition (grass cover on >75% of the area)	68	80	86	90
Impervious areas:				
Open water bodies: lakes, wetlands, ponds etc.	100	100	100	100
Paved parking lots, roofs[2], driveways, etc. (excluding right-of-way)	98	98	98	98
Permeable Pavement (See Appendix C to decide which condition below to use)				
Landscaped area	77	85	90	92
50% landscaped area/50% impervious	87	91	94	96
100% impervious area	98	98	98	98
Paved	98	98	98	98
Gravel (including right-of-way)	76	85	89	91
Dirt (including right-of-way)	72	82	87	89
Pasture, grassland, or range-continuous forage for grazing:				
Poor condition (ground cover <50% or heavily grazed with no mulch).	68	79	86	89
Fair condition (ground cover 50% to 75% and not heavily grazed).	49	69	79	84
Good condition (ground cover >75% and lightly or only occasionally grazed)	39	61	74	80
Woods:				
Poor (Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning).	45	66	77	83
Fair (Woods are grazed but not burned, and some forest litter covers the soil).	36	60	73	79
Good (Woods are protected from grazing, and litter and brush adequately cover the soil).	30	55	70	77

Single family residential[3]: Dwelling Unit/Gross Acre	Should only be used for subdivisions > 50 acres	Average Percent impervious area[3,4]	
1.0 DU/GA		15	Separate curve number
1.5 DU/GA		20	shall be selected for
2.0 DU/GA		25	pervious & impervious
2.5 DU/GA		30	portions of the site or
3.0 DU/GA		34	basin
3.5 DU/GA		38	
4.0 DU/GA		42	
4.5 DU/GA		46	
5.0 DU/GA		48	
5.5 DU/GA		50	
6.0 DU/GA		52	
6.5 DU/GA		54	
7.0 DU/GA		56	
7.5 DU/GA		58	

PUD's, condos, apartments, commercial businesses, industrial areas & & subdivisions < 50 acres	%impervious must be computed	Separate curve numbers shall be selected for pervious and impervious portions of the site	

For a more detailed and complete description of land use curve numbers refer to chapter two (2) of the Soil Conservation Service's Technical Release No. 55 , (210-VI-TR-55, Second Ed., June 1986).

[1] Composite CN's may be computed for other combinations of open space cover type.

[2] Where roof runoff and driveway runoff are infiltrated or dispersed according to the requirements in Chapter 3, the average percent impervious area may be adjusted in accordance with the procedure described under "Flow Credit for Roof Downspout Infiltration" (Section 3.1.1), and "Flow Credit for Roof Downspout Dispersion" (Section 3.1.2).

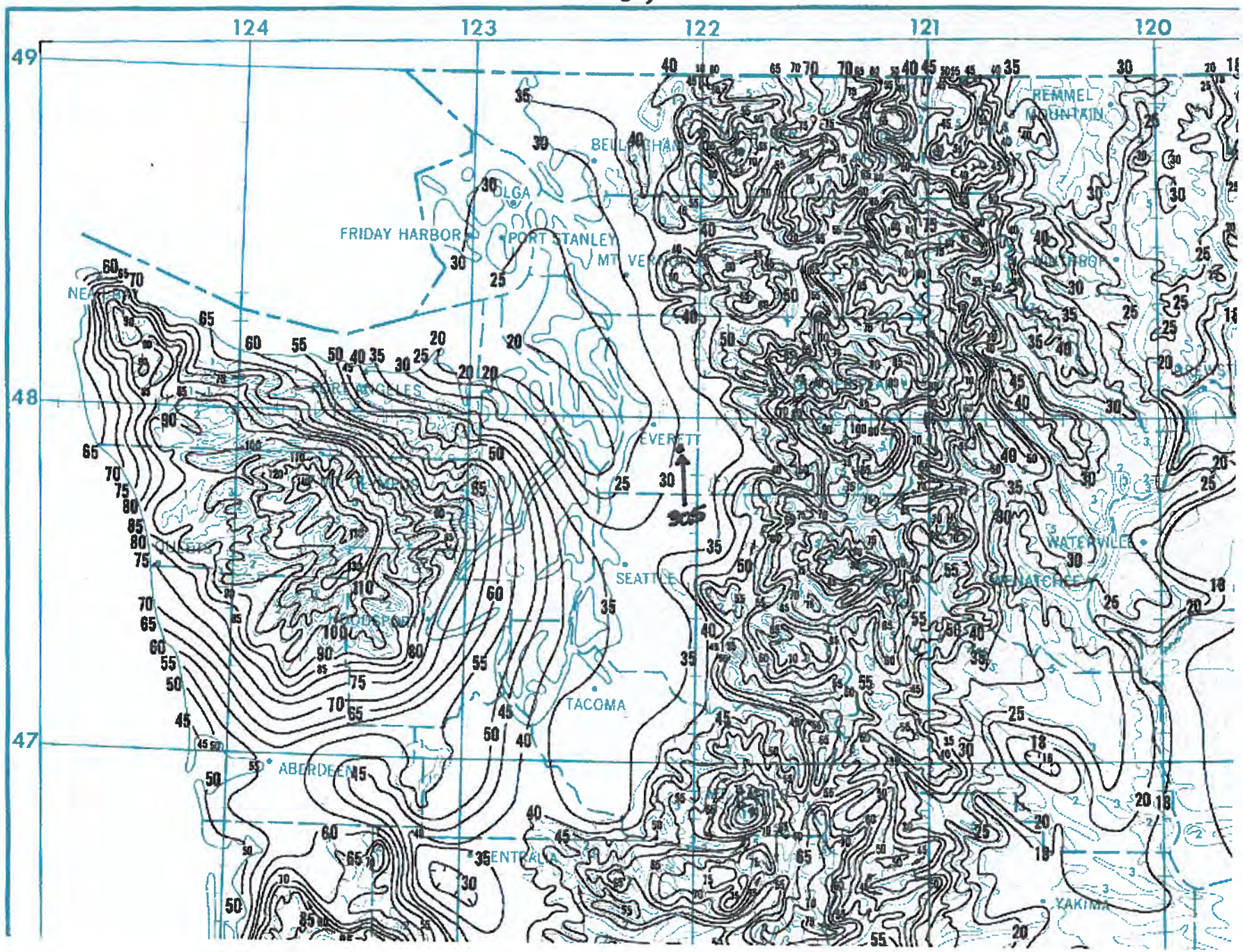
[3] Assumes roof and driveway runoff is directed into street/storm system.

[4] All the remaining pervious area (lawn) are considered to be in good condition for these curve numbers.

Table 4.4.1 Values of "n" and "k" for use in computing Time of Concentration

FOR SHEET FLOW	**n_s**
Smooth surfaces (concrete, asphalt, gravel, or bare hard soil)	0.011
Fallow fields of loose soil surface (no vegetal residue)	0.05
Cultivated soil with crop residue (slope < 0.20 ft/ft)	0.06
Cultivated soil with crop residue (slope > 0.20 ft/ft)	0.17
Short prairie grass and lawns	0.15
Dense grass	0.24
Bermuda grass	0.41
Range, natural	0.13
Woods or forest, poor cover	0.40
Woods or forest, good cover	0.80
FOR SHALLOW, CONCENTRATED FLOW	**k_s**
Forest with heavy ground litter and meadows (n = 0.10)	3
Brushy ground with some trees (n =0.06)	5
Fallow or minimum tillage cultivation (n = 0.04)	8
High grass (n = 0.035)	9
Short grass, pasture and lawns (n = 0.030)	11
Newly-bare ground (n = 0.025)	13
Paved and gravel areas (n = 0.012)	27
CHANNEL FLOW (INTERMITTENT, R = 0.2)	**k_c**
Forested swale with heavy ground litter (n=0.10)	5
Forested drainage course/ravine with defined channel bed (n=0.050)	10
Rock-lined waterway (n=0.035)	15
Grassed waterway (n=0.030)	17
Earth-lined waterway (n=0.025)	20
CMP pipe (n=0.024)	21
Concrete pipe (n=0.012)	42
Other waterways and pipes	0.508/n
CHANNEL FLOW (CONTINUOUS STREAM, R =0.4)	**k_c**
Meandering stream with some pools (n=0.040)	20
Rock-lined stream (n=0.035)	23
Grassed stream (n=0.030)	27
Other streams, man-made channels and pipe	0.807/n

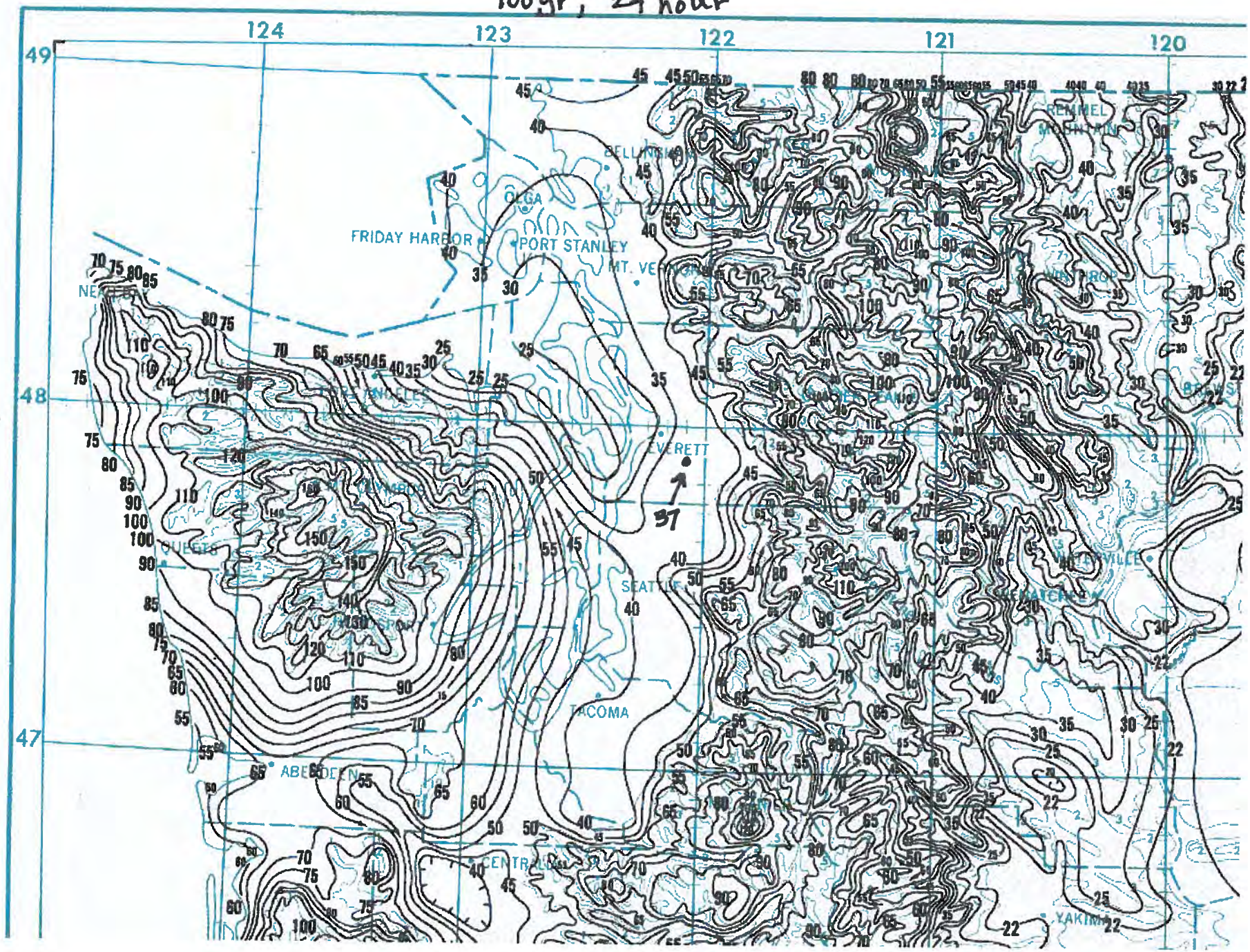
25yr, 24hour



http://www.wrcc.dri.edu/pcpnfreq/wa25y24h.gif

10/3/2012

100yr, 24 hour



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10/3/2012

Detention Facility – 16th and Terrace

URS CALCULATION COVER SHEET Quality

Project Name:	Stormwater Comprehensive Plan Update	**Project Number:**	33763575
Project Location:	City of Snohomish	**Client Name:**	City of Snohomish
PM Name:	Carla Talich	**PIC Name:**	Kevin Weed

IDENTIFYING INFORMATION

(This section is to be completed by the Originator.)

Calculation Medium: ☐ Electronic File Name: K:\City of Snohomish\Stormwater Comp Plan\Stormwater Modeling - NEW moved\Detention – 16th and Terrace

(Select as appropriate) ☒ Hard-copy Unique Identification:

Number of pages *(including cover sheet)*: 8

Discipline: Hydrology

Title of Calculation: Detention Facility – 16th and Terrace

Calculation Originator: C. Talich

Calculation Contributors:

Calculation Checker: John Gillespie

DESCRIPTION & PURPOSE

Use the land use designations within the combined utility area and use WWHM to calculate the water quality volume and flow rates for both on-line and off-line facilities.

BASIS / REFERENCE / ASSUMPTIONS

Assumptions are stated on calculation write up.

ISSUE / REVISION RECORD

Checker comments, if any, provided on: ☒ hard-copy ☐ electronic file ☐ Form 3-5 (MM)

No.	Description	P	S	F	Originator Initials	Date	Checker Initials	Date
0	Initial Issue	☐	☐	☒	cgt	7/29/13	JFG	8-1-13
1		☐	☐	☐	[ ]	[ ]	[ ]	[ ]
2		☐	☐	☐	[ ]	[ ]	[ ]	[ ]
3		☐	☐	☐	[ ]	[ ]	[ ]	[ ]

Note: For a given Revision No. Check off either P (Preliminary), S (Superseding) or F (Final). If there are no revisions to the Initial Issue check off F (Final). Comments may be provided on the hard-copy calculations, electronic file or on Form 3-5 (MM).

APPROVAL and DISTRIBUTION

☐ The calculations associated with this Cover Sheet have been checked.

Carla Talich — Originator Signature — 7/29/13 — Date

John Gillespie — Checker Signature — 8-1-13 — Date

Carla Talich — Project Manager Signature — 8.1.13. — Date

Distribution:

Project Central File – Quality file folder Other Specify: ____

Project Statement:
Proposed project C-5b includes adding a storm drainage system to the Holly Vista neighborhood to improve stormwater conveyance and reduce flooding on private property. The project also includes replacing an under capacity ditch/swale on private property with a storm drain placed in the unopened Terrace Avenue right-of-way.

Stormwater travels from the Holly Vista neighborhood, through the 16th Street and Terrace Avenue area, through the Suncrest development, and then down the unopened Fairview ROW to a 12-inch diameter stormdrain in Maple Avenue. Based on City mapping, the 12-inch diameter pipe in Maple Avenue is sloped at approximately 1 percent (Attachment 1).

The calculation package entitled, "16th &Terrace - Maple Ave" present land use, hydrologic model input and peak flows for consideration for design of the proposed storm drain pipe improvements. Those calculations do not consider existing or proposed detention facilities.

There is an existing detention facility located within the Suncrest development (Attachment 2). The facility is made up of a 76-foot long, 60-inch diameter detention pipe with Type II catch basins on each end (48-inch diameter upstream and 54-inch diameter downstream).

The purpose of this calculation is to determine if detention storage would be recommended for the proposed project C-5b.

Assumptions:
In accordance with the 2005 Ecology Manual, there is no new development or change in land use associated with this project, so it is assumed that detention facilities would not be required other than to evaluate the downstream, manmade system for flood control considerations.

It is assumed that the Suncrest detention pipe provides adequate storage under the existing condition to provide flood control to the downstream drainage system. There have been no reports of flooding within the 12-inch diameter mainline in Maple Avenue.

The 25-year 24-hour storm was used to evaluate the drainage system upstream of Suncrest and develop a conceptual detention system size.

No storm flow routing was included in this conceptual design. It was assumed that the capacity of the storm drainage pipe in Maple Avenue would be used as the upper threshold for discharge during a 25-year 24-hour storm event at the proposed detention facility within the unopened Terrace Avenue.

Capacity of 12-inch diameter Storm drain in Maple Avenue:
Bentley FlowMaster was used to evaluate the available capacity in the existing 12-inch diameter pipe in Maple Avenue. The available capacity is approximately 5 cfs (Attachment 3).

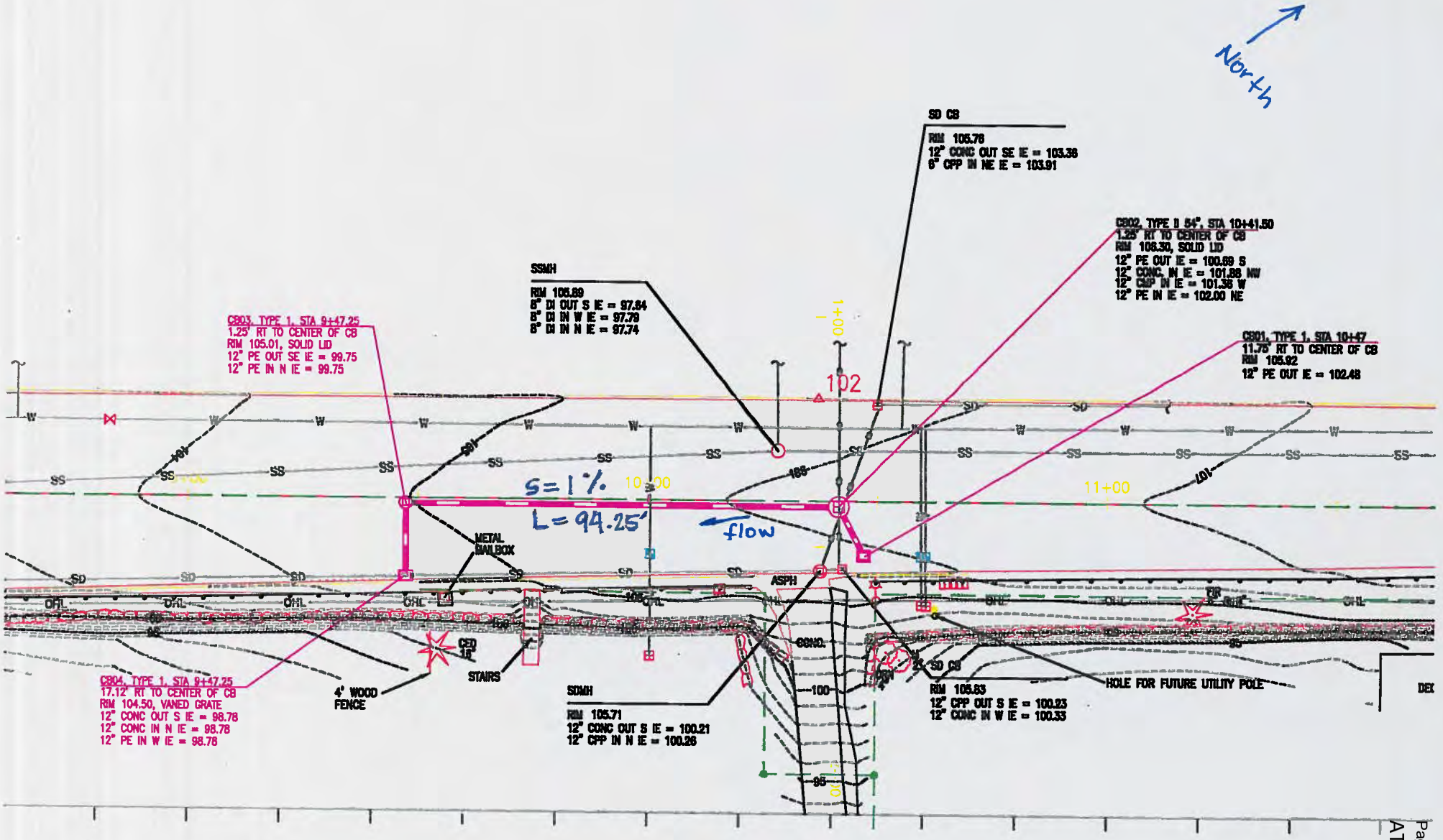
Detention Sizing
The SBUH calculations prepared for the calculation package entitled, "16th&Terrace - Maple Ave" were modified to allow for a discharge rate of 5 cfs. Time steps with discharge greater

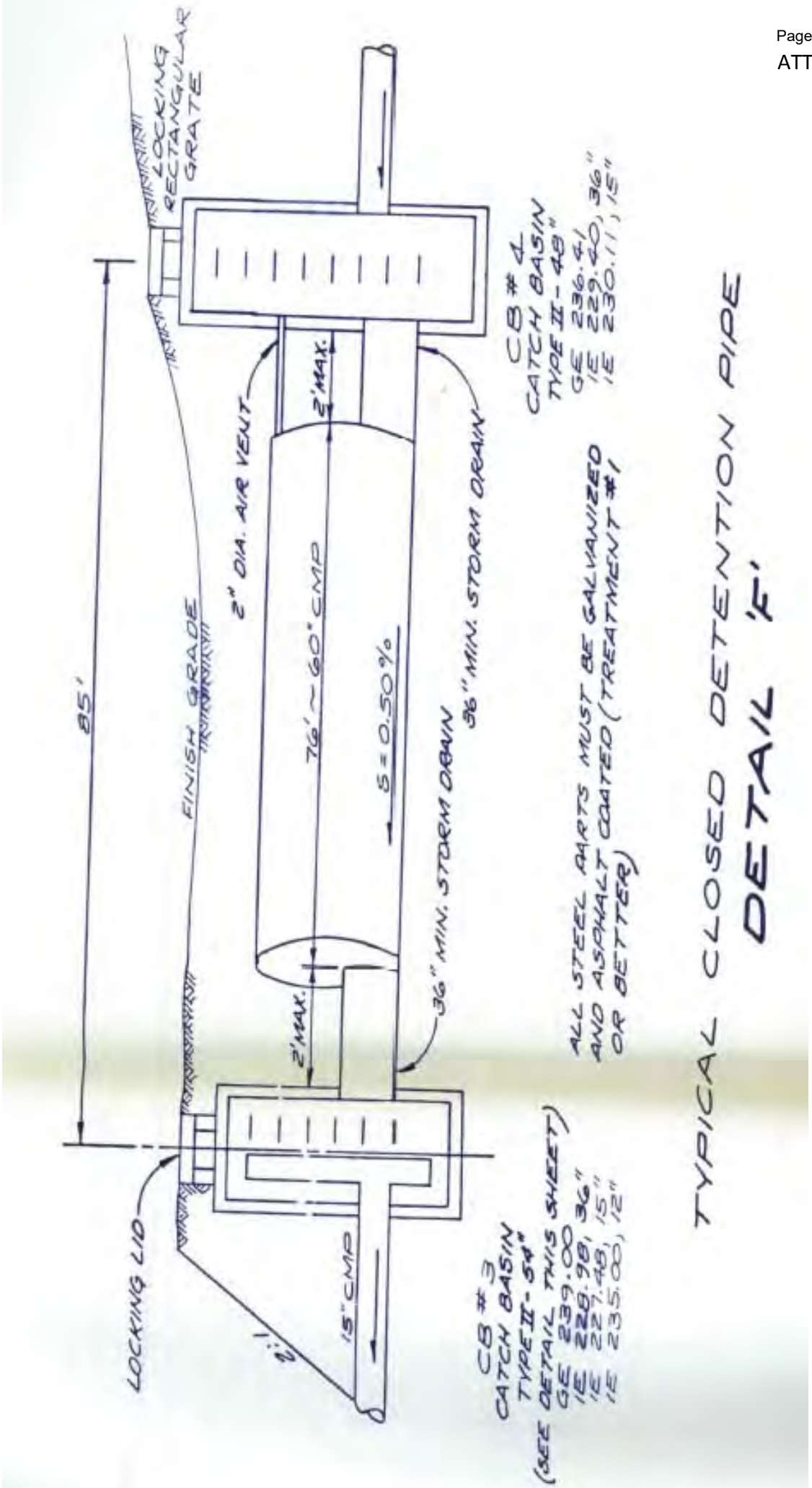
than 5 cfs were separated from the flow analysis. The allowable flow (5 cfs) was subtracted, or allowed to continue downstream, and the remaining flow was stored. The storage volume per time step was added up and the detention storage size was determined. Based on this approach, an 8 foot diameter, 225 foot long detention pipe would be required to control the downstream flow rate to 5 cfs (Attachment 4). The overall contributing watershed (26.43 acres) was then evaluated and it was determined that the area from the Holly Vista and the tight lining of the 16th Street and Terrace Avenue Flow make up much less than 1/2 of the total drainage. No other flooding concerns have been reported in the area. Therefore, for planning purposes, an 8 foot diameter, 100-foot long detention pipe was included in the project estimate. Further analysis, including flow routing for the drainage basin and existing and proposed storm drainage facilities is recommended during the design phase.

Results:
Model results and calculations are attached.

References:
Bentley Systems, Inc. FlowMaster V8i. 2009.

Washington State Department of Ecology. Stormwater Management Manual for Western Washington. February 2005.


North
SD CB
RIM 105.76
12" CONC OUT SE IE = 103.36
6" CPP IN NE IE = 103.91
CB02, TYPE II 54", STA 10+41.50
1.25' RT TO CENTER OF CB
RIM 106.30, SOLID LID
12" PE OUT IE = 100.69 S
12" CONC. IN IE = 101.86 NW
12" CMP IN IE = 101.38 W
12" PE IN IE = 102.00 NE
SSMH
RIM 105.89
6" DI OUT S IE = 97.84
6" DI IN W IE = 97.79
6" DI IN N IE = 97.74
CB03, TYPE 1, STA 9+47.25
1.25' RT TO CENTER OF CB
RIM 105.01, SOLID LID
12" PE OUT SE IE = 99.75
12" PE IN N IE = 99.75
CB01, TYPE 1, STA 10+47
11.75' RT TO CENTER OF CB
RIM 105.92
12" PE OUT IE = 102.48
1+00
102
S=1%
10+00
11+00
L=94.25'
flow
METAL MAILBOX
ASPH
CED 15
STAIRS
4' WOOD FENCE
SDMH
RIM 105.71
12" CONC OUT S IE = 100.21
12" CPP IN N IE = 100.26
CB04, TYPE 1, STA 9+47.25
17.12' RT TO CENTER OF CB
RIM 104.50, VANED GRATE
12" CONC OUT S IE = 98.78
12" CONC IN N IE = 98.78
12" PE IN W IE = 98.78
SD CB
RIM 105.83
12" CPP OUT S IE = 100.23
12" CONC IN W IE = 100.33
HOLE FOR FUTURE UTILITY POLE



TYPICAL CLOSED DETENTION PIPE

DETAIL 'F'

Worksheet for Circular Pipe - 12 in dia. @ 1% slope

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data

Roughness Coefficient	0.010	
Channel Slope	0.01000	ft/ft
Normal Depth	1.00	ft
Diameter	1.00	ft
Discharge	4.63	ft^3/s

Results

Discharge	4.63	ft^3/s
Normal Depth	1.00	ft
Flow Area	0.79	ft^2
Wetted Perimeter	3.14	ft
Hydraulic Radius	0.25	ft
Top Width	0.00	ft
Critical Depth	0.90	ft
Percent Full	100.0	%
Critical Slope	0.00884	ft/ft
Velocity	5.90	ft/s
Velocity Head	0.54	ft
Specific Energy	1.54	ft
Froude Number	0.00	
Maximum Discharge	4.98	ft^3/s
Discharge Full	4.63	ft^3/s
Slope Full	0.01000	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%

Worksheet for Circular Pipe - 12 in dia. @ 1% slope

GVF Output Data

Normal Depth Over Rise	100.00	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.00	ft
Critical Depth	0.90	ft
Channel Slope	0.01000	ft/ft
Critical Slope	0.00884	ft/ft

ATTACHMENT 4

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

Project: City of Snohomish - Stormwater Comp Plan
Basin: 16th / Terrace
Storm Event: 25-YEAR, 24-HOUR
Given:

Area = 26.43 acres
Pt = 3.05 inches
dt = 10 min.
Tc = 47.7 min.

PERVIOUS AREA			IMPERVIOUS AREA (Roads)		
Area	= 15.77	acres	Area	= 10.66	acres
CN	= 86		CN	= 98	
S	= 1.63		S	= 0.20	
0.2S	= 0.33		0.2S	= 0.04	

SUMMARY	
T_{pk}(hrs)=	7.83
T_c (min)=	47.7
Q_{pk}(cfs)=	8.40
Vol(cf)=	201,578

Compute: Runoff Hydrograph

Column (3) = SCS Type IA Rainfall Distribution
Column (4) = Col. (3) x Pt
Column (5) = Accumulated Sum of Col. (4)
Column (6) = [If P <= 0.2S] = 0; Note, use PERVIOUS Area "S" value.
[If P > 0.2S] = (Col.(5) - 0.2S)^2/(Col.(5) + 0.8S); Using the PERVIOUS Area "S" value.
Column (7) = Col.(6) of Present Time Step - Col.(6) of Previous Time Step
Column (8) = Same method as for Col.(6), except use the IMPERVIOUS Area "S" value.
Column (9) = Col.(8) of the present time step - Col.(8) of the previous time step.
Column (10) = ((PERVIOUS area / Total area) x Col.(7)) + ((IMPERVIOUS area / Total area) x Col.(9))
Column (11) = (60.5 x Col.(10) x Total Area) / 10 (dt = 10 minutes)
Routing Constant, w = dt / (2Tc + dt) = 0.0949
Column (12) = Col.(12) of Previous Time Step + (w x [Col.(11) of Previous Time Step
+ Col.(11) of Present Time Step - (2 x Col.(12) of Previous Time Step)])

					Pervious Area		Impervious Area							
(1) Time Increment	(2) Time	(3) Rainfall distri-bution	(4) Incre-mental Rainfall	(5) Accumu-lated Rainfall	(6) Accumu-lated Runoff	(7) Incre-mental Runoff	(8) Accumu-lated Runoff	(9) Incre-mental Runoff	(10) Total Runoff	(11) Instant hydro-graph	(12) design hydro-graph		(13) Volume with discharge	(14) max D/S pipe discharge	(15) discharge to be stored
	min.	% of Pt	in.	in.	in.	in.	in.	in.	in.	cfs	cfs		> 5 cfs	cfs	cfs
1	10	0.0040	0.0122	0.0122	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00				
2	20	0.0040	0.0122	0.0244	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00				
3	30	0.0040	0.0122	0.0366	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00				
4	40	0.0040	0.0122	0.0488	0.0000	0.0000	0.0003	0.0003	0.0001	0.0	0.00				
5	50	0.0040	0.0122	0.0610	0.0000	0.0000	0.0018	0.0015	0.0006	0.1	0.01				
6	60	0.0040	0.0122	0.0732	0.0000	0.0000	0.0044	0.0026	0.0011	0.2	0.04				
7	70	0.0040	0.0122	0.0854	0.0000	0.0000	0.0080	0.0036	0.0014	0.2	0.07				
8	80	0.0040	0.0122	0.0976	0.0000	0.0000	0.0124	0.0044	0.0018	0.3	0.10				
9	90	0.0040	0.0122	0.1098	0.0000	0.0000	0.0174	0.0051	0.0020	0.3	0.14				
10	100	0.0040	0.0122	0.1220	0.0000	0.0000	0.0231	0.0057	0.0023	0.4	0.18				
11	110	0.0050	0.0153	0.1373	0.0000	0.0000	0.0309	0.0078	0.0032	0.5	0.23				
12	120	0.0050	0.0153	0.1525	0.0000	0.0000	0.0395	0.0086	0.0035	0.6	0.29				
13	130	0.0050	0.0153	0.1678	0.0000	0.0000	0.0487	0.0092	0.0037	0.6	0.34				
14	140	0.0050	0.0153	0.1830	0.0000	0.0000	0.0584	0.0097	0.0039	0.6	0.39				
15	150	0.0050	0.0153	0.1983	0.0000	0.0000	0.0686	0.0102	0.0041	0.7	0.44				
16	160	0.0050	0.0153	0.2135	0.0000	0.0000	0.0791	0.0106	0.0043	0.7	0.48				
17	170	0.0060	0.0183	0.2318	0.0000	0.0000	0.0923	0.0132	0.0053	0.8	0.54				
18	180	0.0060	0.0183	0.2501	0.0000	0.0000	0.1060	0.0136	0.0055	0.9	0.60				
19	190	0.0060	0.0183	0.2684	0.0000	0.0000	0.1200	0.0140	0.0057	0.9	0.65				
20	200	0.0060	0.0183	0.2867	0.0000	0.0000	0.1344	0.0144	0.0058	0.9	0.70				
21	210	0.0060	0.0183	0.3050	0.0000	0.0000	0.1490	0.0147	0.0059	0.9	0.75				
22	220	0.0060	0.0183	0.3233	0.0000	0.0000	0.1640	0.0150	0.0060	1.0	0.79				
23	230	0.0070	0.0214	0.3447	0.0002	0.0002	0.1818	0.0178	0.0073	1.2	0.84				
24	240	0.0070	0.0214	0.3660	0.0010	0.0008	0.1998	0.0180	0.0077	1.2	0.91				
25	250	0.0070	0.0214	0.3874	0.0023	0.0013	0.2181	0.0183	0.0081	1.3	0.98				
26	260	0.0070	0.0214	0.4087	0.0040	0.0018	0.2366	0.0185	0.0085	1.4	1.04				
27	270	0.0070	0.0214	0.4301	0.0063	0.0023	0.2553	0.0187	0.0089	1.4	1.11				
28	280	0.0070	0.0214	0.4514	0.0090	0.0027	0.2743	0.0189	0.0093	1.5	1.18				
29	290	0.0082	0.0250	0.4764	0.0128	0.0038	0.2966	0.0224	0.0113	1.8	1.26				
30	300	0.0082	0.0250	0.5014	0.0171	0.0044	0.3192	0.0226	0.0117	1.9	1.37				
31	310	0.0082	0.0250	0.5264	0.0221	0.0049	0.3419	0.0227	0.0121	1.9	1.47				
32	320	0.0082	0.0250	0.5514	0.0275	0.0055	0.3648	0.0229	0.0125	2.0	1.57				
33	330	0.0082	0.0250	0.5765	0.0335	0.0060	0.3879	0.0230	0.0129	2.1	1.65				
34	340	0.0082	0.0250	0.6015	0.0400	0.0065	0.4110	0.0232	0.0132	2.1	1.74				
35	350	0.0095	0.0290	0.6304	0.0481	0.0081	0.4380	0.0270	0.0157	2.5	1.85				
36	360	0.0095	0.0290	0.6594	0.0568	0.0087	0.4651	0.0271	0.0161	2.6	1.98				
37	370	0.0095	0.0290	0.6884	0.0661	0.0093	0.4924	0.0273	0.0165	2.6	2.10				
38	380	0.0095	0.0290	0.7174	0.0760	0.0099	0.5198	0.0274	0.0169	2.7	2.21				
39	390	0.0095	0.0290	0.7463	0.0864	0.0104	0.5472	0.0275	0.0173	2.8	2.31				
40	400	0.0095	0.0290	0.7753	0.0973	0.0109	0.5748	0.0276	0.0176	2.8	2.40				
41	410	0.0134	0.0409	0.8162	0.1136	0.0163	0.6138	0.0390	0.0254	4.1	2.60				
42	420	0.0134	0.0409	0.8570	0.1308	0.0172	0.6530	0.0392	0.0261	4.2	2.89				
43	430	0.0134	0.0409	0.8979	0.1489	0.0181	0.6923	0.0393	0.0266	4.3	3.14				
44	440	0.0180	0.0549	0.9528	0.1745	0.0256	0.7452	0.0530	0.0366	5.9	3.50				
45	450	0.0180	0.0549	1.0077	0.2014	0.0270	0.7984	0.0532	0.0375	6.0	3.96				
46	460	0.0340	0.1037	1.1114	0.2558	0.0544	0.8992	0.1008	0.0731	11.7	4.89				
47	470	0.0540	0.1647	1.2761	0.3504	0.0946	1.0602	0.1610	0.1213	19.4	6.91		5	1.912265905	
48	480	0.0270	0.0824	1.3585	0.4010	0.0505	1.1409	0.0808	0.0627	10.0	8.39		5	3.393401013	
49	490	0.0180	0.0549	1.4134	0.4357	0.0348	1.1949	0.0539	0.0425	6.8	8.40	Q peak	5	3.397325236	
50	500	0.0134	0.0409	1.4542	0.4621	0.0264	1.2351	0.0402	0.0320	5.1	7.93		5	2.933684026	
51	510	0.0134	0.0409	1.4951	0.4889	0.0268	1.2753	0.0402	0.0322	5.2	7.40		5	2.402238478	
52	520	0.0134	0.0409	1.5360	0.5162	0.0272	1.3156	0.0403	0.0325	5.2	6.98		5	1.97951286	
53	530	0.0088	0.0268	1.5628	0.5343	0.0181	1.3421	0.0265	0.0215	3.4	6.47		5	1.47366958	
54	540	0.0088	0.0268	1.5897	0.5525	0.0183	1.3685	0.0265	0.0216	3.4	5.90		5	0.898173238	
55	550	0.0088	0.0268	1.6165	0.5709	0.0184	1.3950	0.0265	0.0217	3.5	5.43		5	0.434917493	
56	560	0.0088	0.0268	1.6433	0.5895	0.0186	1.4215	0.0265	0.0218	3.5	5.06				
57	570	0.0088	0.0268	1.6702	0.6082	0.0187	1.4480	0.0265	0.0219	3.5	4.76				
58	580	0.0088	0.0268	1.6970	0.6271	0.0189	1.4745	0.0265	0.0219	3.5	4.52				
59	590	0.0088	0.0268	1.7239	0.6461	0.0190	1.5010	0.0265	0.0220	3.5	4.33				
60	600	0.0088	0.0268	1.7507	0.6652	0.0191	1.5276	0.0265	0.0221	3.5	4.18				
61	610	0.0088	0.0268	1.7775	0.6845	0.0193	1.5541	0.0265	0.0222	3.6	4.06				
62	620	0.0088	0.0268	1.8044	0.7039	0.0194	1.5806	0.0265	0.0223	3.6	3.96				
63	630	0.0088	0.0268	1.8312	0.7234	0.0195	1.6072	0.0266	0.0224	3.6	3.89				
64	640	0.0088	0.0268	1.8581	0.7431	0.0197	1.6338	0.0266	0.0224	3.6	3.83				
65	650	0.0072	0.0220	1.8800	0.7593	0.0162	1.6555	0.0217	0.0184	2.9	3.72				
66	660	0.0072	0.0220	1.9020	0.7755	0.0163	1.6772	0.0217	0.0185	3.0	3.58				
67	670	0.0072	0.0220	1.9239	0.7919	0.0163	1.6990	0.0217	0.0185	3.0	3.46				
68	680	0.0072	0.0220	1.9459	0.8083	0.0164	1.7207	0.0218	0.0186	3.0	3.37				
69	690	0.0072	0.0220	1.9679	0.8247	0.0165	1.7425	0.0218	0.0186	3.0	3.29				
70	700	0.0072	0.0220	1.9898	0.8413	0.0166	1.7643	0.0218	0.0187	3.0	3.23				
71	710	0.0072	0.0220	2.0118	0.8579	0.0166	1.7860	0.0218	0.0187	3.0	3.19				
72	720	0.0072	0.0220	2.0337	0.8746	0.0167	1.8078	0.0218	0.0187	3.0	3.15				
73	730	0.0072	0.0220	2.0557	0.8914	0.0168	1.8296	0.0218	0.0188	3.0	3.12				
74	740	0.0072	0.0220	2.0777	0.9082	0.0168	1.8513	0.0218	0.0188	3.0	3.10				
75	750	0.0072	0.0220	2.0996	0.9251	0.0169	1.8731	0.0218	0.0189	3.0	3.08				
76	760	0.0072	0.0220	2.1216	0.9421	0.0170	1.8949	0.0218	0.0189	3.0	3.07				
77	770	0.0057	0.0174	2.1390	0.9556	0.0135	1.9122	0.0172	0.0150	2.4	3.00				
78	780	0.0057	0.0174	2.1564	0.9691	0.0135	1.9294	0.0172	0.0150	2.4	2.89				
79	790	0.0057	0.0174	2.1737	0.9826	0.0136	1.9467	0.0173	0.0150	2.4	2.80				
80	800	0.0057	0.0174	2.1911	0.9962	0.0136	1.9639	0.0173	0.0151	2.4	2.72				
81	810	0.0057	0.0174	2.2085	1.0098	0.0136	1.9812	0.0173	0.0151	2.4	2.66				
82	820	0.0057	0.0174	2.2259	1.0235	0.0137	1.9984	0.0173	0.0151	2.4	2.62				
83	830	0.0057	0.0174	2.2433	1.0372	0.0137	2.0157	0.0173	0.0151	2.4	2.58				
84	840	0.0057	0.0174	2.2607	1.0510	0.0137	2.0329	0.0173	0.0152	2.4	2.55				
85	850	0.0057	0.0174	2.2780	1.0647	0.0138	2.0502	0.0173	0.0152	2.4	2.53				
86	860	0.0057	0.0174	2.2954	1.0785	0.0138	2.0675	0.0173	0.0152	2.4	2.51				
87	870	0.0057	0.0174	2.3128	1.0924	0.0138	2.0847	0.0173	0.0152	2.4	2.49				
88	880	0.0057	0.0174	2.3302	1.1063	0.0139	2.1020	0.0173	0.0152	2.4	2.48				
89	890	0.0050	0.0153	2.3455	1.1185	0.0122	2.1172	0.0151	0.0134	2.1	2.45				
90	900	0.0050	0.0153	2.3607	1.1307	0.0122	2.1323	0.0151	0.0134	2.1	2.39				
91	910	0.0050	0.0153	2.3760	1.1429	0.0123	2.1475	0.0152	0.0134	2.1	2.34				
92	920	0.0050	0.0153	2.3912	1.1552	0.0123	2.1626	0.0152	0.0134	2.1	2.30				
93	930	0.0050	0.0153	2.4065	1.1675	0.0123	2.1778	0.0152	0.0135	2.2	2.28				
94	940	0.0050	0.0153	2.4217	1.1798	0.0123	2.1929	0.0152	0.0135	2.2	2.25				
95	950	0.0050	0.0153	2.4370	1.1922	0.0123	2.2081	0.0152	0.0135	2.2	2.23				
96	960	0.0050	0.0153	2.4522	1.2045	0.0124	2.2232	0.0152	0.0135	2.2	2.22				
97	970	0.0050	0.0153	2.4675	1.2169	0.0124	2.2384	0.0152	0.0135	2.2	2.21				
98	980	0.0050	0.0153	2.4827	1.2294	0.0124	2.2535	0.0152	0.0135	2.2	2.20				
99	990	0.0050	0.0153	2.4980	1.2418	0.0124	2.2687	0.0152	0.0135	2.2	2.19				
100	1000	0.0050	0.0153	2.5132	1.2543	0.0125	2.2839	0.0152	0.0136	2.2	2.19				
101	1010	0.0040	0.0122	2.5254	1.2642	0.0100	2.2960	0.0121	0.0109	1.7	2.14				
102	1020	0.0040	0.0122	2.5376	1.2743	0.0100	2.3081	0.0121	0.0109	1.7	2.07				
103	1030	0.0040	0.0122	2.5498	1.2843	0.0100	2.3203	0.0121	0.0109	1.7	2.00				
104	1040	0.0040	0.0122	2.5620	1.2943	0.0100	2.3324	0.0121	0.0109	1.7	1.95				
105	1050	0.0040	0.0122	2.5742	1.3043	0.0100	2.3445	0.0121	0.0109	1.7	1.91				
106	1060	0.0040	0.0122	2.5864	1.3144	0.0101	2.3566	0.0121	0.0109	1.7	1.88				
107	1070	0.0040	0.0122	2.5986	1.3245	0.0101	2.3688	0.0121	0.0109	1.7	1.85				
108	1080	0.0040	0.0122	2.6108	1.3345	0.0101	2.3809	0.0121	0.0109	1.7	1.83				
109	1090	0.0040	0.0122	2.6230	1.3446	0.0101	2.3931	0.0121	0.0109	1.7	1.82				
110	1100	0.0040	0.0122	2.6352	1.3547	0.0101	2.4052	0.0121	0.0109	1.7	1.80				
111	1110	0.0040	0.0122	2.6474	1.3649	0.0101	2.4173	0.0121	0.0109	1.7	1.79				
112	1120	0.0040	0.0122	2.6596	1.3750	0.0101	2.4295	0.0121	0.0109	1.7	1.78				
113	1130	0.0040	0.0122	2.6718	1.3851	0.0101	2.4416	0.0121	0.0109	1.8	1.78				
114	1140	0.0040	0.0122	2.6840	1.3953	0.0102	2.4537	0.0121	0.0110	1.8	1.77				
115	1150	0.0040	0.0122	2.6962	1.4055	0.0102	2.4659	0.0121	0.0110	1.8	1.77				
116	1160	0.0040	0.0122	2.7084	1.4157	0.0102	2.4780	0.0121	0.0110	1.8	1.77				
117	1170	0.0040	0.0122	2.7206	1.4259	0.0102	2.4901	0.0121	0.0110	1.8	1.76				
118	1180	0.0040	0.0122	2.7328	1.4361	0.0102	2.5023	0.0121	0.0110	1.8	1.76				
119	1190	0.0040	0.0122	2.7450	1.4463	0.0102	2.5144	0.0121	0.0110	1.8	1.76				
120	1200	0.0040	0.0122	2.7572	1.4565	0.0102	2.5266	0.0121	0.0110	1.8	1.76				
121	1210	0.0040	0.0122	2.7694	1.4668	0.0102	2.5387	0.0121	0.0110	1.8	1.76				
122	1220	0.0040	0.0122	2.7816	1.4770	0.0103	2.5508	0.0121	0.0110	1.8	1.76				
123	1230	0.0040	0.0122	2.7938	1.4873	0.0103	2.5630	0.0121	0.0110	1.8	1.76				
124	1240	0.0040	0.0122	2.8060	1.4976	0.0103	2.5751	0.0121	0.0110	1.8	1.76				
125	1250	0.0040	0.0122	2.8182	1.5079	0.0103	2.5873	0.0121	0.0110	1.8	1.76				
126	1260	0.0040	0.0122	2.8304	1.5182	0.0103	2.5994	0.0121	0.0110	1.8	1.76				
127	1270	0.0040	0.0122	2.8426	1.5285	0.0103	2.6116	0.0121	0.0111	1.8	1.76				
128	1280	0.0040	0.0122	2.8548	1.5388	0.0103	2.6237	0.0121	0.0111	1.8	1.76				
129	1290	0.0040	0.0122	2.8670	1.5491	0.0103	2.6358	0.0121	0.0111	1.8	1.77				
130	1300	0.0040	0.0122	2.8792	1.5595	0.0103	2.6480	0.0121	0.0111	1.8	1.77				
131	1310	0.0040	0.0122	2.8914	1.5698	0.0104	2.6601	0.0121	0.0111	1.8	1.77				
132	1320	0.0040	0.0122	2.9036	1.5802	0.0104	2.6723	0.0121	0.0111	1.8	1.77				
133	1330	0.0040	0.0122	2.9158	1.5906	0.0104	2.6844	0.0121	0.0111	1.8	1.77				
134	1340	0.0040	0.0122	2.9280	1.6010	0.0104	2.6966	0.0121	0.0111	1.8	1.77				
135	1350	0.0040	0.0122	2.9402	1.6114	0.0104	2.7087	0.0121	0.0111	1.8	1.77				
136	1360	0.0040	0.0122	2.9524	1.6218	0.0104	2.7209	0.0121	0.0111	1.8	1.77				
137	1370	0.0040	0.0122	2.9646	1.6322	0.0104	2.7330	0.0121	0.0111	1.8	1.77				
138	1380	0.0040	0.0122	2.9768	1.6426	0.0104	2.7452	0.0121	0.0111	1.8	1.77				
139	1390	0.0040	0.0122	2.9890	1.6531	0.0104	2.7573	0.0121	0.0111	1.8	1.77				
140	1400	0.0040	0.0122	3.0012	1.6635	0.0104	2.7695	0.0121	0.0111	1.8	1.78				
141	1410	0.0040	0.0122	3.0134	1.6740	0.0105	2.7816	0.0121	0.0111	1.8	1.78				
142	1420	0.0040	0.0122	3.0256	1.6844	0.0105	2.7938	0.0121	0.0111	1.8	1.78				
143	1430	0.0040	0.0122	3.0378	1.6949	0.0105	2.8059	0.0122	0.0112	1.8	1.78				
144	1440	0.0040	0.0122	3.0500	1.7054	0.0105	2.8181	0.0122	0.0112	1.8	1.78				
								Total Volume of Runoff[1] =		201,578	cu. ft.	38,295		11,295	volume to be stored

Notes:
1. Total Runoff Volume is found by summing column (12) and multiplying by the time step, dt as follows:

V = SumQ x dt
V(cu.ft.) = SumQ(cu.ft/s) x dt(min.) x (60 s/min.)

Vault
6 detention struct. Depth (ft)
1882.518783 area
15 width (ft)
125.5012522 length (ft)

K:\City of Snohomish\Stormwater Comp Plan\Stormwater Modeling - NEW moved\16th & Terrace - Detention\support\SBUH-SnoCo-16th-Terrace

Water Quality Analysis – Combined Sewer Area

URS CALCULATION COVER SHEET

Quality

Project Name:	Stormwater Comprehensive Plan Update	**Project Number:**	33763575
Project Location:	City of Snohomish	**Client Name:**	City of Snohomish
PM Name:	Carla Talich	**PIC Name:**	Kevin Weed

IDENTIFYING INFORMATION

(This section is to be completed by the Originator.)

Calculation Medium: ☐ Electronic File Name: K:\City of Snohomish\Stormwater Comp Plan\Stormwater Modeling - NEW moved\Combined Utility Area

(Select as appropriate) ☒ Hard-copy Unique Identification:

Number of pages *(including cover sheet)*: 10

Discipline: Hydrology

Title of Calculation: Water Quality Analysis - Combined Sewer Area

Calculation Originator: Gina Franco

Calculation Contributors:

Calculation Checker: Carla Talich

DESCRIPTION & PURPOSE

Use the land use designations within the combined utility area and use WWHM to calculate the water quality volume and flow rates for both on-line and off-line facilities.

BASIS / REFERENCE / ASSUMPTIONS

Assumptions are stated on calculation write up.

ISSUE / REVISION RECORD

Checker comments, if any, provided on: ☒ hard-copy ☐ electronic file ☐ Form 3-5 (MM)

No.	Description	P	S	F	Originator Initials	Date	Checker Initials	Date
0	Initial Issue	☐	☐	☒	gmf	5/17/13		
1		☐	☐	☐	[ ]	[ ]	[ ]	[ ]
2		☐	☐	☐	[ ]	[ ]	[ ]	[ ]
3		☐	☐	☐	[ ]	[ ]	[ ]	[ ]

Note: For a given Revision No. Check off either P (Preliminary), S (Superseding) or F (Final). If there are no revisions to the Initial Issue check off F (Final). Comments may be provided on the hard-copy calculations, electronic file or on Form 3-5 (MM).

APPROVAL and DISTRIBUTION

☐ The calculations associated with this Cover Sheet have been checked.

Gina Franco — Originator Signature — 5/17/13 — Date

Carla Talich — Checker Signature — 5/17/13 — Date

Carla Talich — Project Manager Signature — 5/17/13 — Date

Distribution:

Project Central File – Quality file folder

Project Statement:
The combined utility basin, as shown on Figure 1 of this report, was analyzed to determine the water quality design volume.

Land Use and Contributing Area:
The contributing land use designation areas were provided by the City Land Use Map (City of Snohomish, 2010). To be conservative the single family residential land use was assumed to be 50 percent pervious and 50 percent impervious. The medium density residential land use was assumed to be 90 percent pervious and 10 percent impervious. The high density residential land use was assumed to be 75 percent pervious and 25 percent impervious (Taylor, 1993). The commercial areas and mixed use land use designations were assumed to be 80 percent impervious and verified by interpretation of the aerial photography. The pervious and impervious area for each designated land use is presented in Table 1.

Table 1: Impervious and Pervious Areas

Land Use Designation	Total Area (ac)	Impervious Area (ac)	Pervious Area (ac)
Commercial Area	32.2	25.76	6.44
Single Family Res	108.97	54.49	54.49
High Density Res	0.42	0.11	0.32
Medium Density Res	14.64	1.46	13.18
ROW	88.47	88.47	0.00
Parks/Open Space	2.05	0.00	2.05
Mixed Use	1.41	1.13	0.28
Total	248.16	171.41	76.75

The total area for each land use designation within the combined utility area is highlighted in Table 3.

Western Washington Hydrology Model (WWHM):
The existing land use designations, in Table 1, are input values into the WWHM model. The pervious input values take into account the hydrologic soil group (HSG) which is classified on Figure 2 of this report as soil type C.

WWHM analyzes the input data and produces a 24-hour water quality volume. The water quality volume calculated by WWHM is based on the 6-month, 24-hour storm event. The water quality 24-hour volume calculated from WWHM is 23.04 acre-feet. WWHM analyzes both the on-line and off-line flow rate. Table 2 provides the water quality results from WWHM.

Table 2: WWHM Results

	15 Minute Flow Rate (cfs)
On-line	32.19
Off-line	18.29

Results:
Results and calculations are attached.

Table 3: Existing Land Use Designations (Acres)

Land Use	Cemetery Creek Upper Section	Cemetery Creek Lower Section	Blackmans Lake	Swifty Creek	Combined Sewer Area	Pilchuck River	Bunk Foss	Snohomish River
Commercial Area								
COMM (Commercial)	24.1	34.1	6.5	53.0	7.7	9.1	0.0	16.7
BUSINESS PARK	246.8	2.2	11.9	14.0	0.0	0.0	0.0	0.0
HISTORIC BUSINESS	0.0	0.0	0.0	0.0	24.5	0.0	0.0	5.3
Total Commercial Area	**270.9**	**36.4**	**18.3**	**67.0**	**32.2**	**9.1**	**0.0**	**22.0**
Residential Area								
SINGLE FAMILY RES	151.6	197.3	276.5	101.8	109.0	150.5	181.3	12.6
HD-RES (High Density Residential)	0.0	0.0	0.0	1.0	0.4	2.5	0.0	13.6
MD-RES (Medium Density Residential)	24.2	0.0	1.4	41.4	14.6	45.0	0.6	0.0
LD-RES (Low Density Residential)	196.9	592.8	2.5	33.6	0.0	6.2	296.2	0.0
Total Residential Area	**372.7**	**790.1**	**280.4**	**177.8**	**124.0**	**204.1**	**478.0**	**26.2**
Open Area								
CITY/ROW	62.2	46.7	56.4	71.4	88.5	61.8	36.2	32.0
URBAN HORTICULTURE	0.0	0.0	0.0	0.0	0.0	8.8	0.0	20.3
RIVERWAY COMM FARMLAND	0.0	0.3	0.0	0.0	0.0	69.3	134.3	23.8
PARKS/OPEN SPACE	0.0	2.3	43.2	9.6	2.1	80.7	0.0	13.1
Total Open Area	**62.2**	**49.3**	**99.6**	**80.9**	**90.5**	**220.6**	**170.5**	**89.2**
Industrial Area								
MIXED USE	0.0	0.0	0.0	4.4	1.4	27.2	0.0	3.5
AIRPORT INDUSTRY	0.0	0.0	0.0	0.0	0.0	0.0	0.0	144.5
INDUSTRY	0.0	138.9	0.0	0.3	0.0	5.0	0.2	159.5
Total Industrial Area	**0.0**	**138.9**	**0.0**	**4.7**	**1.4**	**32.2**	**0.2**	**307.4**
North Planning Area	**169.4**	**0.0**	**9.9**	**0.0**	**0.0**	**0.0**	**376.2**	**0.0**
Blackmans Lake	**0.0**	**0.0**	**57.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
TOTAL AREA	**875.2**	**1014.7**	**465.3**	**330.3**	**248.1**	**466.0**	**1024.9**	**444.8**

References:

City of Snohomish, Washington. Comprehensive Plan. December 2010.

Clear Creek Solutions, Inc. 2006. Western Washington Hydrology Model (WWHM) Version 3. 2006.

Taylor, Brian L. 1993. The Influence of Wetland and Watershed Morphological Characteristeics on Wetland Hydrology and Relationships to Wetland Vegetation Communities. 1993.

Western Washington Hydrology Model
PROJECT REPORT

Project Name: combined utility area
Site Address:
City :
Report Date : 5/17/2013
Gage : Everett
Data Start : 1948/10/01
Data End : 1997/09/30
Precip Scale: 1.20
WWHM3 Version:

PREDEVELOPED LAND USE

Name : Basin 1
Bypass: No

GroundWater: No

Pervious Land Use	Acres
C, Lawn, Flat	69.24

Impervious Land Use	Acres
ROADS FLAT	81.4
DRIVEWAYS FLAT	78.16

Element Flows To:

Surface	Interflow	Groundwater

MITIGATED LAND USE

ANALYSIS RESULTS

Flow Frequency Return Periods for Predeveloped. POC #1

Return Period	Flow(cfs)
2 year	63.399339
5 year	87.191094
10 year	104.446929
25 year	128.011483
50 year	146.878711
100 year	166.899681

Flow Frequency Return Periods for Mitigated. POC #1

Return Period	Flow(cfs)
2 year	63.399339
5 year	87.191094
10 year	104.446929

25 year	128.011483
50 year	146.878711
100 year	166.899681

Yearly Peaks for Predeveloped and Mitigated. POC #1

Year	Predeveloped	Mitigated
1950	52.900	52.900
1951	96.498	96.498
1952	64.528	64.528
1953	52.084	52.084
1954	72.206	72.206
1955	90.561	90.561
1956	79.782	79.782
1957	35.309	35.309
1958	65.985	65.985
1959	121.858	121.858
1960	60.190	60.190
1961	50.248	50.248
1962	158.883	158.883
1963	67.482	67.482
1964	106.665	106.665
1965	44.220	44.220
1966	42.847	42.847
1967	45.359	45.359
1968	141.436	141.436
1969	82.493	82.493
1970	116.436	116.436
1971	49.167	49.167
1972	71.921	71.921
1973	124.450	124.450
1974	70.084	70.084
1975	79.823	79.823
1976	65.404	65.404
1977	56.941	56.941
1978	44.707	44.707
1979	39.267	39.267
1980	96.385	96.385
1981	44.486	44.486
1982	50.673	50.673
1983	51.780	51.780
1984	59.943	59.943
1985	60.738	60.738
1986	78.413	78.413
1987	86.003	86.003
1988	78.850	78.850
1989	61.826	61.826
1990	68.257	68.257
1991	41.588	41.588
1992	42.439	42.439
1993	53.101	53.101
1994	52.627	52.627
1995	37.496	37.496
1996	47.876	47.876
1997	56.749	56.749
1998	85.224	85.224

Ranked Yearly Peaks for Predeveloped and Mitigated. POC #1

Rank	Predeveloped	Mitigated
1	158.8830	158.8830
2	141.4360	141.4360
3	124.4500	124.4500
4	121.8580	121.8580
5	116.4360	116.4360
6	106.6650	106.6650
7	96.4984	96.4984
8	96.3845	96.3845
9	90.5613	90.5613
10	86.0027	86.0027
11	85.2242	85.2242
12	82.4930	82.4930
13	79.8234	79.8234
14	79.7824	79.7824
15	78.8502	78.8502
16	78.4134	78.4134
17	72.2057	72.2057
18	71.9207	71.9207
19	70.0840	70.0840
20	68.2565	68.2565
21	67.4820	67.4820
22	65.9846	65.9846
23	65.4041	65.4041
24	64.5280	64.5280
25	61.8262	61.8262
26	60.7376	60.7376
27	60.1899	60.1899
28	59.9426	59.9426
29	56.9412	56.9412
30	56.7486	56.7486
31	53.1011	53.1011
32	52.9001	52.9001
33	52.6274	52.6274
34	52.0837	52.0837
35	51.7797	51.7797
36	50.6728	50.6728
37	50.2478	50.2478
38	49.1672	49.1672
39	47.8756	47.8756
40	45.3587	45.3587
41	44.7065	44.7065
42	44.4864	44.4864
43	44.2201	44.2201
44	42.8470	42.8470
45	42.4388	42.4388
46	41.5878	41.5878
47	39.2672	39.2672
48	37.4960	37.4960
49	35.3093	35.3093

POC #1
The Facility PASSED

The Facility PASSED.

Flow(CFS)	Predev	Dev	Percentage	Pass/Fail
31.6997	558	558	100	Pass
32.8631	498	498	100	Pass
34.0265	449	449	100	Pass
35.1899	405	405	100	Pass
36.3534	356	356	100	Pass
37.5168	317	317	100	Pass
38.6802	284	284	100	Pass
39.8436	261	261	100	Pass
41.0071	233	233	100	Pass
42.1705	207	207	100	Pass
43.3339	193	193	100	Pass
44.4973	166	166	100	Pass
45.6608	152	152	100	Pass
46.8242	136	136	100	Pass
47.9876	115	115	100	Pass
49.1510	104	104	100	Pass
50.3145	90	90	100	Pass
51.4779	78	78	100	Pass
52.6413	71	71	100	Pass
53.8047	67	67	100	Pass
54.9682	65	65	100	Pass
56.1316	62	62	100	Pass
57.2950	55	55	100	Pass
58.4584	51	51	100	Pass
59.6219	50	50	100	Pass
60.7853	47	47	100	Pass
61.9487	45	45	100	Pass
63.1121	44	44	100	Pass
64.2756	43	43	100	Pass
65.4390	39	39	100	Pass
66.6024	37	37	100	Pass
67.7658	35	35	100	Pass
68.9293	31	31	100	Pass
70.0927	29	29	100	Pass
71.2561	29	29	100	Pass
72.4195	26	26	100	Pass
73.5830	26	26	100	Pass
74.7464	25	25	100	Pass
75.9098	25	25	100	Pass
77.0732	25	25	100	Pass
78.2367	23	23	100	Pass
79.4001	20	20	100	Pass
80.5635	17	17	100	Pass
81.7269	17	17	100	Pass
82.8904	16	16	100	Pass
84.0538	16	16	100	Pass
85.2172	15	15	100	Pass
86.3806	13	13	100	Pass
87.5441	13	13	100	Pass
88.7075	12	12	100	Pass
89.8709	12	12	100	Pass
91.0343	10	10	100	Pass
92.1978	10	10	100	Pass
93.3612	10	10	100	Pass

94.5246	10	10	100	Pass
95.6880	10	10	100	Pass
96.8515	8	8	100	Pass
98.0149	8	8	100	Pass
99.1783	8	8	100	Pass
100.3417	8	8	100	Pass
101.5051	7	7	100	Pass
102.6686	7	7	100	Pass
103.8320	7	7	100	Pass
104.9954	7	7	100	Pass
106.1588	7	7	100	Pass
107.3223	6	6	100	Pass
108.4857	6	6	100	Pass
109.6491	6	6	100	Pass
110.8125	6	6	100	Pass
111.9760	6	6	100	Pass
113.1394	6	6	100	Pass
114.3028	6	6	100	Pass
115.4662	6	6	100	Pass
116.6297	5	5	100	Pass
117.7931	5	5	100	Pass
118.9565	5	5	100	Pass
120.1199	5	5	100	Pass
121.2834	4	4	100	Pass
122.4468	3	3	100	Pass
123.6102	3	3	100	Pass
124.7736	2	2	100	Pass
125.9371	2	2	100	Pass
127.1005	2	2	100	Pass
128.2639	2	2	100	Pass
129.4273	2	2	100	Pass
130.5908	2	2	100	Pass
131.7542	2	2	100	Pass
132.9176	2	2	100	Pass
134.0810	2	2	100	Pass
135.2445	2	2	100	Pass
136.4079	2	2	100	Pass
137.5713	2	2	100	Pass
138.7347	2	2	100	Pass
139.8982	2	2	100	Pass
141.0616	2	2	100	Pass
142.2250	1	1	100	Pass
143.3884	1	1	100	Pass
144.5519	1	1	100	Pass
145.7153	1	1	100	Pass
146.8787	1	1	100	Pass

Water Quality BMP Flow and Volume for POC 1.
On-line facility volume: 21.412 acre-feet
On-line facility target flow: 0.01 **cfs.**
Adjusted for 15 min: 29.973 **cfs.**
Off-line facility target flow: 15.602 **cfs.**
Adjusted for 15 min: 17.017 **cfs.**

Perlnd and Implnd Changes

No changes have been made.

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Evaluate Conversion of Former Wastewater Lagoon to Water Quality Pond

URS CALCULATION COVER SHEET Quality

Project Name:	Stormwater Comprehensive Plan Update	**Project Number:**	33763575
Project Location:	City of Snohomish	**Client Name:**	City of Snohomish
PM Name:	Carla Talich	**PIC Name:**	Kevin Weed

IDENTIFYING INFORMATION

(This section is to be completed by the Originator.)

Calculation Medium: ☐ Electronic File Name: K:\City of Snohomish\Stormwater Comp Plan\Stormwater Modeling - NEW moved\Water Quality Pond Evaluation

(Select as appropriate) ☒ Hard-copy Unique Identification:

Number of pages *(including cover sheet)*: 24

Discipline: Hydrology

Title of Calculation: Evaluate Conversion of Former Wastewater Lagoon to Water Quality Pond

Calculation Originator: C. Talich

Calculation Contributors:

Calculation Checker: John Gillespie

DESCRIPTION & PURPOSE

Evaluate former wastewater lagoon for conversion to a water quality treatment pond and determine potential upgrades needed.

BASIS / REFERENCE / ASSUMPTIONS

Assumptions are stated on calculation write up.

ISSUE / REVISION RECORD

Checker comments, if any, provided on: ☒ hard-copy ☐ electronic file ☐ Form 3-5 (MM)

No.	Description	P	S	F	Originator Initials	Date	Checker Initials	Date
0	Initial Issue	☐	☐	☒	cgt	7/29/13	JFG	8-1-13
1		☐	☐	☐	[ ]	[ ]	[ ]	[ ]
2		☐	☐	☐	[ ]	[ ]	[ ]	[ ]
3		☐	☐	☐	[ ]	[ ]	[ ]	[ ]

Note: For a given Revision No. Check off either P (Preliminary), S (Superseding) or F (Final). If there are no revisions to the Initial Issue check off F (Final). Comments may be provided on the hard-copy calculations, electronic file or on Form 3-5 (MM).

APPROVAL and DISTRIBUTION

☐ The calculations associated with this Cover Sheet have been checked.

Carla Talich — Originator Signature — 7/29/13 — Date

John Gillespie — Checker Signature — 8-1-13 — Date

Carla Talich — Project Manager Signature — 8-1-13 — Date

Distribution:

Project Central File – Quality file folder Other Specify: ____

Project Statement:
The calculations entitled, "Combined Sewer Basin" was referenced in preparation of this calculation. The purpose of the "Combined Utility Basin" calculation was to determine the water quality design volume and flow rates for the currently zoned condition within the approximately 248 acre combined utility area.

The objective of this calculation is to determine potential upgrades to the former wastewater treatment lagoon that would be needed to convert the existing lagoon into a stormwater treatment pond. The City requested that future build out conditions be considered during this planning phase. To be conservative and to evaluate model sensitivity, the entire area was evaluated as impervious in the Future Build-out condition.

Land Use and Contributing Area:
The contributing land use designation areas were provided by the City Land Use Map (City of Snohomish, 2010). Land use for the current zoning condition is described in the calculation, "Combined Sewer Basin." The pervious and impervious area for each option evaluated is presented in Table 1.

Table 1: Impervious and Pervious Areas

Zoning Condition Evaluated	Total Area (ac)	Impervious Area (ac)	Pervious Area (ac)
Current Zoning	248.16	171.41	76.75
Future Build-out	248	248	0

Western Washington Hydrology Model (WWHM):
The existing land use designations, in Table 1, were input into the WWHM model. The pervious area was classified as hydrologic soil group (HSG) C, or till. The water quality volume calculated by WWHM correlates to the 6-month, 24-hour storm event. Table 2 provides the water quality modeling results from WWHM for a Basic Wetpond for the current zoning condition and the future complete built-out scenario.

The Ecology Manual describes two types of wetponds, basic and large. For the basic wetpond, the designed wetpool volume is the total volume of runoff from the water quality design storm (the 6-month, 24-hour storm event). Large wetponds are designed for higher levels of pollutant removal. A large wetpond requires a wetpool volume at least 1.5 times larger than the total volume of runoff from the 6-month, 24-hour storm. During design, influent water quality should be evaluated. Table 2 also provides the size of the large wetpond that would be needed for the future build-out condition.

Table 2: WWHM Results

Zoning Condition Evaluated	Water Quality Volume (ac-ft)	On-line 15 Minute Flow Rate (cfs)	Off-line 15 Minute Flow Rate (cfs)
Current Zoning (Basic Pond)	23	32.2	18.3
Future Built-out (Basic Pond)	30	48.3	27.7
Future Built-out (Large Pond)	45	48.3	27.7

Proposed Wetpool Geometry

The medium sized pond with a volume of 30 acre-feet, per Table 2, was used to develop pond geometry based on Figure 10.1a and Figure 10.1b of the 2005 Ecology Manual. These figures were marked in red text to show approximate pond geometry and dimensions, see Attachment 1. Based on a minimum depth requirement for the first cell of 4 feet, the proposed water quality design water surface elevation is 17 feet.

Existing Pond Geometry / Available Storage

Attachment 2 presents the stage, storage, and surface area relationships for the existing pond based on City GIS and survey data. The City provided survey data for the existing spillway; this information is included in Attachment 2. Based on the stage versus storage curve, the existing pond with a water surface elevation of 17 provides a storage volume of approximately 75 acre-feet. This demonstrates that the pond has adequate storage capacity for the three scenarios shown in Table 2. At the invert elevation of the existing spillway, the pond is estimated to have a corresponding volume of 180 acre-feet.

The existing pond embankment interior slopes range from 3 feet horizontal to 1 vertical (3H:1V) to 5H:1V. These slopes are within the range recommended by the 2005 Ecology Manual for interior slopes (Volume III, Section 3.2, page 3-21).

Inlet and Outlet Structures

Based on the large size of the existing pond (180 acre-feet available), this evaluation assumes an on-line system is feasible. An on-line system would assume that all flood frequencies are routed through the facility. An off-line pond would provide a high flow bypass for larger flows to be diverted around the facility. The pond system should be further evaluated hydraulically during design to determine the best configuration for flow routing through and/or around the pond.

The 30-inch diameter inlet pipe will require armoring within the pond. The on-line 15-minute inflow rates (Table 2), range from 32.2 to 48.3 cfs. Bentley FlowMaster was used to evaluate the flow velocity of water discharging to the pond. This evaluation assumes gentle pipe slopes ranging from 0.6 to 1.3% and no tail water condition within the pond. Estimated flow velocities are less than 10 feet per second (see Table 3). Typical outlet protection for flow velocities less than 10 feet per second is 24-inch minus riprap.

Flow and culvert calculations are included in Attachments 3A and 3B.

Table 3: Inlet Pipe Flow & Velocity

30" RCP slope = 0.6%		30" RCP slope = 1.3%	
Flow (cfs)	Velocity (cfs)	Flow (cfs)	Velocity (cfs)
32.2	6.7	48.3	9.84

HEC-14 was referenced for determining approximate dimensions of the riprap apron for protecting the pond bottom at the 30-inch pipe outlet. For planning purposes the D_{50} of the riprap was assumed to be 14 inches (assuming D_{100} = 24 inches). Attachment 4 presents the approximate dimensions of the rock apron needed for erosion protection at the pond inlet.

The pond outlet shown in Figure 10.1b (Attachment 1) is a manhole structure. The existing pond should be evaluated in conjunction with permit requirements during the design phase to determine if the outfall manhole is appropriate. A weir type structure could also be used as an overflow between the pond and river.

Quantities for Pond Upgrades:

A summary of improvements is provided in the table below. Supporting documentation is provided in Attachment 5.

Item	**Quantity**
Inlet Protection	
24" minus riprap (heavy loose)	24 CY
Gravel filter	10 CY
First Wetpool Cell	
Excavation (keyway for berm)	790 CY
Excavation (first cell)	3,630 CY
Fill (berm)	1,580 CY
Outlet Structure	
Manhole or weir structure	1 Each
Erosion protection (similar to inlet protection)	1 Each
Slope Improvements	
Assume slopes are in good condition and need some repairs in isolated areas	1,000 CY
Revegetation	
Re-seeding	7 AC
First Cell	98,010 SF (2.25 AC)
Berm (assume 20' wide x 640' long)	12,800 SF (0.3 AC)
Disturbed areas (assume 15% of 30 acre pond)	4.5 AC
Ramp/Access Improvements	2 Each

Other Considerations:

A geotechnical investigation/analysis is recommended to evaluate several items, including but not limited to:

- The condition of the bottom lining system in the existing pond.
- Depth to seasonal high groundwater.
- Slope stability, seepage, embankment, inlet, and outlet condition.

Results:

Model results and calculations are attached.

References:

Bentley Systems, Inc. FlowMaster V8i. 2009.

City of Snohomish, Washington. Comprehensive Plan. December 2010.

Clear Creek Solutions, Inc. 2006. Western Washington Hydrology Model (WWHM) Version 3. 2006.

U.S. Department of Transportation Federal Highway Administration. Hydraulic Engineering Circular No. 14 (HEC-14), Third Edition. Publication No. FHWA-NHI-06-086. Hydraulic Design of Energy Dissipators for Culverts and Channels. July 2006

Washington State Department of Ecology. Stormwater Management Manual for Western Washington. February 2005.

ATTACHMENT 1

Total Water Quality Volume = 30 acre-feet

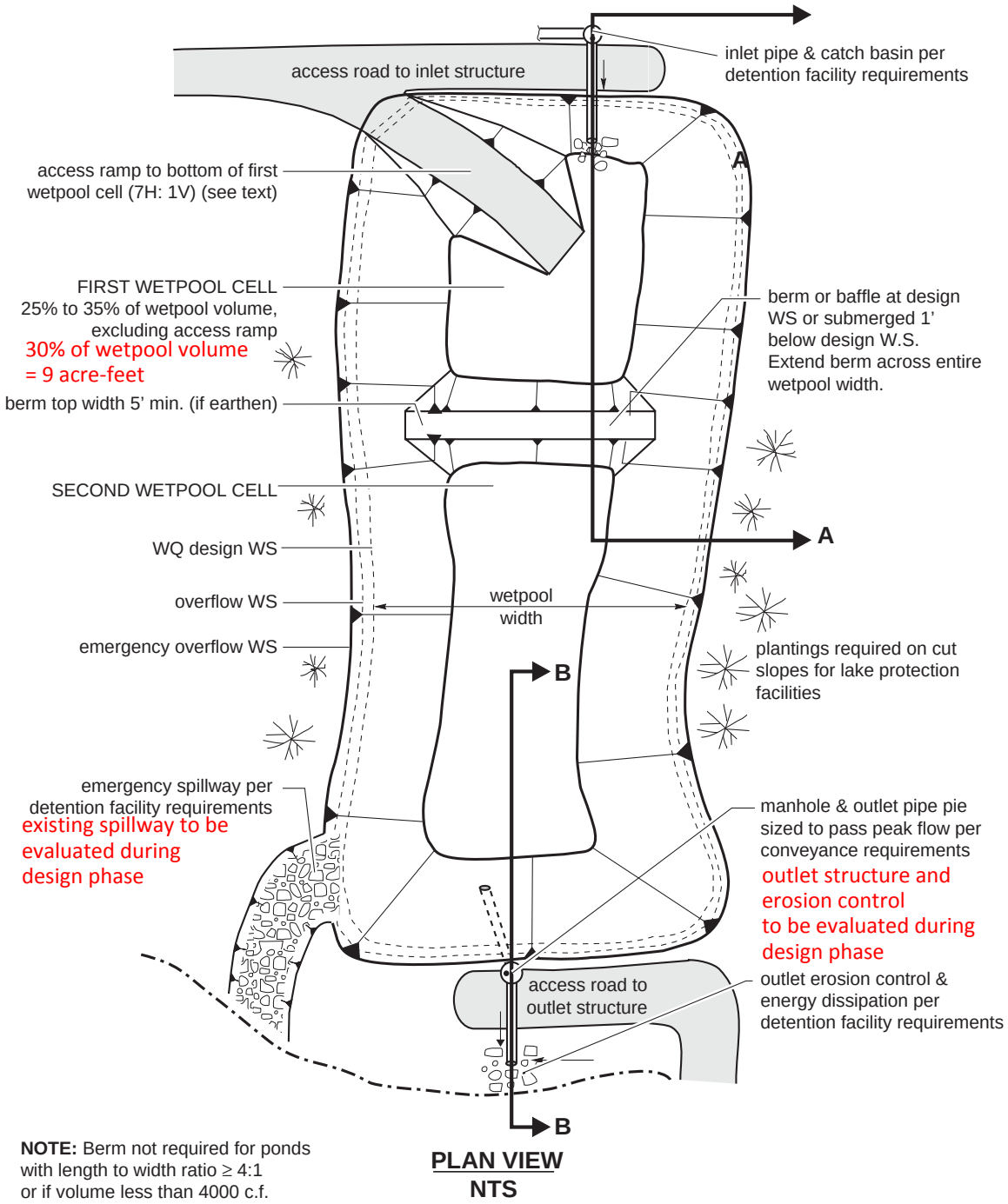


Figure 10.1a – Wetpond

Reference: Washington State Department of Ecology Stormwater Management Manual for Western Washington

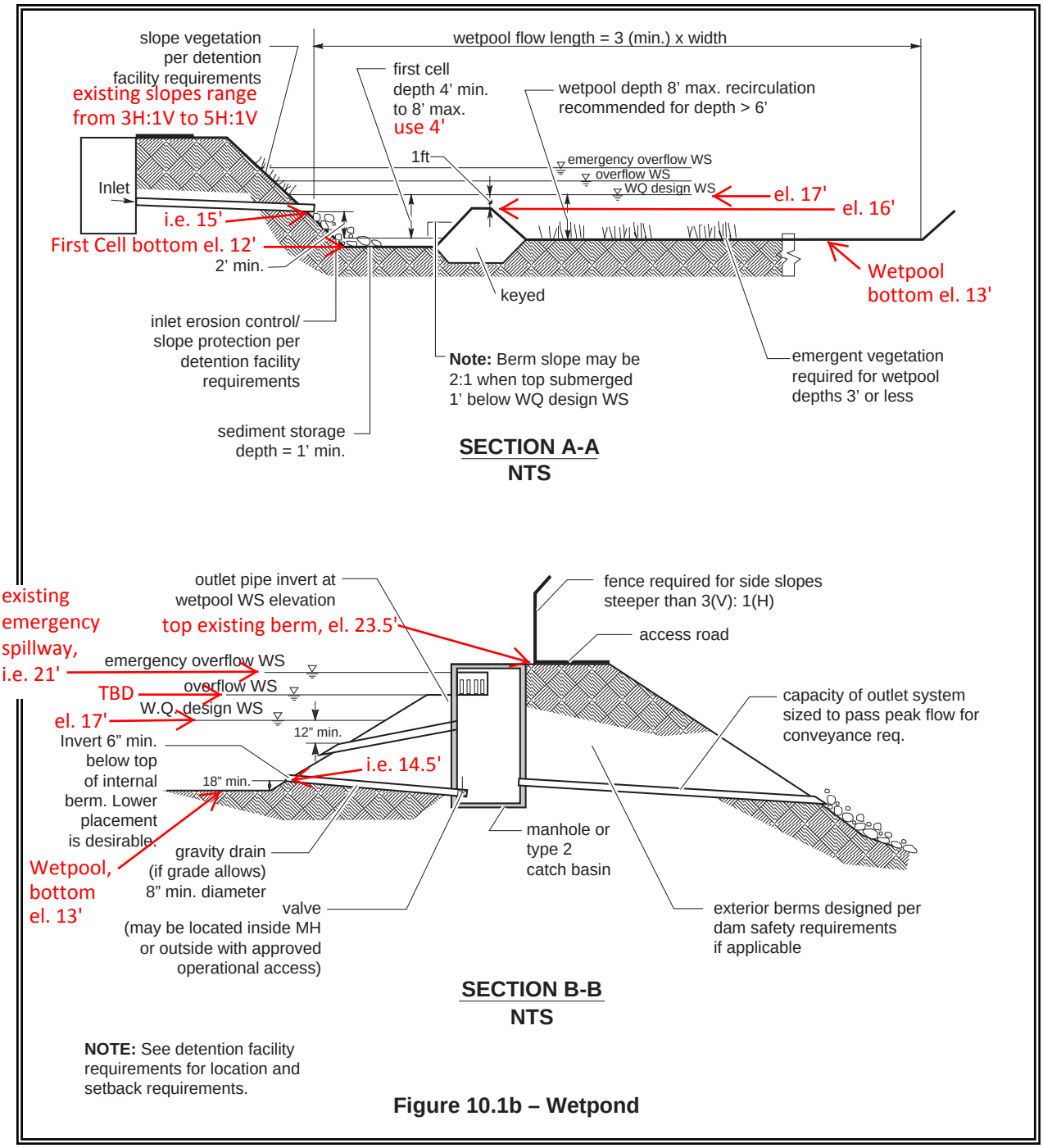


Figure 10.1b – Wetpond

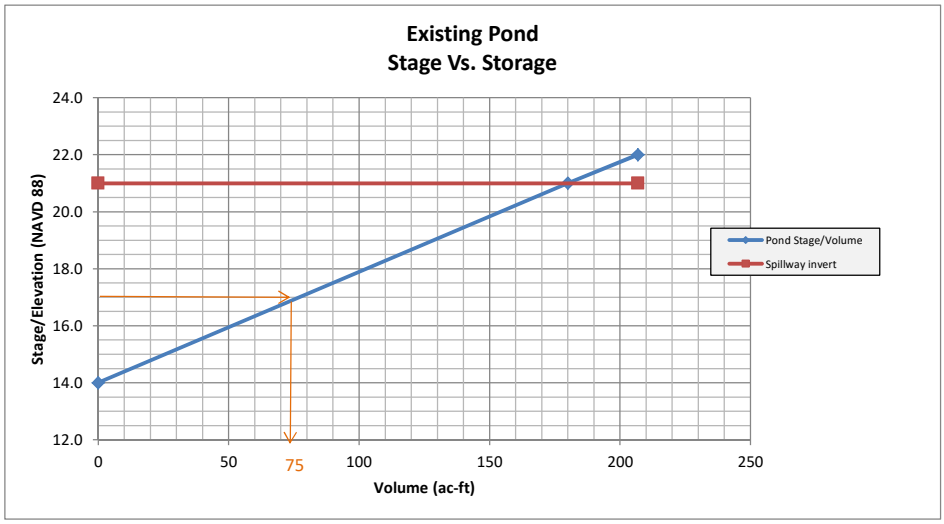
Applications and Limitations

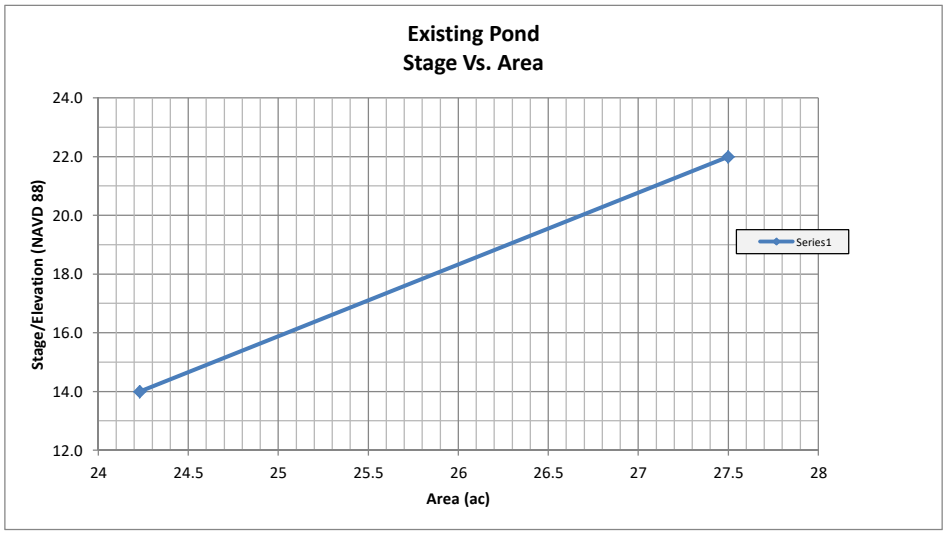
A wetpond requires a larger area than a biofiltration swale or a sand filter, but it can be integrated to the contours of a site fairly easily. In till soils, the wetpond holds a permanent pool of water that provides an attractive aesthetic feature. In more porous soils, wetponds may still be used, but water seepage from unlined cells could result in a dry pond, particularly in the summer months. Lining the first cell with a low permeability liner is one way to deal with this situation. As long as the first cell retains a

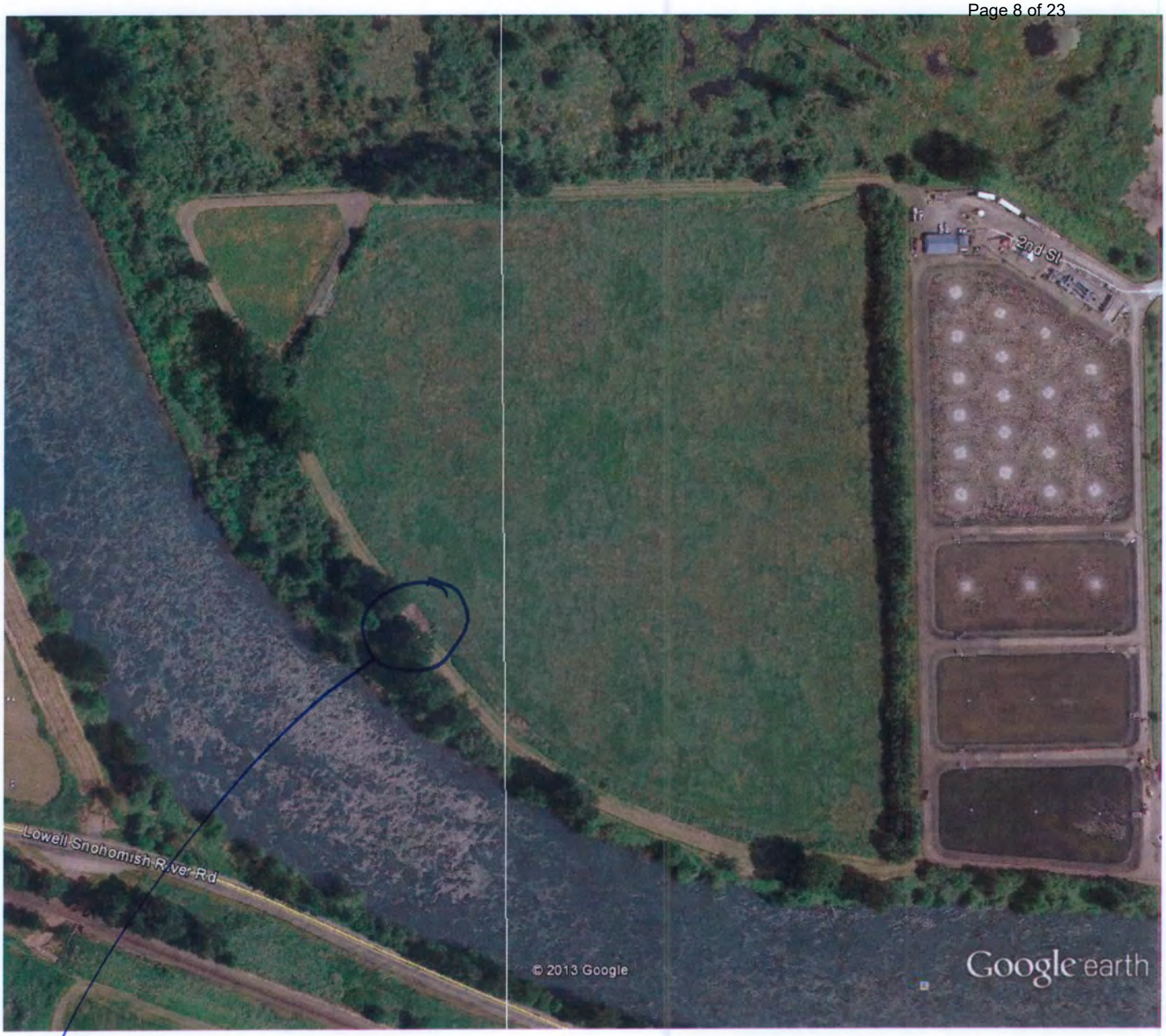
CITY OF SNOHOMISH, EXISTING POND
STAGE, STORAGE, SURFACE AREA COMPARISON
7/29/2013

ATTACHMENT 2

	Stage, ft.	Depth ft	Surface Area, Ac.	Cum.Vol. Ac-ft.	Spillway Invert ft	Reference
Pond Bottom	13.0	0.0				Elevation based on GIS
	13.5	0.5				
	14.0	1.0	24.23	0.00	21.00	
	14.5	1.5				
	15.0	2.0				
	15.5	2.5				
	16.0	3.0				
	16.5	3.5				
	17.0	4.0				
	17.5	4.5				
	18.0	5.0				
	18.5	5.5				
	19.0	6.0				
	19.5	6.5				
	20.0	7.0				
	20.5	7.5				
Spillway Invert	21.0	8.0		180.00		Elevation based on City Survey (Attachment x)
	21.5	8.5				
	22.0	9.0	27.50	206.92	21.00	
	22.5	9.5				
	23.0	10.0				
Top Pond	23.5	10.5				Elevation based on City Survey (Attachment x)
	24.0	11.0				

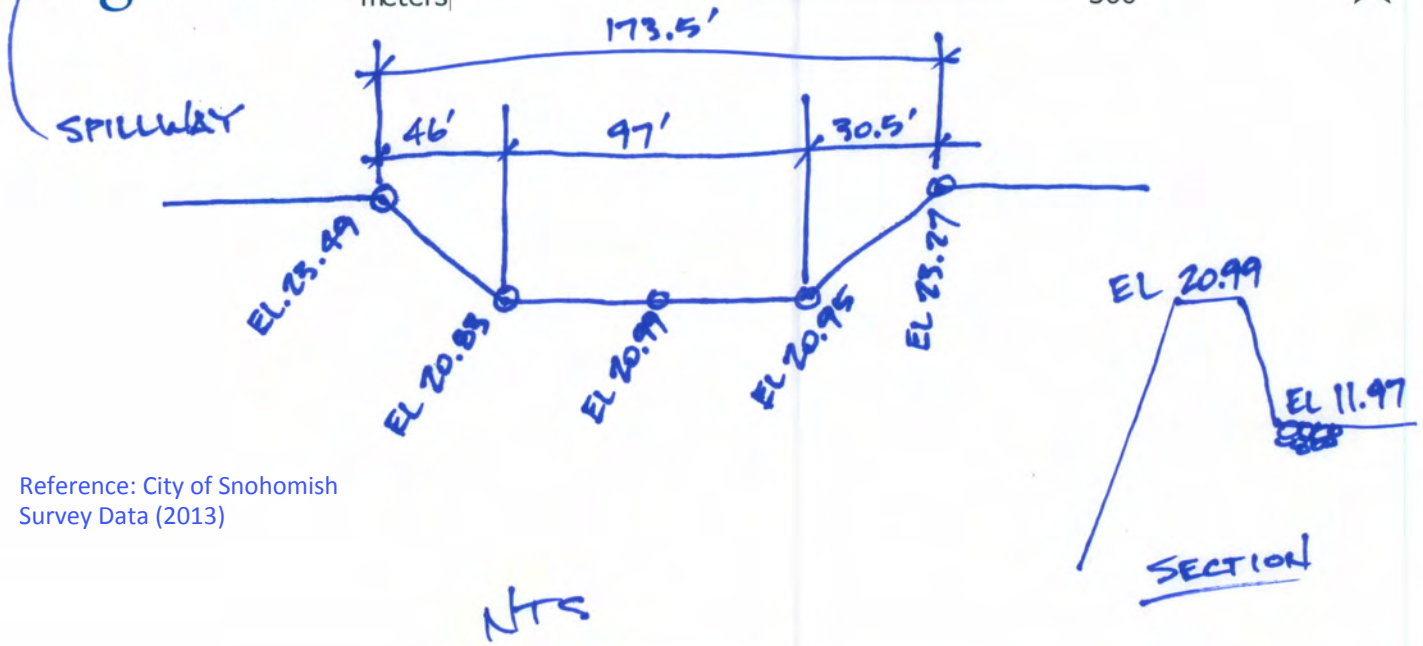






Google earth

feet 1000
meters 300



Reference: City of Snohomish
Survey Data (2013)

Western Washington Hydrology Model
PROJECT REPORT

Project Name: default
Site Address:
City :
Report Date : 7/29/2013
Gage : Everett
Data Start : 1948/10/01
Data End : 1997/09/30
Precip Scale: 1.20
WWHM3 Version:

PREDEVELOPED LAND USE

Name : Basin 1
Bypass: No

GroundWater: No

Pervious Land Use	**Acres**

Impervious Land Use	**Acres**
ROADS FLAT	**248**

Element Flows To:

Surface	**Interflow**	**Groundwater**

Name : Basin 1
Bypass: No

GroundWater: No

Pervious Land Use	**Acres**

Impervious Land Use	**Acres**
ROADS FLAT	**248**

Element Flows To:

Surface	**Interflow**	**Groundwater**

MITIGATED LAND USE

ANALYSIS RESULTS

Flow Frequency Return Periods for Predeveloped. POC #1

Return Period	Flow(cfs)
2 year	89.245078
5 year	118.794819
10 year	139.697492
25 year	167.684294
50 year	189.708413
100 year	212.76445

Flow Frequency Return Periods for Mitigated. POC #1

Return Period	Flow(cfs)
2 year	89.245078
5 year	118.794819
10 year	139.697492
25 year	167.684294
50 year	189.708413
100 year	212.76445

Yearly Peaks for Predeveloped and Mitigated. POC #1

Year	Predeveloped	Mitigated
1950	74.101	74.101
1951	126.898	126.898
1952	99.763	99.763
1953	75.413	75.413
1954	101.105	101.105
1955	127.463	127.463
1956	106.498	106.498
1957	51.749	51.749
1958	85.925	85.925
1959	156.661	156.661
1960	87.640	87.640
1961	67.176	67.176
1962	202.337	202.337
1963	88.677	88.677
1964	137.548	137.548
1965	66.740	66.740
1966	66.449	66.449
1967	67.029	67.029
1968	214.221	214.221
1969	114.442	114.442
1970	147.175	147.175
1971	70.263	70.263
1972	96.156	96.156
1973	161.842	161.842
1974	98.394	98.394
1975	111.145	111.145
1976	89.487	89.487
1977	80.069	80.069
1978	65.731	65.731
1979	55.982	55.982
1980	126.185	126.185
1981	65.617	65.617
1982	72.538	72.538
1983	79.512	79.512

1984	82.930	82.930
1985	86.989	86.989
1986	118.141	118.141
1987	112.464	112.464
1988	106.715	106.715
1989	90.738	90.738
1990	90.495	90.495
1991	60.828	60.828
1992	65.819	65.819
1993	73.931	73.931
1994	74.924	74.924
1995	58.126	58.126
1996	72.923	72.923
1997	82.794	82.794
1998	105.009	105.009

Ranked Yearly Peaks for Predeveloped and Mitigated. POC #1

Rank	Predeveloped	Mitigated
1	214.2210	214.2210
2	202.3370	202.3370
3	161.8420	161.8420
4	156.6610	156.6610
5	147.1750	147.1750
6	137.5480	137.5480
7	127.4630	127.4630
8	126.8980	126.8980
9	126.1850	126.1850
10	118.1410	118.1410
11	114.4420	114.4420
12	112.4640	112.4640
13	111.1450	111.1450
14	106.7150	106.7150
15	106.4980	106.4980
16	105.0090	105.0090
17	101.1050	101.1050
18	99.7625	99.7625
19	98.3938	98.3938
20	96.1555	96.1555
21	90.7377	90.7377
22	90.4953	90.4953
23	89.4868	89.4868
24	88.6767	88.6767
25	87.6401	87.6401
26	86.9888	86.9888
27	85.9252	85.9252
28	82.9303	82.9303
29	82.7941	82.7941
30	80.0686	80.0686
31	79.5121	79.5121
32	75.4125	75.4125
33	74.9244	74.9244
34	74.1006	74.1006
35	73.9306	73.9306
36	72.9225	72.9225
37	72.5375	72.5375
38	70.2630	70.2630

39	67.1764	67.1764
40	67.0285	67.0285
41	66.7399	66.7399
42	66.4492	66.4492
43	65.8188	65.8188
44	65.7307	65.7307
45	65.6167	65.6167
46	60.8280	60.8280
47	58.1258	58.1258
48	55.9815	55.9815
49	51.7492	51.7492

POC #1
The Facility PASSED

The Facility PASSED.

Flow(CFS)	Predev	Dev	Percentage	Pass/Fail
44.6225	0	0	0	Pass
46.0881	0	0	0	Pass
47.5536	0	0	0	Pass
49.0191	0	0	0	Pass
50.4846	0	0	0	Pass
51.9501	0	0	0	Pass
53.4156	0	0	0	Pass
54.8811	0	0	0	Pass
56.3467	0	0	0	Pass
57.8122	0	0	0	Pass
59.2777	0	0	0	Pass
60.7432	0	0	0	Pass
62.2087	0	0	0	Pass
63.6742	0	0	0	Pass
65.1397	0	0	0	Pass
66.6052	0	0	0	Pass
68.0708	0	0	0	Pass
69.5363	0	0	0	Pass
71.0018	0	0	0	Pass
72.4673	0	0	0	Pass
73.9328	0	0	0	Pass
75.3983	0	0	0	Pass
76.8638	0	0	0	Pass
78.3294	0	0	0	Pass
79.7949	0	0	0	Pass
81.2604	0	0	0	Pass
82.7259	0	0	0	Pass
84.1914	0	0	0	Pass
85.6569	0	0	0	Pass
87.1224	0	0	0	Pass
88.5880	0	0	0	Pass
90.0535	0	0	0	Pass
91.5190	0	0	0	Pass
92.9845	0	0	0	Pass
94.4500	0	0	0	Pass
95.9155	0	0	0	Pass
97.3810	0	0	0	Pass
98.8466	0	0	0	Pass

100.3121	0	0	0	Pass
101.7776	0	0	0	Pass
103.2431	0	0	0	Pass
104.7086	0	0	0	Pass
106.1741	0	0	0	Pass
107.6396	0	0	0	Pass
109.1051	0	0	0	Pass
110.5707	0	0	0	Pass
112.0362	0	0	0	Pass
113.5017	0	0	0	Pass
114.9672	0	0	0	Pass
116.4327	0	0	0	Pass
117.8982	0	0	0	Pass
119.3637	0	0	0	Pass
120.8293	0	0	0	Pass
122.2948	0	0	0	Pass
123.7603	0	0	0	Pass
125.2258	0	0	0	Pass
126.6913	0	0	0	Pass
128.1568	0	0	0	Pass
129.6223	0	0	0	Pass
131.0879	0	0	0	Pass
132.5534	0	0	0	Pass
134.0189	0	0	0	Pass
135.4844	0	0	0	Pass
136.9499	0	0	0	Pass
138.4154	0	0	0	Pass
139.8809	0	0	0	Pass
141.3465	0	0	0	Pass
142.8120	0	0	0	Pass
144.2775	0	0	0	Pass
145.7430	0	0	0	Pass
147.2085	0	0	0	Pass
148.6740	0	0	0	Pass
150.1395	0	0	0	Pass
151.6051	0	0	0	Pass
153.0706	0	0	0	Pass
154.5361	0	0	0	Pass
156.0016	0	0	0	Pass
157.4671	0	0	0	Pass
158.9326	0	0	0	Pass
160.3981	0	0	0	Pass
161.8636	0	0	0	Pass
163.3292	0	0	0	Pass
164.7947	0	0	0	Pass
166.2602	0	0	0	Pass
167.7257	0	0	0	Pass
169.1912	0	0	0	Pass
170.6567	0	0	0	Pass
172.1222	0	0	0	Pass
173.5878	0	0	0	Pass
175.0533	0	0	0	Pass
176.5188	0	0	0	Pass
177.9843	0	0	0	Pass
179.4498	0	0	0	Pass
180.9153	0	0	0	Pass
182.3808	0	0	0	Pass

183.8464	0	0	0	Pass
185.3119	0	0	0	Pass
186.7774	0	0	0	Pass
188.2429	0	0	0	Pass
189.7084	0	0	0	Pass

Water Quality BMP Flow and Volume for POC 1.
On-line facility volume: 29.893 acre-feet
On-line facility target flow: 0.01 **cfs.**
Adjusted for 15 min: 48.278 **cfs.**
Off-line facility target flow: 24.516 **cfs.**
Adjusted for 15 min: 27.703 **cfs.**

Perlnd and Implnd Changes

No changes have been made.

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30" RCP @ 32.2 cfs

Project Description

Friction Method	Manning Formula
Solve For	Channel Slope

Input Data

Roughness Coefficient	0.013	
Normal Depth	2.50	ft
Diameter	2.50	ft
Discharge	32.20	ft^3/s

Results

Channel Slope	0.00616	ft/ft
Flow Area	4.91	ft^2
Wetted Perimeter	7.85	ft
Hydraulic Radius	0.63	ft
Top Width	0.00	ft
Critical Depth	1.93	ft
Percent Full	100.0	%
Critical Slope	0.00693	ft/ft
Velocity	6.56	ft/s
Velocity Head	0.67	ft
Specific Energy	3.17	ft
Froude Number	0.00	
Maximum Discharge	34.64	ft^3/s
Discharge Full	32.20	ft^3/s
Slope Full	0.00616	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%
Normal Depth Over Rise	100.00	%
Downstream Velocity	Infinity	ft/s

30" RCP @ 32.2 cfs

GVF Output Data

Upstream Velocity	Infinity	ft/s
Normal Depth	2.50	ft
Critical Depth	1.93	ft
Channel Slope	0.00616	ft/ft
Critical Slope	0.00693	ft/ft

30" RCP @ 48.3 cfs

Project Description

Friction Method	Manning Formula
Solve For	Channel Slope

Input Data

Roughness Coefficient	0.013	
Normal Depth	2.50	ft
Diameter	2.50	ft
Discharge	48.30	ft^3/s

Results

Channel Slope	0.01387	ft/ft
Flow Area	4.91	ft^2
Wetted Perimeter	7.85	ft
Hydraulic Radius	0.63	ft
Top Width	0.00	ft
Critical Depth	2.28	ft
Percent Full	100.0	%
Critical Slope	0.01210	ft/ft
Velocity	9.84	ft/s
Velocity Head	1.50	ft
Specific Energy	4.00	ft
Froude Number	0.00	
Maximum Discharge	51.96	ft^3/s
Discharge Full	48.30	ft^3/s
Slope Full	0.01387	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%
Normal Depth Over Rise	100.00	%
Downstream Velocity	Infinity	ft/s

30" RCP @ 48.3 cfs

GVF Output Data

Upstream Velocity	Infinity	ft/s
Normal Depth	2.50	ft
Critical Depth	2.28	ft
Channel Slope	0.01387	ft/ft
Critical Slope	0.01210	ft/ft

Publication No. FHWA-NHI-06-086
July 2006

U.S. Department of Transportation

Federal Highway Administration

Hydraulic Engineering Circular No. 14, Third Edition

Hydraulic Design of Energy Dissipators for Culverts and Channels

National Highway Institute

L_B min = $4W_o$ = 4(6) = 24 ft, use L_B = 24 ft

$W_B = W_o + 2(L_B/3) = 6 + 2(24/3) = 22$ ft

However, since the trial D_{50} is not available, the next larger riprap size (D_{50} = 0.83 ft) would be used to line a basin with the given dimensions.

Step 4 (3rd iteration). Determine the basin exit depth, $y_B = y_c$ and exit velocity, $V_B = V_c$.

$Q^2/g = (A_c)^3/T_c = [y_c(W_B + zy_c)]^3/ (W_B + 2zy_c)$

$135^2/32.2 = 566 = [y_c(22 + 2y_c)]^3/ (22 + 4y_c)$

By trial and success, y_c = 1.02 ft, T_c =26.1 ft, A_c = 24.5 ft^2

$V_c = Q/A_c$ = 135/24.5 = 5.5 ft/s (acceptable)

Two feasible options have been identified. First, a 2.3-ft-deep, 23-ft-long pool, with an 11.5-ft-apron using D_{50} = 0.5 ft. Second, a 1.4-ft-deep, 18-ft-long pool, with a 6-ft-apron using D_{50} = 0.83 ft. The choice between these two options will likely depend on the available space and the cost of riprap.

Step 5. For the design discharge, determine if $TW/y_o \leq 0.75$

TW/y_o = 2.0/2.7 = 0.74, which satisfies $TW/y_o \leq 0.75$. No additional riprap needed.

10.2 RIPRAP APRON

The most commonly used device for outlet protection, primarily for culverts 1500 mm (60 in) or smaller, is a riprap apron. An example schematic of an apron taken from the Federal Lands Division of the Federal Highway Administration is shown in Figure 10.4.

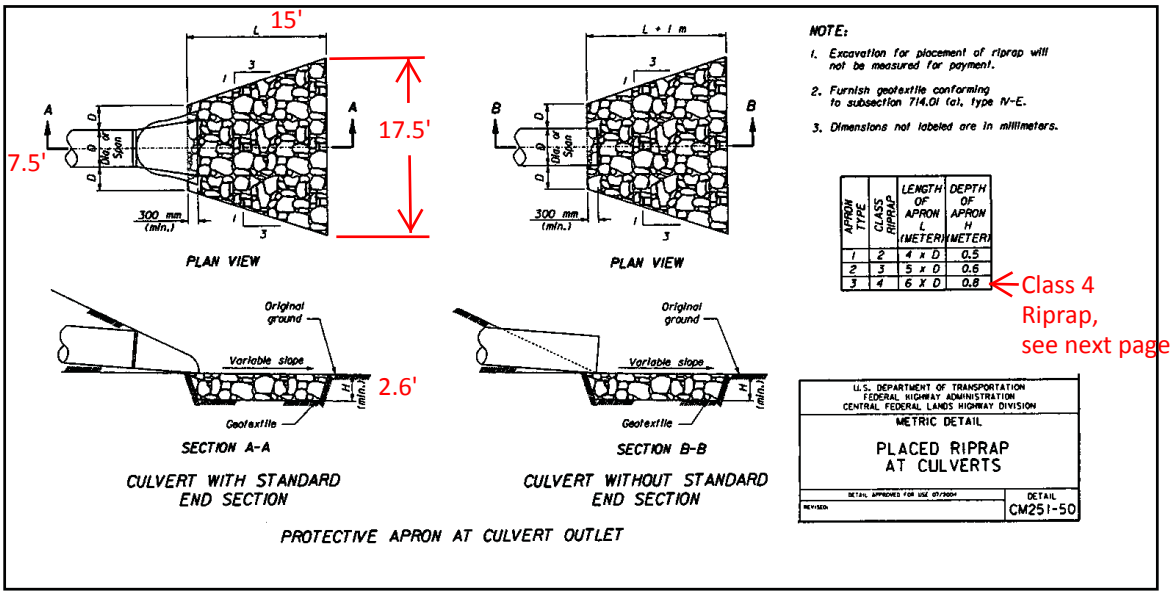


Figure 10.4. Placed Riprap at Culverts (Central Federal Lands Highway Division)

They are constructed of riprap or grouted riprap at a zero grade for a distance that is often related to the outlet pipe diameter. These aprons do not dissipate significant energy except

Table 10.1. Example Riprap Classes and Apron Dimensions

Class	D_{50} (mm)	D_{50} (in)	Apron Length[1]	Apron Depth
1	125	5	4D	$3.5D_{50}$
2	150	6	4D	$3.3D_{50}$
3	250	10	5D	$2.4D_{50}$
4	350	14	6D	$2.2D_{50}$
5	500	20	7D	$2.0D_{50}$
6	550	22	8D	$2.0D_{50}$

[1]D is the culvert rise.

For flows 10 fps or less, typical rock size in industry is 24 inch-minus. Assuming D100 is 24" and D50 is 14", use Class 4 Riprap.
Apron Length = 6 x 2.5' = 15'
Apron Depth = 2.2 x 1.17' = 2.6'

The apron dimensions must also be specified. Table 10.1 provides guidance on the apron length and depth. Apron length is given as a function of the culvert rise and the riprap size. Apron depth ranges from $3.5D_{50}$ for the smallest riprap to a limit of $2.0D_{50}$ for the larger riprap sizes. The final dimension, width, may be determined using the 1:3 flare shown in Figure 10.4 and should conform to the dimensions of the downstream channel. A filter blanket should also be provided as described in HEC 11 (Brown and Clyde, 1989).

For tailwater conditions above the acceptable range for Equation 10.4 (TW > 1.0D), Figure 10.3 should be used to determine the velocity downstream of the culvert. The guidance in Section 10.3 may be used for sizing the riprap. The apron length is determined based on the allowable velocity and the location at which it occurs based on Figure 10.3.

Over their service life, riprap aprons experience a wide variety of flow and tailwater conditions. In addition, the relations summarized in Table 10.1 do not fully account for the many variables in culvert design. To ensure continued satisfactory operation, maintenance personnel should inspect them after major flood events. If repeated severe damage occurs, the location may be a candidate for extending the apron or another type of energy dissipator.

Design Example: Riprap Apron (SI)

Design a riprap apron for the following CMP installation. Available riprap classes are provided in Table 10.1. Given:

Q = 2.33 m^3/s
D = 1.5 m
TW = 0.5 m

Solution

Step 1. Calculate D_{50} from Equation 10.4. First verify that tailwater is within range.

TW/D = 0.5/1.5 = 0.33. This is less than 0.4D, therefore,

use TW = 0.4D = 0.4(1.5) = 0.6 m

$$D_{50} = 0.2\,D\left(\frac{Q}{\sqrt{g}D^{2.5}}\right)^{4/3}\left(\frac{D}{TW}\right) = 0.2\,(1.5)\left(\frac{2.33}{\sqrt{9.81}(1.5)^{2.5}}\right)^{4/3}\left(\frac{1.5}{0.6}\right) = 0.13\text{ m}$$

Step 2. Determine riprap class. From Table 10.1, riprap class 2 (D_{50} = 0.15 m) is required.

URS

Job CITY OF SNOHOMISH Project No. _____ Page _____ of _____

Description STORMWATER COMP. PLAN WQ POND Computed by C. TALICH Date 7/2013 Sheet 1 of 2

Checked by _____ Date _____

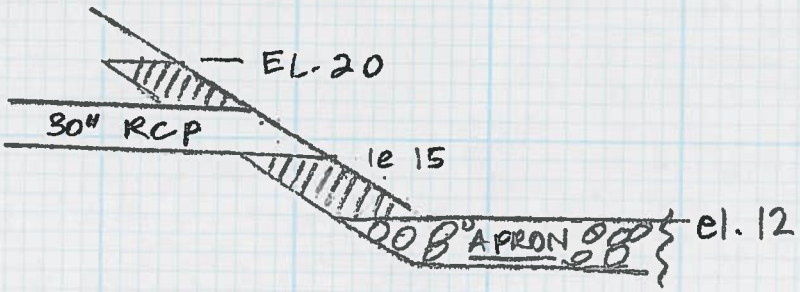
Reference

Rock Armor Pond Inlet

Apron: see HEC-14 marked up Fig. 10.4

Area = 7.5 X 15 + 5 X 15 = 187.5 sf
Depth = 2.6'
Vol = 487.5 cf = 18.1 cy

Slope Around Pipe



Width = 3D = 7.5
Depth = 2.6
Height = 20 - 12 = 8
Vol = 156 cf = 5.8 cy

▷ ROCK RIPRAP = 23.9 cy ⇒ USE 24 cy

Granular Filter

Assume 1' thick beneath riprap Area

A = 187.5 + 7.5(8) = 247.5 SF
V = 247.5 CF = 9.2 cy

▷ GRANULAR FILTER, USE 10cy.

Job CITY OF SNOHOMISH | Project No. ____ | Sheet 2 of 2

Description STORMWATER COMP PLAN WQ POND | Computed by C.TAUCH | Date 7/2013.

Checked by ____ | Date ____

Reference

Berm for First Wetpool Cell

$WQ_{total} = 30$ ac-ft

First cell, use 30%, $V = (30)(0.3) = 9$ ac-ft

min depth $= 4$ ft

Area, First cell $= \left(\frac{9 \text{ ac-ft}}{4 \text{ ft}}\right)\left(\frac{43560 \text{ ft}^2}{\text{ac}}\right)$

$A = 98{,}010 \text{ ft}^2$

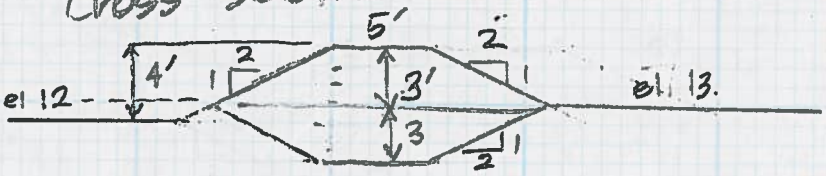
Assume first cell is square

$A = b^2$

$b = 313$ ft use 320'

New berm total length = 640'

Cross section



FILL $A = [(3 \times 5) + 2(3)(3)] \times 2$

$A = 66$ SF

$V = 66 \times 640 = 42240$ CF $= \underline{1564 \text{ CY}} \Rightarrow$ USE $\underline{1580}$

CUT (KEY) $V = 1/2(1564) = \underline{782 \text{ CY}} \Rightarrow$ USE $\underline{790 \text{ CY}}$

CUT (First Cell One foot exc. over entire Area

98010 CF $= \underline{3630 \text{ CY}}$