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Chapter 8 DRAINAGE AND WASTEWATER INFRASTRUCTURE

This chapter presents Design Standards and Guidelines (DSG) standards and guidelines for Seattle Public Utilities (SPU) storm drain, wastewater (sewer) and combined sewer facilities.

Standards appear as underlined text.

Guidelines for public storm drain facilities and stormwater management BMPs are provided to external users in CAM 1180 Design Guidelines for Public Storm Drain Facilities and the Stormwater Manual. References are included in this document along with background considerations and SPU preferences not captured in those documents. References for guidelines for green stormwater infrastructure (GSI) facilities are in Appendix 8C GSI Design Manual, Volumes 2 and 3: Option Analysis and Design Manual

Sewer and combined sewer mainline design guidance is provided in this document. Combined sewer overflow control facilities are not included in this document. For design information on CSO Control facilities, consult with SPU project engineers and plans for Windemere, Henderson and Genesee projects.

The information in this chapter should be used in conjunction with other DSG chapters.

The primary audience for this chapter is SPU engineering staff.

Note: *This DSG does not replace the professional judgment of an experienced engineer.*

8.1 KEY TERMS

The abbreviations and definitions given here follow either common American usage or regulatory guidance.

8.1.1 Abbreviations

Term	Abbreviation
ACI	American Concrete Institute
ADA	Americans with Disabilities Acts
AISC	American Institute of Steel Construction
ANSI	American National Standards Institute
ASTM	ASTM International, originally, the American Society for Testing and Materials
AWWA	American Water Works Association
BMP	best management practice

Term	Abbreviation
CCTV	closed circuit television
CDF	controlled density fill
cfs	cubic feet per second
CIP	Capital Improvement Program or cast iron pipe
City	City of Seattle
CMP	corrugated metal pipe
CSO	combined sewer overflow
DI	ductile iron
DIP	ductile iron pipe
DR	Director's Rule
DWSM	Drainage and Waste Water System Maintenance
EPA	Environmental Protection Agency
ft	feet
GIS	Geographic Information System
HDD	horizontal directional drilling
HDPE	high density polyethylene
I/I	infiltration and inflow
ID	inside diameter
in/hr	inches per hour
L&I	Washington State Department of Labor and Industry
max	maximum
MIA	Masonry Institute of America
min	minimum
NCPI	National Clay Pipe Institute
NPDES	National Pollutant Discharge Elimination System
O&M	operations and maintenance
OD	outer diameter
PACP	Pipeline Assessment and Certification Program
PC	point of curvature
PS	Public Sewer
PSD	Public Storm Drain
PSDD	Public Storm Drain Detention
psi	pounds per square inch
PSS	Public Sanitary Sewer
PT	point of tangency
PVC	polyvinyl chloride
RCP	reinforced concrete pipe
ROWIM	Right-of-Way Improvement Manual
SDOT	Seattle Department of Transportation
SDCI	Seattle Department of Construction and Inspections
sf	square feet
SMC	Seattle Municipal Code
SMT	Seattle Municipal Tower
Spec	specification
SD	Service drain
SS	Side-sewer, combined
SSS	Side-sewer, sanitary
Std	standard
TPH	total petroleum hydrocarbon
VCP	vitrified clay pipe

Term	Abbreviation
WSDOT	Washington State Department of Transportation
ZPG	zeolite, perlite, and granular activated carbon

8.1.2 Definitions

Definitions used in this document may be part of data models used in asset tracking and work management in GIS and Maximo. Others may be defined by regulation or in general use. Key elements of the SPU drainage and wastewater system are given in Table 8-1 in DSG section 8.2.3, which describes those elements.

Term	Definition
catch basin	A **catch basin** is a connector to the storm drain system that typically includes an inlet where stormwater enters the catch basin and a sump to capture sediment, debris, and associated pollutants. Catch basins usually have a trap to prevent floating debris from entering and clogging the sewer or drainage line.
cleanout	See Standard Plans 280, 281, and 283. Small pipe access, purpose varies. And pipe rising from a stormwater or sanitary sewer lateral to ground surface with a removable cap or plug. Used to access the lateral to free blockages. A sewer cleanout is usually located just inside the property line and within 18 inches of the building foundation. Can be used on public catch basin with quality pipe connection to a main.
combined sewer	Public combined sewers are publicly-owned and maintained systems which carry drainage water and wastewater to a publicly owned treatment works. SMC 22.801.170
combined sewer overflow (CSO)	A combination of untreated wastewater and stormwater that can flow into a waterway when a combined sewer system reaches its capacity.
CSO control facility	Any structure or device that meters the sewage flows to reduce the number of combined sewer overflows. Typically, these are storage tanks.
culvert	A **culvert** is a conduit used to enclose a flowing body of water. Culverts can be made of many different materials; steel, polyvinyl chloride (PVC), and concrete are the most common. In the City of Seattle, culverts are commonly associated with the informal drainage system and are often part of larger ditch systems. They are used to convey surface water under driveways and roadways, ultimately to a formal mainline or receiving water body.
ditch	A **ditch** is usually defined as a small to moderate depression created to channel water. In the City of Seattle, ditches generally occur in areas where no formal drainage mainlines exist (mainly north of 85th St and in southeast and southwest sections). The bottom of ditches can be composed of many different materials, but grass, dirt, and asphalt are the most common types. Ditches in the right-of-way are maintained by SPU Operations.
ditch and culvert system	Combination of surface ditches and culverts that convey stormwater. Sometimes called informal system.
drain	A buried pipe or other conduit (closed drain) for stormwater runoff. A ditch (open drain) for conveying surface water or groundwater.
Designated receiving water	The Duwamish River, Puget Sound, Lake Washington, Lake Union, Elliott Bay, Portage Bay, Union Bay, the Lake Washington Ship Canal and other receiving waters determined by the Director of SPU and approved by Ecology as having sufficient capacity to receive discharges of drainage water such that a site discharging to the designated receiving water is not required to implement flow control. SMC 22.801.050.
engineering	Generic term for SPU engineering staff.
ditch and culvert system	Combination of surface ditches and culverts that convey stormwater Also, sometimes called informal system.
drainage system	A system intended to collect, convey and control release of only drainage water. The system may be either publicly or privately owned or operated, and the system may serve public or private property. It includes components such as pipes, ditches, culverts, and drainage control facilities. Drainage systems are not receiving waters. SMC 22.801.150.
Ecology	Washington State Department of Ecology. Note: The Washington State department that oversees receiving water discharges of wastewater and stormwater. The U.S. Environmental

Term	Definition
	Protection Agency has delegated authority to enforce the Clean Water Act and to administer the National Pollutant Discharge Elimination System (NPDES) permit program to Ecology.
flow control	Controlling the discharge rate, flow duration, or both of drainage water from the site through means such as infiltration or detention. SMC 22.801.070.
flow control facility	A drainage control facility for controlling the discharge rate, flow duration, or both of drainage water from a site. SMC 22.801.070.
flow control structure	See Standard Plans 270 and 272.
force main	Discharge pipe of a pumping station.
green stormwater infrastructure (GSI)	A **drainage facility** that uses **infiltration**, **evapotranspiration**, or **stormwater reuse**. Examples of green stormwater infrastructure include **permeable pavement**, **bioretention facilities**, and **green roofs**. SMC 22.801.080.
guidelines	Advice for preparing an engineering design. Guidelines document suggested minimum requirements and analysis of design elements in order to produce a coordinated set of design drawings, specifications, or lifecycle cost estimates. Design guidelines answer what, why, when and how to apply design standards and the level of quality assurance required.
inlet	An inlet is a grated structure that conveys surface drainage to an off-line structure such as a catch basin.
main (or mainline)	Publicly-maintained pipe system, usually 8 inches or larger in diameter for sewers and 12 inches or greater in diameter for stormwater and located in streets or easements. SPU has three types of mains: 1) Public Sewer (PS) is a combined sewer, 2) Public Sanitary Sewer (PSS), and 3) Public Storm Drain (PSD).
maintenance hole	Abbreviated as MH. Also and commonly referred to as manhole. Structure used on mainlines for maintenance and inspection and for change in pipe size or change in horizontal or vertical direction.
natural drainage system	A form of green stormwater infrastructure (GSI). Natural or constructed rain gardens, swales, ravines, and stream corridors. Natural drainage systems cross privately- and publicly-owned property and can flow constantly or intermittently. See also green stormwater infrastructure.
NPDES permit	An authorization, license or equivalent control document issued by EPA or Ecology to implement requirements of the NPDES program. SMC 22.801.150.
Operations	Generic term for SPU staff responsible for Operations and Maintenance.
outfall	Generally, the point of discharge from a storm drain to a receiving water. Can also include combined sewer flows.
outlet	Generally, the point of discharge. Used both in context of catch basin outlet or stream outlet.
Public Sewer (PS)	Public combined sewer pipe. Also abbreviated S. Also called main or pipe.
Public sewer system	The sewer facilities owned and maintained by the City or other agencies having jurisdiction (e.g. Valley View Sewer District, Southwest Suburban Sewer District, King County), or any sewer or drainage facilities acquired or constructed by such agencies. 21.16.030 SMC.
Public Storm Drain (PSD)	Part of the public drainage system that is wholly or partially piped, and designed to carry only drainage water. 22.801.180 SMC. Also called main or pipe.
Public Storm Drain Detention (PSDD)	Detention facility located within the right-of-way for street drainage that SPU is responsible to maintain. Normally these are large-diameter pipes. See Standard Plan 270. Also called detention pipe.
Receiving water	The surface water, such as a creek, stream, river, lake, wetland or marine water or groundwater receiving drainage water. Drainage systems and public combined sewers are not receiving waters. SMC 22.801.190.
Sanitary Sewer (PSS)	Public sanitary sewer pipe that conveys wastewater and is not designed to carry drainage water. Also called sewer main or pipe.
service drain (or lateral)	A privately owned and maintained drainage system that conveys only stormwater runoff, surface water, subsurface drainage, and/or other unpolluted drainage water. Service drains include, but are not limited to, conveyance pipes, catch basin connections, downspout connections, detention pipes, and subsurface drainage connections to an approved outlet. Service drains do not include subsurface drainage collection systems. SMC 22.801.030

Term	Definition
side sewer (or lateral)	A privately owned and maintained pipe system that is designed to convey wastewater, and/or drainage water to the public sewer system or approved outlet. This includes the pipe system up to, but not including, the tee, wye, or connection to the public main. SMC 21.16.030.
standards	Drawings, technical or material specifications, and minimum requirements needed to design a particular improvement. A design standard is adopted by SPU and generally meets functional and operational requirements at the lowest life-cycle cost. It serves as a reference for evaluating proposals from developers and contractors. For a standard, the word must refers to a mandatory requirement. The word should is used to denote a flexible requirement that is mandatory only under certain conditions. Standards appear as underlined text in the DSG.
trenchless technologies	Technologies, such as pipe-bursting and pipe lining, are methods of rehabilitating pipes to extend useful life and do not require digging a trench to lay a pipe.
stormwater	Stormwater means runoff during and following precipitation and snowmelt events, including surface runoff, drainage and interflow. SMC 22.801.200.
wastewater	Wastewater is a comprehensive term including industrial waste, sewage, and other polluted waters, as determined by the Director of Health or Director of SPU. SMC 22.16.030.
water quality	A term used to describe the chemical, physical and biological characteristic of water for its suitability for a particular purpose
water quality treatment	Method of pollutant removal that include sedimentation, settling filtration, plant uptake, ion exchanges adsorption and bacterial decomposition.

8.2 GENERAL INFORMATION

SPU owns and operates many types of stormwater, wastewater, and combined sewer facilities. King County also owns and operates many of the largest pipes in the system and the sewer treatment plants. Both King County and Seattle are responsible for reporting and controlling different combined sewer overflows from the system. Agreements between the two agencies are available at the City Clerk's office Removed for security

SPU regulates side sewers for construction on private property and has a memorandum of agreement with SDCI to provide review, permit and inspection services.

8.2.1 Comprehensive Plans, Codes and Policies

The guiding policy documentation for SPU drainage and sewer infrastructure is the individual comprehensive plans for each utility. The following are the most current policy sources for the DSG:

- City of Seattle 2004 Comprehensive Drainage Plan, Section 3, General Policies
- City of Seattle 2006 Wastewater System Plan (Not formally adopted through council but is the best available plan for wastewater system)
- Seattle Municipal Code for stormwater and side sewers are written on multi-year cycles. Technical details supporting the codes are written and implemented through Director's Rules (DR). Side Sewer Code, Title 21.16
  - Requirements for Design and Construction of Side Sewers (Drainage and Wastewater Discharges SDCI Director's Rule 4-2011 / SPU Director's Rule 2011-004
  - Side Sewer Code Enforcement SDCI Director's Rule 5-2011/SPU Director's Rule 2011-005
- Stormwater Code, Title 22.800

  - Stormwater Manual and Appendices A to I, SDCI Director's Rule 21-2015/SPU Director's Rule DWW-200
- Consent Decree: As of July 2013, Seattle has entered into a historic agreement with the Environmental Protection Agency, Department of Justice, and the Washington State Department of Ecology to reduce sanitary sewer overflows (SSO) and combined sewer overflows (CSO) into Seattle's receiving water bodies. Some key points about the history and desired outcome include:
  - Long Term Control Plan-The Long Term Control Plan under developed by the City in accordance with Section V. B. of the Consent Decree, as well as any additional remedial measures for eliminating or reducing the City's CSOs included in any Supplemental Compliance Plan developed and implemented in accordance with Section V.B. of the Consent Decree
- SPU Strategic Business Plan 2015 to 2020

For more information, see SPU's Policies, Procedures & Other Rules

Tip: *Often the easiest place to research code and rules is the SDCI web site. City of Seattle Comprehensive Sewer and Drainage Plan 1973, often referred to as the Wayne Greer Plan, is also very helpful for design.*

8.2.2 System Maps

SPU storm drainage, wastewater, and combined sewer system maps are available from:

- GIS Removed for security
- Base Maps
- SPU GIS Mapping Counter (SMT 47th floor)
- Combined Sewer Overflow (CSO) Control Facilities Operations and Maintenance folders (SMT 44th floor)
- SPU/King County Wastewater Sewer/Drainage Topography maps (SMT 45th floor)
- Seattle Department of Construction and Inspections (SDCI) Side Sewer and Storm Drainage Information desk (SMT 20th floor) Side Sewer Cards are available there.

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8.2.3 Drainage and Wastewater System

SPU is responsible for maintaining the network of drainage and wastewater systems throughout Seattle. The system includes approximately:

- 448 miles of sanitary sewers
- 460 miles of storm drain pipe
- 968 miles of combined sewers
- 77 pump stations
- 92 permitted combined sewer overflow (CSO) outfalls
- 170 storm drain outfalls
- 38 CSO control detention tanks/pipes
- 300,000 ft^2 total GSI cells maintained

The flow in the SPU drainage and wastewater system is divided roughly into thirds. One-third of City of Seattle storm drains flows in a pipe to a receiving water body to Puget Sound. Another one-third flows to a ditch or culvert and the final one-third flows to a combined sewer.

Elements within SPU's drainage, wastewater, and combined sewer network include infrastructure for collection and conveyance, and storage and treatment (Table 8-1).

Table 8-1
SPU Drainage and Wastewater System Components

Types of Infrastructure and Related Components*		
Collection	Conveyance	Storage/Treatment
catch basin	culvert	CSO control facility
cleanout	ditch	flow control structure
inlet	ditch and culvert system	GSI
GSI	force main	
	GSI	
	main (or mainline)	
	maintenance hole	
	outfall	
	Public Sewer (PS)	
	Public Storm Drain (PSD)	
	Public Storm Drain Detention (PSDD)	
	Public Sanitary Sewer (PSS)	
	service drain (or lateral)	
	side sewer (or lateral)	

*See section 8.1.2 for definitions of these terms.

8.2.4 DSG Design Resources

DSG design resources include technical or material specifications developed specifically for and found only in the DSG. They include drawings, standard specifications, design calculations and other resources not available from other sources:

- **Drawings.** No drainage and wastewater infrastructure technical drawings were developed for the DSG. Several figures illustrating typical layouts were developed and appear in this chapter. For new drawings that will appear in the next edition of the City of Seattle *Standard Plans and Specifications*, see SPU website.

- **Technical Specifications.** No drainage and wastewater infrastructure technical specifications were developed for the DSG. See Standard Specifications and Plans.
- **Design Calculations.** SPU sizing guidance for maintenance holes are presented in the SDCI website.
- See CAM 1180 for design guidelines for public storm drain facilities. These guidelines have been reviewed by SDOT.
- Tip 531: Green Stormwater Infrastructure (GSI) on Private Property: Post Construction Soil Management.
- Approved Tree List - Note: Trees in the Small Category are not eligible for credit.
- SIP notes: These notes were not developed for use with SPU CIP projects, but for private development work under permit by the City, but not City contracts. They may be of interest and are referred to from CAM 1180. Notes for CIP projects should typically not refer to the relevant specification section, as these notes do.

8.3 GENERAL REQUIREMENTS

The design engineer must be familiar with industry standards and code requirements.

8.3.1 Industry Standards

Industry standards for drainage and wastewater pipes are shown in Table 8-2.

Table 8-2
Industry Standards and Specifications

Organization	Standard	Description
Vitrified Clay Pipe (VCP)		
ASTM	C12	Installing vitrified clay pipe (VCP) lines
ASTM	C301	Test methods for VCP
ASTM	C425	Spec for compression joints for VCP and fittings
ASTM	C700	Spec for VCP- Extra Strength, Standard Strength, and Perforated
ASTM	C828	Test methods for low-pressure air test of VCP lines
ASTM	C896	Terminology relating to clay pipe
ASTM	C1091	Test methods for hydrostatic infiltration and exfiltration testing of VCP lines
Ductile Iron (DI) Pipe		
ANSI	21.51	Ductile-Iron Pipe Centrifugally Cast in Metal Molds or Sand-Lined Molds, for water or Other Liquids
ANSI	21.53	Covering ductile iron compact fittings for 350 psi water pressure plus water hammer
AWWA	C151	Ductile-Iron Pipe, Centrifugally Cast, for Water or Other Liquids
High Density Polyethylene (HDPE) Pipe		
ASTM	D3350 F2648	Corrugated smooth wall
ASTM	D3350 PE 3608 / PE 3408	Smooth wall

Organization	Standard	Description
Polyvinyl Chloride (PVC) Pipe		
ASTM	C900	PVC
ASTM	D 2241	Pressure rated PVC pipe
ASTM	D3034	PVC pipe and fittings
ASTM	F789	PVC pipe
AWWA		Disinfection, piping and other elements of drinking water systems
Concrete Pipe		
ASTM	C14	Non-reinforced Concrete Sewer, Storm Drain, and Culvert Pipe
ASTM	C76	Reinforced Concrete Culvert, Storm Drain and Sewer Pipe
Polypropylene pipe		
ASTM	F2736	6" to 30" Polypropylene (PP) Corrugated Single Wall Pipe and Double Wall Pipe
ASTM	F2764	30" to 60" Polypropylene (PP) Triple Wall Pipe and Fittings for Non-Pressure Sanitary Sewer Applications
Other		
ACI	318-95	Building code requirements for reinforced concrete
ACI	350R-89	Environmental engineering for concrete structures
ADA	Part 36	American with Disabilities Act guidelines for buildings and facilities
IBC		International Building Code
UPC		Uniform Plumbing Code 2009
SBC		Seattle Building Code
UBC		Uniform Building Code
UFC		Uniform Fire Code
MIA	Handbook	Reinforced Masonry Engineering Handbook, J.E. Amrhein, 5th edition
AISC	Manual	Manual of Steel Construction or Load Resistance Factor Design

Note:

ACI: American Concrete Institute

AISC: American Institute of Steel Construction

ANSI: American National Standards Institute

ASTM: ASTM International, originally, the American Society for Testing and Materials

AWWA: American Water Works Association

MIA: Masonry Institute of America

8.3.2 Regulations

All drainage and wastewater facilities must be built to the applicable City of Seattle, Washington State and federal guidelines.

Table 8-3 lists the relevant City of Seattle and Washington State regulations for drainage and wastewater facilities. Under the National Pollution Discharge Elimination System (NPDES) Permit, jurisdictions in Washington must be deemed either equivalent to Ecology's 2012 *Stormwater Management Manual for Puget Sound* **or** adopt Ecology's *Stormwater Manual*. The City of Seattle 2016 Stormwater Code and related Director's Rules were granted NPDES equivalency in 2015. The City of Seattle Stormwater Code was made effective January 3, 2016.

Table 8-3
City and State Regulations for Drainage and Wastewater Facilities

Title	Document
City of Seattle	
City Standard Plans and Specifications	City of Seattle Standard Specifications for Road, Bridge, and Municipal Construction and the Standard Plans for Municipal Construction, current edition
Environmental Critical Areas Code	Environmental Critical Area Code (ECA) SDCI.
Noise Ordinance	Noise Abatement, SMC 25.08
Pavement Opening and Restoration	City of Seattle Pavement Opening and Restoration Rules
Right-of-Way Improvements Manual	SDOT Director's Rule/
Seattle Fire Code	International Fire Code w/ Seattle amendments
Seattle Land Use Code	Seattle Land Use and Zoning Code, SMC 23
Seattle Street Use Code	Street Use Code, SMC 15
Shoreline Master Program	Shoreline Master Program from SDCI
Side Sewer Code	Side Sewer Code (SMC 21.16) SDCI/SPU Requirements for Design and Construction of Side Sewers Directors' Rule 2011-04 (Drainage and Wastewater Discharges)
Stormwater Code*	City of Seattle Stormwater Code (SMC 22.800 – 22.808). Stormwater Manual Directors' Rule DWW 200
Grading Code	Grading Code (SMC 22.170).
Washington State	
NPDES	Construction Stormwater General Permit
WAC 51-13	WAC 51-13 Ventilation and indoor air quality 2006
Consent Decree	As of July 2013, Seattle has entered into a historic agreement with the Environmental Protection Agency, Department of Justice, and the Washington State Department of Ecology to reduce sanitary sewer overflows (SSO) and combined sewer overflows (CSO) into Seattle's receiving water bodies. Some key points about the history and desired outcome include: Long-Term Effort, Landmark Agreement, Commitment to Protect

8.4 BASIS OF DESIGN

For this DSG, basis of design documentation communicates design intent primarily to plan reviewers and future users of a constructed facility. By documenting the basis of design in the basis of design sheet and archiving it with the project record drawings (as-builts), future staff has access to design decisions.

8.4.1 Basis of Design Plan Sheet

The basis of design sheet is a general sheet that shows a plan overview and lists significant design assumptions and requirements for major design elements (

Figure 8-1). The following are SPU standards for this sheet:

- The design engineer must include a basis of design plan sheet in the plan set.
- The sheet must be archived with the record drawings.

Figure 8-1
Basis of Design Plan Sheet Data for Drainage and Wastewater Infrastructure

Basis Of Design Plan Sheet

WASTEWATER---

Basin Area (sf/acre): ______________________ Base Flow Rate: __________________________cfs

Design Storm(s) or modeling report for Conveyance, when applicable: ________________Maximum Flow Rate: ____________________cfs

Peaking factor

Project Specific/Special Information:

STORM DRAINAGE---

Basin Area (sf): ____________________ Design Storm(s) or modeling report for Conveyance: ______________________; Land use____________________

Base Flow Rate (cfs):______________________ Flow Rate (cfs):_____________________________

Peak flow (cfs):100-yr event

Project Specific/Special Information:

STORM WATER CODE COMPLIANCE---

Type of Project (Roadway, Trail/Sidewalk, Parcel)____

Basin (Listed Creek, Non-Listed Creek, Combined, Receiving Water, Wetland)__________________

Area Mitigated by Flow Control (sf):____________ Flow Control (cfs): _______________________

Area Mitigated by WQ Treatment (sf):_________________Type of FC:_______________________

On-site Requirement BMPs:
____

Basic WQ Facility: _________________________ WQ Volume/Flow Rate:____________________

Enhanced WQ Facility:__________________________ Oil Control Facility: ___________________

Bioretention Type (Cell, Cascade) Top Area (sf):________________Bottom Area (sf):_________ Contributing Area (ac)_____________

Landscaped Area (sf):___________________Material Type (Grass, Planted)_________________

Ponding Depth (inches)__________________Depth of Bioretention Soil (inches)_____________

Native Soil Infiltration Rate (in/hr)___________ Planting Date:____________________________

Permeable Pavement Type (Facility, Surface) Material:________________________________

Measured Soil Infiltration Rate (in/hr)____________ Correction Factor Design Soil Infiltration Rate (in/hr) Pavement Area (sf):______________________

Project Specific/Special Information:

The Basis of Design Plan Sheet is not intended for construction and should **not** be included with the bid set. The form is modified to fit the project. The sheet is inserted during the record drawings (as-builts) preparation (90% design). See *DSG Chapter 1, Design Process*.

For drainage and wastewater infrastructure, basis of design plan sheets may include:

- Standards used (i.e. min/max allowable velocities)
- Sizing information (i.e. design storm, number of equipment, minimum dimensions of a structure, design flow rate, min/max flow rate)
- Boundary conditions assumed
- Pipe calculation assumptions
- General design assumptions
- Design engineer's name

The design engineer should exercise judgment on what type of information can adequately explain the basis for sizing and selection. The sheet can show equipment type, size, minimum inlet and outlet velocities, and assumptions for redundancy. It should include all project utility needs (e.g. power, fire flow, potable water). The sheet should also include major safety considerations such as whether or not an area is classified, occupancy ratings, and fire-rated walls. The information should be shown with appropriate units and clarifying notes.

8.4.1 Basis of Design Document

In addition to the Basis of Design Plan Sheet, the designer engineer must provide record of more detailed design assumptions and major design decisions in a document format. This is a living document through the design phase and will be finalized and archived in the project file for record.

8.4.2 Design Criteria List

The design engineer should use a design criteria list to develop a basis of design plan sheet. The design criteria list is a shortened version of the most important design requirements (Table 8-4). This information is **not** intended for construction and should not be included with the bid set. If included with the bid set, the design criteria list should be labeled *Informational Only*.

Typically, the design criteria list is completed with the Preliminary Engineering Report as a concise summary. However, that report can provide a much lengthier description of design requirements.

Table 8-4 is an example of what a design criteria list might contain for a stormwater design.

Note: *Table 8-4 is only an example. It is not intended to explain technical concepts.*

Table 8-4
Design Criteria List for a Typical Stormwater Design (Example)

Description	Design Criteria	Sample Values
Precipitation	storm	inches
	6-mo 15-min	0.58
	2-yr 15-min	0.88
	25-yr 15-min	1.60
	100-yr 15-min	2.11
Design Flow Rate		
Conveyance:		
Pipe Sizing Rational Method = CiA	25-yr 15-min storm C value, impervious = 0.90	(Area = 1.0 acre, pervious + impervious = total drainage area) 0.90 x 1.6 x 1.0 = 1.44 cfs
Pipe Velocity	Minimum = 3.0 fps Maximum = 7.5 fps	12" diameter Concrete pipe (n=0.012); Slope = 1.0% (min.) Qfull = 3.4 cfs; Vfull = 4.8 fps
Flow Control: See Stormwater Manual Vol. 1, Section 2 for minimum requirements for stormwater flow control based on project types. Refer to Section 5.3.2 to 5.3.4 for specific flow control standards (wetland protection, predeveloped forested, pre-developed pasture and peak control.		
Peak Flow Control Standard 22.805.080B4	The post-development peak flow with a 4% annual probability (25-year recurrence flow) must not exceed 0.4 cubic feet per second per acre. Additionally, the peak flow with a 50% annual probability (2-year recurrence flow) must not exceed 0.15 cubic feet per second per acre.	
Water Quality Treatment: See Stormwater Manual Vol. 1, Section 5.4		
Basic Treatment: 22.805.090B2	A basic treatment facility must be required for all projects meeting the thresholds for that project type. Basic treatment means a drainage control facility designed to reduce concentrations of total suspended solids in drainage water.	
Miscellaneous Design Considerations		
Pipe Type	Reinforced concrete pipe (RCP)	12" diameter ASTM C76 Class V 8" diameter ASTM C14 CL3
Catch Basins Maintenance holes Inlets	Std Plan 240 (a, b, c or d) Std Plan 204 – 232 Std Plan 250-252	Std Plan 240 Std Plan 204 (48" diameter) Std Plan 250, 252
Minimum Slope		
Inlet Connection	5.0% minimum	
Storm Main Line	1.0% minimum	*Based on conveyance sizing
Catch basin Connection	2.0% minimum	Site dependent, exceptions per City approval. Use DI pipe
Trench Compaction		
Non-Roadway	90% compaction	90% of Standard Proctor
Roadway	95% compaction	95% of Standard Proctor

8.5 DESIGN PROCESS

See *DSG Chapter 1, Design Process*. It explains the design process and deliverables for a typical pipeline project.

8.6 OTHER DISCIPLINE DESIGN

This section presents design considerations specific to drainage and wastewater projects by design discipline. For general design considerations that apply to all SPU infrastructure projects, see *DSG Chapter 4, General Design Considerations*.

8.6.1 Structural

A civil engineer may design common structural elements. These elements include headwalls, retaining walls, vault, pipe encasements, concrete caps, foundations, footings, concrete channels, shear, sluice and flat gates, multiple-access top slabs for MH covers, pipe loading analysis, and weir walls. Cast-in-place vaults require a licensed structural engineer.

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8.6.2 Architectural and Landscaping

8.6.2.1 Architectural

Generally, SPU drainage and wastewater infrastructure projects do not require architectural design.

Note: *Large projects receive a 1% for art contribution from the project proponent.*

8.6.2.2 Landscaping

The following are general guidelines for landscaping:

- Consult with SDOT Urban Forestry for planting, tree protection, removal, replacement in the ROW. Refer to tree siting and consultation process outlined in Appendix 8C GSI Design Manual and the current SDOT approved street tree list. Consider long-term Operation and Maintenance implications of planting choices.
- Consult with Environmental Specialist for permitting requirements. See *DSG Chapter 2, Design for Permitting and Environmental Review.*
- Consult the Stormwater Manual for landscaping guidelines on BMP installation.
- Select non-invasive plant species that fit with the neighborhood landscaping and grow in the type of soil present. Note that many common plants can be invasive in the wrong location (plants travel with creeks and rivers). For GSI planting guidance in the ROW, consult Appendix 8C GSI Manual Volume III.
- Minimize ground disturbance and protect/preserve native vegetation. Retain/preserve mature trees.
- When piping or venting is aboveground, consider screening it with bushes.
- Coordinate with Operation & Management for needs of irrigation, plant selection, and maintenance plan.

8.6.3 Instrumentation & Control

Instrumentation and control (also referred to as Supervisory Control and Data Acquisition or SCADA) are common electrical design elements for drainage and wastewater infrastructure. These design elements include flow monitors, level sensors, and local control panels. Some SPU drainage and wastewater systems have controlled gates. For detailed information on this topic, see *DSG Chapter 10, Instrumentation & Control.*

8.7 STORM DRAIN DESIGN

This section describes standards and guidelines for SPU storm drains.

Many reference materials are available for storm drain design process from text books and design manuals published by various public agencies. This document will provide a general understanding of storm drain design as well as some significant SPU storm drain design standards. The general approach of the writing is to refer the designers to design criteria that are available in various City of Seattle published documents and only to emphasize the most significant design considerations and some of the rationale behind them.

For stormwater code requirements on designing conveyance, flow control facilities, stormwater quality treatment, or on-site requirements, see the Seattle Department of Construction and Inspections (SDCI) website on Stormwater Code and related Director's Rules (SWC).

For drainage infrastructure guidelines, see City of Seattle CAM 1180, which was developed in coordination with SDOT and covers:

- Grade roadway and ally for drainage collection.
- Select the preferred types and material for public storm drain (PSD), detention facilities, catch basin (CB) and inlet connection pipes, shallow street culvert, and maintenance hole (MH).
- Size and locate the various drainage infrastructures.
- Design for exception and alternatives to the standards.

8.7.1 Hydrologic and Hydraulic Evaluation

Hydrology is a broad term concerning the various scientific branches of studying water on Earth. In relationship to storm drain design, hydrologic evaluation process generates runoff peak flow, volume, and duration using many different variables. Seattle has a long history of rainfall measurement. Refer to *DSG Chapter 7, Drainage and Wastewater System Modeling.* See the Stormwater Manual for modeling requirements for specific stormwater BMPs and Hydrologic Analysis and Design in Appendix F.

For storm drain design of single upstream pipe segments, the rational method is generally appropriate for speed and ease of use. Single event modeling using short, medium and long duration storm data is generally appropriate for storm drain pipe design. This includes cases when backwater from the lakes is involved in the calculation. The Stormwater Manual includes high water surface elevations. For storm drain systems discharging to tidal waters, continuous simulation of rainfall and tide are appropriate. Matching the peak observed tidal elevation to a single event storm peak as required in the Stormwater Manual Appendix F is conservative and can lead to oversizing of the drainage system so continuous modeling is recommended. Note that for public systems, Appendix F requires analysis of sea level rise by adjusting the tidal record.

Prior to conducting any detailed stormwater runoff calculations, consider the overall relationship between the proposed project site and the runoff it will create. The choice of a hydrologic analysis method depends on the types of facility being designed (conveyance, flow control, or water quality) and the required performance standard.

Some of the data required include watershed characteristics such as size of the tributary area/basin delineation, soil type, land cover, rainfall/precipitation data, topography, conveyance network and boundary condition. Section 7.5.3 of *DSG Chapter 7, Drainage and Wastewater System Modeling* has some useful information regarding hydrology and modeling.

Tip: *The Corps of Engineers controls levels in Lake Washington, Lake Union, Portage Bay, and the Ship Canal and maintains levels approximately two feet higher in the summer.*

8.7.2 General

Stormwater in Seattle flows to a number of locations depending on the basin in which it originates.

Use trace tools to track the route and do not assume that flow following topography. In many parts of Seattle, the piped drainage path is vastly different.

Tip: *The Longfellow creek drainage basin, for instance, can be hard to define. Combined Sewers can increase the basin area by one third under and storm drains at ridge top can decrease the basin area by one third. Different flow conditions change the contributing basin area.*

Ultimately, most stormwater flows to Lake Washington or Puget Sound. Typically, stormwater flows through a natural drainage system, creek, wetland, small lake, ditch and culvert system, PSD, or a PS. It is possible that stormwater will pass through a combination of these systems before it reaches natural water bodies.

Storm and subsurface water collects on a site through footing drains, gutters, yard drains, and impervious surfaces. Storm and subsurface water is then conveyed to one of the following:

- Ditch and culvert system
- GSI system
- Public storm drain
- Public combined sewer
- Creek or wetland
- Lake, creek, bay, canal, river and ultimately to Puget Sound

If no discharge point is available, onsite infiltration or dispersal can be used if soil conditions allow.

The following are general standards for design of PSD facilities. These standards may not apply to all cases:

1. New public storm drains must be placed in the standard location shown on Standard Plan 030 whenever possible. This standard location is 7 feet south or west of the right-of-way (ROW) centerline to the center of the PSD.
2. The Street Improvement Permitting section of SDOT in consultation with SPU must approve alternate alignments.

For corrosion protection for drainage and sewer pipes, please see *DSG Chapter 6, Cathodic Protection.*

8.7.3 Grading and Surface Water Collection

Surface grading and the proper layout of inlets and other structures are critical to efficiently convey water to a drainage system. This section describes design criteria for system layout.

8.7.3.1 Roadway Grade

A. Standard Grade

- The minimum allowable roadway grade is 0.5%. SPU prefers a 1.0% grade.
- The standard roadway cross slope is 2.0%. For guidelines for roadway grades, see the SDOT Right-of-Way Improvement Manual (ROWIM).

B. Non-Standard Grade

For flat arterials (grade <1%), drainage tends to migrate into travel lanes when the grade is flat or the road changes horizontal alignment. This condition can impact safety and damage roadways and sidewalks.

1. Arterial streets with a grade flatter than 1.0% must have drainage pickups (CBs and inlets) at least every 350 feet. Gutter flow calculations is required.
2. The design engineer must evaluate the following:
   a. Changes in grade and the overall topography of the area.
   b. Turns in horizontal alignment.
   c. Existing and planned locations of laterals.
   d. Other site-specific conditions.

Tip: *Typically, drainage CBs and inlets should be located at intersections and based on maintenance access points. However, in flat roads, locate drainage pickups based on drainage area. Avoid grade changes that result in closed contours.*

8.7.3.2 Roadways and Alleys

See CAM 1180 for standards on grading for drainage collection for roadway and alleys (including curb returns and burb bulb).

Tip: *If the distance from a high point to the intersection, crosswalk, or end of an alley is less than 100 feet, drainage collection may not be necessary.*

8.7.3.3 Curbs and Gutters

See ROWIM Chapter 4 for curb and gutter design requirements and standards. The topics include curb type, height, location, flow line elevation, and curb bulb.

Tip: *A gutter section carrying runoff should not have a joint between the curb and roadway.*

Gutter flow design spreadsheets are available from WSDOT. Gutter flow calculation should be used when designing for arterial streets.

8.7.4 Inlets and Catch Basins

Inlets and CBs collect surface water from the street or curb line. These facilities route water through a CB to trap oil with a downturned elbow and sediment in a sump before discharge into a storm main or combined sewer. Inlets and CBs may also be used in the informal system.

See CAM 1180 for guidelines on "What Type of Catch Basin or Inlet to Use Where." The following is a quick summary of SPU preference from CAM 1180. See Appendix 8C GSI Design Manual for overflow structure requirements in bioretention cells.

Tip: *The following applies to inlets and CBs (Table 8-5) and also details SPU's preference and reasoning of using CB or inlet:*

SPU prefers CBs over inlets because of the greater reliability. Inlets and inlet connection pipe tend to clog faster. That is why the minimum slope for inlet connections is 5%, instead of 2%. In addition, maintenance of inlet connection pipe would typically be rodding the pipe as opposed to a vactor operation, which is why the pipe orientation and straightness requirements for inlet connection pipe allow for less flexibility during construction. For both types of structures with rectangular grates, the orientation of the connection pipe should allow for utilization of the longer length of opening when the grate is removed. For CBs, it is important that crews can see, reach and replace the trap from the opening.

SPU prefers a CB or inlet that has a curb opening using Standard Plan 263 frame. The curb opening provides some back up for grates clogged with debris or leaves. In addition, on Seattle hills, significant collected flows sometimes bypass the grate because the flange requires that the edge of grate openings will be more than an inch from the face of curb. A curb opening helps to minimize this issue.

SPU prefers a large sump volume in a CB to reduce maintenance. Annual inspections of CBs are required and cleaning is triggered when sediment is within 18 inches of the outlet pipe.

SPU requires a CB prior to discharge to conveyance pipes to provide an easier to maintain location to control sediment entering the main system.

Each CB should typically have a sump, a trap and an independent connection to the main. Alternate uses of the structure type may be appropriate, but should be designated differently on the drawings with a detail. For instance, in some areas of flat and shallow pipes or ditch and culvert, a sump-to-sump connection may be the only feasible hydraulic connection. When for example using a type 241 CB structure as a junction box, it is most likely not a CB for asset inventory purposes. Remember, a CB in the system requires annual inspection.

Remember that CBs can be a relief point in a surcharging system. Consider the hydraulic implications of flow entering or leaving the system at any location. SPU has been moving to in-line elastomeric backflow prevention valves, if needed. Consult with operations.

SPU does not allow private property to connect to any CB in the street. This is because the City's liability is increased in the case of a backup that could be traced to clogging of the SPU CB. Walls, even walls in the ROW owned by SDOT should have CBs separate from the street CB because of the risk of surcharging the wall in the event of CB failure for any reason. Removed for security

Connections to street CBs in storm drain systems are typically not allowed. Consult with the Line of Business. Removed for security

Removed for security

See Standard Plan 266 for a vane grate replacement for old type 261 inlets. The vane grate is a bicycle safety improvement over the slotted grates.

Table 8-5
SPU Standard Inlets and Catch Basins

Type	Frames, Grates, Covers, Location and Installation	Description	Typical Application
240A	230	4-ft diameter CB with top slab and 24" ring and cover. Use locking lid in non-travelled roadway	When inlets are used at curb line
240B	264	4-ft diameter CB with top slabs and 20" x 24" grate	Parking lots and alleys
240C	262, 265	4-ft diameter CB with top slab and 16" x 31" vane grate	Higher outlet is desired
240D	263, 265	4-ft diameter CB with top slab, vane grate and curb inlet	Higher outlet is required with 6" curb height
241	264	Small CB (rectangular) with 20" x 24" grate	In alleys and unpaved areas in the ROW Other use in ROW requires SPU approval
242A	262, 265	3.5-ft diameter CB with 16" x 31" vane grate and eccentric cone	Curb and gutter
242B	263, 265	3.5-ft diameter CB with 16" x 31" vane grate, curb inlet and eccentric cone	Curb and gutter and closed contour
250A	262, 265	16" x 31" vane grate inlet	Curb and gutter
250B	263, 265	16" x 31" vane grate with curb inlet	Curb and gutter with 6" minimum curb height

Type	Frames, Grates, Covers, Location and Installation	Description	Typical Application
252	264	20" x 24" grate inlet	Alleys and parking lots with utility conflicts
NA	269	Beehive Grade for Bioretention	Grate for Bioretention overflow

8.7.4.1 Layout

A. Requirements and Standards

See CAM 1180 for standard design requirements. Following captures some of the major points but is not representative of CAM 1180 in its entirety.

The following standards apply to layout of SPU CBs and inlets in the ROW:

1. All locations where stormwater is collected must have a CB in line before going to the main. Direction of flow must be street to curb to inlet to CB to mainline.
2. Inlet and CBs must be located upstream of curb ramps and crosswalks.
3. The downstream edge of the inlet grate must be a minimum of 1 foot clear of the curb ramp landing. It is desirable to have the downstream edge of the inlet grate placed at the upstream edge of the ramp wing. For location of new curb ramps, see Standard Plan 422B.
4. The standard location for inlets and CBs must be 1.5 feet from the centerline of the inlet or CB to the point of curvature (PC) or point of tangency (PT) of the curb return (see Standard Plan 260A).
5. Refer to SPU Core Tap Procedures for Storm and Sewer Mains for lateral to main connection requirement, including private drainage and sewer service drain.
6. All private service drains must be individually connected to the main.
7. A service drain or side sewer connection to a public main must be at least 1 pipe size smaller than the mainline size unless approved by SPU. The connection may not be sized on size.
8. No private side sewer or service drain connections are allowed to a CB or an inlet.
9. An inlet connection may not exceed 50 feet without bends at a minimum slope of 5%.
10. CB connection to the main line must be at a minimum slope of 2%.

B. Guidelines

The following are guidelines for catch basins and inlets:

- Avoid street flooding or ponding on the roadway during a storm. On multi-lane arterial roadways, gutter flow spread may be allowed to approximately ½ the outside lane width.
- Avoid locating grates in a sidewalk. SDOT approval would be required for non-standard locations.
- Avoid locating ring and cover castings in a sidewalks. SDOT approval would be required for non-standard locations. If a cover must be located in sidewalks, SPU requires a locking mechanism.

- Vane grates should be used whenever bicycle traffic is anticipated.
- Avoid placing depression lines in a traveled wheel lane.
- Avoid placing grates within a tree drip line.
- For higher outlet pipe, Standard Plans 240C and 240D may be used in lieu of Standard Plan 242.
- If located in areas where new permanent pavement will be installed, new CBs and inlets should be considered.

C. Typical Layouts

1) Alleys

In alleys, use a Standard Plan 241 catch basin before connecting to the PSD or public combined sewer. Curb discharge requires SPU and SDOT approval.

2) Streets

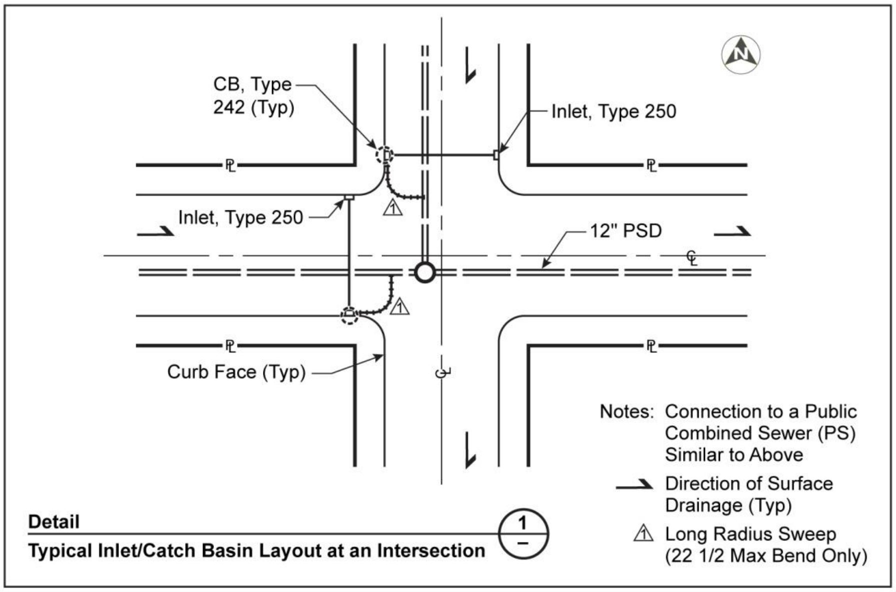
CAM 1180 provides detail layout instruction and details. The following are some important highlight:

- CBs provide more reliable drainage pickups and are preferred over inlets. CB Type 242B and 240D (vane grate and through curb opening) are preferred. Exceptions and detail drawings are provided in CAM 1180.
- See CAM 1180 details for inlet placement along new curb, at utility conflicts, and CB layout at closed-contours (low points).
- Additional drainage pickups will be required to limit clogging from tree leaves.
- Arterial streets with a grade flatter than 1% must have a CB at minimum 350 feet.

In streets, use Standard Plan 250 inlets and Standard Plan 242 or 240 catch basins (See Figure 8-2):

- At closed-contours (low points), with crowned streets, use independent CBs with curb inlets (type 242B or 240D) and independent connection to the storm drain or combined sewer.

Figure 8-2
Typical Inlet/Catch Basin Layout at Intersection



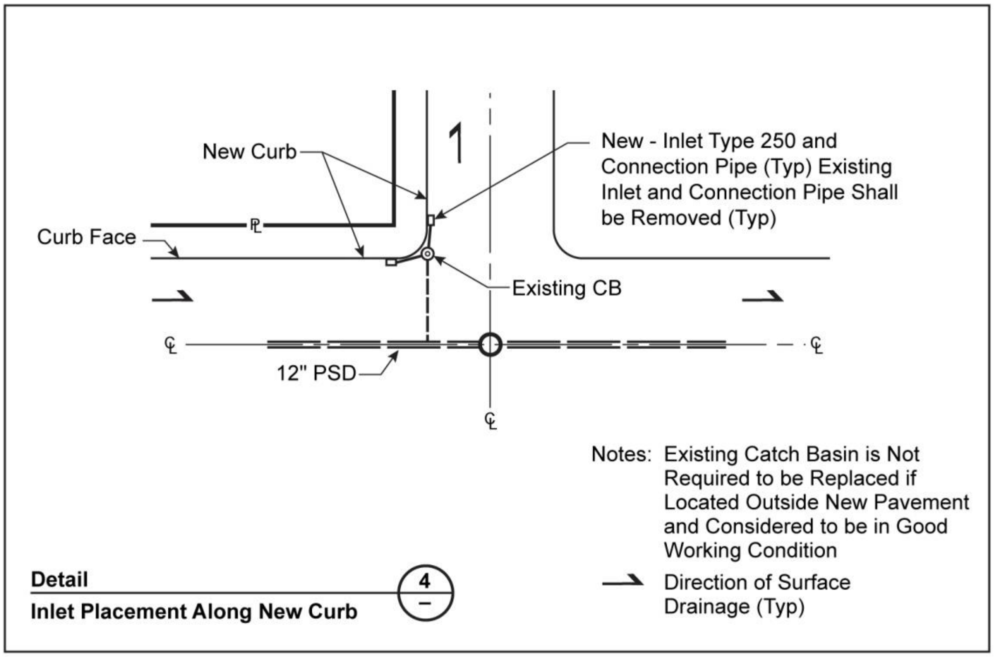
D. Long Block Layout

Design must ensure that water from no more than 1,000 lineal feet of residential street curb can discharge into a single CB. This standard applies to the length of curb for inlets that discharge into a CB and the CB itself. For curb lengths between 500 and 1,000 feet, a CB may be needed on both sides of the street.

E. New Curb Layout

1. If located where new permanent pavement will be installed, existing CBs and inlets that do not conform to current standards must be replaced.
2. If located where new curbs will be installed, existing inlets that do not conform to Standard Plan 250 must be replaced.
3. If a CB or inlet is replaced, the connection pipe to the CB or mainline must be replaced unless otherwise supported by conditional assessment CCTV of the connection pipe. Reconnect existing CBs to the mainline using new pipe as required (Figure 8-3).

Figure 8-3
Inlet Placement along New Curb



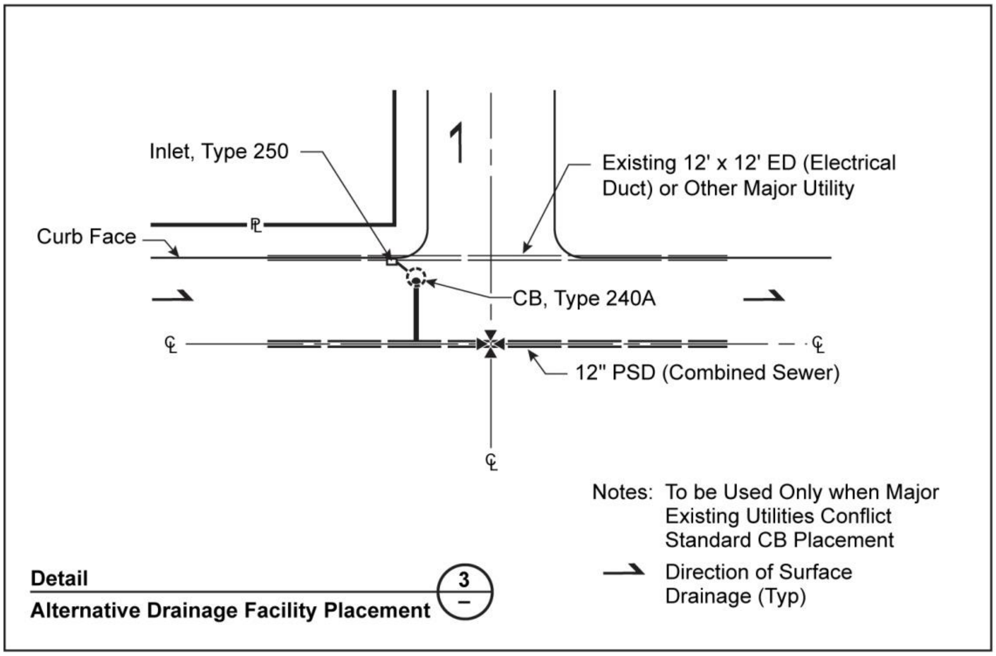
F. Curb Bulb Layout

- See CAM 1180 detail 4 for inlet/CB layout at Curb Bulbs.
- See Appendix 8C GSI Design Manual for curb bulb layout and bioretention cell placement.
- Standard Plan type 250 inlet should be used only if the longitudinal slope is greater than the cross slope (Figure 8-4).
- See **Appendix 8B - Useful Figures and Concepts** for more information about curb bulb layout.

G. Alternative Layout

- A Standard Plan 240A CB in the first lane of traffic must be located as close to the curb as practical so that only one lane must be closed to traffic for maintenance (Figure 8-4).

Figure 8-4
Alternative Drainage Facility Placement



8.7.4.2 Inlet/Catch Basin Connections

See CAM 1180 for more discussion about inlet and CB connection pipes.

To the extent feasible, SPU uses straight pipe connections between inlets and CBs. The inlet connection pipe should exit the structure as shown in Standard Plan 250.

SPU uses Standard Plan 261 for CB connections:

- **Type A connection** shows a public storm drain connecting to a CB using vertical bends with a maximum of 22.5° (1/16 bend) at each bend. There are no horizontal bends. Type A connections should be used with a square or round grate or casting. The shorter straighter pipe is desirable from both an installed cost and maintenance perspective.
- **Type B connection** should be used when a rectangular grate opening is use. The outlet trap is under the grate and when the grate is removed for maintenance access, the longer length of the opening can be used.

Each inlet and CB standard plan shows an allowable outlet pipe location for operations and maintenance purposes. The trade-off is shorter, straighter pipe is more desirable and easier to maintain when a square or round

8.7.4.3 Inlet/Catch Basin Connection Pipe Material

Ductile iron pipe is preferred for inlet and CB connections. Inlets in particular are shallow and ductile iron can take the impact loading. The SPU warehouse carries a C-900 compatible tee for use with DIP pipe laterals. See Standard Specification 7-08.3(4) Catch Basin Connections, which describes an additional one foot short of DIP is required at the connection to the cut in tee. This is because the long stick of DIP can act as a lever on the tee and damage the mainline.

When corrosion from streetcar or light rail electrical systems are present, or extremely corrosive soils, use of PVC pressure pipe with fittings may be an alternative to consider. For CB connections with multiple bends and awkward bedding situations, pressure pipe, as opposed to pipe per ASTM 3034, is preferred for increased rigidity. When using PVC it is good to have a push on joint option specified, since glued joints are difficult to construct in the rain.

8.7.4.4 Inflow Capacity

Inflow capacity is the maximum amount of water that can enter a storm grate. SPU evaluates grates for the correct capacity.

A. Catch Basins and Inlets

Approximate catchment area thresholds are listed in Table 8-6.

Table 8-6
Catch Basin Service Areas

Type of Catch Basin	Maximum Area Served (square feet)	Sump Required
Private Lawn and Garden Area Drain (Non-Traffic)	500 sq ft (4" outlet)	No
Private Inlet (Non-Traffic)	2,000 sq ft (4" outlet)	No
Private Catch Basin (Traffic)	4,000 sq ft (4" outlet)	Yes
Catch Basin Std Plan 241 (Traffic)	7,500 sq ft (4" outlet)	Yes
	15,000 sq ft (6" outlet)	Yes
Catch Basin Std Plan 240 (Traffic)	30,000 sq ft (8" outlet)	Yes
Catch Basin Std Plan 242 (Traffic)	25,000 sq ft (8" outlet)	Yes

B. Grates: Simple Computational Approach

General design intent is to use standard grates whenever possible in the roadway since standard products are easily replaced. Since grates going missing is an urgent safety concern that happens frequently, discuss any non-standard item and spares warehousing with Operations and the Warehouse. The City of Seattle has used a wide variety of grates since the late 1800s. Grates in the early system were wood. In the early 1900s, round and rectangular slotted cast iron grates were favored. During the 1960s to 1980s larger size cast iron, slotted grates were used. By the mid-1980s ductile iron vane grates evolved as the industry favorite because they capture high flows about 30% more efficiently. The vane grate is also more bicycle safe. Many existing grates were replaced with vane grates. See Standard Plan 266 for a vane grate that will fit many smaller existing inlets built under old Standard Plan 261. See Standard plan 290 for bridge drain. Approval for non-standard grates are very rare. It is important to avoid non-standard grates. If installing non-standard grates, discussion with Operation and Maintenance staff as well as SDOT might be necessary. Most Seattle streets are crowned and are easily handled by one grate for each side of the street. The simplest method to calculate grate capacity is the Inlet Grate Capacity Calculator, which uses the weir equation for gutter flow and the orifice equation for sumps.

Other foundries may have actual laboratory test results that will be more accurate than the calculation. Check the manufacturer's website. The design engineer should account for the effect of debris on the actual capacity of the grate.

C. Other Analytical Tools: Gutter Flow and Grate Inflow Calculations

Gutter flow calculations are not always required by SPU and SDOT. The designer should consider whether there is a change in the street collection, the street configuration and the length of the project when deciding if gutter flow calculations are necessary. Typically, for arterial streets with any change in curb location gutter flow calculations should be done.

The following spreadsheets and computer programs are available to evaluate grate inflow capacity:

- WSDOT has several Excel spreadsheets for calculating grate inflow. These are based on procedures and examples in the WSDOT *Hydraulics Manual*.
- Detailed methods and charts for calculating gutter flow, grate inlet flow, and side inlet flow are included in the FHWA's *HEC 22 - Urban Drainage Manual*. This reference is highly recommended for complex drainage situations beyond normal continuous gutter calculations.

The City has not adopted strict gutter spread standards. For each street SPU and SDOT should discuss the allowable flow spread. As a starting point, look at a peak flow with 10% annual probability (10-year recurrence interval). The concerns are hydroplaning depths, which most often are not reached with standard spacing and flow spread. Flow spread to the edge of a parking lane, or one-half of the curb side travel lane when there is no parking, is generally acceptable. However, a small adjustment to the allowable spread may make a huge difference in the number of structures required. SPU has an interest in minimizing new CB infrastructure when the street function is not compromised. On the other side, flow spread to half a street is not going to be acceptable near a bus stop or where there is no planting strip. Consider the function of the entire street including pedestrians and bicycles.

Tip: *Carefully consider drainage entering or leaving at side streets by looking at the intersection geometry. Bypass flow in charts and spreadsheets is frequently not properly considered, and can add major expense to the project and the long-term maintenance.*

8.7.5 Storm Drain Pipe or Main Line

Most storm drain pipelines carry storm flows to approved discharge points, commonly called *outfalls*. Storm drain pipelines generally collect stormwater flow from CBs and private service drains in a formal system of pipes with a standard depth of cover of 6 feet, as opposed to the more informal ditch and culvert system.

8.7.5.1 Conveyance Size in Public ROW

PSDs must be a minimum of 12-inch diameter.

CB connection pipe must be a minimum 8 inches in diameter.

CB connections to an 8-inch-diameter main must be 6-inch diameter.

Service drains and side sewers must be a minimum of 6 inches in diameter in the ROW.

Tip: *PSD mainline must be designed for full gravity peak flow with a 4% annual probability (25-year recurrence). For more information on requirements for hydrologic analysis, including tidal and* *lake backwater constraints, see Stormwater Manual, Appendix F - Hydrologic Analysis and Design.*

8.7.5.2 Velocity

When a pipe is full flowing, minimum velocity must be 3 feet per second (fps) to facilitate self-cleaning during larger storms.

The effects of excess energy must be investigated whenever pipe velocity exceeds 10 fps. Velocities greater than 10 fps must have special provisions to protect against displacement of pipe by erosion and impact. Energy dissipation features may be required in these situations. Design should be evaluated on a project-specific basis.

Tip: *Velocity of flow should not be excessively high. High velocities (greater than 10 fps) produce very large energy losses in a storm drain system. High velocities also cause pipe abrasion and hydraulic jumps can cause system overflows or popping MHs. If velocity exceeds 20 fps, energy dissipation is required to minimize hydraulic jumps.*

8.7.5.3 Pipe Slope

A. Minimum Slope

Minimum slope for all storm drains must be 0.5%. Pipe slope must generally follow the surface topography at a standard depth of cover of 6-feet. Desired minimum pipe slope is 1%. Typical exceptions include:

1. Downstream system is deeper, or shallower than 6 feet.
2. Surface topography is flat and pipe slope is 0.5%.
3. Connection cannot be made unless pipe slope is less than 0.5%.

Tip: *There are circumstances where minimum slopes even down to 0% or reverse grade have been used. Discuss with your supervisor and Operations as early as possible when slopes less than 0.5% may be necessary. Expect that mitigation for the reduced velocities and higher maintenance costs may be needed.*

B. Slope between Maintenance Holes

Storm drains must be laid with a consistent slope between maintenance holes.

SPU approval is required for bends. One horizontal or vertical bend may be allowed on storm drains with a maximum bend of 22.5 when access for cleaning is still available˚.

8.7.5.4 Cover

Storm drain mainlines must have at least 6 feet of cover over the top of the pipe as shown in Standard Plan 030. This requirement allows a CB to properly drain with a 25-year HGL storm drain within the ROW.

Lateral lines must be covered a minimum depth of 18 inches. If the minimum pipe cover cannot be achieved, SPU recommends ductile iron pipe (class 50 minimum).

Side sewers and service drains must be per Standard Plan 283 as a minimum.

All pipes should be placed deep enough to drain the surrounding area and provide opportunities for adjacent properties to connect.

8.7.5.5 Hydraulic Grade Line (HGL)

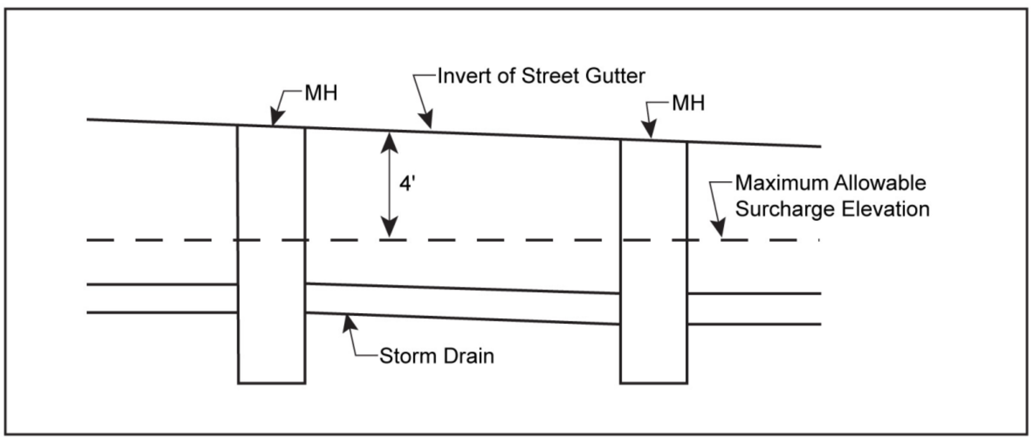
Any hydraulic grade lines (HGL) that surcharge the pipe should be shown on the pipe profile with notes about the storm conditions responsible for the surcharge. During peak flows with 4% annual probability (the 25-year design storm), it is generally acceptable to allow stormwater surcharge within maintenance holes to a level not more than 4 feet from the surface or 1 foot below the lowest service elevation, whichever is lower. This level provides freeboard within the system and CBs to continue to function. It does not provide protection from backups or overflows, so it is important to look at elevations of private service drains and all CBs and BMPs, including on private property.

A. Design Rainfall Event

The storm drain HGL for a design rainfall event must be the lower elevation of the following restrictions:

1. No higher than 4 feet below the street gutter elevation (Figure 8-5), or
2. 1 foot below the service invert elevation of adjacent private property. Service elevation is defined as 2 feet below the lowest elevation served on the site minus the product of a 1% slope and the distance from the location of the low point to the storm drain connection.

Figure 8-5
Maximum Allowable Hydraulic Grade Line (Surcharge)



B. Maximum Allowable Hydraulic Grade Line

1) General

If calculations show that a storm drain is surcharged during a 25-year storm, the HGL must be shown on the pipe profiles of the plans.

Design must use the high-water elevation of the receiving waters to calculate hydraulic gradients (NAV 88 Datum):

1. For Lake Union and Lake Washington, high water is **+16.8**.
2. For Elliott Bay and the Duwamish River, high water is **+12.14**.

2) New Connections to Existing

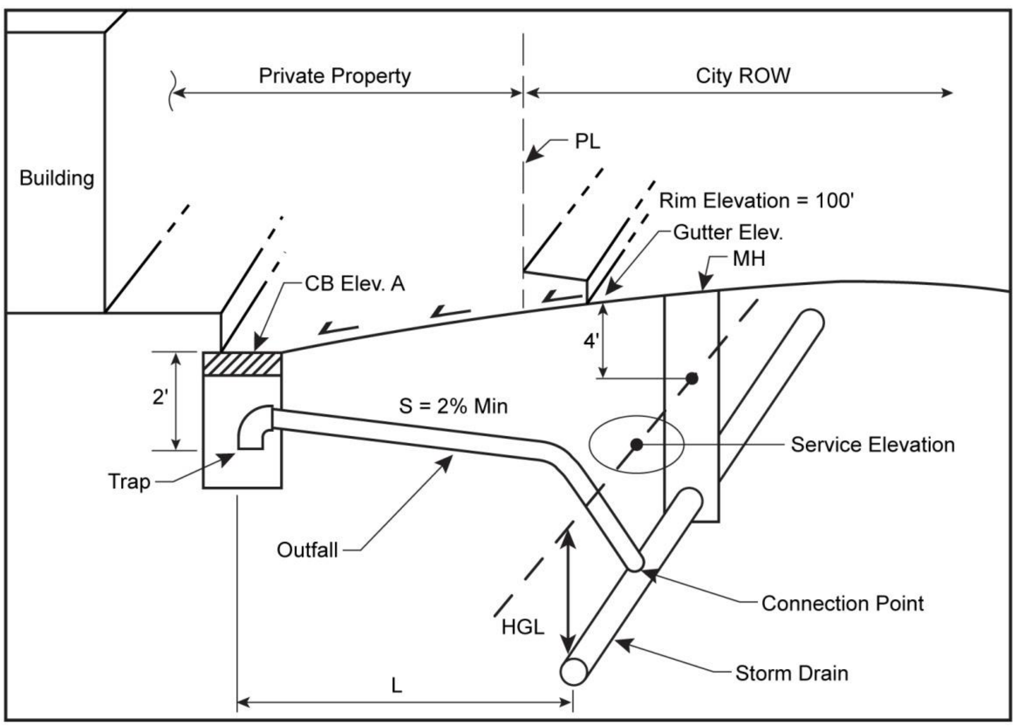
New connections to an existing public storm drain must consider the following:

1. Connections to a mainline must consider the anticipated mainline HGL, specifically the surcharge condition.
2. New laterals and associated inlet structures must be designed assuming a surcharge condition in the mainline.
3. New features must be designed to prevent overflows at the inlet structures.
4. New lateral connections must also evaluate the impacts to the mainline HGL based on the flows added by the new lateral. This prevents increases in the mainline HGL beyond the desired limit.

C. Public Storm Drain Profile

All storm drain plans must have a pipe profile showing maintenance hole spacing, pipe size, pipe material, and HGL. The design HGL must be the lowest of service elevation or gutter elevation minus 4 feet (Figure 8-6):

Figure 8-6
Profile Service Elevation on Public Storm Drain



8.7.5.6 Buoyancy

Where high groundwater conditions are anticipated, buoyancy of installed pipelines must be considered. Flotation of the pipe and maintenance holes must be prevented.

8.7.5.7 Alignment

Generally, pipes must be laid with straight alignment between maintenance holes. Straight alignment must be checked by either using a laser beam.

8.7.5.8 Pipe Material

Standard material used for storm drains includes reinforced concrete, clay, and ductile iron. SPU has allowed PVC or high-density polyethylene (HDPE) pending evaluation of soils data and design criteria. Corrugated metal pipe (CMP) is not allowed within the ROW. For detailed information on pipe materials, see Standard Specifications 9-05. The drawings must show the design pipeline material on the profile, or if more than one material is allowed for contractor choice, on a note. Materials are not considered equivalent unless identified in the bid documents.

In general with all thing equal, SPU preferred ductile iron (DI) for stormwater pipe due to higher confidence in product installation result and clay pipe for smaller diameter (8” to 15”) sewer pipe.

However, pipe material selection should include the following considerations:

- Constructability based on site conditions
- Construction and maintenance cost
- Design life
- Ease of installation
- Live and dead loading
- Soil condition

PSD materials to evaluate include ductile iron and clay. Clay should generally not be used in shallow applications or at depths greater than 20 feet. Clay is often unpopular with contractors, when given a choice.

Reinforced concrete should only be used when issues of pipe permeability, abrasion, pipe bottom erosion and joint testing and hydrogen sulfide (Seattle temperatures have generally minimized pipe crown corrosion due to hydrogen sulfide – but this could change with increasing temperatures) have been addressed. In the SPU pipe inventory, concrete pipe is generally wearing faster than the older clay pipe, mainly due to erosion of the bottom. In addition, concrete pipe has a construction history of the joints not passing air tests, which can lead to significant delays in schedule while repairs are figured out. Avoids bends in concrete pipe.

Corrosive soils are a concern with DI, which have sometimes been addressed by specifying a thicker DIP so there is more sacrificial material, requiring a sand bedding, sacrificial anodes, or a combination. Polybags are not used around drainage or wastewater pipe since pinhole leaks can lead to collecting sewer/drainage water on the outside of the pipe and accelerate corrosion. Active corrosion protection is not appropriate.

Plastic pipe is another choice to consider in corrosive soils. PVC larger than 10-inch diameter needs trench design for the surrounding in situ soils, which complicates the design somewhat. Design of flexible pipe other than PVC should include consideration of how future service connections will be made. New connections on already installed HDPE are more complicated and most pipe should be designed for future surface connections. There are various other flexible pipeline materials that are not currently in the asset inventory or approved. So, expect design delays for coordination within SPU if proposed. Note that any proposal to use flexible pipe is subject to deflection testing 30 days after backfill and prior to paving, so scheduling impacts must be addressed.

Butt welded solid wall HDPE is generally preferred for drainage on steep hillsides with landslide potential. Pipe anchoring on the upstream end with an allowance for thermal expansion/contraction is required.

When pipes are installed in casings, the carrier pipe is most often restrained-joint DI. Casing pipe can be steel, or for direct bury applications, polypropylene may be appropriate.

Allowable detention pipe materials are shown on Standard Plan 270. For detention pipe 48" diameter and less, polypropylene is generally the most cost effective choice. At the time of this publication, standard specifications on flexible pipe do not differentiate between mainline installations and detention pipe. However, the roundness of detention pipe does not have the same long-term pipeline assessment and maintenance implications.

8.7.5.9 Pipe Easements

For public pipes not located in the ROW, easements will need to be acquired (see DSG section 8.11.1). Acquiring easements requires legislation by the Seattle City Council and takes up to 18 months to secure. Easement width is a function of pipe size and depth.

8.7.5.10 Public Storm Drain Pipeline Installation

A. Open Cut/Trenching of Mainlines

Trenching is safe excavation of the ground to install utilities, such as pipe.

The following are SPU standards for trenching:

1. Trench width must allow the pipe to be laid and jointed properly and the bedding and haunching (material placed on either side of pipe) to be placed and compacted to adequately support the pipe. See Standard Plan 284.
2. Trench sides must be kept as vertical as possible.
3. When wider trenches are specified, appropriate bedding class and pipe strength must be used.
4. Deep excavations must include shoring. The design engineer should check to see if Washington State Department of Labor and Industry (L&I) or OSHA requirements are more restrictive than those of SPU.

1) Pipe Bedding

Pipe bedding must be installed per Standard Plan 285. Typical bedding types for SPU drainage pipes are:

- Concrete pipe: Class B with pea gravel bedding
- Clay pipe: Class B with Mineral Aggregate Type 22.
- Ductile iron pipe: Class D Mineral Aggregate Type 9 or sand bedding
- Flexible pipe: Class B with Mineral Aggregate Type 22.

For non-standard soil conditions, consult with the geotechnical engineer who will recommend a bedding detail.

B. Private Side Sewers/Service Drains

See Standard Plan 283 and Standard Specification Section 7-18 (2014 edition) and Side Sewer code for side sewers and services drains installation and design requirements.

8.7.5.11 Connections and Tie-In Requirements

The following are standards for connections and tie-ins:

1. All CBs, private sewer, and private storm drain connections to an existing main must be perpendicular cut in tees. If they are in good condition, existing tees and wyes may be used for the connection. See the updated SPU core tap procedure.
2. All new main installations must use prefabricated tees for pipes less than 24 inches in diameter.
3. Reconnection of dissimilar pipe must use stainless steel shielded couplings (e.g. mission ARC or approved equal).
4. Vertical drop connections require SPU approval.

SPU does not typically allow connections to maintenance holes.

8.7.5.12 Cleanouts

The following are standards for cleanouts:

1. Spacing of the cleanouts must not exceed 100 feet.
2. Cleanout must have a wye branch on side sewers and service drains (DR 2010-02).
3. Cleanouts are not allowed on mains in lieu of maintenance holes.
4. Cleanouts require SDOT approval in the ROW.

Generally, cleanouts should be integrated into sewer system design for each total change of 90° in grade or alignment. SPU prefers cleanouts to be located out of the traveled way.

Cleanouts should be constructed per Standard Specification 7-19.

See Standard Plan 280 for an 8-inch diameter cleanout with a ⅛ bend and a cast iron frame and cover (for a vertical drop connection).

8.7.5.13 Trenchless Technology

A. Types of Trenchless Technology

For a general discussion of types of trenchless technology, see *DSG Chapter 5, Water Infrastructure*, section 5.8.3.8 (this section provides similar and overlapping information). Trenchless technologies frequently are used for utility installation in existing roadways and developed areas (Table 8-7). While more expensive than traditional open-cut trenching, trenchless installations require minimal restoration.

The contractor is responsible for identifying and protecting existing underground utilities (DR 2010-02). However, potholing during design maybe appropriate to minimize risks.

Table 8-7
Trenchless Technology Alternatives

Method	Pipe Diameter (in inches)	Preferred Soil Conditions	Soil Conditions Not Conducive	Install Below Groundwater Table
Pipe Ramming	4 – 55"	clay, silt or sand above groundwater table	flowable sands, non-cohesive soils, gravel, cobbles, boulders or rock	Not Recommended
Boring and Jacking	4 – 72"	clay, silt, sand or gravel	cobbles, boulders or rock	OK
Microtunneling	12 – 90"	clay, silt, sand or soft rock	wood, cobbles or boulders greater than 1/3 of bore diameter	OK
Horizontal Directional Drilling (HDD)	2 – 72"	clay, silt, sand or soft rock	gravel, cobbles, boulders or wood	OK

1) Pipe Ramming

Generally, pipe ramming is used to replace either clay or concrete pipe. Typically, it is not done on a metallic pipeline. Pipe ramming uses a system of hydraulic jacks to push casing pipes horizontally through the ground. A pneumatic tool is used to hammer the pipe through the ground from an entry pit to an exit pit. A ramming tool is attached to the rear of a steel casing pipe, and hammers the pipe into the ground. Once the casing pipe is in place, and the soil within it removed, pipe can be installed. Pipe ramming is generally limited to installations less than 150 feet long. It is only feasible in soft to very soft clays, silts and organic deposits, and sands (very loose to dense) above the water table. The soil plug formed within the casing pipe is the only resistance against inflowing soils.

2) Boring and Jacking

Boring and jacking, also known as horizontal auger boring, is commonly used for utility installation where there are surface obstacles. In boring and jacking, an auger-type cutting head is used to bore a hole horizontally between two boring pits. Helical auger flights are added as the bore gets longer, and are used to move the cuttings out of the hole and into the drive pit, where they can be removed to the surface. A casing pipe is installed behind the auger, and the product pipe is installed inside the casing.

For boring and jacking, a thorough geotechnical subsurface investigation must be completed to classify subsurface conditions. Existing underground utilities must be located so they may be avoided.

The direction of drilling and soil conditions must be examined carefully when drilling into the hillside. There has been loss of life in the past when a contractor drilled uphill and a saturated soil mass flowed into the casing. Work safety is the responsibility of the contractor, but the submittals must be reviewed carefully for anticipated risks.

3) Microtunneling

Microtunneling is commonly used for larger diameter utility installations. In this method, hydraulic jacks are used to push pipes (pipe-jacking) through the ground behind a tunneling shield on a microtunnel boring machine at the same time that excavation is taking place. The boring machine travels horizontally from a jacking shaft to a receiving shaft. Cuttings are then conveyed from the excavation face through the tunnel and up the driving shaft to the surface. Pipe jacking, alignment control, boring machine location, and cuttings transport are remotely controlled.

4) Horizontal Directional Drilling

Horizontal directional drilling (HDD) is typically less accurate than other types of trenchless technologies. HDD can be a feasible alternative to open-cut installation, particularly when existing utilities, roads, or other surface obstacles preclude an open cut. Cobbles, boulders, and wood are significant risks to utility installation using this method. For larger diameter (>12 inches) pipes, the risks associated with horizontal directional drilling significantly increase.

For HDD, a thorough geotechnical subsurface investigation and baseline must be completed before design.

5) Rehabilitation Methods with Trenchless Technology

SPU repairs and replaces drainage and wastewater pipe. The LOB evaluates and prioritizes repairs and replacements. Several rehabilitation methods are available (Table 8-8). Most require highly skilled engineers and contractors. The methods shown assume all joints are separated, all joint problems are marginal and there is no change in friction from existing pipe to rehabilitated pipe. Most methods will reduce pipe diameter, but may also decrease friction loss, and may result in no net change in capacity, e.g. vitrified clay pipe lined with a PVC material. Check on current evaluation, design and contracting requirements within the Sewer Rehab and Design program at initiation of any rehabilitation project.

Tip: *Any significant reduction in diameter from larger pipe upstream to smaller downstream has significant clogging potential and early discussions of impacts and mitigation should be discussed with Operations.*

Table 8-8
Rehabilitation Methods for Specified Defects in Pipelines

Rehabilitation Method	Corrosion	Crack/ Holes	Inflow, Infiltration, Exfiltration	Structural Problems	Inadequate Hydraulic Capacity
Cured in place pipe	Yes	Yes	Yes	Yes	No
Sliplining	Yes	Yes	Yes	Yes	No
Close-fit pipe	Yes	Yes	Yes	Yes	No
Pipe bursting	Yes	Yes	Yes	Yes	Yes
Pipe removal	Yes	Yes	Yes	Yes	Yes
Localize repair (robotic)	No	Marginal	Yes	Marginal	No
Localized repair (grouting)	No	Marginal	Yes	No	No
Localized repair (internal seal)	No	Yes	Yes	Yes	Yes
Localized repair (cured in place)	Yes	Yes	Yes	Yes	No
Modified sliplining (panel lining)	Yes	Yes	Yes	Yes	No

Rehabilitation Method	Corrosion	Crack/ Holes	Inflow, Infiltration, Exfiltration	Structural Problems	Inadequate Hydraulic Capacity
Modified sliplining (spiral wound)	Yes	Yes	Yes	Yes	No
Pipe reaming	Yes	Yes	Yes	Yes	Yes
Underground coatings & linings (cement mortar)	Yes	Yes	Marginal	No	No
Underground coatings & linings (epoxy lining)	Yes	Yes	Marginal	No	No
Underground coatings & linings (shotcrete)	Marginal	Yes	Marginal	Yes	No
Underground coatings & linings (gunite)	Marginal	Yes	Marginal	Yes	No
Thermoformed pipe	Yes	Yes	Yes	Yes	No
Carbon filter lining	Yes	Yes	Yes	Yes	Yes

Source: *Trenchless Technology Pipeline and Utility Design, Construction and Renewal*, Narafi and Gokhale 2005.

The condition and location of adjacent buried utilities and foundations and surface improvements should be considered. Dense or rocky soil may also limit the suitability of this method. Pipe bursting is not recommended for either reinforced concrete or steel pipe.

6) Lining

Lining is commonly done by impregnating a felt or fiberglass mat with a resin that is cured by hot water, steam, hot air or Ultraviolet (UV) light. Specialty contractors can do these repairs.

Table 8-9
Advantages and Disadvantages of Lining

Advantage	Disadvantage
Economical	Entry pits may be required
Strong	Bypass pumping of sewage or stormwater required
Excavation of existing line not required in tight easement situations, conflicts with other utilities	Requires specialty contractor with lining experience
Laterals can be opened remotely via inside of mainline pipe	Hydraulic capacity reduced

7) Slip-Lining

Slip-lining is insertion of a new pipe, either continuous (typically butt-fused HDPE) or segmented (e.g. ductile iron, PVC, or HDPE), of smaller diameter into an existing pipe.

Table 8-10
Advantages and Disadvantages of Slip-Lining

Advantage	Disadvantage
Economical	Entry pits usually required

Advantage	Disadvantage
Strong	Service lateral connections must be excavated for reconnection
Bypass pumping of sewage may not be needed for segmented slip-liner pipe	Hydraulic capacity reduced

Tip: *The line must be kept from floating during grouting of the annular space. Additionally, the condition of existing pipe may limit the length of slip-lined runs between pits, diameter of slip-lined pipe, and/or lengths of segmented pipe pieces.*

8) Pipe Bursting

Pipe bursting is another form of trenchless technology and a common method for replacing aging, deteriorated, or undersized utility pipelines. In pipe bursting, the existing pipeline is fragmented and forced into the surrounding soil by pulling a bursting head through the line. A new pipe (typically butt-fused HDPE) of equal or larger diameter is pulled behind the bursting head. New maintenance holes are usually provided at insertion and withdrawal pits.

Table 8-11
Advantages and Disadvantages of Pipe Bursting

Advantage	Disadvantage
Creates a new, strong pipeline, not just rehabilitation of existing pipes	Entry pits are required
Capacity can be increased	Service lateral connections must be excavated for reconnection
Preparation of existing line is not critical	Bypass pumping of sewage required during repair
	Maintenance holes must usually be replaced
	Not practical for reinforced concrete or ductile iron

9) Pipe Reaming

Similar to pipe bursting and horizontal directional drilling, pipe reaming is a method for replacing undersized utility pipelines. In pipe reaming, the existing pipeline and some surrounding soil is removed and a new pipe (typically butt-fused HDPE or DI) of larger diameter is pulled behind the drilling head.

Table 8-12
Advantages and Disadvantages of Pipe Reaming

Advantage	Disadvantage
Creates a new, strong pipeline, not just rehabilitation of existing pipes	Entry pits are required
Capacity can be increased	Service lateral connections must be excavated for reconnection
Preparation of existing line is not critical	Bypass pumping of sewage required during repair
	Maintenance holes must usually be replaced
	Not practical for reinforced concrete or ductile iron

Advantage	Disadvantage
	Holding line and grade is difficult, so it is not appropriate for flat mains (5% recommended)

B. Spot Rehabilitations

SPU traditionally has used direct spot rehabilitation methods to repair pipe leaks. Emergency repairs are commonly spot rehabilitations. New methods for spot repair that do not require pipe excavation use technology similar to lining. Lateral connections and short sections of pipe can be relined.

Tip: *All new pipe and main installations must be tested for SPU acceptance. Typically, an air pressure or hydrostatic test is followed by a CCTV inspection. Pipes and mains that are repaired by rehabilitation methods are normally CCTV inspected. Inlet and CB pipes are not normally tested but must past CCTV inspection. See Standard Specification 7.17.3(4).*

8.7.6 Maintenance Holes

Maintenance holes (MH), formerly referred to as manholes, provide access to safely service and maintain storm drains and sewers. Maintenance holes are also used for changes in horizontal or vertical alignment. Generally, SPU uses maintenance holes for main lines only.

8.7.6.1 Maintenance Holes Up to 40 Feet Deep

SPU standard plans are available for the MH sizes shown in Table 8-13.

Table 8-13
Typical SPU Maintenance Hole Sizes

Diameter	Standard Plan No.	Maximum Depth
4'-0"	204a and b	40'
4'-6"	204.5	40'
5'-0"	205a and b	40'
6'-0"	206a and b	40'
7'-0"	207a and b	40'
8'-0"	208a and b	40'
9'-0"	209a and b	40'
10'-0"	210a and b	40'
11'-0"	211a and b	40'
12'-0"	212a and b	40'

8.7.6.2 Maintenance Holes Greater than 40 Feet Deep

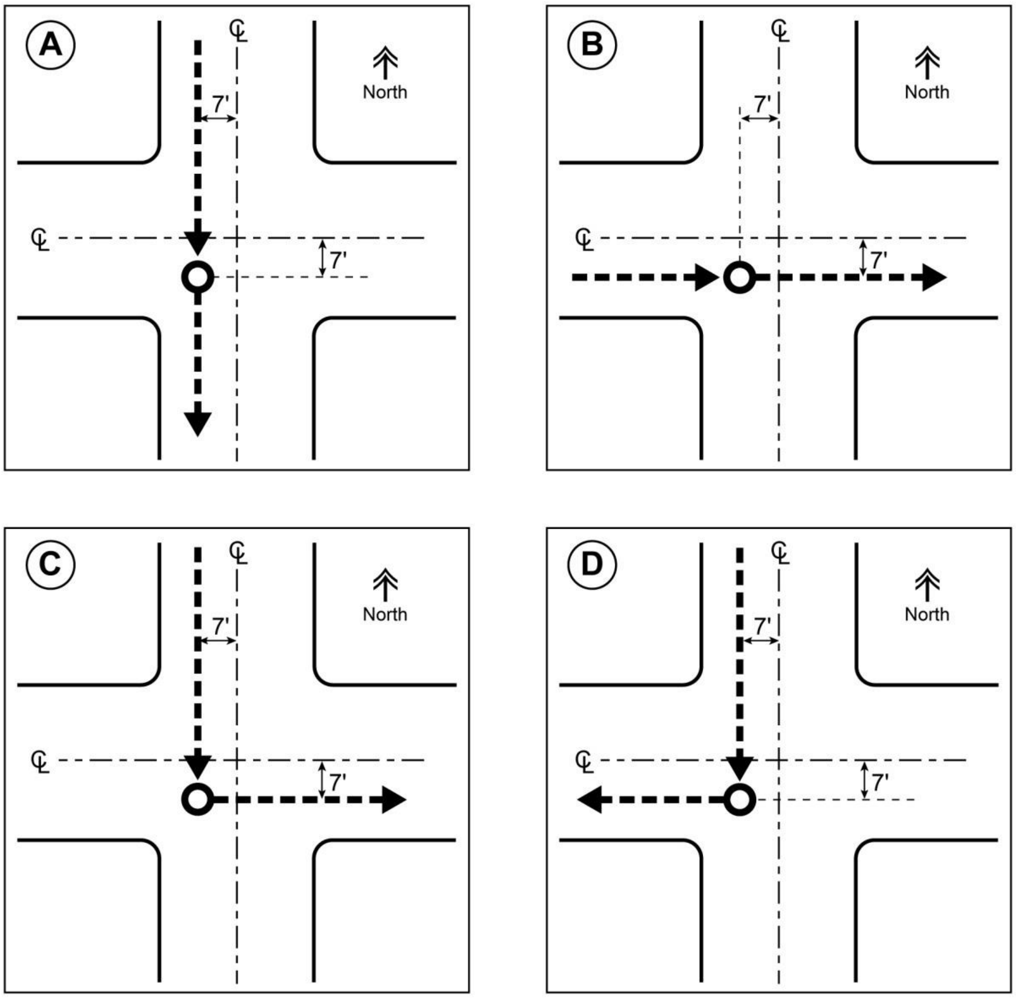
Maintenance holes deeper than 40 feet must be designed by a Professional Engineer, registered in Washington State.

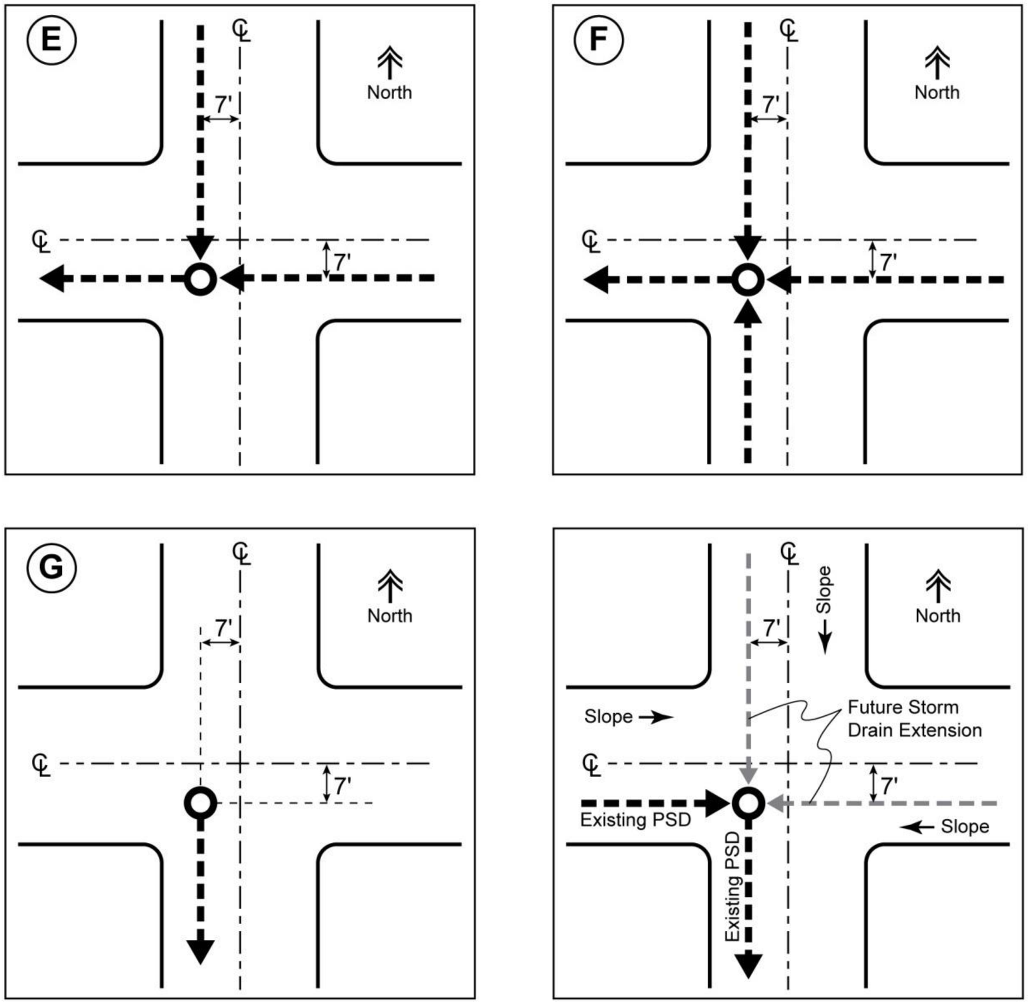
8.7.6.3 Layout

Maintenance holes should be placed near intersections in standard locations per Standard Plan 030 whenever possible to allow for future extensions into side streets (Figure 8-7).

Stubs to the side streets must be used to facilitate CB connections. The slope and depth of the stubs must allow future extension into side streets.

Figure 8-7
SPU Maintenance hole Layouts





A. Location

The following are SPU standard locations for maintenance holes:

1. Maintenance holes must be located at pipe junctions, breaks in grade, and changes in vertical or horizontal alignment. MHs should be located to minimize traffic impacts during maintenance activities (e.g. not in driveways). MH covers should be located outside of the wheel path in the travel lane to minimize wear and noise .When a small-diameter storm drain intersects a very large-diameter storm drain, it may be appropriate to set the MH on the small-diameter pipe 10 to 30 feet away from the junction. The small pipe nominal diameter should be less than half that of the larger pipe.
2. Maintenance holes must be located using stations and offsets or dimensions from street centerlines or established City of Seattle monument lines.
3. Maintenance hole numbering and asset identification should be assigned and shown on the Drawings to allow for easier record tracking and acceptance during construction. In general, MH numbering starts at downstream end of the proposed plan but it is not a requirement.

4. Where possible, the crowns of pipe must match at the MH. Invert elevations must be calculated by projecting the pipe slopes to the center of the MH.
5. When located in a non-roadway location, locking covers must be used.
6. Maintenance holes should not be located in front of ADA curb ramps.
7. Maintenance hole covers must not be located within a curb. SPU does not accept utility covers.

B. Spacing

The following are SPU standards for spacing maintenance holes:

1. Spacing between MHs must not exceed 350 feet without SPU approval.
2. If pipe is more than 100 feet long, MHs must be placed at the upstream end of all pipe runs. In some cases, SPU may require a MH regardless of pipe length. Storm drains may have one horizontal or vertical bend (maximum 22.5˚) between MHs with SPU approval.

8.7.6.4 Maintenance Hole Material

Standard material for MHs is reinforced concrete. Historically, SPU structures were brick until the 1950s.

8.7.6.5 Maintenance Hole Sizing

Maintenance hole sizing requires determining the size and grade of all pipe ingress and egress to the MH (Figure 8-8). Change in flow direction must not be less than 90°. Refer to Maintenance Hole Selection figure in CAM 1180 for more detailed information and requirements.

8.7.6.6 Structural Considerations

All MH standard plans are based on depths of cover and maximum depth shown on the standard drawing. The following are SPU standards for MHs:

1. Deviations must be specially designed by a Professional Engineer licensed in Washington State.
2. All MH must be designed for a minimum traffic loading of AASHTO HS-25.
3. If located in a main traffic lane, a MH must be designed for HS-25 or as otherwise specified by either SPU or SDOT.

For more detail on sewer and drainage appurtenances, see Standard Plan series 204 to 212. Each MH size includes a note on the standard plan on minimum and maximum hole size added to the outside dimension of the connecting pipe. Rough sizing of a MH can be based on that maximum hole size addition. The chart below from Hanson Pipe & Precast may also be used (Hanson Pipe & Precast are no longer in business). For MH structures where hole size is critical in the selection, talk to the manufacturer’s engineer at a precast company. They will need to know pipe OD and slope of the pipe. Steep pipe slopes necessitate larger holes.

Figure 8-8
Hanson Hole Size Chart

Reinforced Concrete Pipe

Hanson Pipe & Products - Hole Size Chart

Pipe I.D. (In)	Concrete O.D. (In)	Pipe Hole (In)	PVC Hole (In)	D.I. Hole (In)	HDPE Hole (In)	CMP Hole (In)	ADS Hole (In)	PVC Rib Hole (In)
6	8	12	12	12	12	12	12	12
8	10.5	12	12	12	12	12	12	12
10	12.5	16	16	16	16	16	16	16
12	17	20	16	16	16	16	16	16
15	20	24	20	20	20	20	20	20
18	23	28	24	24	24	24	24	24
21	28	32	24	24	24	24		
24	30	36	28	28	28	28	32	32
27	34	38				32		
30	37	42	34	36	36	36	42	42
36	44	48	42	48	42	42	48	48
42	51	56		52	48	52	60	60
48	58	64	60	60	60	60	64	64
54	65	72		72	72	64	72	72
60	72	78	78	78	78	78	78	78
72	86	92	92	92	92	92	92	92

What is the largest hole that a manhole can have?

36" Hole in a 48" Manhole	60" Hole in a 72" Manhole
42" Hole in a 54" Manhole	72" Hole in a 84" Manhole
48" Hole in a 60" Manhole	84" Hole in a 96" Manhole

Per WSDOT STD. Plan B-23C, the largest hole must be 12" smaller than the manhole inside diameter.

What are the largest holes at 90° that will fit?

2 ea. 28" holes in a 48" manhole	2 ea. 36" holes in a 60" manhole
2 ea. 32" holes in a 54" manhole	2 ea. 42" holes in a 72" manhole

TITLE	PAGE	DATE	
Hole Size Chart	5	11-01-04	Hanson

8.7.6.7 Bases

Bases for all designated maintenance holes are shown in Standard Plan series 204-212. Both pre-cast and cast-in-place options are shown.

Contractors prefer precast bases. Cast-in-place bases are typically used on existing mains when bypassing flows is difficult, not feasible, or construction space is tight. Note that when using cast-in-place base, the contractor must submit a lay plan for the reinforcing.

8.7.6.8 Bends

Bend refers to a change in pipe direction or grade. SPU prefers a straight pipe alignment. However, one bend is allowed horizontally or vertically for storm drains only. Bends are not allowed on any sewer or combined mains. The maximum bend allowed is 22.5°. Bends greater than 22.5° are subject to SPU approval. When proposing a bend, discuss the use and location with Operations.

8.7.6.9 Connections to Existing Maintenance Holes

SPU allows public connections to existing MHs if the connections do not compromise the structural integrity of the maintenance hole. Generally, SPU does not allow private connections to existing MHs. If the structural integrity of the MH is compromised, replace the existing MH with a new properly sized MH.

Maintenance hole steps may have to be removed and replaced to provide access to stand above the channel and to avoid conflict with the flow and entry to the MH.

The following are SPU standards for MH connections:

1. Maintenance holes must be rechanneled.
2. Pipe ends must be trimmed flush with the inside walls of the MH.
3. The first pipe joint outside of the MH must be placed within 1 foot or half the diameter of the pipe, whichever is greater.
4. If concrete, openings must be core drilled, sealed with grout, and watertight. Brick MH may be either core or line drilled.

8.7.6.10 Junction Flow and Channeling

Standard MHs must have full depth channels. The use of a sump in a storm drain MH will require a detail on the Drawings and be approved by Operations. Sumps can be useful for sediment collection, energy dissipation, and occasionally when the direction of flow conflicts require dissipation.

8.7.6.11 Frames, Covers and Lids

For new appurtenances with 2-foot-diameter openings, frames and covers must follow Standard Plan 230. The typical frame is 7 inches deep.

A. Rings

Rings and covers must be per Standard Plan 230. For existing brick MHs, the cover may be 18 inches and is substandard. Follow Standard Plan 220 to upgrade the opening.

B. Covers

In non-traveled roadways, any access requires locking covers. For 24-inch-diameter covers, specify type 230L. Larger covers may be heavy enough that vandals cannot tamper with the covers and may not need to be locked.

C. Water-Tight Ring and Cover

Where the top of a MH may be covered with floodwater or pressurized, a watertight frame and cover may be specified. These covers feature a rubber gasket and are bolted into place with pent-head (five-sided) bolts. Watertight covers require approval from Operations.

D. Hatches

For square or rectangular access, SPU prefers the hatch lid. Hatches can be heavy. If a lid weighs more than 200 pounds it should be torsion-spring assisted. The hatch door should be locked with either padlock hasp or pent-head bolts. Aluminum lids are an option, where galvanized lids cannot be used.

SPU prefers that hatches not be placed in the roadway. The castings should be located outside of the wheel track and pedestrian pathway. The hatch can be coated to prevent slippage if located in the pedestrian pathway.

E. Hydraulic Assistance

Use of these hydraulic covers requires Operations and Maintenance approval.

F. Ring and Cover Auxiliary Lid (Lid within a Lid)

A lid within a lid (24" inside a 48" diameter) option may be used if a maintenance hole requires inspection rather than major maintenance. If needed, the larger lid could be pulled for equipment access. The SPU design engineer along with their supervisor and Operations must approve this option.

8.7.6.12 Ladders/Access

Ladders and access must follow Standard Plan 232.

Steps/handholds, and ladders in MHs must meet AASHTO M 199 and ANSI A14.3-2002 requirements.

For additional information on ladders and access, see Standard Specification 7-05.3(1)Q.

The current standard for maintenance holes deeper than 20 feet is a harness system with no platforms. Workers are harnessed and must be retrieved without obstruction during an emergency.

8.7.6.13 Drop Connections

A. Inside Drop Connection

SPU prefers the inside drop connection. See Standard Plan 233B for the inside drop connection. It uses a maximum 18-inch diameter pipe. The drop connection pipe diameter and fitting must be equal to the diameter of the drainage or sewer line it serves.

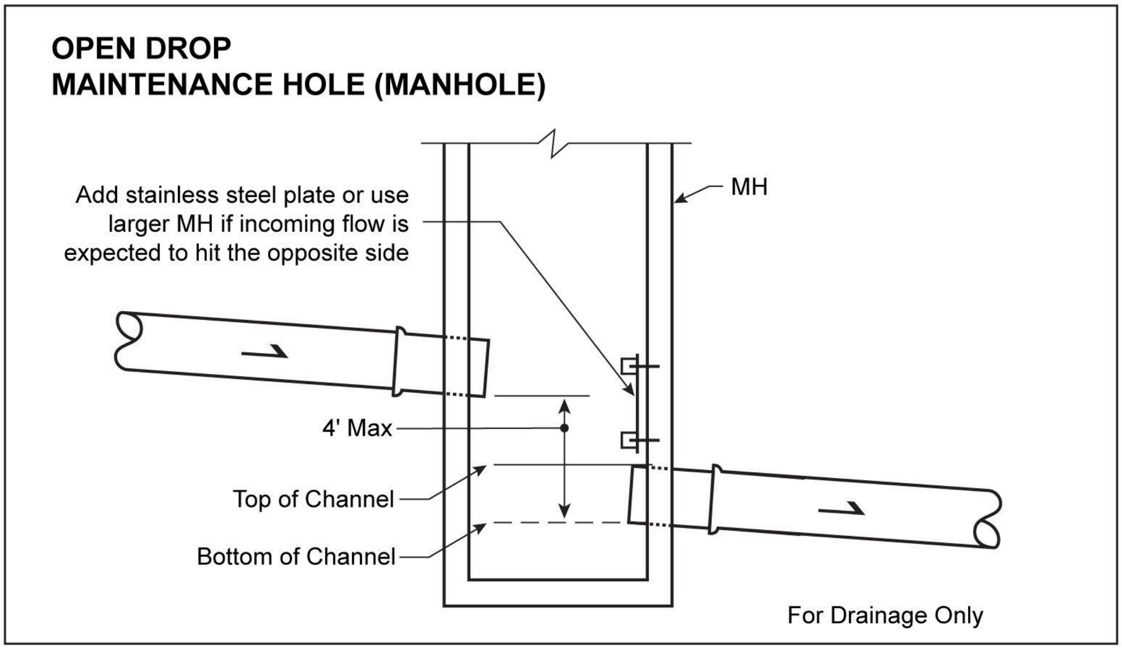
B. Outside Drop Connection

For connecting to existing maintenance holes, SPU uses Standard Plan 233A for an outside drop connection. The outside drop can corrode and degrade and replacement has risks to the entire MH.

C. Open Drop Connection

Figure 8-9 shows an open drop connection for drainage maintenance holes and is not allowed for sanitary or combined sewer connections. If allowed, SPU prefers that the open drop not exceed 4 feet. Use of an open drop should be reviewed and approved by Operations.

Figure 8-9
Open Drop Connection for Maintenance Holes



8.7.6.14 Design Considerations for Maintenance

Design should consider that MH inspection must accommodate the following:

- **Debris.** Buildup of debris can indicate potential upstream defects that allow backfill and bedding materials to enter the line.
- **Flow conditions**. Evidence of poor hydraulic conditions, high flows, and MH surcharging are typical examples of observable conditions.
- **Corrosive atmosphere**. Evidence such as hydrogen sulfide odors or exposed aggregate in the MH can indicate corrosion potential not only for the MH but also for any concrete pipe in the vicinity. The turbulence of the drop can release sewer gases, which is somewhat mitigated by the full depth channeling shown in the standard plans.
- **Infiltration/Inflow (I/I).** Maintenance holes can be the source of significant I/I. It can occur through the pick holes in the cover, around the frame, joints or cracks in the MH or

base, and the annular space of connecting lines. High I/I through the frame and cover can result from MHs located in gutters, in roadways with inadequate storm drainage, near surface water subject to flooding, or in any low spot or high groundwater table. Potential for these problems can be estimated any time of year.

- At a minimum, MH design must consider L&I standards for confined spaces. Consultation with Operations staff might be needed for special situations

8.7.7 Ditches

The primary purpose of a ditch is to convey surface water runoff water away from roadways or adjacent land. Construction of new ditches is uncommon in the SPU system. Existing ditches in the system may not meet SPU standards because those ditches may have been designed or built as part of the roadway without engineering before pipe drainage standards were in place.

Ditches should not be confused with biofiltration swales or bioretention cells. In addition to collecting and conveying drainage, swales treat runoff by filtering out sediment. If properly maintained, vegetated ditches may have some water quality benefit.

In creek basins, City of Seattle policy prohibits ditch filling. See Stormwater Policy 7, Chapter 3, 2004 *Comprehensive Drainage Plan*.

For additional design information for ditches, see WSDOT *Hydraulics Manual* or *FHWA HEC 15*.

8.7.7.1 Ditch Geometry

Ditch geometry refers to the following characteristics:

- Preferred longitudinal slope, which should be no flatter than 0.5%. Ditch design should include an evaluation that considers flow depth, velocity, channel erosion, and scour. Measures to control erosion and flooding should be prescribed on a site-specific basis.
- Side slopes should depend on the soil conditions, depth of excavation, depth to ground water, space available, and public safety.

8.7.7.2 Pedestrian/Vehicle Safety

Typically, the minimum side slope adjacent to roadways is 4 (horizontal) to 1 (vertical).

See the SDOT ROWIM for thresholds for side slopes, fencing requirements, and other public safety measures for open channel ditches adjacent to streets and roads.

8.7.7.3 Depth and Freeboard

The minimum channel depth for a ditch should be the design flow depth plus room for freeboard and sedimentation, as applicable.

Design flow depth should consider design flow rate, ditch geometry, longitudinal slope, roughness characteristics, and future vegetation growth. Most ditches can be analyzed using simple methods, such as **Manning's equation**.

Freeboard is the vertical distance between the design water surface elevation and the elevation of the barrier that contains the water. Freeboard is a safety factor. The amount of freeboard provides room for additional flow or storage before an overtopping that might damage downstream features. Typically, freeboard in a ditch is set at 1 foot above design flow depth. See stormwater manual for additional guidance.

8.7.7.4 Velocity

The velocity in ditches is ideal if neither scouring nor sedimentation occur. Because flows in most ditches are intermittent, velocity will fluctuate. Generally, ditches are designed for the maximum design flow and the allowable average velocity in the ditch section.

Sedimentation occurs when suspended solids within surface water flow drop out and accumulate within a structure or conveyance system. Sedimentation within ditches should be evaluated on a case-by-case basis. It will depend on three factors: 1) erodability of soils upstream of a project, 2) ditch slope within the site, and 3) changes in shape or grade of the ditch. If ditch flows are less than 2 fps, sedimentation is likely. Sediment storage depth depends on the size of the ditch, but typically ranges from 6 to 12 inches.

If the anticipated flow exceeds 5 fps, then check dams may be included in the design per Ecology's *Stormwater Management Manual for Western Washington*.

8.7.7.5 Ditch Lining

Ditches are lined with various materials typically used to control erosion. The following are SPU standards for ditch lining. Generally, SPU discourage lining ditches with impervious material unless it is absolutely needed (e.g. for erosion protection or prevent water seeps through hazardous material in adjacent area).

A. Vegetation-lined Channels

The maximum velocity at design flow in ditches must be 5 fps. Seed mixes and plant species should be evaluated on a site-specific basis. See the WSDOT *Hydraulics Manual* for general design guidance for vegetation-lined channels.

B. Rock-lined Channels

When design flow velocities exceed 5 fps, rock-lined channels must be used.

For velocities up to 10 fps, see Standard Specification 9-13.2(1).

For design of riprap-lined channels, see FHWA HEC-15 or King County Surface Water Design Manual.

C. Asphalt-lined Channel

Asphalt-lined ditches that are in disrepair should be removed and replaced. This type of ditch normally has a velocity > 5 fps. Asphalt lining can vary in thickness, usually a 2-inch minimum, depending on site conditions. Existing asphalt-lined ditches are repaired either by removal and replacement or by adding another overlay of asphalt.

D. Concrete-lined Channels

For ditches with velocity > 5 fps, concrete lining may vary in thickness and be specified with or without reinforcement depending on site conditions. Existing concrete lined ditches can be removed and replaced in kind or better. In some cases, it may be appropriate to add an asphalt overlay.

E. Pipe-lined Channels

Sometimes you may find a pipe-lined channel where pipes are cut in half and laid longitudinally along the ditch (used for velocity> 5 fps). Typically, the pipe material is corrugated metal or concrete. This type of ditch can be rehabilitated in kind or can use concrete or asphalt lining. However, it is not used for new design.

F. General Guidelines

The following are guidelines for ditch lining:

- **Erosion Control Fabric**. Erosion control fabric is made of straw, coconut fiber, wood fiber, netting, or a combination of these materials. Generally, these materials have a life of 6 months to 3 years and are intended to last until vegetation is established. See manufacturer for design guidance.
- **Turf Reinforcement Matting**. Turf reinforcement matting is a synthetic material that has limited degradation from ultraviolet rays. This long-lasting material is intended for permanent protection from erosion. See manufacturers for design guidance.
- **Check Dams**. Check dams made of rock, concrete, silt dikes, and hay bales provide grade control on steeper slopes.
- **Other Linings**. For ditches where infiltration is not desired, other synthetic linings include geo-membrane. An evaluation of depth to groundwater is required to determine the feasibility of this application. Groundwater can cause the liner to float.
- **Flow Control Characteristics**. Sometimes the base of the ditch is lined with one type of erosion control material and the side slopes with other materials, usually a material less robust than the bottom lining. It is important to consider flow characteristics during a variety of design storms when prescribing erosion control materials. This evaluation may save in construction costs.

Tip: *Some ditches are considered "waters of the state" and will require State of Washington permits for consultation and/or major maintenance. See DSG Chapter 2, Design for Permitting and Environmental Review.*

8.7.7.6 Design Considerations for Maintenance

Design for ditches must allow for a condition inspection of the following:

- Amount of sediment that has accumulated
- Vegetation growth, if any
- Occurrence of erosion, down cutting and overtopping
- Condition of the liner, if applicable.

A condition assessment should be completed regularly and as needed following significant storms.

See Appendix G of the Stormwater Manual for maintenance requirements.

Ditch maintenance access must be available along at least one side of a ditch. During design and follow-up maintenance, assure that large trees are not allowed to block access. Grass and low-growing shrubs are recommended plantings for the channel side used for maintenance access. For bioretention cells, see Appendix 8C GSI Design Manual.

Tip: *SPU rarely uses a Ditch Master to form a new ditch or to repair an existing one. SPU maintains ditches via mowing, weeding, and removing debris. Maintenance is annual or more frequent depending on site-specific conditions.*

8.7.8 Culverts

Culverts sections of pipe generally used to convey stormwater under or adjacent to roadways, driveways, railroads, canals, or other embankment. In some areas of Seattle, culverts may extend several blocks.

In addition to serving hydraulic functions, culverts also carry construction, highway, railroad or other traffic, and earth loads. Therefore, culvert design includes both hydraulic and structural considerations. Culverts often significantly influence upstream and downstream flood risks, floodplain management, and public safety.

Culverts range from small circular pipes to extremely large arches sometimes used in place of bridges. For SPU, culverts range from pipes 12 inches in diameter to pipes large enough to accommodate a stream at high-flow events. The most commonly used culvert shape is circular. However, arches, boxes, and elliptical shapes are also used. Generally, in the SPU system, pipe arch, elliptical, and rectangular shapes are used in lieu of circular pipes. Circular pipes have limited room for cover over the pipe. Arch culverts have application in locations where less obstruction to a waterway is a desirable feature. Where culverts are installed in fish-bearing streams, the use of a bottomless culvert may be required. Culverts may require a structural headwall.

8.7.8.1 Culvert Materials

SPU prefers reinforced concrete structures, designed for a HS-25 roadway loading for stream culverts. Corrugated metal pipe or arches are typically not approved for new SPU assets because of corrosion concerns.

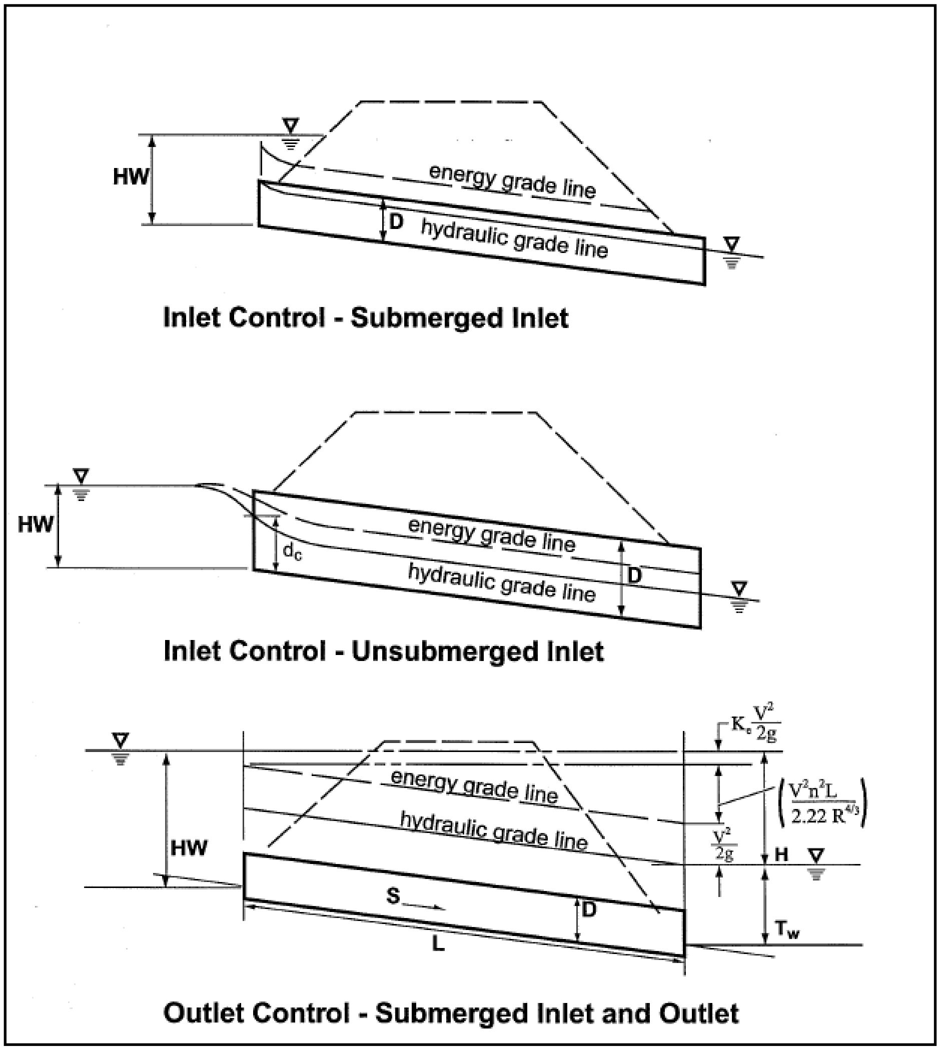
Ductile iron is generally preferred for shallow culvert pipe installations due to pipe loading issues. Concrete pipe, both reinforced and unreinforced has been used widely in the informal system in the past. Unreinforced concrete is not appropriate for the anticipated roadway loads. Reinforced concrete may be designed for the loading but should only be used when issues of abrasion, pipe bottom erosion, low pressure air testing have been addressed. Bends in concrete pipe are not preferred. A variety of flexible pipe materials with smooth interiors, have been used with variable to negative results both for new connections and maintaining pipe roundness. When considering use of any flexible pipe for culverts, discuss with Operations. Note that any proposal to use flexible pipe is subject to deflection testing 30 days after backfill and prior to paving, so scheduling impacts must be addressed. Often this requirement make flexible pipe not feasible due to construction schedule constraints.

8.7.8.2 General Design and Hydraulic Evaluation

Culvert capacity can be extremely complex. However, simple procedures have been developed to classify and analyze flow conditions based on control sections. A control section is a location where there is a unique relationship between the flow rate and upstream water surface elevation. Many flow conditions occur over time, but at any given time flow is either governed by the culvert's inlet geometry (inlet control) or by a combination of inlet geometry, barrel characteristics, and tail water elevation (outlet control). Figure 8-10 shows typical conditions of inlet and outlet control. Procedures presented in the WSDOT *Hydraulics Manual* show the analysis of inlet and outlet control conditions.

Culverts located in streams or channels that may contain fish should consider guidelines for fish passage available from the Washington State Department of Fish and Wildlife (WDFW), WSDOT, and/or local tribes. State and federal agencies review and approve design before issuing permits to work in a stream. Design reference may include WDFW Water Crossing Design Guidelines (2013) and Stream Habitat Restoration Guidelines (April 2012 draft). See *DSG Chapter 2, Design for Permitting and Environmental Review.*

Figure 8-10
Inlet/Outlet Control Conditions



8.7.8.3 Headwater

The maximum headwater for the flows with 1 percent annual probability (100-year design flows) should be 1.5 times the culvert diameter, or 1.5 times the culvert rise dimension for shapes other than circular. The headwater depth may be limited by the street overtopping criteria per SDOT

8.7.8.4 Velocity

For large culverts, both minimum and maximum velocities must be considered. A minimum velocity is required to assure a self-cleaning condition of the culvert. Maximum velocities are limited to prevent excessive erosion (Table 8-14). However, fish passage requirements may dictate velocity requirement. Consult with WDFW and ACOE. See *DSG Chapter 2, Design for Permitting and Environmental Review.*

Table 8-14
Erosion Protection for Culvert Design

Velocity	Condition
Minimum: 3 fps	All conditions unless fish passage requirement dictates otherwise.
Maximum:	Level of outlet protection required at maximum velocity
<5 fps	Minimal erosion protection required (quarry spalls, 4" to 8", Std Spec 9-13.7) No special consideration
5 – 10 fps	Substantial erosion protection required at outlet. Consider pipe flow and fish passage problems
>10 (not recommended)	Energy dissipater, shaped riprap basin, or other measures requiring a special design required at outlet. Consider abrasion of pipe when selecting pipe material and scour of bed material in bottomless culverts

8.7.8.5 Size

The following are SPU standards for culvert size:

A. Culverts in Public ROW or Private Property

Standard minimum culvert size is 12 inches in diameter. Consult with SDOT when a proposed culvert span is at or beyond 20 feet wide because SDOT may consider it a bridge structure, which has special requirements. SDOT usually takes ownership and maintenance of a bridge structure and SPU crew will maintain the channel function. There is no formal policy yet so continuing check-in and a written agreement is very important for design and ownership assumptions.

B. Street Crossings

Minimum culvert size is based on the allowable street overtopping for various street classifications determined by SPU and SDOT and allowable headwater depth. Street overtopping must never occur for a 10-year frequency or smaller storm.

C. Other Conditions

Other conditions may require a larger culvert size, particularly for public safety, fish passage, and upstream and downstream impacts.

Tips: *Fish passage requirement usually dictates the size of a culvert (typically require a much larger culvert than from capacity requirement). Enlarging a culvert may increase downstream flood risk and alter the upstream ecology (lowering of the Ordinary High Water Mark). Sometimes a culvert issue might require solution that is beyond the existing culvert location and involve* *upstream or downstream channel and/or addition modification to the system. Modeling tools such as HEC-RAS modeling, is a helpful tool in analyzing culvert issue.*

In addition, sedimentation and landscaping/wetland/riparian mitigation are often an integral and important part of the design and permitting process. Try to schedule survey during fall or winter time when vegetation is less dense.

8.7.8.6 Alignments and Junctions

Wherever practical, culverts should be placed on a straight alignment and grade and should have straight entrance and exit channels. The alignment and grade should be as close as possible to the natural streambed or channel. When conditions make the ideal alignment and grade impractical, the design engineer should consider relocating a portion of the channel or small angle bends.

If junctions in a culvert alignment or grade are required, junction boxes per Standard Plan 277 may be used. Standard plan 277 allows for either a cover or grate. The standard may also be modified to include a sump if desired to allow for sediment collection and cleaning. Deeper culvert or maintenance holes may also be used.

8.7.8.7 Inlet/Outlet

Culvert design should consider headwalls, wingwalls, aprons, or flared end sections at the inlet and outlet.

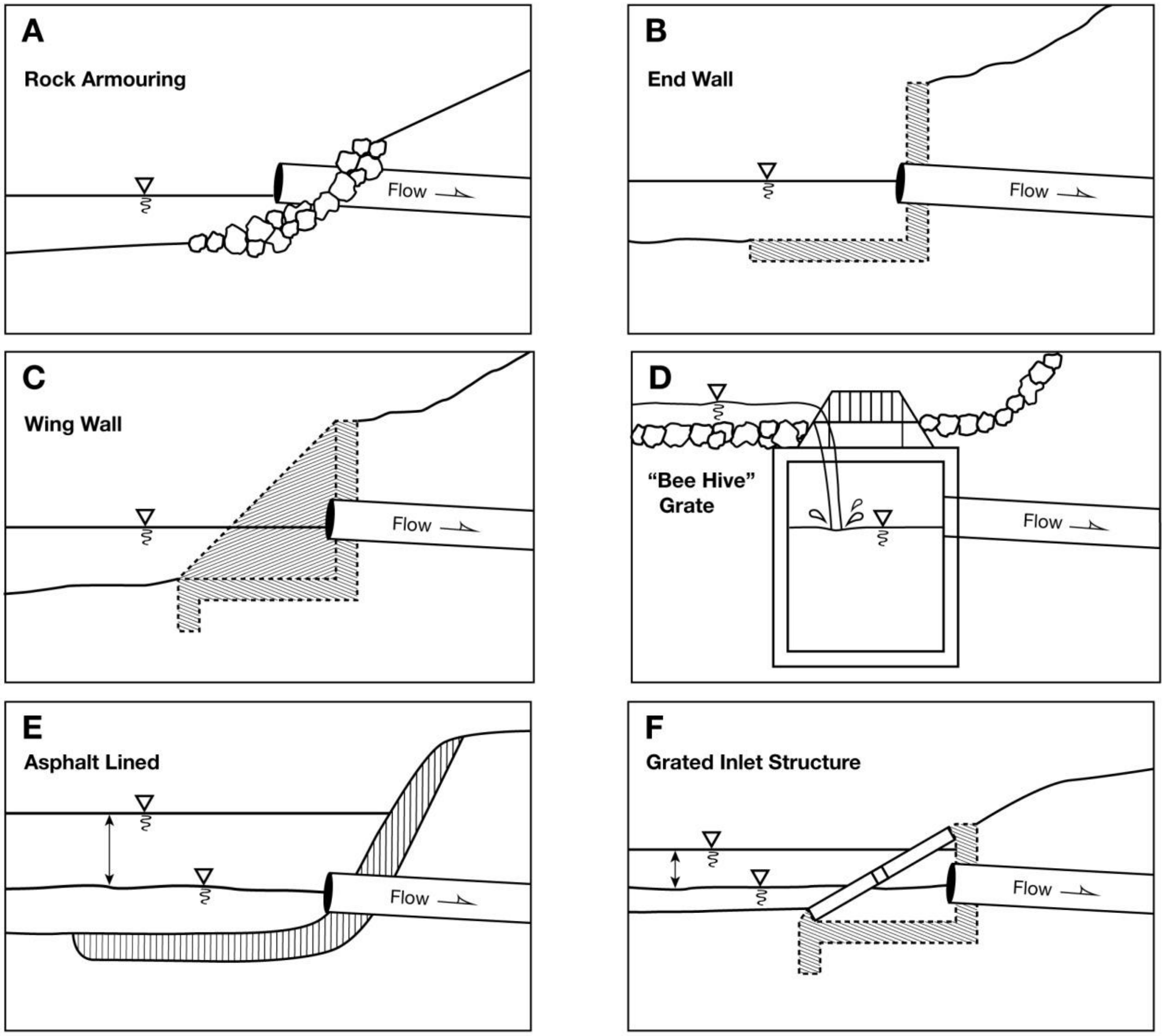
Additional protection in the form of riprap may be required at the inlet and outlet due to the potential scouring velocities (Table 8-15). Riprap is often discouraged by Environmental agencies and may require additional mitigation during the permitting negotiation process. Bioengineering for bank stabilization is preferred (e.g. soil wrap, planting, large woody materials).

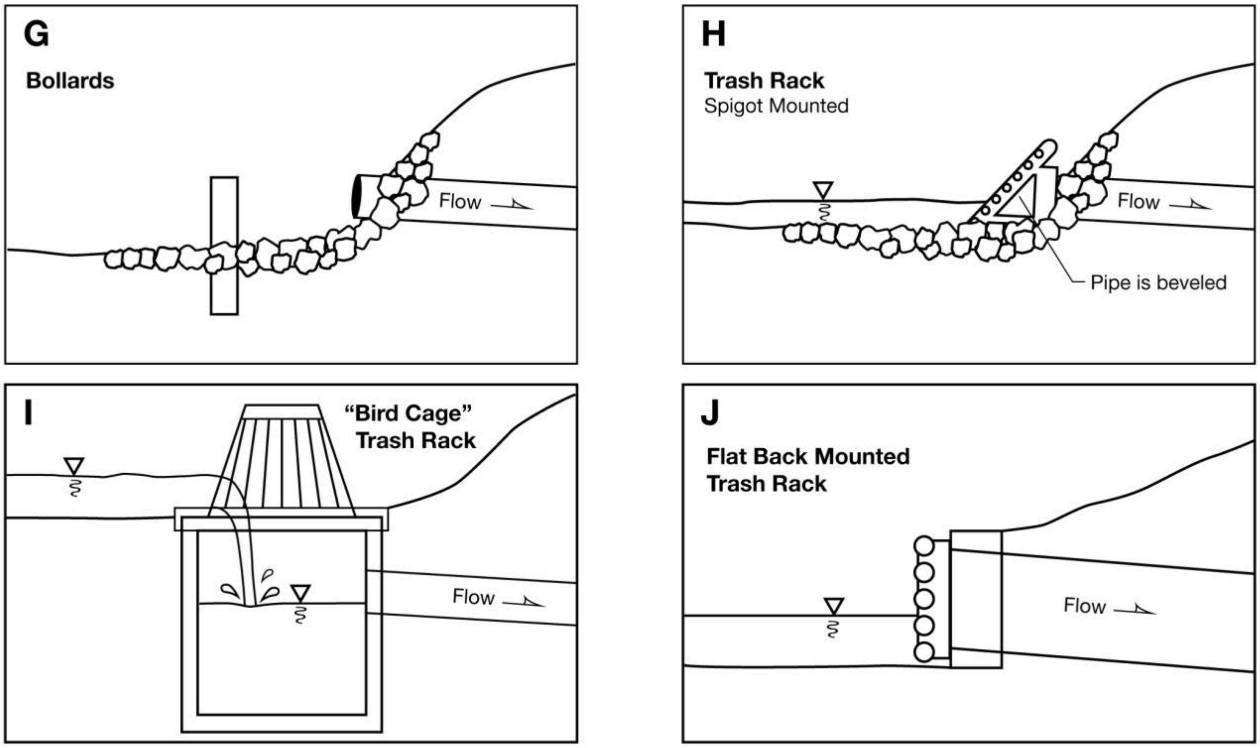
Table 8-15
Inlet/Outlet Protection Required Conditions at Given Velocities

Maximum Velocity at Outlet (fps)	Protection Required
<5	Quarry Spalls, 4" to 8" (Std Spec 9-13.7)
5 – 10	Light Loose Riprap (Std Spec 9-13.2(2) and larger
10 – 15	Heavy Loose Riprap (Std Spec 9-13.2(1) and larger
>15 (not recommended)	Energy dissipater, shaped riprap basin, or other measures requiring a special design

Figure 8-11 shows typical culvert inlet protection used in the SPU system.

Figure 8-11
Typical Culvert Inlet Protection





A. Trash Racks

Trash racks may be required upstream of culverts on a case-by-case basis to reduce blockages and facilitate cleaning and debris removal. Note that a trash rack typically increases the frequency of maintenance, but can reduce the effort necessary to clear a blockage when compared to clogging the culvert. Generally, trash racks are not placed at the downstream end of culverts. Public safety is the highest priority when determining whether to include and how to design a trash rack. For larger diameter pipes, a downstream barrier may be appropriate.

Trash racks are generally sloped so that debris will ride up the rack and not block flow. Trash racks are usually sloped up at 3: 1 to 5:1 to allow trash to slide up the rack with rising water levels. The slower the approach velocity, the flatter the trash rack slope must be.

Special consideration must be made for maintenance requirements, and to provide additional allowable head at the entrance if there is potential blockage.

For typical trash racks (debris barriers), see the *King County Surface Water Design Manual*.

For areas of heavy debris loading, see *FHWA HEC-9* for special designs required.

B. Fish Screen

Fish screen maybe required at the outfall of the culvert. See **Appendix 8B - Useful Figures and Concepts** for fish screen design details.

8.7.8.8 Design Considerations for Maintenance

Culverts are regularly examined for scour, sedimentation, or debris at the inlet and outlet, and then cleaned and repaired as necessary. Design for culverts should consider system inspection of:

- Ends of culvert for undercutting (water eroding the foundation of the structure)
- Silt and debris accumulation, which can block the culvert and lose capacity
- Erosion around structure, specifically near base and close to the road, if applicable
- Cracks in structure, specifically at entrance and exit of culvert

Consider access for maintenance during design and culvert layout. Adequate access is required to clean out entrances (especially with trash racks or debris catchers) and to maintain outlets. Culverts under high fills may require an access road to the inlet and outlet.

8.7.9 Flow Control

The Stormwater Code and associated DWW-200 regulate activities that impact quality and quantity of stormwater runoff.

> ***Note:*** *This section of the DSG frequently directs the user to Stormwater Manual. That document is the SPU source for detailed design information on flow control BMPs.*

8.7.9.1 General

Historically, development in Seattle has converted landscaped and natural areas to impervious surface. When unmitigated, such change may reduce infiltration, increase runoff, prolong flow duration, and impact downstream creeks and other receiving waters. Flow control BMPs can include bioretention systems, detention pipes, and GSI such as trees and soil amendment. When a BMP is a structure, such as a tank, it is commonly called a flow control *facility*.

8.7.9.2 Flow Control Facility Options

Flow control is a requirement based on project type, location, and other factors. To determine if flow control is required for a project, see Stormwater Manual Volume 1 Chapter 4 Minimum Requirements Based on Project Type. See Stormwater Manual Volume 1 Figure 4.1b for Flow Control Minimum Requirements for Roadway Project

SPU prefers, in order of importance, the following BMP categories for managing stormwater flow, peak, duration, and volume:

- Impervious surface reduction (reducing the total impervious surface onsite)
- Green stormwater infrastructure
- Traditional detention facilities (detention pipes, ponds, vaults, or tanks). Detention pipes are preferred over vaults or tanks for maintenance purposes.

A. Green Stormwater Infrastructure/On-site management

GSI includes stormwater BMPs designed to reduce runoff and pollutants from development using infiltration, evapotranspiration, or stormwater reuse. Because GSI includes emerging stormwater management techniques, see Appendix 8C GSI Manual for guidance on SPU bioretention projects. See the Stormwater Manual volume 1 Section 5.2.2 for *on-site* requirements, which has replaced the term GSI in the regulations.

At the time of this update, SPU has a GSI program and is in the process of providing more policy and design clarity. The SDOT ROWIM is also being updated and is scheduled to be finalized and available sometime in 2016.

B. Traditional Detention Facilities

Flow control detention facilities temporarily store increased surface water runoff from development. Stormwater is then released through a control structure (see DSG section 8.7.8.3) at an attenuated rate to meet flow control performance standards.

1) Detention Facilities in the ROW

The following facilities are approved for use in the ROW and are in order of SPU general preference:

a) Detention Pipe

The SPU flow control system primarily consists of detention pipes that vary in size from 12 inches to 12 feet in diameter. The system can be either on- or offline. SPU uses detention pipes because it has limited ROW and utility locations are expensive Typically, SPU detention tanks are designed as offline facilities. SPU detention pipes may also be designed as flow-through systems with maintenance holes in line to promote sediment removal and facilitate maintenance. See Standard Plan 270 and 272.

b) Detention Vault

Detention vaults are box-shaped underground storage facilities typically constructed with reinforced concrete.

SPU prefers detention pipes rather than detention vaults because vaults are more difficult to maintain. Detention vaults may be designed as flow-through systems with bottoms level (longitudinally), or they may be sloped toward the inlet to facilitate sediment removal. Distance between the inlet and outlet should be maximized (as feasible). Detention vaults are uncommon in the SPU system due to construction costs and underground conflicts. Typically, they are used on private, commercial developments.

Detention Vault Bottom. The detention vault bottom may be sloped at least 0.5% from each side towards the center to form a broad “v” to facilitate sediment removal. More than one “v” may be used to minimize vault depth. However, the vault bottom may be flat with 0.5 to 1 foot of sediment storage if access hatches are provided for the entire vault.

Detention Vault Lid. Vault lids should be designed to handle the weight of vehicle traffic, including maintenance vehicles, such as a vactor truck. The vault footprint is likely the only place to provide access for vault maintenance. This condition may require that the lid be designed to handle HS-25 loading or greater. This type of lid often requires special equipment for removing the lid. The locations of the lids are subject to SPU maintenance requirements.

2) Detention Facilities in the Non-ROW

SPU approves the following facility for use **only** in non-ROW applications:

a) Detention Pond

Detention ponds are surface water basins that temporarily store runoff to decrease downstream discharge peak flows and durations.

When a detention pond is designed with significant dead storage depth, it traps pollutants collected by the initial surge of stormwater and allows them to settle out before leaving the pond. These detention ponds are usually referred to as *wet ponds.* See DSG section 8.8, Water Quality Treatment.

Tip: *Embankments that impound water must comply with the Washington State Dam Safety Regulations (Chapter 173-175 WAC). If the impoundment has a storage capacity, including both water and sediment storage volumes, greater than 10 acre-feet above natural ground level, then Ecology requires dam safety design and review. See DSG Chapter 13, Dam Safety.*

8.7.9.3 Flow Control Structures

Flow control structures control the rate at which water is released from or through a facility. SPU typically uses maintenance holes with a restrictor device for controlling outflow from a facility to meet the desired performance. These structures can include shear gates, drilled hole orifices (> 0.5 inches), and weirs. See Standard Plan 272A. SPU Facilities and Operations and Maintenance must approve other methods of flow control for installation in the ROW.

A. Minimum Standards

The following are SPU standards for flow control structures:

1. Access must be provided to the flow control structure from the ground surface with a circular ring and solid cover or access hatch.
2. If the flow control structure is located in a driveway, the lid must be strong enough to bear the weight of vehicles, typically HS-25 loading or greater.
3. The ring and cover must be set so the flow control device or the ladder is visible at the edge of the access opening.
4. The invert elevation of the detention pipe must be at least 2 inches higher than the invert elevation of the outlet pipe.
5. The top of the overflow pipe must be at least 6 inches below the bottom of the MH top slab. The top of the pipe must be no lower than the upstream end of the detention pipe.
6. Minimum orifice size must be 0.5 inches without screening.

B. Other Standards

The inside diameter of a flow control structure depends on pipe size. The minimum diameter of the flow control structure outlet pipe is the same as the minimum diameter required for the Detention pipe outlet connections.

8.7.9.4 Maintenance Access Requirements

City of Seattle vactor trucks use vacuum rather than positive displacement to clean stormwater vaults. Their maximum effective sucking depth is about 25 feet. Allowing for 5 feet from the vactor truck to the rim of the structure, the maximum cleanable vault is about 20 feet deep.

SPU prefers to limit the maximum vault depth to 15 feet, which allows more flexibility during regular maintenance activities. See *DSG Chapter 4, General Design Considerations.*

8.7.9.5 Design Considerations for Maintenance

Flow control facility maintenance must be conducted in accordance with *Stormwater Manual* Appendix G

8.7.10 Green Stormwater Infrastructure

GSI includes stormwater BMPs designed to reduce runoff and pollutants from development using infiltration, evapotranspiration, or stormwater reuse. Because GSI includes emerging stormwater management techniques, refer to the SPU GSI website for updates and supplemental information. See Appendix 8C GSI Manual for guidance on SPU bioretention projects. See the Stormwater Manual for "on-site" requirements, which has replaced the term GSI in the regulations.

At the time of this update, SPU has a GSI program and is in the process of providing more policy and design clarity. The SDOT ROWIM is also being updated and is scheduled to be finalized and available sometime in 2016.

8.7.11 Water Quality Treatment

Water quality treatment BMPs remove pollutants in stormwater runoff. These pollutants include sand, silt, and other suspended solids, metals, nutrients, bacteria and viruses, and organic contaminants. Methods of pollutant removal are sedimentation (or settling), filtration, plant uptake, ion exchange, adsorption, and bacterial decomposition. Separator structures can be used to remove floatable pollutants such as oil, debris, and scum.

> ***Note:*** *This section of DSG frequently directs the user to (Stormwater Manual). That document is the SPU source for detailed design information on water quality treatment BMPs.*

For detailed guidelines for water quality treatment facilities, see Stormwater Manual Vol. 3, Chapter 5, *Water Quality Treatment Design*.

8.7.11.1 Control Structures

SPU water quality features are typically designed to handle only small storms (up to the approximate 6-month, 24-hour event). Larger storms must be designed to bypass the water quality facility.

8.7.11.2 Treatment Facility Options

This section provides a list of approved water quality treatment BMPs with SPU-preferences for design and use. To determine if water quality treatment is required for a project, see Volume 1 of the Stormwater Manual or Chapter 18 Plan Review for stormwater flow charts for projects in the ROW.

Treatment requirements fall into four basic categories:

1. Basic treatment
2. Enhanced treatment
3. Phosphorus treatment
4. Oil control

See Stormwater Manual Volume 3, section 3.5.2 for Treatment Performance Goal and BMP Options.

This following provides a list of accepted BMP in SPU's preference for water quality treatment. In general, all things being equal, SPU prefers technology in the following order: GSI technology (infiltrating or non-infiltrating), infiltration, non-infiltrating BMPs using filtration technology, settling, traditional infrastructures (e.g. ponds, sand filters, vaults), Proprietary and Emerging Water Quality Treatments, and Treatment Train.

Tip: *As in all projects, a triple bottom line analysis is essential to selectin a BMPs. The order of preference is a general guideline and project specifics and constraints must be considered in electing the appropriate BMPs. SPU Resolution 31459 was adopted by Council in July 2013 in establishing a City policy that GSI is critical to a sustainable drainage system. The resolution adopted a 2025 goal for GSI implementation in Seattle. For more information, contact the SPU GSI program team.*

A. Basic Treatment Facilities

Basic Treatment facilities include all those listed in Stormwater Manual Vol. 3, section 3.5, Enhanced Treatment. Facilities described in this section remove 80% of total suspended solids from stormwater.

1) Infiltrating BMPs

- Infiltration bioretention (GSI)
- Infiltration trench
- Permeable pavement facility (GSI)
- Infiltration basin
- Infiltration chamber
- Permeable Pavement Surfaces (GSI)

2) Non-infiltrating BMPs

- Non-infiltrating bioretention (GSI)
- Biofiltration swales
- Basic Filter Strip
- Compost-Amended Vegetated Filter Strips
- Media Filter Drain
- Sand Filter

- Basic Wet Pond
- Wet Vault
- Combined Detention and Wet Pool
- Stormwater Treatment wetland

3) Proprietary and Emerging Technologies

The following list is in order of preference.

- Filterra
- PerkFilter
- Stormfilter

B. Enhanced Treatment Facilities

These facilities are intended to remove more dissolved metals than basic treatment facilities, while meeting the treatment performance goal for basic treatment. The performance goal for enhanced facilities is to have a net reduction in dissolved copper and zinc. The following is a list of enhanced treatment facilities in order of preference.

1) Infiltrating BMPs

- Infiltration bioretention (GSI)
- Infiltration trench
- Permeable pavement facility (GSI)
- Infiltration basin
- Infiltration chamber
- Permeable Pavement Surfaces (GSI)

2) Non-infiltrating BMPs

- Non-infiltrating Bioretention (GSI)
- Compost-Amended Biofiltration Swale
- Compost-Amended Vegetated Filter Strip
- Media Filter Drain
- Large Sand Filter
- Stormwater Treatment Wetland

3) Proprietary and Emerging Technologies

- Filterra

4) Treatment Train

- See Stormwater Manual, Volume 3, Table 3.5 for details

C. Oil Control Facilities

Oil control facilities should achieve the goals of no ongoing or recurring visible oil sheen, an average effluent total petroleum hydrocarbon concentration of 10 mg/L, and a maximum discrete sample concentration of 15 mg/L. SPU approves the following oil control facilities:

- Linear Sand Filter
- API-Type Oil/Water Separator
- Proprietary and Emerging Water Quality Treatment Technologies
- Coalescing Plate/Water Separator (not preferred)

D. Phosphorus Treatment

Phosphorus Treatment BMPs are designed to achieve 50% total phosphorus removal for a range of influent concertation of 0.1 to 0.5 mg/L.

1) Infiltrating BMPs

- Infiltration trench
- Infiltration bioretention (GSI)
- Permeable pavement facility (GSI)
- Infiltration basin
- Infiltration Chamber

2) Non-infiltrating BMPs

- Media Filter Drain
- Large Sand Filter
- Large Wet pond

3) Proprietary and Emerging Technologies

- Proprietary and Emerging Water Quality Treatment for phosphorus removal. See Stormwater Manual, Volume 3, section 5.8.11

4) Treatment Train

- See Stormwater Manual, Volume 3, Table 3.6 for details

8.7.11.3 Green Stormwater Infrastructures

For detailed guidelines on green stormwater infrastructures, see Appendix 8C GSI Design Manual, the SDOT ROWIM, the SPU GSI website, and the Puget Sound Partnership web page. See DSG section 8.7.8.4, Maintenance Access Requirements.

8.7.11.4 Design Considerations for Maintenance

SPU water quality facility components, vegetation, and source controls must be inspected for proper operations and structural stability. These inspections must follow the requirements of the Stormwater Manual Appendix G.

8.7.12 Outfalls

In DSG, an outfall is a discharge point into a body of water. SPU outfalls discharge into Puget Sound, lakes, rivers, or streams. Outfall also refers to discharge of concentrated flow into a stormwater facility.

Properly designed outfalls are critical to reducing adverse impacts from concentrated discharges from pipe systems and culverts. Typically, outfalls involve erosion protection for fish passage or restriction. Outfall protection systems include rock splash pads, flow dispersal trenches, gabion or other energy dissipaters, and tightline systems.

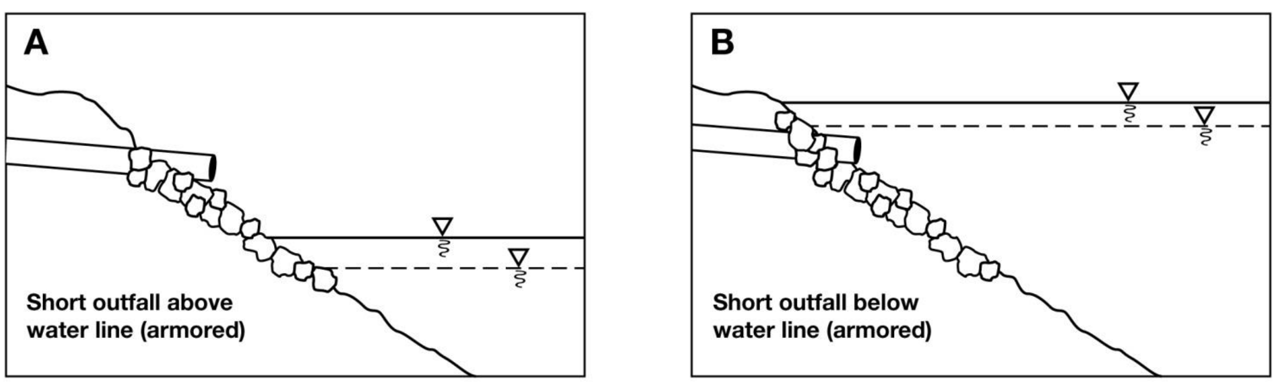
Any new outfall is subject to a Hydraulic Project Approval (Chapter 77.55 RCW) from the Washington Department of Fish and Wildlife (WDFW). A U.S. Army Corps of Engineers permit may be required for any work within the ordinary high-water mark of streams and shorelines. Additional permits may be required from Washington Department of Natural Resources and Ecology. Shoreline permits are required within 200 feet of shoreline in environmentally critical areas (ECAs).

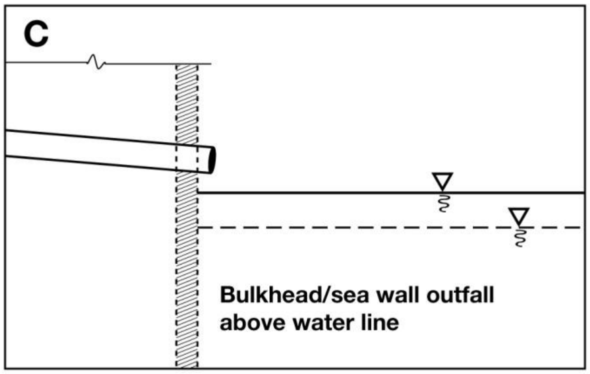
For additional design guidance on outfalls, see the Ecology *Stormwater Management Manual for Western Washington* and King County *Surface Water Design Manual*. The Washington State Department of Natural Resources (DNR) will require intense permitting if they own the tidelands and that situation could trigger the need for upstream water treatment. New public outfalls to a water body are rare in the SPU system. Permitting and permit conditions from a multitude of agencies are a major part of outfall design. Identifying those conditions needs to be early, since they will impact feasibility and costs. See *DSG Chapter 2, Design for Permitting and Environmental Review*.

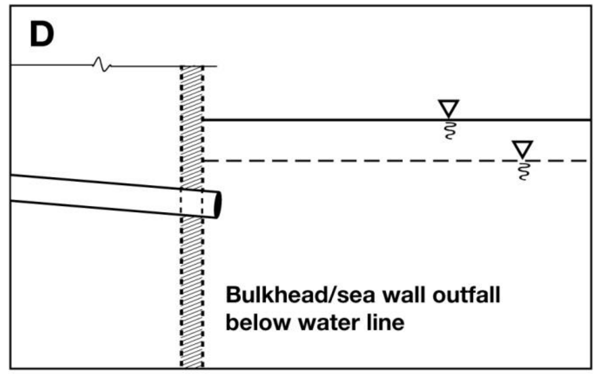
8.7.12.1 Types of Outfalls

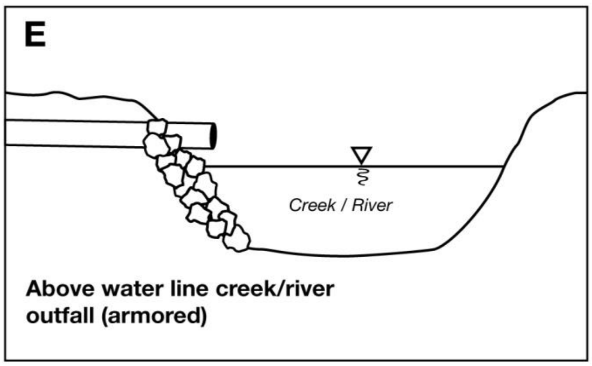
SPU has many types of outfalls within its drainage and wastewater system (Figure 8-12). All outfalls are site-specific for permitting, regulations, engineering, and maintenance.

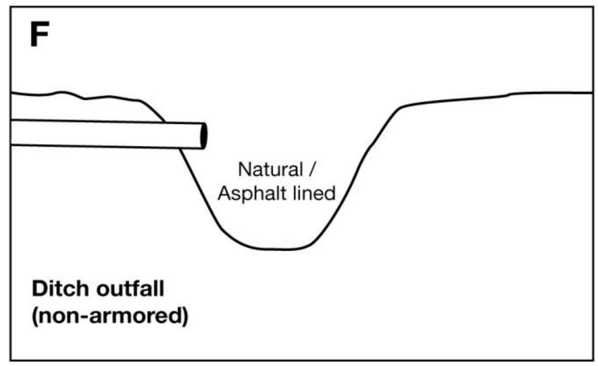
Figure 8-12
Types of Outfalls in SPU System

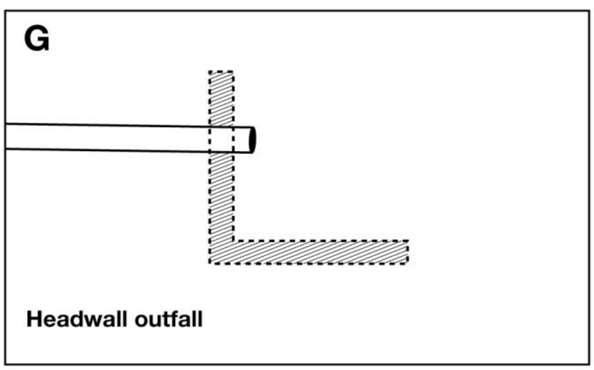


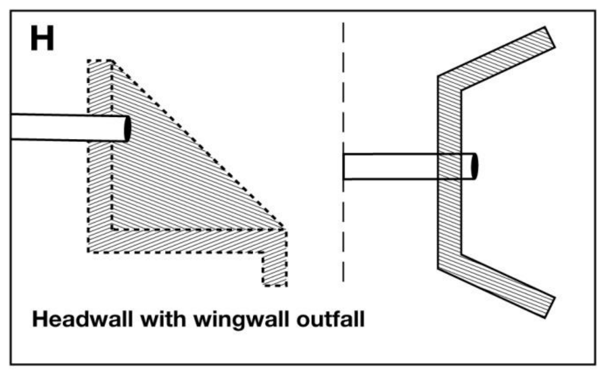

C
Bulkhead/sea wall outfall
above water line

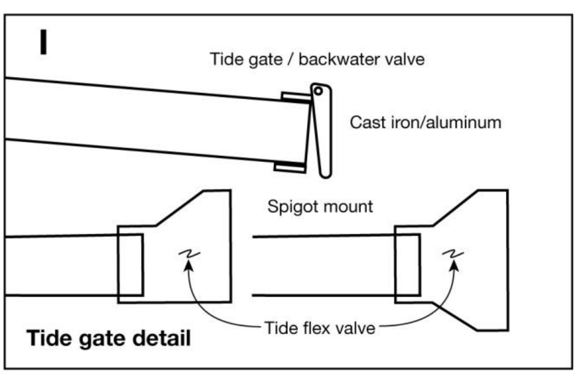

D
Bulkhead/sea wall outfall
below water line

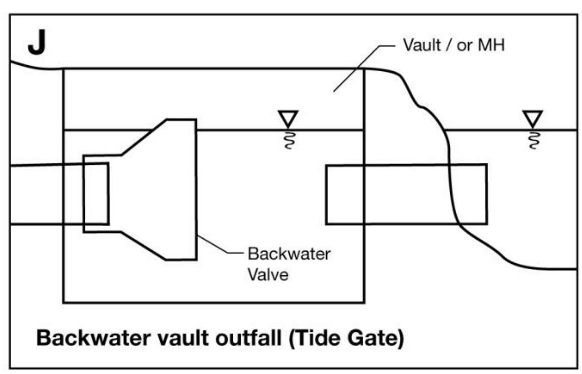

E
Creek / River
Above water line creek/river
outfall (armored)

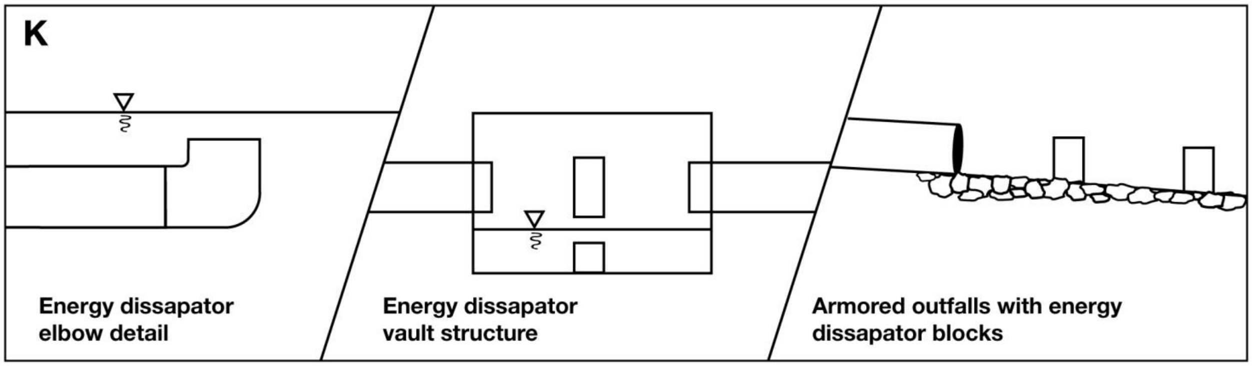

F
Natural /
Asphalt lined
Ditch outfall
(non-armored)

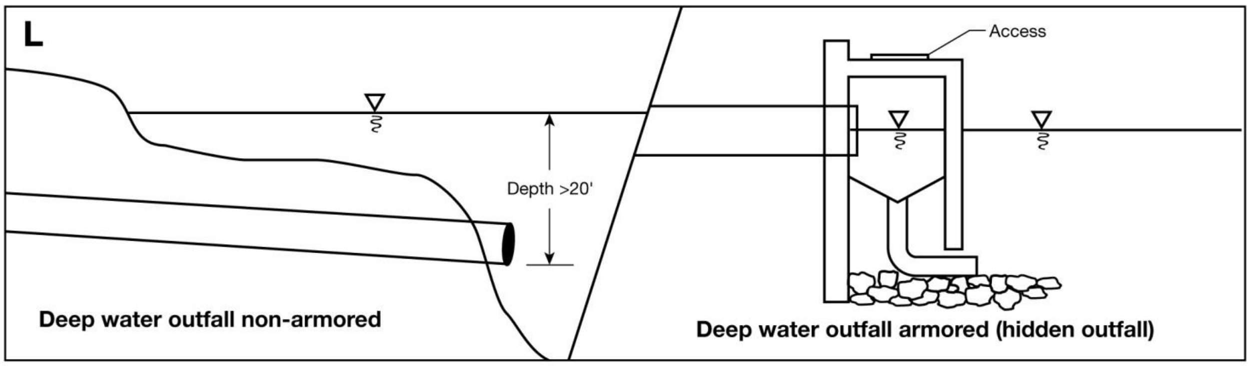

G
Headwall outfall

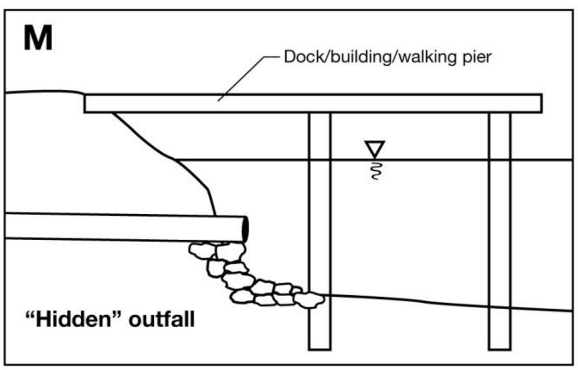

H
Headwall with wingwall outfall

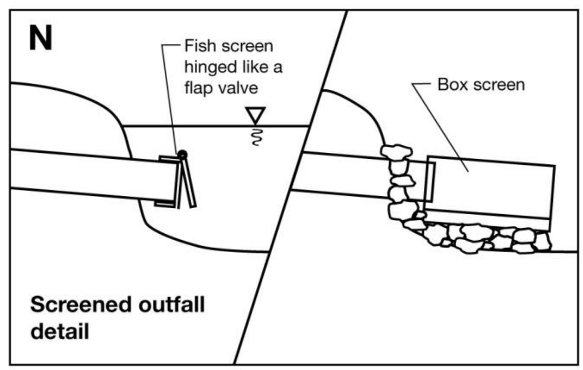

I
Tide gate / backwater valve
Cast iron/aluminum
Spigot mount
Tide flex valve
Tide gate detail

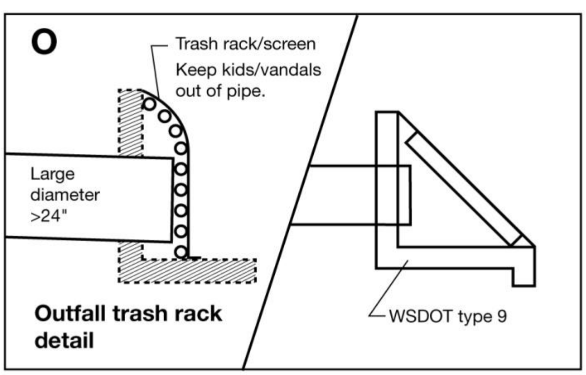

J
Vault / or MH
Backwater
Valve
Backwater vault outfall (Tide Gate)

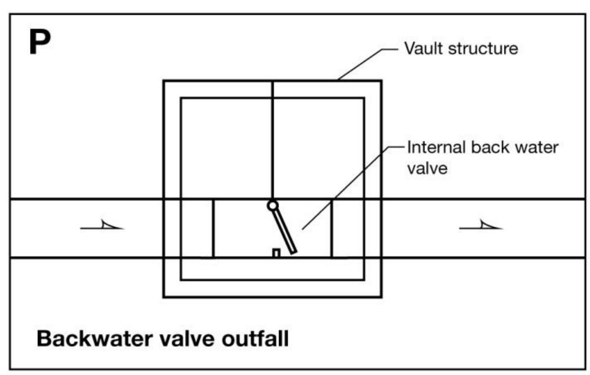

K
Energy dissapator elbow detail
Energy dissapator vault structure
Armored outfalls with energy dissapator blocks

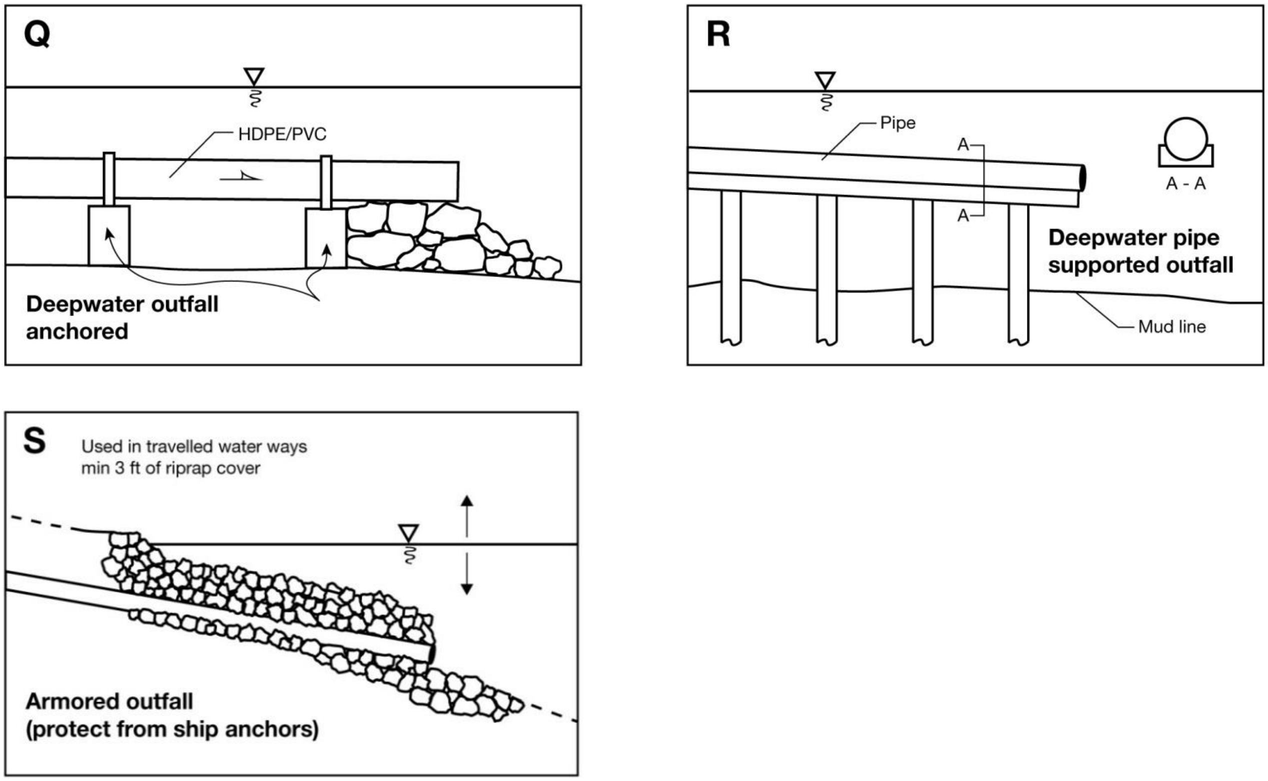

L
Depth >20'
Access
Deep water outfall non-armored
Deep water outfall armored (hidden outfall)


M
Dock/building/walking pier
"Hidden" outfall


N
Fish screen hinged like a flap valve
Box screen
Screened outfall detail


O
Trash rack/screen
Keep kids/vandals out of pipe.
Large diameter >24"
WSDOT type 9
Outfall trash rack detail


P
Vault structure
Internal back water valve
Backwater valve outfall



8.7.12.2 Design Criteria

Outfall design is based on transporting drainage from an existing collection point to larger water bodies in the Seattle area. All outfalls should be provided with armoring when velocities and conditions dictate. As shown on Table 8-16, sizing assumes that outfall energy is dominant. In many cases, receiving waters govern sizing.

For examples of typical energy dissipaters, see *FHWA HEC-14*. Site-specific designs are required when the outlet velocity exceeds 10 fps. The FHWA, Army Corps, Bureau of Reclamation, and USDA (Natural Resources Conservation Service) all provide procedures for the design of high-velocity energy dissipaters.

Table 8-16
Required Armoring for Various Discharge Velocities

Discharge Velocity at Design Flow (fps)		Minimum Dimensions					Notes
Greater than	Less or equal to	Type	Thickness	Width	Length	Height	
2 fps	5 fps	Rock lining	1 ft	Dia. +6 feet	8 feet or 4 x diameter whichever is greater	Crown + 1 foot	Must be quarry spalls w/ gradation passing:: 8-in sq sieve: 100% max 4-in sq sieve: 40-60% max 2-in sq sieve: 0-0% max
5 fps	10 fps	Riprap	2 ft	Dia. +6 feet or 3 x dia.		Crown + 1 foot	Must be reasonably well graded w/gradation: Max stone size: 24 in

Discharge Velocity at Design Flow (fps)		Minimum Dimensions					Notes
				whichever is greater			Median stone size: 16 in Min. stone size: 4 in
10 fps	20 fps	Gabion outfall	As req'd	As req'd	As req'd	Crown + 1 foot	Should not be used in streams w/ heavy sand, gravel and cobble loads
20 fps	N/A	Engineered energy dissipater req'd					

Source*: King County Surface Water Design Manual* (2005)

8.7.12.3 Tide Valves

Tide valves, or flap gates, may be required to prevent backflow into storm drain systems from high water in rivers, streams, and other tidally influenced water bodies

Tide valves must be provided on all new outfalls through flood containment levees. Tide valves in flood control levees must be designed in accordance with *U.S. Army Corps of Engineers Manual for Design and Construction of Levees*.

8.7.12.4 Fish Barriers

For new or rehabilitated outfall below the water level, the WDFW requires a fish barrier to prevent fish from entering pipes. SPU prefers not to have fish barriers because they can clog the entire drainage system.

SPU prefers fish screens that function like a tide gate for systems that might experience an increase in head loss. The use of a box screen can clog the drainage system. See **Appendix 8B - Useful Figures and Concepts** for fish screen design example.

8.7.12.5 Armoring

Armoring of the bank adjacent to a pipe outlet must continue up the bank to a minimum height of a 1 foot above the crown of the pipe.

For an outlet, the armoring should extend a minimum of 10 feet.

For a larger diameter pipe (>30”), armoring may extend more than 10 feet.

For an inlet, armoring should extend a minimum of 5 feet horizontally beyond the outfall edge.

8.7.12.6 Aesthetics

Outfall design in natural channel, ponds or other areas should consider aesthetics. Ponds can be free form to imitate nature and appropriate trees and shrubs planted.

8.7.12.7 Design Considerations for Maintenance

Outfall design must accommodate the need for crews to visually inspect the main. Outfalls are repaired by specialty contractors with the equipment and ability to work in the water.

8.8 SANITARY SEWER DESIGN

This section includes only information for sanitary sewer design. For common design elements, this section cross-references DSG section 8.7, Storm Drain Design.

8.8.1 General

Sewer mains are publically maintained systems that convey sewage (wastewater) to a treatment facility. Wastewater is water released by internal sources (e.g. toilets, bathtubs, or businesses) and other everyday sources of contaminated water. All residence and building structure plumbing outlets are connected to the sanitary sewer system.

Where separate stormwater and sewer systems are available, drainage features, including downspouts, are connected to a separate storm drainage system. Some areas in Seattle are not served by a sewer system but have individual septic systems. The Seattle-King County Department of Health regulates septic systems.

Not all water can be disposed of as wastewater in the City of Seattle sewer system. Contaminated water containing petroleum products, certain chemicals, or biohazards cannot be effectively treated by sewage treatment facilities. Such water must be pre-treated at a specialized facility, typically on-site, or managed another way. These specialized facilities are non-standard facilities and are therefore not covered in this DSG.

For additional information on wastewater, see Side Sewer Code.

8.8.2 Capacity Analysis

Generally, sewer capacities should be designed for the population. Similarly, consideration should be given to the maximum anticipated capacity of institutions, industrial parks, and similar large facilities. See the Ecology 2008 Criteria for Sewage Works Design.

8.8.3 Public Sanitary Sewer Facilities

SPU's gravity sewer infrastructure is a system of pipes that transport sanitary sewage from commercial, industrial, and residential structures to a network of facilities. These SPU facilities include gravity and pressurized mains, pump stations, and interceptors. Sewage flows to the King County trunk system and ultimately to a treatment facility. Typically, the sewer system in the central part of Seattle was built as combined sewers and many annexed parts of the city to the north and south had systems built as sanitary only sewers.

This section describes design criteria for public sanitary sewer facilities. These guidelines are general and may not apply to all cases. Information presented in this section is referenced from DR 2010-02 (Side Sewer Code) and the Ecology 2008 Criteria for Sewage Works Design.

8.8.3.1 System Layout

A. General

A sanitary sewer system begins with sewage flowing from inside a residential, industrial, or commercial building by gravity to a main sewer line via a side sewer. Sewage then flows to a larger mainline, also known as a *trunk*. Pump stations and force mains can be integrated into the gravity system when sewage is required to flow up-gradient to a main and ultimately onward to a treatment facility.

Generally, side sewers should be sufficiently deep to receive wastewater from basements or lowest floors and to prevent damage from external loading. Side sewers should have a minimum depth of 18 inches on private property to prevent freezing.

B. Sanitary Sewer Location

The standard sanitary sewer mainline location must be on the centerline of the street (see Standard Plan 030). Profile clearances between water and sewer pipes are shown in Standard Plans 283 and 286A, including dimensions for parallel installation, crossing water over sewer, and crossing water under sewer. See Standard Plan 286B for spacing and clearances.

The following are SPU standards for sewer pipe layout:

1. New sewer mains must be a minimum 12 feet below proposed grade.
2. All maintenance holes must be full-depth channeled (see Standard Plan series 200).
3. Generally, the sewer system must remain within the City of Seattle ROW to provide sewer service to both side of a street.

8.8.3.2 Sanitary Sewer Pipe

Sanitary sewer pipes carry wastewater. This section includes only information for sanitary sewer design. Sewer mains are publicly maintained systems. For common design elements, this section cross-references DSG section 8.7, Storm Drain Design.

A. Conveyance Size

Sewer pipe must be a minimum of 8 inches in diameter.

B. Velocity

All sewer pipe must be designed and constructed to give mean velocities, when flowing full, of not less than 3 fps.

C. Slope

Pipe slope must be set to achieve a velocity of 3 fps minimum. Slopes that are <0.5% must have SPU approval. The following requirements must be met for sewer pipe slope for privately maintained side sewers. See the Side Sewer Code (DR 2010-02):

1) Sewer Pipe Located in ROW or Easement

Pipe located in the ROW must have a minimum slope of at least 2% (1 vertical: 50 horizontal). Pipe slopes exceeding 50% (1 vertical: 2 horizontal) requires the use of restrained joint ductile iron.

2) Side Sewer Pipe Located on Private Property

See Standard Plan 283 for more details and See Side Sewer Director's Rule.

1. Pipe located on private property must have a slope of at least 2% (1 vertical: 50 horizontal).

2. Pipe slopes exceeding 100% (1 vertical: 1 horizontal) must use restrained joint ductile iron pipe.
3. Pipe with slopes less than a 2% minimum grade requires an owner to fill out a Grade Release Form.

8.8.3.3 Sanitary Sewer Pipe Materials

SPU prefers clay pipe for most sanitary sewers because properly installed clay pipe is resistant to almost all wastewater components and spilled materials and is not subject to corrosion. Further, it has superior resistance to abrasion and erosion. See DSG section 8.7.6 for other pipe material issues to consider.

SPU prefers DIP for force mains.

8.8.3.4 Cover

Standard Plan 030 requires that sanitary sewers have a minimum 12 feet of cover. Any amount of cover less than 12 feet must have SPU approval.

8.8.3.5 Hydraulic Grade Line

Generally, the HGL for new sanitary sewers is not a concern, since they are not designed for surcharge. However, some sewers connected to pump stations will have HGL.

8.8.3.6 Buoyancy

See DSG section 0.

8.8.3.7 Alignment

For sanitary sewers, where a smaller sewer joins a larger one, the invert of the larger sewer should be lowered sufficiently to maintain the same energy gradient. A simple approach is to match the crown elevation to both pipes. Pipe sizes should only be increased at MHs.

See DSG section 8.7.5.7.

8.8.3.8 Sewer Pipe Installation

For sewer pipe installation, see DSG section 8.7.5.10.

8.8.3.9 Testing Procedures

For testing procedures for sewer pipes, see DSG section 8.10.3.

8.8.3.10 Connections and Tie-In Requirements

Pre-fabricated tees for side sewers must be used for new mainline pipes less than 24 inches in diameter. Bell less tees are recommended with clay pipe so side sewers can be connected with a shielded flexible coupling.

For pipes greater than or equal to 24 inches in diameter, all connections must be core drilled. See Standard Specification section 7.17.

Drainage appurtenances must never connect to sanitary sewers, unless approved by SPU (e.g. combined systems).

8.8.3.11 Cleanouts

See DSG section 8.7.5.12.

8.8.3.12 Pipe Rehabilitation and Replacement

See DSG Table 8.8 and section 8.7.5.13B.

8.8.3.13 Design Considerations for Maintenance

Design of sewer pipes should consider that the crown of the pipe must be inspected for evidence of degradation of the concrete on the inside. This degradation is associated with sanitary sewer gas, which when settled can become sulfuric acid and melt the grout concrete but not the rocks. If aggregate is observable at the top of the pipe, the pipe may be degraded. This condition occurs in sewers of low velocity, turbulence and heat.

8.8.4 Maintenance Holes

Generally, maintenance holes should only be used for sanitary sewer mains for either change in horizontal direction and grade or for a maximum length of 350 linear feet.

8.8.4.1 Maintenance Holes Up to 40 Feet Deep

See DSG section 8.7.6.1.

8.8.4.2 Maintenance Holes Greater Than 40 Feet Deep

See DSG section 8.7.6.2.

8.8.4.3 Location and Spacing

The following are SPU standards for locating and spacing sewer pipes:

1. Sanitary sewer lines must be placed on the centerline of the ROW.
2. Maximum spacing between maintenance holes is 350 feet.
3. Maintenance holes must be installed at the upstream end of each line with 8-inch diameter or greater pipe.
4. Maintenance holes must be installed at all changes in grade, size of pipe, or pipe alignment.
5. Maintenance holes must be installed at intersections. Exceptions are subject to SPU approval.

8.8.4.4 Material

See DSG section 8.7.6.4.

8.8.4.5 Sizing

See DSG section 8.7.6.5.

8.8.4.6 Bases

See DSG section 8.7.6.7.

8.8.4.7 Bends

No bends are allowed in any SPU sanitary sewer lines between MHs.

8.8.4.8 Connections to Existing Maintenance Holes

See DSG section 8.7.6.9.

8.8.4.9 Junction Flow and Channeling

See DSG section 8.7.6.10.

8.8.4.10 Frame and Covers

See DSG section 8.7.6.11.

8.8.4.11 Ladders/Access

See DSG section 8.7.6.12.

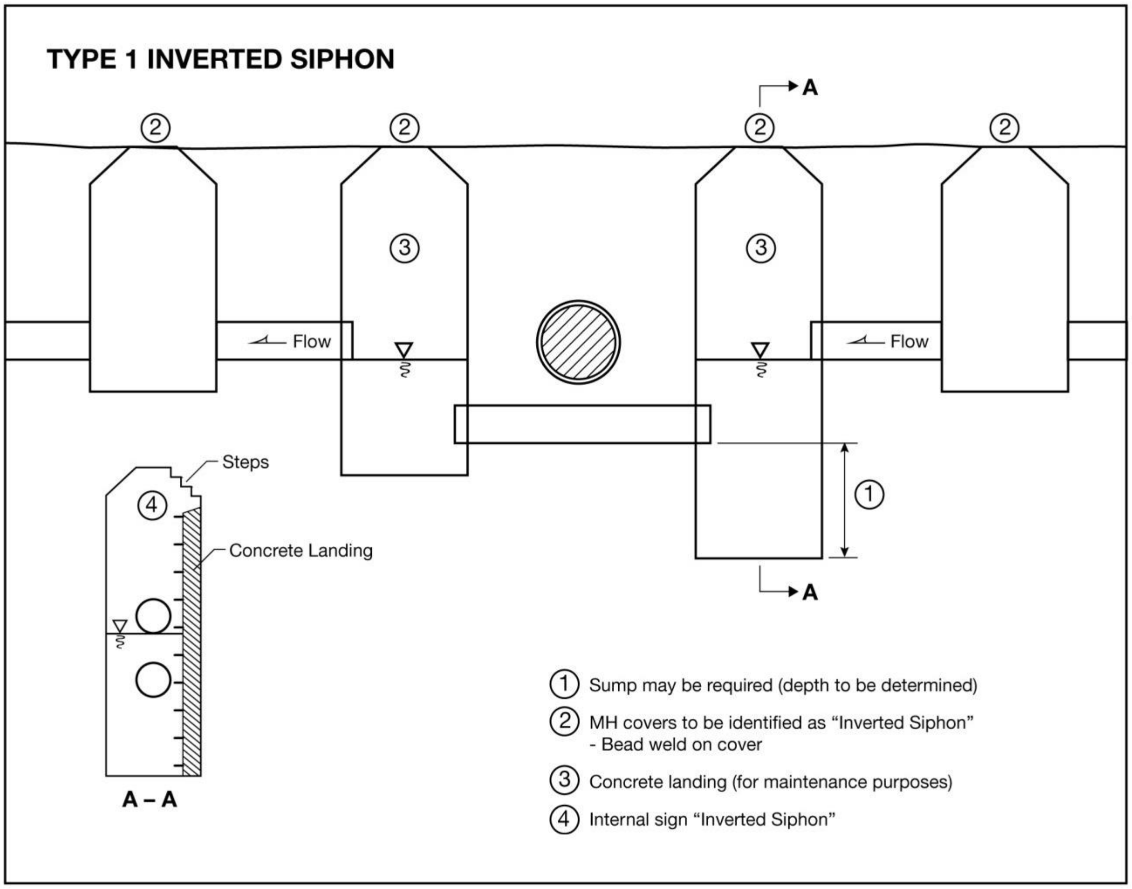
8.8.4.12 Design Considerations for Maintenance

Maintenance hole design should consider the need for grease interceptors or traps on upstream connections and that grease can build-up in these areas and affect sewer mains.

8.8.5 Inverted Siphons

Siphons are not allowed on sanitary sewer mains or drain lines without SPU approval. If siphons are approved, design must follow that shown on Figure 8-13.

Figure 8-13
Inverted Siphon



8.9 COMBINED SEWER DESIGN

Public combined sewer facilities are gravity systems that carry both stormwater and sewage to a treatment facility owned and operated by King County. Treated water is released to Puget Sound. Originally, a combined drainage and wastewater sewer system was used throughout the central areas of the city. Over time, separate storm drains, detention facilities, and a variety of drainage systems were constructed. Storm rainfall can result in combined sewer overflows (CSOs) into natural water bodies.

For information on the combined sewer overflow program and new CSO Control facilities, consult with SPU project engineers and plans for Windemere, Henderson, and Genesee projects.

> ***Note:*** *This section includes only information relevant to combined sewer design. For common design elements, this section cross-references DSG section 8.7, Storm Drain Design and DSG section 8.8, Sanitary Sewer Design.*

8.9.1 Inlets and Catch Basins

See DSG section 8.9.1.

8.9.2 Pipe

See DSG section 8.9.2.

Combined sewer pipe can be very large in diameter. For pipes larger than 48-inch diameter, a project-specific pipe material selection process may be required. Reinforced concrete and fiberglass reinforced plastic mortar pipe may be suitable.

8.9.3 Maintenance Holes

See DSG section 8.7.6. SPU does not allow any bends in sewer mains between MHs.

8.9.3.1 Design Considerations for Maintenance

See DSG section 8.7.6.14.

8.9.4 Flow Control

Much of the City of Seattle's combined sewer system has capacity concerns. Since 1979, the City has used the Stormwater Code to help reduce these problems by requiring flow control. Private development, redevelopment or a City project may trigger the City's flow control requirement. See DSG section 8.7.9 and the Stormwater Manual for requirements.

8.9.5 Outfalls

See DSG section 8.7.12.

8.9.6 Overflow Monitoring

All combined sewer locations are monitored for overflows to water bodies. When an overflow is detected, SPU must contact Ecology within 24 hours. All combined sewers are allowed one overflow event per year during wet weather.

8.9.6.1 Flow Monitoring

See *DSG Chapter 7, Drainage and Wastewater System Modeling.*

8.9.7 Force Mains

A force main is the discharge pipe of a pump station. For detailed information on force mains, see *DSG Chapter 11, Pump Stations*.

8.9.7.1 Gravity Sewer Main Connection to Force Main

A. General

SPU does not recommend discharging a gravity pipeline into a force main. If this occurs, SPU recommends the following design considerations:

- Calculating Hydraulic Grade Line (see DSG section 8.7.5.5)
- Evaluating effect of any surcharge conditions that could occur in gravity main
- Checking gravity pipe to ensure it can handle pressures from the force main
- Engineering evaluation even if live tap can be done.

Tip: *Pressures can change on force mains and that can change whether the design of the gravity connection is adequate, or not. Results can be sewer backups and gravity pipeline failures. Since both King County and SPU operate sewer pump stations, communications have lapsed at different times. Proceed with extreme caution.*

B. Private Force Main Connection to Sewer Main

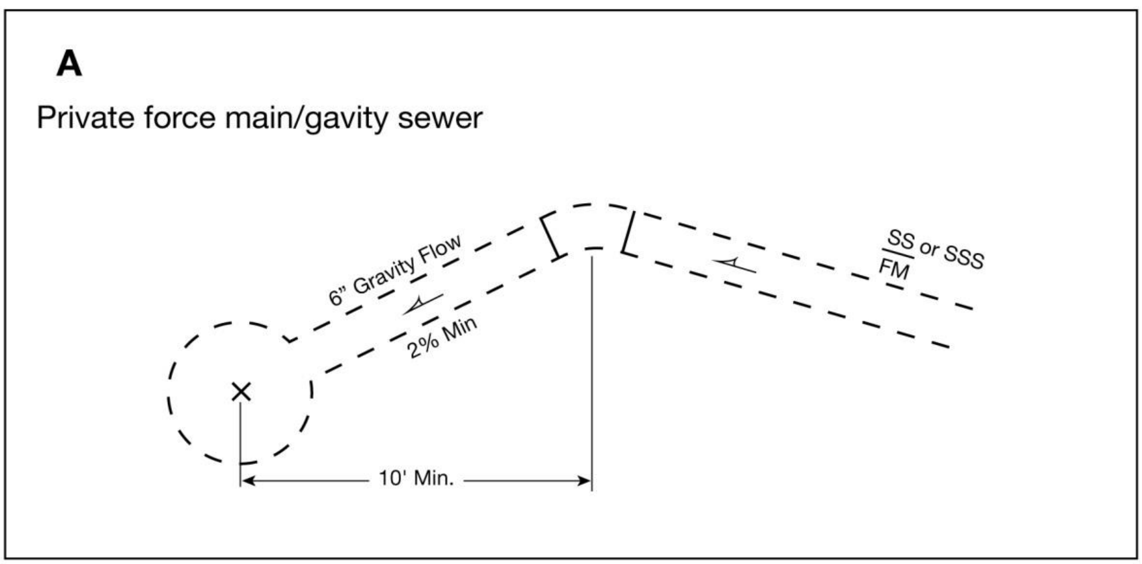
All private force mains must have gravity flow before connection to a sewer main (see view A on Figure 8-14).

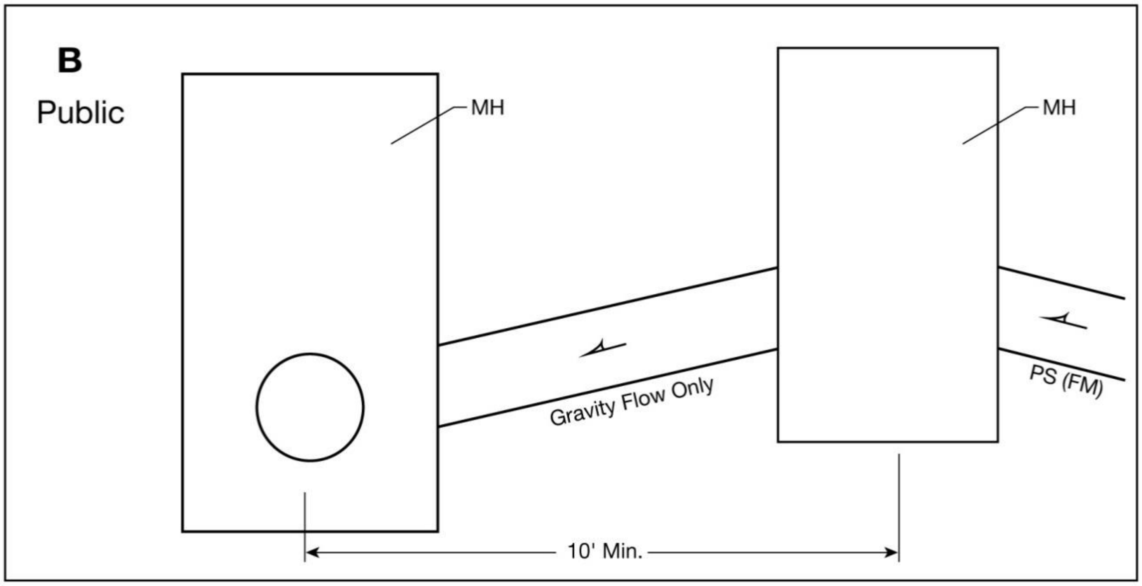
For more detailed guidelines on private force main connections to SPU sewer mains, see Exhibit 11 in DR 2010.02 (Side Sewer Code).

C. Public Force Main Connection to Sewer Main

SPU force mains must connect to gravity sewer mains through a maintenance hole (see view B on Figure 8-14).

Figure 8-14
Gravity Force Main Options Profile





8.10 CONSTRUCTION

This section describes construction procedures common to all drainage and wastewater infrastructure. The time it takes to obtain project permits often impacts the construction schedule for these facilities. See *DSG Chapter 2, Design for Permitting and Environmental Review*, for requirements for SPU projects.

8.10.1 Temporary Facilities

Temporary facilities for SPU drainage and wastewater infrastructure include those for erosion control and bypass of existing utilities.

8.10.1.1 Erosion Control

See *DSG Chapter 3, Design for Construction,* for details on erosion control for drainage and wastewater projects.

8.10.1.2 Bypassing Flow in Existing Sewer

Drainage or wastewater projects often need to bypass flow around the construction area to maintain service. Pipes and pumps should be sized to convey the maximum expected flow during the construction period. A system wide model is available. Contact the SPU modeling group.

For more detailed information on bypassing, see Standard Specification 7-17.3(2)K. and Section 3.10.

The following are SPU minimum standards for bypassing existing sewer utilities:

1. Contractor must maintain uninterrupted sewer service on projects for existing sewer mains.

2. Pump and bypass conduit must be of adequate size and capacity to handle the flow. The effluent level in the bypass pumping maintenance hole must not be allowed to rise more than 1 foot above the crown of the incoming sewer pipe. Work must follow Standard Specification 1.07.

For additional information, see *DSG Chapter 3, Design for Construction*.

8.10.2 Abandonment and Disposal

8.10.2.1 Pipeline

Pipes that are replaced in the same location and grade are normally removed and hauled away. Pipes that are abandoned in place are plugged at the end and filled with flowable concrete or sand if the pipe diameter is ≥12 inches. See Standard Specifications 2.02.3 (5).

8.10.2.2 Hazardous Materials

The SPU drainage and wastewater system contains some asbestos-concrete and asbestos truss pipe materials.

8.10.2.3 Asbestos-Containing Pipe

Asbestos-containing pipe may be encountered during construction, including modifications to or tying in with existing facilities. This pipe includes ABCO Truss pipe or corrugated metal pipe with asbestos coating. The designer engineer should include on project drawings or specifications that when working with asbestos-containing pipe, the contractor is required to maintain workers' exposure to asbestos material at or below the limit prescribed in WAC 296-62-07705.

The following are SPU standards and guidelines for asbestos pipe:

1. A piece of pipe that is smaller than 1 square foot must be disposed of according to current asbestos policies and procedures.
2. Pipe sections that are greater than 1 square foot and in the same horizontal and vertical control (i.e. the same pipe) may be left in the same trench.
3. If asbestos-containing pipe is to be abandoned in place, the end should be capped and filled during construction if pipe size is ≥8 inches in diameter.

8.10.2.4 Other Hazardous Materials

If there is evidence of spills or the presence of hazardous materials, care should be taken to evaluate possible hazards within accumulated solids to ensure worker safety during construction and crew safety during maintenance. Maintenance records and environmental studies should be reviewed to evaluate the potential for hazardous materials. Removed materials should be disposed of offsite at an approved facility in accordance with local, state, and federal regulations, including testing to identify pollutants and concentrations. After testing, consult with Operations about possible disposal at SPU facilities and any potential exposures of SPU crews.

8.10.3 Acceptance Procedures

The design engineer must include testing procedures in the project manual. Testing is incidental to bid items, unless modified in the project manual.

8.10.3.1 Leak and Pressure Testing

All tests must be performed in the presence of the resident engineer. For repairs, the inspector observes the installation, but testing is not done. Low pressure air test is the most common test. Note that pipe under the water table or a fluctuating water table should also be looked at for leaks at joints while the water table is up. Passing the low pressure air test does not demonstrate no leaks. Exfiltration testing is required where exfiltration could contribute to landslide potential. Exfiltration and infiltration testing can require use of a lot of water, which can be a significant cost for potable water and for disposal. pH is a significant pollutant issue when using water to test new concrete structures. Table 8-17 lists typical SPU pressure test procedures, but does not cover all leak and pressure testing needs for new SPU pipes and especially structures.

Table 8-17
Leak and Pressure Testing Standard Specifications

Section	Description
7-17.3(4)B	Exfiltration Test
7-17.3(4)C	Infiltration Test
7-17.3(4)D	Air pressure test
7-17.3(4)F	hydrostatic test for sanitary sewer mains

8.10.3.2 Flexible Pipe Testing

PVC and HDPE pipe require a mandrel test. Wait 30 days after backfilling to test. No final pavement restoration can occur until the pipe is accepted. If it passes the 5% deflection rule for smaller pipes and the 3% deflection rule for larger pipes and the pressure test and CCTV inspection, the pipe is accepted. SPU requirements for roundness in flexible pipes are based on both cleaning equipment needs and PACP standards for pipe evaluation. See SPU Standard Specification 7-17.3(4)H.

8.10.3.3 CCTV Inspection

Before close-out and acceptance of any segment of newly constructed storm drain or sewer mainline, or CB connection, pipes must be CCTV inspected. See Standard Specification 7-17.3(4)I. This requirement applies to sanitary sewer and storm drain pipes that are too small to be visually inspected. On a project-specific basis, laterals may also be included.

Before the CCTV inspection, all sewer and storm mains must be cleaned and pressure tested per Standard Specification 7-17.3(4)A.

CCTV inspection should be from MH to MH or from CB to main and tracked to asset identification numbers. CCTV is stored in the granite database as a pipe record by asset identification numbers.

8.10.4 Connecting to Existing Systems

The storm, sanitary sewer, and combined sewer systems in the SPU-maintained network are comprised of many types and sizes of materials with varying ages and conditions. When connecting new pipe into existing systems, SPU recommends determining:

- Age of the system.
- Material composition of the existing system, including lateral connections.
- Design criteria that were followed (e.g. design storm and flow, street loading).

See DSG section 8.7.5.5B.2).

8.11 OPERATIONS & MAINTENANCE

This section describes O&M elements common to all SPU drainage and wastewater infrastructure. See the appropriate sections of this chapter for O&M design issues specific to the infrastructure under design consideration.

Design considerations for O&M include:

- Avoid stand pipe, drop connection and surge tanks.
- Stay within ROW and avoid going into property (must acquire easement if in private property).
- Accessibility evaluation includes slope evaluation and allowance for large vactor truck access, CCTV and cleaning tool as well as fall protection.
- Placement of MH at the end of a pipe run.

8.11.1 Drainage and Sewage Easements

An easement gives SPU the right to access a utility, such as a pipe or CB, on property it does not own. Easements must be project specific. Construction easements may differ from standard utility O&M easements because they are temporary and typically need a larger area. Table 8-18 lists SPU minimum requirements for drainage and sewer pipe easements for maintenance. This table is a guideline. Engineering judgment, depth, access restrictions and future expansion may require larger easements. For pipelines in easements, consider installing the carrier pipe in a casing.

Table 8-18
SPU Minimum Drainage and Sewer Easements

Inside Pipe Diameter or Nominal Pipe Diameter (inches)	Minimum Easement Width (feet)
<12 to 16	12
18 to 24	14
30 to 48	18
60	20
72	24
84	28

Inside Pipe Diameter or Nominal Pipe Diameter (inches)	Minimum Easement Width (feet)
96	32
108	36
120	40
132	44
144	48

8.12 RESOURCES

Documents

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7. FHWA, Design of Roadside Channels with Flexible Lining, HEC-15, 2005
8. FHWA, Hydraulic Design of Energy Dissipaters for Culverts and Channels, HEC-14, 2006
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10. King County, Surface Water Design Manual, King County, WA, 2016
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17. USDI-IWPR Air-Water Flow in Hydraulic Structures, U.S. Dept of Interior Water and Power Resources Service. Engineering Monograph No. 41. December 1980
18. USDI-IWPR, Hydraulic Design of Stilling Basins and Energy Dissipators, Engineering Monograph No. 25. USDI Water and Power Resources Service. May 1984
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22. SPU DR-02-06 (Requirements for Design and Construction of Service Drains)
23. SPU Wastewater System Plan, 2006