SEATTLE PUBLIC UTILITIES
2013 WATER SYSTEM PLAN

C. POLICIES, PROCEDURES AND STANDARDS

APPENDIX C-2

DESIGN STANDARDS AND GUIDELINES – WATER INFRASTRUCTURE

SPU Design Standards and Guidelines, Chapter 5

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Contents

Appendices

List of Figures

List of Tables

Chapter 5 WATER INFRASTRUCTURE

This chapter presents Design Standards and Guidelines (DSG) standards and guidelines for Seattle Public Utilities (SPU) water infrastructure. Standards appear as underlined text.

Facilities included here are transmission and distribution pipelines, storage tanks, standpipes, and reservoirs. The information in this chapter should be used in conjunction with other DSG standards. For water service connections, see *DSG Chapter 17*.

The primary audience for this chapter is Seattle Public Utilities (SPU) engineering staff.

Note: This DSG does not replace the experienced engineering judgment of a registered professional engineer. All design for upgrade, repairs, and new infrastructure should be done under the supervision of an experienced licensed engineer.

5.1 KEY TERMS

The abbreviations and definitions and given here follow either common American usage or regulatory guidance. Definitions for key elements of the SPU water system are given near the beginning of section for that element. For standard City of Seattle abbreviations for construction drawings, see section 1-01.2 of the City of Seattle Standard Plans.

5.1.1 Abbreviations

Abbreviation	Term
AC	asbestos concrete
ANSI	American National Standards Institute
AREMA	American Railway Engineering and Maintenance-of-Way Association
ASTM	American Society for Testing Materials
AWS	American Welding Society
AWWA	American Water Works Association
BNSF	Burlington Northern Santa Fe
CDF	controlled density fill
CI	cast iron
CIP	Capital Improvement Program
CSO	combined sewer overflow
DI	ductile iron
DIP	ductile iron pipe
DIPRA	Ductile-Iron Pipe Research Association
DOH	Department of Health
DPD	Department of Planning and Development
DV	district valve
ECA	environmentally critical area

Abbreviation	Term
fps	feet per second
ft	foot or feet
gpm	gallons per minute
HDD	horizontal directional drilling
HPA	Hydraulic Project Application
HPC	heterotrophic plate count
IBC	International Building Code
ID	inside diameter
LOB	line of business
mgd	million gallons per day
NACE	National Association of Corrosion Engineers
NPDES	National Pollution Discharge Elimination System
NSF	National Sanitation Foundation
O&M	operations and maintenance
OD	outside diameter
OSHA	Occupational Safety and Health Administration
PR	pressure regulating valve
PRV	pressure relief valve
psi	pounds per square inch
psig	pounds per square inch gauge
QA/QC	Quality assurance/quality control
RE	Resident Engineer
ROV	remotely operated vehicle
ROW	right-of-way
SCADA	Supervisory Control and Data Acquisition
SDOT	Seattle Department of Transportation
SDWA	Safe Drinking Water Act
SMT	Seattle Municipal Tower
Spec	specification
SPU	Seattle Public Utilities
Std	standard
TC	total coliform
USM	Utility Systems Management
WAC	Washington Administrative Code
WISHA	Washington Industrial Safety and Health Administration

5.1.2 Definitions

Term	Definition
anode	Location where metal is corroded.
cathodic protection	A means of providing a sacrificial material (usually a metal) to become the point where corrosion occurs. Cathodic protection is a technique used to provide corrosion control to buried or submerged metallic materials. Cathodic protection shifts the electrical potential off anodic sites in a pipeline or other structure. See also anode.
Capital Improvement Program (CIP)	Administered by SPU through its Capital Planning Committee (CPC) to plan, budget, schedule, and implement capital improvement projects, including flooding and conveyance improvements, protection and enhancement of water quality and habitat, protection of infrastructure, and drainage improvements within projects of other City agencies
Customer Service	The section within SPU through which customers purchase all new water services and receive notification of planned outages.
engineering	Generic term for SPU staff responsible for plan review and utility system design for CIP

Term	Definition
	projects.
guidelines	Advice for preparing an engineering design. Design guidelines document suggested minimum requirements and analysis of design elements in order to produce a coordinated set of design drawings, specifications, or life-cycle cost estimates. Guidelines answer what, why, when and how to apply design standards and the level of quality assurance required.
O&M	Generic term for SPU staff responsible for Field Operations and Maintenance.
resistivity	The resistance of an environment (either water or soil) to promote electrical current flow.
standards	Drawings, technical or material specifications, and minimum requirements needed to design a particular improvement. A design standard is adopted by the department and generally meets the 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.
Water Quality	A section within SPU that takes water samples and performs drinking water quality tests on new and existing water mains and inspects construction projects to assure pipe work is kept clean.

5.2 GENERAL INFORMATION

SPU water facilities supply water to more than 1.3 million people in the Seattle area, including wholesale customers (purveyors). The Tolt and Cedar watersheds supply most of the drinking water. The Seattle well fields serve as a supplemental water source during droughts and emergencies. Large transmission pipelines deliver water to treatment plants, and from the plants to in-town storage facilities such as tanks and reservoirs. Smaller water pipelines distribute water from in-town storage facilities to the public. Valves control water and isolate sections in the distribution mains, which are monitored by Supervisory Control and Data Acquisition (SCADA). Water services and fire hydrants are connected to distribution mains. Purveyors are connected to transmission mains.

In the SPU system, most water flows via gravity from the watersheds to storage facilities in Seattle. Storage facilities are set at high elevations to supply water via gravity to customers. Where necessary, pumps are used to lift water to higher elevation storage facilities or to increase water pressure. The system is managed by SPU Facility Operations and Maintenance and monitored through SCADA.

5.2.1 Policy

The guiding policy document for water infrastructure is the SPU 2007 Water System Plan. See Chapter 4 of the plan for SPU policy on water transmission. See Chapter 5 of the plan for SPU policy on water distribution.

5.2.2 System Maps

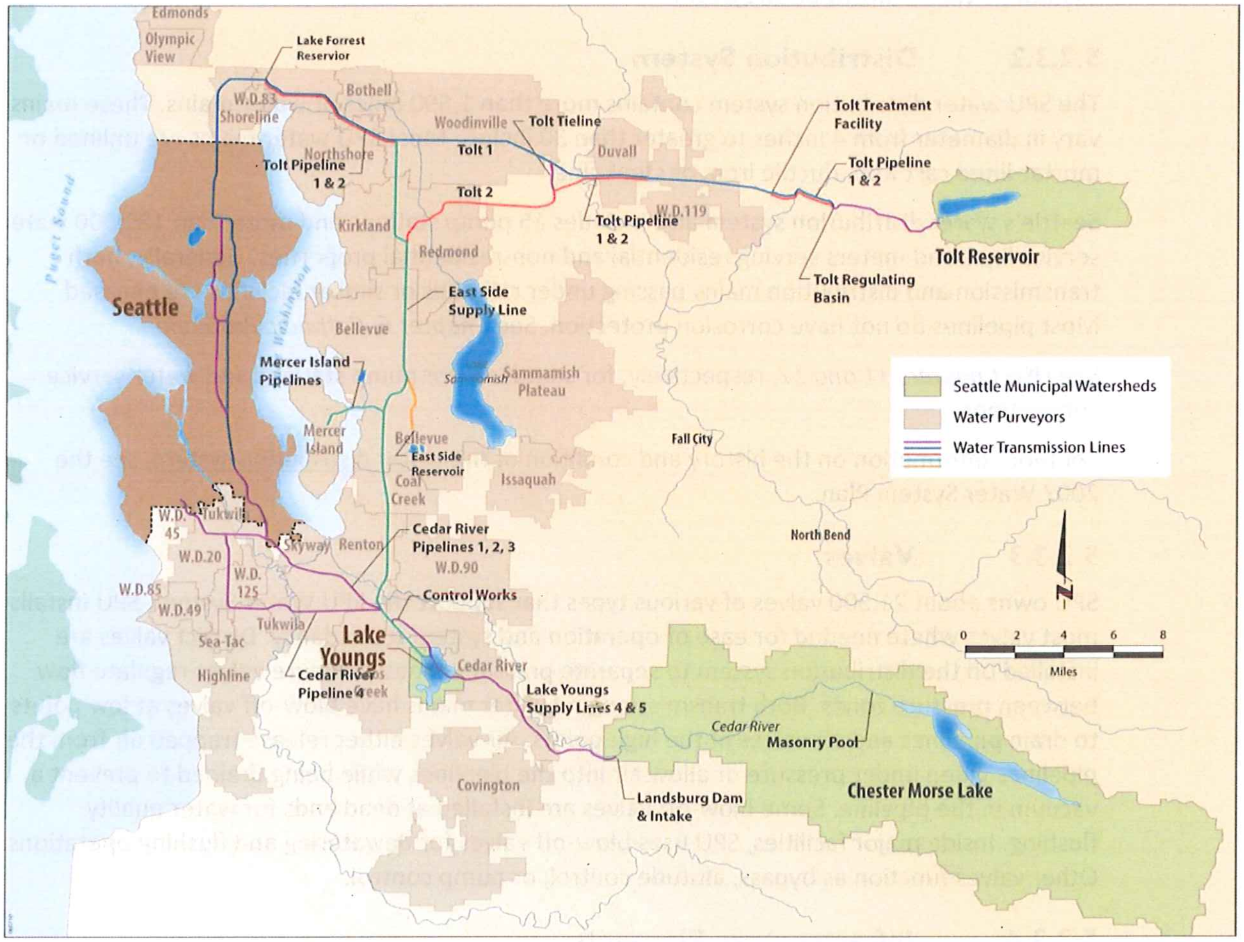
SPU's water maps are available at the following locations:

- Base Maps
- Customer Service Water GIS (software program). Contact SPU IT Service Desk
- Printed 400' Water System Map books
- SPU GIS Mapping Counter (SMT 47th floor)

5.2.3 Water System

The SPU Water System is comprised of transmission and distribution pipelines, and storage facilities and pressure zones. The system extends far beyond the Seattle city limits (Figure 5-1).

Figure 5-1
SPU Water Transmission System



5.2.3.1 Transmission System

The SPU regional and sub-regional water transmission system includes 189 miles of 16- to 96-inch steel, ductile iron or concrete pipeline. Some of the large transmission pipelines are the following:

- Lake Youngs supply lines 4 and 5
- Cedar River pipelines 1 through 4
- Tolt pipelines 1 and 2
- Eastside supply line
- Mercer Island pipeline
- West Seattle pipeline

The major supply transmission pipelines from the Cedar and Tolt sources deliver water to wholesale customer master meters and intertie locations, such as the City of Tukwila.

Transmission pipelines deliver water to various tanks, standpipes, and reservoirs throughout the system and on occasion directly to the distribution system. Twelve reservoirs and 14 tanks comprise the in-town storage facilities. Water from the in-town facilities is distributed to customers via the distribution system.

5.2.3.2 Distribution System

The SPU water distribution system contains more than 1,690 miles of water mains. These mains vary in diameter from 4 inches to greater than 30 inches. Most SPU water mains are unlined or mortar-lined cast iron, ductile iron, or steel pipe.

Seattle's water distribution system also includes 15 pump stations and more than 180,000 water service lines and meters serving residential and non-residential properties. Generally, both transmission and distribution mains passing under railroads or similar facilities are encased. Most pipelines do not have corrosion protection. See *Chapter 6, Cathodic Protection*.

See *DSG Chapters 11 and 17*, respectively, for standards for pump stations and water service connections.

For more information on the history and condition of the water distribution system, see the 2007 Water System Plan.

5.2.3.3 Valves

SPU owns about 21,500 valves of various types that support the SPU Water System. SPU installs most valves where needed for ease of operation and system redundancy. District valves are installed on the distribution system to separate pressure zones. Pressure valves regulate flow between pressure zones. Both transmission and water mains have blow-off valves at low points to drain pipelines and air valves at the high points. Air valves either release trapped air from the pipelines when under pressure or allow air into the pipelines while being drained to prevent a vacuum in the pipeline. Some blow-off valves are installed at dead ends for water quality flushing. Inside major facilities, SPU uses blow-off valves for dewatering and flushing operations. Other valves function as bypass, altitude control, or pump control.

5.2.3.4 Infrastructure Elements

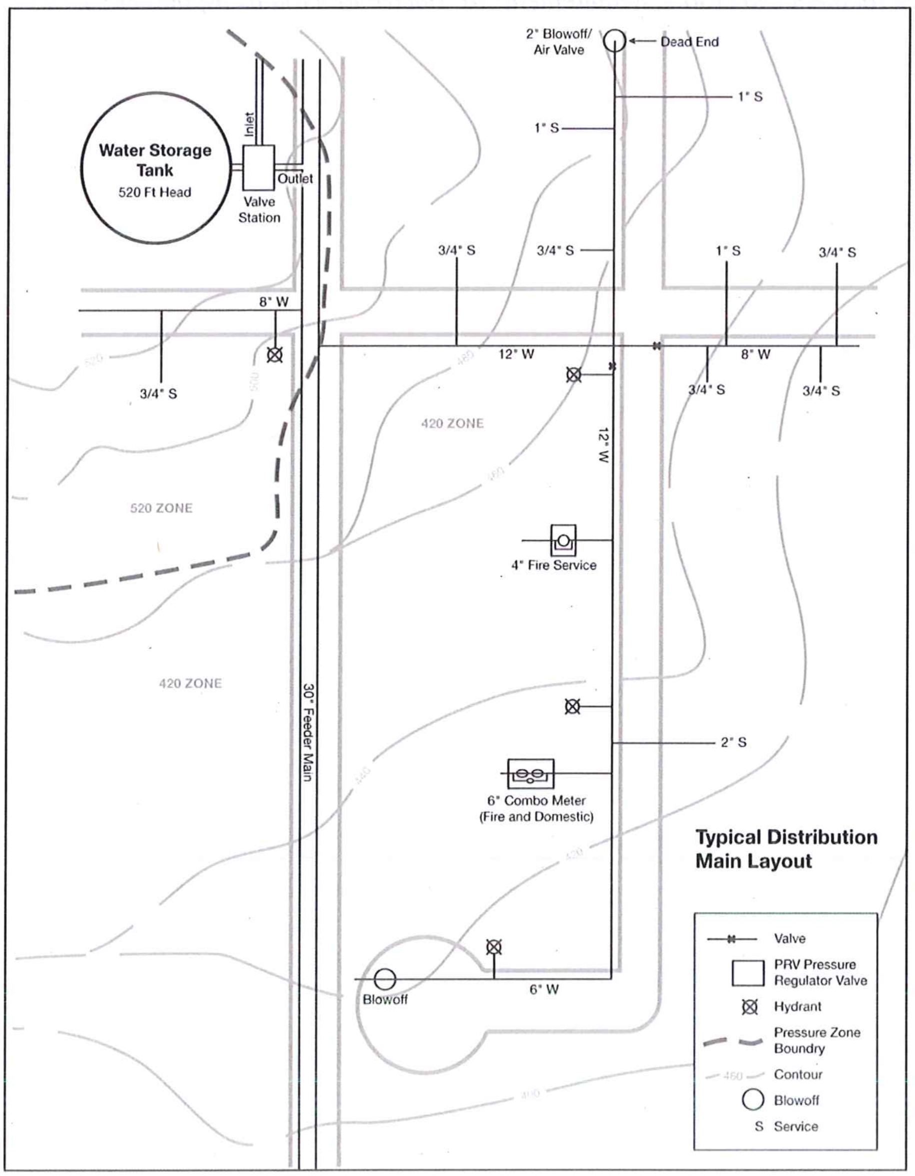
The following are key components in SPU water system infrastructure:

Infrastructure	Description
Water Main	
transmission main	Large diameter (generally >3 ft) pipeline that transfers water from source to feeder mains or storage tanks. There are no service connections on transmission lines, except for purveyors.
feeder main	Smaller diameter pipeline (generally <3 ft). The backbone of SPU distribution mains. Taps are allowed on feeder mains. Feeder mains may cross through multiple pressure zones. When crossing between zones, no services are allowed.
distribution main	Small to mid-sized pipeline (<2 ft) used to distribute water from a feeder main to a local service area. Distribution mains have service connections to adjacent properties.

Infrastructure	Description
Storage Facility	
standpipe	An aboveground, supported pipe with a height that is generally greater than the diameter. Used where additional height is needed to provide additional pressure without pumping.
reservoir	Tank that is at or below ground level with a diameter or footprint that is typically greater than the height. Reservoirs are usually large in size and storage capacity. SPU is currently covering all open reservoirs or will be removing them from service.
elevated tank	Elevated tanks have a supporting structure that elevates the lower operating elevation of water in the tank to a level above ground elevation.

Typical layout of SPU water system infrastructure is shown on Figure 5-2.

Figure 5-2
Typical Layout of SPU Water System Infrastructure



5.2.4 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, and other technical guidelines not available from other sources:

- **Drawings.** DSG standard drawings for an Access Port are in **Appendix A**:
  - DSG-5-01 24" Access port
  - DSG-5-02 24" Access port detail
- **Settlement Monitoring Requirements.** Settlement monitoring requirements for water mains are in Appendices B and C:
  - *Settlement Monitoring Requirements for Cast Iron Mains* (**Appendix B**)
  - *Settlement Monitoring Requirements for Ductile Iron Mains* (**Appendix C**)

5.3 GENERAL REQUIREMENTS

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

If industry standards and City of Seattle requirements or regulations conflict, the design engineer must discuss the discrepancy with the line-of-business (LOB) owner, Facilities Maintenance and Operations manager, specifier and the owner of this DSG chapter through the formal resolution process.

5.3.1 Industry Standards

Water facilities must be designed to American Water Works Association (AWWA) standards. In addition, water facilities must meet Seattle-King County and Washington State Department of Health (DOH) standards.

Water storage facility design standards for SPU must also meet standards set forth in the Water Research Foundation's Maintaining Water Quality in Finished Water Reservoir.

5.3.1.1 American Water Works Association

AWWA standards and specifications must be followed, except when superseded by more strict requirements set forth in this DSG and City of Seattle Standard Plans and Specifications.

Table 5-1 lists relevant AWWA standards and specifications, organized by subject and intended as minimum requirements. Most of the specifications listed below may be found in the SMT 45th floor library. It is the design engineer's responsibility to use the latest version of these standards.

Table 5-1
AWWA Standards and Specifications for SPU Water Facilities

Designation	Title
Ductile-Iron Pipe:	
C104/A21.4	Cement Mortar Lining for Ductile Iron (DI) Pipe and Fittings for Water
C116/A21.16	Protective Fusion-Bonded Epoxy Coatings Interior or Exterior Surface DI
C105/A21.5	Polyethylene Encasement for DI Pipe Systems
C111/A21.11	Rubber-Gasket Joints for DI Pressure Pipe and Fittings
C115/A21.5	Flanged DI Pipe with Ductile Iron or Gray Iron Threaded Flanges
C150/A21.50	Thickness Design of Ductile Iron Pipe
C151/A21.51	DI Pipe; Centrifugally Cast, for Water or Other Liquids
C153/A21.53	DI Pipe; Compact Fittings for Water Service
Steel Pipe	
C200	Steel Water Pipe 6" and larger
C207	Steel Pipe Flanges for Waterworks Service Sizes 4"-144"
C216	Heat-Shrinkable Cross-Linked Polyolefin Coatings for the Exterior of Special Sections, Connections and Fittings for Steel Water Pipes
C206	Field Welding of Steel Water Pipe
C215	Extruded Polyolefin Coatings for the Exterior of Steel Water Pipelines
C217	Petrolatum and Petroleum Wax Tape Coatings for the Exterior of Connections and Fittings for Steel Water Pipelines
C210	Liquid-Epoxy Coating Systems for the Interior and Exterior of Steel Water Pipelines
C225	Fused Polyolefin Coating Systems for the Exterior of Steel Water Pipelines
C223	Fabricated Steel and Stainless Steel Tapping Sleeves

Designation	Title
C203	Coal-Tar Protective Coatings and Linings for Steel Water Pipelines, Enamel and Tape, Hot-Applied
C205	Cement-Mortar Protective Lining and Coating for Steel Water Pipe, 4" and Larger, Shop Applied
C208	Dimensions for Fabricated Steel Water Pipe Fittings
C213	Fusion-Bonded Epoxy Coating for the Interior and Exterior of Steel Water Pipelines
C218	Coating the Exterior of Aboveground Steel Water Pipelines and Fittings
C219	Bolted, Sleeve-Type Couplings for Plain-End Pipe
C220	Stainless-Steel Pipe, ½" and Larger
C221	Fabricated Steel Mechanical Slip-Type Expansion Joints
C222	Polyurethane Coatings for the Interior and Exterior of Steel Water Pipe and Fittings
C224	Nylon-11 Based Polyamide Coating System for the Interior and Exterior of Steel Water Pipe and Fittings
C226	Stainless Steel Fittings for Waterworks Service, Sizes ½"-72"
Valves/ Hydrants:	
C517	Resilient-Seated Cast-Iron Eccentric Plug Valves
C512	Air Release, Air/Vacuum, and Combination Air Valves for Waterworks Service
C561	Fabricated Stainless Steel Slide Gates
C563	Fabricated Composite Slide Gates
C560	Cast-Iron Slide Gates
C502	Dry-Barrel Fire Hydrants
C504	Rubber-Seated Butterfly Valves
C507	Ball Valves, 6"- 48"
C508	Swing-Check Valves for Waterworks Service, 2"- 24" National Pipe Size (NPS)
C509	Resilient-Seated Gate Valves for Water Supply ductile iron only
C510	Double Check Valve Backflow Prevention Assembly
C511	Reduced-Pressure Principle Backflow Prevention Assembly
C513	Open-Channel, Fabricated-Metal, Slide Gates and Open-Channel, Fabricated-Metal Weir Gates
C515	Reduced-Wall, Resilient-Seated Gate Valves for Water Supply Service (Does not meet City Spec, but can be used in special cases)
C540	Power-Actuating Devices for Valves and Slide Gates
C550	Protective Epoxy Interior Coatings for Valves and Hydrants
Pipe Installation:	
C600	Installation of Ductile-Iron Water Mains and Their Appurtenances
C602	Cement-Mortar Lining of Water Pipelines in Place—4" and Larger
C606	Grooved and Shouldered Joints
Disinfection	
C651	Disinfecting Water Mains
C652	Disinfection of Water-Storage Facilities
Storage	
D104	Automatically Controlled, Impressed-Current Cathodic Protection for the Interior of Steel Water Tanks
D110	Wire- and Strand-Wound, Circular, Pre-stressed Concrete Water Tanks
D100	Welded Carbon Steel Tanks for Water Storage
D102	Coating Steel Water-Storage Tanks
D103	Factory-Coated Bolted Steel Tanks for Water Storage
D115	Tendon-Pre-stressed Concrete Water Tanks
D120	Thermosetting Fiberglass-Reinforced Plastic Tanks
D130	Flexible-Membrane Materials for Potable Water Applications

Table 5-2 lists relevant AWWA design manuals for water supply practice. The list is not inclusive. Some of these manuals are available on SMT 45th floor. The manuals most frequently used by SPU are M11 (Steel Pipe Design), M41 (Ductile Iron Pipe Design) and M22 (Sizing Water Service Lines and Meters).

Table 5-2
AWWA Design Manuals for Water Supply Practice

Designation	Title
M1	Principles of Water Rates, Fees and Charges
M2	Instrumentation and Control
M3	Safety Practices for Water Utilities
M4	Water Fluoridation Principles and Practices
M5	Water Utility Management
M6	Water Meters: Selection, Installation, Testing, and Maintenance
M7	Problem Organisms in Water: Identification and Treatment
M9	Concrete Pressure Pipe
M11	Steel Water Pipe: A Guide for Design and Installation
M12	Simplified Procedures for Water Examination
M14	Recommended Practice for Backflow Prevention and Cross-Connection Control
M17	Installation, Field Testing, and Maintenance of Fire Hydrants
M19	Emergency Planning for Water Utilities
M20	Water Chlorination/Chloramination Practices and Principles
M22	Sizing Water Service Lines and Meters
M25	Flexible-Membrane Covers and Linings for Potable-Water Reservoirs
M27	External Corrosion: Introduction to Chemistry and Control
M28	Rehabilitation of Water Mains
M29	Water Utility Capital Financing
M31	Distribution System Requirements for Fire Protection
M32	Computer Modeling of Water Distribution Systems
M33	Flow meters in Water Supply
M36	Water Audits and Leak Detection
M41	Ductile Iron Pipe Fittings
M42	Steel Water-Storage Tanks
M44	Distribution Valves: Selection, Installation, Field Testing, and Maintenance
M48	Waterborne Pathogens
M49	Butterfly Valves: Torque, Head Loss, and Cavitation Analysis
M51	Air-Release, Air/Vacuum, and Combination Air Valves
M52	Water Conservation Programs-- Planning Manual
M55	PE Pipe--Design and Installation

5.3.2 Regulations

All water facilities must be built to the applicable City of Seattle, King County, Washington State and federal guidelines.

5.3.2.1 City Standards

The City of Seattle Standard Plans and Specifications are available online or from the Engineering Records Vault. The sections that apply to water systems are Standard Specifications

Sections 7 and 9, and Details Section 300. These standards are primarily based on AWWA industry standards.

5.3.2.2 King County

All water system works are subject to the provisions and requirements of Title 12 of the King County Board of Health Code.

5.3.2.3 Washington State Department of Health

The Washington State Department of Health (DOH) is the regulatory agency that ensures that water systems comply with system capacity requirements of the federal Safe Drinking Water Act (SDWA). Authority to regulate the public water supply system is granted under Washington Administrative Code (WAC), Chapter 246-290 "Public Water Supplies," also known as the Public Water System Rule. A key term under the rule is *system capacity*, which is defined as having the technical, managerial, and financial capacity to achieve and remain in compliance with all applicable local, state and federal regulations.

A. Water System Plan

The public water system rule (WAC 246-290) includes the Washington State Legislature-approved Municipal Water Law and the federal law, Long Term 2 Enhanced Surface Water Treatment Rule. DOH requires water purveyors to submit a Water System Plan to ensure water quality and protection of public health (WAC 246-290-100 and WAC 246-291-140, respectively). SPU's Water System Plan was last updated in 2007.

Water systems plans must be updated every 6 years. If a purveyor installs distribution lines or makes other improvements and the project requires State Environmental Protection Act (SEPA) analysis, a water system plan amendment is required (WAC 246-03-030[3][a]) before construction.

B. Water System Design Manual

The Washington State DOH Water System Design Manual (December 2009) provides guidelines and criteria for design engineers to use for preparing plans and specifications for Group A water systems, such as SPU, to comply with the Group A Public Water Supplies (chapter 246-290-WAC). This manual delineates mandatory requirements of the WAC that must be adhered to by SPU. Design engineers may use design approaches other than those in this manual as long as they do not conflict with chapter 246-290 WAC. DOH will expect the design engineer to justify the alternate approach used and the criteria that apply.

5.3.2.4 Other

Recommended Standards for Water Works (10-States Standards) – Part 7, Finished Water Storage is a source for water storage design.

5.3.2.5 Federal Safe Drinking Water Act

The Safe Drinking Water Act (SDWA) protects public health by regulating the nation's public drinking water supply. The law requires many actions to protect drinking water and its sources. SDWA does not regulate private wells that serve fewer than 25 individuals. SDWA authorizes the

U.S. Environmental Protection Agency (EPA) to set national health-based standards for drinking water to protect against both naturally-occurring and man-made contaminants.

5.4 BASIS OF DESIGN

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

5.4.1 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 5-3). The following are SPU standards for this sheet:

- <u>The design engineer must include a basis-of-design plan sheet in the plan set</u>.
- <u>The sheet must be archived with the record drawings (as-builts).</u>

Figure 5-3
Basis-of-Design Plan Sheet Data for Water Infrastructure

Basis-Of-Design Plan Sheet

WATER---
Type of Main (Transmission, Distribution, Feeder)
Design Flow Rate: ____________________
Flow Velocity: __________________________
Typical Pressure: _____________________ Pressure Zone(s):________________________
Working Pressure: ____________________ Surge Pressure: _________________________
Pipe Materials:
____
(type, lining, coating, joints, pressure class minimum slope, buoyancy safety factor, minimum cover [roads, non-roadway], deflection lag factor, construction tolerance, steel deflection limit)
Bedding Compaction:
____
(roadway, non-roadway, bedding constant, modulus of soil reaction [E'])
Appurtenances:
____
(isolation valves, blow-offs/drains, line valves, air-vacuum and air-release valves, valve limit settings for control valves, design criteria for all valves)
Access Ports:
________________________________Datum:___________________________________
Basis of HVAC Design:____
Basis of Process Control:____
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 sheet is inserted after the project has begun. See *DSG Chapter 1, Design Process*.

5.4.2 Design Criteria List

The design engineer may 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 5-2). For water system infrastructure, this information includes how key design criteria were selected, including working pressure, flow rate, and types of joints.

The list shows information that may be shown on the basis-of-design plan sheet. However, the list 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 5-3 is an example of what a design criteria list might contain for a water facility design.

Note: Table 5-3 is only an example. It is not intended to explain technical concepts.

Table 5-3
Design Criteria List for a Typical Water Facility Design (Example)

Description	Design Criterion/Design Data	Comments
General:		
Design Flow Rate	19,100 gpm (27.5 mgd)	Year 2040 peak flow rate in a 36-inch pipeline
Flow Velocity	6.02 fps	Year 2040 peak flow rate in a 36-inch pipeline
Typical Operating Pressure	120-180 psi	
Design Working Pressure, Pw	250 psi	
Design Transient (Surge) Pressure, Pt	332 psi	Based on 133% of working pressure and allowable stress of 66.7% of yield stress
Minimum D/t ratio	240	
Pipe Materials:		
Pipe Type	Mortar-Lined and Polyurethane Coated Welded Steel Pipe, AWWA C200	
Lining	Cement Mortar, AWWA C205	
Coating	Polyurethane Coated, AWWA C222	
Joints	Restrained Joint	Double lap-welded joint provides thrust restraint at bends, seal testing, and seismic restraint. Maximum joint length and resulting joint location is 60 ft. for steel pipe. Consider thermal expansion and fittings to allow movement, specifically with exposed pipe. Example: pip supported by hangers under bridges.
Pressure Class	250 psi	40,000 psi yield strength steel
Minimum Slope	0.001	
Pipe Buoyancy Safety Factor	1.1	
Minimum Cover – Roads	3 ft	
Minimum Cover – Non-Roadway	4 ft	
Pipe Loading – Traffic	HS-20 AASHTO	
Traffic – Trench Condition	HS-20 AASHTO "Prism Trench" design condition assumed	
Separation from Utilities	12 inch vertical, 10 ft horizontal	See Std Plan 286
Deflection Lag Factor, Dl	Minimum 1.25	
Construction Tolerance	½-inch from specified line and grade	Tolerances during tunneling higher as specified
Steel Deflection Limit	2.25% of Diameter	
Bedding Compaction – Non-Roadway	90% of Modified Proctor	
Bedding Compaction – Roadway	95% of Modified Proctor	
Bedding Constant	0.10	
Modulus of Soil Reaction (E')	700 psi	See Geotechnical Report
Appurtenances:		
Isolation Valves	Butterfly Valves, 250 psi rating	Located at tie-ins and interties to existing mains
Blow-offs/drains	6-inch size. Provide at all low points in pipeline	Used double valves, one for isolation and one for throttling.
Line Valves	2,000 ft	
Combination Air-Vacuum and Air Release Valves	4-inch size. Provide at all high points in pipeline	Also located at abrupt downward grade breaks

Description	Design Criterion/Design Data	Comments
Access Ports	24-inch	Located every 1,000 feet along pipeline and at both ends of tunneled crossings

5.5 DESIGN PROCESS

See *DSG Chapter 1, Design Process*. The design process for water infrastructure does not differ from that described in Chapter 1.

5.6 DISTRIBUTION AND FEEDER MAIN DESIGN

This section describes distribution and feeder main design. Distribution mains are smaller diameter (<3ft) pipes that carry water from a source (reservoir or tank) to a local service area (neighborhood or city block). Feeder mains are similar to transmission mains except that service connections are allowed.

5.6.1 Modeling and Main Sizing

When designing a water main that is 12 inches of larger in diameter, a hydraulic network modeling analysis must be completed (for sizing minimum sizing criteria see Section 5.6.3.1). SPU Utilities System Management (USM) maintains the models of the water distribution and transmission system and works with SPU engineering on modeling analyses. The modeling analysis will determine the capacity of the main to provide peak hourly demand and fire flow. In some cases, field hydrant flow tests will be required to verify modeling results.

5.6.1.1 Pressure Zones

The SPU water distribution system is divided into approximately 45 pressures zones that operate within a pressure range of about 30 to 130 psi. Individual zones are separated by closed line valves (district valves or DVs), pressure regulators, and control valves. Pressure zone boundaries are shown in the 400-foot map books and in GIS. USM specifies the pressure zone to which new water mains and service connections will be added.

5.6.1.2 Maximum and Minimum System Pressure

SPU Policy on Distribution System Water Service Pressure (SPU-RM-006) establishes SPU's pressure standards. Minimum pressure criteria for new water mains are 30 pounds per square inch (si) under peak hour demand (PHD) conditions, and 20 psi when flows are a combination of average maximum day demand (MDD) and required fire flow. In no cases shall pressure at the customer's meter be less than 20 psi. Pressures within distribution mains are not limited to a set maximum. All new services with static pressure above 80 pis require a pressure reducing valve (PRV) per plumbing code requirements.

5.6.1.3 Fire Flow Rate and Duration

The City of Seattle, City of Shoreline and King County have adopted the International Fire Code (IFC). Site specific fire flow requirements as determined by the appropriate Fire Marshall are used when issuing Water Availability Certificates and sizing of new water mains.

5.6.2 Location

Distribution mains are typically located within the right-of-way (ROW) in a standard location at a standard depth. See City of Seattle Standard Plan 030. Standard locations allow Field Operations and Maintenance to easily access the mains while keeping the ROW available to other utilities. SPU does not allow build-overs on water mains.

SPU may install or allow installation of water mains in private streets or easements. Location of the mains is determined case-by-case in easements less than 20 feet.

5.6.2.1 Separation from Other Utilities

Standard horizontal and vertical separations may not always be feasible in highly developed urban corridors. Special construction methods can be used to provide equivalent levels of protection to the standard separation criteria. Separation distances to provide structurally sound installations depend on the available working space for construction and soils and groundwater conditions at the site. See Standard Plans 286A and 286B.

For height, the design engineer must look for overhead power and maintain a safe distance to the power lines and structures. The distance depends on the power line voltage and the distance to a structure. Consult with the electrical utility to determine the project-specific safety distances and with the Department of Planning and Development (DPD) for any structural permit requirements.

Where standard pipeline separations cannot be achieved, an engineered design must be developed for adequate separation. The Washington State Departments of Health and Ecology jointly publish the Pipeline Separation Design and Installation Reference Guide. The design engineer must use this guide to design pipeline separations whenever standard SPU criteria are not feasible.

5.6.2.2 Geotechnical Investigations and Test Holes

Geotechnical (subsurface) investigations and test holes are typically not as critical for distribution lines as they are for transmission mains. The design engineer must review DSG section 5.8.2.2 (Geotechnical Report) and consider the necessity of subsurface information for the project.

5.6.2.3 Alternative Locations

For some projects, space may not be available to locate the water main in the standard location shown on Standard Plan 030. Other controlling factors such as water supply require that an existing water main be kept in service while a new main is installed in a non-standard location.

5.6.3 Materials

This section describes standard materials used in SPU water distribution system projects.

5.6.3.1 Minimum Pipe Size

The standard water distribution main size is:

- 8-inch-diameter pipe for residential areas
- 12-inch diameter pipe for industrial and commercial areas

Dead-end distribution mains typically include fire hydrants and must be at least 8-inches in diameter. Typically, feeder mains are 16- to 30-inch diameter pipes. Some SPU feeder mains are more than 30 inches in diameter. Pipes more than 30 inches in diameter must not have service connections.

5.6.3.2 Material Types

All new or replaced water pipe in the City of Seattle must meet the standard material types shown in Table 5-4.

Table 5-4
Standard Materials for SPU Distribution and Feeder Mains

Structure	Material
Pipe	• 2-inch diameter pipe must be Type K copper (when allowed by SPU). • 4-inch diameter and larger pipe must be ductile iron pipe, class 52 or thicker, cement lined-double thickness. • Feeder mains larger than 20-inch diameter must be ductile iron or steel.
Bends and Fittings	• Typically, bends and fittings must be the same material as the pipeline. • Fittings for 2-inch copper soft coil must be brass, either flared or compression.
Joints	• Joints for ductile iron water mains must be restrained joint, slip joint, or mechanical joint. • Joints on steel casing pipe must be welded and conform to AWS D1.1 Structural Welding Code, Section 3, Workmanship.
Casing	• Whether installed above- or below-grade, casing pipe must be smooth steel, with the diameter and wall thickness specified in the drawings. • All joints must be welded by qualified operators. Steel casing pipe is discussed in Std Spec 9-30.2. • Casing seals and spacers must be per Std Spec 9-30(15). • If specified in the contract, the space between the carrier pipe and casing pipe must be filled with sand, grout, or some other material.

Non-standard mains less than 8 inches in diameter and approved by SPU, must be ductile iron, except for 2-inch pipe, which must be Type K copper.

5.6.3.3 Pipe Cover

Depths of cover for water mains are shown on Standard Plan No. 030. The depths vary depending on size of pipe. Mains larger than 12 inches in diameter typically use butterfly valves. Butterfly valves require less cover due to their shape and allow large mains to be buried at shallower depths. Generally, SPU attempts to bury the pipes as shallow as feasible for ease of installation and maintenance, but no less than 35 inches deep except in special cases as directed by SPU. The depth to the pipe invert should be kept to less than 6 feet to reduce the need and cost for excavation and shoring.

5.6.3.4 Bedding and Backfill

The design engineer must require sand bedding for water mains unless another agency dictates otherwise. Sand bedding creates a less corrosive environment around a pipe than does native soil. Sand bedding also eliminates point loads on the pipe caused by stray rocks. Sand bedding is typically Class B, Sand Mineral Aggregate Type 6 or 7 unless otherwise specified. *Note: Type 9 is for transmission mains.*

Backfill is either suitable native material, Mineral Aggregate Type 17, or other material as approved by the design engineer. For suitable native backfill material, see Standard Specification 7-10.3(10) for requirements. For requirements for Mineral Aggregate Type 17, see Standard Specification 9-03.16.

For more information on bedding and backfill, see Standard Specifications 7-10.3(9), 9 03.12(3) and 9-03.16.

A. Standard Trench Section

For requirements for a standard trench section, see Standard Plan 350.

B. Controlled Density Fill

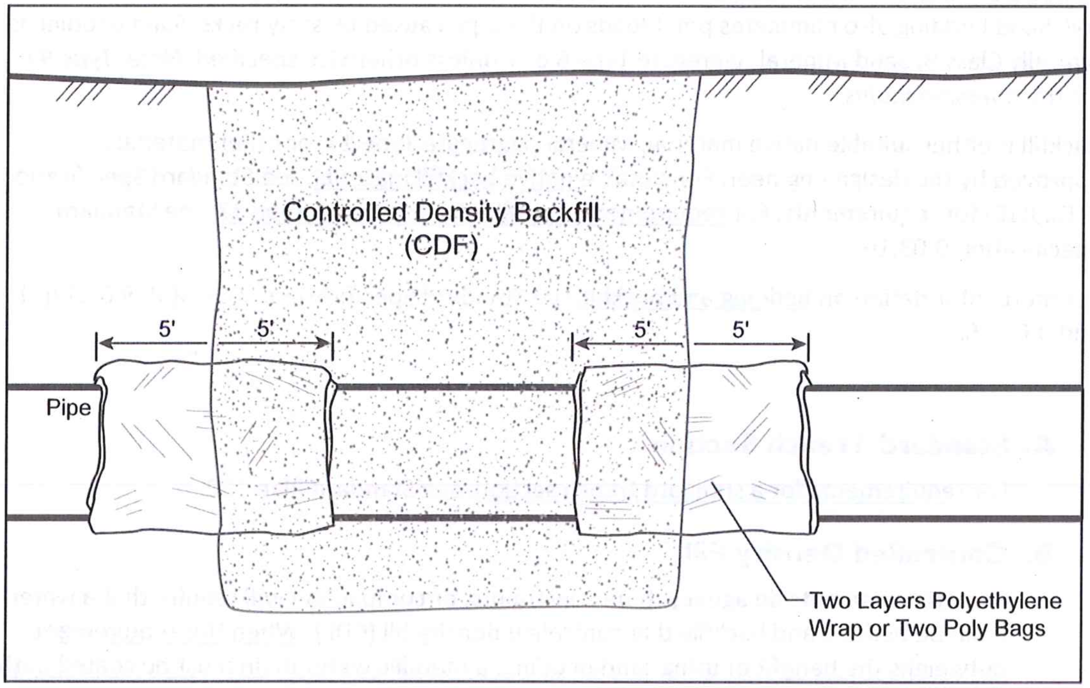
Sometimes an outside agency, time constraints, or compaction will require that a water main be bedded and backfilled in controlled density fill (CDF). When this requirement outweighs the benefit of using sand bedding, a metallic water main must be coated both where embedded in CDF and for some distance beyond the CDF encasement. Typically, SPU uses either two layers of 5-foot-wide visqueen or two polyethylene bags over the main to keep it separated from the CDF (Figure 5-4).

When CDF is used near the metallic pipe, a corrosion specialist should be consulted because CDF can create a corrosion cell.

The CDF used to encase the water main must be the weaker (diggable) CDF mix. All CDF must be ⅓ sack mix, less than 200 psi, and preferably less than100 psi. SPU has approved various types and uses of CDF. CDF can be used as a trench plug, trench backfill, or for grouting an annular space. Each use has a different mix ratio. The design engineer must reference the City Standard Plans and Specifications for each CDF use. See Standard Specification 9-01.5.

When CDF is used to fill pipe and the annular space between two pipes, it must have 100 psi strength at 28 days. See Standard Specification 9-05.15.

Figure 5-4
Controlled Density Fill



5.6.3.5 Line Pressure

Distribution water mains must be designed to withstand both external loads and test pressure according to Standard Specification 7-11.3(11)A1.

Most distribution lines serve a portion of the city, and are within a designated pressure zone. In cases where there is an extreme pressure differential (e.g. downhill pipeline), it may be advisable to change material thicknesses along the pipeline route and/or install a pressure reducing valve. Test pressure is measured at the downhill end of the pipe run. Before considering installation of a pressure reducing valve, the design engineer must coordinate with USM to ensure the valve will not negatively affect the system.

If a pressure regulating valve (PR) is used, an emergency pressure relief (PRV) must be installed and set to relieve pressure at 80 psi or maximum zone pressure.

Note: Some current City zones have pressures up to about 120 psi. These zones lie at the bottom of steep hillside areas. If the site is steep, do not put a PRV where it might cause unstable soil conditions (i.e. landslides).

Tip: *It is best to install both PRVs and PRs at the lowest point possible. However, sites in environmentally critical areas (ECAs) may not allow for that.*

5.6.3.6 Pipe Supports

A licensed civil or structural engineer must design the pipe supports and review pipe loads and potential deflections caused by lateral and vertical movement. AWWA M11 (Steel Pipe Design) and AWWA M41 (Ductile Iron Pipe Design) manuals provide some explanation on how to properly design pipes on supports. The Ductile Iron Pipe Research Association (DIPRA) also publishes a computer program for selecting supports and spacing of ductile iron pipes.

A. Pile Supports

Pile supported pipelines are rare in the SPU water system. However, in some locations, such as crossing a wetland or in loose soils, pile-supported pipelines may be necessary. A licensed civil or structural engineer must design the pile support and calculate pipeline thickness. Because pipelines installed on piles are typically not continuously supported, they present unique design challenges. Among the issues are additional stresses placed on the pipeline due to the lack of support. Such design issues must be investigated and modeled by a licensed structural engineer.

i Above Grade Pile Support

For an above-grade exposed pile support, the design engineer should consider the pipeline and pile coating system. In most cases, both the pile and pipe will require a coating, and cathodic protection must be considered. Additionally, pipeline insulation may be needed to protect the line from freezing temperatures and in no-flow situations.

ii Buried Support

If the pipeline is on piles and buried, a qualified licensed civil or structural engineer must carefully review the connection to the piles to ensure the pipe and piles operate as one entity during seismic and uplift conditions.

B. Aerial/Bridge Supports

SPU owns and operates a few aerial (aboveground) pipelines in its water system. A structural engineer licensed in Washington State should be involved in aerial pipeline design. Like pipelines on piles, aerial pipelines are not continuously supported, and therefore present unique design challenges.

Aerial pipelines can either be supported from above, by hanging the pipe, or cradled in a utility corridor under the bridge. In either case, the pipe supports place additional loadings on the pipe wall.

The following are special considerations for aerial design:

- Where possible, aerial pipelines should be avoided for security and vibration concerns.
- When pipes are hung under existing bridges, roadway clearance design must consider the potential for damage from trucks traveling above the legal height limit. Additional protection should be considered such as line valves or structural modifications to the bridge.
- With an exposed pipe design, the design engineer must consider the pipeline coating system. Additionally, pipeline insulation may be needed to help control thermal expansion of the pipeline, and keep the line from freezing temperatures and no flow situations. AWWA Manual M11 provides an analysis method to determine if freezing is a concern.

- The design engineer must carefully review the buried-to-aerial transition to ensure the pipeline will be able to handle ground movement from earthquakes. In most cases, a restrained joint with both rotational and expansion capabilities (e.g. a double ball expansion joint fitting) is recommended. See also DSG section 5.8.4, Seismic Design.

- Freeze protection design must be considered. Potential options include one or more of the following:

  1. Insulation of the pipe;

  2. Heat tape.

  3. In case of a temporary change in the way the pipe is used resulting in low flows consider installation of a system to allow a release of a small volume of water to a location that does not cause an environmental impact or safety hazards

C. Temporary Supports during Construction

Supporting existing utilities during construction can be difficult, but is necessary to ensure no damage occurs to the existing pipelines. Typically, the construction contractor is responsible for supporting all existing utilities throughout construction. The contractor must provide a support plan that is stamped by a Professional Engineer licensed in Washington State. SPU engineering and Field Operations and Maintenance will review temporary supports in the field and notify the contractor of deficiencies. SPU Water Operations staff does not direct repairs.

The following is a list of cautions contractors must take to avoid damage to pipelines:

- Contractors must not use chains to move or support any pipe materials because it will damage the pipeline.
- Contractors must not rest the pipe on any sharp or pointed objects, including the bucket of any equipment, single point supports, or rods.
- Pipelines must not be unsupported for a length longer than one stick of pipe or one joint.
- If the joints are not restrained, the contractor must ensure crew safety by restraining the pipe from movement, which could separate the joints.
- Pipelines must be supported in cradles or on wide support beams sufficiently spaced so the pipeline does not sag and cause undue stress on the joints or pipeline wall. This is especially important for cast iron with lead joints.
- Do not expose more than one unrestrained joint.
- Lead joint cast iron water mains must not be allowed to deflect while they are exposed.

5.6.3.7 Casing

Water mains are installed in casings to protect the mains from excessive loads and to provide a means of replacing the pipe beneath structures such as rail road tracks. Casings also reduce the damage to facilities over the water main in the event of a leak or main break. Sometimes casings are required by other entities (e.g. railroads) where SPU utilities cross over or under them. Casings can be installed via open cut if there are no obstacles.

Casing materials must follow Standard Specifications 9-30.2 (14) and 9-30.2(15).

A. Jacked Casings

Casings installed under the railroad are often jacked into place. When designing jacked casings, adequate space is required for the casing and pipe jacking pit. Jacking pit size can vary depending on the lengths of casing or pipe. Restrained joint pipe must be used through the casing and beyond to a logical location to terminate the restrained joint pipe. Keep in mind that the cased length of pipe offers no thrust resistance via skin friction as does a buried pipe. Access must be provided for the pipe to be cut and connected to a new pipe. SPU preference is to have the jacking pit located on each side of the casing.

Note: *Jacking casing is dependent on pipe size. The larger the pipe size, the larger the jacking pit is. Keep the casing as far as practical from the other utilities to allow future access for pipe removal.*

B. Other Utility Crossings

The design engineer must determine where casings are needed at locations where an SPU transmission main is crossing either over or under other utilities. For separation requirements between water mains and other utilities, see Standard Plans 286A and 286B. All pipes in casings must be restrained joint. See Standard Specifications 7-11 3(6)D and 7-11.3(7)C-D2.

C. Railroad Crossings

Where water mains cross under a rail system (e.g. street car, light or heavy rail, or other as determined by SPU), the main must be placed inside a casing. The casing must extend such a distance from the tracks that maintenance can be performed from the side without affecting the rail. For cathodic protection for pipes crossing a rail line, see *DSG Chapter 6, Cathodic Protection,* Test Procedure (TP) 31 – Light Rail and Street Car Cooperative Interference Testing.

i Heavy Rail

- When crossing beneath heavy rail, a casing must extend from ROW line to ROW line unless the main is more than 25 feet from the track centerline. If the railroad agrees, the casing must extend a minimum of 25 feet from the track centerline. See the American Railway Engineering and Maintenance-of-Way Association (AREMA) Design Guideline before designing a heavy rail crossing.
- Pipelines parallel to heavy rail must be encased if they are 40 feet or less from the track centerline.

ii Light Rail

Light rail does not impose the extreme loading on pipelines that heavy rail does. However, light rail imparts some loading and causes significant pipeline access issues and stray current corrosion concerns.

Water mains crossing beneath Sound Transit Central Link light rail tracks are encased a minimum distance of 12 feet perpendicular to the centerline of the track. The tracks have a 5.5 foot minimum separation between the top of the rail and the top of the casing. See the Sound Transit Design Criteria Manual.

Casings crossing a light rail line must be electrically isolated from the carrier pipe. A permanent test station should be installed to perform future isolation checks. See *DSG Chapter 6, Cathodic Protection*, Test Procedure (TP) 31 – Light Rail and Street Car Cooperative Interference Testing.

iii Street Car

The presently used street car designs have the least impact on buried pipelines of the three types of rail. Street cars are smaller and lighter, but still limit pipeline access and generate stray current.

The design engineer must consider depth of cover, pipeline size, age, thickness, material, importance, and access.

The design engineer should consider various pipeline protection methods ranging from do nothing to casings and protective concrete slabs.

D. Parallel Rail Installations

For worker safety, parallel mains should not be closer than 15 feet from the rail center line. However, rail installation will likely have to be considered case by case.

5.6.3.8 Permanent Restraint Systems

Restraining of forces due to internal pressure at fittings, valves, or dead ends is a major consideration in pipe installation. Thrust restraint is by welded or mechanically restrained joints or poured in place concrete thrust blocks depending on pipe size and type.

All bends, fittings, and line valves must be restrained by a joint restraint system compatible with the pipe type.

A. Thrust Restraint Calculations

For all projects requiring thrust restraints beyond that required by Standard Plans 330a, 330b, 331a, and 331b, the design engineer must calculate the thrust restraint.

Restrained joint pipe is self-restrained. The restrained length for pipe and fittings depends on the test pressure, backfill, depth, soil characteristics and pipe coating. The design engineer must calculate the restrained length for both pipe and fittings.

B. Connecting to the Existing System

In the SPU water system, most connections to existing (non-steel pipe) are unrestrained. A difference in outside diameters of various materials can create a force imbalance at the connection similar to that of a reducer.

For example, a 100-year-old cast iron, 20-inch-diameter water main could be ½-inch greater in outside diameter than a new 20-inch-diameter ductile iron main. This force imbalance must be accounted for at the connection, especially if corrosion preventative isolation couplings are used to make the connection. At 100 psi, this difference in outside diameter creates a force imbalance of more than 3,000 lbs in a 20-inch-diameter pipe connection. The connection coupling can be restrained by using tie-backs, wedge restraint glands, or welded tabs on the smaller pipe, or some combination. The idea is to keep the connection coupling from sliding off the larger pipe and onto the smaller pipe due to the force imbalance.

Be very careful with restraint for new valves near connections to existing pipe, especially when new restrained joint pipe is connected with unrestrained pipe. When closed and under pressure only from the existing side, the valve will tend to collapse the new flexible restrained joints and pull away from the unrestrained connection. This effect is usually overcome with a concrete thrust collar on the new pipe that is fixed rigidly to the new valve.

5.6.3.9 Types of Pipe Restraints

This section describes the types of pipe restraints used in the SPU water distribution system. Typically, ductile iron pipe is joined by a non-restrained bell and spigot joint. Some steel pipe is also joined in this manner. Thrust blocks are the SPU standard for restraining pipe when non-restrained bell and spigot joints are used. The design engineer should use Standard Plans 330A, 330B, 331A, and 331A and the AWWA Manual M41 to design thrust blocks. Some situations will not allow space for concrete thrust blocks. In those situations, use a pipe with a built-in restrained joint, or pile supported thrust restraint systems.

A. Concrete Blocking

Concrete thrust blocks are the most common joint restraint in the SPU system. Thrust blocking relies on the surface area of the block being in contact with undisturbed soil to counteract the pressure acting on the pipeline fitting. Conditions may require a pile-supported thrust restraint system. The soil conditions are a very important factor in concrete thrust block design.

In concrete thrust block design, excavations or disturbance of soils behind thrust blocks should be avoided. An assessment should be performed by a qualified engineer to determine if there is a safe distance away from the thrust block that an excavation could be performed.

NOTE: During design consider future disturbance of thrust blocks

i Horizontal Thrust Block

Horizontal thrust block sizing calculation must follow either Standard Plan 331 or AWWA Manual M-41.

ii Vertical Thrust Block

In some cases, vertical thrust blocks may be needed. Vertical thrust block must follow Standard Plan 330.

B. Concrete Thrust Collars

Concrete thrust collars are occasionally used as a method of thrust restraint. Typically, thrust collars are used to restrain large valves in chambers and valves near casings or connections to existing pipe. Collar refers to the section of concrete formed around the pipe to counteract thrust forces. Collars withstand thrust force by both passive soil pressure and friction on the bottom surface of the block. To keep the pipe from sliding within the collar, the concrete needs to interface with the pipe. The wedge restraints on ductile iron pipe should be wrapped in polyethylene so the concrete does not seep into the wedges of the wedge restraint gland and stop it from working.

i Steel Pipe

If using concrete collars on a steel pipe, a factory integrated thrust ring must be welded around a pipe section, then embed in concrete.

ii Ductile Iron Pipe

If using concrete collars on ductile iron pipe, a factory ring must be installed on a pipe section. An alternative is to install two wedge style restraints face-to-face to act as a thrust ring.

iii Poor Soil Conditions

Design should consider the potential settlement impact the concrete thrust collar could have on the pipe.

iv Pipe Anchors/Tie Backs

Pipe anchors consist of a large mass of concrete usually on one side of a pipeline. The concrete is attached to the pipeline by steel rods. Anchors act like vertical thrust blocks (except in a horizontal plane) to restrain the pipe at a bend. Typically, pipe anchors are only installed for temporary service because the rods can corrode.

C. Rigid Restrained Joints

Flanges, welded joints, and threaded couplings are types of rigid restrained joints. Flanges can be used on both ductile iron and steel pipes. SPU does not use threaded couplings in water mains.

i Flanges

SPU does not recommend burying flanges in soil. Flanged fittings are used where joint flexibility is not needed and are typically found in vaults associated with valves or other appurtenances. Flanged pipe must be installed perfectly to fit up and offers no flexibility. A dismantling joint must be used to allow disassembly and repairs. Flanged valves are usually used in the installation of a large run of flexible restrained joint pipe. Each flanged valve will have a short flange by flexible restrained joint adapter on each side of it.

Manufacturers can weld a flange to the steel pipe. See AWWA Manual M-11 for the class of flange rating. Consult with the manufacturer to ensure the flanged connection can be provided. An electrical isolation kit may be necessary if joining the steel pipeline to a ductile iron appurtenance. Steel and ductile iron are dissimilar materials that can corrode.

ii Welded Joints

Steel pipe can be assembled with welded joints, making the pipeline fully restrained. Field-welded joints provide restraint against the unbalanced hydrostatic and hydrodynamic forces acting on the pipe. There are several styles of welded joints. The most common are the lap-weld, butt-weld, and butt strap joints. Refer to AWWA Manual M-11 for a photo of each type of joint:

- **Lap-Weld Joint.** In general, SPU prefers a lap-weld joint because they are easy to install. Lap-welded pipe is a bell and spigot pipe with the bell welded to the spigot where they overlap. The design engineer can select an interior only weld, exterior only weld, or double lap weld (interior and exterior). SPU recommends the double lap weld. It provides an added safety factor at each joint, but can only be done in larger diameters because it requires a welder to make an interior weld. Also, each joint can be checked for leakage with an air test. With a lap-weld joint, small deflections can be made at each joint before welding. Given the geometry of the double welded lap joint, it experiences twice as much strain as the pipe wall when post-construction forces (settlement) cause pipe movement.
- **Butt-Weld Joint.** Butt-weld joints are made by aligning the ends of two pipe sections and welding at the point of "near-contact" of the two ends. To complete a butt-weld joint, both ends of the pipe must be the same size. A butt-weld joint is more difficult in the field because the pipes must be near perfectly aligned. This style weld eliminates the geometric strain that can be induced at a lap-weld joint. SPU has used butt-welded joints for pipelines designed for higher levels of seismic loading. The butt-weld joint is also used in horizontal directional drilling (HDD) applications, where having a bell shape on the pipe is not recommended. A full penetration butt-welded steel pipe is one of the best choices for seismic protection.
- **Butt-Strap Joint.** A butt-strap joint consists of a strip of steel that overlaps two plain end pieces of pipe by several inches. The butt strap is joined to each pipe by an exterior weld (and an interior weld if the pipes have sufficient diameter). The two pipe ends do not have to have identical outside diameters, but they must be relatively similar. Typically, a butt-strap joint is used to join a new steel pipe to an existing steel pipeline.

SPU follows the recommendations of the American Welding Society (AWS) Structural Welding Code.

D. Flexible Restrained Joints

Flexible restrained joints allow some deflection and movement of the joint, but restrain the joint while under pressure. These joints are the standard restrained joints used by SPU. All ductile iron pipe manufacturers make a boltless restrained joint ductile iron pipe that uses a restraining ring and locking lugs to restrain joints yet provide flexibility. Check the manufacturer's literature because products vary.

The use of flexible restrained joint pipe systems should be used when special site or system conditions are present and the use of concrete thrust blocks is not appropriate. Flexible restrained joint pipe systems are required when site/project needs have the following characteristics:

- The water main is to be located in an area of liquefiable soils.
- The area is defined to have soils with a poor bearing capacity.

- The area is on a steep slope and particularly if the water main is to be in an area determined to be a slide area.
- If the site is congested with underground utilities or other facilities such that concrete thrust blocks are unfeasible.
- To provide flexibility in shutdown areas and avoid using temporary thrust restraints.
- In areas where excavations, soil settlement or subsidence is anticipated, restrained joint pipe should be considered.
- In pipelines critical to the functioning of the water supply system after a major seismic event.

i Wedged Restraints

Other examples of flexible restrained joints are a wedge restraint gland type device or a restrained gasket type of pipe. Wedge restraint glands must follow Standard Specification 9-30.5(5)B. Wedge restraint glands are typically used on mechanical joint pipe and fittings and grip the pipe, which forces a lug with teeth to imbed into the pipe. Most wedge restraint systems remain flexible after installation.

ii Gasket Restraint

The restraint gaskets are readily available and can be installed on field-cut push-on joint pipe. The restraining gaskets have stainless steel teeth imbedded in them that grip the pipe for restraint. The restraint gaskets are only pseudo-flexible restrained joints. Once assembled, they offer little or no deflection capability. They also require special tools to disassemble.

Note: SPU has used the restraint gaskets on occasion, but found they do not save costs. The AWWA M41 Manual or DIPRA computer program can be used to calculate ductile iron pipe restraint requirements.

Restrained joint pressure ratings for each type and pipe size must be verified with the manufacturer. The length of pipe in casings on any run of ductile iron pipe does not count towards its overall restraint length, unless the casings are filled with grout after the pipe is installed. When using restrained joint pipe, all pipe in each individual system must be restrained joint. In addition to pipe joint restraint, concrete thrust blocks must be provided unless site-specific conditions do not allow.

Note: Field cutting and modifying a factory restrained joint pipe is difficult and time consuming. The pipe must be ordered specific to the project site. Contractors must submit and receive approval of a 3-D lay plan before ordering pipe.

iii Grooved Restraint

Grooved restraint couplings can be used to restrain ductile iron and steel pipe. These couplings are uncommon in the SPU system but can be found on some blow-off facilities. Grooved restraint couplings are generally not used in buried service.

The standard grooved restraint coupling engages a groove that is cut on the exterior of the full circumference of the pipe. Thicker pipe must be used for these couplings.

Grooved restraint couplings can also be used with a rolled groove in thin wall steel pipe and with a welded end ring on both ductile iron and steel pipe. Flexible steel restrained joints come in the form of a coupling that connects two pipe sections. The restraint is obtained by grooves on the coupling engaging a steel rod that is welded to the outside of the pipe. These couplings are custom designed to each project and can be ordered with some minor expansion capability. While quick and easy to install, grooved restraint couplings are expensive. One manufacturer is Victaulic brand.

For how to design restrained joint pipe systems without concrete blocking, see the Ductile Iron Pipe Research Association (DIPRA) program.

E. Flexible Single-Ball and Double-Ball Expansion Joints

For projects where extreme flexibility is needed, several manufacturers offer river crossing pipe that has restrained, ball joints that provide a high flexibility in alignment. Another flexible product is a single or double-ball expansion joint, which is very expensive. The double-ball expansion joint can rotate, extend, contract, and adjust in any direction, yet will not separate. However, improperly installed expansion joints can expand unintentionally under pressure. The design engineer should use care in designing expansion joints in the pipe system.

At a location on each side, the pipe must be fixed by a thrust collar or other means to keep the expansion joint from moving.

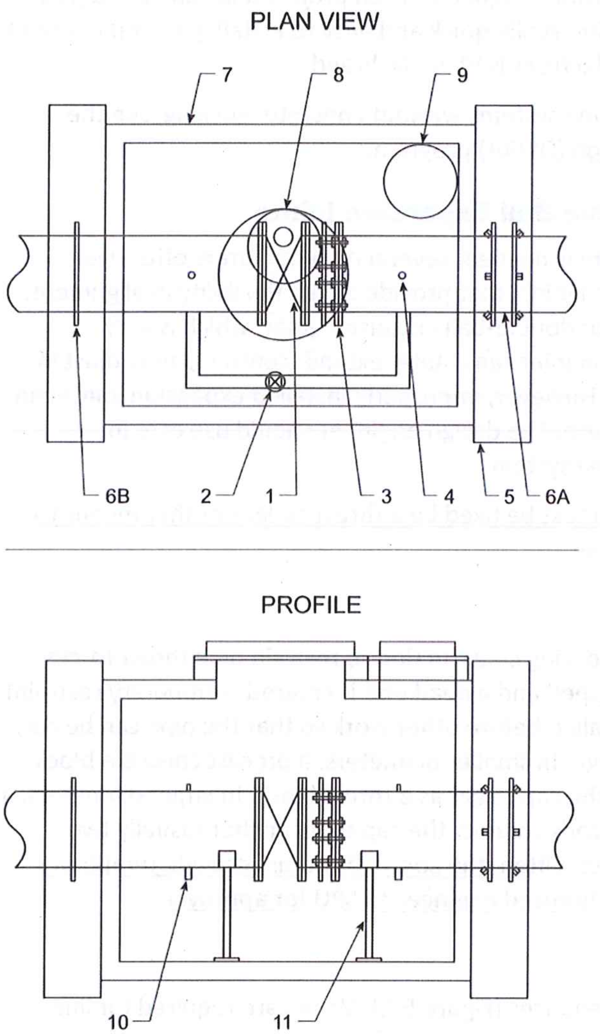
5.6.3.10 Temporary Restraint

Temporary restraint is sometimes required during construction to restrain pipe thrust forces usually where the pipe has been cut and capped and a dead end is created. Temporary restraint can come in many forms, and usually is installed before other work so that the pipe can be cut, capped, and turned back on in a single outage. In smaller diameters, a precast concrete block (Ecology block) is usually placed in front of the cap to act as a thrust block. In larger diameters, a tie-back system is usually used where steel rods connect the cap to an anchor (usually two precast concrete blocks) and sometimes piles. Often, the contractor must provide temporary restraint and submit a design stamped by a licensed engineer to SPU for approval.

5.6.3.11 Vaults

Vaults are used to provide access to appurtenances (Figure 5-5). Vaults are required for line valves 16 inches or larger in diameter and air, complex blow-off, pressure reducing, pressure relief, check, and district valves. These vaults require sumps and sump pumps with drains when there is electrical equipment inside. Vaults should not be located in the roadway and should provide hatch doors for ease of access. Provide enough space inside the vault to accommodate required electrical clearances and work space. For detail on aboveground pipe supports and standard vaults, see *DSG Chapter 4, General Design Considerations*.

Figure 5-5 Typical Layout of a 16-inch or Larger Line Valve



NOTES:

1. 16"-30" LINE VALVE (SHOWN AS FLXFL)
2. BYPASS VALVE (GENERALLY 4") W/ VALVE BOX. CAN GO OUTSIDE VAULT
3. FLXFL DISMANTLING JOINT
4. AWWA X IPT CORP ONE EACH SIDE OF VALVE, TOP OF PIPE
5. REINFORCED CONCRETE THRUST COLLAR (GENERALLY NOT NECESSARY ON WELDED STEEL PIPE)

6A. BACK TO BACK OPPOSING WEDGE RESTRAINT GLANDS POLY BAGGED (OPTION A) (NOT APPLICABLE TO WELDED STEEL PIPE)

6B. WELDED STEEL COLLAR (OPTION B) (GENERALLY NOT NECESSARY ON WELDED STEEL PIPE)

7. PRECAST OR CAST IN PLACE VAULT. IF CAST IN PLACE, THRUST COLLARS CAN BE INTEGRAL TO VAULT.
8. 42" RING AND COVER WITH 24" INNER COVER. CENTER 42" COVER OVER VALVE AND 24" COVER OVER VALVE OPERATOR.
9. 24" RING AND COVER FOR ACCESS
10. AWWA X IPT CORP ONE EACH SIDE OF VALVE, BOTTOM OF PIPE
11. PIPE SUPPORT STAND TYPICAL OF 2.

GENERAL NOTES:

A. DESIGNS WILL VARY DEPENDING ON PIPE TYPE (DUCTILE VS STEEL) AND JOINT TYPE.

B. SIZES OF ALL VALVES SHOWN CAN VARY DEPENDING ON LINE VALVE SIZE AND USE.

C. VAULT SIZE AND PIPE ALIGNMENT WITHIN THE VAULT WILL VARY DEPENDING ON SITE CONDITIONS.

D. FOR CLARITY, NOT ALL PIPE JOINTS ARE SHOWN. A PIPE JOINT SHOULD BE INSTALLED OUTSIDE THE VAULT WITHIN A FEW FEET OF THE THURST COLLARS WHEN USING FLEXIBLE JOINT PIPE.

5.6.4 Appurtenances

Pipeline appurtenances (line valves, access ports, blow-off/drains, and air release/air vacuum valves) must be provided along the pipeline as needed to support the pipeline function and operation. Appurtenance locations should be determined during design and consider conflicts with other structures, vehicular traffic, and existing utilities. Appurtenance locations should avoid areas most vulnerable to damage or vandalism.

5.6.4.1 Valves

When selecting a valve for a distribution main, pay close attention to the type of valve, whether a bypass is required, clearance for future maintenance, and purpose of valve (sacrificial, throttling, isolation). The types of valves used in the SPU water system are shown in Table 5-5. For more information on valves, see Standard Specification 9-30.3.

Table 5-5
Valve Uses within SPU Water System

Use	Type	Function	Size (in inches)	Comments
Line Valve	Gate, C509 resilient	On/Off	4" – 12"	Typically used for smaller line valves
	Gate, C500 double disc	On/Off	4" – 12"	• No longer commonly used • Much larger sizes in system
	Butterfly	On/Off	4"-12"	• No longer commonly used • More head loss than others
		On/Off	16"-84"	• Typically used for line valves • More head loss than others
	Ball	On/Off, throttle	4"-48"	• Costly • Low head loss
District Valve	Gate	On/Off	4"-12"	In chamber, generally closed, locked out
Backflow Prevention	Check Valve	Prevents backflow	4'-12'	Only allows flow in one direction
Air Relief, Air Vacuum, Air Release	Stand Pipe, Air Valve, Combo Air Valve	Allows air in and/or our of pipe	2"-16"	• Air release allows trapped air to escape pipeline and improve flow characteristics • Air vacuum allows air into pipe to prevent collapse during draining. • Largest likely future need is 8"
Pressure Regulating/ Pressure Relief Valve	Control Valve	Maintain system pressure	2"-16"	Maintains a constant downstream pressure
Sacrificial/ Throttling	C500 Gate	Limit discharge	4"-8"	Typically the "Throw away valve" in double valve setup
	C515 Gate	Limit discharge	4"-8"	Typically the "Throw away valve" in double valve setup
	C509 Gate	Limit discharge	4"-8"	Typically the "On/Off valve" in double valve setup
	Ball	Limit discharge	4"-8"	Long-term high head throttling valve
	Plug	Limit discharge	4"-8"	Long-term high head throttling valve

A. Types of Valves

The following are types of valves used in the SPU Water System

Valve	Use in SPU Water System
Line	Line valves are typically either gate or butterfly valves, depending on pipeline size. Ball and plug valves may be used in the following situations: high pressure (±250 psi), significant throttling under high flow rates, control of pressure surges, or where throttling of high pressure differentials may be required.
Gate	Gate valves are preferred where possible. They completely exit the flow path when fully open and allow drained water mains to fill without bypasses. Gate valves require space for a valve bonnet above or to the side (laydown valves) of the pipeline. Cover over water main may be critical. <u>In cases where substandard cover is allowed, the gate valve operating nut must be below the bottom of the paving</u>. This is particularly sensitive for concrete pavement, which tends to be thick. Gate valves are typically more expensive than butterfly valves. <u>Laydown valves must be operable from the street surface and require a sealed right angle gearbox</u>. (See Std Plan 030 for standard cover requirements.)
Butterfly	Butterfly valves are frequently used on larger pipelines. All valves 16-inches and larger should be full-size inline butterfly valves and be installed in vaults. Valves under 16-inches can be either gate or butterfly valves. Standard practice is to use gate valves. <u>Butterfly valves 16" or larger must be installed with a bypass to allow a drained pipe to fill without throttling the butterfly valve seats</u>. Throttling of large-diameter butterfly valves with pressure differentials of over 50 psi is a primary reason seats have been destroyed after only one or two usages. Make provision for replacement of butterfly valves in the vault design. Include a dismantling joint, or similar, to enable disassembly of the pipe.
Distribution	Distribution line valves should be placed at interties and roadway intersections located at street margins. The valves should be spaced to provide operational flexibility and redundancy to the water system and reduce impacts of shut down blocks.
District	District valves are typically gate valves and separate different pressure zones. They require the valve to be installed in a chamber with a special lock-out tag or cover on the operator to prevent accidental operation.
Check	Check valve is a special valve that only allows flow in one direction through the valve. Check valves are usually installed in vaults. Several styles are available. Check the valve's coefficient value (C) and slam characteristics before finalizing check valve design.
Pressure Relief and Pressure Regulating	Control valves (pressure reducing, pressure sustaining, etc) typically are installed at the interface between pressure zones. They are sized based on anticipated fire flow at projected peak hour demand conditions. Control valve stations should be below-grade in a concrete vault, and include a mainline meter and a bypass to the main waterline.
Air Relief, Air Vacuum, Air Release	Air valves are most commonly found on transmission pipelines and large feeder mains. They are not common on small-diameter distribution mains. There are two general types of air valves: air and vacuum valves and air release valves.
Air and Vacuum	Air and vacuum valves are large-orifice valves used to allow large volumes of air to flow into or out of the pipe during filling and draining and to prevent a vacuum from valve operations, rapid draining, column separation, or other causes. Without air vacuum valves, a vacuum can cause the pipe to collapse from atmospheric pressure. Fire hydrants can be used to release air at the high points of the distribution system and between isolation valves while filling water mains.
Air Release	Air release valves are small orifice valves that may be required at pipe high points or at significant changes in pipe grade to release small amounts of slowly accumulating air buildup in the pipeline. Air is dissolved or entrained in water from many sources including naturally occurring surface waters, at open reservoirs and while filling the pipeline at locations of cascading flow in a partially filled pipe to name a few. Entrained air may be dissolved into the water as pipeline pressure increases (decreasing pipe slope). Entrained air may collect at the top of the pipe at abrupt downward changes of pipe grade. Dissolved air may come out of solution many miles from the air source as the pressure decreases, especially at high points. Air may bubble out of solution where there is significant increase of flow velocity caused by changing pipe diameters (Bernoulli principle) and increasing pipe slope, and changes in pipeline elevations and reduced pressure. Reducing the accumulation of air within a pipe decreases head loss in the pipeline.

Valve	Use in SPU Water System
Combo Air Release/ Air Vacuum	Combination air release/air vacuum valves are air valves that have both large orifices and small orifices and provide the combined functions of both types of valves. These valves must comply with the requirements of ANSI / AWWA C512. They are sized per AWWA M51 based on 2-psi pressure differential for filling and draining. Air release valve orifice sizes are chosen based on water main operating pressure and air release rate, which must be selected to avoid abrupt pressure surges. Air vacuum and air release valves must be equipped with isolation valves and be installed in vaults. Discharge from all air valves must be plumbed to the surface. Washington State DOH regulations for cross connections do not allow discharge into the vault. On large pipelines, open air stand pipes are sometimes used in lieu of a combination valve.

B. Bypass Requirements

Bypass assemblies are used on larger valves to ease valve opening. When a line has been closed, and one side of the pipeline drained, pressure on the valve becomes unbalanced making it very difficult to open the valve. A bypass line allows water to backfill the unpressurized side of the valve, which equalizes pressure on the valve allowing it to open more easily. Bypass assemblies also allow the operator to fill an empty pipe more precisely. Bypass assemblies must be installed on all valves 16-inches and larger in diameter. A typical bypass assembly is included in the standard line valve vault detail. Typically, SPU will use a hydrant or an adjacent active line with a PRV and temporary piping to do this. See Figure 5-5 Typical Layout of a 16-inch or Larger Line Valve.

C. Valve Turns

The number of turns to close a valve is very important. Rapidly closing a valve can create a surge pressure wave in the pipeline and damage the line and appurtenances. See Standard Specification 9-30.3(4).

D. Valve Spacing and Location

Line valves are to be located at grid junctions in the distribution system, such that each of the converging main segments can be independently isolated. Additional intermediate valves may be required between grid connections, such that any single shutdown segment will be no more than one block (approximately 300 to 500 feet) in length within commercial/multi-family residence zones.

On primary distribution mains and feeder mains larger than 12 inches in diameter, valves are to be located where these mains intersect with other mains larger than 12 inches, such that each of the converging large diameter main segments can be independently isolated. Additional intermediate valves may be required between large diameter pipe junctions, such that any shutdown segment of a main larger than 12 inches in diameter will be no more than 1,300 feet in length. The actual number and positioning of intermediate line valves on a main larger than 12 inches in diameter is to be guided by an analysis of secondary outage impacts associated with the isolation of individual segments of mains larger than 12 inches in diameter. As a general guideline, the total outage area resulting from the isolation of any one main segment including all of its subordinate dead-end systems (if any), should include no more than 130 accounts or 20 fire hydrants or 200 gpm of average daily consumption. Placement of line valves will typically be at the margins of the street intersection that contains a grid junction and also intermediate line valves at street margin of the desired location.

E. Clearances

Clearances around a valve are very important to operations and maintenance of the valve. When placing a valve in a vault, the design engineer should ensure that maintenance staff will have access to all valve parts for maintenance and enough space for wrenches and other tools. Typically, a minimum of 1-foot space is needed around all valves. SPU prefers a 3-foot space.

F. Valve Restraint Systems

All valves in chambers and those installed on a restrained joint pipe should be fully restrained. There are several options for restraining valves, including flanges and a mechanical joint with a wedge restraint gland. The system chosen should be consistent with other SPU designs and consistent across the project.

G. Valve Replacement

The design engineer should pay close attention to removal of the valve. Valves 16-inch and larger should have an access hatch directly over the valve, adequately sized to remove the valve.

Another consideration for valve removal is a dismantling joint. When flanged valves are installed, the pipeline is extremely tight. If the valve needs to be replaced, unbolting it may not provide sufficient space to slide the valve out. A dismantling joint has a special sleeve that can be retracted a few inches. This allows enough extra space to remove the valve. The dismantling joint also provides some adjustment if a different brand or style of valve is installed in the future. SPU standard practice is to install a dismantling joint on valves 16-inch and larger in diameter.

5.6.4.2 Access Ports

SPU installs access ports only on large-diameter (24" or greater) pipelines.

Access ports provide access during construction and to Field Operations and Maintenance staff. Typical access port sizes are 24-inches in diameter. Typical spacing for a large transmission main is 1,200 feet except in low areas subject to high groundwater tables. Because access ports typically only extend 1 to 2 feet above the pipeline surface, they can be buried or encased in a maintenance hole that extends to the surface. If the access port is fully buried, it should be well documented on the record drawing (as-built) so future O&M staff can find it. If possible, a waterline marker should be installed over the access port.

SPU typically installs all access ports vertically. In certain cases, a side-mounted access port may be necessary given space restrictions. See the DSG standard access port details (**Appendix A**).

5.6.4.3 Air Gap Structures

Air gaps, also known as goosenecks, are required to prevent cross connections between the domestic water supply and any other liquid. The ultimate function of this air gap is similar to that of a check valve. Typically, air gap structures are located on facilities (e.g. tanks) or equipment (e.g. pumps) connected to the system. The gooseneck discharge must be a minimum of two discharge pipe diameters aboveground or receiving water surface. Floodwater surface levels may need to be considered when designing air gap height. Air gaps are usually found at the end of the discharge line on pipeline and tank blow-offs.

5.6.4.4 Blow-offs

Blow-offs are outlets located at low points in a pipeline profile. They consist of a tangential outlet off the bottom of the pipeline with an isolation valve and riser located in an access vault opening to grade. Blow-off valves are used when pipelines need to be drained or flushed for repairs. Drain rates are limited by the receiving utility or water body. A tap to add sodium thiosulfate or ascorbic acid for dechlorinating water can be provided at the blow-off, but is not common.

All blow-off outlets must have an air gap between the pipeline discharge point and the ground (or surface water elevation of the receiving body) equal in length to a minimum of two discharge pipe diameters. See example plans in the Virtual Vault 776-227 and 776-203. Both show examples with sacrificial throttling valves. Example plan 776-203 also shows a pipeline-to-pipeline pumping connection.

For detail on design of small blow-off valves, see Standard Specification 7-10.2(11) and Standard Details 340a and 340b.

Fire hydrants can also be used as blow-offs on dead-end mains.

5.6.4.5 Flow Meters

Flow meter selection is covered in more detail in *DSG Chapter 10, Instrumentation & Control*. When selecting a flow meter, make sure to follow the upstream and downstream clearances requested by the manufacturer. In general, there should be smooth straight pipe (no appurtenances, bends, fittings, etc) for the equivalent length of 10 pipe diameters upstream of the meter and the equivalent length of 5 pipe diameters downstream.

5.6.4.6 Fire Hydrants

Fire hydrant installations must be in accordance with the Standard Specification 7-14 and Standard Plans 310a, 310b, 311a, 311b, 312, 313, and 314.

Hydrants must be located in areas that are accessible and approved by the Seattle Fire Department or other fire departments with jurisdiction.

5.6.5 Rehabilitation of Existing Mains

SPU rehabilitates existing water distribution main either through slip-lining the pipe or re-lining the large diameter pipe. Additionally, cathodic protection can be used to prevent further corrosion of the buried exterior. For detailed information on cathodic protection, see *DSG Chapter 6*.

5.6.5.1 Slip-lining

In slip-lining, a pipe of smaller diameter is installed within the original larger pipe. Usually slip-lining is performed on distribution or feeder main pipes 30-inches or larger in diameter. The existing pipe becomes the casing for the new pipe. It is often a cost-effective no-dig alternative to traditional open-cut installation of pipe. Typically, slip-lining is used as a structural repair. However, it cannot be used if there is substantial damage (crushed or misaligned joints) to the pipe. The annular space between the two pipes is sometimes filled with grout. The design engineer should carefully consider the hydraulic implications of reducing the pipeline diameter.

5.6.5.2 Relining

If video inspection of the pipeline interior shows significant deterioration of the lining, relining of the pipe may be possible. Pipes are relined by thoroughly cleaning the existing pipe interior then using a machine to spray-coat new cement mortar lining inside the pipe. The method used depends on pipe size. The relining can be designed to strengthen the pipe through use of a structural mesh embedded in the spray-coated cement mortar lining.

5.6.5.3 Cathodic Protection

Cathodic protection is one method SPU uses to rehabilitate existing water pipelines. For more detail on cathodic protection for distribution and feeder mains, see DSG section 5.6.8 and *DSG Chapter 6, Cathodic Protection.*

5.6.6 Emergency Pump Connections

In some emergencies, a connection between two nearby pipelines may be needed. If the pipelines operate in different pressure zones, then a pump may be needed between the two lines. If possible, use an existing interconnection. If no inter-connecting pipe structure is available, SPU recommends using a nearby blow-off location and installing a pump between the two pipelines.

5.6.7 SCADA

See *DSG Chapter 10, Instrumentation & Control*, for SCADA system design. The design engineer should consider whether any monitoring or controls are needed and if the controls should be linked to the system wide SCADA system.

5.6.8 Corrosion Control

Corrosion control of SPU pipelines comes from both active and passive protection systems. Bare metal steel or ductile iron pipe will rust when exposed to corrosive soils or water if no protection system is installed. The rate of corrosion depends on the corrosivity of the environment (typically soil or water). The rate of corrosion is mostly a function of how well the environment conducts electrical current.

Resistivity plays a key role in corrosion control of pipelines. Resistivity refers to the resistance of the environment to promote electrical current flow. When the resistivity of water or soil is high, less current can flow through that environment and the rate of corrosion is lower. For internal corrosion (inside of pipes), water resistivity is constant. For external corrosion (exterior surfaces of pipes), soil resistivity is highly variable. SPU GIS maps show the results of tests taken to date for soil resistivity. SPU staff can test for specific areas for soil resistivity.

The internal corrosion of pipes is managed through a combination of water chemistry adjustments and the use of internal linings..

SPU controls external (on the soil-pipe interface) corrosion through one of three methods:

1. Testing the soil environment for resistivity

2. Applying external bonded coatings or polyethylene film encasements (unbonded film)
3. Using a cathodic protection system

See *DSG Chapter 6, Cathodic Protection*, for detailed discussion of that protection method.

5.6.8.1 Soil Resistivity

Resistivity refers to the resistance of the environment to promote electrical current flow. It is the inverse unit measurement used to determine conductivity/corrosiveness of the internal or external environment in contact with the pipe surfaces. By selecting appropriate backfill (soil) or modifying chemical properties of the water being carried within the pipe, resistivity can be adjusted. When resistivity is adjusted, the corrosion rate on pipe surfaces is reduced. See *DSG Chapter 6, Cathodic Protection*, Tables 6-9, 6-10, and 6-11.

For the soil pipe interface, adjusting soil resistivity is usually neither possible nor practical. Providing select backfill has a short-term effect. Over time, constituents in the soil surrounding the pipe will degrade the backfill and resistivity will approach that of the surrounding material.

Soil corrosivity is based on resistivity measurements of the soil in the pipeline location. Typically, several measurements are taken and an average value is determined. Where soils are very near a classification break point, engineering judgment is required to classify the soil (Table 5-6). Where resistivity tests in one area vary, greater weight is given to the lower values found.

Table 5-6 Corrosion Protection Requirements for Water Piping Systems*

Soil Resistivity (ohm/cm)	Soil Corrosivity Classification
0 – 900	Severely-corrosive
901 – 3,000	Very-corrosive
3,001 – 10,000	Moderately-corrosive
10,001 – 50,000	Mildly-corrosive
> than 50,000	Non-corrosive

*Large projects may have several soil classifications and will need to accommodate each type appropriately.

Table 5-7 shows SPU requirements for water pipelines where coating is dictated by resistivity.

Table 5-7 SPU Corrosion Protection Requirements for Corrosive Soil

Soil Classification	Corrosion Protection Requirements
Severely-corrosive	approved bonded coating joint bonding - #2 AWG insulating coupling or flange kit @ connections full dielectric covering on service lines to meter setter electrolysis test station class b bedding (sand) magnesium anodes @ 18' intervals (17 lbs high potential magnesium anodes)
Very-corrosive	[same as above – except anodes are spaced @ 36' intervals]
Moderately-corrosive	[same as above – except anodes are spaced @ 100' intervals]
Mildly-corrosive	- polyethylene encasement – 8 mil - class b bedding (sand)
Non-corrosive	- no protection required unless organic or clay materials are encountered - additional soil tests may be required for proper recommendation
Notes:	

- All steel pipe must have bonded coating for all soil conditions
- Additional corrosion protection may be required where stray current is present (i.e. rail transit)
- If bonded coating cannot be provided where required, pipe can be installed bare and additional anodes supplied at SPU engineer's direction; impressed current cathodic protection may be required.

5.6.8.2 Coatings

Coating refers to products applied to the outside of pipes. Steel and ductile iron pipelines have different coating requirements. Before selecting a coating system, soil sampling (resistivity testing) should be completed to determine the corrosive nature of the soil.

A. Steel Pipe Coatings

All steel pipes must be coated. Several different coating options are available. The design engineer should use best judgment in deciding among coatings. Table 5-8 lists coating types found in the SPU water system in order of use and preference.

Table 5-8 Steel Pipe Coating Types for SPU Water System

Coating	Description
Polyurethane Coating	SPU standard for steel pipe coating. This is a thin film bonded dielectric coating with both water and chemical resistance. It is typically factory-applied and thickness is customized to a specific application. Surface preparation and curing process is very critical.
Fusion Bonded Epoxy (FBE)	FBE is typically applied at the factory on the pipe, and field applied on the joints. Applied by heating the steel pipe, then blowing epoxy in powder form on the heated pipe. Generally considered one of the most durable coatings. Typically most costly.
Paint Coatings	Paint systems work well with cathodic protection systems. Resilient and extremely abrasion resistant. Paint coatings are applied according to AWWA C210 and C218. Commonly used where there is minor damage to the existing coating or the extent of damage is small.
Heat Shrink Wrap Sleeve	Tubular sleeves that can provide effective coating protection around field-welded joints. It is field-applied. Known to be reliable and effective against thermal, chemical, and environmental attack. Economical due to ease of application and no need for primer.
Tape Coating	Most commonly specified dielectric coating systems. Has a good performance record at reasonable cost. Typical application includes 80-mil cold-applied plastic tape in three layers over a properly prepared steel surface.
Cement-mortar Coating	No longer used, but may be encountered on existing pipes. Chemically protects pipe from corrosion by providing an alkaline environment where oxidation of steel is inhibited. Can be applied in various thicknesses. Provides mechanical protection against handling and installation damage. Typical application thickness is 1inch.
Coal-tar Enamel Coating	One of oldest methods to provide corrosion protection for steel pipelines. Coal-tar enamel is applied over a coal tar or synthetic primer. Application includes cleaning, priming, application of hot enamel, and covering of a fiberglass matte and/or felt outer wrap. Recommended application includes 7/32-inch coal tar with fiberglass reinforced mineral felt with heat-shrinkable cross-linked polyolefin sleeves at joints.

B. Ductile Iron Pipe

Due to its thickness, ductile iron pipe does not always need a coating. It generally only needs coating when soil conditions warrant. Soils should be tested to identify that need.

For ductile iron pipe, the standard factory coating is an asphaltic coating approximately 1-mm thick. This coating minimizes atmospheric oxidation, but provides no in-ground protection.

Ductile iron pipe must conform to Standard Specification 9-30.2(1).

Table 5-9 lists ductile iron pipe coating options. SPU requires a double cement mortar lining thickness for ductile iron pipe. See AWWA C104 for more detail on cement mortar linings for ductile iron pipe.

Table 5-9 Ductile Iron Pipe Coating Types for SPU Water System

Coating	SPU Preference
Thermoplastic Powder Coating	SPU standard coating for ductile iron (DI) pipe in a corrosive environment. See Standard Spec 9-30.1(6)C. Can also be used on steel pipe.
Wax Tape system	When used with appropriate primer and a fiber reinforced outer wrap, this coating can protect any buried metal surface, bolts, nuts, rods, copper, ductile, steel, etc.
Polyethylene film encasement (un-bonded film)	Common application for corrosion control. Acts as an environmental barrier to prevent direct contact between pipe and corrosive soils. Not watertight; groundwater can seep beneath the wrap. Integrity depends on proper installation, careful handling by contractor, and inspection by owner. Polyethylene encasement must be per Standard Spec 9-30.1(6) D. SPU has limited success using this product.
Fusion-Bonded Epoxy, Polyurethane, and Tape Coatings	Can be considered as an alternative coating system. Manufacturer has been unwilling to apply bonded coating at factory. Design engineer should recognize potential invalidation of pipe warranty if this is field applied.

C. Linings

Lining refers to a product used to protect the inside of a pipe from corrosion and improve performance and service life. SPU requires a lining for all pipelines. All linings must be National Sanitation Foundation (NSF) 61-approved.

Ductile iron pipe is typically supplied with a double thickness Portland cement-mortar lining unless otherwise specified. See Standard Specification 9-30.1(1).

Welded steel pipe is furnished with two primary lining options: cement-mortar or polyurethane. Cement mortar is a nominal thickness of ¼- to ½-inch. For interior linings, polyurethane thickness is typically around 20-mils. See Standard Specification 9-30.1(1).

D. Cathodic Protection

Cathodic protection is a means of providing a sacrificial material to become the point where corrosion occurs.

For a pipeline, cathodic protection provides a separate metal known as a sacrificial anode to be the point where corrosion occurs. This anode protects the pipeline from corrosion. By use of either an impressed current rectifier or materials that are galvanically active (zinc or magnesium), the pipeline becomes the cathode and corrosion is transferred to the anode.

See DSG Chapter 6, Cathodic Protection, for standards for cathodic protection systems.

E. Environmental Modifications

SPU employs corrosion control techniques such as modifying the pH at its water treatment plants to reduce internal corrosion of water pipelines. This practice is controlled by federal regulation under the Safe Drinking Water Act and EPA's Lead and Copper Rule and is a water quality operational methodology beyond the scope of this DSG.

Other engineering practices such as selecting less corrosive soils for pipelines are design considerations for corrosion control.

5.7 WATER SERVICE CONNECTIONS

For standards and guidelines for water service connections, see *DSG Chapter 17, Water Service Connections.*

5.8 TRANSMISSION MAIN DESIGN

This section describes transmission main design. Transmission mains are major (16- to 64-inch diameter) pipelines within the SPU water system. They convey or transport water from a source to a reservoir and typically do not have any service connections. This section covers the types of materials used, appurtenances, and restraint systems used in transmission main design. For detailed information on water storage tanks, standpipes and reservoir design, see DSG section 5.9.

> This section of the DSG frequently directs the user to DSG section 5.6, Distribution Main Design. Many of the elements of transmission main design are identical to those for distribution mains.

5.8.1 Modeling and Main Sizing

See DSG section 5.6.1 for distribution mains. SPU's contracts with its wholesale customers specify the minimum hydraulic gradient or head at each wholesale service connection. The newer wholesale service contracts also specify the maximum flow rate at a given hydraulic gradient that would be provided for each service connection. Any modification to the transmission system should consider these hydraulic criteria. While these hydraulic criteria may be modified if beneficial to the regional system, SPU may make these modifications only once during any 15 year period provided that 4 years advance written notice is given. At a minimum, transmission mains must be sized to maintain a pressure of 5 psi or more, unless the mains are directly adjacent to the storage tanks.

5.8.2 Location

SPU transmission mains are primarily located in the right-of-way (ROW). However, their design is based on least conflict with other utilities and cost of easements. SPU transmission mains within Seattle are not moved for other utilities. Outside of Seattle, SPU generally owns the transmission pipeline ROWs and mains are typically not moved. An exception is some holdings that belong to WSDOT.

5.8.2.1 Separation from Other Utilities

See DSG section 5.6.2.1.

5.8.2.2 Geotechnical Report

With a new or major refurbishment to transmission main, a geotechnical engineering study must be done for the proposed route (alignment) and documented in a geotechnical report. Consult the SPU Materials Lab for recommendations on what the report should cover. The Materials Lab geotechnical staff must review findings on all projects, even when an outside consultant completes the geotechnical evaluation.

5.8.3 Materials

Transmission mains must be designed to withstand internal working pressure, external loads, and transient pressures. Design should minimize the use of pump stations.

5.8.3.1 Minimum Pipe Size

Transmission mains must be sized to carry the designed peak flow required including fire flow without exceeding the design velocities or head losses.

5.8.3.2 Material Types

A. Pipe

Water transmission mains are typically constructed of steel or class 52 ductile iron. Both ductile iron pipes and steel pipes are to be cement mortar lined in most instances. For more detail on materials for water transmission mains, see Standard Specification 9-30.

Note: ductile iron pipe is only manufactured up to 48-inch diameter. SPU does not use pre-stressed concrete cylinder. Large diameter steel pipe (>48-inches), fittings, and structures housing valves and appurtenances should be designed or overseen by a licensed engineer.

See DSG section 5.6.7.

B. Casing

See DSG section 5.6.3.7.

5.8.3.3 Pipe Cover

Transmission mains are subject to special pipe strength design considerations and analysis by the design engineer. The minimum depth of cover for water transmission mains is given in the contract for each project. Use AWWA M11 or other applicable design manual to meet the requirements of the project. SPU typically buries transmission mains with 4 feet of cover to allow smaller utilities to cross over the pipeline and to reduce live-load on the pipe.

5.8.3.4 Bedding and Backfill

See DSG section 5.6.3.4.

A. Standard Trench Section

For detail on a standard trench section, see Standard Plan 350.

B. Controlled Density Fill

See DSG section 5.6.3.4B.

5.8.3.5 Line Pressure

Pipelines must be designed to withstand the required internal working pressure, external loads, and transient pressures.

A. Standard Conditions

Transmission lines do not have a typical operating pressure, but rather operate at the pressures required by the system. The design engineer should review the modeling results to determine the maximum operating pressure in the pipeline and design the pipeline system for that pressure. Transmission mains must not be designed for less than 100 psig. In cases where there is an extreme pressure differential (e.g. downhill pipeline) it may be necessary to change pressure capacity of the pipeline along the pipeline route.

B. Transient Conditions

Transient pressures result from sudden velocity changes in the water flowing through a pipeline. These transient (or surge) pressures can propagate from closing a valve rapidly, an electrical power failure at a pumping facility that causes a sudden pump shut down, large or abrupt fluctuations in water demand from major users along the pipeline, or a sudden release of entrapped air from the pipeline. Methods to control transient pressures are standpipes, surge tanks, pressurized tanks, surge anticipator valves, vacuum relief valves, regulated air release valves, and optimizing main size and alignment. Valve operator speed controls can also mitigate valve-related surge events.

Each pipeline material has a standard allowance for surge conditions (typically at 1.5 times the pipeline design pressure for steel or 100 psig for ductile iron). The design engineer should consult AWWA Manuals to determine pipeline surge allowance. Those allowances should then be compared with the maximum surge pressure from the modeling results to ensure the pipeline can withstand the surge pressure. In the SPU water system, surges of 100 to 150 psig have occurred, particularly in commercial and industrial areas.

5.8.3.6 Pipe Supports

Transmission lines should rarely be allowed to run aboveground. If that occurs, the design mechanical engineer should evaluate temperature differences between the pipe and atmosphere that will affect expansion and contraction at the joints. The issue should be addressed either through HVAC temperature controls, pipe insulation, or design pipe supports to allow movement.

5.8.3.7 Casing

See DSG section 5.6.3.7.

5.8.3.8 Trenchless Technology

Trenchless technologies such as bore and jacking, micro-tunneling, horizontal directional drilling, and pipe ramming are alternative methods of construction to the more typical cut-and-cover. Typically, trenchless technology is considered to avoid environmental or construction impacts. Before considering trenchless technologies, the design engineer should rule out alternatives.

Every trenchless project is unique and requires custom evaluation and analysis. Items to consider include topography, soil conditions, regulatory issues, and site constraints.

A. Bore and Jacking

Bore and jack installation (also called horizontal auger boring) consists of installing a casing by jacking and concurrently auguring the soils out through the casing. Alignment is fairly accurate with bore and jacking. However, there can be potential problems with high ground water and excessive lengths. Once the casing pipe is installed, the carrier pipe is installed with spacers to support the pipe. The gap can be filled, typically with blown sand or a non-shrink grout.

B. Micro-tunneling

Micro-tunneling is typically a closed-face pipe jacking process. Micro-tunneling requires both launching and receiving shafts, which are typically constructed out of slurry walls. Micro-tunneling machines are laser controlled remotely from the surface. Micro-tunneling installs a casing pipe, and then a carrier pipe is installed. Because this process allows precise grade control, it is frequently used in water and sewer applications.

C. Horizontal Directional Drilling

Horizontal directional drilling (HDD) consists of drilling progressively larger diameters from ground surface to ground surface in an arch under the obstruction. No shafts are constructed with HDD construction. Typically, the first pass of a drilling operation creates the route. The pipeline route is then increased in diameter by forward and back reaming the drill path. The hole is kept open with drilling fluids, typically a bentonite slurry. During drilling, various methods are used to track the drill bit and determine the route. Recent history has shown HDD pipeline installation to be relatively accurate. Once the desired diameter is achieved, the carrier pipe is pulled through the drilled path. No casing pipe is used in HDD applications.

D. Pipe Ramming

Pipe ramming consists of using a hydraulic hammer to push the pipe through the soil. Once the casing pipe is installed, the center channel is removed, typically by an auger method or compressed air. With small diameters, the carrier pipe may be rammed with a closed end. Frictional forces can limit the overall length of the pipe ramming, and there is no line or grade control.

5.8.3.9 Restraint Systems

See DSG section 5.6.3.9.

5.8.3.10 Vaults

See DSG section 5.6.3.11.

5.8.3.11 Appurtenances

Pipeline appurtenances, such as line valves, access ports, blow-off/drains, or air release/air vacuum valves should be provided along the pipeline as needed to support the transmission main function and operation. Appurtenance locations should be determined to avoid conflicts with other structures, vehicular traffic, existing utilities, and locations vulnerable to damage or vandalism. See DSG section 5.6.3.12.

5.8.3.12 Line Valves

Each transmission main project should examine the proposed route for the best location of isolation line valves. Consideration should be given to future operational issues such as draining the pipeline and isolating a mainline break. SPU recommends placing isolation valves at least every 2,000 ft and at every intertie location. All line valves should be installed within a vault per the standard line valve vault detail in the DSG (see Figure 5-5 in section 5.6.3.11).

5.8.4 Seismic Design

This section describes seismic requirements for water system design.

5.8.4.1 Critical Needs Assessment

The purpose of a critical needs assessment is to establish design requirements to provide for the highest level achievable for continuity of service, i.e. for the transmission pipeline to function within its design limits with as little service interruption as possible. A critical needs assessment of the proposed new or refurbished transmission main and associated facilities should be completed as part of the basis of design. From the critical needs assessment, design criteria should be clearly established for the following:

- Design operational life of the transmission main.
- Maximum length of time that the transmission main can be out of service for repairs or maintenance without negatively affecting the water demand requirements. Identify seasonal considerations that affect the length of time the main can be out of service.
- Redundancy of critical components or functions, such as line isolation valves.
- Accessibility for the transport of repair and maintenance equipment.
- Access to the interior of pipes, vaults, and other structures for inspections and repairs.
- Impacts from geologic events (landslides, erosion) and seismic events (ground movement), including:
  - Foundation and backfill requirements
  - Drainage and control of or protection against groundwater
  - Allowable pipe movement
  - Allowable joint leakage (if any)
  - Need for and location of seismic valves

5.8.4.2 Seismic Joints and Connections for Pipe Movement

This section describes potential design issues when SPU water pipes must cross settlement prone areas, faults, liquefaction zones, slides, or where two types of pipe with different restraint characteristics must be connected. In both cases, design must allow pipe movement.

A. Cast Iron Pipe

Much of the SPU Water System piping is non-restrained, inflexible cast iron pipe with lead joints. No matter how robust a system design may be for crossing a given fault or landslide zone, if a connection to the existing pipe is faulty it will fail when the ground moves. Either of two methods will stabilize the structure within the zone:

1. Extend flexible restrained joint pipe a significant distance beyond the fault/slide zone.
2. Install some immovable structure on the new flexible restrained pipe near its connection with the existing pipe.

B. Ductile Iron Pipe

Where smaller (≤24") diameter pipes cross movement prone areas, they are usually ductile iron. The options are:

- **Standard Flexible Restrained joint pipe with expansion fitting(s) such as a restrained telescoping sleeve**. A telescoping sleeve allows axial elongation of the piping system.
- **Restrained Ball Joint pipe with expansion fitting(s) such as a restrained telescoping sleeve**. Ball joint pipe is the most flexible and the most expensive pipe available. The balls must be encased in polyethylene bags to keep dirt out of the ball.
- **Standard Flexible Restrained joint pipe with double ball expansion joints placed where the most differential movement is expected**. Flexible Single/Double Ball Expansions Joints are discussed in DSG section 5.6.3.9.E. Currently these fittings are only available up to 48-inch diameter and one size beyond at 72 inches. The large-diameter sizes are extremely expensive.

See **Appendix C** for the allowable ductile iron deflections. In all of the options above, shorter sections of pipe with extra joints can be used to provide more pipeline flexibility.

C. Steel Pipe

Where larger (≥24") diameter pipes cross movement prone areas, they are generally steel. Steel pipe is somewhat flexible and the nature of the material allows it to yield and elongate significantly before failure. Some studies indicate that good welds can elongate 20% before failure. However, bending and buckling of the steel pipe can be a problem when the settlement trough is not smooth. Best options for steel pipes are:

- **Full penetration butt welded steel for heavier wall thickness than normal**. See DSG section 5.6.3.9B1. Steel pipe with no special fittings works well for long smooth settlement troughs. See Virtual Vault plan set 774-569 for an example of a 24-inch butt welded steel pipe with several design features included to increase seismic survivability of the system in a liquefiable zone.
- **Full penetration butt welded steel with expansion fittings.** Large-diameter steel expansion sleeves are available, but offer little expansion or deflection capability. If possible, double ball joint expansion fitting(s) should be installed if large differential ground movements are expected. Due to their current limited

range of available sizes, steel pipe size may need to be reduced in the immediate vicinity of the ball joints. See Virtual Vault plan set 785-38 for an example of an 89-inch OD steel pipe crossing a slide plane with a 48-inch double ball expansion joint.

Where fault crossings/slide planes are encountered, a double ball expansion joint should be installed right at the fault crossing as shown in Virtual Vault plan set 785-38. If this is not possible, the thickest pipe wall and strongest steel should be used, with some flexibility built in elsewhere if possible.

Design considerations such as predicted ground movement, installation cost, cost of failure, and reliability must be analyzed. It may be cheaper to install an inexpensive pipe system and replace it every 10 years than to install a system that will last 100 years. Some SPU pipelines are extremely critical and must be designed to withstand the largest expected ground movement.

5.8.4.3 Seismically Actuated Valves

Seismically actuated valves automatically close during an earthquake to prevent the uncontrolled drainage from water storage tanks due to broken downstream pipelines. Many factors must be determined for each valve installation: sensitivity, speed to close, battery life requirements, power availability, and SCADA.

The seismic actuator must be properly matched to the valve it protects.

All valves must have a manual operator for emergency operation.

5.8.5 Inter-Connection of Parallel Mains

In some cases, pipelines may be installed parallel, or a new line may be installed near an existing main. The design engineer should consider whether a connection between the two pipelines is possible and beneficial. A primary reason to consider the interconnection is draining of the pipelines. Typically, when a pipeline is drained, millions of gallons of water are wasted. Pumping from pipeline to pipeline allows for much faster draining than can normally be achieved by draining to the water system. If parallel or nearby pipelines are interconnected, water from the pipeline to be drained can be pumped into the other pipeline, thus not wasting water.

The interconnection between mains will likely require room for a pump. If possible, route an interconnection line from each pipeline into a single vault, leaving a gap for a pump and the final connecting piping. The size of the interconnection should be based on flow calculations and an acceptable amount of time to drain the line. A good location for an intertie is at the blow-off.

5.8.6 Rehabilitation of Existing Mains

See DSG section 5.6.5.

5.8.7 Emergency Pump Connections

See DSG section 5.6.6.

5.8.8 SCADA

See DSG section 5.6.7.

5.8.9 Corrosion Control

See DSG section 5.6.8.

5.9 WATER STORAGE TANKS, STANDPIPES AND RESERVOIR DESIGN

This section describes water storage facility design. Water storage facilities primarily function to provide adequate flow and pressure for all design conditions where the transmission and distribution system cannot otherwise maintain the flow or pressure required. Water storage tanks, stand pipes, and reservoirs are critical infrastructure that directly influences public health and safety. These SPU facilities must be designed and operated to prevent cross-contamination of water and degradation of water quality. For more detail on SPU reservoirs, see *DSG Chapter 13, Dam Safety*.

5.9.1 Planning

USM determines the need for a new or refurbished water storage facility. This planning includes determining the facility's general characteristics, size, location, and a timeline for service based on hydraulic modeling and demand projections. If approved by SPU management, a storage facility project is incorporated into the Capital Improvements Program (CIP) plan.

5.9.1.1 Service Life

A. Concrete Reservoirs

For new concrete water storage reservoirs, service life must meet the specific project requirements. Most water utilities use a typical service life of not less than 50 years for concrete structures. For refurbished existing concrete water storage reservoirs, the design service life will be established case-by-case based on the specific conditions and requirements for the reservoir.

B. Steel Storage Tanks

For new steel water storage tanks, most water utilities use a design life of 75 or more years, assuming that the coatings are well maintained. An economic analysis of coating and cathodic protection systems should be done to determine the most cost-effective method for preventing corrosion. For refurbished existing steel water storage tanks, design service life is established case-by-case based on specific conditions and requirements for the tank.

5.9.1.2 Hydraulic and Capacity Requirements

Generally, the size of a finished water storage facility must provide sufficient capacity to meet both domestic demands and any requirements for fire flow.

Specific capacity requirements must meet the applicable elements of the Washington State Department of Health Water System Design Manual or SPU's system reliability criteria under defined emergency scenarios, whichever is less. Storage facilities are expensive to construct, operate and maintain, plus they increase the water age and as such should not be unnecessarily oversized.

Capacity must be established and documented by an engineering study using the following basic criteria:

- The planning horizon for demand projections must be not less than 20 years. For new facilities, the planning horizon should be 50 years or more.
- Volume should be sufficient to deliver design peak hourly demand at 30 psi to the pressure zone(s) served. This volume requirement may be reduced when the source water facilities have sufficient capacity with standby power for pumping to the reservoir and/or when another storage reservoir can be used to supplement peak demands of the zone(s). During fire flow conditions, the combination of storage and delivery system capacity must be adequate to provide water at the required flow rate and a minimum 20 psi in the main.
- To determine the emergency /standby storage component, identify the reasonable emergencies, define the duration and level of service during the emergency, then apply SPU's reliability criteria as described in the current WSP.
- Water quality impact of storage and design considerations to enable regulatory compliance throughout the life of the facility.

5.9.1.3 New or Modifications/Expansions of Existing Storage Facilities

A. General Considerations for New Facilities

The following are general considerations for planning and preliminary design of new storage facilities or for modifications, expansions of existing facilities, retirements of facilities or downsizing facilities:

- Hydraulic grade line of the water supply system
- Pressure zones served by the storage facility
- Sizes and capacities of transmission or feeder mains and, where applicable, booster pumping stations, that supply the storage facility (existing and future)
- Sizes and capacities of distribution mains in the pressure zones served by the storage facility (existing and future)
- Availability and type of discharge points for overflow and drain-down water from the storage facility
- Geotechnical and seismic characteristics
- Vehicle access for all anticipated vehicle and equipment types
- Security
- Fire services (fire flow, emergency engine fill points post-earthquake)
- Land ownership and future use by City of Seattle departments
- Environmental impacts to adjacent properties

- Multi-use site considerations (e.g. public access, recreation, memorandum of agreement addressing maintenance and use on reservoir sites and sites adjacent to reservoirs)
- Anticipated future development of adjacent properties

B. Communications Equipment

Antennas and other communications equipment can be mounted on a separate towers on the site or on a storage facility. If antennas or communications equipment are mounted on the storage facility, proposals must include structural and wind-load engineering calculations demonstrating the tank can safely accommodate the additional weight of equipment and cables. SPU Real Property is the lead for communicating with tenants and issues the permits for use of SPU property.

Calculations must factor in other equipment already installed on the tank. Equipment should be clamped to the facility rather than welded when possible, to avoid damage to interior and exterior coatings.

Note: It is extremely important to ensure that the interior coating of the tank is undamaged either by welding or by an activity that may jeopardize the interior lining or the exterior coating. The cost of such damage is significant.

C. Location of New Facilities

Location of new storage facilities should consider site features and constraints that affect the sanitary and structural integrity of the facility:

- Drainage of site and structure
- Locate storage facilities at least 50 feet from the nearest potential source of contamination
- For above-grade facilities: foundations should be at least 3 feet higher than the 100-year flood elevation
- For below-grade facilities:

At least 50% of reservoir or tank should be above highest point of groundwater table Accessible vents and hatches should be at least 2 feet above normal ground surface. Grade should slope away from the reservoir. Access points and vents are located above the 100-year storm elevation

- Proximity to closest sanitary sewer and storm drainage mains
- Overflow route

D. Green Stormwater Infrastructure and Flow Control for New Facilities

The City of Seattle requires green stormwater infrastructure (GSI) on all new facilities. Flow control may be required. For detailed information on GSI and flow control requirements, see *DSG Chapter 8 section 8.7.8.*

5.9.1.4 Operations and Maintenance (O&M) Requirements

A. Routine Operations

At a minimum, each water storage facility must follow water supply and quality goals for operational procedures common to all facilities as shown on Table 5-10.

Table 5-10 Sample Requirements for Routine Operation of Water Storage Facilities

Parameter	Requirement	Comments
Pressure Maintenance to Zone(s) Served:	30 psi	Maintain 30 psi under peak hourly demand conditions Maintain 20 psi under fire flow conditions
Minimum	20 psi	
Drawdown and Filling	Typical draw between 8AM and 5PM Typical fill between 8PM and 5AM	Draw and fill cycles for some storage facilities may vary from this objective to meet other requirements. Note: These times are a starting point. Drawdown occurs during day and fill overnight as a general rule
Water Age (turnover rate)	3 – 5 days	Longer water ages may be acceptable for some storage facilities based on chlorine residual data, water mixing systems and ease of chemical injection
Operational Volume	As required to meet seasonal demands, pressure requirements, and water age targets	Operational volumes will vary seasonally for many of the storage facilities
Sample Collection	Easily accessible sample port enclosed in cabinet	Sampling may be required at different elevations within the tank
Supervisory Control and Monitoring	Water elevation Overflow indication Inlet and outlet metering	

B. Emergency Operations

The following are minimum design requirements for operation of water storage facilities under emergency conditions that can result in loss of power or a water quality condition that could be harmful to health:

- Maintain at least one storage cell on-line if facility has two or more storage cells. If the facility is a single cell, maintain at least 50% of the volume online
- Fill all storage cells
- Draw from at least one storage cell to meet emergency demands for at least (as required) hours
- Hydraulically isolate all storage cells from the supply and distribution system
- Complete drain-down of a storage cell as specified in the basis of design
- Inject a solution of treatment chemical
- Collect a water quality sample from an easily accessible collection point

5.9.2 Water Storage Facility Structures

The following are the primary structural functions of a water storage facility:

- Remain as water tight as achievable for the design seismic, geotechnical, and thermal conditions over its design life
- Survive the design seismic event so that its operational purpose (fill, storage, and draw of potable water) is maintained
- Maintain the sanitary integrity of the tank so that its water quality is not compromised.

The following are general design requirements for structural and material design elements of storage facilities to meet the above requirements. All elements must be evaluated and addressed to establish the basis of design for every new or refurbished storage facility.

5.9.2.1 Geotechnical and Seismic Requirements

The following are SPU standards:

1. A geotechnical study must be performed before design of any new or structurally refurbished storage facility. Soils and groundwater characteristics for each site are unique, so the geotechnical study must be tailored accordingly.
2. The methods, findings, and recommendations of the geotechnical study must be documented in a geotechnical report.
3. The structural design requirements of storage facilities must address specific seismic criteria for Essential Structures per the Seattle Building Code (SBC) and AWWA D-100.

The following are guidelines for the geotechnical report:

- Identification of previous geotechnical work for the storage facility site and the key observations and conclusions from the previous work.
- A detailed description of subsurface soils and groundwater conditions.
- Identification and descriptions of known geologic hazards, including seismic, steep slopes and landslides, erosion, and contaminated soils hazards
- Identification of locations for additional field explorations/borings, if needed.
- Conclusions and recommendations for design, including geologic hazards, seismic criteria (e.g. probabilities of peak ground acceleration), excavation and shoring, dewatering, foundation and backfill requirements, erosion and sedimentation control measures, and hazardous materials.

5.9.2.2 Structural Materials

A. Concrete Reservoirs

Two primary issues for concrete storage reservoirs must be addressed in design:

1. Corrosion of exposed reinforcing steel and corrosion caused by use of dissimilar metals, such as stainless steel ladders adjacent to mild steel, either coated or embedded.
2. Foundation failure due to settlement or leaks causing undermining of the foundation.

The low alkalinity and pH of cement materials can cause deep cracking on the interior of the facility and may expose the reinforcing steel to air and moisture, resulting in corrosion. As reinforcing steel corrodes, the integrity of the structure will weaken and eventually fail if not repaired.

Cracking in walls roofs and floors, failed expansion joints, failed water stops, are also common concerns with concrete reservoirs that should be addressed in design.

For concrete reservoirs, the following AWWA standards must be applied:

- D110 – Wire- and Strand-Wound, Circular, Pre-stressed Concrete Water Tanks
- D115 – Circular Pre-stressed Concrete Water Tanks With Circumferential Tendons.

B. Steel Tanks

The structural integrity of steel storage tanks is primarily affected by corrosion. Corrosion can attack specific portions of the tank and cause significant structural problems.

For steel tanks, the following AWWA standards must be applied:

- D100 – Welded Steel Tanks for Water Storage
- D103 – Factory-Coated Bolted Steel Tanks for Water Storage.

5.9.2.3 Coatings

For steel tanks, the following AWWA standards must be applied:

- D102– Coating Steel Water Storage Tanks

5.9.2.4 Liners

For liners and floating covers in contact with potable water, the following AWWA standards must be applied:

- D130 – Flexible-Membrane Materials for Potable Water Applications.

5.9.2.5 Corrosion Control Systems

If used for steel tanks, the following AWWA standards must be applied:

- D104– Automatically Controlled, Impressed-Current Cathodic Protection for the Interior of Steel Water Tanks.

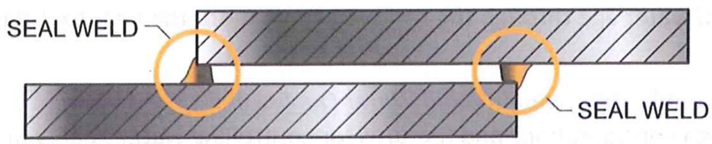
The design engineer should consult with a corrosion control specialist and evaluate the following:

- Conditions above and below the water level

- Fasteners and appurtenances located within the tank.

Surfaces exposed to fluctuating water levels and the undersides of roofs are particularly at risk, yet they receive little benefit from cathodic protection. Proper coating systems are critical for these surfaces. Do not use dissimilar materials inside the tank (e.g. steel structure and stainless steel ladders).

Seal weld all adjacent metal to avoid corrosion between the plates (see illustration).



For more detail on corrosion control systems, see *DSG Chapter 6, Cathodic Protection*.

5.9.2.6 Demolition

Demolition of other structures or buried utilities adjacent to or below a water storage facility's foundation or footings requires careful consideration to avoid damaging the foundation, footings, or yard piping associated with the facility. Before design of demolition, geotechnical and structural analyses should be done to determine potential impacts of the proposed demolition to establish a basis of design for their protection. For information on demolition permit requirements, see *DSG Chapter 2, Design for Permitting and Environmental Review*.

5.9.2.7 Configuration and Control for Service Reliability

The configuration and control for service reliability should consider the number of cells and flow control.

A. Number of Cells

To the extent practicable, new or refurbished facilities should have two or more cells to provide for greater reliability/redundancy.

If it is determined that a single cell meets the project requirements, it should be a dual outlet system. The lower outlet typically uses an earthquake/seismic valve.

B. Flow Control

The following are the minimum flow control requirements for storage facilities:

- Isolation valves on inlet and outlet lines that can be controlled locally and via SCADA
- Piping and valves to provide for the bypass and drainage of the storage cell

5.9.3 Hydraulic Mixing for Water Age and Water Quality Control

To prevent hydraulic dead zones and excessive water ages within a storage tank or reservoir, there must be a means for complete hydraulic mixing throughout the entire volume of the storage cell. The configuration and sizes of inlet and outlet pipes to the cell have a direct impact on the degree of hydraulic mixing achievable.

Each storage cell should have a volume in which water age (hydraulic detention time) is not more than 5 days at projected average water demands when the reservoir operates at full capacity. The goal is to keep total water age through the reservoir to no more than a 5-to-7-day range.

The Water Research Foundation publication, *Maintaining Water Quality in Finished Water Storage Facilities*, describes design considerations and features for controlling water quality in storage facilities.

5.9.3.1 Inlet and Outlet Pipes

Generally, a separation of the inlet and outlet points within a storage cell will enhance mixing and help avoid water quality problems associated with dead zones and short circuiting. For ground tanks, this is done by locating the inlet discharge near the perimeter of the cell with an upward bend. The tank outlets are then placed into the center of the tank floor. In elevated tanks, inlet an outlet points are separated one of two ways:

- Bring separate inlet and outlet lines up through the tank
- Split the line in the riser and use check valves to introduce water into the center of the tank near the top of the water column. In this option, the outlet pipes are placed at the tank perimeter with a vertical separation to the inlet elevation of not less than about ½ the total cell height.

Proprietary pipe and valve systems for storage facilities can be specifically designed based on the momentum mixing principle. The Red Valve Company system has gained widespread use.

For smaller tanks (less than 0.5 million gallons), the inlet and outlet may not need to be separated. Smaller tanks have smaller volumes, which allow adequate momentum for mixing.

A. Inlet Pipe

The inlet pipe should be as small as practicable to maximize inlet velocity to provide for adequate momentum mixing throughout the storage cell to preclude hydraulic short-circuiting. Reductions of inlet diameter have also been retrofitted on existing SPU tanks during tank renovation by using a reducer on the discharge end of the inlet pipe.

B. Outlet Pipe

In ground level reservoirs, each storage cell should have two outlet pipes, one near the mid-level and the other near the bottom of the cell. Both outlets should have isolation valves. The mid-level and lower outlets remain open for normal operation. The lower outlet should have a seismic valve that closes automatically during an earthquake to prevent the cell from draining past the mid-level.

5.9.3.2 Sizing Inlet Nozzles for Momentum Mixing

The inlet pipe and nozzle to each reservoir cell should be sized to provide a velocity of the entering water to enable complete hydraulic mixing throughout the entire cell. Typical time to mix the cell should be 4 to 6 hours at the designed inlet flow rate for lower-demand periods.

5.9.3.3 Mechanical Mixing Systems

If adequate momentum mixing cannot be achieved using inlet jet velocity (due to flow rates in relation to reservoir cell size), consider enhancing using a mechanical method. The following are three mechanical mixing methods:

1. **Pumped recirculation.** The only form of reservoir mixing SPU currently uses is pumped recirculation. This system features a pumped recirculation loop with the suction line from the reservoir and the discharge line entering the reservoir through a single or multiple ports.
2. **Mechanical mixers within the reservoir**
3. If higher-pressure water is available, consider a **gravity hydraulic mixing system** that pipes the higher pressure water to the tank and mixes through a series of nozzles attached to a riser pipe in the tank.

A. Recirculation

- Recirculation systems should be designed for continuous pumping. A general estimate for recirculation pump sizing is 1 hp per million gallons of storage volume.
- Provide at least two pumps for full redundancy.
- To the extent practicable, select pump sizes and types that are compatible with recirculation pumps at other reservoirs so that pumps are interchangeable and can be used as replacements or spares.
- The recirculation grid size depends on the size of the storage cell, but should extend to cover all areas of the cell. Pipe sizes for these grids are typically 4 to 6 inches in diameter.
- Orifice sizes and spacing are designed to achieve the velocities necessary for adequate localized momentum mixing. Typically, the range of velocity needed is 8 to 10 fps at the orifice discharge.
- Provide an easily accessible sample collection point on the recirculation piping.
- Provide an easily accessible chemical injection point on the recirculation piping.

5.9.4 Water Level and Flow Measurement

- <u>Each storage cell must have provisions for online measurement and recording of water levels between lowest anticipated operating and overflow levels</u>.
- Provide a totalizing meter on the outlet side to accurately measure demand from the reservoir.

- Provide positive online indication of overflow.

5.9.5 Mechanical Appurtenances and Equipment

This section describes mechanical appurtenances and equipment for water storage facilities.

5.9.5.1 Location

To the extent practicable, mechanical appurtenances such as valves, pumps, and controls should be located in clusters. If applicable, they should be located in mechanical rooms or vaults for ease of maintenance and security.

5.9.5.2 Penetrations to Storage Cells

Penetrations for pipes, hatches, vents, and sensors into storage cells require special design considerations to preclude the intrusion of contaminants. The following are general considerations for mechanical appurtenances and equipment that penetrate storage cells:

- Materials and coatings of appurtenances should provide for high resistance to corrosion.
- Open ends of vents and overflow lines should be oriented downward and provided with 24-mesh, corrosion resistant screens.
- Wall and roof penetrations are welded on steel tanks and equipped with seep rings on concrete reservoirs.
- Valve stem penetrations must be sealed to prevent entry of contaminants.
- Materials used at penetrations must be selected to avoid creating galvanic currents between dissimilar metals.

5.9.5.3 Vents

- Vents should be located at least 2 feet above finished grade or the 100-year flood elevation, whichever is greater.
- Vents must be sized to allow for adequate air intake during rapid drawdown of the water level such that the maximum pressure drop within the storage cell does not impose structural stresses. The acceptable maximum pressure drop is a function of structural materials and configuration of the storage cell. Acceptable maximum pressure drop must be established by a design engineer or manufacturer.

5.9.5.4 Overflows

The following are SPU standards for overflow pipes:

1. Overflow pipes must be sized to accept flow rates equal or greater to the maximum inflow rate to the storage cell.
2. Overflow pipes must terminate 1 to 2 feet but a minimum of two pipe diameters above grade to provide an air gap, and should be easily visible to O&M staff. Provide a minimum of two pipe diameters gap.

3. The surface below the air gap must slope away from the storage cell and direct the flow to a sump or catch basin from which the flow is conveyed to the designated discharge point.

The following are guidelines for overflow pipes:

- If the overflow water enters a sewer, check sewer pipe hydraulics for any constraints to accepting the design overflow rate.
- If the overflow water can enter a natural stream or pond directly from the discharge point, a passive dechlorination system should be installed. For example, a passive dechlorination system is a catch basin within which bags of a dechlorination chemical (ascorbic acid or sodium thiosulfate) are placed. The overflow water is passed through the dechlorination structure before discharge to the receiving water body.
- In addition to a screen, consider installing a flap gate or duckbill valve at the end of the overflow pipe to prevent animal access.

Note: Overflows usually go to a reservoir's dedicated storm drain line. This line must also be capable of the flow rate. The receiving water body must likewise be able to receive this flow rate.

5.9.5.5 Connections

Connections between the storage cell structure and pipes external to the structure (either exposed or buried pipes) should allow for longitudinal expansion and lateral movement that occurs during earthquakes and through long-term differential settlement. Pipes located under ground-level reservoirs should be encased in reinforced concrete to minimize future maintenance.

5.9.5.6 Hatches

The following are SPU standards for water storage hatches:

1. All access hatches not bolted to the main structure must be lockable and provide intrusion switches linked to the SCADA system.
2. Hatch lids must be designed to prevent drainage runoff from entering interior of the hatch and/or accumulating next to the hatch area. This also provides protection from ice damage. For hatches with raised curbs or frames, the lid should overlap the curb/frame.

The following are guidelines for hatches:

- For accessible ground-level hatches to concrete reservoirs, the hatch should be designed either to lock or to accommodate a 600-lb block or lid on top.
- Hatches manufactured by LW Products or Bilco have typically met SPU requirements.
- Hatches installed in graveled areas should be raised above grade to prevent gravel from becoming lodged and jammed between the frame and the lid, or becoming lodged in the locks.

5.9.5.7 Access Ladders and Catwalks

- Fall protection equipment must be provided and used before accessing structure

- Select material and coatings to provide for high resistance to corrosion and graffiti
- For above grade facilities, entries to ladders or catwalks should be elevated at least 10 feet above grade and have a lockable gate or door. The gate or door must be designed to allow for safe access from a "cherry-picker" man-lift.
- For elevated stairwells inside of storage cells, the steps should be solid plates with raised edges to help prevent dirt from entering the water.

5.9.5.8 Mechanical Rooms and Vaults

- Provide for proper interior drainage within the valve vault or chamber, including floors sloped to drains and/or sumps.
- Provide for perimeter drainage.
- Top of chamber should be at least 1 foot above finished grade.
- For access hatches and vents to valve chambers, see DSG section 5.9.5.6.

5.9.5.9 Storage Cell Drainage Equipment and Features

- Cell drain pipes must not be cross-connected to a storm or sanitary sewer line. They also need an air gap or backflow prevention device.
- The floor of a storage cell should be sloped to enable drainage to a single sump.
- If feasible, the sump should have a pipe that drains via gravity to the designated cell drain point with an air gap. The sump should be sized to accommodate a portable sump pump, even if there is no drain pipe.
- Size drain pipes to accept flow rates such that the cell can be drained in the minimum amount of time without exceeding the capacity of the vents. The maximum drain line capacity should approach the maximum operational inflow rate to the storage cell.
- Control valves for drain pipes should be easily accessible. Wherever possible, the location of drain valves should be within the valve chamber for the storage facility.
- Provide a removable mud/silt stop at the entry to the drain pipe.

A. Roof Drains

- Roofs must be water tight and sloped for drainage.
- Roof drains must be connected to a permitted drainage system.
- Roof downspouts must be external and not mounted within the storage cell. None of the drain system should be within the storage cell.
- Domestic water and stormwater must not co-mingle.
- SPU requires certain Green Stormwater Infrastructure (GSI) elements be incorporated into structural design of new projects. For more information on GSI, see *DSG Chapter 8, section 8.7.8.*