Chapter 3
Water Quality and Treatment

This chapter of the *2013 Water System Plan* focuses on the Water Quality and Treatment Business Area, which administers SPU's drinking water quality and treatment programs, projects, services, and capital assets from the supply source to the customers' taps. Key functions of this business area include managing SPU's drinking water regulatory compliance, oversight of the Tolt and Cedar Water Treatment Facilities and their contract operations, ensuring appropriate monitoring of water quality for regulatory and operational purposes, managing distribution system water quality, overseeing water quality and treatment related capital improvement projects, and participating in other water system projects that have the potential to impact water quality. The Water Quality and Treatment business area is unlike other business areas in that its programs affect infrastructure and practices in the Major Watersheds, Water Resources, Transmission and Distribution business areas. This chapter also includes descriptions of the drinking water regulatory requirements SPU must meet or exceed, as well as SPU's history of compliance.

SPU's water system includes two state-of-the-art water treatment facilities for the Cedar and Tolt source waters. The treatment facilities provide multiple barrier treatment processes to offer high levels of treatment prior to transmission and distribution.

3.1 ACCOMPLISHMENTS SINCE 2007 WSP

Since completion of the *2007 Water System Plan*, SPU has implemented the following major improvements in the Water Quality and Treatment business area:

- Reservoir Covering/Burying: Reconstructed the following from open reservoirs to covered reservoirs to improve water quality, increase security, and create new public open space opportunities:
  - Myrtle Reservoir (2008)
  - Beacon Reservoir (2009)
  - West Seattle Reservoir (2010)
  - Maple Leaf Reservoir (2012)
- Kerriston Road: Purchased approximately 148 acres to increase control of lands accessed by Kerriston Road through the lower Cedar River Watershed, avoid future risk and costs associated with illegal trespass in and around the Cedar River Watershed, and reduce risk and liability costs associated with continuing residential build-out of the Kerriston community (2011).

- Laboratory Information Management System (LIMS): Implemented an updated LIMS system at SPU's Water Quality Laboratory to allow for efficient sample scheduling, coordination of analyses, recording of results, quality assurance/quality control tracking, and data retrieval (2007).
- Cross-Connection Control: Set up and installed a database for management of the cross-connection control program, which includes the oversight of over 20,000 backflow assemblies in the city (2009). The database made possible a new enforcement strategy implemented in 2011 which greatly improved compliance with backflow assembly testing requirements. The backlog of assemblies overdue for testing was reduced from fifteen percent down to four percent.

3.2 Service Level Performance

SPU's service level in the Water Quality and Treatment business area focuses on meeting federal and state regulatory requirements. This is captured in a single service level objective and target for drinking water quality as shown in Table 3-1.

Table 3-1. SPU's Service Level for Managing Water Quality and Treatment Assets

Service Level Objective	Service Level Target
Promote a high level of public health protection and customer satisfaction with drinking water quality.	Meet all health-related and aesthetic regulations administered by the WDOH Drinking Water Program for the Seattle regional water system.

SPU's service level target is to meet health-related regulations (i.e., primary maximum contaminant levels and treatment requirements), aesthetic regulations (i.e., secondary maximum contaminant levels), and other aesthetic criteria (i.e., taste, and odor). SPU has been successful in meeting this service level. Since the *2007 Water System Plan* was developed, SPU met all drinking water regulatory requirements. SPU has a Reservoir Covering Plan approved by Washington State Department of Health (WDOH) that is being implemented ahead of schedule (see Section 3.3.6.1). More information on how SPU is meeting regulations is provided in the remainder of this chapter.

3.3 Existing Facilities and Practices

SPU's water system includes state-of-the-art water treatment facilities for the Cedar and South Fork Tolt source waters, treatment and intake screening facilities at Landsburg, intake screening facilities at the Tolt Regulating Basin, and in-town disinfection facilities at reservoirs and well sites. Each of these facilities is operated and maintained to ensure that the potable water SPU delivers to its customers meets high public health and aesthetic standards.

To achieve its water quality and treatment service level, SPU has expended a great deal of effort over the past decades and continues to make concerted efforts in order to ensure compliance with WDOH drinking water regulations. SPU operates its facilities, monitors water quality at those facilities, and engages in a number of practices designed to bring safe, high-quality drinking water to its customers. This section summarizes SPU's record of regulatory compliance, identifies SPU's treatment facilities, and summarizes its operation and maintenance practices to ensure excellent water quality and a high level of customer satisfaction.

3.3.1 Regulatory Requirements and Compliance

Federal and state statutes and administrative regulations require the utility to meet certain water quality criteria and performance standards. The following subsections identify the standards and requirements that SPU must achieve and summarize SPU's performance in meeting those standards and requirements.

3.3.1.1 Total Coliform Rule

SPU has been well within regulatory requirements for coliform since the startup of the Cedar Water Treatment Facility in 2004.

The Total Coliform Rule requires monitoring to demonstrate that a water system is operating and maintaining its distribution system in a way that minimizes the risk of bacterial intrusion or regrowth. SPU collects required monthly samples from its retail service area distribution system and tests for coliforms, which are naturally present in the environment and are used as an indicator of whether other, potentially harmful, bacteria may be present. As system improvements, especially better disinfection facilities and covered reservoirs, have been implemented over recent years, Seattle's success in meeting the total coliform rule requirements have improved greatly.

As indicated by Figure 3-1, SPU has been continuously in compliance with the Total Coliform Rule. Since the startup of the Cedar Water Treatment Facility in August 2004, SPU has been well within the regulatory requirement of less than 5 percent of samples with detectable total coliform. The highest detection month since August 2004 was 2.1 percent, which occurred in July 2008.

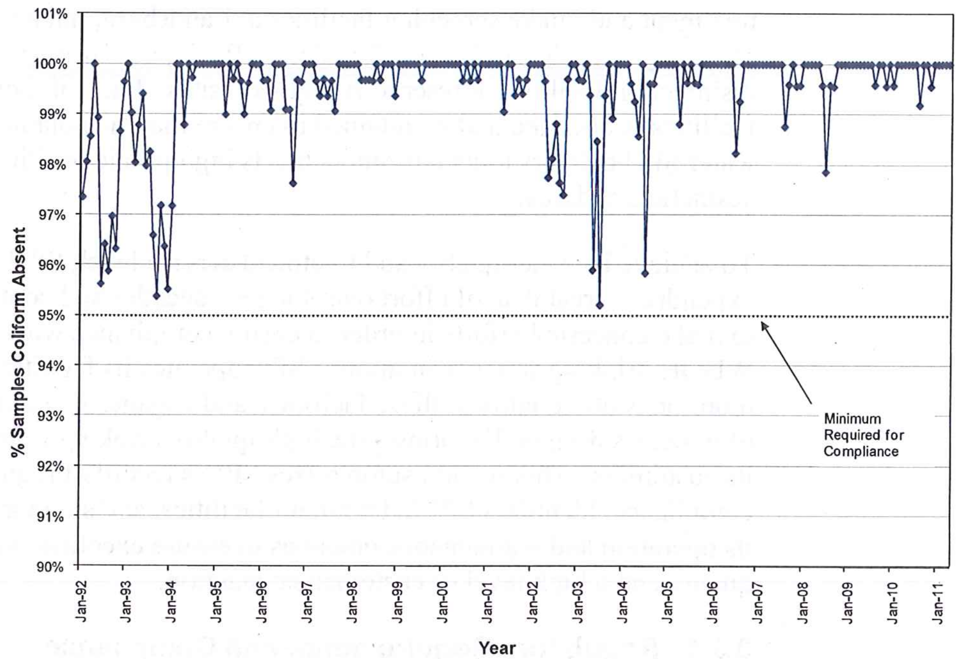

Figure 3-1. Monthly Coliform Data from SPU Water Distribution System

There have been over 15,000 coliform samples collected since January 2006. Of those 15,000 distribution samples, 27 have been positive for total coliform, and two have been positive for *E. Coli*. All follow-up sampling for the *E. Coli* positive samples showed no indication of contamination, and compliance with the Total Coliform Rule was met. Public notification was not required.

3.3.1.2 Surface Water Treatment Rule

The Surface Water Treatment Rule (SWTR) contains disinfection and filtration requirements for all public water systems that use surface water supplies. Several revisions to the original rule have been made since 1989, with the latest revision being the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR).

Tolt Supply. With completion of the Tolt Water Treatment Facility in 2001, the supply from South Fork Tolt River must meet all the requirements of a surface supply using filtration and disinfection. The Tolt Water Treatment Facility operations contract includes water quality performance requirements that meet and, in most cases, exceed the regulatory filtration and disinfection requirements. The Tolt Water Treatment Facility has had no treatment violations since startup.

Cedar Supply. Construction of the Cedar Water Treatment Facility was completed in 2004. The Cedar River supply has a regulatory designation known as a "Limited Alternative to Filtration" (LAF), which authorizes SPU to operate the Cedar source without filtration treatment. LAF status is granted because Cedar source water is produced from a watershed that is 100 percent in public ownership, with no residential, commercial or industrial development, and the treatment system employs a multi-stage disinfection process that provides greater protection against microbial contamination than can be provided by traditional filtration and chlorine disinfection. The Cedar supply continues to operate in compliance with the LAF criteria.

Like the Tolt Water Treatment Facility, the Cedar Water Treatment Facility operations contract includes water quality performance requirements that meet and, in most cases, exceed regulatory requirements. Since it began operating in 2004, the Cedar Water Treatment Facility has experienced no treatment violations.

Long Term 2 Enhanced Surface Water Treatment Rule. The LT2SWTR, focuses on controlling *Giardia* and *Cryptosporidium* in surface water supplies. This rule affects the Seattle water system in two ways: source monitoring for *Cryptosporidium* and covering of open distribution reservoirs. The source monitoring for *Cryptosporidium* is now complete. The results for both the Cedar and Tolt were in the lowest category (highest quality), so no changes are needed to the existing treatment provided.

The LT2ESWTR also requires that open, treated-water reservoirs be covered or provided with treatment on the outlet. SPU already had a reservoir covering plan approved by WDOH when the LT2EWTR was issued. SPU reaffirmed its covering plan with DOH in 2009. SPU's reservoir covering program is described in further detail later in this chapter.

3.3.1.3 Groundwater Rule

The Groundwater Rule was issued in November of 2006 and went into effect in 2009. SPU has not used its wells for production purposes since the rule has been in effect. SPU's wells draw from a deep aquifer that is well protected from contamination. When the Seattle Wells are next used, SPU's plan for compliance is to conduct triggered source water monitoring as necessary. While not part of the current regulatory compliance strategy, chlorine contact time for disinfection of viruses is achieved in the pipelines a short distance from the wells.

3.3.1.4 Disinfection By-Products Rule

In general, Seattle's high quality source water and upgraded treatment result in low concentrations of disinfection by-products (DBPs), such as trihalomethanes and haloacetic acids, by-products that can result from reactions between chlorine and natural organic matter. Trihalomethane and haloacetic acid monitoring results since 2006 are presented in Figure 3-2 and Figure 3-3. The results are all well below the regulatory limits. Historically, disinfection by-product levels have been relatively low in the Cedar River water. Disinfection by-product levels in the South Fork Tolt River water decreased substantially with startup of the Tolt Water Treatment Facility and are now comparable to those of the Cedar source.

SPU has completed the Stage 2 DBP Rule Initial Distribution System Evaluation (IDSE) sampling program that identified sites in the distribution system where the highest disinfection by-product levels were likely to be found. Based on IDSE testing results, SPU does not anticipate any difficulty meeting the by-product limits under the new rule.

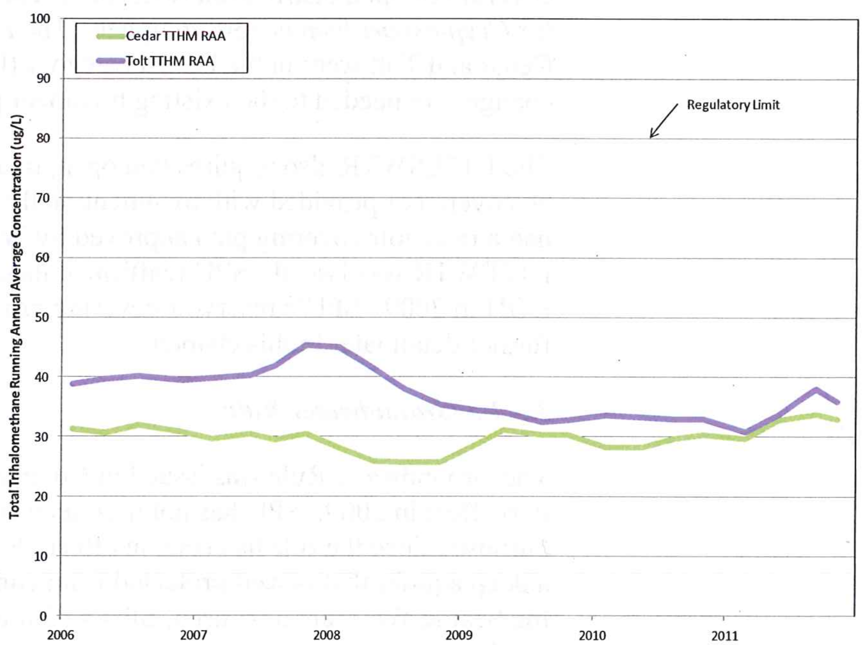

Figure 3-2. Trihalomethane Concentrations, 2006 to 2011

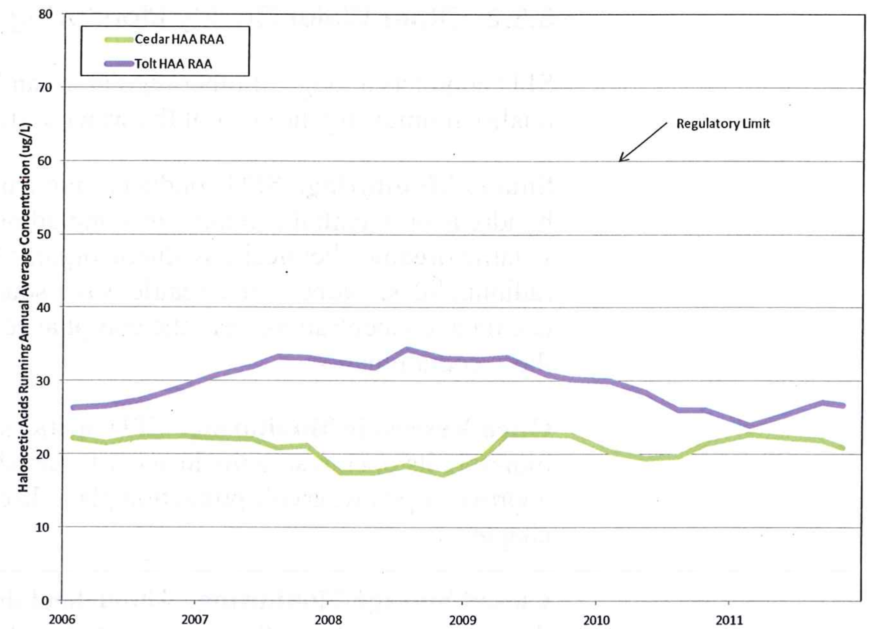

Figure 3-3. Haloacetic Acid Concentrations, 2006 to 2011

3.3.1.5 Lead and Copper Rule

Seattle's source and distribution water contains no significant amounts of lead or copper. Household plumbing, however, is often made of copper, and household systems can include components containing lead, such as lead-tin solder and leaded-brass fixtures. These components can leach lead and copper into the water.

Beginning in 2005, compliance for Seattle's Regional Lead and Copper Monitoring Program was divided into sub-regions. Compliance for Seattle has been based on samples collected from the Seattle direct service area only since 2005. Compliance for the other sub-regions (Bellevue, Tolt Wholesale, and Cedar Wholesale) is based on results from those sub-regions.

The Lead and Copper Rule requirement is to be below 15 ug/L for lead, and below 1,300 ug/L for copper, with both at the 90^{th} percentile. Seattle's 90^{th} percentile lead levels since 2005 have been between 5.0 to 6.4 ug/L, well below the lead action level. For copper, Seattle's 90^{th} percentile levels have been between 120 to 160 ug/L. These levels have allowed Seattle to conduct reduced monitoring for lead and copper. Fifty samples are now collected once every three years from qualified homes in the Seattle direct service area. The next sampling period for the Seattle subregion will occur in 2013.

3.3.2 Other Water Quality Monitoring

SPU conducts a range of other regulatory and non-regulatory water quality monitoring throughout the water system.

Source Monitoring. SPU conducts source monitoring for hundreds of potential contaminants, including inorganic chemicals, volatile organic chemicals, synthetic organic chemicals, and radionuclides. None of the Seattle water sources have had chemical concentrations near the compliance limits for any of these contaminants.

Open Reservoir Monitoring. SPU operates, maintains, and monitors its open reservoirs in accordance with a WDOH-approved open reservoir protection plan, discussed later in this chapter.

Closed Storage Monitoring. Throughout the year, SPU monitors the quality of water within covered storage facilities as part of its routine water quality monitoring program. The information guides system operations, reservoir turnover, spot disinfection, and decisions about when to take facilities out of service for cleaning or other actions.

Taste and Odor Sampling. Taste and odor testing is conducted at least bi-weekly by a trained flavor profile analysis panel at SPU. The testing monitors and characterizes changes in tastes and odors associated with the source waters and distribution reservoirs, especially the open reservoirs. The test data are used to ensure source treatment performance criteria are met and to inform operators about the need to take reservoirs out of service, increase reservoir turnover, overflow reservoirs, or blend sources of supply.

Emerging Contaminants. Emerging contaminants are not regulated, they are generally new to drinking water scientists, and there is typically limited information about their occurrence and health effects. EPA requires water systems to perform monitoring for some of these contaminants in order to learn about their occurrence. In addition, SPU has chosen to test for other emerging contaminants for its own information and to inform the public. Details of this monitoring are described later in this chapter.

Miscellaneous Monitoring. SPU also conducts extensive water quality monitoring at the Landsburg Diversion on the Cedar River, Chester Morse Lake, Lake Youngs, the Tolt Reservoir, and the Tolt Regulating Basin. Nutrients, algae, and other basic chemical and physical parameters such as pH, temperature, total organic carbon, ultraviolet absorbance, dissolved oxygen, reservoir stratification, and visibility throughout the water column are monitored. This water quality information is used to better understand the conditions in the water bodies, to learn about potential shifts or changes with significance to the drinking water supply, and to inform decisions about water treatment and other system operations.

3.3.3 Source Water Protection Programs

SPU's finished water quality is excellent, in part, because of SPU's substantial efforts to protect its water sources. Those source protection efforts are described below.

3.3.3.1 Watershed Protection

By owning almost all of the land in the Cedar Watershed and 70% of the Tolt Watershed, SPU maximizes source water protection.

The primary tool for maintaining source water quality is Seattle's extensive watershed ownership, which allows SPU to restrict human access and activities within the watersheds. SPU has adopted watershed protection programs for the Cedar River and South Fork Tolt River Municipal Watersheds, including the Lake Youngs Reservation, to ensure that SPU's source water remains of high quality and free from contamination. These programs are described in SPU's *Watershed Protection Plan*, which details SPU's ongoing efforts to control activities that have the potential to adversely affect water quality in both of its surface water supplies. The latest Plan was approved by WDOH in 2011.

3.3.3.2 Wellhead Protection

While the two municipal watersheds supply nearly all of Seattle's raw drinking water, Seattle supplements its drinking water supplies with groundwater from the Riverton well field and the Boulevard Park well, located in SeaTac. As part of the *2001 Water System Plan*, SPU prepared and WDOH approved a wellhead protection program, including an inventory of potential contaminants. The program has not changed since 2001, except for the updates to the potential contaminant inventory completed every other year. After each update is completed, notification letters are sent to businesses handling or storing potential contaminants within or near the wellhead protection area, as well as to agencies that have influence over activities in the wellhead protection area, including King County Department of Natural Resources and Parks, Groundwater Protection Program. These letters contain maps of the wellhead protection area boundaries and steps that businesses can take to protect the groundwater supply from contamination.

3.3.4 Source Water Quality Summary

Water quality characteristics of the raw water from each of SPU's sources, including its three wells, are shown in Table 3-2.

Table 3-2. Water Quality Characteristics of SPU's Source Water 2007-2011

Surface Water Sources	Cedar River/Landsburg		Cedar River/Lake Youngs Outlet		South Fork Tolt River/Regulating Basin	
Parameter and Unit	Average	Typical Range	Average	Typical Range	Average	Typical Range
Turbidity, NTU	0.8	0.2 – 2.0	0.4	0.2 – 1.0	0.7	0.2 – 2.2
Temperature, °C	9	5 - 13	12.4	6 - 20	8.7	3 - 14
pH	7.6	7.3 – 7.9	7.7	7.1 – 8.5	7.4	7.0 – 7.8
Alkalinity, mg/L as $CaCO_3$	22	14 - 30	19	16 - 25	6.6	5.0 – 7.0
Conductivity, umhos/cm	55	36 - 75	57	48 - 70	23	20 - 25
UVA (@254 nm), cm-1	0.025	0.01 – 0.05	0.017	0.01 – 0.023	0.05	0.04 – 0.06
Total Organic Carbon, mg/L	0.75	0.4 – 1.1	0.8	0.6 – 1.0	1.3	1.1 – 1.6
Total coliform, per 100 mL	310	40 - 700	660	0 - 2400	53	1 - 225
Fecal coliform, per 100 mL	10	0 - 23	<1	0 - 3	<1	0 - 2

Groundwater Sources	Boulevard Well		Riverton Wells	
Parameter and Unit	Average	Typical Range	Average	Typical Range
Temperature, °C	11	10 - 12	10	9 - 11
pH	7.0	6.8 – 7.1	7.8	7.7 – 7.9
Alkalinity, mg/L as $CaCO_3$	143		85	83 - 87
Hardness, mg/L as $CaCO_3$	148		107	
Conductivity, umhos/cm	313		243	241 - 245

Contaminants of concern that have been identified in the wells include radon in all of the wells and trace levels of dacthal mono- and di-acid degradates in the Riverton Wells. Radon is a naturally-occurring element found in groundwater sources. Dacthal is an active ingredient in herbicides and is found in soils wherever it is used. These contaminants are currently not regulated by the EPA.

3.3.5 Source Treatment Facilities

As described below, treatment facilities located at both surface water sources and at the well locations are operated to provide high-quality finished water to the regional system.

3.3.5.1 Cedar Supply Treatment Facilities

SPU operates two facilities to treat Cedar River source water, the Landsburg Water Treatment Facility and the Cedar Water Treatment Facility.

Landsburg Water Treatment. At the Landsburg Water Treatment Facility, SPU fluoridates and chlorinates the Cedar supply. Prior to the construction of the Cedar Water Treatment Facility at Lake Youngs in 2004, the Landsburg Water Treatment Facility was the primary disinfection site for water from the Cedar River watershed. The chlorine addition at Landsburg now serves to minimize microbial growth in the transmission pipeline between Landsburg and Lake Youngs and to aid in the control of new organisms (e.g., algae from Chester Morse Lake) entering Lake Youngs.

The Cedar Water Treatment Facility uses ozone, UV, and chlorine applied in series to ensure inactivation of Giardia, Cryptosporidium, and viruses.

Cedar Water Treatment Facility. The Cedar Water Treatment Facility uses ozone, UV, and chlorine applied in series to ensure inactivation of *Giardia*, *Cryptosporidium*, and viruses. The ozone process also improves the taste and odor of the water from this source. Lime is added at the facility in order to reduce the corrosivity of the water to in-premise plumbing. The new facility has a capacity of 180 mgd.

The Cedar Water Treatment Facility is operated under contract by CH2M HILL OMI with oversight from SPU. The operations contract began in late 2004. In both 2019 and 2024, the 15- and 20-year marks of the contract, SPU will have the option to renew the existing contract for 5 more years, hire another operations contractor, or use SPU staff to operate the treatment facility.

3.3.5.2 Tolt Water Treatment Facility

A 120-mgd ozonation and direct filtration treatment facility for the South Fork Tolt River water began operation in 2001. The facility also provides fluoridation, chlorination, and adjustment of pH and alkalinity for corrosion control.

The Tolt Water Treatment Facility is operated by American Water / Camp Dresser & McKee with oversight from SPU. The 15-year operations contract began in 2001. In 2016 and 2021, SPU will have the same 5-year contract renewal options as it has for the Cedar Water Treatment Facility.

3.3.5.3 Well Field Treatment Facilities

Both well locations include sodium hypochlorite disinfection to provide chlorine residual in the distribution system, fluoridation, and sodium hydroxide addition for corrosion control. Although sodium hydroxide addition is not required, it makes the well water quality more consistent with that of treated water from the Cedar River, with which it is normally blended before delivery to SPU customers. Treatment of well water is maintained under normal circumstances, though for emergency supply the wells could be started and run for a short period of time prior to startup of the treatment systems.

3.3.5.4 Condition of Source Treatment Facilities

The Tolt Water Treatment Facility produces water comparable in quality to that of the Cedar.

Because of their recent construction, the Cedar and Tolt Water Treatment Facilities are both in excellent condition. Condition assessment of the major equipment is performed on an annual basis and preventative maintenance is ongoing. No major equipment replacement is currently planned. Equipment at the well treatment sites is generally in very good condition. Some components with shorter lifespan have been replaced as needed, but no major replacements are planned.

The older Landsburg Water Treatment Facility is outdated, and SPU is in the process of implementing an alternative to replace the building and upgrade the SCADA systems. In addition, the decision has been made to replace the existing chlorine feed system with sodium hypochlorite for risk management purposes.

3.3.5.5 Overall Finished Water Quality

The water quality characteristics of treated water as it enters SPU's transmission system are shown in Table 3-3.

Table 3-3. SPU's Finished Water Quality Characteristics

Surface Water Sources	Cedar/Lake Youngs (2007-2010)		Tolt River (2007-2010)	
Parameter and Unit	Average	Typical Range	Average	Typical Range
Turbidity, NTU	0.4	0.2 – 0.9	0.06	0.04 – 0.10
Temperature, °C	12.7	5 – 22	9	3.5 – 15
pH	8.2[a]	8.0 – 8.4	8.2[a]	8.0 – 8.4
Alkalinity, mg/L as $CaCO_3$			19[a]	18 – 20
Conductivity, umhos/cm	67	55-77	61	56-66
UVA (@254 nm), cm^{-1}	0.010	0.007-0.013	0.012	0.010-0.014
Chlorine residual, mg/L	1.5[a]	1.4 – 1.7	1.5[a]	1.4 – 1.6

Groundwater Sources	Boulevard Park Well (2000-2010)[b]		Riverton Wells (2000-2010)[b]	
Parameter and Unit	Average	Typical Range	Average	Typical Range
Temperature, °C	12	10 - 14	11	9 - 12
pH	8.25[a]		8.25[a]	
Alkalinity, mg/L as $CaCO_3$	112		80	
Conductivity, umhos/cm	330	285 - 362	218	206 - 255
Chlorine residual, mg/L	1.0[1]		1.0[a]	

[a] Treatment target or criterion

[b] Wells are used infrequently, so data set is relatively small.

3.3.6 In-Town Storage Facilities

SPU operates several water storage facilities downstream of its Cedar and Tolt Water Treatment Facilities, including open reservoirs, covered reservoirs, and standpipes and elevated tanks. SPU operates these facilities to ensure that water quality within the distribution system is protected. SPU has established a regular program of inspections for the open and closed reservoirs and reports the results of the surveys to WDOH upon request.

3.3.6.1 Reservoir Covering/Burying

SPU is nearing completion of its open reservoir covering program. The approach for covering the open reservoirs has remained closely on track with that outlined in the *2007 Water System Plan,* and has focused on replacing SPU's open reservoirs with new buried structures to improve water quality, increase security, and create new public open space opportunities. Although new park space will be a feature at many of the new buried reservoir sites, the paramount purpose of these sites remains as the storage and distribution of city water supplies and the safety of the drinking water. The replacement projects represent a significant amount of work. Table 3-4 summarizes the covering program and completion dates.

Table 3-4. Schedule for Covering or Upgrading In-Town Open Reservoirs

Reservoir	Open Reservoir Size (million gallons)	Covered Reservoir Size (million gallons)	Completion
Bitter Lake	21.5	21.3	2001[a]
Lake Forest Park	60	60	2003[a]
Lincoln	20	12.7	2006
Myrtle	7	5	2008
Beacon	61	50	2009
Roosevelt	50	0[b]	2015[b]
West Seattle	68	30	2010
Maple Leaf	60	60	2012
Volunteer	20	0 or 10[b]	2015[b]
Total	**367.5**	**239 (or 249)**	

[a] Floating cover replacement options, including buried storage, will be evaluated at end of useful life of floating cover (i.e., in about 10-15 years).

[b] Roosevelt and Volunteer Reservoirs are planned to be removed from service following the completion of the new buried Maple Leaf Reservoir—see text below for more information. Roosevelt is shown here as decommissioned, and Volunteer is shown as either decommissioned or downsized to 10 MG.

Construction of the new buried Maple Leaf Reservoir is planned to reach substantial completion in 2012. The only two remaining open reservoirs (Roosevelt and Volunteer) are planned to be removed from service following the completion of Maple Leaf Reservoir. They will remain out of service for several years to gain operational experience, and to confirm analytical conclusions that system reliability will not be affected by their decommissioning.

Why did we have to cover the reservoirs?

Federal regulations require that all treated drinking water reservoirs be covered. SPU installed floating covers on two reservoirs, and is replacing its other open reservoirs with underground structures that both improve the quality and security of our water system and provide 76 acres of new open space for everyone to enjoy.

3.3.6.2 Open Reservoir Protection Plan

In order to ensure that the quality of treated water is not diminished during its residence in open reservoirs, SPU operates and maintains its open reservoirs in accordance with a WDOH-approved, open reservoir protection plan. This plan includes provisions for reservoir maintenance and operation, security, water quality monitoring at locations within the reservoir itself and just downstream of the chlorine addition, follow-up actions, and emergency response.

3.3.6.3 Water Quality Enhancements at Storage Facilities

Some of SPU's enclosed storage facilities were constructed with a common inlet and outlet, or were otherwise designed without considering the optimal water flow conditions needed to maintain water quality by avoiding stagnant conditions. When major maintenance or upgrades are performed on tanks and standpipes, such as interior painting, SPU has been making modifications to improve water-quality management. Upgrade methods include separation of inlets and outlets, installation of mixing systems, multiple level sample taps, and sodium hypochlorite injection points. The completed Myrtle Tank project included separation of the inlet and outlet piping as well as sample taps at multiple levels. The ongoing Richmond Highlands Tank project has a mixing system and multiple sample taps as part of the design.

3.3.6.4 In-Town Reservoir Treatment

Additional chlorination is provided at some of SPU's in-town storage reservoirs to ensure that chlorine residual is maintained in the drinking water supply until it reaches customer taps. SPU's addition of filtration treatment on the Tolt supply back in 2001 along with the reservoir covering program that is now nearing completion have reduced the amount of chlorine addition in the distribution system previously necessary. In most cases, the treatment involves addition of sodium hypochlorite to increase the residual chlorine. At some reservoirs, hypochlorite is generated on-site, while at other reservoirs it is delivered to the reservoir site. Open reservoirs that were using chlorine gas have been converted to sodium hypochlorite, except in one case where the facility is scheduled for decommissioning. All of the hypochlorite and chlorine gas equipment is in good condition. A list of the chlorination facilities is provided in the treatment facilities inventory in the appendices.

3.3.7 Operations

SPU operations ensure that its customers receive high-quality drinking water.

SPU undertakes a number of activities to ensure that its customers receive high-quality drinking water. Operations activities include water quality monitoring, preventing or eliminating cross connections, responding to customer complaints, storage reservoir cleaning, testing and flushing watermains, and maintaining transmission pipeline water quality. Each activity is summarized below.

3.3.7.1 Comprehensive Water Quality Monitoring Plan

A comprehensive monitoring plan was updated in 2011 and is included as an appendix. The Comprehensive Water Quality Monitoring Plan covers the entire water system, from the watersheds through the transmission and distribution systems to the customer taps. The monitoring plan addresses the following:

- Monitoring requirements under state and federal drinking water regulations.
- Future regulations, which are currently under development at the federal level.
- Non-regulatory monitoring, which SPU conducts for informational purposes and to assist in operating the water system.
- Sampling procedures.
- Managing laboratory information.
- All parameters, locations, and frequency of monitoring conducted by SPU.

3.3.7.2 Cross-Connection Control Program

SPU implements a cross-connection control program in order to protect the quality of the water supply from cross connections. Within Seattle and the retail service area south of Seattle, SPU's cross-connection program is a joint undertaking with Public Health Seattle-King County (PHSKC). Within the City of Shoreline, SPU works with Shoreline city staff members. The program includes elements to isolate and disconnect cross-connections both within the customer's premises and at the service connection. The cross-connection control policy and procedures were included with the *2007 Water System Plan*.

Under the cross-connection control program, SPU oversees more than 20,000 backflow assemblies owned by customers within SPU's retail service area. In 2009, SPU implemented a new database for management of the cross-connection control program. This database has enabled staff to more efficiently and more accurately ensure that these backflow assemblies are protecting the drinking water supply. The database made possible a new enforcement strategy implemented in 2011 which greatly improved compliance with backflow assembly testing requirements. The backlog of assemblies overdue for testing was reduced from fifteen percent down to four percent

3.3.7.3 Customer Complaint Response

SPU has procedures for responding to complaints and problems reported by its retail customers about drinking water quality. The vast majority of complaints concern discolored water. Discolored water comes from internal pipe rust and sediment getting stirred up. It is an inconvenience, but does not represent contamination of the water supply. From 2006 to 2010, an average 1,500 water quality complaints were received per year. This is for a customer base of 188,000 connections. Figure 3-4 shows the breakdown of the types of complaints for that period.

SPU retail customers with water quality concerns, water service problems, or questions contact the SPU Call Center during normal business hours and the SPU Operations Response Center after hours and on the weekends. Calls that involve water quality concerns or that identify high priority problems–calls that concern public health issues or safety risks–are passed on to an inspector who will investigate the problem until it is resolved.

The process for receiving complaints puts the customer in immediate contact with SPU staff and provides SPU with up-to-date knowledge of where the complaints are coming from, the nature of the complaints or problems, and how many calls are being received from a given area of Seattle. SPU logs the complaint information in a computer system and is able to bring these complaints up on a map for further analysis. Because the cause of a problem is usually not known at the time a complaint is called in, improvements are planned to allow revision of complaint data after follow up with the customer so that if the probable cause of the problem is determined, it can be noted and tracked.

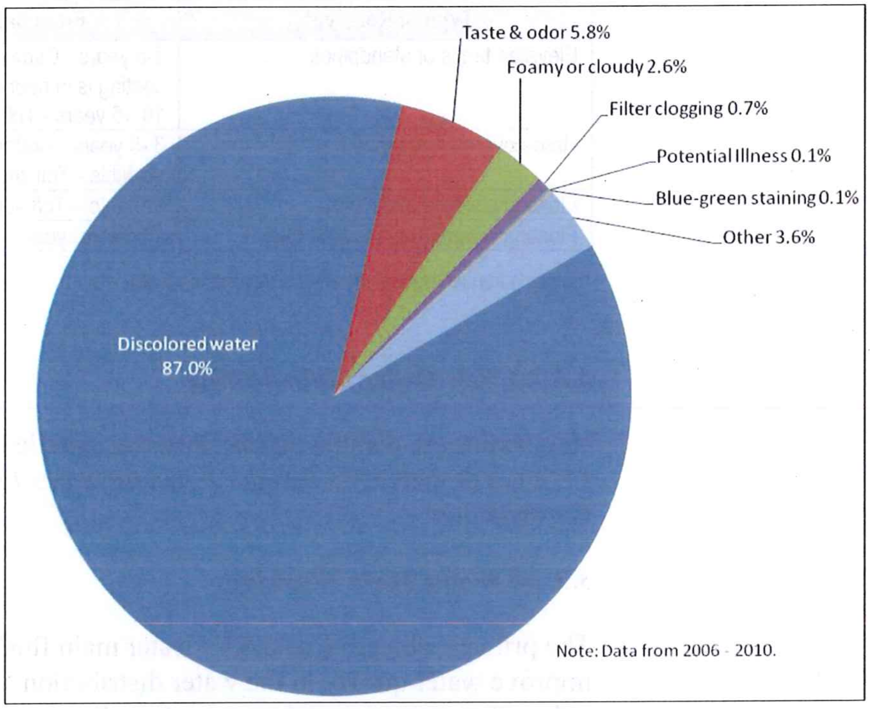

Figure 3-4. Types of Water Quality Complaints

3.3.7.4 Transmission and Distribution Storage Facility Cleaning

A key to maintaining water quality after the treated water enters the transmission and distribution system is making sure that storage facilities are regularly cleaned. SPU ensures its in-town, open reservoirs are drained and cleaned at least annually. SPU monitors water quality analytical results and customer complaints to identify trends that would indicate more frequent cleaning is necessary. Currently, Roosevelt Reservoir is scheduled for cleaning in the spring, and Volunteer Reservoir is scheduled for cleaning in the fall. Cleaning employs high-pressure washing equipment to remove algae and debris buildup; then the facilities are disinfected and sampled before they are put back into service.

SPU also ensures that its enclosed storage facilities are regularly cleaned to ensure water quality protection. SPU's approximate cleaning frequency for closed storage facilities is shown in Table 3-5. These cleaning frequencies may be adjusted based on inspections. Facilities that store Cedar water are on a more frequent cleaning schedule than those that receive Tolt water because the Cedar supply is not filtered.

Table 3-5. Closed Storage Cleaning Schedule

Type of Reservoir	Frequency of Cleaning
Elevated tanks or standpipes	3-5 years - Cedar supply and/or if interior coating is in poor condition 10-15 years - Tolt supply
Hard-covered reservoirs	3 -5 years - Cedar supply Variable - Tolt supply[1]
Floating covered reservoirs	Variable – Tolt supply[1]
Floating covers (top of cover only)	1 time per year

[1]Cleaning frequency depends on dive inspection results.

3.3.7.5 New Water Main Testing

New mains are disinfected and tested as detailed in Section 7-11.3(12) of the City's *Standard Specifications for Municipal Construction*.

3.3.7.6 Water Main Flushing

The primary objective of SPU's water main flushing program is to improve water quality in the water distribution system and to reduce customer complaints regarding discolored water and unacceptable taste and odor. There is currently a two-person crew dedicated to water main flushing. SPU is planning to review its flushing practices and its level of resources allocated to flushing.

3.3.7.7 Water Quality in Transmission Lines

Large-diameter transmission pipelines composed of metal (e.g., steel, ductile iron, cast iron) are often lined with cement mortar to prevent corrosion and deterioration of the metal pipe wall. Cement lining of pipelines can cause the pH in the water to increase (i.e. the water to become more alkaline or basic) when a section of pipeline is taken out of service for repair or maintenance but kept full of water. Although pH is typically not a health issue, unless it becomes extremely low or extremely high, customers may find that water with moderately elevated pH tastes or feels different than that to which they are accustomed. Higher pH can also decrease the effectiveness of chlorine for disinfection. Additional customer concerns could include loss of aquarium fish or adverse impacts on commercial and industrial facilities.

The EPA-recommended lower and upper values for pH are 6.5 and 8.5, respectively. For the temporary situations where water in transmission lines exhibits elevated pH, SPU established the following guidance:

- Water with pH up to 9.5 can be sent to the distribution system.
- If water in the pipeline has pH above 9.5, the pipeline will be flushed.
- In emergency circumstances, the SPU Director may allow the pH 9.5 limit to be exceeded.

If future experience shows that the upper pH limit of 9.5 is inappropriate, this guideline will be revised.

3.3.8 Water Treatment Infrastructure SAMP

SPU has developed a strategic asset management plan (SAMP) for its water treatment facilities, including in-town disinfection facilities. This SAMP describes the infrastructure, their operations and maintenance, relevant service levels, repair and replacement needs, data needs, and other relevant asset information. Relevant information from the SAMP has been included in this chapter.

3.4 NEEDS, GAPS, AND ISSUES

In the past decades, SPU has made significant strides towards ensuring that its water is of the highest quality while meeting current and future regulations. In particular, SPU's recent completion of the Tolt and Cedar Water Treatment Facilities has significantly improved SPU's water quality. In addition, SPU's recent and planned activities to cover, bury, or decommission its open reservoirs also demonstrate SPU's efforts towards ensuring excellent water quality in its system.

There are always new challenges for SPU to confront as it strives to meet its high standards for drinking water quality. The following sections summarize the needs, gaps, and issues facing the Water Quality and Treatment business area and describe SPU's plans to address them.

3.4.1 Future Regulatory Changes

The federal government is expected to pass a number of new water quality regulations over the next several years. These include the revised total coliform rule, the radon rule, and revisions to the lead and copper rule. These future regulations and their expected impacts on SPU are summarized in Table 3-6.

As noted in Table 3-6, the proposed radon rule and the revisions to the total coliform rule and lead and copper rule could have minimal to moderate impacts on SPU's infrastructure and practices. Since the final form of the proposed rules and revisions and their impacts are still unclear, SPU plans to stay informed on the status of the rules. As the rules become clearer, SPU will develop comprehensive action plans to address any potential issues that arise.

Table 3-6. Future Regulations and Impact on SPU

Regulation or Issue	Provisions	Impact or Consideration
Total Coliform Rule Revisions/ Distribution System Rule	Proposed rule would change the MCL for total coliform to a trigger level for follow up investigation and action. Other distribution water quality issues are further out on the regulatory horizon.	Existing SPU practices generally address the proposed approach regarding coliform.
Radon Rule	Proposed both an MCL of 300 pCi/L and Alternative MCL of 4,000 pCi/L. Proposal was made in 1999 with little known action since that time.	Seattle wells would require treatment or blending prior to supplying customers to comply with MCL, but they are currently below Alternative MCL. Blending would likely be the more economical alternative, but a final decision would need to be supported by a more detailed analysis. No radon detected in Tolt or Cedar.
Lead and Copper Rule: Long-Term Revisions	Likely to address lead service lines. Possible changes to optimal water quality parameters and sampling sites. May include schools.	Full impact of revisions not clear at this time. Some adjustment may be needed to monitoring plan and schedule. Lead service lines not used in Seattle.

3.4.2 Emerging Contaminants of Concern

Emerging contaminants are not regulated, they are generally new to drinking water scientists, and there is typically limited information about their occurrence and health effects. Understanding the significance of emerging contaminants can be difficult and complex given that lack of clear data. EPA takes on emerging contaminants primarily through the Contaminant Candidate List and the Unregulated Contaminant Monitoring Rule. In addition, SPU has made its own efforts in regard to some emerging contaminants in order to better understand the quality of SPU's water supply.

3.4.2.1 Contaminant Candidate List

The majority of the CCL contaminants present relatively low concern to SPU.

The Safe Drinking Water Act directs EPA to publish a Contaminant Candidate List (CCL) every 5 years and EPA finalized the third list (CCL3) in 2009. It includes 104 chemicals or chemical groups and 12 microbiological contaminants. These contaminants occur or are anticipated to occur in public water systems. Contaminants on the CCL3 are not currently regulated and the list does not impose requirements on public water systems. EPA uses the list to prioritize research and data collection efforts to help determine if a contaminant should be regulated. Regulatory determinations must be made on at least 5 of the contaminants every 5 years.

Since SPU published its *2007 Water System Plan*, EPA determined in July 2008 that no regulatory action was necessary for eleven of the CCL2 contaminants, including the dacthal mono- and di-acid degradates, which had been detected previously at very low levels in the Riverton Wells. One microbial contaminant Mycobacterium Avium Complex (MAC) was listed on CCL2 and remains on CCL3.

Over the past several years endocrine disrupting chemicals (EDCs) and pharmaceuticals and personal care products (PPCPs) have been of concern nationally and are included on CCL3. EDCs and PPCPs include prescription drugs, hormones, preservatives in cosmetics, and other personal care product chemicals that have been detected in water supplies located downstream of wastewater discharges. None of SPU's water sources are downstream of any wastewater discharges, so these contaminants are not of concern to SPU drinking water quality. More information on PPCPs is provided below.

The majority of the CCL3 contaminants present relatively low concern to SPU because of its excellent source protection practices, state-of-the-art water treatment facilities, and distribution system practices. SPU will continue to stay up to date on EPA regulatory determinations as well as participate in or stay informed on related studies and national occurrence of emerging contaminants.

3.4.2.2 Unregulated Contaminant Monitoring Rule

The Unregulated Contaminant Monitoring Rule (UCMR) is EPA's program for gathering public water system data on contaminants without current health based standards. Monitoring results are used for determination of future drinking water regulations. EPA requests or requires participation from a utility, depending on its size.

The UCMR monitoring rounds occur on a 5-year cycle, is largely based on the CCL, and the list may contain no more than 30 contaminants. SPU participated in UCMR 1 (conducted 2001-2005) and UCMR 2 (conducted 2007-2010). As a system serving more than 10,000 people, SPU and its wholesale customers are required to participate in UCMR 3 as well. The list of contaminants for UCMR 3 contains several categories of compounds that are unlikely to occur in our system given our protected source water. This includes seven hormones, six perfluorinated compounds, five metals, and seven VOCs.

For UCMR 3, SPU will collect quarterly samples at entries to the distribution system (treated Tolt and Cedar water) for a 12-month period sometime between 2013 and 2015. Distribution system samples are also required for UCMR 3 at the same frequency.

3.4.2.3 Chromium

SPU has routinely tested for total chromium (the combined total of chromium-0, chromium-3 and chromium-6) at the source and in the distribution system. In the past, SPU has not tested specifically for chromium-6, because there is no maximum contaminant level (MCL) for chromium-6, SPU's source waters have no adjacent industrial activities that would introduce chromium-6, and no reportable levels of total chromium have been found in SPU's water. The current MCL for total chromium is 100 ug/L. The naturally occurring background levels of total chromium in SPU's water range from non-detectable to 1.0 ug/L, with average results near our minimum detection limit (MDL) of 0.2 ug/L using EPA Method 200.8.

In March 2010, EPA announced that it had initiated a reassessment of chromium and published a draft human health assessment for chromium-6 in September 2010. The risk assessment should be finalized in 2011. On a related note, the California Office of Environmental Health Hazard Assessment (COEHHA) proposed a health goal for chromium-6 of 0.06 ug/L in August 2010 and subsequently proposed an even lower health goal of 0.02 ug/L on December 31, 2010.

Given the current level of review and discussion for potentially revising the chromium standard, EPA has provided guidance on voluntary, though strongly encouraged, monitoring for chromium-6. Recommendations included sampling quarterly at source and distribution locations currently sampled for Disinfection By-products Rule (DBP) Stage 1 and 2 testing. This would be approximately 8 quarterly samples for SPU.

With respect to testing, the standard method for total chromium analysis in drinking water has MDL's that are well above the potentially low-level (COEHHA) goal. The SPU laboratory MDL for total chromium using EPA Method 200.8 is 0.2 ug/L. EPA method 218.6 has a more sensitive detection limit and, depending on the laboratory, can measure chromium-6 at levels approaching 0.02 ug/L.

Based on SPU source water quality and lack of potential sources of chromium-6, the background total chromium level is presumably from naturally occurring chromium-3. It is possible for chromium-3 to convert to chromium-6 in treated drinking water depending on pH and disinfection treatment processes. To better quantify the low chromium levels in SPU's water, SPU began following the EPA recommended quarterly monitoring in 2011.

3.4.2.4 Pharmaceutical/Personal Care Products

Testing has confirmed the absence of PPCPs and EDCs in SPU's source water.

SPU conducted three rounds of testing in 2008 for pharmaceuticals and personal care products (PPCPs) and endocrine disrupting compounds (EDCs) in our source water. Results confirmed the absence of PPCPs or EDCs in SPU's source water, which was not surprising considering SPU's exceptional source water protection efforts.

Prior to 2008, SPU conducted regulatory monitoring of its source water for synthetic organic compounds (SOCs) and for unregulated compounds, as part of UCMR 2. The sampling panels included some EDCs. Samples were collected from only the finished water for the Cedar and Tolt supplies. The analyses were conducted using a certified lab, following accepted field sampling procedures, and included QA/QC procedures. Historical results showed no detections of any suspected EDCs, including Atrazine, Butylbenzyl phthalate, Diazinon, Linuron, Methoxychlor, and bisphenol A.

Because prior UCMR testing did not include any PPCPs and samples were collected from locations following treatment, SPU conducted additional more extensive testing of source water and treated water beginning in April 2008. SPU conducted two rounds of sampling from Tolt and Cedar supplies at locations before and after treatment. SPU collected a third set of samples from Riverton and Boulevard Park wells in December 2008. SPU detected none of the PPPCPs and EDCs tested.

3.4.3 Kerriston Road in the Cedar River Watershed

Kerriston Road is a King County road that has more than two miles lying within the hydrographic boundary of the Cedar River watershed in the vicinity of Brew Hill. The road provides the only existing access to 322 acres of privately-owned property located outside of the municipal watershed hydrographic boundary. WDOH has expressed concern about the potential public health and water quality impacts that could result from public use of the road. The 2009 acquisition of the 4,000 acres by King County and the Washington Department of Natural Resources in the Raging River area reduced the total area of privately-owned property accessed by the Kerriston Road by 84 percent, significantly reducing the scale of the potential future development threat and investment to acquire remaining properties. In 2008 SPU conducted a feasibility study and cost estimates for acquiring the private properties accessed by the Kerriston Road. A portion of the property, about 148 acres, has been purchased. Before proceeding with further acquisitions, SPU is conducting a risk-cost analysis of public access on the Kerriston Road to determine if additional land acquisition is the preferred approach for mitigating risk.

3.4.4 Lake Youngs Water Quality

Lake Youngs is a high quality, oligotrophic lake, meaning it has low nutrient content and low biological productivity. In recent years, SPU has observed some changes in Lake Youngs' water quality, particularly some new dominant algal species and less predictability in the timing of algal blooms. SPU held a workshop of limnology experts in 2009 to look more closely at the water quality data and determine if these changes in algae are indicative of more fundamental or permanent changes in the lake. The expert panel concluded that the types of changes observed are well within normal ranges and do not suggest any significant degradation of the lake.

Algal blooms have been observed in Lake Youngs since the 1920s. Prior to the startup of the Cedar Water Treatment Facility, these algal blooms would cause undesirable tastes and odors in the drinking water. The new treatment facility has eliminated nearly all these effects. Another effect of algae has been that over time it can accumulate on water filters used in homes and businesses. One of the new dominant types of algae in the lake, *Cyclotella*, has been found to produce fine filaments that not only clog filters, but accumulate on screens used in the water system. Because of the more problematic nature of these filaments, SPU strives to avoid this algae by bypassing Lake Youngs during a bloom.

SPU has an extensive lake monitoring program. In response to the changes in the lake and recommendations of the expert panel, SPU has added to that program in order to better characterize the lake. Water quality monitoring has been improved with the addition of some sampling and the installation of a remote floating water quality monitoring station on the lake. A water quality modeling effort has also been taken on in order to better understand the lake and to look at the impacts of operational changes and potential improvement projects.

3.4.5 Aquatic Nuisance and Invasive Species

Several aquatic organisms currently create or have the potential to create nuisance conditions in Washington state waters, including SPU's drinking water supplies. Once established in an aquatic system, infestations of these nuisance organisms can be difficult to control and impossible to eradicate, resulting in deleterious effects on water quality and water system operations.

Several aquatic nuisance species are specific targets of SPU's prevention program because of their proximity to the Cedar River, ease of invasion, or significance of impact. The invasive aquatic plant species include: *Eurasian milfoil*, parrotfeather, *Hydrilla*, *Brazilian elodea*, fanwort, water hyacinth, and others. The microorganism species include *Didymosphenia geminate* (didymo), Whirling Disease, and others. The animal species include the zebra mussel, quagga mussel, New Zealand mud snail (NZMS), Chinese mitten crab, and others. All of the aquatic nuisance plant species listed here have been positively documented in freshwaters of Washington State, including NZMS in Seattle's Thorton Creek.

SPU's "Prevention of Aquatic Nuisance Species Plan" outlines general responsibilities of field personnel working in any of the water supply reservoirs and watersheds. A detailed equipment decontamination procedure is included in the plan. In addition to preventing the introduction of aquatic nuisance species, the decontamination procedure is designed to prevent contamination by any biological organism (i.e., plant, animal, or microbe) that is either a native or exotic species and may be terrestrial or aquatic in origin, and by any chemical or petroleum product.

3.5 Implementation/Action Plan

With the construction of four new buried reservoirs to replace the pre-existing Beacon, Myrtle, West Seattle, and Maple Leaf open reservoirs, SPU has accomplished a great deal since the *2007 Water System Plan*. These actions have supported SPU in meeting drinking water quality regulations and have placed SPU in position to continue to meet water quality requirements in the future. In addition, SPU has a list of important upcoming projects and actions in the Water Quality and Treatment business area that include the following:

- Remove Roosevelt and Volunteer Reservoirs from service following the completion of the Maple Leaf reservoir burying project. Evaluate water system operation without Roosevelt and Volunteer Reservoirs and confirm a decision on how to go about the decommissioning of Roosevelt and whether to decommission or cover Volunteer Reservoir.

- In about 2020, evaluate options for replacing the floating covers at Bitter Lake and Lake Forest Park Reservoirs, given that the covers at these sites will reach the end of their useful life within the next 10 to 15 years

- Complete the conversion from chlorine gas to sodium hypochlorite at Landsburg.

- Evaluate contract extension options for the Tolt and Cedar Water Treatment Facilities.

- Review distribution system flushing practices and the level of resources allocated to flushing.

- Stay abreast of EPA and WDOH regulatory development efforts and make adjustments as necessary to ensure that SPU's water quality service level is always met.

- Continue monitoring the science regarding new or emerging contaminants of concern, and continue to monitor source and finished drinking water to determine whether these contaminants are at levels of concern in SPU's supplies.

- Conduct a risk-cost analysis of public access on the Kerriston Road to determine if additional land acquisition is the preferred approach for mitigating the risk of impairing Cedar source water quality.

- Continue to monitor and characterize limnological conditions in Lake Youngs as it affects Cedar supply operations and treated water quality.

- Bypass Lake Youngs to avoid problematic algae from entering the water system.

- Continue efforts to prevent aquatic nuisance and invasive species from being introduced into SPU's drinking water supplies.

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Chapter 4
Water Transmission System

SPU's water transmission system consists of the large diameter pipelines, storage facilities, pump stations, and related infrastructure that convey raw water to the treatment facilities and treated water to the distribution systems of SPU's wholesale customers and its own retail service area. The water transmission system consists of both regional and sub-regional facilities, as defined in the wholesale water contracts.

4.1 Accomplishments Since 2007 WSP

Since completion of the *2007 Water System Plan*, SPU has implemented the following improvements to the water transmission system:

- Control Works Surge Tanks: Installed painted, welded mild steel structural covers on these tanks to protect drinking water quality (2010).
- Lake Youngs Supply Lines Standpipes: Extended open air standpipe air vents to prevent or reduce occasional overflows when Lake Youngs is bypassed (gravity operation from Landsburg to Cedar Treatment).
- Cedar/Tolt Transfer Improvements: In Seattle, installed a modulating valve at Maple Leaf Gatehouse to allow the Tolt source to supply farther south into areas normally supplied from the Cedar source. On the Eastside (Woodinville), upgraded the diesel backup pump at TESS Junction that delivers Cedar water into the upper reaches of Tolt Pipeline No. 1 at times of Tolt source outage (2010).
- Cedar River Pipeline Improvements and Upgrades:
  - Slip-lined portions of Cedar River Pipeline 4 (CRPL4) where it crosses I-405 in Tukwila and protected the segment of CRPL4 where it crosses SR-167 in Renton to prevent this major transmission pipeline from potential damage during widening of both highways by the State of Washington, as well as to extend its useful life (2010).

  - Completed a sonic leakage test of Cedar River Pipeline 2 from Volunteer Reservoir to Maple Leaf Reservoir (also known as the 430 Pipeline) using "smart ball" technology to assess its condition and found no leaks (2007).
  - Improved the supports under above-ground sections of Cedar River Pipelines 1, 2, and 3 in Tiffany Park in Renton to increase the likelihood of the pipelines remaining operational after a larger earthquake.
  - Replaced sections of Cedar River Pipelines 1, 2 and 3 where they cross the Sound Transit Light Rail at Martin Luther King Way in Seattle, to protect these transmission pipelines.

- Cathodic Protection Program: Installed cathodic protection on a concrete cylinder pipe section of CRPL4 near South Center in conjunction with the I-405 widening improvements discussed above.
- Tolt Slide Monitoring: After ground movement in 2009 and subsequently finding that Tolt Pipelines No. 1 and No. 2 both cross an ancient slide located between the Regulating Basin and Tolt Water Treatment Facility, installed a 48-inch double ball joint expansion sleeve on TPL2 to allow the pipeline to better conform to the creeping slide. Also initiated an on-going survey and inclinometer monitoring program to monitor slide movement.
- Wholesale Customer Meters: Added several new wholesale services as requested by its whole sale customers primarily to improve retail service reliability within the wholesale customers' service areas.

In addition, Maple Leaf and West Seattle Reservoirs, which are part of the transmission system, were replaced with buried reinforced concrete tanks as described in Part I, Chapter 3.

4.2 Service Level Performance

SPU has developed service levels that deal with the water service SPU provides to its wholesale customers. From a wholesale customer's perspective, the quality of water service can be measured by the amount of water flow provided, the pressure of that water, and the duration of any water system outages. Many of the drinking water quality service levels, as stated in the Water

Quality and Treatment chapter, also apply to the transmission system. Table 4-1 summarizes SPU's service levels concerning service provision to wholesale customers.

Table 4-1. SPU's Service Levels for Managing Transmission System Assets

Service Level Objective	Service Level Target
Provide agreed-upon service to wholesale customers.	• Meet wholesale contract requirements for pressure and flow. • Limit each unplanned outage in the transmission system to be within the maximum outage duration set for each pipe segment (24, 48 or 72 hours).

These service level targets have been met since 2006. SPU's wholesale contracts require SPU to provide a minimum pressure and maximum flow rate at each wholesale service connection, with contingencies for emergency or unusual conditions. There have been no contractual compliance issues in recent years. Additionally, there have been no unplanned outages of the transmission pipelines that have exceeded SPU's service level for maximum outage durations.

4.3 Existing System and Practices

SPU's regional and sub-regional water transmission systems include 193 miles of pipeline, 7 covered reservoirs, 15 pump stations, 6 elevated tanks and standpipes, and 129 wholesale customer taps with meters.

SPU's transmission system consists of the facilities that convey bulk water to wholesale customers throughout the regional service area, as well as to SPU's own retail service area distribution system. SPU's transmission system facilities include the large-diameter transmission pipelines, storage facilities, pump stations, wholesale customer meters, and other appurtenances that are used in conveying water from SPU supply sources to its wholesale customers and the SPU retail service area.

4.3.1 Existing Infrastructure

The regional and sub-regional water transmission systems include approximately 193 miles of pipeline, seven covered reservoirs, 15 pump stations, and six elevated tanks and standpipes. Taps off of the major supply transmission pipelines from the Cedar and Tolt sources deliver water to 129 wholesale customer master meters and intertie locations. Wholesale customers operate their own distribution systems serving their own retail customers. Brief descriptions of the elements that comprise transmission system infrastructure are presented below, along with assessments of the condition of related assets. Inventories of the primary transmission system facilities are provided in the appendices.

4.3.1.1 Pipelines

SPU's transmission system contains approximately 193 miles of large-diameter pipelines. These pipelines convey untreated water from the supply sources to the treatment facilities and treated water from the treatment facilities to the wholesale and retail service areas. These pipes vary in size from 16 to 96 inches in diameter, with some connections and bypasses being smaller. The bulk of these pipelines are made of steel and concrete, with a small portion consisting of ductile or cast iron, as shown in Figure 4-1.

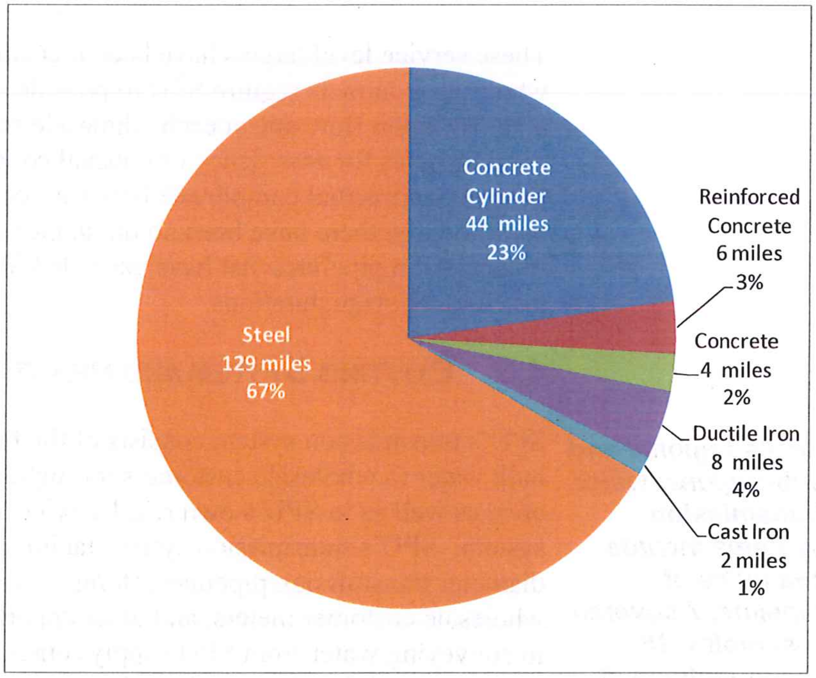

Figure 4-1 Breakdown of Transmission Pipeline Material

SPU relies on the leakage history and visual inspections of its transmission pipes to provide an indication of condition. Leaks are identified by SPU crews that drive along the alignments of the transmission pipes weekly to look for water ponding on the surface.

4.3.1.2 Storage

SPU owns, operates, and maintains 15 storage facilities in its transmission system. All store treated water. An assessment of the condition of these facilities is described below.

Reservoirs. With completion of the Maple Leaf and West Seattle reservoir burying projects in 2010, all seven of SPU's treated transmission system reservoirs are covered. With the exception of Lake Forest Park Reservoir, these reservoirs are pre-stressed or reinforced concrete tanks. Lake Forest Park Reservoir was constructed in 1961-62, and its structure consists of a hypalon-lined, reinforced concrete slab with a floating cover that was added in 2003.

The condition of the reservoirs is typically assessed by inspecting the structures, the embankment stability, the valves and piping, and any internal lining, and measuring the leakage rate from the reservoirs. When evaluating leakage rates, SPU looks for increasing trends and anomalies that could indicate deteriorating conditions at the reservoir. SPU performs routine structural inspections of the tanks during cleaning activities to assess their condition and ensure that they meet regulatory requirements. Minor and major deficiencies are addressed through capital programs when they are identified.

Inspections revealed that the storage reservoirs are in good condition.

Inspections conducted since 2005 reveal that the storage reservoirs are in good condition. The leakage rates from Soos North and Soos South Reservoirs are low, 0.11 gallons per minute per million gallons (gpm/MG) and 0.04 gpm/MG, respectively, when tested in 2006-2007. Riverton Heights Reservoir was last tested in 2007 and had negligible leakage. The leakage rates for Lake Forest Park and Eastside Reservoirs are 1 and 2 gpm/MG, respectively, which has been typical for these reservoirs since 1994.

In 2008 and 2009, a detailed condition assessment was performed by a consultant for the Eastside Reservoir, and its inlet-outlet pipeline up to its connection to the Tolt Eastside Supply Line at SE 16th Street in Bellevue. The effort was intended to provide information to the Cascade Water Alliance on the condition of these facilities for a possible acquisition. The work included inspection of the pre-tensioning wire of the reservoir, internal inspection of the pipeline at two locations, and soil corrosivity assessment along the pipeline. Both the reservoir and the pipeline were found to be in good condition; however, Cascade has since decided not to pursue acquisition of these facilities for other reasons.

Standpipes and Elevated Tanks. The SPU water transmission system includes five elevated tanks, one standpipe, and two control works surge tanks to provide drinking water storage. The elevated tanks and standpipes were constructed between 1925 and 1959. They range in capacity from 0.3 to 2 MG. Richmond Highlands #1

Tank and Foy Standpipe are to be removed from service and decommissioned. Decommissioning of Myrtle #1 Tank is also proposed, but approval by WDOH is pending. More information on system performance without these facilities is provided in the appendix on System Storage Level of Reliability.

Tanks, including standpipes, are expected to have a service life of approximately 100 years with regular maintenance. SPU inspects the tanks visually to evaluate their condition and appearance. Structural inspections are conducted when tanks are drained for cleaning. Exterior sanitary inspections are conducted quarterly. The condition of the tanks is evaluated for the condition of interior and exterior coatings, as well as its valves and pipes. The condition of each tank varies, depending on its year of construction and the year the last interior and exterior coatings were applied.

SPU has an on-going tank and standpipe recoating program. The program involves safety modifications at tank sites, minor structural repairs, and interior and exterior surface preparation and coating following a regular maintenance cycle. Tank painting generally follows an approximate 20-25 year cycle. The timing will vary with need as shown by inspections and economic analysis. Myrtle Tank #2 was recoated in 2010, and Richmond Highlands Tank #2 is scheduled for recoating in 2012.

4.3.1.3 Pump Stations

SPU operates 15 transmission system pump stations. These pump stations are inspected regularly and equipment is repaired or replaced as needed. The only significant modification to the pump stations was the upgrade of the diesel pump at the Tolt Eastside Supply (TESS) Junction Pump Station to provide for improved delivery of water from the Cedar system to the upper reaches of TPL1 and the Tolt Water Treatment Facility clearwells in the event of a Tolt source outage.

The condition of SPU's pump stations varies depending on the age and condition of their components, their usage, past maintenance or rehabilitation activities, and other factors. Recently, SPU has begun implementing a Reliability Centered Maintenance (RCM) program for its pump stations, which is described more fully in Section 4.3.3.3. Since it will take several years to complete RCM on all active pump stations, the current practice is to determine replacement/upgrade schedules according to the expertise of SPU Maintenance Division staff. Pumps are monitored for efficiency and overhauled every 5 to 7 years.

4.3.2 Operations

> ***How long does it take the water to get to my house?***
>
> *It typically takes about two weeks for the water to get from the treatment plants to your faucet.*

Since completion of the Cedar Water Treatment Facility in 2004, water from the Cedar source is pumped from Lake Youngs into the treatment facility and flows through the treatment processes by gravity to the clearwells. From the clearwells, flow to Control Works is through two finished water pipelines (FWP) and flow control facilities (FCF). FWP No. 4 and FCF No. 4 deliver water directly to Control Works through the former Lake Youngs Bypass No. 4 pipeline. FWP No. 5 and FCF No. 5 deliver water to the Lake Youngs tunnel through the former Lake Youngs Bypass No. 5 pipeline. From the Control Works, water flows to the four Cedar River Pipelines (CRPLs) for transport to wholesale customers generally east and south of Lake Washington, and to SPU's retail service area. A maximum of 200 mgd of treated water can be transmitted from the Cedar Water Treatment Facility clearwells through the Cedar River pipelines, but flow is constrained by the Cedar Water Treatment Facility treatment capacity of 180 mgd.

For the Tolt source, raw water is delivered from the South Fork Tolt Reservoir to the Regulating Basin either through the original South Fork Tolt Pipeline or through the Seattle City Light penstock pipeline installed in 1995. From the Regulating Basin, which serves as a break in the hydraulic grade line and as regulating storage for hydropower production, the raw water moves through a screenhouse and then into Tolt Pipelines Nos. 1 and 2 to the inlet of the Tolt Water Treatment Facility. Treated water from the clearwells of the Tolt Water Treatment Facility flows west in the original and, in some places, replaced Tolt Pipeline No. 1 (TPL1) to the Duvall area where TPL1 bifurcates into TPL1 and Tolt Pipeline No. 2 (TPL2). TPL2 follows a separate southwesterly alignment and connects to the Tolt Eastside Supply Line in Kirkland. TPL1 runs west and connects to the north end of the Tolt Eastside Supply Line (TESSL) in Woodinville. West from the Woodinville area TPL1 and TPL2 follow the same original right-of-way to Lake Forest Park Reservoir. TPL2 is in active mode along this stretch whereas TPL1 is in standby mode at lower pressure. TPL1 is kept fresh by maintaining a low level continuous discharge directly into Lake Forest Park Reservoir whereas the main supply to the reservoir comes from TPL2. The Tolt transmission facilities are capable of hydraulically delivering 135 mgd through the treatment facility and downstream transmission pipelines; the treatment capacity is 120 mgd.

SPU has performed extensive hydraulic modeling analysis, and has implemented capital improvements to reduce the likelihood of water service interruption in case of unplanned source outage. As a result, the SPU system is expected to be able to meet indoor and off-peak season water use of the entire service area, most likely including the wholesale customer demand, for at least seven days with only one of its two main sources available. In case of an unexpected source outage during higher demand periods, SPU plans to reduce water demand to indoor levels through aggressive public messaging in the media. More information on system performance under these scenarios is provided in the appendix on System Storage and Reliability Standard. Such responses to emergency outages are covered in the Water Shortage Contingency Plan contained in the *2007 Water System Plan*.

4.3.3 Maintenance

Proper maintenance of SPU's transmission system components ensures that SPU will be able to deliver reliable water service, reduce the risk of unexpected failures, and provide safe drinking water quality to its wholesale and retail customers. SPU has prepared a number of strategic asset management plans (SAMPs) for each major class of transmission system infrastructure components. The SAMPs outline maintenance strategies for each asset. Summaries of those maintenance strategies are provided in this section.

4.3.3.1 Pipelines

Maintenance activities for water transmission pipelines include cleaning of exposed pipes and periodic inspections of pipelines. Moss and dirt are cleaned from exposed transmission pipes at least once every three years. Internal inspections are performed when pipes are emptied and out of service for repairs or maintenance, allowing inspectors to enter the pipe. External inspections are typically performed only when opportunities present themselves, such as when a pipeline is exposed for other work. However, since the *2007 Water System Plan*, SPU performed five dig-up inspections on Cedar River Pipeline No. 4, a reinforced concrete pipeline, to confirm that it was in good structural condition. Earlier, dig-up inspections were done on the Tolt Pipeline between the Tolt Water Treatment Facility and Kelly Road where the original 66-inch concrete cylinder pipe is still in service.

4.3.3.2 Reservoirs and Tanks

Storage facility cleaning is performed to remove sediment, debris, and/or microbial growth. Cleaning is done on a scheduled basis or when water quality inside the storage has declined, as evidenced by regular water quality monitoring. The cleaning schedule is explained in the Water Quality and Treatment chapter.

4.3.3.3 Pump Stations

In 2007, SPU piloted a Reliability Centered Maintenance (RCM) program and brought in a consultant to train in-house staff. RCM is a major shift from traditional maintenance programs that primarily apply time-based maintenance on system components, in this case, components of pump stations. Instead, RCM focuses on the function, failure mode, and criticality of a component to determine the frequency and type (i.e., preventive, predictive, or corrective) of maintenance to perform.

SPU adopted RCM as the core of our maintenance program and has analyzed Burien Pump Station and implemented changes to maintenance tasks and frequency in Maximo (SPU's computerized maintenance management system).

Maintenance activities at water pump stations ensure that the stations continue to operate with minimal loss of function, thereby reducing the likelihood of customer outage, loss of pressure, and potential introduction of pathogens into the distribution systems. SPU performs three types of maintenance activities for its pump stations as described below.

Preventative Maintenance. Preventative maintenance is maintenance which is carried out on a routine basis on elapsed time schedules or equipment run-time hours. Preventative maintenance is designed to eliminate routine failures. Table 4-2 lists typical preventive maintenance activities, the craft responsible for performing them, and the normal frequency at which those activities are performed.

Table 4-2. Typical Pump Station Maintenance Activities

Craft	Task	Approximate Frequency
Carpenter	Building inspection	Annually
Electrician	Generator exercising	Monthly
Electrician	Pump motor starter maintenance	Annually
Electrician	Valve operator	Annually
Mechanics	Overhaul pressure regulator	2 to 5 years
Mechanics	Flow meter inspect/overhaul	2 to 5 years
Mechanics	Diesel engine exercising	Every 2 months
Mechanics	HVAC filter change	Every 2 to 3 months
Mechanics	Air conditioner inspection	Annually
Mechanics	Pump station check	Weekly
Grounds	Basic site check	Weekly

Corrective Maintenance. When preventative maintenance tasks or other data indicate minor equipment malfunctions, corrective maintenance is performed. This type of equipment malfunction does not restrict normal operation of the pump station.

Emergency/Reactive Maintenance. Emergency maintenance is generally carried out when a piece of equipment has failed and the need to restore its performance is critical. The criticality of each pump has been predetermined and incorporated into SPU's computerized work management system to ensure that repair of these facilities receives higher priority than other, non-critical repairs and that critical facilities are quickly put back into service.

4.3.3.4 Wholesale Customer Meters

Wholesale customer meters are tested annually and maintained to meet accuracy standards.

SPU owns and maintains 129 wholesale water meters at intertie locations with wholesale customer systems that measure usage and provide a basis for billing wholesale customers. The most significant change to SPU's wholesale meters since the *2007 Water System Plan* has been the installation of radio frequency modules on almost all of the wholesale meter registers, which allow safer and faster meter reading by enabling the meters to be read without requiring personnel to enter the meter chamber. Meter installations that raise safety concerns, cannot be tested on site, or have older meters that are difficult to maintain are being replaced.

Wholesale customer meters are 3 to 24 inches in diameter and classified as "large meters." SPU's policy is to install, test, and maintain all customer service water meters in such a way as to meet the accuracy standards of the American Water Works Association (AWWA). SPU's meter testing and maintenance practices are described below.

Meter Testing. SPU's approach to field testing of wholesale meters varies with the type of the meter. There are three types of meters: compound, turbine and electronic. Typically, compound meters are field tested annually. Based on operational experience, SPU recently extended the period between tests for turbine meters to once every three years. First, the measuring element is replaced in the field with a measuring element that has been bench tested and known to be accurate. The removed measuring element is then tested on the bench, and repaired as needed. Electronic meters, which are mostly magnetic flow meters, are tested once a year for accuracy of the zero set point and for other applicable electronic settings; due to their size they cannot be typically tested by the conventional method of flowing water and comparing to a reference meter.

Meter Maintenance. SPU performs scheduled maintenance activities on large meters based on a variety of criteria including manufacturer recommendations, AWWA standards and consumption history. Unscheduled maintenance activities are performed in response to billing questions and customer requests. Typically maintenance is performed at the time of testing.

Meter Replacement. Meter replacement includes pipe work and vault modification necessary to bring meter installations up to current standards for accuracy, safety, and maintenance access, and to ensure that the impacts of supply interruptions due to meter maintenance and testing are maintained at levels that are acceptable to customers. Some upgrades may include relocation of the meter installation. Meter replacements are discussed with the customer prior to scheduling to ensure current and future customer needs are met, as well as to ensure proper meter application and coordination to limit customer impacts. Reasonable efforts are made to coordinate meter upgrade work with local street improvement projects to minimize street cuts.

4.4 NEEDS, GAPS, AND ISSUES

SPU has identified several needs, gaps, and issues in regards to the transmission system. Needs include mitigating the risk of pipeline failure in the Tolt slide area and extending the life of transmission pipe using cathodic protection. The following subsections summarize these issues and SPU's approach to addressing them.

4.4.1 Tolt Slide Monitoring

In 2009, Tolt Pipelines 1 and 2 were found to cross a historic slide located between the Regulating Basin and Tolt Water Treatment Facility. The slide had been dormant, and therefore unknown, since the pipelines were installed in the 1960s and late 1990s, but has become more active apparently due to a combination of logging in upland area and erosion by the North Fork Tolt River. This slope movement has affected both pipelines: the ground in the vicinity of TPL2 has moved up to 6 inches, or about 3 inches per year, and near TPL1 it is about one-half of that rate. Since discovery of the slide, TPL1 has been kept empty most of the time to reduce the risk of new small joint leaks triggered by the ground movement and aggravating slope stability. A 48-inch double ball joint expansion sleeve was installed on the newer steel TPL2 to allow the pipeline to better conform to the creeping slide. The ball joint can elongate up to 18 inches, and has moved about 0.8 inches since installation. In addition, SPU initiated an on-going survey and inclinometer monitoring program to track the slide and pipeline movement.

SPU plans on performing the following analysis and actions to gain a better understanding of the situation and mitigate the risk of pipeline failure:

- Continue to collect geotechnical data to better understand the causes behind ground movement.
- Acquire ownership of the slide area to preclude future logging and deforestation, and to gradually reduce the water load on the slide through re-vegetation.
- Perform periodic internal inspections of the Tolt pipelines when monitoring indicates possible stress buildup at certain locations, and implement stress relief measures when necessary, such as cutting and re-welding the pipe, and/or installing additional expansion couplings.
- Perform biannual leak testing of Tolt Pipeline No. 1 to monitor for new small joint leaks that would further aggravate slope stability.
- If and when necessary, implement stress relief or other measures to mitigate the risk of pipe failure.

Cathodic protection is a method used to minimize the rate of electrochemical corrosion of metallic materials, such as pipes, by shifting the corrosion process away from the metal to be protected and onto other more easily corroded "sacrificial" pieces of metal.

4.4.2 Cathodic Protection Program

SPU's transmission system consists primarily of two types of pipe, distinguished by their material and their distinct modes of failure:

- Concrete cylinder pipe can have sudden, unexpected, and oftentimes very destructive failures.
- Steel and ductile iron pipelines usually develop increasing numbers of leaks that are detectable and repairable well before catastrophic failure.

Failure issues associated with each type of pipeline differ because of their different failure modes and risks. Cathodic protection systems have been shown to extend the life of pipe and reduce the risk of failures for both types of pipes, as described below.

4.4.2.1 Concrete Cylinder Pipe

Concrete cylinder pipe (CCP) is manufactured by lining the interior of a thin-walled, steel cylinder with concrete mortar, then wrapping the exterior of the steel cylinder with steel reinforcing rod under slight tension. The entire exterior is then coated with concrete mortar to provide additional stiffness and corrosion protection. CCP derives its strength from the combined strength of the steel cylinder and the pretensioned rod reinforcing. However, should the tensioning rods corrode or deteriorate to the point where they no longer provide sufficient tension to hold the pipe together, the pipe cylinder can fail, sometimes producing explosive bursts of water.

SPU's only sudden CCP failure due to pipe deterioration occurred in 1987 on the TPL1. The failure caused significant flooding and property damage. Detailed investigations revealed that the failure was caused by a particular type of corrosion known as hydrogen embrittlement, where chemical reactions with hydrogen ions in the soil cause the steel to turn brittle and lose its strength. The chemical process is irreversible, and the only remedy is to replace the pipe or to use it as a casing and to install new, smaller-diameter, fully competent pipe inside. Only the steel that was used for the spiral wrap by one particular pipe manufacturer (United Pipe) was found to be susceptible to hydrogen embrittlement. In SPU's system, all pipe made by United and prone to hydrogen embrittlement has been either replaced or slip-lined with new steel or ductile iron pipe.

Investigations in the early 1990s through dig-up inspections revealed some deterioration of the rest of the CCP lines but that these lines are still in serviceable condition. In an effort to mitigate further deterioration of CCP, SPU piloted a cathodic protection project. Cathodic protection has the effect of reducing the rate of metal corrosion in pipelines. The pilot installation proved successful and showed that a single deep cathodic protection well can protect one to three miles of concrete cylinder pipe with fairly even electric potential distribution.

The likelihood of catastrophic failure varies across pipeline sections. In some places the steel cylinder is thick enough to withstand normal working pressure even if the entire rod corrodes away. SPU is in the process of developing a comprehensive strategy to identify where it would be cost-effective to install cathodic protection. Cost effectiveness is generally defined as the avoided risk costs being higher than the costs to install and operate a cathodic protection system. Pipeline segments that are likely to fail catastrophically, and are located in urban areas where consequences of failure would be significant, are likely to qualify for cathodic protection installation.

In addition to the cathodic protection program, SPU plans to reduce of risks of failure in its CCP lines using the following strategies, which were identified in the *2007 Water System Plan*:

- In the unlikely event that a failure does occur, plans are in place to respond expeditiously and repair the pipe and place it back on line, as provided in the outage service levels.
- Stay current on new pipeline inspection technologies. When high tech tools and methods for non-destructive, no-dig condition assessment for this particular type of concrete cylinder become available, they could be used to inspect pipe sections. After such inspections, SPU can apply asset management principles to decide if any should be replaced.

4.4.2.2 Steel and Ductile Iron Pipe

Steel and ductile iron pipelines differ significantly from CCP in that they develop increasing numbers of leaks well before catastrophic failure. In most cases, leaks can be repaired without depressurizing or taking the pipeline out of service. An aging steel pipeline is more likely to present an economic concern due to its increasing repair costs well before its structural strength is imperiled.

When the incidence of leaks on a steel pipeline starts to increase, installing cathodic protection can stop further increases. SPU has used cathodic protection, coupled with internal cement mortar relining, on numerous sections of steel pipelines where either significant leaks have been experienced in the past or may be expected in the future due to corrosive soils. Cathodic protection is a viable alternative to replacement along higher risk areas, like steep slopes or near critical utilities and transportation corridors where an undetected leak may result in high damage costs and where replacement costs are high.

4.5 Implementation/Action Plan

As described earlier, the primary issues facing the transmission system include mitigating risks in the Tolt slide area and extending the life of existing pipelines through continued deployment of cost-effective cathodic protection systems, especially for concrete cylinder pipe. To address those and other issues discussed in this chapter, SPU has identified the following major implementation and action plan items:

- Mitigate the risk of pipe failure in the Tolt slide area through continued slope monitoring, geotechnical data collection, periodic internal inspections, and biannual leak testing, and by taking such actions as acquiring ownership of the slide area and implementing stress relief measures when necessary.
- Continue to implement cost-effective cathodic protection projects for the concrete cylinder and steel transmission pipelines to protect these from corrosion and extend their service lives well into the future.
- Continue to operate the regional water system and manage outage durations for transmission pipelines to meet service level targets.
- Decommission Foy Standpipe and Richmond Highlands Tank #1, as well as Myrtle #1 Tank if approved by WDOH.