June 2022

Resiliency Assessment

Northwest Washington Water RRAP Project

The reliable delivery of safe drinking water and the protection of public health requires our water professionals continually plan for routine and extraordinary events. This document describes the anticipated response from the water systems that serve over 2.3 million residents in northwest Washington. It is hoped the information in this document could lead to the development of a CSZ Water Playbook. The Department of Health wishes to thank the water systems for their significant contributions to inform this document, and the CISA and INL staff for their technical expertise and leadership in this effort.

— WA Department of Health

Some of the earliest discovered writings were records to measure on-hand water and quantities needed to survive a season. Through the course of thousands of years the importance and significance of this resource has never lessened. Water system operators are often overlooked and unacknowledged for the vital role they play in safeguarding our communities. Following a significant disruption in service, potable water becomes a time sensitive priority for emergency management to assist our critical infrastructure partners in restoring. These collaborative preparedness activities serve to strengthen our partnerships to make resilient communities and a better prepared state.

— WA State Emergency Management Division

Program Overview

The Regional Resiliency Assessment Program (RRAP) is a cooperative assessment of specific critical infrastructure within a designated geographic area and a regional analysis of the surrounding infrastructure that address a range of infrastructure resilience issues that could have regionally and nationally significant consequences. These voluntary, non-regulatory RRAP projects are led by the Cybersecurity and Infrastructure Security Agency (CISA) and are selected each year with input and guidance from federal, state, and local partners.

Program Goals and Participants

The goal of the RRAP is to generate greater understanding and action among public and private sector partners to improve the resilience of a region's critical infrastructure. To accomplish this, the RRAP does the following:

- Resolves infrastructure security and resilience knowledge gaps;
- Informs risk management decisions;
- Identifies opportunities and strategies to enhance infrastructure resilience; and
- Improves critical partnerships among the public and private sectors.

Strong partnerships with Federal, State, local, tribal, and territorial government officials and private sector organizations across multiple disciplines are essential to the RRAP process. These include private sector facility owners and operators, industry organizations, emergency response and recovery organizations, utility providers, transportation agencies and authorities, planning commissions, law enforcement, academic institutions, and research centers.

RRAP Activities and Results

Each RRAP project typically involves a year-long process to collect and analyze data on the critical infrastructure within the designated area, followed by continued technical assistance to enhance the infrastructure's resilience. Individual projects can incorporate opportunities for valuable information and data exchanges, including voluntary facility security surveys, first responder capability assessments, targeted studies and modeling, and subject matter expert workshops. An RRAP project can usually be described as having three phases: a data collection phase, an assessment/analysis phase, and an implementation phase.

The culmination of RRAP activities, research, and analysis is presented in a Resiliency Assessment documenting project results and findings, including key regional resilience gaps and options for addressing these shortfalls. Facility owners and operators, regional organizations, and government agencies can use the results to help guide strategic investments in equipment, planning, training, and infrastructure development to enhance the resilience and security of facilities, surrounding communities, and entire regions.

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Executive Summary

Executive Summary

A Cascadia Subduction Zone (CSZ) earthquake and tsunami off the Pacific Northwest coast of the United States would be one of the most devastating natural disasters to strike the United States. While infrastructure damage will affect nearly all sectors, one of the most consequential impacts of a CSZ earthquake will be damage to the water supply and delivery systems across western Washington. The Department of Homeland Security's baseline study of a CSZ earthquake and tsunami concluded that—other than emergency supplies—an estimated 1.2 million people in western Washington will be without potable water for several months to years; others will suffer water supply interruptions for weeks or months.[1] Physical damage to water supply infrastructure, coupled with grid outages and damage to surface transportation systems will result in a true "black sky" event[2], made even more challenging and complex by communications system failures that impede situational awareness and encumber response and recovery efforts.

Following a disruption of this magnitude, federal, state, tribal, and local officials will face enormous challenges in delivering potable water to the population. The post-CSZ logistics of securing water outside the impacted area, transporting it to the impacted area, and distributing it to the population within the impacted area demonstrate the need to explore water supply solutions closer to home. The Northwest Washington Water Resiliency Assessment project was conducted to assess the resilience of a group of small, medium, and large water utilities within the Washington Department of Health's (DOH) Northwest Drinking Water Region, which includes Whatcom, Skagit, San Juan, Island, Snohomish, King, and Pierce counties, and their ability to supply drinking water to the population in the four-week aftermath of the incident.[3]

The analysis focused exclusively on the 44 water utilities that participated in the project[4] and found that other than water stored by citizens or supplied by non-governmental organizations (NGOs) or other entities, the region's most viable option for obtaining emergency drinking water from existing supplies is likely to be treated water held in hardened, finished water storage tanks or water pumped from wells (and aquifers) that withstand the impacts of the earthquake. Key outcomes of the project included identification of wells and treated water storage tanks with relatively greater seismic resilience, based on locational risk and the seismic attributes of the infrastructure. Given the need to access water system infrastructure to both mitigate water loss and collect and distribute water, the project leveraged the outcomes and analysis of the Washington State Transportation Systems Resiliency Assessment, which analyzed projected damage to surface transportation routes[5] and the capacity of surface transportation systems in western Washington to support the movement of emergency supplies and resources into the affected area. Finally, the project sought to assess and promote

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1 The Homeland Infrastructure Threat and Risk Analysis Center (HITRAC), a predecessor organization to the National Risk Management Center, published its baseline CSZ study in 2011. [HITRAC]

2 A black sky hazard is a catastrophic event that severely disrupts the normal functioning of critical infrastructure systems in multiple regions, for long durations. The Electric Infrastructure Security (EIS) Council called attention to "black sky hazards in 2014, noting that "Cyber weapons, coordinated physical attacks on key grid components, electromagnetic Pulse (EMP) weapons, severe solar storms, catastrophic earthquakes and other hazards of unprecedented destructiveness can all create 'black sky days'". [EIS Council]

3 The timing of the RRAP coincided with planning initiated by the Statewide Catastrophic Incident Planning Team (SCIPT), which enabled the RRAP to indirectly support the SCIPT's efforts to plan for and anticipate the impacts of severe and prolonged disruption to water services. The SCIPT's mission is to facilitate collaborative planning among state, tribal and local governments to prepare for, respond to, and recover from catastrophic incidents. The RRAP's focus on emergency water and identification of regional capabilities and gaps also complemented the SCIPT's development of a Catastrophic Incident Annex: Infrastructure Systems. https://mil.wa.gov/statewide-catastrophic-incident-planning-team.

4 The 44 utilities studied for this RRAP project represent less than five percent of the 893 Group A drinking water systems in the Northwest Drinking Water Region, although the focus on larger systems resulted in a much higher coverage based on population served. Group A Public Water Systems have 15 or more service connections or serve 25 or more people per day for 60 days or more per year. Key requirements and responsibilities of Group A systems can be found at https://www.doh.wa.gov/portals/1/Documents/pubs/331-084.pdf. Many systems that were not included in the study are likely to have developed emergency water capabilities that emergency managers and planners should explore and include in contingency plans and operational activities.

5 This is the third CSZ-focused RRAP project conducted in the state of Washington. This study benefits from the Washington State Transportation Systems RRAP and its Resiliency Assessment report, published in 2019, which created the Bridge Seismic Screening Tool (BSST) to determine and illustrate how surface transportation routes would be affected by a CSZ earthquake. This project relied on the BSST to determine the accessibility of emergency water resources post-CSZ. The Transportation Systems report is available at https://mil.wa.gov/asset/5d8ba2a03a1b7

coordination between EMD, DOH, water utilities, and state, county, and city emergency managers on emergency water awareness, capabilities, and access.

Based on this work, this project resulted in seven Key Findings:

- Many water utilities that participated in this study have the capability to supply some emergency drinking water; but pre-earthquake coordination is needed to leverage those capabilities securely and effectively.
- Water utilities need guidance and actionable information from wholesale water suppliers, emergency management agencies, and utility leadership regarding post-CSZ priorities and expectations.
- For many utilities, the preservation of drinking water for emergency use will be impeded by the inability of utility staff to report to facilities in a timely manner.
- Washington's Post-Disaster Re-Entry Framework provides a solution for safe, orderly access to facilities following a disaster, but water utilities are generally unaware of the framework and local jurisdictions have yet to adopt and implement it.
- Water quality laboratories and the availability of water quality testing will be degraded post-CSZ, as will the ability to transport samples to laboratories for testing. The short-term loss of testing capacity will pose an additional challenge to supplying drinking water following an earthquake.
- Emergency fuel planning is a priority for the Washington Department of Commerce (COM) Energy Emergency Management Program and individual water systems.
- State departments, county and city emergency managers, and water utilities should emphasize personal and family preparedness in the communities they serve. Public messaging should be consistent, persistent, and actionable.

Each of these Key Findings is accompanied by Resilience Enhance Options that identify actions that municipal, county, state, federal, tribal, and regional partners could undertake to increase water supply resilience and the capacity to provide emergency water to the population. In addition to the Resiliency Assessment, separate appendices were created for each participating county. The County Appendices are intended to provide county and city emergency managers with a targeted reference guide relative to the risk, location, access requirements, water supply capabilities and other relevant features of the participating utilities. These appendices will also be provided to DOH, EMD, county and city emergency managers, and participating utilities. The findings, analysis, and Resilience Enhancement Options are intended to support targeted and efficient preparedness, response and recovery activities relative to a CSZ earthquake. CISA will continue to work with all project stakeholders to address the varied risks that threaten water supply infrastructure in the region, and to collectively increase the resilience of these vital systems.

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Project Overview

Project Overview

Project Description

Situated off the coast of the Pacific Northwest, the Cascadia Subduction Zone (CSZ) extends roughly 700 miles from northern California to British Columbia. A CSZ earthquake is capable of producing a magnitude 9.0 (M9.0) earthquake, impacting all of western Washington and causing widespread damage from ground shaking, liquefaction, landslides, and tsunami. [Resilient Washington State 2012] The region's infrastructure will not be spared. Surface transportation networks, ports and shipping channels, airports, energy systems, communications networks and water systems are all expected to sustain extensive systemic damage. Estimates to restore a level of functionality to drinking water infrastructure range from three weeks to seven months. Total restoration of some systems could take years. [CREW 2013] To advance CSZ preparedness, regional stakeholders have undertaken three collaborative RRAP projects. Two previous projects focused on regional transportation systems.[6] This project assessed the capability of selected water utilities in the DOH's Office of Drinking Water – Northwest Drinking Water Region[7] to supply drinking water to the population in the immediate aftermath of a CSZ M9.0 earthquake. The project had three principal goals:

- Identify wells and treated water storage tanks with the greatest likelihood of surviving a CSZ M9 earthquake based on locational risk and the seismic attributes of the infrastructure;
- Determine the ability to access those resources given projected damage to surface transportation routes [Transportation Systems RRAP]; and
- Assess and promote coordination between the EMD, DOH, water system operators, and emergency managers on emergency water awareness, capabilities, and access, including the availability of apparatus necessary for the provision of emergency water.

The Northwest Washington Water Resiliency Assessment occurred over a 3-year period beginning in August 2019. Initial scoping activities refined the project focus and identified central research questions. Since the project contemplated partnering with a set of drinking water utilities in each of the seven counties, the DOH developed a preliminary set of candidate water systems based primarily on population served. Geospatial analysts took those preliminary selections, mapped the utilities' service areas and assets, including treatment plants, finished water storage tanks, wells, interconnects, and intakes and overlaid CSZ M9 and local fault shake maps, liquefaction susceptibility zones, and tsunami inundation zones. Infrastructure analysts used these geospatial products to evaluate candidate utilities based on critical asset locations in or near areas of high liquefaction susceptibility and intensity of shaking. The team selected utilities that optimized population served, geographic dispersal, and source water diversity.[8] Ultimately 44 water utilities participated in the RRAP project. Figure 2 provides a complete list of utilities that participated in the project, and Figure 1 illustrates the water utility service areas for the systems the project team worked with and studied.

Following orientation meetings with wholesale water utilities within the Water Supply Forum (WSF)[9] and WSF member Cascade Water Alliance, the project team conducted open-source research to inform discussions with utility stakeholders and learn about their systems and challenges. Subsequent activities were focused

6 Previous DHS resiliency assessments include the Washington State Transportation Systems Resiliency Assessment and the Washington State Airports Seismic Resilience Project.

7 In 1976, the Environmental Protection Agency (EPA) conferred authority for implementing the Safe Drinking Water Act on DOH's Office of Drinking Water. This authority is called "primacy." Primacy requires the state to adopt and administer state rules that meet or exceed federal requirements. Details can be found on the DOH website. https://www.doh.wa.gov/CommunityandEnvironment/DrinkingWater/RegulationandCompliance/RuleMaking/FormalAgreementwithEPA.

8 Initially, the selection of candidate utilities was based solely on population served within each county. Within that subset, analysis of shake maps and liquefaction susceptibility resulted in the removal of some utilities and substitution of others based on seismic risk to critical emergency water assets.

9 The WSF consists of member agencies within the central Puget Sound region that work cooperatively to promote the reliable delivery of safe, clean water throughout the region. Member agencies include Alderwood Water & Wastewater District, Bellevue Utilities, Cascade Water Alliance, City of Auburn, City of Everett, City of Kent, Covington Water District, Everett Water Utility Committee, King County, Lakehaven Water & Sewer District, Regional Water Cooperative of Pierce County, Seattle Public Utilities, and Tacoma Public Utilities – most of whom participated in this study. https://www.watersupplyforum.org/home/about-water-supply-forum.html#menu, accessed November 26, 2021. The Forum's ground-breaking work on earthquake resiliency, completed in 2018, provided key inputs to this analysis. https://www.watersupplyforum.org/home/resiliency.html.

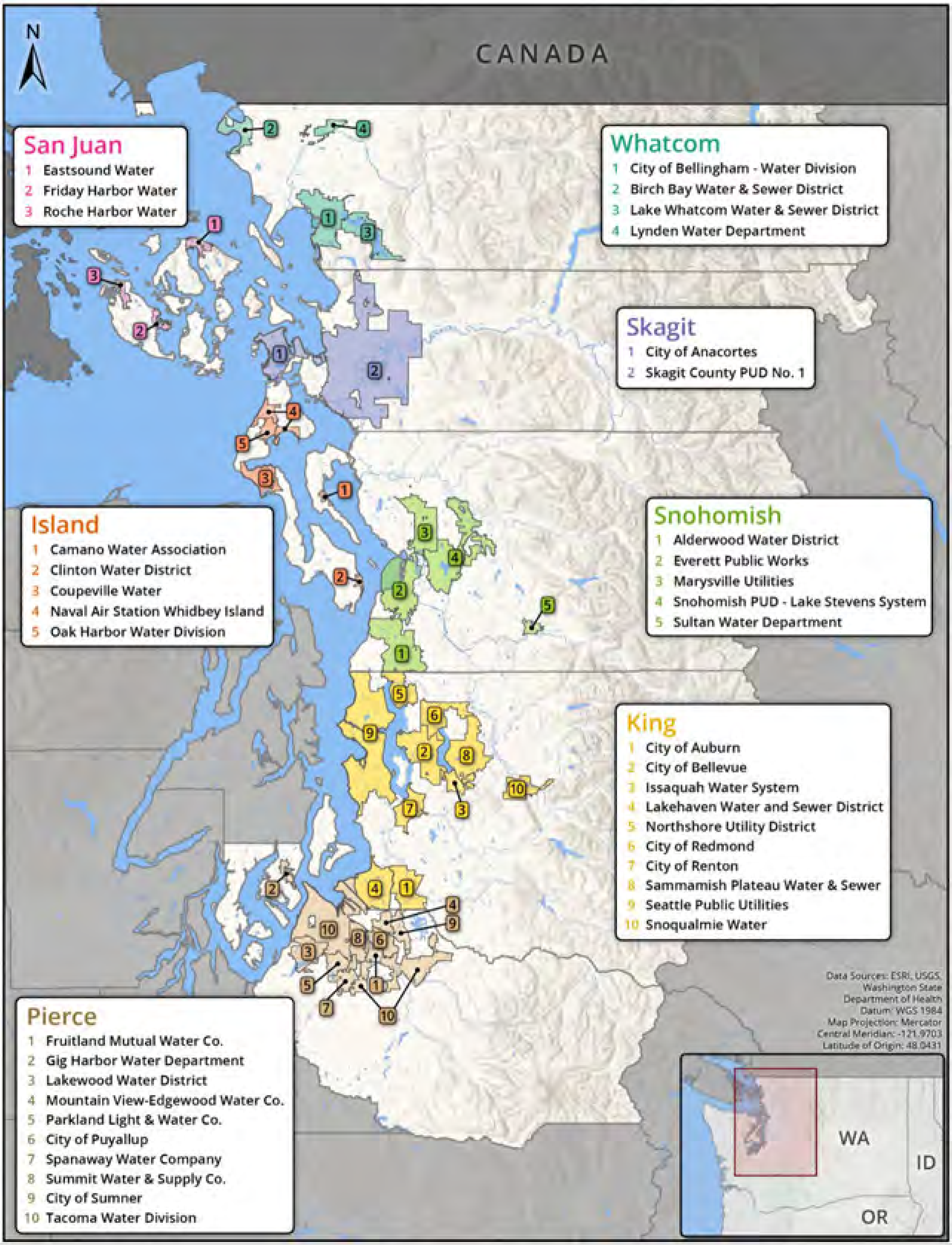

FIGURE 1.—Water Utility Service Areas.

on utility interviews and facilitated discussions to identify, collect, and validate preliminary research on participating water systems. These interviews and facilitated discussions also provided an opportunity to explore each utility's capacity to provide emergency drinking water. In February 2020, the project team conducted facilitated discussions with county and city emergency managers and participating water utilities in Whatcom, Skagit, and San Juan counties to demonstrate hazard analysis, determine seismic capabilities and vulnerabilities of water tanks and wells, and explore the utilities' preparedness and capacity to provide emergency water in a post-CSZ environment. Travel was suspended in March 2020 due to COVID-19 and in September 2020 stakeholder outreach resumed with discussions and information exchanges with emergency managers and water utilities in Island, King, Pierce, and Snohomish Counties via telephonic interviews, emails, and virtual meetings.

Interview outcomes were summarized and a synopsis of each utility's capacity to provide emergency water was provided to the utility for validation. The utility summaries were grouped by county in the County Appendices that accompany this Resiliency Assessment. The final phase of this project involves implementation activities scheduled to occur no later than June 2022. During the implementation phase, CISA will continue to work with all project stakeholders to improve the region's emergency water capabilities.

Project Participants

This project was reliant on the voluntary participation of water utilities, emergency management organizations, and a variety of associations that provided information, perspectives, and the benefit of years of experience in emergency management and water utility operations. Candid feedback from system operators, associations, and county and city emergency management personnel was particularly valuable as the resilience assessment proceeded and the Key Findings and resiliency enhancement options began to crystalize. Figure 2 lists the organizations that contributed to this project. Individuals from each of these organizations provided a diverse range of perspectives, experience, data, and operational information, which were critical to overall project success.

FEDERAL GOVERNMENT

- Federal Emergency Management Agency, Region 10
- U.S. Environmental Protection Agency, Region 10
- U.S. Environmental Protection Agency, Office of Water
- CISA Region 10

STATE, COUNTY, AND CITY GOVERNMENT

- Washington State Department of Commerce
- Washington State Department of Ecology
- Washington State Emergency Management Division
- Washington State Department of Health – Office of Drinking Water
- Washington State Department of Natural Resources, Geological Survey
- Island County Department of Emergency Management
- King County Office of Emergency Management
- Pierce County Department of Emergency Management
- San Juan County Department of Emergency Management
- San Juan County Department of Health
- Skagit County Department of Emergency Management
- Skagit County Public Health
- Snohomish County Department of Emergency Management
- Whatcom County Sheriff's Office – Division of Emergency Management

King County

- City of Auburn Emergency Management
- City of Bellevue Office of Emergency Management
- City of Issaquah Emergency Management
- City of Seattle Office of Emergency Management
- City of Snoqualmie Department of Emergency Management
- Northshore Emergency Management Coallition
- Redmond Emergency Management

Pierce County:

- City of Edgewood
- City of Gig Harbor
- City of Puyallup Emergency Management Division
- City of Tacoma Emergency Management
- Lakewood Emergency Management

Skagit County:

- City of Anacortes

Whatcom County

- City of Bellingham

PRIVATE SECTOR ORGANIZATIONS

- American Water Works Association
- Cascade Water Alliance
- Evergreen Municipal Water Consulting
- Regional Water Cooperative of Pierce County
- Washington Public Utility District Association
- Water Supply Forum

PUBLIC WATER SYSTEMS

Island County:

- Camano Water Association
- City of Oak Harbor Water Division
- Clinton Water District
- Naval Air Station - Whidbey Island
- Town of Coupeville Utilities

King County:

- Bellevue Utilities
- City of Auburn Public Works
- City of Issaquah Public Works
- City of Redmond Utilities
- City of Renton Water Utility
- Lakehaven Water and Sewer District
- Northshore Utility District
- Sammamish Plateau Water
- Seattle Public Utilities
- Snoqualmie Public Works – Utilities Division

Pierce County:

- City of Gig Harbor Utilities
- City of Puyallup
- City of Sumner Utilities
- Fruitland Mutual Water Company
- Lakewood Water District
- Mountain View – Edgewood Water Company
- Parkland Light & Water
- Spanaway Water Company
- Summit Water & Supply Company
- Tacoma Public Utilities

San Juan County:

- Eastsound Water Users Association
- Lopez Village Water System
- Roche Harbor Water System, Inc.
- Town of Friday Harbor Water Department
- Washington Water Service

Skagit County:

- Blanchard-Edison Water Association
- City of Anacortes Water Department
- Skagit Public Utilities District

Snohomish County:

- Alderwood Water and Wastewater District
- City of Marysville Public Works
- City of Sultan Water Utility
- Everett Public Works
- Snohomish County Public Utility District

Whatcom County:

- Birch Bay Water & Sewer District
- Blaine Public Works
- City of Bellingham Water Utility
- Ferndale Public Works Department
- Lake Whatcom Water & Sewer District
- Lynden Water Department

All participation in this RRAP project was voluntary. The type and degree of participation varied among organizations. Participation does not imply a formal role in the review or approval of this report.

FIGURE 2.—Participants.

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Analytic Outcomes

Analytic Outcomes

The RRAP project analyzed short-term emergency water supply options based on an evaluation of the infrastructure and capabilities of 44 water utilities in Whatcom, Skagit, San Juan, Island, Snohomish, King, and Pierce counties as well as emergency water supply equipment and apparatus currently available to water utilities and emergency managers in the region. The shaking associated with a CSZ M9 is likely to cause damage to water utility transmission lines, treatment plants and distribution piping that could take weeks to months to repair. Although there is abundant surface water in the region, currently there are no existing portable/mobile water treatment systems in the region that would enable emergency management agencies or water utilities to leverage surface water sources at scale and earthquake-related damage to transportation infrastructure will likely delay the arrival of water from outside the region. Other than water stored by citizens or supplied by Non-Governmental Organizations (NGOs) or other organizations, the region's most viable option for obtaining emergency drinking water supplies is likely to be treated water held in hardened, finished water storage tanks or water pumped from wells (and aquifers) that withstand the impacts of the earthquake.

Given the difficulty of predicting the extent of damage to specific facilities and underground infrastructure, the project team focused on identifying wells and finished water storage tanks with a higher likelihood of surviving intact, based on location and the seismic attributes of the infrastructure.[10] Figures 3, 4, and 5 depict the forecasted shaking severity, liquefaction susceptibility, and tsunami inundation susceptibility within the service areas of the utilities examined in this study.[11] Further background on the CSZ is provided in Appendix A.

10 Water may also be available in portions of distributions system piping that remain pressurized.

11 The County Appendices examine the seismic risk to wells, finished water storage tanks and water treatment plants on a more granular level.

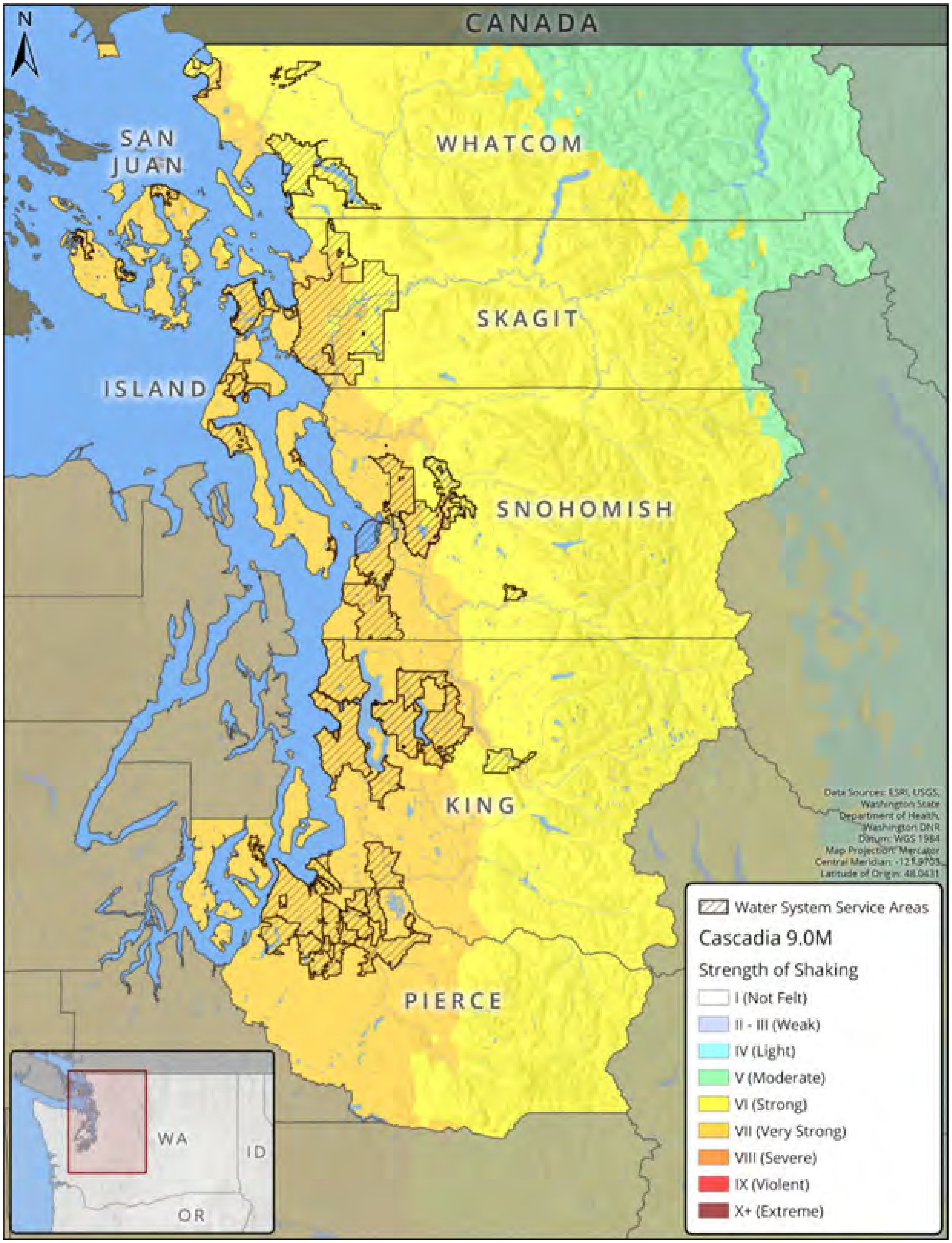

FIGURE 3.—ShakeMap - USGS M9.0 CSZ Scenario.

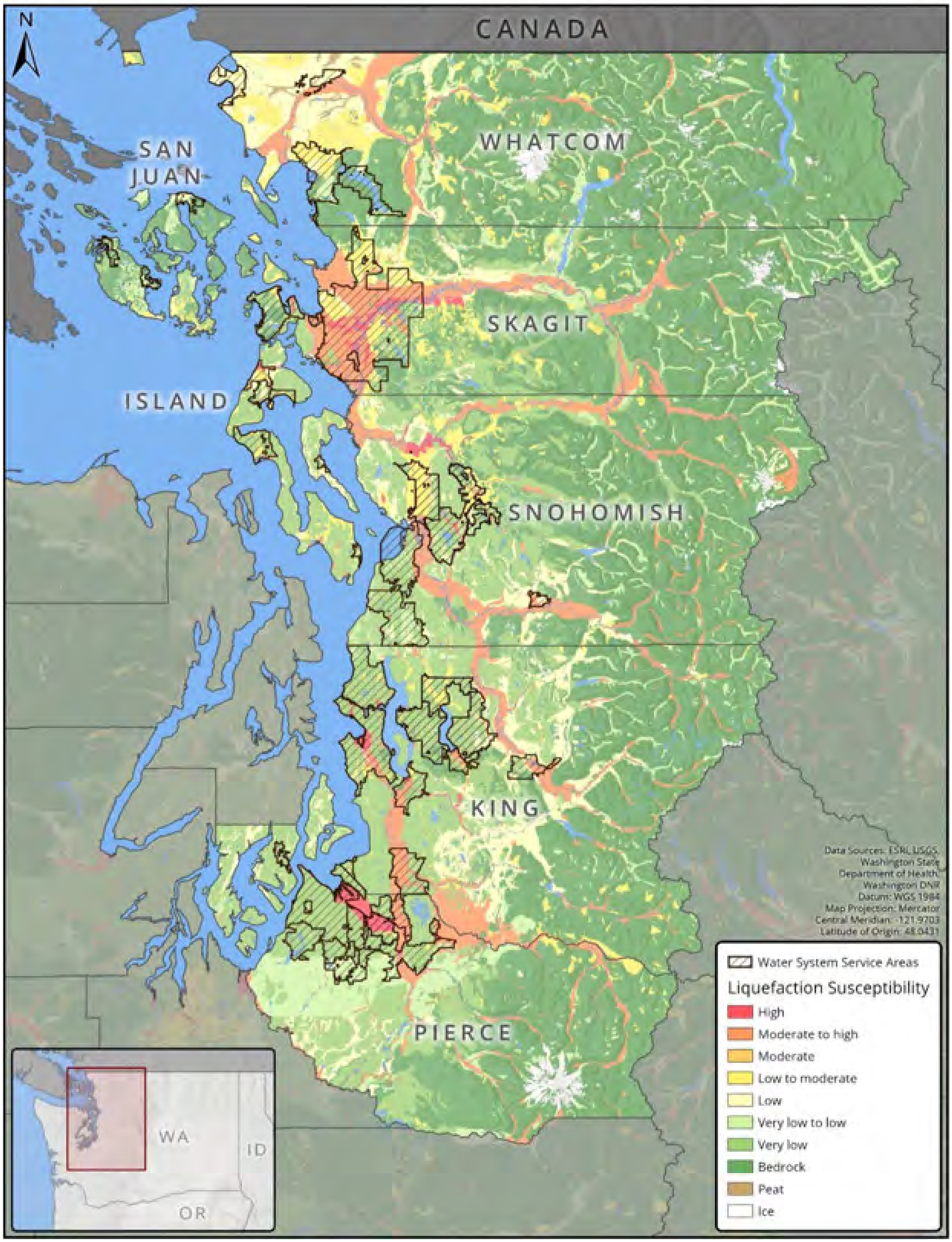

FIGURE 4.—Soil Liquefaction Susceptibility.

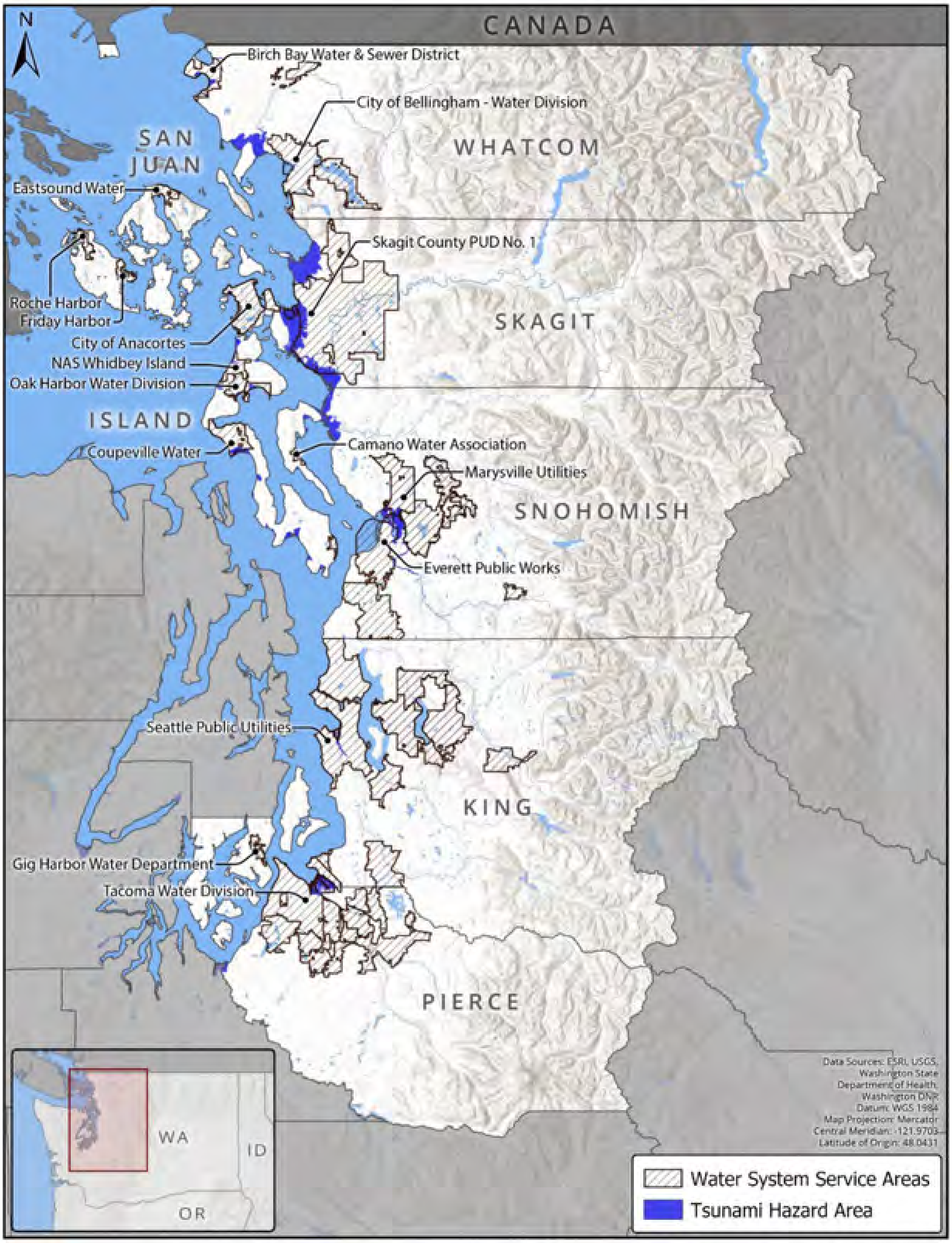

FIGURE 5.—Tsunami Inundation Hazard Areas.

For potable emergency water examined in this study, the relevant infrastructure components, which are shown in Figure 6, are wells, water storage tanks, and distribution system piping that remains under pressure. However, identifying potential sources of emergency water is just the first step in a series of actions that must occur before water can be delivered to the population. Delivery of emergency water from wells and storage tanks depends on the following:

- An available workforce,[12]
- A functional surface transportation system between points of departure and destination,
- Communications systems for awareness of accessible routes and operational coordination,
- The ability of utility personnel to move through potential safety and security checkpoints,
- Prioritization of debris removal to enable access to critical water utility resources, and
- Access to necessary water treatment chemicals and generator power for wells.

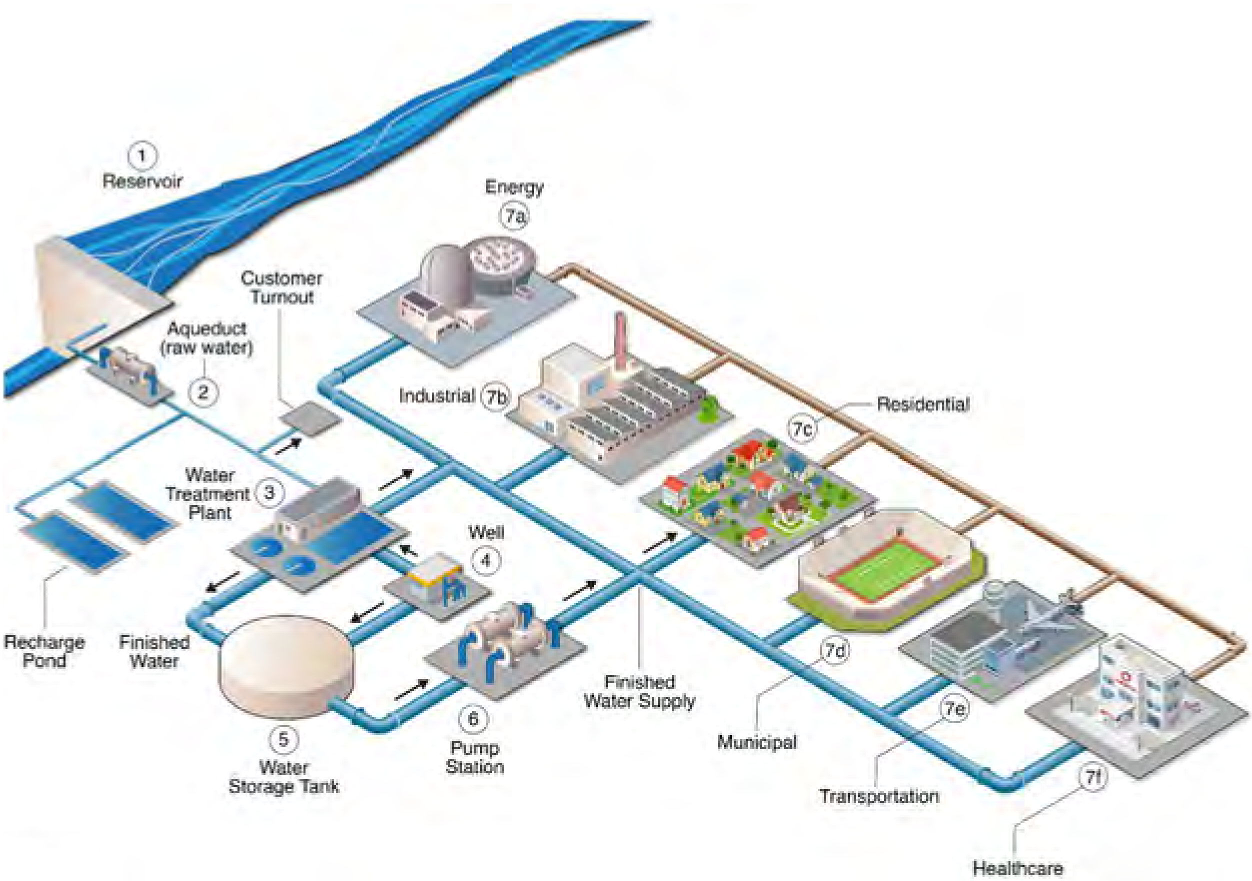

FIGURE 6.—Drinking Water Lifecycle.

12 Most of the water utilities surveyed for this project reported that system operators and utility response personnel live outside their respective utility's service area, and many would need to travel substantial distances to access facilities for damage assessments or to turn valves manually to mitigate water loss. Key Finding 3 explores this issue in greater depth.

Consequently, the region's ability to rely on surviving potable water supplies for emergency use will be affected by the condition of other infrastructure systems and the extent and effectiveness of pre-incident planning and coordination. WA EMD's Statewide Catastrophic Incident Planning Team (SCIPT) has developed planning assumptions for a CSZ earthquake and tsunami relative to water, transportation, communications, power, and petroleum.[13] Water utilities should be aware of planning assumptions for other infrastructure systems because systemic damage and delays in restoring functionality of these systems will affect water utility response operations (and utility workers' access to facilities), impede situational awareness, and impair emergency response operations. The complete set of planning assumptions for water systems is provided in Appendix B. Selected planning assumptions for transportation, communications, energy, and mass care[14] that have the capacity to impact water system response and emergency watering operations are enumerated below. Water utilities should carefully consider the ways in which these assumptions, if realized, would affect their emergency plans and functional capabilities.

Catastrophic Planning Assumptions

Transportation (Relevance for water systems: Access/Fuel/Route Prioritization):

- Fuel requirements for assessment and repair crews will exceed local capabilities; fuel and highway infrastructure must come via barge or air; power will be critical for fuel distribution
- It will take months or years to restore highway segments affected by bridge damage, fault offsets, landslides, and liquefaction
- Mutual aid agreements may not be workable due to the catastrophic nature of the incident because requests will quickly surpass capacity
- There will be a limited number of qualified inspectors to support assessments of both public and private transportation infrastructure
- **Air Transport**
  - » Access and supporting infrastructure to and from airports will be a limiting factor for aerial delivery of resources
  - » Air transportation will be the only viable means of delivering supplies and evacuating people in many areas in the initial days after the disaster, due to the event's impacts to roads, bridges, ports, and rail
  - » Commodities may accumulate at airport landing zones if shortages in supply movement capabilities occur.
- **Ground Transport**
  - » Much of Interstate 5 (I-5) will be unusable due to damage to key bridges from Canada to California
  - » The initial earthquake and tsunami will destroy most of Highway 101 and roads that provide access to the coast
  - » I-90 from Moses Lake to I-5 in Bellevue will be the most likely route to survive impact and will be a priority for reopening
  - » Washington Department of Transportation (WSDOT) restoration priorities will be based on initial assessments of routes. The highest priority will be given to routes with life safety considerations and the identified WSDOT Seismic Lifeline route.[15]

Communications (Relevance for water systems: Situational Awareness/Response Coordination/System Monitoring)

- Communication to coastal communities will be limited to radio frequency and satellite
- Debris and road damage will prevent access to communications towers, central offices, remote switches, cable head-ends, and other critical communications infrastructure to assess damages, conduct repair operations, and refuel generators

13 The Catastrophic Incident Planning Framework (2017) (CIPF) published on the EMD website includes some of the planning factors listed above. Future updates to that document will include the planning factors that were provided to the RRAP team. The CIPF is available at https://mil.wa.gov/asset/5bac12298ef00. The Catastrophic Incident Annex (CIA), scheduled for publication in 2022, will also include planning factors; however, the factors will focus solely on state considerations. The CIPF, in contrast, is planning guidance that can apply to state, tribal, and local catastrophic planning. The CIA is currently under development with a new version slated for release in 2022.

14 Emergency Support Function (ESF) #6 (Mass Care, Emergency Assistance, Temporary Housing, and Human Services) provides life-sustaining resources and human services to the affected population, to include hydration, feeding, sheltering, temporary housing, evacuee assistance, reunification, and distribution of emergency supplies. https://mil.wa.gov/asset/610b0278f0292. Emergency water provisioning is critical to ESF #6 (Mass Care).

15 WSDOT's Seismic Lifeline GIS Map can be accessed at https://geo.wa.gov/datasets/WSDOT::wsdot-seismic-lifelines

- Communications infrastructure will be significantly degraded immediately following the event. It will continue to deteriorate due to the nature of backup power systems at communications towers and wire centers and the inability to replenish limited fuel supplies, which will be depleted 8-12 hours after the initial event
  - Based on the current capability assessment, limited crews will be available to assess communications facilities
  - Remote communications nodes and lines (wire and optical) will be inaccessible and unrepairable for a period exceeding 30-90 days
- Overuse of cellular networks may result in latency and call failures. Systems to manage access such as the Government Emergency Telecommunications Service (GETS) and Wireless Priority Service (WPS) will help alleviate these issues for responders and other officials
- Based on the current capability assessment, limited crews will be available to assess communications facilities
- Wireless, wired, and fiber systems will be severely damaged, causing failures in trunked radio, microwave, cellular, internet, and public switch telephone network (PSTN) relay points.
- Many tower-based systems will fail or otherwise be unavailable during and after an incident because of misalignment, tower collapse (full or partial), transport, interconnectivity failure, loss of redundant systems, power failure, fuel resupply, or overutilization
- Satellite communications will be severely limited due to congestion during the first 14 days of a CSZ event. Sat phones may not work indoors, limiting their use in operations.
- Responders and survivors in heavily impacted areas will be without internet, cell phone, landline, television, or two-way radio service
- Cellular towers may not be able to link customers to switching centers, leaving callers with no access to emergency and telecommunications service.

Planning Assumptions for Energy

- **Electricity** (Relevance for water: utility operations, IT and SCADA systems, pumps, wells)
  - Electric grid impacts will include damage to transmission and distribution systems.
  - Critical facilities will require backup power sources (generators), necessitating prioritized fuel distribution
  - Electrical equipment will be damaged at most of the substations in the impacted area.
  - Both overhead and in-ground transmission and distribution lines will be damaged
- **Natural Gas** (Relevance for water: backup generators, heating, electricity generation)
  - Natural gas transmission pipelines, compressors, city gates and distribution systems will experience damage, outages, and restoration challenges
- **Petroleum** (Relevance for water: Availability of fuel for backup generators, evacuation, workforce)
  - Useable fuel stocks are low and local fuel resupply is limited
  - Unrationed fuel use is expected to exceed supply (prioritized rationing required)
  - Limited local law enforcement staff will be unable to secure fuel stocks on hand or in transport
  - Once fuel arrives via air or water, it is beyond local capacity to administer (regional coordination required)
  - Restoration of fuel refinery operations will require both water and electrical components
  - Damage to petroleum ports and rail may impact crude stock for refineries
  - Damage to refined product pump stations will impact end consumers. Fuel stations with generators are limited and consumers may not be able to easily access gasoline for evacuation or small generators
  - Refined product pipelines may experience breaks and leaks, impacting refined product availability in the western US

- » Damage to transportation corridors may reduce the overall demand for petroleum products, however fuel demand for response and recovery efforts will increase and be a high priority for the first weeks and months of a catastrophic incident
- » Short-term distributed generation (generators) will be required to provide energy to critical facilities. The use of generators will require short and long-term prioritization of fuel distribution

Planning Assumptions for Mass Care (Relevance for water: shelters and other facilities housing vulnerable/ displaced populations will depend on water to remain open and functioning)

- Within the impact zone, officially managed shelter facilities will not be opened or maintained if damage to the area is beyond the ability to provide life-sustaining resources.
- Some facilities may be retrofitted and/ or have emergency backup power.
- The scarcity of appropriate vehicles (e.g., ambulances, paratransit, canteens, box trucks, refrigerated trucks, passenger vans/buses) to provide mass care services will hamper the delivery of life-sustaining services and the coordination of response and recovery activities to disaster survivors.
- Disaster-related interruption of services may disrupt water treatment and supply plants, increasing the risk of waterborne diseases.
- Disruption of water, power, communications, transportation, and other critical infrastructure sectors will impact the ability to move to sheltering locations and receive or access goods and services.
- It will be essential to work with counties and local jurisdictions on coordination of water systems. Counties will have a variety of resource capabilities to serve their populations.
- Mass care operations will be unavailable in some areas due to loss of community lifelines and resulting concerns for the safety of survivors and responders.

These planning assumptions underscore the anticipated breadth and severity of a CSZ earthquake and foreshadow the competition for scarce resources that will occur in the aftermath of the earthquake. To that end, it is prudent to emphasize the extent to which other lifeline sectors depend on water for continuity of operations. The near universal dependencies on water depicted in Figure 7 emphasizes the need for priority restoration of water utility service due to the speed of functional degradation and the virtually universal lack of alternate sources or onsite backup for water. While the focus of this study is the provision of water under catastrophic conditions - not the restoration of full water system functionality - it is nevertheless worthwhile to note that many systems and assets within the dependent sectors depicted in Figure 7 are also within the CSZ impact zone and would be expected to lose functionality for some period of time due to shake-related damage, liquefaction, and workforce impacts. Just as water utilities' demand for treatment chemicals will decrease while systems are being repaired, it is reasonable to expect that some infrastructure systems' demand for water may be diminished while in a disabled or compromised state. This complex set of circumstances gives rise to resource prioritization decisions with far-reaching and potentially enduring consequences. It is therefore vital that decision-makers understand the speed and extent to which other infrastructure sectors are affected by a disruption in water service and the trade-offs inherent in the decisions they make.

Criticality of Water Sector Operations

Water services are critical to community resilience. Loss of service can cause significant interruption or degradation of dependent sectors, as illustrated in Figure 7. Between January 2011 and April 2014, DHS conducted security and resilience surveys at 2,661 public and private sites across multiple sectors. An overwhelming majority of those sites reported an operational dependency on water. The data collected by DHS indicated that when water services are lost for even short periods (less than eight hours), there can be significant degradation in critical services resulting in severe and dramatic consequences.[16] Secure and resilient water systems are essential for daily life and economic vitality.

While Figure 7 illustrates that all infrastructure sectors depend on water to maintain critical functions, the water sector, in turn, is interdependent with four sectors, each of which provides inputs necessary to water operations. Under steady-state, non-emergency conditions, these interdependencies include:

- **Chemical Sector:** Chemicals are required for water treatment and water is typically needed for chemical manufacturing.
- **Communications/Information Technology (IT) Sectors:** The water sector relies on communications and IT for operations, including control systems, monitoring systems, and internal and external communications. Communications and IT rely on water services for equipment cooling and facility operations.
- **Energy Sector:** The water sector relies on electricity to operate pumps, treatment facilities, non-gravity fed delivery systems, and office processes. The energy sector relies on water for multiple aspects of energy production and generation.
- **Transportation Sector:** The water sector depends on surface transportation for delivery of chemicals, other supplies, emergency services, and access to facilities. Multiple components of the transportation sector require water to maintain operations. [NIAC]

Emergency Water Supply Options and Apparatus

Since water stored in hardened water storage tanks will be accessed on site or gravity fed to a location where it can be collected, the project also investigated the availability of tanker trucks, portable bladder tanks, manifold systems for filling containers, and other strategic assets needed to move water to shelters and other locations. Finally, the project examined coordination between water utilities and emergency management agencies.

Based on analysis performed over the course of this RRAP project, previous work conducted by the Water Supply Forum (WSF),[17] and a survey of emergency water resources available to or controlled by the utilities that participated in this study, emergency water provided by regional water utilities will primarily be derived from finished water storage tanks and wells that have the attributes needed to survive the event. For water storage tanks, the most likely candidates for supplying emergency water are those equipped with isolation valves, which either close automatically or can be closed manually. Closure of the valves, whether automatic or manual, will prevent water from escaping the tank due to shearing at the tank or downstream breaks in distribution piping. Automatic seismic valves have seismic controllers that sense seismic movement and send a signal to the valve actuator to close the valve. [Porter] In the case of structures with manual shut-off valves, mitigating water loss will require human intervention – until the valve is physically closed, water will escape the tank. Without knowing the size of the tank or the location and nature of the break, it is impossible to predict the speed with which the structure would empty. Water from surviving wells will require electric power to pump water. Given the likelihood of post-CSZ power outages, wells will require back-up generators. Table 1 lists the water utilities surveyed for this study and the number of finished water storage tanks and wells in their portfolio equipped with automatic or manual isolation valves or backup generation, respectively.

16 The information provided in Figure 7 is based on a sample of 2, 661 voluntary facility assessments conducted by Protective Security Advisors (PSA) between January 2011 and April 2014, as documented by the Office of Cyber and Infrastructure Analysis (OCIA), a predecessor organization to NRMC, in the OCIA's 2014 Sector Resilience Report, pp. 19-20.

17 Analysis conducted by the WSF on Short-Term Emergency Supply Options [WSF App. J] in 2018 identified a range of emergency water supply approaches that can meet categories of essential water services such as fire flows, emergency shelters, and domestic/household needs. These categories are examined in Table 3 and the accompanying test.

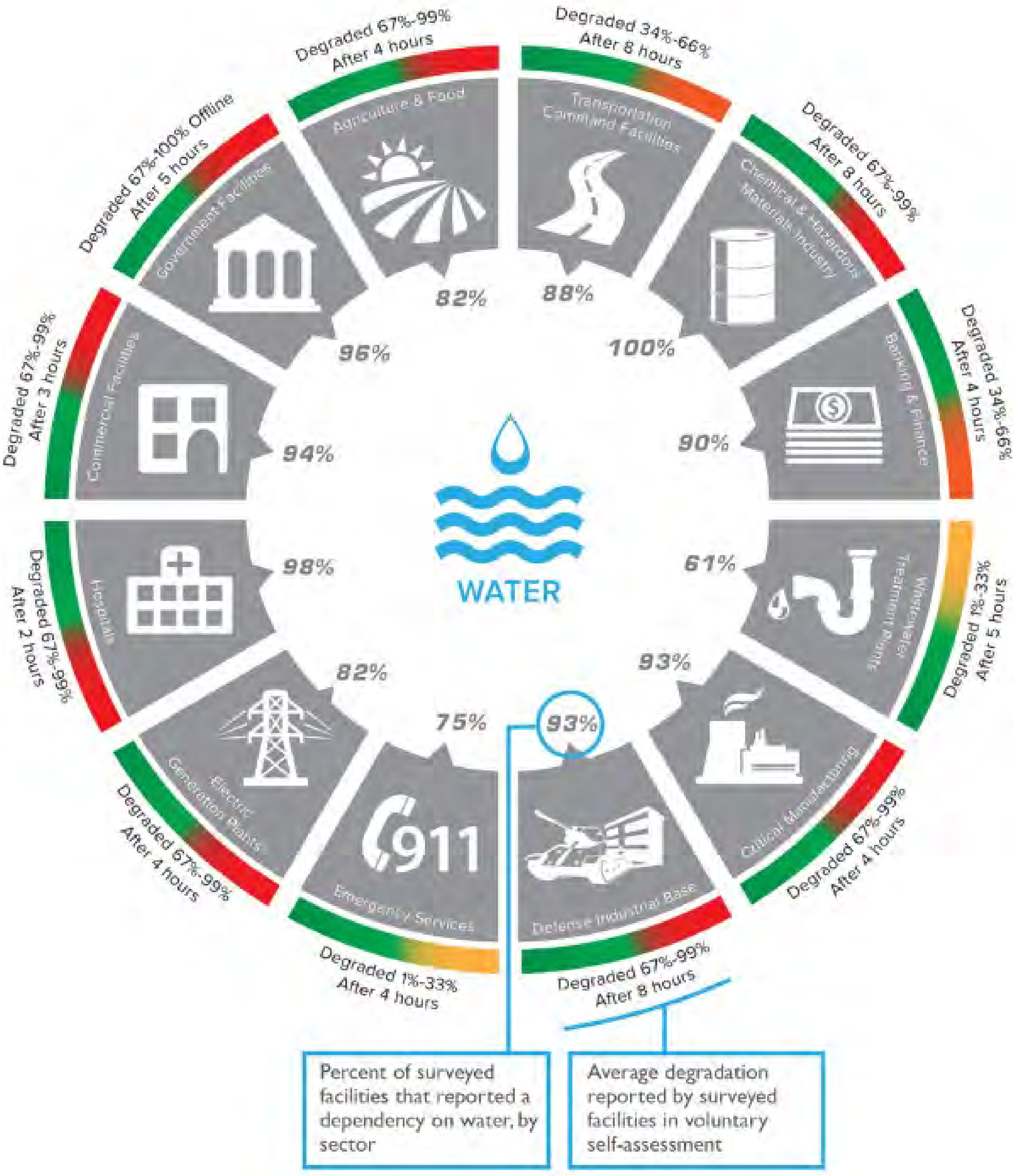

FIGURE 7.—Critical Infrastructure Dependence on Water and Potential Function Degradation Following Loss of Water Services. (Source: National Infrastructure Advisory Council)

TABLE 1. – Potential emergency water storage tanks and wells.

Water Utility	Storage Tanks	Tanks with Isolation Valves		Wells	Wells – Backup Power		Spring/ Artesian Well
		Automatic	Manual		Fixed	Mobile	
ISLAND							
Camano Water Association	3		3	3	3		
Clinton Water District	2		2	6			
Coupeville Water	3		3	6	4	2	
Naval Air Station Whidbey Island	4			1			
Oak Harbor Water Division	3		3	3	2	1	
KING							
City of Auburn	3	3		1	1		1
City of Bellevue	10	3	7				
Issaquah Water System	11	11					
Lakehaven Water and Sewer District	4		4	10	8	2	
Northshore Utilities District	8	8					
City of Redmond	5	3	2	5		5*	
City of Renton	3	3					1
Sammamish Plateau Water & Sewer	6	1	5	8	8		
Seattle Public Utilities	7	3	4				
Snoqualmie Water	3		3	3	1	2	
PIERCE							
Fruitland Mutual Water Co.	3		3	4	2	1	
Gig Harbor Water Department	1			6	1	1	
Lakewood Water District	13	13		14	7	7	
Mt. View-Edgewood Water Co.	3	2		7	5	1	
Parkland Light & Water Co.	3	1	2	6	4		
City of Puyallup	3		2	2		2	2
Spanaway Water Company	1	1		2	2		
Summit Water & Supply Co.	5	3		3	3		
City of Sumner	2	1					
Tacoma Water Division	2	2		3		3	

Legend: Asset Possessed (dark green); Not Available (light green)

TABLE 1. – *Continued*

Water Utility	Storage Tanks	Tanks with Isolation Valves		Wells	Wells – Backup Power		Spring/ Artesian Well
		Automatic	Manual		Fixed	Mobile	
SAN JUAN							
Eastsound Water	1		1	6	6		
Friday Harbor Water	1						
Roche Harbor Water	3		3	4			
SKAGIT							
City of Anacortes	4	4					
Skagit County PUD No. 1	19	1	18				
SNOHOMISH							
Alderwood Water District	7	3	4				1
Everett Public Works	10		10				
Marysville Utilities	7	1	6	2	2		
Snohomish PUD - Lake Stevens System	6		6				
Sultan Water Department	2		2				
WHATCOM							
City of Bellingham - Water Division	3	1	2				
Birch Bay Water & Sewer District	3		3	1	1		
Lake Whatcom Water & Sewer District	3	1	2				2
Lynden Water Department	2			1		1	

Legend ■ Asset Possessed □ Not Available

In most instances, supplying emergency water from finished water storage tanks or wells will require moving additional equipment to the location.[18] In addition, water utility personnel will be required to set up and initiate the service. Following the initial set up, water distribution to the public or to portable vessels that can be moved to other distribution sites can be overseen by utility personnel, trained volunteers, or a combination of the two. However, this result must be predicated on utility coordination with county or city emergency management officials. Table 2 illustrates the emergency water supply equipment currently controlled by water utilities surveyed for this study.

18 Very few water utilities reported storing emergency water supply equipment and materiel at the source location.

TABLE 2. – Emergency Water Supply Equipment

Water Utility	Water Table/ Manifold	Reusable Portable Containers	Blivet	Tanker Truck	Moveable Water Tanks	Other
ISLAND						
Camano Water Association						
Clinton Water District						RSS, WSS
Coupeville Water			1			
Island County Emergency Management	1				3	EWPS
Naval Air Station Whidbey Island						
Oak Harbor Water Division						RSS
KING						
City of Auburn	1					
City of Bellevue	1+	25,000	2			
Issaquah Water System						
Lakehaven Water and Sewer District	4					
Northshore Utilities District	10					
City of Redmond						
City of Renton	1*					
Sammamish Plateau Water & Sewer	1					
Seattle Public Utilities	7		6			
Snoqualmie Water	1					
PIERCE						
Fruitland Mutual Water Co.	3					
Gig Harbor Water Department						
Lakewood Water District	2					
Mountain View-Edgewood Water Co.	1					BFS
Parkland Light & Water Co.	2	1,000			1	
City of Puyallup	1					FT
Spanaway Water Company	1					
Summit Water & Supply Co.	4	3,000				
City of Sumner						
Regional Water Cooperative (Pierce County)					2	
Tacoma Water Division	1					

Legend ■ Asset Possessed ■ Not Available

TABLE 2. – *Continued*

Water Utility	Water Table/ Manifold	Reusable Portable Containers	Blivet	Tanker Truck	Moveable Water Tanks	Other
SAN JUAN						
Eastsound Water	1					WT
Friday Harbor Water	1					
Roche Harbor Water	1					
SKAGIT						
City of Anacortes						
Skagit County PUD No. 1						BFS (3), ROWPU
SNOHOMISH						
Alderwood Water District						
Everett Public Works	3			1		
Marysville Utilities	1				3	
Snohomish PUD - Lake Stevens System	1					
Sultan Water Department					7	
WHATCOM						
City of Bellingham - Water Division						BFS (4), ROWPU
Birch Bay Water & Sewer District						
Lake Whatcom Water & Sewer District						BFS
Lynden Water Department						

Legend ■ Asset Possessed □ Not Available

BFS Bulk Fill Station
EWPS Emergency Water Purification System
FT Flushing Trucks (Non-potable)
ROWPU Reverse Osmosis Purification Unit
RSS Reservoir Sample Station
WSS Well Sample Station
WT Water Trailer

*Lacks connections to deploy manifold

Other Emergency Supply Solutions

In 2018 the WSF published a paper exploring Short-Term Emergency Supply Options [WSF App. J]. The report considered categories of essential water services, three of which – fire flows, emergency shelters, and domestic needs - are included in Table 3. It then identified a range of water supply approaches that can meet some or all of those needs. These supply approaches and their availability are discussed below.

- **Hardened, dedicated infrastructure:** Select storage tanks, pipelines, pump stations, or other elements of water distribution infrastructure designed and constructed to be earthquake resistant and dedicated to high priority uses. [Solution is highly effective if stored water remains available or hardened features are connected to a functioning supply source – hardening infrastructure is costly and may be disruptive in highly urbanized environments.]

- **Water customers routinely store on site:** To the extent citizens store water on site, the demand for public-sector delivery is reduced. State, county, and municipal emergency management agencies and some water systems encourage citizen storage of emergency water. Onsite storage could be applied to a broader range of customers, to include businesses, schools, and other institutions.

- **Bottled water purchased/trucked/flown in:** Bottled water supplies on hand will sell out quickly. Emergency supplies can be delivered to the region by truck, airplane, or helicopter following the seismic event assuming transportation infrastructure is open and operational, and transport is not constrained by fuel shortages.

- **Public and private wells:** Many water systems in the region maintain supply wells, as do private citizens, businesses, and institutions. Wells can supply water to individuals who walk or drive to them, or can be used to fill large tankers or containers depending on their pumping capacity. Wells may be damaged by seismic events, and most will require a back-up power source, assuming a loss of grid power. Regional wells with onsite or portable backup generation are included in Table 1.[19]

- **Tanker trucked water or flexible bladder tanks:** Large tanker trucks can physically bring water to distribution points. None of the water utilities that participated in the study own or have tanker trucks at their disposal. Tanker truck must meet DOH regulations and damaged roadways will limit their usefulness. Portable bladder tanks designed for potable water can be delivered by flatbed trucks for distribution. These tanks can also be airlifted by helicopter. There are a few bladder tanks, also known as blivets, within the region (see Table 2). Tanker trucks and bladder tanks are delivery resources that rely on a potable water source.

- **Public utility reservoir/tank:** Some regional reservoirs and tanks are equipped with isolation valves which can be closed by a seismic trigger, preserving the water supply in the event of water main breaks in the distribution system. These storage tanks could serve as points of distribution and be used for filling tanker trucks or bladder tanks. As shown in Table 1, there are several water storage tanks with relevant seismic features within the region.

- **Large onsite tanks:** Public buildings and institutions could maintain water tanks at their facilities. These tanks must be integrated into the facilities' normal water systems to maintain potability.

- **Rivers, lakes, seawater:** These assets could serve as sources for non-potable uses, including firefighting and bathing.

- **Truck- or ship-mounted filtration "plant":** Small portable treatment facilities can be built inside vehicles and driven to distribution points. A constant supply source, such as a lake or well, is required. There are no portable filtration plants in the region. Ship-based treatment plants are unlikely to be a viable option given the lead time to obtain one, their limited range, and ability to produce potable water at scale. [WSF App.J]

The categories discussed above consist of a combination of water sources (stored water, wells, surface water sources); treatment capabilities (truck or ship-mounted filtration plant); and water delivery apparatus (bottled water flown or trucked; tanker trucks and bladders). The viability of all these short-term options must be considered in the context of the planning factors discussed above and the likely operational environment following a CSZ earthquake. These potential supplies, capabilities, and delivery mechanisms are evaluated in Table 3 based on their compatibility with three essential water service needs: fire flows, emergency shelters, and domestic needs (general public outside shelters).

19 Many of the water systems that participated in this resiliency assessment have production/supply wells that are used to produce drinking water on a steady state basis as well as "emergency wells;" accordingly, several regional utilities that use surface water sources for drinking water production also have emergency wells. The project's survey of water systems found that in many cases, emergency wells are rarely used, are less productive and reliable, and due to age, location, water quality, and lack of backup generation capability present a less viable emergency water alternative than wells routinely used by the water utilities.

TABLE 3. – Potential emergency water storage tanks and wells.

Potential Supplies	Fire Flows	Emergency Shelters	Domestic Needs
Hardened, dedicated infrastructure	An Auxiliary Water Supply System (AWSS) could be developed in portions of utility service areas, as a retrofit or during redevelopment projects. This is a capital-intensive option	Smaller shelters could be outfitted with on-site reservoirs	N/A
Water that customers store routinely on-site	N/A	Absent a predictable population, water stored on-site is not a reliable option	Households in earthquake-prone areas should ideally store a two-week supply of water
Bottled water (purchased, trucked, flown in)	N/A	Bottled water delivery	Bottled water delivery
Public and private wells	Fire flow locations unpredictable	May be beneficial if near shelter	Local wells could serve as distribution sources
Tanker trucked water or flexible bladder tanks	A Portable Water Supply System (PWSS) uses portable pumps and hose tenders to pull water from smaller, spatially diverse sources which could include tanker trucks or local ponds/pools/lakes	Large shelters could be well served by trucked water and/or water bladders (including by helicopter)	Domestic areas could be served by trucked water and/or water bladders (including by helicopter)
Public utility reservoir, tank	May be beneficial if near fire flow location	Public utility reservoirs could serve as a distribution source	Public utility reservoirs could serve as a distribution source
Large on-site tanks	Fire flow locations unpredictable	Smaller, pre-identified facilities could be outfitted with large on-site tanks	N/A
Rivers, lakes, seawater	* Fireboats could serve downtown harbor areas in Tacoma, Seattle, Everett, and Bellingham, as well as on lakes Washington and Union in Seattle * Surface water drafting can pump water 1000 to 2000 feet for localized firefighting, or fill the fire engine tank	Only beneficial if nearby and with filtration services	Only beneficial if nearby and with filtration services
Truck- or ship-mounted filtration "plant"	Filtration not necessary	Could be beneficial, depending on location and availability of trucks/tanks to move water to shelters	Could be beneficial, depending on location and availability of trucks/tanks to move water to population
Stored rainwater	N/A	N/A	Stored rainwater could be an effective source for non-potable uses

Legend: Beneficial; Less Beneficial Solution; Not Available/Beneficial

Coordination Between Water Utilities and Emergency Management Agencies

The CSZ planning factors recounted above highlight the challenges inherent in relying on local utilities to supply emergency water in the aftermath of a CSZ earthquake. During the data collection phase of this project, emergency management representatives from the relevant cities and counties were invited to participate in facilitated discussions and structured interviews with water utility operators focused on identifying emergency water sources and discussing options for delivering water to the public.[20] Most interviews were attended by a representative of the county emergency manager, and about a third of the utility interviews were attended by city emergency managers or their designee. The interviews revealed an interest in emergency watering capabilities, but there is a near universal absence of the planning and coordination required to water the population following an event as challenging as a CSZ earthquake. Several utilities have forged relationships with emergency managers during efforts to establish grant funding requirements for hazard mitigation projects through the Building Resilient Infrastructure and Communities (BRIC) grant program or other grant programs sponsored by FEMA, EPA, or other organizations. These mutually beneficial collaborations provide emergency management officials with insight into water utility capabilities and resource needs, but they are not a substitute for the planning and coordination required to create and execute an emergency water plan.

20 Washington State EMD, a principal stakeholder in this RRAP project, attended nearly every interview with water utilities.

Key Findings

Key Findings

The remainder of this report focuses on documenting Key Findings for the Northwest Washington Water Resiliency Project. Key Findings are derived from the information-gathering and analytic activities conducted during this project. Each finding is supported by an explanation of its significance, relevant options for consideration to improve resilience, and suggested partners to engage in implementing these options. The County Appendices, which are available to EMD, DOH, relevant county and city emergency managers, and participating utilities, identify potential emergency water resources[21] and map them in relation to expected road and bridge impacts.

Key Finding #1: Many water utilities that participated in this study have the capability to supply some emergency drinking water; but pre-earthquake coordination is needed to leverage those capabilities securely and effectively.

Many water utilities that participated in the study have made or purchased emergency water supply apparatus known by various names, including water trees, water tables, and octopus. These apparatuses are essentially manifolds that can be connected to a potable water source in order to provide emergency drinking water. Multiple spigots are available and accessible to enable the public to fill water jugs or containers. These devices, which can be connected to a range of potable water sources, such as hydrants, water storage tanks, or blivets, provide a readily deployable, cost-effective emergency water solution. However, some water utilities are concerned that set up and operation of emergency water manifolds may prevent water utility personnel from attending to utility priorities such as damage assessments and system repairs. To address that concern, a few water utilities have begun to identify alternate resources, such as Community Emergency Response Teams (CERT), emergency management personnel, or other qualified resources to staff the manifolds, but all agreed that qualified utility personnel are needed for the initial set up.

While manifold systems are a relatively low-cost solution for watering the population,[22] some of the region's larger water utilities have relatively few of them in relation to the size of the service area and population served. Conversely, some smaller utilities have several manifold systems.[23] A significant number of utilities, both large and small, are concerned about crowd control, order, and security around the provisioning of emergency water. Concerns about security and staffing requirements may impede the willingness of some systems to invest in more emergency water manifold systems.

This study was limited to a review of the region's current emergency water equipment and capabilities. The region should also explore options to develop and fund more expansive, longer-term solutions, considering:

- Water Systems typically have long capital spending and planning horizons
- Several water systems surveyed during this study have few or no seismically resilient reservoirs
- Seismic valves for reservoirs and seismic adaptors on wells should be elevated to a higher priority. Some water systems suggested that low interest loans should be made available to incentivize investment in seismic resilience.
- Regional water supply capabilities would benefit from larger, higher volume solutions that leverage the availability of surface water; however, most water systems cannot justify investment in expensive solutions that might never be used during their useful lifetime.

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21 The identified resources pertain solely to the utilities that participated in this study. As previously noted, emergency managers should work with other water utilities to identify additional emergency water options.

22 Although manifold systems are the most widely available and easily deployable emergency water apparatus in the region, one county emergency management official reported that efforts to secure FEMA grant funding to build or purchase these emergency watering systems were unsuccessful.

23 Table 2 provides a snapshot of the emergency water supply equipment controlled by the utilities that participated in this study.

Currently, county emergency managers are not typically aware of which water systems own this equipment (or other emergency water equipment), where the equipment is stored, or where it could potentially be deployed. Typically, set-up locations for manifolds are tied to the location of existing water resources such as water storage tanks or hydrants. Larger portable tanks such as blivets provide a measure of flexibility in terms of set up locations, but relatively few water utilities have access to blivets. Planning and coordination between utilities and emergency managers is necessary to increase the likelihood these emergency water resources can be effectively deployed.

Resilience Enhancement Options

- City and county emergency managers should engage in planning and coordination with water system operators to ensure training, staffing, and crowd control requirements at water distribution locations are established and met. Water utility operators should be encouraged to discuss emergency water supply capabilities with emergency managers, who should incorporate these coordination and capability findings into the appropriate sections of the jurisdiction's Comprehensive Emergency Management Plan (CEMP).
- Emergency management agencies and water system operators should explore cross-training solutions using CERT teams or other qualified resources to assist in emergency water distribution. Emergency managers should discuss the need to maintain order and security at emergency water distribution sites with relevant public safety personnel.
- Emergency managers and water utilities should exercise emergency water manifold set up and distribution; some water utilities have practiced set up and operation of emergency water manifolds at community events.
- Emergency managers should work with water utility operators to stage emergency water supply equipment - manifolds and other supply apparatus - at or near pre-identified set up locations.
- Washington EMD should use the information gathered through this Resiliency Assessment to understand the capability gaps that can be converted to a resource request.
- Water systems should work with county emergency managers to examine eligibility for grants to improve overall system resiliency as well as opportunities to build capacity to ensure emergency water supplies. FEMA's Building Resilient Infrastructure and Communities (BRIC) grant supports state, local, tribal and territorial initiatives to reduce risk and mitigate the impacts of natural hazards on infrastructure systems.

Key Finding #2: Water utilities need guidance and actionable information from wholesale water suppliers, emergency management agencies, and utility leadership regarding post-CSZ priorities and expectations.

Over the course of this study, multiple water utility operators reported suboptimal information sharing by their wholesale water suppliers, and inadequate guidance from utility or, in some cases, municipal leadership regarding post-CSZ priorities. An even broader group expressed concerns about support from state and federal entities and their expectations of regional water utilities, as well as overarching concerns about prioritization of water service functionality relative to other lifeline infrastructure systems. These concerns manifested in several ways, which are discussed below.

Municipal utilities that purchase water from large wholesale water suppliers reported difficulty coordinating on disaster preparedness and restoration plans. Some municipal systems are reliant on wholesalers for all or nearly all their water supply; consequently, wholesale suppliers' plans for system restoration are critical to dependent systems. Due to their complete or near complete dependency on their supplier, lack of awareness of suppliers' plans and response priorities creates a significant knowledge gap and undermines effective contingency planning by the dependent utility.

For some water utilities, emergency water preparedness efforts have been hindered by the absence of guidance from decision-makers within their chain of command. Specifically, some utilities reported a lack of guidance on how to balance the competing priorities of preserving drinking water for the population or keeping the system pressurized for fire flows. As noted in the Water Supply Forum's technical memorandum entitled "Short-term Emergency Supply Options Following an Earthquake," there is a tension between maintaining fire flows and preserving drinking water. This planning conundrum is described as follows: "A paradox in resiliency planning affects water systems. Water systems may equip large water storage tanks with earthquake valves that shut-off automatically in the event of an earthquake. This is important for water retention, but results in preventing flow into undamaged parts of the system for firefighting." [WSF App. J] While some utilities wait for direction from leadership, others are implementing plans to employ earthquake valves to retain water in some storage tanks while allowing water to flow freely from others. In any case, since water for firefighting need not be potable, a few municipalities have implemented or are exploring capabilities and requirements for surface water drafting.

Several large utilities expressed concern and uncertainty about post-earthquake support from the state and federal governments, governments' expectations of water utilities, and prioritization of water utilities relative to other lifeline infrastructure during response and recovery operations. Utility operators also pointed out that water utilities are often overlooked or taken for granted (perhaps as a result of their relative reliability under most disaster scenarios), citing the 2016 Cascadia Rising exercise, where water utilities experienced very little play. Water utilities reported that, more recently, state officials declined to prioritize water utility personnel for access to the COVID-19 vaccine, which put small systems in jeopardy. Some water utility operators believe policy makers and some emergency managers simply do not recognize the consequences of losing water system functionality. Whether leadership fails to recognize potential outcomes or cannot envision the consequences of the incident, either constitutes a failure of imagination with potentially severe and unnecessary outcomes.[24] With respect to prioritization of water sector needs, the risk of avoidable consequences is exacerbated by the absence of an ESF specifically dedicated to water,[25] potentially signifying the absence of a champion in the State Emergency Operations Center (SEOC)[26] or Joint Field Office (JFO)[27]. Potential outcomes include a lack of prioritization for debris removal, facility access, resources needed for repair and system restoration and ultimately, cascading failures of other infrastructure systems.

Coordination between local/county emergency management and water systems is generally good – but it is considerably less robust at the state and federal levels, where many impactful decisions will occur following a CSZ M9 earthquake. A significant number of water utility operators reported lack of coordination between state and federal emergency management and water systems, leading to confusion and uncertainty about roles, responsibilities, and expectations in the following areas:

- Water utilities assert their primary responsibilities are to restore system operability, provide emergency water if available and, if possible, ensure/provide water for firefighting – not be distributors of bottled water. While state emergency managers signaled agreement on that point, many water utility operators are not confident that view will prevail during a water supply emergency.
- With many different organizations and multiple levels of government involved in a CSZ M9 response, water utility representatives expressed uncertainty about prioritization of water restoration relative to other infrastructure systems, and which response and restoration measures fall within the purview of the water system versus those the system can and should rely on EMD or county and city emergency managers to handle.

Resilience Enhancement Options

- Emergency managers should harmonize plans, discuss priorities, and clarify expectations with wholesale water purveyors and their municipal customers.
- Top-down/bottom-up communication between state, county, and city emergency managers and water utilities should focus on the following:
  - » To aid planning and preparedness for earthquake hazards, emergency management agencies (local, county, state, and federal) should communicate response and recovery phase expectations of water utilities; water utilities, in turn, should share critical asset lists, emergency

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24 Admiral Thad Allen recently addressed this risk, noting "In short, we need to continually sense the threat environment and mitigate the risk of failures in imagination, policy, capabilities, and management." Adm. Thad W. Allen, State of Homeland Security: Preventing Future 'Failures of Imagination," (2021), https://www.hstoday.us/911/state-of-homeland-security-preventing-future-failures-of-imagination/, accessed September 2021.

25 All other lifeline sectors – transportation, energy, and communications – have a dedicated ESF. Responsibility for the water and wastewater emergency service support is dispersed across five ESFs: ESF #3 – Public Works and Engineering, ESF #4 – Firefighting, ESF #6 – Mass Care, ESF #8 – Public Health and Medical Services, and ESF #14 – Cross-Sector Business and Infrastructure. This point was underscored in the NIAC Water Report. [NIAC].

26 During state emergencies, EMD activates the SEOC. The SEOC serves as the central location for information gathering, disaster analysis and response coordination. Executives use the information gathered to make decisions concerning emergency actions and identify and prioritize the use of state resources. https://mil.wa.gov/emergency-management-division, accessed November 2021.

27 A Joint Field Office, or JFO, is a temporary federal multi-agency coordination center established locally to facilitate incident management activities. The JFO provides a central location for coordination of federal, state, local, tribal, territorial (FSLTT), NGO and private sector organizations with primary responsibility for incident support activities. FEMA, Joint Field Office Activation and Operations, 2006, https://www.fema.gov/pdf/emergency/nims/jfo_sop.pdf, accessed November 2021.

water capabilities, and resource and access constraints/requirements with relevant emergency management agencies and state departments

» Emergency managers should share information with water utilities about pre-identified shelters and Community Points of Distribution (CPODs)[28] to enable planning and prepositioning of equipment needed to supply emergency water.

» Emergency managers should share planning factors and assumptions with water utilities (and vice-versa) to enable more informed planning.

» Water utilities should share emergency power requirements with COM's Energy Emergency Management Program and with emergency management agencies.

» Water utilities should alert emergency managers to emergency water capabilities, constraints, and resource requirements for the delivery of emergency water.

» County and municipal emergency management officials should discuss alternative firefighting capabilities and ability to draw water from surface water sources with local water utilities.

- Emergency management agencies and water utilities should explore avenues of continued collaboration, e.g., information sharing workshops, exercises focused on water supply disruptions, and emergency water capabilities, and scenario-based activities.

Key Finding #3: For many utilities, the preservation of drinking water for emergency use will be impeded by the inability of utility staff to report to facilities in a timely manner.

Water utilities' post-earthquake response challenges will be exacerbated by disruptions to surface transportation systems and communications networks. In the immediate aftermath of a CSZ M9 earthquake, water utilities will be challenged to muster staff, conduct damage assessments, and coordinate a response due to communications and transportation challenges. Nearly every water utility that participated in this study reported that utility maintenance and operations staff live outside the utility's service area. Assuming an 8-to-10-hour workday, it is reasonably likely that staff will not be on the job when an earthquake occurs. As a result, the workforce must travel to access facilities. Most roads and bridges in the region will experience some form of damage due to ground shaking or liquefaction and much of the damage to bridges is forecasted to take months to more than one year to repair. [2019 Transportation RRAP] Damage to roads and bridges is expected to impede surface transportation for months.

For water utility workers attempting to respond to facilities to mitigate damage and loss of water from a CSZ M9 earthquake, the structural integrity of bridges will be an unknown factor, as inspections will not have occurred. In addition, damage to communications infrastructure will limit situational awareness of which routes are open and passable. Water utilities that participated in this study routinely communicate via cell phone; however, following a CSZ M9, cell phone circuits will be overloaded.[29] Radio communication will be difficult. Relative to overall staff, many utilities reported the following: 1) sparce deployment of radios;2) a relatively small number of utility staff trained to use them; and 3) most radios are in trucks assigned to specific utility personnel.

The absence of information about the condition of roads and bridges will delay access to facilities, undermine preservation of water in storage tanks, and impede early understanding of operational status. It is unknown whether WSDOT and local transportation agencies will restrict travel on state, county, and local roads prior to conducting damage assessments, developing recovery priorities, and establishing detours and alternative routes. It is also unknown whether public safety officials will caution emergency responders not to drive across a bridge until a bridge assessment has been conducted.

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28 EMD defines a CPODs as follows: "Community Points of Distribution are centralized locations where the public picks up life-sustaining commodities following a disaster or emergency." EMD, CPOD Manager Course (EMD-4026), https://mil.wa.gov/asset/5ba420f3d08a5

29 One important component of a water utility's diagnosis of damage to the distribution network is public reporting of a loss of water pressure. Water utilities rely on the public to report problems and outages and post-earthquake cell phone congestion will impede reporting by utility customers. In addition to cell phone congestion, which will worsen as back-up power for cell towers is depleted, the planning assumptions for communication systems indicate that communications systems will be severely compromised and unreliable for a significant period of time following the incident.

Supervisory Control and Data Acquisition (SCADA) systems depend on communications infrastructure, which may or may not be functional. Loss of SCADA means a lack of situational awareness about the operational status of the water system. Under normal conditions this would result in manual validation of asset/system operations. In the immediate aftermath of a CSZ earthquake, however, manual validation may not be possible or safe. Inability to confirm system damage and report findings back to operations centers will delay situational awareness of the systems' operational status and deployment of resources, assuming resources could be deployed. The potential inability to respond is directly relevant to preservation of emergency water. Some water storage tanks are equipped with seismic valves engineered to close automatically, preventing water loss due to broken pipes, but some must be closed manually. The inability of staff to respond in a timely manner will result in loss of water from storage tanks requiring manual adjustments.

Resilience Enhancement Options

- Water utilities should conduct targeted employee surveys to determine staff travel requirements and pre-identify potential alternate routes and post-CSZ staffing capabilities. Both City of Redmond and Sammamish Plateau Water and Sewer District have analyzed staff commutes under normal conditions to plan for and mitigate post-earthquake impacts on staff response to water infrastructure emergencies. Utilities can enhance their understanding of likely transportation impacts and potential alternate routes by using the Bridge Seismic Screening Tool (BSST), which analyzes how routes would be affected post-CSZ. Employee surveys should also shed light on whether response staff have special needs or concerns that would delay their response. The OUO County Appendices to this report map potential emergency water resources and provide a bridge reopening forecast for bridges in proximity to those assets. Utilities and emergency planners can use the BSST to conduct a realistic assessment of CSZ impacts on utility staff facing longer commutes.[30]

- Water utilities and emergency management agencies should identify and map facility and staff locations and crosswalk with results from the BSST (as well as shake map, liquefaction, landslide, and tsunami modeling) to anticipate and plan for staffing shortages. This analysis should be used to identify key facilities likely to be understaffed.

- Water utility management will improve worker response (and lessen post-earthquake staff attrition) by providing guidance, food, shelter (if needed), fuel, and "go-bags" to essential staff and, if needed, reasonable and necessary support to workers' families. Several water utilities, recognizing that staff will be reluctant to respond if their families are not secured, emphasized the need to focus on staff/family preparedness. Several reported the capacity to provide food and lodging to workers and some reported plans to house workers' families, if needed.

- Water utility management should communicate critical facilities and access requirements to city and county emergency management officials. Response priorities should also be discussed with staff and exercises and drills should be conducted to optimize performance, mitigate loss, and reduce uncertainty about roles, responsibilities, and priorities.

- To address potentially understaffed facilities, water utilities could coordinate with other utilities to identify proximate staff and explore a potential water system staffing pool comprising skilled staff from multiple utilities across the region. In the event skilled staff cannot access the utility that employs them, they may be able to assist at a utility closer to home. For SPU and Everett, the optimal solution could be regional response planning with wholesale customers.

- Water systems should consider wider provisioning of radios and evaluate the need for training on the use of radios.

- As discussed in Key Finding 4, Washington EMD should socialize and institutionalize the Washington Re-Entry Framework to ensure that essential employees have the credentials needed to travel to work sites. This will require local government endorsement of the program and broader awareness of the program by water utilities.

30 Water utilities, emergency responders and planners and other interested parties can access the Bridge Seismic Screening Tool at: https://wsdot.maps.arcgis.com/home/item.html?id=030c578820454709938ac966957069dc.

Key Finding #4: Washington's Post-Disaster Re-Entry Framework provides a solution for safe, orderly access to facilities following a disaster, but water utilities are generally unaware of the framework and local jurisdictions have yet to adopt and implement it.

Many water utility responders must travel through several jurisdictions to reach facilities.[31] Some may be in personal vehicles, and all may be stopped – and potentially turned back – at checkpoints along the way. During multiple interviews with regional utilities, operators expressed concerns about public safety checkpoints and travel restrictions resulting in denial of access to facilities. Several utility operators reported that during the COVID 19 pandemic, water utilities, and therefore utility work crews, were not prioritized or recognized as first responders, despite the fact that water is critical to mass care, hospitals, infrastructure systems, and survival of the population. Based on this experience, utilities are concerned they will not be prioritized for emergency access following an earthquake.

In 2018, EMD developed, in conjunction with other primary and supporting agencies, a Re-Entry Framework to provide uniform guidance for local jurisdictions addressing access to impacted areas following a disaster. [EMD-Re-Entry] Washington's constitution accords cities all the police powers possessed by the state government, so long as local regulations are not in conflict with state laws.[32] Accordingly, the Re-Entry Framework does not supplant local authority. Instead, it provides uniform guidance and processes local jurisdictions can adopt (and customize) to enable orderly access to affected area(s) for restoration of essential services and infrastructure. [EMD – Re-Entry]. Assumptions underlying the operation of the Re-Entry Framework include the following:

- Access to areas impacted by a disaster may be controlled by local officials for purposes of public health, safety, welfare, and security.
- Information related to access control and subsequent re-entry is provided to the news media and the public through the designated Public Information Officer (PIO) for the jurisdiction and/or Joint Information Center (JIC) for the incident, respectively.
- Safety procedures will be enforced at all times during re-entry operations.
- Re-entry operations will occur at designated routes and checkpoints pre-determined during evacuation and closures, as designated by the Incident Commander.
- First Responder and Damage Assessment Teams will provide information immediately following the disaster to identify and prioritize damage levels.
- Local jurisdictions will have primary control over re-entry for their jurisdictional areas.
- The State Emergency Operations Center (SEOC) provides coordination support to re-entry operations conducted by or on behalf of local jurisdictions.
- The private sector will follow the guidelines identified in this Appendix.[33]

The Business Re-Entry (BRE) Registration program explicitly encourages registration by "Association(s) with an owner or operator of 'critical infrastructure' qualified under one of the 16 Critical Infrastructure Sectors as defined by the Department of Homeland Security." [EMD-BRE Registration] However, awareness of this relatively new program among both water utilities and county and municipal emergency managers appears to be limited.

Resilience Enhancement Options

- WA EMD should continue to work with county and city public safety and emergency management officials and prioritize efforts to socialize and establish the value proposition underlying the Post-Disaster Re-Entry Framework.
- WA EMD should leverage the Cascadia Rising 2022 exercise to raise awareness of the Framework as a solution that benefits public safety, improves disaster management, mitigates impacts, and accelerates recovery.
- Water utilities with awareness of the Business Re-Entry Framework should discuss the program and the need for a standardized re-entry process with city and county emergency managers. Organizations such as the Water Supply Forum, Regional Water Cooperative of Pierce County, and the Washington Water/Wastewater Agency Response Network

31 This issue is discussed in detail in Key Finding 3.

32 Hugh Spitzer, "Home Rule" vs. "Dillon's Rule" for Washington Cities, 38 Seattle U.L.Rev. 809 (2015).

33 Applicable guidance for the private sector can be found at https://mil.wa.gov/asset/5bac13552b786, accessed November 21, 2021.

(WA WARN) should seek to learn more about the program and share information within their respective members. Water utilities should be encouraged to submit applications for Re-Entry credentials.

- State, county, and city emergency management organizations should incorporate the Re-Entry Framework process into planned drills and exercises. Water utilities should participate in those events to ensure an understanding of operational processes.

Key Finding #5: Water quality laboratories and the availability of water quality testing will be degraded post-CSZ, as will the ability to transport samples to laboratories for testing. The short-term loss of testing capacity will pose an additional challenge to supplying drinking water following an earthquake.

DOH regulations require routine and episodic testing for water quality.[34] In addition to routine testing, significant events such as water line breaks and the consequent loss of pressure, triggers coliform sampling. Coliform samples must be at the lab within 24 hours of collection; the lab, in turn, has 24 hours to complete the analysis. For planning purposes, during a disruption that affects water utility operations, utilities should assume that compliance with state drinking water regulations will be required unless DOH issues formal regulatory relief. Utilities may be reluctant to provide emergency water during or following a water system disruption absent guidance from DOH with respect to approved emergency procedures. As of this writing, disinfection protocols have not been developed for emergency water manifolds, tanks, and other equipment likely to deployed.

The DOH approved water quality testing laboratories are distributed across five of the seven counties in the Northwest Drinking Water Region. The distribution breaks down as follow: King County (10); Whatcom County (5); Pierce County (3); Snohomish County (3); Skagit County (1); Island and San Juan counties (0). Some of the region's larger water utilities have in-house testing capabilities; smaller systems tend to rely on DOH or commercial labs. Of the 22 DOH approved laboratories shown in Figure 8, only five – Seattle Public Utilities Water Quality Lab (#10), Everett Environmental Lab (# 16), Monroe Water Quality Laboratory (#17), Bellingham Water Filtration Plant (#20), and Lynden Water Treatment Plant Lab (#23) – are associated with drinking water utilities. It is likely that the same workforce availability, access, and transportation issues previously discussed with respect to water utility response operations will also affect operations at DOH laboratories, which could disrupt normal operations for some period of time following the incident. Surface transportation disruptions will also affect the ability of water utilities to transport samples to laboratories for testing. Currently, most samples are shipped to labs via the U.S. Postal Service, UPS, FedEx, or another commercial courier service, which are likely to experience workforce and operational disruptions following a significant earthquake and may encounter difficulties at public safety checkpoints. The absence of approved water quality testing laboratories in Island and San Juan counties will pose additional challenges for those utilities, given the need to transport samples to the mainland.

Figure 8 shows the locations of approved DOH laboratories in the Northwest Drinking Water Region. All are expected to experience strong to very strong shaking. Three are in areas of high and two are in areas of moderate to high liquefaction susceptibility. One is susceptible to tsunami flooding, and three others are close. Table 4 documents shaking, liquefaction, and tsunami-related impacts.

34 Regulations of executive branch agencies such as DOH are issued by authority of statutes and documented in the Washington Administrative Code (WAC). https://apps.leg.wa.gov/wac/, accessed November 21, 2021. Water quality monitoring requirements are documented in WAC 246-290-300.

FIGURE 8.—DOH Approved Laboratories (Northwest Drinking Water Region)

TABLE 4. – DOH Approved Laboratories (Northwest Drinking Water Region) Earthquake-Related Risk

DOH Approved Testing Laboratory	CSZ Strength of Shaking	Liquefaction Susceptibility	Tsunami Hazard Risk
King			
Am Test	VII (Very Strong)	Very Low	No Risk
Aqua Test	VII (Very Strong)	Low	No Risk
Cedar Water Treatment - Jacobs	VII (Very Strong)	Very Low	No Risk
DOH Public Health Lab	VII (Very Strong)	Very Low	No Risk
Fremont Analytical	VII (Very Strong)	Very Low	No Risk
King County Environmental Lab	VII (Very Strong)	Low to Moderate	Nearby Risk
LabCor, Inc.	VII (Very Strong)	Very Low	No Risk
MicroChem Laboratories, Inc.	VII (Very Strong)	Very Low	No Risk
Seattle Public Utilities Water Quality Lab	VII (Very Strong)	High	No Risk
Department of Public Health Laboratory	VII (Very Strong)	Very Low	No Risk
Pierce			
Crystal Mountain WWTP Lab	VI (Strong)	N/A (Bedrock)	No Risk
Spectra Laboratories	VII (Very Strong)	High	At Risk
Water Management Laboratory	VII (Very Strong)	Very Low	No Risk
Skagit			
Edge Analytical - Burlington	VI (Strong)	High	No Risk
Snohomish			
Everett Environmental Lab	VII (Very Strong)	Moderate to High	Nearby Risk
Monroe Water Quality Laboratory	VII (Very Strong)	Moderate to High	No Risk
Mukilteo Water District WWTP Lab	VII (Very Strong)	Very Low	Nearby Risk
Whatcom			
Avocet Environmental Testing	VI (Strong)	Low to Moderate	No Risk
Bellingham Water Filtration Plant	VI (Strong)	N/A (Bedrock)	No Risk
Edge Analytical - Bellingham	VI (Strong)	Low	No Risk
Exact Scientific Services	VI (Strong)	Low	No Risk
Lynden Water Treatment Plant Lab	VI (Strong)	Low	No Risk

Resilience Enhancement Options

EPA has developed guidance and a scalable, customizable template to assist drinking water and wastewater laboratories in the development of Continuity of Operations Plans (COOP). [EPA COOP] The template provides useful recommendations for preparing for disruptions to normal laboratory operations. including recognition of time-sensitive core functions necessary to maintain operations. COOP planning benefits laboratories by:

- Ensuring laboratories will be able to continue essential functions
- Providing policies and procedures that should be followed before, during, and after an event
- Pre-identifying resources that may be required during an incident
- Ensuring analytic capability and capacity for customers (the public) during incidents.

Both state and utility-based in-house drinking water laboratories should leverage EPA tools and guidance to develop COOP. The process of creating a COOP will aid laboratories in:

- Identifying essential functions that must be continued
- Recognizing actions that must be taken if the primary worksite is compromised
- Planning for internal and external communications, alternate work locations, and mission critical systems and staff.

DOH posts emergency publications for water systems on its website.[35] These downloadable publications cover a number of emergency situations and should be examined for applicability. Absent guidance applicable to post-earthquake contingencies, water utilities should develop and seek DOH approval of protocols for disinfection of emergency water manifold systems, blivets, portable tanks, and other emergency water apparatus and equipment needed to supply emergency water. Pending DOH approval, utilities could rely on the related DOH guidance or procedures provided by the American Water Works Association in AWWA C651-14 (disinfection of water mains); AWWA C654-13 (disinfection of wells); and C652-19 (disinfection of water storage facilities).

Water utilities should develop a communications plan for post-CSZ messaging. The plan should address coordination with local and regional emergency managers and customers in the event of extended power, telecommunications, and water outages. In the event that lab confirmation of potability is not available, water quality would be considered suspect, and a boil water advisory should be issued.

Key Finding #6: Emergency fuel planning is a priority for the Washington Department of Commerce (COM) Energy Emergency Management Office and individual water systems

Many water utilities have fixed or portable emergency generators for key components of their system. During grid outages, most of these utilities depend on liquid fuels, primarily diesel, to provide generator power to system components.[36] For many water utilities that participated in this RRAP project, critical system components could run for little more than a day on existing fuel reserves, yet most have limited fuel storage capacity and some emergency water locations that require power – particularly wells – may be especially difficult to access. Very few utilities interviewed for this study have created emergency fuel shortage plans or prioritized fuel distribution for their operations. In addition to backup generators, fuel shortages would affect utility work trucks and other equipment that could be deployed for debris clearance or earth moving for damage assessment and repairs. Finally, the State of Washington does not require gas stations to have emergency generators to ensure the ability to pump liquid fuels during a loss of grid power. As a result, few retail gas stations have generators and utilities may find it advantageous to provide fuel to workers who must travel to worksites in personal vehicles.

Against this backdrop, regional planners should expect damage to liquid fuels terminals, refineries, and pipelines to disrupt liquid fuel supply chains. Simultaneously, demand for liquid fuels, particularly diesel, will surge across multiple infrastructure sectors due to response and recovery efforts and reliance on generator power. EMD's catastrophic planning assumptions for liquid fuels recognize the likelihood of supply chain disruptions, anticipate the difficulty of moving fuel to the impacted zones, and emphasize the need for both short and long-term prioritization of fuel distribution.

35 Emergency Publications for Water Systems, https://www.doh.wa.gov/Portals/1/Documents/Pubs/331-115.pdf, accessed November 2021.

36 One water utility interviewed for this study relies on propane powered generators.

The COM's Energy Emergency Management Office is developing the State Fuel Action Plan, which will include planning resources for state, local, tribal, and territorial governments, including a fuel needs assessment form. Upon completion, an emergency fuel planning toolkit will be hosted on the COM website. The State Fuel Action Plan will include a priority guideline for allocation and distribution of fuel during an energy emergency impacting the state's fuel supply.

The plan prioritizes the four priority critical infrastructure sectors (water/wastewater, transportation, communication, and energy). The Energy Emergency Management Office has not been provided a list of water utilities with backup generators, or the estimated run time for those generators based on fuel they have on hand. It also lacks information about onsite storage, and the type of fuel needed.

Resilience Enhancement Options

The following proposed steps identify planning and preparedness-focused opportunities for mitigating the impact of a fuel shortage or fuel distribution disruption following an earthquake and consequent power outage:

- Water utilities should know and share the following information with county and city emergency management agencies, who in turn should report this information to the COM's Energy Emergency Management Office through the fuel needs assessment form:
  - Daily burn rate by fuel type for critical system components.
  - Criticality metrics (for prioritization purposes), including population served, critical sites served (e.g., hospitals, shelters, emergency operations center, refineries, terminals, data center, and other local/regional priorities).
  - Information about onsite generators (permanent or portable), including accessibility or lack thereof. For facilities without onsite generators, provide pertinent information relative to pre-determined requirements for quick connects/transfer switches.
- EPA's Power Resilience Guide for Water and Wastewater Utilities provides strategies and practical suggestions to increase water utility resilience during a loss of grid power.[37] In addition to keeping more fuel on site, utility operators should consider:
  - Entering into emergency contracts with an out-of-area supplier and with multiple vendors from different regions (which, in the earthquake scenario, may not provide a solution if fuel suppliers are unable to access facilities and move product across damaged roads and bridges).
  - Options for transporting fuels post-earthquake to fixed and portable generators.
  - Routinely testing onsite generators under load, which is a best practice that several utilities currently employ. Given the likely demand for available emergency generators and the potential difficulty of moving them to specific and often remote sites, it may take weeks for a vendor or emergency generator pool to move a generator, assuming one is available. Consequently, system operators should be cautious about relying solely on a government-supplied emergency generator.
- Water utilities should evaluate the locations where fixed generators are placed and portable emergency generators are stored. Emergency generators should be stored in seismically resilient structures.

Key Finding #7: State departments, county and city emergency managers, and water utilities should emphasize personal and family preparedness in the communities they serve. Public messaging should be consistent, persistent, and actionable.

Earthquakes occur without warning. Following a CSZ earthquake, it could take months to restore lifeline infrastructure services.[38] Disruptions to transportation systems will delay the arrival and distribution of external supplies, such as food, water, and services.[39] As a result, households in the study area should be prepared to survive without utilities (or significant external support) for at least two weeks. In response

37 EPA, Power Resilience Guide for Water and Wastewater Utilities, 2019, https://www.epa.gov/sites/default/files/2016-03/documents/160212-powerresilienceguide508.pdf, accessed December 2021.

38 Specifically, water, wastewater, energy - power and natural gas, transportation and communications.

39 A key planning assumption for a catastrophic earthquake is that air transport will be the only viable means of delivering supplies in the early days and weeks of the disaster due to the impact to roads, bridges, ports, and rail lines. However, these assumptions further acknowledge that ground transportation to and from airports will be a limiting factor for aerial delivery of resources.

to the risk posed not only by a CSZ earthquake, but by other regional faults, EMD launched Disaster Ready Washington to encourage citizens and households to be “2 Weeks Ready” to ride out a disaster without external assistance. [EMD – 2 Weeks Ready] In contrast to EMD’s 2 Weeks Ready campaign, the seven counties that comprise DOH’s Northwest Drinking Water Region currently recommend that citizens prepare to manage without essential services – including water – for a range of durations. Whatcom and Skagit counties recommend three days; Island, San Juan, and Pierce counties recommend 14; and King and Snohomish Counties recommend citizens prepare for three days to two weeks, and seven to ten days, respectively.

Based on CSZ modeling and previously referenced planning assumptions, recommendations at the lower end of the scale are difficult to rationalize given the region’s earthquake risk. To encourage earthquake preparedness, citizens need realistic downtime assessments in guidance that is both easy to find and easy to follow. While there is no requirement that every county provide consistent guidance, it is inarguable that a three day water supply will not bridge the gap between a CSZ earthquake and restoration of water service, or even widespread provision of emergency water.[40] Given the scale and devastation expected to result from a CSZ earthquake, downtime estimates of less than two weeks may result in a lack of personal preparedness based on overly optimistic assumptions about the severity of the threat, its likely scale and consequences, and the region’s capacity to counter it.

A review of county emergency management websites reveals the following emergency water preparedness messaging:

- All address emergency preparedness
- Guidance on potential durations without external services ranges from 3 days to 2 weeks
- Most recommend emergency kits include one gallon of water per person per day
- Few provide other water specific guidance, such as how to safely store water, extract water from a water heater, disinfect water with unscented bleach, use water purification tablets or a personal water filter
- Some inconsistencies among counties may be attributable to divergent guidance provided by Washington State departments[41]
- Websites often provide links to multiple sources that provide inconsistent guidance.

Although state, county, and city emergency management agencies typically assume responsibility for citizen preparedness and risk communication, water utilities can augment their efforts by posting targeted presentations, how to videos, and links to authoritative information on utility websites. The Water Supply Forum’s messaging on disaster preparedness, including videos and actionable information on water storage, extracting water from water heaters, and emergency water treatment techniques, provides a model for other utilities. [42]

40 In an April 2019 You Tube video, Paul Kamin, then-General Manager of Eastsound Water Users Association on Orcas Island, in San Juan County, recommended citizens store no less than a 30-day supply of water. https://www.youtube.com/watch?v=RJltXiFreVs

41 For example, Snohomish County Department of Emergency Management directs the public to WA EMD’s site (14 days), https://www.snohomishcountywa.gov/719/Personal-Preparedness and Whatcom County Department of Emergency Management links to the WA DOH site for emergency supplies and guidance (at least 3 days), https://www.doh.wa.gov/Emergencies/BePreparedBeSafe/GetReady/EmergencySupplies

42 https://www.watersupplyforum.org/home/disaster-preparedness.html

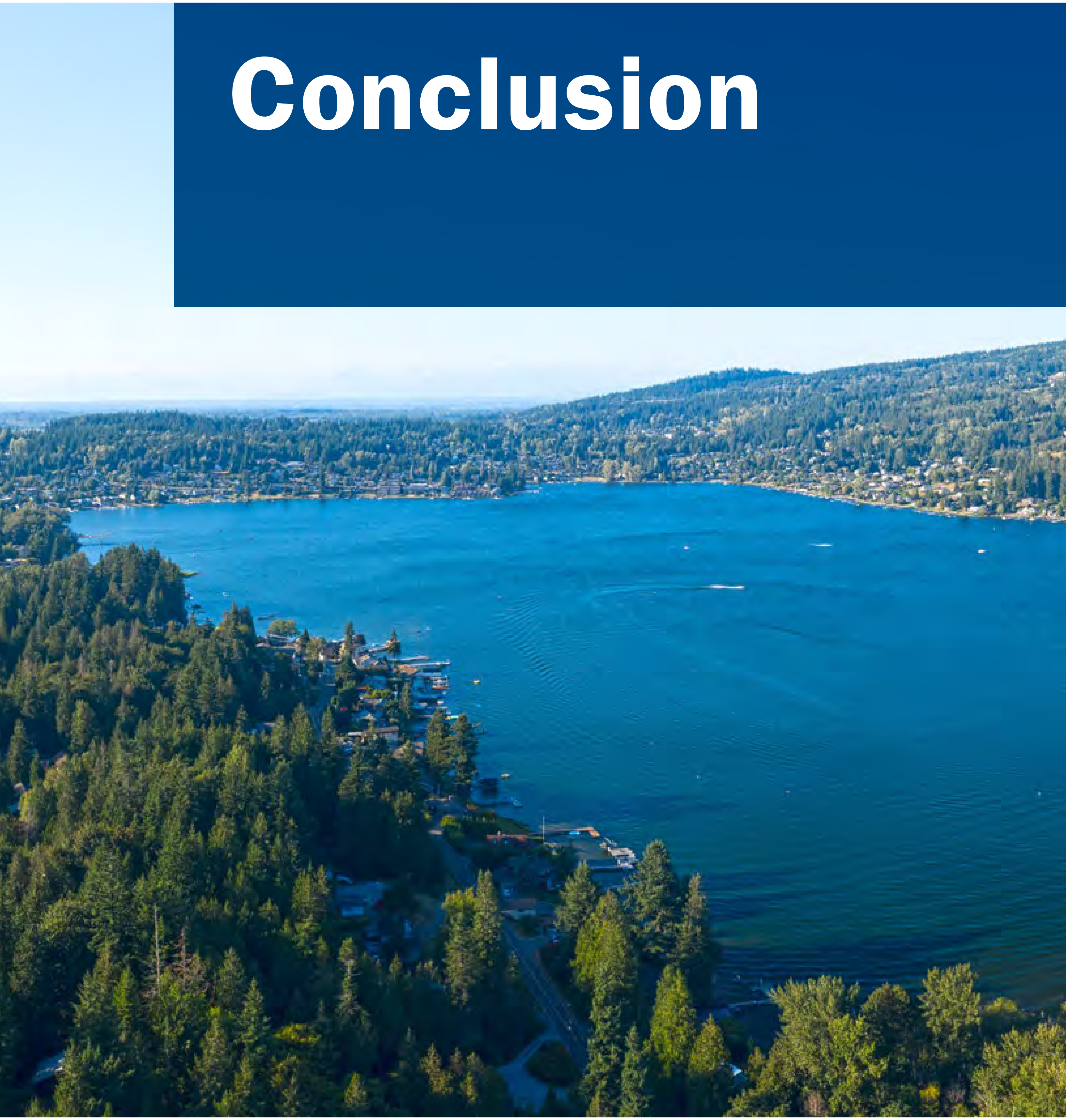
Resilience Enhancement Options

- Water utilities should coordinate with county and city emergency managers to communicate preparedness goals to citizens within their service areas. Communications channels might include bill stuffers, brochures, public service announcements, posting consolidated information that is downloadable and printable on county and water utility websites, and staffing booths at community events.
- Water utilities and county and city emergency managers should also provide practical, actionable information to customers about extracting water from a hot water heater, using purification kits (small micron filter, pump, and bleach), and maintaining at least a 14-day supply of bottled water. Information available from the Centers for Disease Control and Prevention[43] and other authoritative sources can be leveraged and posted on utility and emergency management websites.[44] Links to YouTube videos demonstrating how to access alternative forms of emergency water, use a water filter, activate an emergency shut-off and other useful capabilities should be posted on utility and emergency management websites.

43 CDC guidance on preparing a home water supply includes the following artifacts: 1) making water safe in an emergency (printable fact sheet); 2) creating and storing an emergency water supply; and 3) finding other water sources in an emergency. https://www.cdc.gov/healthywater/emergency/preparing-a-home-water-supply.html These products are available in English and Spanish. Guidance for households on Treating Drinking Water for Emergency Use is also available from DOH. https://www.doh.wa.gov/Portals/1/Documents/Pubs/331-115.pdf, accessed October 2021.

44 Messaging should be scrutinized to ensure it is appropriate for the severe earthquake risks in Northwest Washington. For example, the CDC guidance on how much emergency water to store provides: Store at least 1 gallon of water per person per day for 3 days for drinking and sanitation. Try to store a 2-week supply if possible. https://www.cdc.gov/healthywater/emergency/creating-storing-emergency-water-supply.html In Northwest Washington the emphasis should be shifted to: Try to store a 2-week supply if possible.

Conclusion



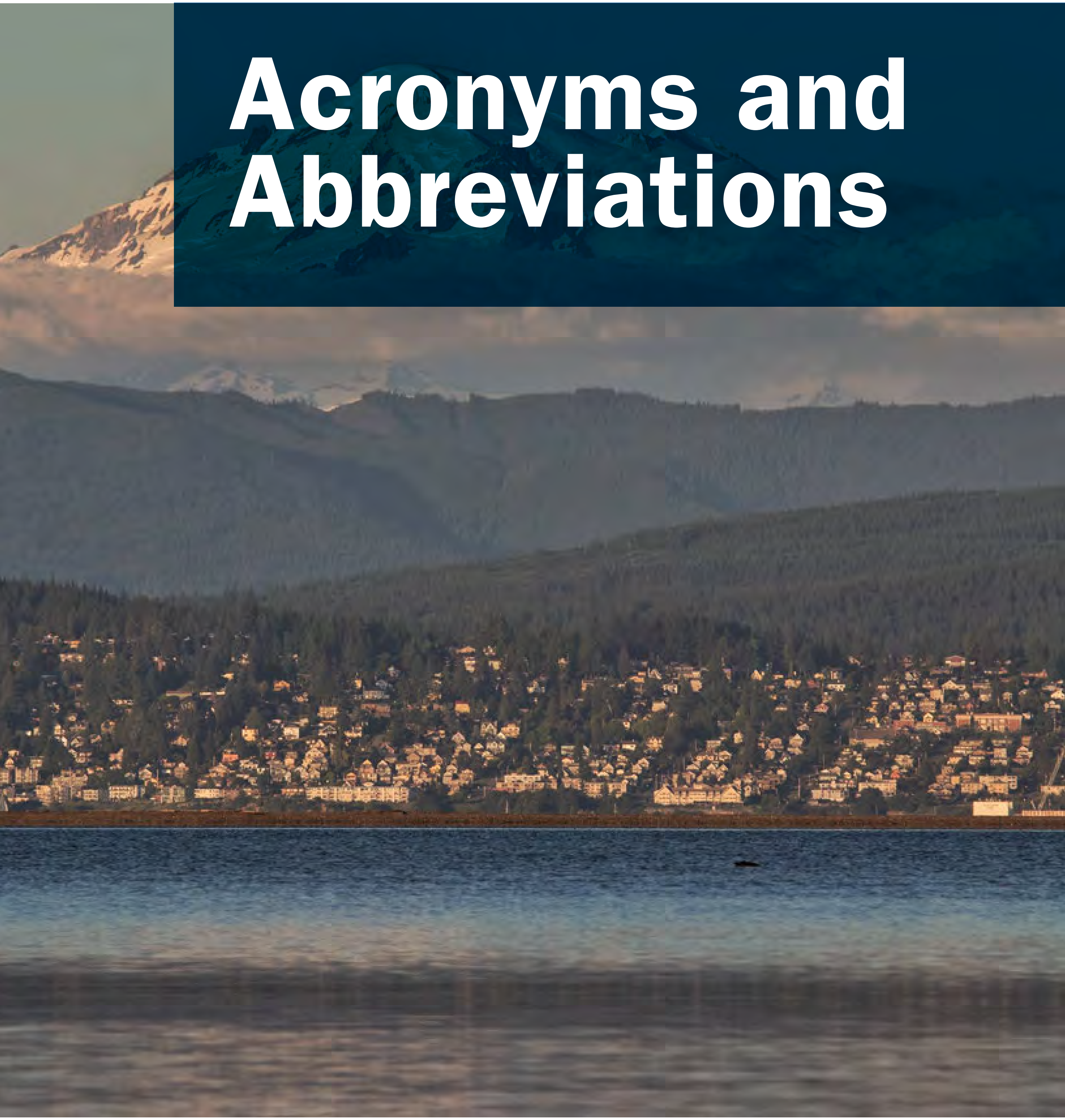
Conclusion

The Northwest Washington Water Resiliency project highlighted the formidable challenges emergency managers, first responders, and water utilities will face in their effort to provide drinking water to the population following a CSZ earthquake. The breadth and severity of the hazard challenges the resources and capabilities of emergency management agencies at all levels of government, as well as the water utilities they will turn to for emergency water. Cascadia Rising 2022 continues to animate planning around core capabilities critical to operational coordination, mass care, and infrastructure systems.[45] And while intensive planning is evident through state planning initiatives such as the SCIPT, to date these efforts have not reached many of the water utilities or emergency managers they will rely on to meet local needs pending the arrival of external support or restoration of services. Against this backdrop, participating utility owners and operators expressed doubts about post-earthquake support from state and federal governments, concerns about expectations of water utilities, and disappointing experiences with prioritization of water system needs relative to other utilities. A significant number of water utility operators reported a lack of coordination between state and federal emergency management and water systems. This gap, and EMD's current catastrophic planning focus on water systems' functional capabilities following a catastrophic incident, provides an opportunity for catastrophic planning and information sharing informed by policy and ground truth.

The Key Findings, REOs, and emergency water capability analyses in the County Appendices can assist state, county, and city emergency managers in fostering productive, bi-directional information sharing with water utilities to solidify planning necessary to the delivery of emergency water. CISA Region 10 will remain engaged with emergency managers and utilities as they consider potential actions described in this report. For more information about this resilience project, please contact the CISA Region 10 Chief of Protective Security, Allen Chung, at Allen.Chung@cisa.dhs.gov. Inquiries may also be directed to CISA Region 10 at CISARegion10@hq.dhs.gov and/or CISA Headquarters at Resilience@hq.dhs.gov.

45 Originally planned as a National Level Exercise (NLE), in October 2021, FEMA Region 10 announced the decision to transition Cascadia Rising 2022 from a functional exercise to a discussion-based series of targeted engagements "including recorded webinars, seminars, workshops, tabletop exercises, and Senior Officials Exercises." Cascadia Rising 2022 Newsletter, October 2021 Edition, https://content.govdelivery.com/accounts/USDHSFEMA/bulletins/2f59637, accessed November 28, 2021.

Acronyms and Abbreviations



Acronyms and Abbreviations

AWWA	American Water Works Association
BSST	Bridge Seismic Screening Tool
CISA	Cybersecurity and Infrastructure Security Agency
CPOD	Community Point of Distribution
COM	Washington Department of Commerce
COOP	Continuity of Operations Plan
CREW	Cascadia Region Earthquake Workgroup
CSZ	Cascadia Subduction Zone
DHS	Department of Homeland Security
DOH	Washington Department of Health
DNR	Washington Department of Natural Resources
EMD	Washington Emergency Management Division
EOC	Emergency Operations Center
EPA	Environmental Protection Agency
ESF	Emergency Support Function
FEMA	Federal Emergency Management Agency
FSLTT	Federal, State, Local, Tribal and Territorial
JFO	Joint Field Office
JIC	Joint Information Center
NGO	Non-governmental Organization
NIAC	National Infrastructure Advisory Council
PIO	Public Information Officer
REO	Resilience Enhancement Option
RRAP	Regional Resiliency Assessment Program
SCADA	Supervisory Control and Data Acquisition
SEOC	State Emergency Operations Center
USGS	U.S. Geological Survey
WAC	Washington Administrative Code
WAWARN	Washington Water/Wastewater Agency Response Network
WSDOT	Washington State Department of Transportation
WSF	Water Supply Forum
WTP	Water Treatment Plant

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Appendix A

Appendix A

The CSZ is a megathrust fault zone located off the west coast of North America that stretches approximately 700 miles from northern Vancouver Island, Canada, to Cape Mendocino, Calif. (Figure 2). Along this fault, three regional tectonic plates—the Explorer, Juan de Fuca, and Gorda plates—are pulling away from the larger Pacific plate and moving toward the North American plate. At the North American plate boundary, these three regional plates are descending—or subducting—underneath the North American plate (Figure 3). As this subduction occurs, "a large portion of the boundary between the subducting and overriding plates resists the convergent motion, until this part of the boundary breaks in a great earthquake" (CREW 2013). Historic records suggest that the last such great earthquake along the CSZ boundary occurred in January 1700 with an estimated magnitude of 8.7–9.2 (Atwater et al. 2015). Furthermore, paleo seismology studies evaluating centuries' worth of seismic history in the region have identified numerous prior earthquakes that occurred as early as 1400 BC (Atwater et al. 2003). These studies place the likelihood of a major CSZ earthquake occurring in the next 50 years at approximately 10 percent (Goldfinger et al. 2012).[46]

This RRAP project is the third in a trilogy of CSZ-focused resiliency assessments concerning Washington State. For economy and consistency, the background discussion of CSZ and associated hazards is reprinted from and consistent with the Washington State Transportation Systems RRAP project and the Washington State Airports Seismic Resilience Project, with acknowledgements to Argonne National Laboratory.

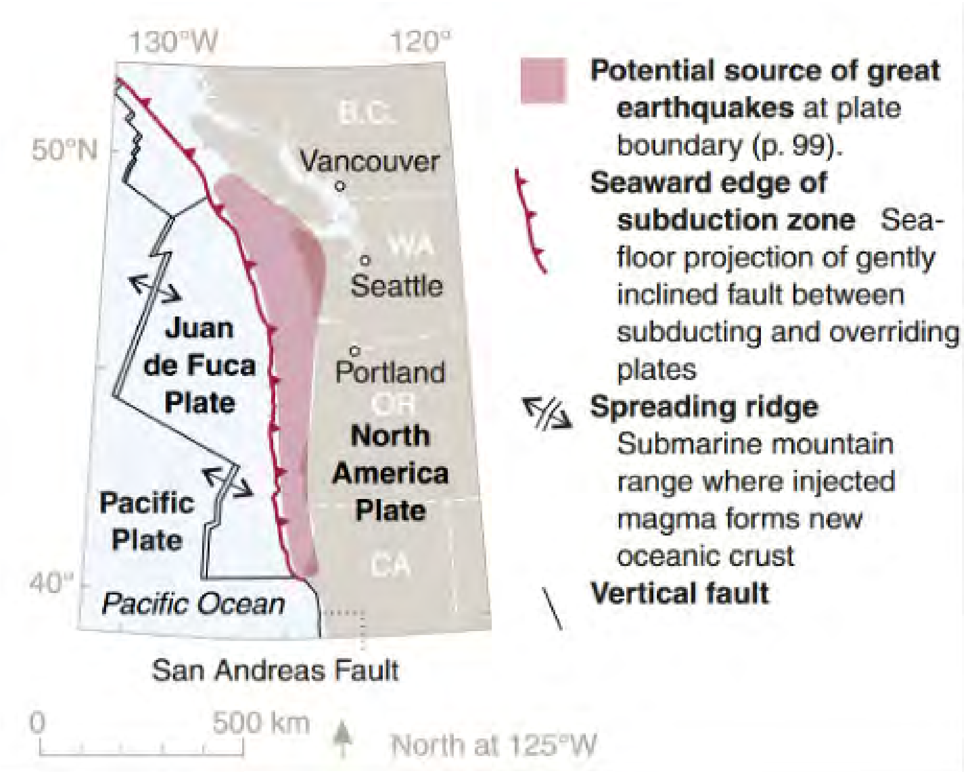

FIGURE 1.—CSZ Geographical Extent. (Source: Atwater et al., 2015)

46 Goldfinger et al. (2012) note that "time-independent probabilities for segmented ruptures range from 7–12 percent in 50 years for full or nearly full margin ruptures to ~21 percent in 50 years for a southern-margin rupture. Time-dependent probabilities are similar for northern margin events at ~7–12 percent and 37–42 percent in 50 years for the southern margin."

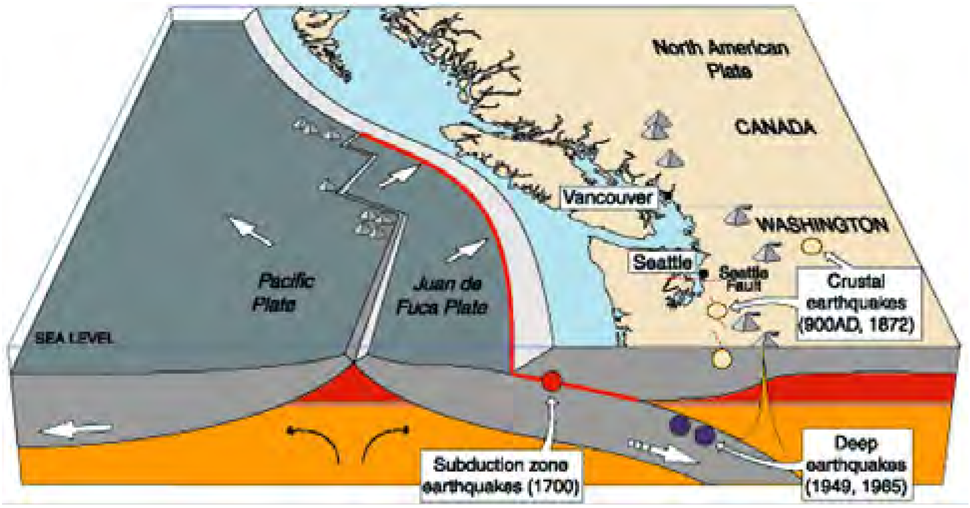

FIGURE 2.—Plate Tectonics in the CSZ. (Source: Wells et al. 2016)

Scientists project that a CSZ earthquake could occur with a magnitude of 9.0 and that the ground could shake for several minutes, releasing tremendous amounts of energy that could damage infrastructure and affect communities along the west coast of the United States and Canada. Since the mid-20th century, several other subduction zone earthquakes have occurred around the Pacific region that provide context for what the Pacific Northwest region could experience during a CSZ earthquake. These include an M9.2 earthquake in Prince William Sound, Alaska (1964); an M9.1 earthquake in Aceh-Andaman, Sumatra (2004); an M8.8 earthquake in Maule, Chile (2010); and an M9.0 earthquake in Tohoku, Japan (2011) (CREW 2013).

The primary hazard associated with a CSZ earthquake is strong and prolonged shaking, or ground motion, and the forces that such shaking can impart on infrastructure and the built environment. However, the primary earthquake can also trigger several secondary hazards associated with a CSZ earthquake. This study considered a limited number of secondary hazards, including ground failure (e.g., liquefaction, ground displacement or deformation) and tsunamis. Other secondary hazards that can affect water utility infrastructure include landslides, rock falls, and avalanches. The research team surveyed these additional secondary hazards only insofar as they have the potential to affect likely emergency water assets and capabilities. This section discusses the several hazards associated with a CSZ earthquake that this project considered, the supporting hazard data and information available that the research team used to inform this study's analysis.

Ground Motion

Ground motion is the most apparent and direct hazard associated with an earthquake. The size of an earthquake is expressed most commonly (by U.S. Geological Survey [USGS] and others) using the Moment Magnitude Scale (MMS), which quantifies the amount of energy that an earthquake releases (USGS undated[a]). In this project, the core stakeholder group agreed that the "USGS M9.0 Scenario Earthquake – Cascadia M9.0 Scenario (mean value)" should form the basis for all analysis (USGS undated[c]). This USGS CSZ scenario is a 2017 update to an earlier 2011 USGS scenario that the Cascadia Region Earthquake Workgroup (CREW) identified for use in regional catastrophic planning (CREW 2013), and it was also the basis for analysis in the Washington State Transportation Systems RRAP and Oregon Transportation Systems RRAP projects (CISA 2019, 2021). Earlier versions of this USGS CSZ scenario were also used in the National Infrastructure Simulation and Analysis Center / Homeland Infrastructure Threat and Risk Analysis Center study, the Cascadia Rising 2016 exercise, and FEMA's *CSZ Catastrophic Earthquake and Tsunami Response Plan (Ver. 2.0)* (FEMA 2013, 2016; NISAC and HITRAC 2011).[47]

47 The University of Washington and the USGS's current "M9 Project" (University of Washington 2021) offers improved characterization of a CSZ earthquake using dozens of scenarios; the research team, with the agreement of the core stakeholder group, decided to use the USGS M9.0 CSZ scenario to enable more consistent regional planning with the Washington State Transportation Systems RRAP project (CISA 2019).

Peak ground acceleration (PGA) is a quantitative measure of shaking intensity that is commonly used in infrastructure-related seismic design specifications and building codes. Whereas MMS is a measure of an earthquake's overall size, PGA is a location-specific measure of ground shaking intensity that can be used to approximate the seismic forces that a specific location or structure will experience during an earthquake.[48] PGA is the primary metric for earthquake intensity used in this study to assess the vulnerability of selected water infrastructure to ground motion. Figure 4 shows the Geographic Information System (GIS) data collected from the USGS for PGA projected across Washington under the USGS M9.0 CSZ scenario. The strongest shaking is projected to occur in the coastal, Olympic Peninsula, and southwestern parts of the state, and it will generally diminish moving east across the state. The USGS scenario study area ends at approximately 118° west longitude (just west of Spokane) with projected PGA values of approximately 0.04g. Minor shaking of 0.04g or less could still be expected to occur east of the USGS scenario study area in eastern Washington.

Subduction earthquakes, in general, typically experience a longer-duration of shaking as compared with other types of earthquakes, which increases the potential for structures to sustain damage or to fail. The duration of shaking for a CSZ earthquake is projected to range from 2–6 minutes (CREW 2013). The effects of longer-duration shaking on structures have not been widely studied, and current seismic design specifications and codes do not explicitly consider shaking duration in structural design and assessment practices (Chandramohan 2016). The earlier Washington State Transportation Systems RRAP project (CISA 2019) had incorporated some findings from this nascent field of research to account for the effects of longer-duration shaking on bridge structures, but this study made no special considerations to incorporate the effects of long-duration shaking on water system components.

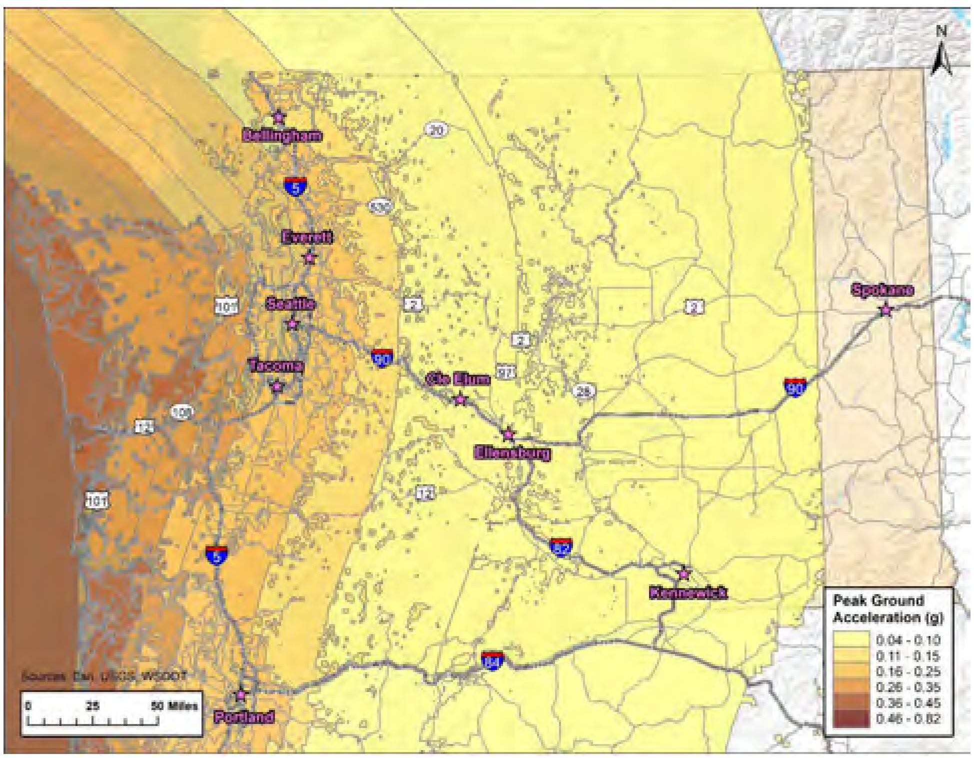

FIGURE 3.—Projected PGA for Washington under the USGS M9.0 CSZ Scenario.

48 PGA is expressed as an acceleration in units of g; 1 g is the Earth's gravitational acceleration, or 9.81 m/s2.

Ground Failure

Ground failure refers to a range of secondary hazards that an earthquake can trigger, in which ground and soils become unstable, shift, flow, or lose their load-bearing capacity and ability to support structures. Ground failure includes a range of outcomes, including soil liquefaction, landslides, rock falls, lateral shifting, and sinkholes.

Soil liquefaction (also referred to as liquefiable soils) refers to the phenomenon where certain types of soils that are saturated with water can behave like a liquid when they experience seismic shaking. Liquefaction can result in the loss of support for surface structures (e.g., buildings and bridges), in soil flows on even very gentle slopes, and in large differential settlements where areas of the ground surface sink in comparison to nearby or surrounding soils. Soil liquefaction occurs typically in alluvial soils—loose sand and silty soils that are characteristic of river valleys, river deltas, and other areas with flowing water (USGS 2016). Washington Department of Natural Resources (DNR) maintains a statewide geospatial database that characterizes soil liquefaction susceptibility in the top-most layer of soil for all of Washington (Figure 5) (DNR 2010). This dataset served as the primary basis for analyzing seismic-related ground failure impacts to the statewide surface transportation system in Washington State.

As Figure 5 shows, highly liquefiable soils in Washington State occur most frequently along river valleys, with some broader concentration of soils with very low to low liquefaction susceptibility in the low-lying areas surrounding these rivers and streams. Soils with some liquefaction susceptibility— ranging from very low to high—underlay much of the Puget Sound region.

The impacts of seismic-induced soil liquefaction to infrastructure are commonly quantified as permanent ground deformation (PGD), which refers to the vertical and lateral deformation of soil resulting from

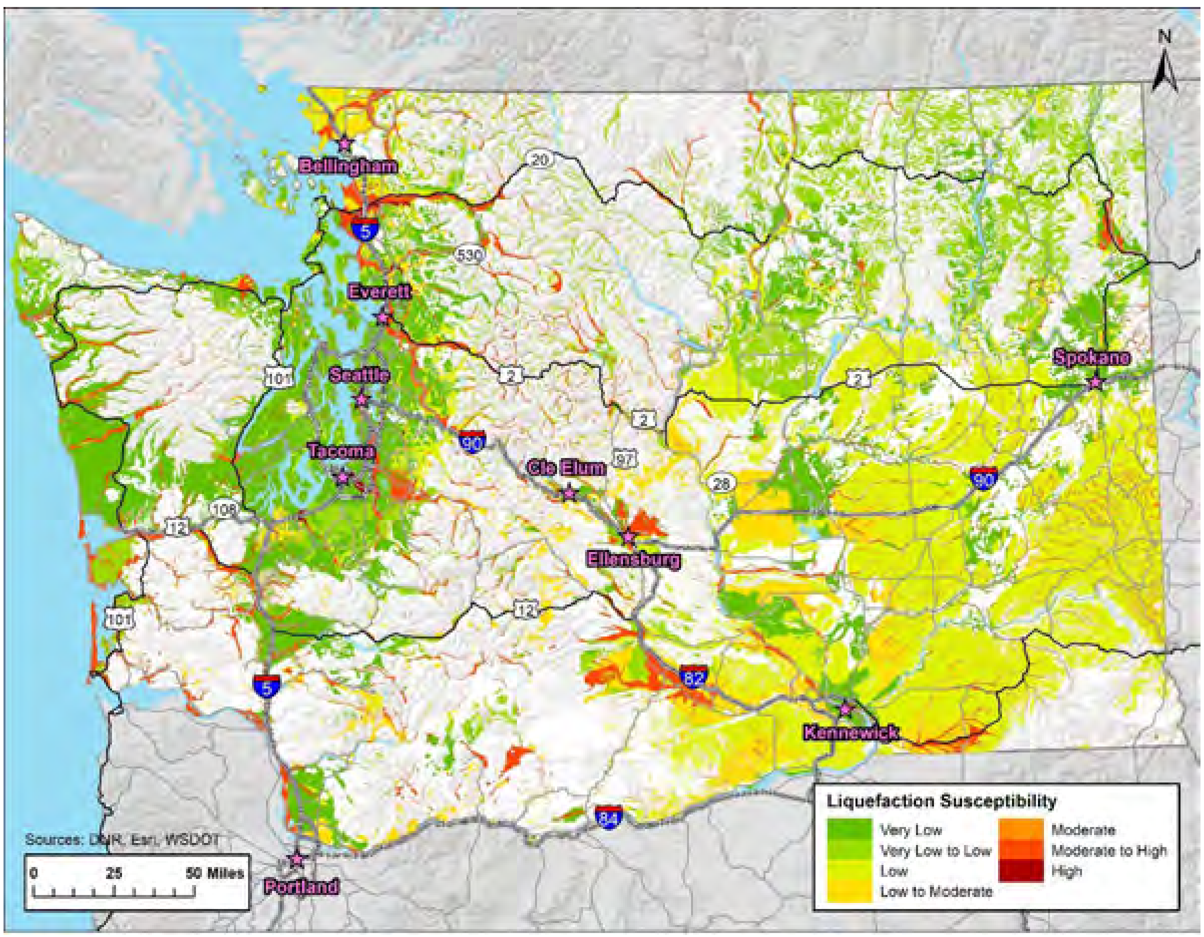

FIGURE 4.—Soil Liquefaction Susceptibility in Washington.

soil liquefaction, as measured in inches or feet of displacement. PGD can create significant disruptions to regional water systems. Ground underlying and supporting pipelines and structures such as treatment plants, operations centers, maintenance yards, reservoirs, tanks, pump houses, intakes and other system components can sink or shift, causing significant discontinuities, cracking, sliding, and even toppling of vertical tanks and reservoirs due to deformation or differential settlement.

Tsunamis

A tsunami is a large ocean wave (or series of waves) that occurs when some incident or disruption displaces a large volume of water. In the context of a CSZ earthquake, the fault rupture causes the sudden movement of tectonic plates, displacing the ocean floor and propagating an ocean wave. The amplitude of the wave will increase as it travels out from the fault line and approaches shallower water near the coastline. The first CSZ tsunami wave is projected to reach the coastline within 20 to 30 minutes of the initial earthquake with wave heights up to 30 to 40 feet. Given experiences with similar coastal subduction zone earthquakes around the world, subsequent large waves could follow this initial tsunami wave in the hours following the earthquake (CREW 2013).

DNR publishes GIS datasets representing tsunami impacts along Washington State's shorelines, each of which aggregate a number of smaller studies conducted along portions of the state's coastline. In 2021, DNR released the Extended L1 Scenario, which characterizes the entirety of Puget Sound, and a greater extent of Washington's Pacific coastline (Dolcimascolo et. al, 2021). Figure 6 shows the modeled inundation area for the Extended L1 Scenario, which was used as the basis for analysis in this project.

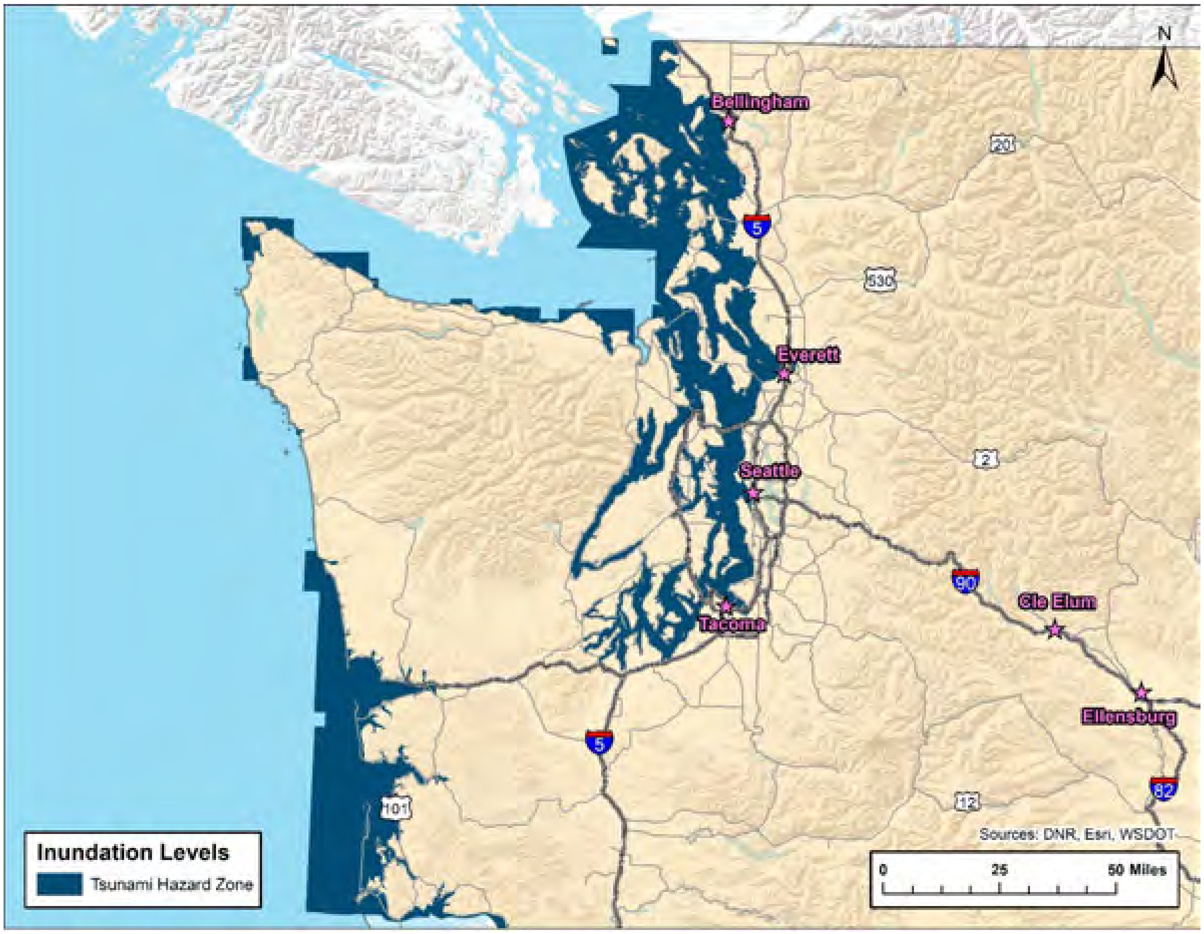

FIGURE 5.—Comparison of Tsunami Inundation Datasets from Washington DNR.

Appendix B

Appendix B - Catastrophic Incident Planning Assumptions for Water [CIA]

- The resources available post-incident may be insufficient to both provide services AND restore systems
- Essential water utility personnel will likely not be available in sufficient numbers to operate, maintain, repair, and restore significant portions of the water system for the first few weeks of the incident
- During a catastrophic incident there will be limited resources to accomplish both focus areas of restoring systems and services
- The stabilization of threats may take place to protect infrastructure from additional or reoccurring hazards
- Water utilities may have the capabilities to do limited debris clearance and removal
- Water systems in dense urban settings may be out of water within 24 hours
- Residents may flee these population settings and self-evacuate to other outlying areas (e.g., friends and family residences)
- Those with access and functional needs (AFN) may be unable to flee and will require support
- Hospitals that lack a working connection to water infrastructure may no longer be able to provide services
- It may not be possible to prioritize all hospital types
- Even with additional/alternative water provision (i.e., water tankers), it may not be possible to support a hospital's short-term needs
- Dense urban settings may have a lower threshold to meet the requirements of a catastrophic incident
- Impacts to water infrastructure may negatively impact other critical infrastructure and lifeline sectors involved in immediate response operations. Conversely, impacts to other critical infrastructure or lifeline sectors may adversely impact or impair the ability of water utilities to function
- Utilities that have infrastructure components in or on liquifiable soils, river valleys, or that utilize non-seismically retrofitted pipe bridges should be considered non-functioning post-earthquake.
- Communities that are located at the "end of line" or on peninsulas should be pre-identified as needing immediate assistance from outside or alternative water resources
- Populations may require relocation from areas where water infrastructure is non-functioning and water service needs cannot be met by local utilities or response agencies
- Water utilities in areas or regions that utilize materials such as concrete, asbestos, wood, or ductile iron may likely fail at the points where these materials exist following a significant earthquake
- Some water systems have dedicated emergency wells, though most are unsure if they will be available post-earthquake
- Source water may be expected to be the primary source to draw water from post-incident
- Damage assessments can take a week to occur and are dependent on time of occurrence
- Some actions may occur simultaneously rather than in a step-by-step order
- Priorities vary widely among water systems for the restoration of water for firefighting, hospitals, and hydration for the population
- For some water systems there may be no established priorities; other water system's priorities are dictated in the governing body
- Priority planning may be a challenge for small communities with limited planning resources
- Older facilities and those owned by smaller utilities are likely to not have conducted the full suite of seismic resiliency studies to understand the hazard risk
- Even with seismic resiliency planning and retrofitting, not all components to the system may survive
- Water utilities will follow internal and local government priorities for infrastructure restoration unless otherwise indicated or established
- Distribution systems may take many years to fully restore
- Restoration en masse will not occur within the first 30 days
- Non-potable water may need to be used for emergency services (where appropriate).

Appendix C

Appendix C - Sankey Diagrams

Anacortes Water Department

Everett Public Works

Seattle Public Utilities

Tacoma Public Utilities

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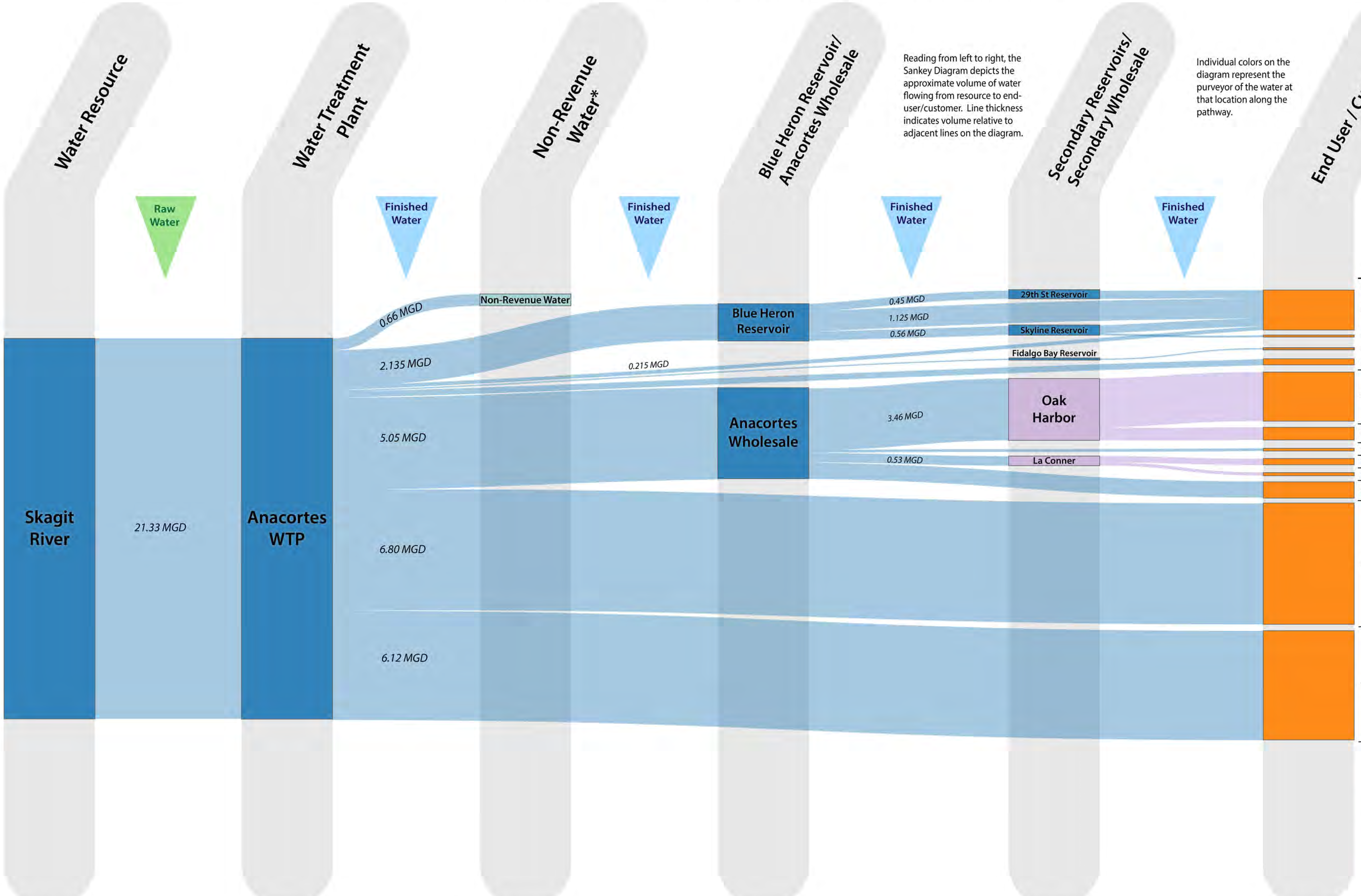
Anacortes Water System - Water Resources and Demand

Projected Average Daily Water Use (2020)



Reading from left to right, the Sankey Diagram depicts the approximate volume of water flowing from resource to end-user/customer. Line thickness indicates volume relative to adjacent lines on the diagram.

Individual colors on the diagram represent the purveyor of the water at that location along the pathway.

According to Lawrence-Livermore National Laboratory "Water use data is notoriously hard to compile. Accounting policies vary between different water management districts and water use is not metered in the same way that higher-priced commodities are sold. Quantifying water use by location and sector requires substantial estimation. Water disposition is even more difficult to quantify."

Despite varying data from multiple organizations and water districts, this diagram will aid understanding of water use patterns from resource to end user throughout the Anacortes Water System.

Customer	Population	Average Daily Demand (MGD)
Anacortes		
Residential & Commercial	21,105	2.24
Del Mar	654	0.11
Fidalgo Bay Estates	69	0.01
Agricultural Block	N/A	0.34
City of Oak Harbor	22,591	2.75
Naval Air Station-Whidbey Island	16,595	0.71
Swinomish	3,000	0.15
Town of La Conner	1,585	0.35
Shelter Bay	2,212	0.18
Skagit PUD Fidalgo Island System**	1,945	0.91
Shell Oil Refinery	N/A	6.80
Tesoro Oil Refinery	N/A	6.12

- Water resources and assets owned and operated by City of Anacortes
- Water resources and assets owned and operated by local municipalities and other water wholesalers
- Non-revenue water use*
- Finished water customers (end users)

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Terry Nemeth (Anacortes Public Works Supervisor, Water Maintenance) in phone discussion, December 2020.

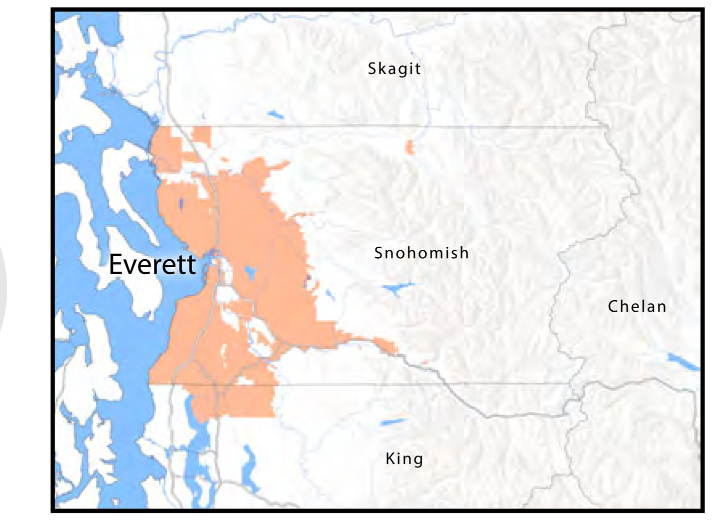
* Non-revenue water is the difference between the full volume of water managed by a water district and the volume of finished water delivered to the district's customers. It includes reservoir storage, aquifer recharge, industrial use, irrigation, fire fighting, effluent water discharged during water treatment processes, unaccounted for losses including seepage, runoff, evaporation, environmental releases, etc.

** Skagit PUD Fidalgo Island System A portion of this water also supplies several large industrial consumers in the greater Skagit PUD service area.

Idaho National Laboratory
Completion Date: 21 December 2020

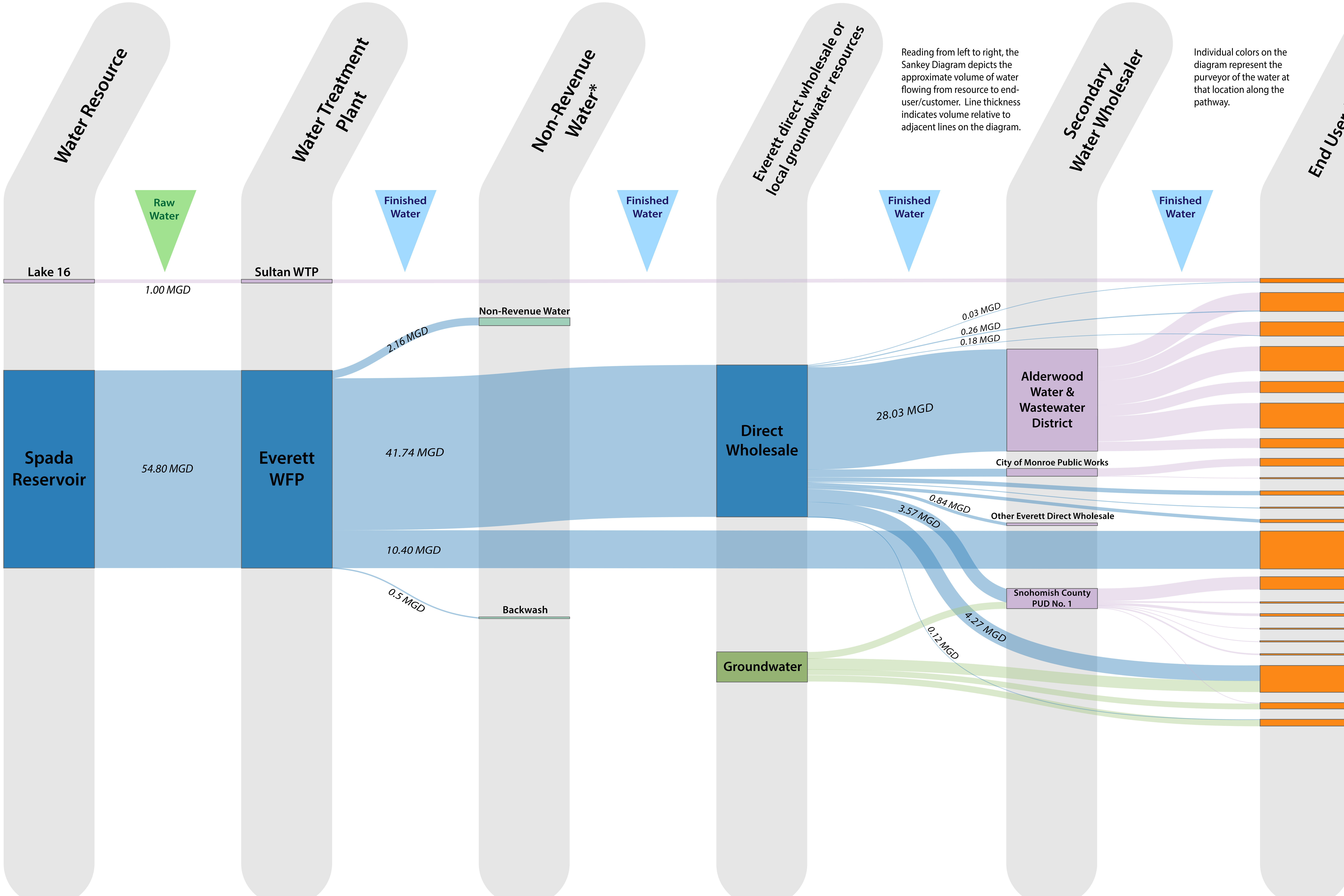
Everett Water System - Water Resources and Demand

Projected Average Daily Water Use (2020)



Reading from left to right, the Sankey Diagram depicts the approximate volume of water flowing from resource to end-user/customer. Line thickness indicates volume relative to adjacent lines on the diagram.

Individual colors on the diagram represent the purveyor of the water at that location along the pathway.



According to Lawrence-Livermore National Laboratory "Water use data is notoriously hard to compile. Accounting policies vary between different water management districts and water use is not metered in the same way that higher-priced commodities are sold. Quantifying water use by location and sector requires substantial estimation. Water disposition is even more difficult to quantify."

Despite varying data from multiple organizations and water districts, this diagram will aid understanding of water use patterns from resource to end user throughout the Everett Water System.

Customer	Population	Average Daily Demand (MGD)
City of Sultan	4,650	1.03
Silver Lake	55,127	5.19
Mukilteo	24,428	3.92
Alderwood	190,177	6.75
Edmonds	41,586	3.10
Lynnwood	54,614	6.88
Mountlake Terrace	20,090	2.60
Monroe	22,917	2.14
Marbello	245	0.02
City of Snohomish	12,383	1.18
Three Lakes	2,143	0.22
Tulalip Tribes	2,800	0.91
Everett Retail	137,000	10.40
Lake Stevens/Granite Falls	5,823	3.50
Kayak	979	0.40
May Creek	1,215	0.72
Skylite Tracts	383	0.10
Sunday Lake	485	0.20
Warm Beach	1,578	0.40
Marysville	67,820	7.36
Arlington	18,952	1.71
Cross Valley	17,280	1.86

- Water resources and assets owned and operated by Everett Water
- Water resources and assets owned and operated by local municipalities and other water wholesalers
- Non-revenue water use*
- Finished water customers (end users)
- Groundwater

References

City of Everett, Washington, City of Everett Draft 2020 Comprehensive Water Plan, scheduled to be published January 2021.

Environmental Protection Agency, SDWIS Federal Reports, https://ofmpub.epa.gov/apex/sfdw/f?p=108:103:::NO:RP::, submitted 2020, Quarter 2, webpage visited July 2020.

Erika Lindsey, (NW Regional Office of Drinking Water Regional Engineer, Washington State Department of Health) email message to Idaho National Laboratory, July 2020.

Lawrence Livermore National Laboratory, Energy Flow Charts: Charting the Complex Relationships Among Energy, Water, and Carbon. https://flowcharts.llnl.gov/, webpage visited July 2020.

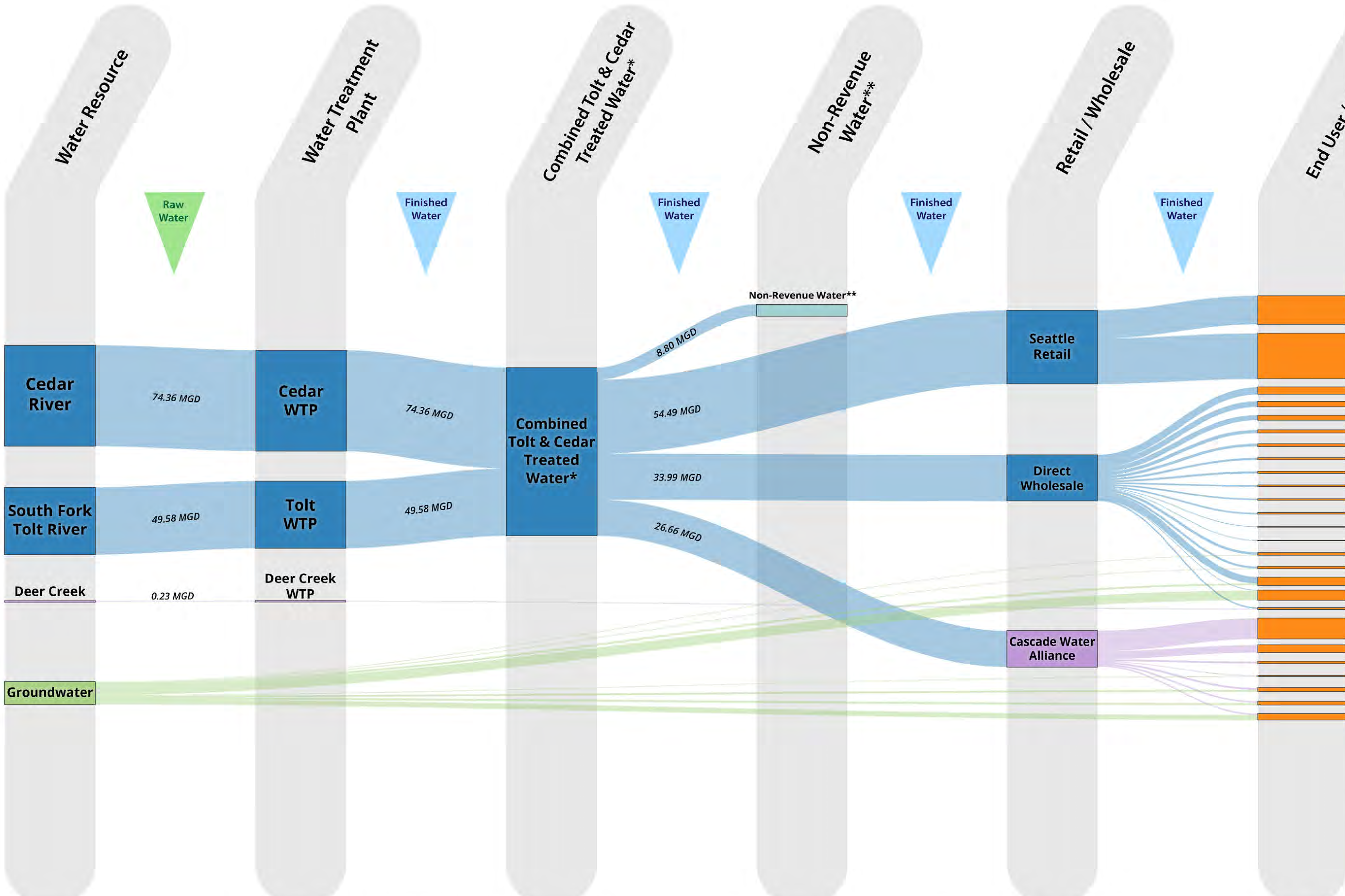
Souheil Nasr (Principal Engineer, Everett Water) in phone discussion with Idaho National Laboratory, June 2020.

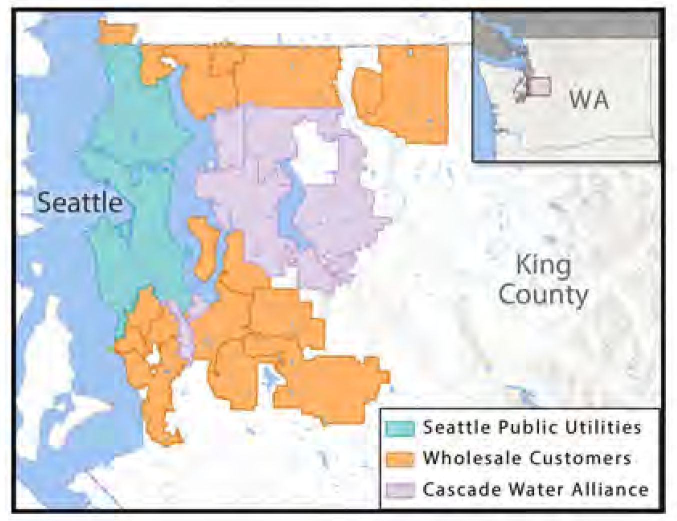
* Non-revenue water is the difference between the full volume of water managed by a water district and the volume of finished water delivered to the district's customers. It includes reservoir storage, aquifer recharge, industrial use, irrigation, effluent water discharged during water treatment processes, unaccounted for losses including seepage, runoff, and evaporation, environmental releases, etc.

Idaho National Laboratory
Completion Date: 29 September 2020

Seattle Public Utilities - Water Resources, Demand, and Alternative Sources Available to End Users

Average Daily Water Use (2019)





Reading from left to right, the Sankey Diagram depicts the approximate volume of water flowing from resource to end user/customer. Line thickness indicates volume relative to adjacent lines on the diagram. Exchanges of water between customers are not depicted in the diagram. Most notably, Redmond received a combined total of approximately 3.09 MGD from Bellevue and Kirkland in 2019.

Individual colors on the diagram represent the purveyor of the water at that location along the pathway.

Customer	Population	Average Daily Demand (MGD)
Seattle Public Utilities	805,712	54.49
Residential		21.02
Commercial		33.47
Northshore Utility District	98,052	5.21
Soos Creek Water & Sewer District	64,534	3.97
Woodinville Water District	48,400	3.67
Water District No. 20	38,974	2.46
City of Mercer Island	22,699	2.00
North City Water District	30,229	1.51
City of Bothell	30,060	1.48
Water District No. 49	16,065	1.22
Water District No. 125	17,546	1.19
Coal Creek Utility District	14,014	1.18
City of Duvall	8,992	0.54
Water District No. 119	3,796	0.24
Cedar River Water & Sewer District	25,323	1.86
Water District No. 90	19,600	1.88
Highline Water District	76,581	6.37
City of Renton	96,614	6.98
Olympic View Water & Sewer District	15,091	1.27
City of Bellevue	261,506	15.39
City of Kirkland	61,564	5.82
City of Tukwila	45,138	1.82
Skyway Water & Sewer District	11,011	0.68
City of Redmond	123,565	6.96
City of Issaquah	39,399	2.76
Sammamish Plateau Water	65,543	4.93

- Water resources and assets owned and operated by Seattle Public Utilities
- Water resources and assets owned and operated by local municipalities and other water wholesalers
- Non-revenue water use**
- Finished water customers (end users)
- Groundwater, including spring sources, outside of the ownership of Seattle Public Utilities

References

American Water Works Association, Best Practice in Water Loss Control, https://www.awwa.org/Portals/0/AWWA/ETS/Resources/WLCFlyerFinal.pdf?ver=2015-02-10-083650-287, webpage visited April 2021.

Environmental Protection Agency, SDWIS Federal Reports, https://ofmpub.epa.gov/apex/sfdw/f?p=108:103:::NO:RP::, submitted 2021, Quarter 1, webpage visited April 2021.

Kelly O'Rourke, (Water Conservation Manager, Seattle Public Utilities) email communication with Idaho National Laboratory, April 2021.

Seattle Public Utilities, Washington, 2019 Water System Plan, Volume 1, published January 2021, https://www.seattle.gov/Documents/Departments/SPU/Documents/SPUFinal2019_WSP_Volume1.pdf, webpage visited April 2021.

* In addition to the two surface water sources, SPU has wells that are available for summer peak and emergency use, though these are used infrequently. The wells can supply up to 10 mgd for approximately four months.

** Non-revenue water is the difference between the full volume of water managed by a water district and the volume of finished water delivered to the district's customers. According to the American Water Works Association (AWWA) the components of non-revenue water include unbilled authorized consumption, apparent losses, and real losses.

Idaho National Laboratory
Completion Date: 30 April 2021

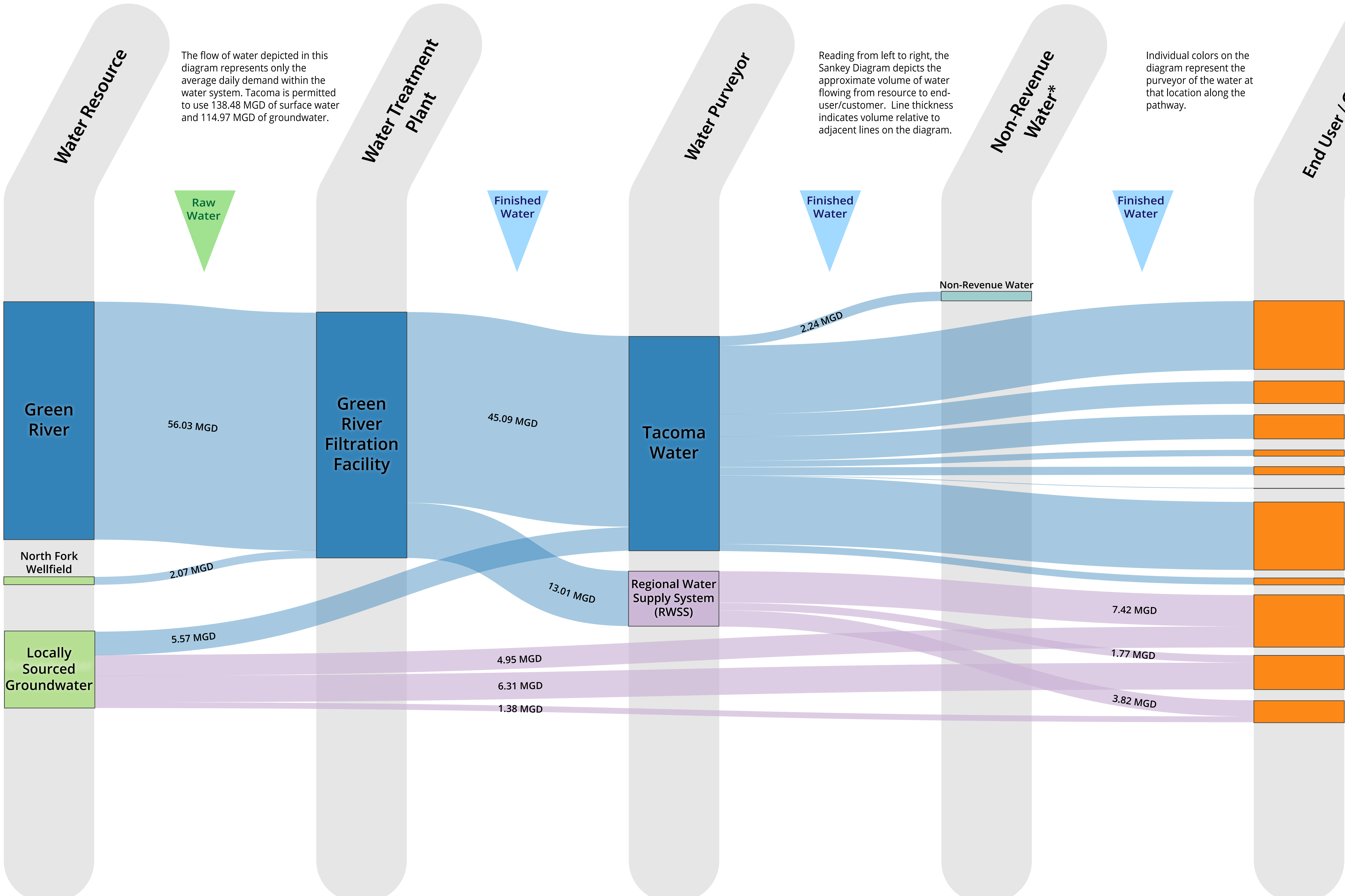
Tacoma Water System with RWSS Partners – Water Supply and Demand

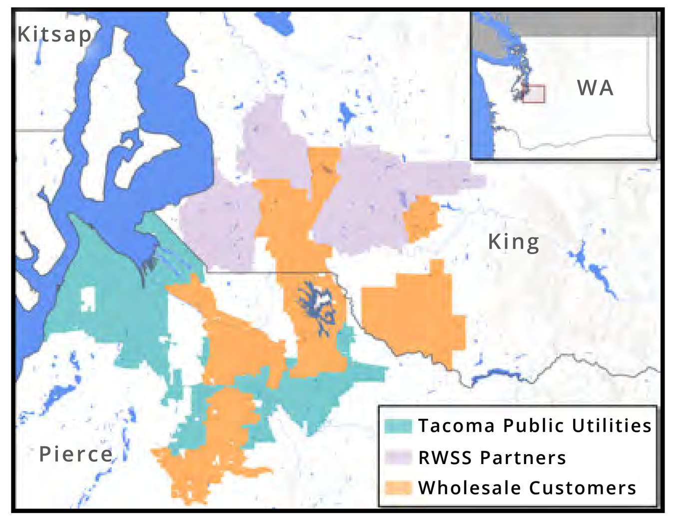
Projected Average Daily Water Use (2024)

The flow of water depicted in this diagram represents only the average daily demand within the water system. Tacoma is permitted to use 138.48 MGD of surface water and 114.97 MGD of groundwater.

Reading from left to right, the Sankey Diagram depicts the approximate volume of water flowing from resource to end-user/customer. Line thickness indicates volume relative to adjacent lines on the diagram.

Individual colors on the diagram represent the purveyor of the water at that location along the pathway.





According to Lawrence-Livermore National Laboratory "Water use data is notoriously hard to compile. Accounting policies vary between different water management districts and water use is not metered in the same way that higher-priced commodities are sold. Quantifying water use by location and sector requires substantial estimation. Water disposition is even more difficult to quantify."

Despite varying data from multiple organizations and water districts, this diagram will aid understanding of water use patterns from resource to end user throughout the Tacoma Water System.

Customer	Population	Average Daily Demand (MGD)
Tacoma Water	339,572	48.42
Single-Family Residential		16.23
Multi-Family Residential		5.34
Commercial/Industrial		5.71
Irrigation		1.47
Large Volume Commercial/Industrial		1.92
Private Fire		0.04
West Rock Paper Mill		16.07
Wholesale Customers**		1.64
Lakehaven Water & Sewer	117,000	12.37
City of Kent	70,952	8.08
Covington Water District	50,000	5.20

- Water resources and assets owned and operated by Tacoma Water
- Water resources and assets jointly funded under the Regional Water Supply System (RWSS)
- Non-revenue water use*
- Finished water customers (end users)
- Groundwater under the ownership of end user

References

Covington Water District, Washington, Water System Plan (2016), https://www.covingtonwater.com/DocumentCenter/View/67/Water-System-Plan-FINAL---May-2016, webpage visited February 2021.

City of Kent, Washington, Water System Plan 2019-2029, https://www.kentwa.gov/city-hall/public-works/water-system-plan, webpage visited February 2021.

City of Tacoma, Washington, Water System Plan (2018), https://www.mytpu.org/about-tpu/services/water/water-source/water-system-plan/, webpage visited February 2021.

Environmental Protection Agency, SDWIS Federal Reports, https://ofmpub.epa.gov/apex/sfdw/f?p=108:103::::RP::, submitted 2020, Quarter 4, webpage visited February 2021.

Lakehaven Water & Sewer District, Washington, Water System Plan Update (2016), https://www.lakehaven.org/ArchiveCenter/ViewFile/Item/1483, webpage visited February 2021.

Lawrence Livermore National Laboratory, Energy Flow Charts: Charting the Complex Relationships Among Energy, Water, and Carbon. https://flowcharts.llnl.gov/, webpage visited February 2021.

Michael Washington, (Principal Engineer, Tacoma Water) email message to Idaho National Laboratory, January 2021.

* Non-revenue water is the difference between the full volume of water managed by a water district and the volume of finished water delivered to the district's customers. It includes reservoir storage, aquifer recharge, industrial use, irrigation, effluent water discharged during water treatment processes, unaccounted for losses including seepage, runoff, and evaporation, environmental releases, etc.

** Tacoma wholesale customers include City of Fife, City of Auburn, Firgrove Mutual Water Co., City of Bonney Lake, Mountain Terrace, Fruitland Mutual Water Co., Ranier View Water Co. City of Puyallup, Summit, RSN Enterprises Inc., Coal Creek, Water Society, City of Enumclaw, Valley Water District, City of Black Diamond, and Water District #111, and Cumberland, which is solely reliant on Tacoma for potable water.

Idaho National Laboratory
Completion Date: March 17, 2021

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