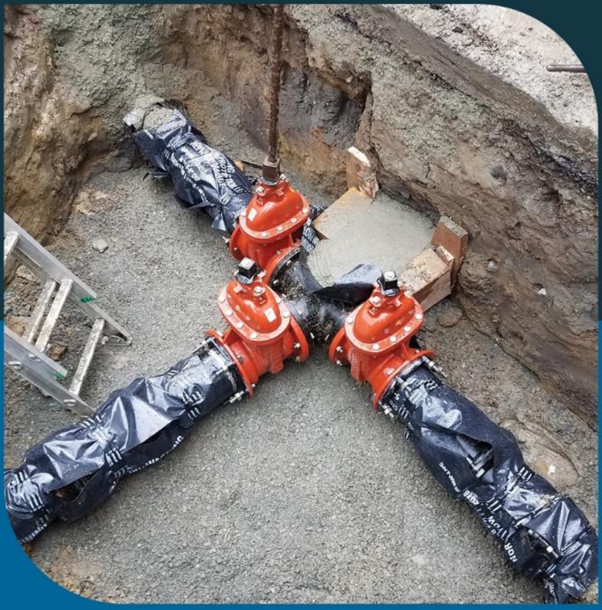
EMERGENCY WATER SUPPLY MASTER PLAN

2022

Draft



UTL-22-6747

City of Bellevue

Emergency Water Supply Master Plan

DRAFT – October 2022

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Cover Photos

From Bottom Left to Top Right: Nisqually Earthquake Damage; Installation of new distribution mains with tee and "3-pack" of isolation valves; Parksite Reservoir; Installation of Earthquake-Resistant Ductile Iron Pipe on West Lake Sammamish Pkwy; Newport Pump Station

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- Appendix A. Well Condition Assessment (Golder Associates, 3/13/2018)
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Attachment 3: Public Engagement Survey Report

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https://mil.wa.gov/preparedness

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Abbreviations

AC	Asbestos Cement
BCP	Bellevue Comprehensive Plan
BSD	Bellevue School District
BV400	Bellevue 400 Pressure Zone
CCUD	Coal Creek Utility District
CESSL	Cedar Eastside Supply Line
CIP	Capital Improvement Plan
CPOD	Community Point of Distribution (a.k.a. POD)
CSZ	Cascadia Subduction Zone
DI	Ductile Iron
DOH	Department of Health
EOC	Emergency Operations Center
ERDIP	Earthquake resistant Ductile Iron Pipe
FEMA	Federal Emergency Management Agency
gpm	Gallons per minute
HGL	Hydraulic Grade Line
LH520	Lake Hills 520 Pressure Zone
MGD	Million Gallons per Day
NIMS/ICS	National Incident Management System / Incident Command System
PE-LOS	Post-Event (or Post-Earthquake) Level of Service
Plan	Emergency Water Supply Master Plan
POD	Point of Distribution (a.k.a. CPOD)
PR	Pressure Reducing Valve
PSE	Puget Sound Energy
R&R	Renewal and Replacement
RJ	Restrained Joint Pipe
SBCC	??
SCADA	Supervisory Control and Data Acquisition

SFZ	Seattle Fault Zone
SOP	Standard Operating Procedure
SPU	Seattle Public Utilities
SS850	Somerset 850 Pressure Zone
SVA	Water Distribution System Seismic Vulnerability Assessment (Attachment 1)
TESSL	Tolt Eastside Supply Line
UASI	Urban Area Security Initiative
USEPA	United States Environmental Protection Agency
Utilities	City of Bellevue Utilities Department
WA DNR	Washington State Department of Natural Resources
WAC	Washington Administrative Code
WA-WARN	Washgington Water/Wastewater Agency Responce Network
WD97	King County Water District 97
WSDOT	Washington State Department of Transportation
WSP	City of Bellevue 2016 Water System Plan
WTPO	Water Treatment Plant Operator

1. Executive Summary

This Emergency Water Supply Master Plan (Master Plan) addresses severe and long-lasting community impacts anticipated from disasters in Bellevue's service area (shown yellow in Figure 1). It fulfills Federal law (America's Water Infrastructure Act) and Bellevue Comprehensive Plan (BCP) policy requirements for resilience planning, while increasing public awareness of water system resilience and documenting emergency levels of service as required by Washington Administrative Code (WAC) 246-290-420.5.

The Master Plan summarizes water supply vulnerabilities, estimates risks to residents and businesses, proposes new policies specific to water supply emergencies, and recommends short- and long-term mitigation, including capital investments. The Master Plan is not intended to address emergency response, nor localized brief impacts to water service (e.g. water main breaks), which are addressed in the Bellevue Utilities Emergency Management and Response Plan.

New policies are established in Chapter 2. Policies address prioritizing service to certain customers who directly support community recovery, such as hospitals, first responders, designated shelters, and essential businesses. Post-Earthquake Level of Service (PE-LOS) performance goals are established, to define expectations for how long it should take to restore service. Finally, mitigation policies to achieve those goals are proposed, including a risk-based capital investment strategy, personal preparation encouragement, and expansion of existing groundwater usage for independent supply.

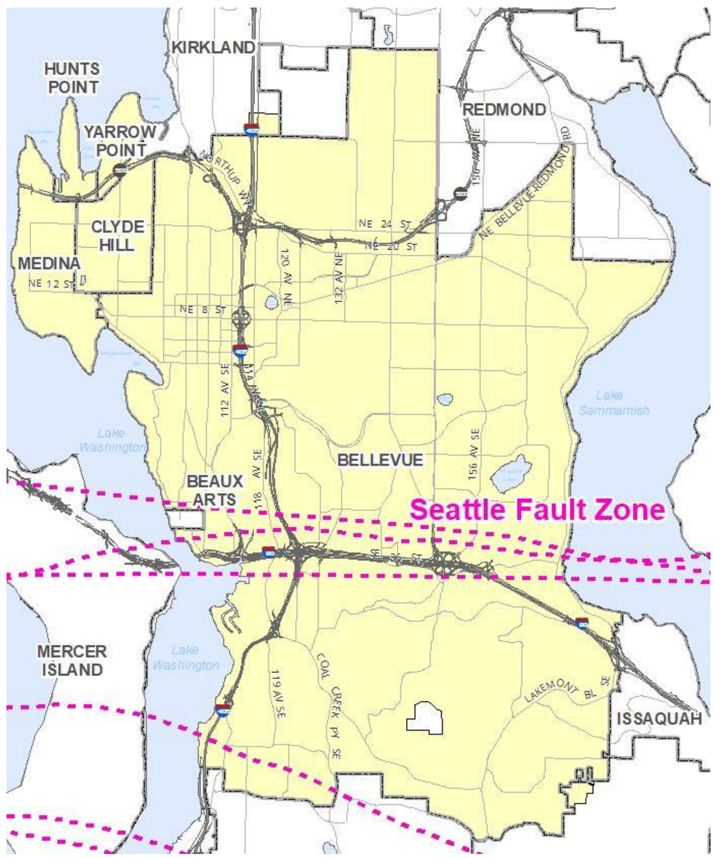


Figure 1: Bellevue's Water Service Area with Seattle Fault Zone (Source: WA DNR)

The primary hazards addressed by the Master Plan are severe earthquakes along the Seattle Fault Zone (SFZ; see Figure 1) and the Cascadia Subduction Zone (CSZ). As discussed in Chapter 3, there is less apparent risk to Bellevue's water supply from other hazards such as floods, wildfires, volcanic eruption, terrorism, etc., and many of the actions to mitigate earthquake damage would also address those hazards.

The existing water system's performance during and after the SFZ and CSZ events was simulated, based on the industry's current knowledge and observations from recent worldwide earthquakes. Results predicted over 500 main breaks and 3+ months recovery for the SFZ event in Bellevue, and over 200 main breaks with 2+ month recovery for CSZ event. The economic impacts to Bellevue solely due to water service disruption were estimated to be $8.3 and $2.3 billion for the SFZ and CSZ events, respectively.

Annualized community risk based on these impacts and the recurrence of each event is estimated at $5.2 and $4.6 million per year, respectively. Because both events will reoccur based on geologic records, the total is a cumulative annual risk of $9.8 million per year. Additional detail is provided in Chapter 3.

Impacts and Risks with Existing Infrastructure:

200-500 Main Breaks

3+ Month Recovery

$9.8M/year Annual Risk

Figures 2 and 3 show the simulated time to restore water service following the SFZ and CSZ earthquake events. Existing performance is represented in blue, demonstrating a complete loss of water supply for up to 3 weeks, and 2 to 3 months for full system recovery. Red, green and purple lines show the shortened restoration time following improvements recommended in the short-term (2035), mid-term (2050) and long-term (2070), consistent with the PE-LOS goals in Chapter 2.

In developing the PE-LOS goals, various improvement timeframe strategies were evaluated. Improvements will take time, as they require replacing a substantial amount of infrastructure. An aggressive timeframe (< 20 years) exceeds local industry norms, and does not appear to be feasible due to community impacts, availability of contractors and materials, and questions of affordability with extra-ordinary rates of construction work. A more generational approach (100 years) would leverage already planned spending with little to no added costs, but benefits would not be fully realized in our lifetimes. A targeted, risk-based approach with prioritized improvements over 50 years is recommended, as it balances optimized risk reduction, attainable goals and affordability, consistent with other utilities in Washington and Oregon.

Figure 2 – Simulated Seattle Fault Earthquake Restoration Time with Proposed Improvements

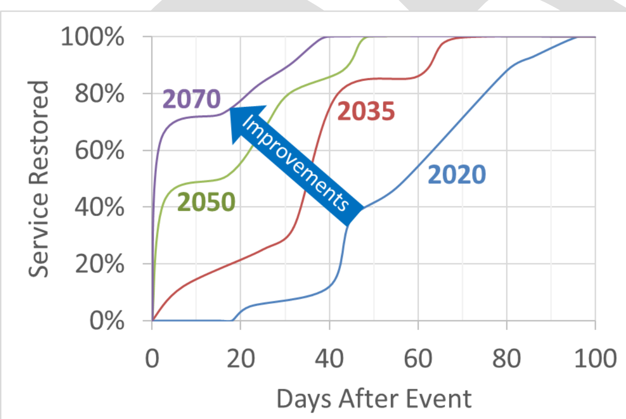
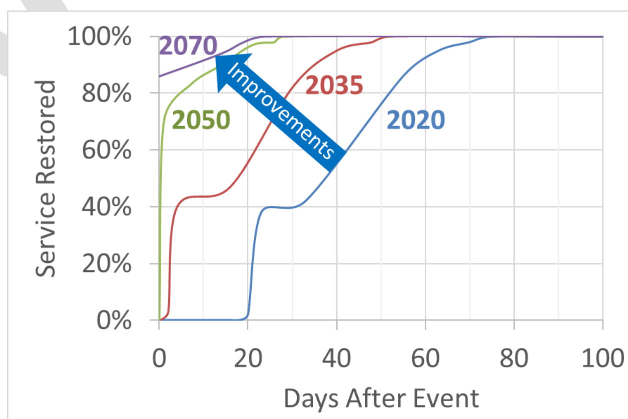


Figure 3 – Simulated Cascadia Earthquake Restoration Time with Proposed Improvements



Recovery Period*, with Proposed Improvements

2020	2035	2050	2070
2-3 Months	1-2 Months	1-4 Weeks	1-21 Days

*Time to 80% - 90% of service restored, following SFZ or CSZ event

Emergency water supply needs are evaluated in Chapter 4, to provide criteria for planning. Anticipated emergency water demands were evaluated, and a public engagement process provided insights to customer values, sensitivities, personal preparedness and ancillary needs (e.g. physical access and language translation). Estimated emergency water needs vary based on type of use, urgency, location, water volume, customer vulnerability, and other relevant factors. Immediate needs focus on life safety and first response, such as hospital operations, fire fighting and support for vulnerable populations. Short-Term needs that would be met with emergency supplies (while infrastructure is being repaired) include hygiene, basic domestic needs, and business continuity, with the goal of avoiding widespread evacuation due to unlivable conditions. Long-Term needs, after the normal water supply is restored, include ongoing maintenance and training to ensure readiness.

Coordination between City departments and across agencies in multiple levels of government is essential for responding to any catastrophic emergency. Chapter 5 addresses roles and responsibilities, agreements, inter-dependencies and shared resources across agencies, and how these factors can affect mitigation and response activities.

Recommended improvements are described in three categories:

Supply

- Improve existing wells; Install emergency wells
- Lobby Cascade/SPU to replace regional pipelines

Backbones

- Resilient pipe to key points
- Reduce valve closure delays

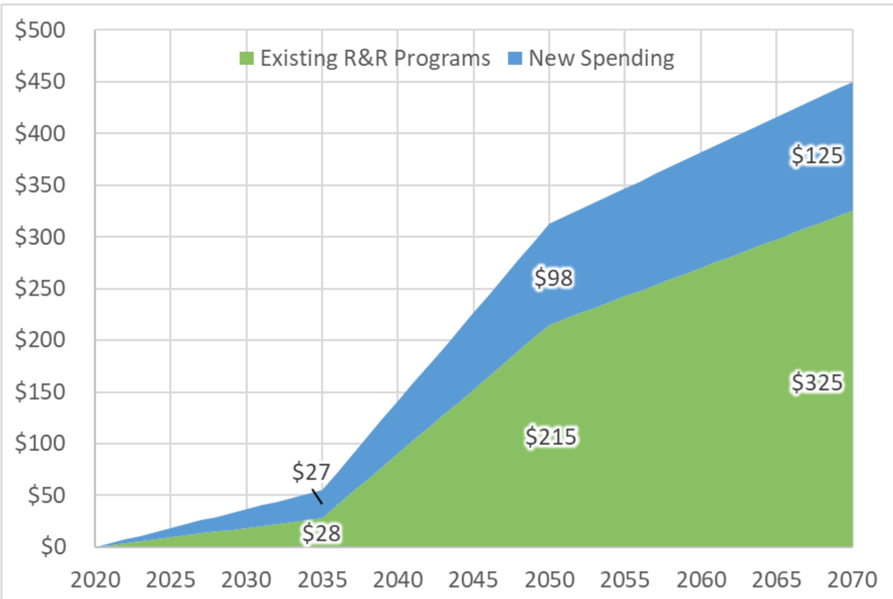
Distribution System

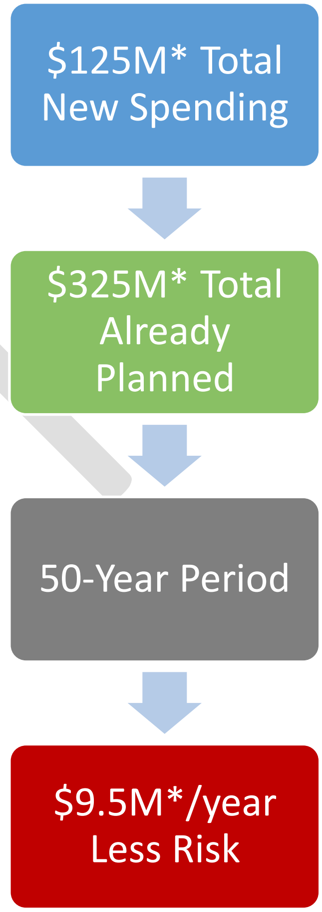
- Continue water main, pump station replacement
- Consider seismic risk when prioritizing projects

Most of the recommended improvements involve replacement of existing, aging infrastructure such as water mains, pump stations and reservoirs. These improvements are already included in the City's existing renewal and replacement (R&R) programs, so will not represent new spending (only re-prioritizing) relative to current long-term plans. In addition to the existing drivers of maintaining reliable service and minimizing long-term, life-cycle costs, these R&R programs should more heavily consider seismic resilience as part of prioritization and planning.

New proposed spending includes resilient backbone piping, improvements to the City's existing municipal water supply wells (currently used for non-potable supplies and standby service), and the siting and construction of new, emergency-only wells. In the near-term (15-year) timeframe, improvements to the City's Crossroads Wells are recommended to improve readiness in a neighborhood with numerous critical customers, essential businesses and vulnerable populations, while also making more effective use of this existing water resource. Figure 4 shows recommended spending over time, including existing R&R programs (already budgeted), and proposed new spending for groundwater wells and backbones.

Figure 4: Estimated Cumulative Recommended Spending ($ Millions)*





* Costs presented are in 2019 dollars, prior to COVID-related inflation

To quantify the basis for recommended projects, benefit/cost ratios specific to earthquake mitigation were estimated, as discussed in Chapter 7. For new spending, benefits exceed cost by ratios of 2.5:1 (over 50-years) to 5.2:1 (over 15-years). For existing programs, spending is already justified and budgeted for R&R purposes, but seismic benefits alone provide additional benefits at ratios of 0.7:1 (50-year) to 2.6:1 (15-year).

The Master Plan recommends mitigation of community impacts due to real potential disasters, using a risk-based, customer-focused rationale. The recommended actions are proposed with the goal of balancing responsiveness, attainability and affordability within a reasonable timeframe.

2. Emergency Water Supply Policies

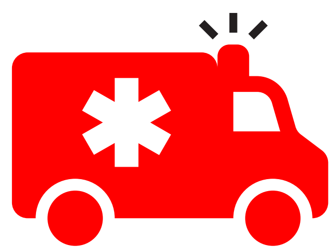
Emergency water supply policies have been developed based on seven guiding principles:

- Public Safety: Support first responders and the community to help save lives in the aftermath of a disaster.
- Social Equity: Support the City's Diversity Advantage Plan to provide access, equity, inclusion, opportunity and cultural competency.
- Economic Vitality. Support the economic health of the community during recovery from a disaster through business continuity and by allowing employees to get back to work.
- Regional Preparedness: Coordinate mitigation actions with other infrastructure sectors, adjacent water utilities, and emergency responders.
- Value: Make investments where risk reduction benefit exceeds the cost.
- Resilience. Maintain operations through resilient critical infrastructure.
- Resource Conservation. Protect and continue to use available groundwater sources .

Emergency water supply policies are listed below in **bold**, followed by the applicable guiding principle(s) and explanations to provide context. References to the City of Bellevue Comprehensive Plan (BCP) show consistency with City-wide policies

2.1 Health Care Providers

Invest in resiliency with the goal to provide uninterrupted water service at emergency rooms, and prioritize service restoration to other health care providers.



Guiding Principles: Public Safety, Regional Preparedness, Resilience

Emergency room hospitals depend on water to stay in operation, and play an immediate and crucial role in saving lives at all times, and particularly after a disaster such as a severe earthquake. Regional[1,2], and national[3] industry guidance recognizes that the highest level of service is justified for these facilities.

Other health care providers such as dialysis centers and urgent care clinics are important and necessary for supporting public health and safety, and should be prioritized. These facilities do not typically provide immediate care for life-threatening situations, and are distributed broadly throughout the City, making it impractical to ensure uninterrupted service to them all. Long-term resiliency improvement plans should prioritize improving resiliency to all medical facilities.

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[1] *Regional Water Supply Resiliency Project, Phase 2 Summary Report*. Water Supply Forum, July 2018.
[2] *Resilient Washington State*. Washington State Seismic Safety Committee, Emergency Management Council, 2012.
[3] *Community Resilience Planning Guide for Buildings and Infrastructure Systems (NIST Special Publication 1190)*. National Institute of Standards and Technology, US Dept of Commerce, May 2016.

2.2 Alternative Fire Fighting Methods

Coordinate, facilitate and develop alternative fire-fighting strategies identified by the Fire Department for use during disaster recovery, prior to full system restoration.

Guiding Principles: Public Safety

This policy acknowledges that the water system's normal capacity to support firefighting will be compromised following a water supply emergency. Fires can occur anywhere in the water service area, making it impractical to prioritize service restoration based on fire response.

The Utilities Department should communicate and review water supply risks with the Fire Department, understand post-disaster firefighting tactics, and develop ways to support firefighters with access to water when appropriate during periods of limited service. The Fire Department employs numerous strategies in response to fire events, many (but not all) of which require water. Examples of water-based tactics may include hydrants directly connected to reservoirs or resilient pipelines, groundwater fill sites, and siting of such facilities where surface water drafting (e.g. boat ramps, pools) are unavailable..

2.3 Personal Preparedness

Encourage residents to store 14 days of water.

Guiding Principles: Public Safety, Resilience

This policy is consistent with current guidance from the Washington State Emergency Management Division[4], and with City of Bellevue Comprehensive Plan policy N-3[5].

[4] https://mil.wa.gov/preparedness

[5] BCP N-3: "Equip residents, businesses, and community service providers through education and training to be active participants in public safety (including, but not limited to, emergency preparedness, crime prevention, first aid and fire prevention)."

2.5 Shelters and Points of Distribution

Prioritize mitigation and response efforts to support the readiness of pre-identified shelters and points of distribution.

Guiding Principles: Social Equity, Resilience

Pre-identified Community Points of Distribution (CPODs) and/or shelters are locations where basic supplies of water can be provided to residents who lack the means or ability to store or obtain water following a disaster. Currently such locations include some City-operated facilities such as specific parks or community centers[6], some schools[7], and other locations as identified by the City's Office of Emergency Management. By supporting the readiness of CPODs and shelters, the City supports community stability.

Depending on the extent of infrastructure damage, water might be supplied to a CPOD or shelter via the normal water distribution system, trucks carrying bulk water from other locations, an on-site groundwater supply or reservoir, or some other method, and then distributed in suitable individual containers. Pre-bottled water might also be supplied following a disaster, but would typically be procured through the Emergency Operations Center from outside the City, while the City works to restore normal supplies. This policy supports investment in a more resilient water distribution system and faster restoration of normal service to CPODs.

2.6 Business Continuity

Establish water service restoration goals to support business continuity.

Guiding Principles: Economic Vitality, Resilience

Non-essential businesses should be a lower priority than critical customers such as hospitals, or community recovery facilities such as schools. However, consistent with BCP policies[8,9,10], businesses based in Bellevue should be confident that water service will be restored in a timely manner. Historical disaster events in the United States and worldwide have shown that if service recovery does not occur steadily or sufficiently, businesses may permanently relocate out of the impacted area, with long-term negative consequences to the local economy.

[6] *Community Points of Distribution Annex (Draft)*. City of Bellevue, 2011.
[7] *Emergency Assistance Mutual Aid Agreement*. The City of Bellevue and Bellevue School District, 2017.
[8] BCP ED-1: "Maintain a business climate that supports the retention and expansion of the city's economic base."
[9] BCP ED-32: "Continue to identify, construct and maintain infrastructure systems and facilities required to promote and sustain a positive economic climate. Anticipate needs and coordinate city infrastructure investments with economic development opportunities."
[10] BCP ED-33: "Maintain and improve communications, electric utility, and other infrastructure needed to support the city's economic needs and growth."

2.7 Inter-Dependent Sector Coordination

Coordinate and optimize emergency preparation with inter-dependent infrastructure sectors (power, transportation, communications, etc).

Guiding Principles: Public Safety, Economic Vitality, Regional Preparedness

The regional nature of risks posed to Bellevue's water distribution system necessitate a coordinated approach to disaster mitigation and response. Efforts to restore water service following a regional disaster such as a severe earthquake will be complicated by impacts to other sectors such as transportation, power, communications, etc. Conversely, efforts to restore health care services, schools, wastewater service, local construction and other economic activity will be impeded by lack of water service.

2.8 Emergency Mitigation Investments

Identify and invest in water system reliability and resiliency improvements where the benefits of reduced risk to the community exceed the costs of the improvement. Prioritize improvements with the highest benefit per cost.

Guiding Principles: Value

Economic, social and environmental risks to the broader community, not merely direct risks to the water system, should all be used to estimate risks, event impacts, and the benefits (reduced risk) of mitigation projects. In situations where one customer or a group of customers benefit disproportionately, the City may partner with those customers for joint-funded improvements.

The City should also identify and pursue grant funding opportunities to mitigate water supply emergencies and improve the benefit/cost for rate payers.

This policy conforms to industry best practices, including AWWA Standard J100[11].

[11] Standard J100: Risk and Resilience Management of Water and Wastewater Systems. AWWA, 2010. "Calculate the net benefits and benefit-cost ratio (and/or other criteria that are relevant in the utility's resource decision-making) to estimate the total value and risk-reduction efficiency of each option."

2.10 Post-Event Level of Service Goals

The City will establish short-term (2035), medium-term (2050) and long-term (2070) post-event level of service (PE-LOS) goals, and invest as needed in resiliency to meet those goals.

Guiding Principles: Regional Preparedness, Resilience

This policy acknowledges that with existing infrastructure, widespread water service disruption is likely in the event of a severe earthquake. Significant investments are required to improve anticipated performance of the water system during and after such an event.

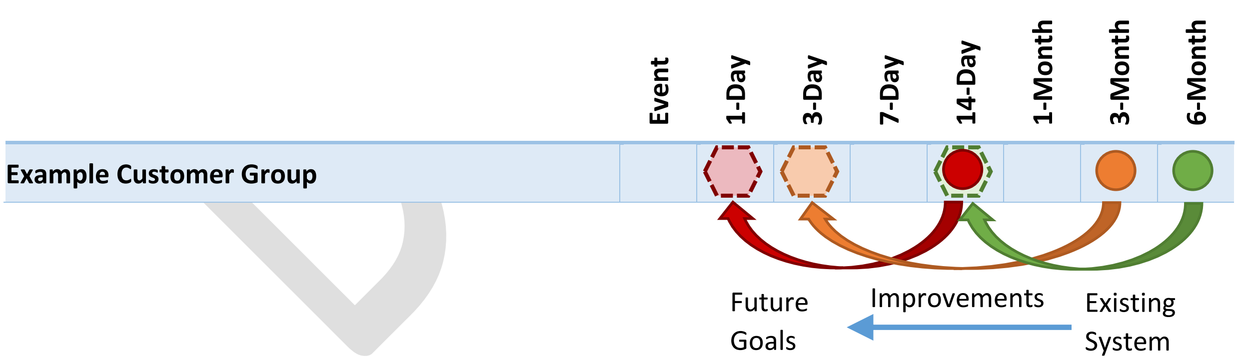
Washington Administrative Code (WAC) does not establish minimum levels of service for emergency conditions. WAC stipulates that the level of reliability during emergency conditions shall be "in accordance with consumer expectations" (WAC 246-290-420.5). Therefore it is required that PE-LOS goals be understood and agreed upon by the community.

This policy conforms to and implements BCP Policies N-4[12], CF-8[13], CF-12[14], UT-2[15] and UT-41[16].

Short-term (2035), medium-term (2050) and long-term (2070) PE-LOS goals are shown on the following pages. More information on the development of these goals, including the alternatives considered, is provided in Section 6.4. Further detail is in Attachment 1-G.

The figure below provides an example of how PE-LOS goals are illustrated, and how improvements reduce the time required to restore service after the event.

Figure 5: PE-LOS Goals – Example



Existing PE-LOS: ● = 20%-30% Operational. ● = 50%-60% operational. ● = 80%-90% operational

PE-LOS Goals: ⬡ = 20%-30% Operational. ⬡ = 50%-60% operational. ⬡ = 80%-90% operational

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[12] BCP N-4: "Plan and prepare for the response, recovery, and mitigation of potential disasters and hazards."
[13] BCP CF-8: "Use adopted Level of Service, operating criteria or performance standards to evaluate capital facilities' needs."
[14] BCP CF-12: "Maintain the post-disaster Response and Recovery Plan that ensures the city's capability to recover and reconstruct from a disaster."
[15] BCP UT-2: "Build and manage city-owned utility infrastructure assets to reduce the likelihood of risks to public safety, property and environment, and disruption due to asset failure."
[16] BCP UT-41: "Provide reliable water service for domestic use, fire flow protection, and emergencies."

Figure 6: Seattle Fault Zone Event – 2035 PE-LOS Goals

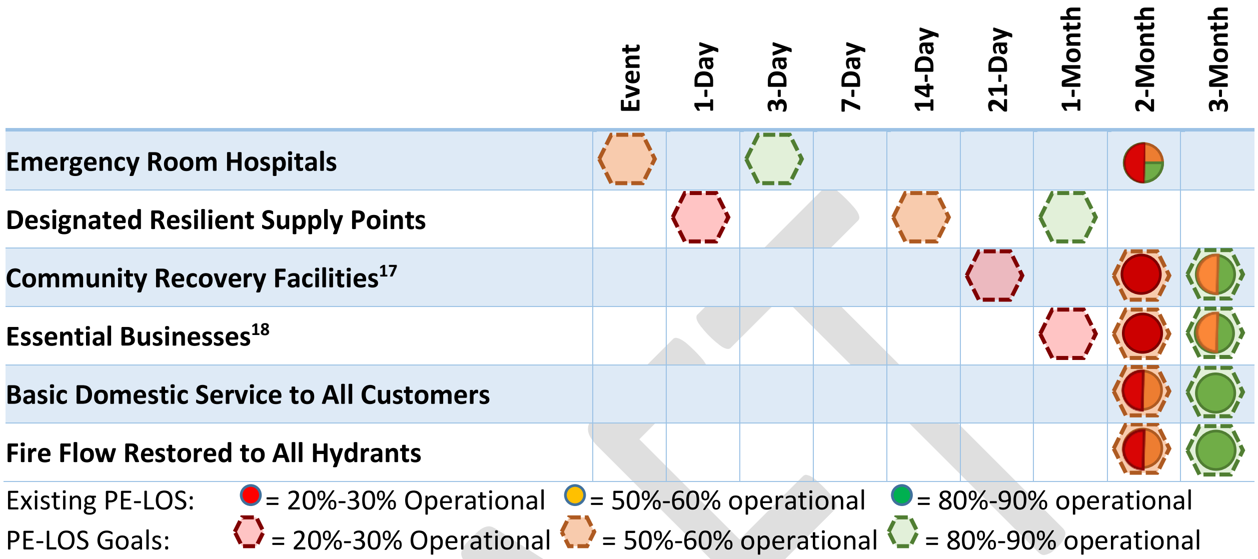
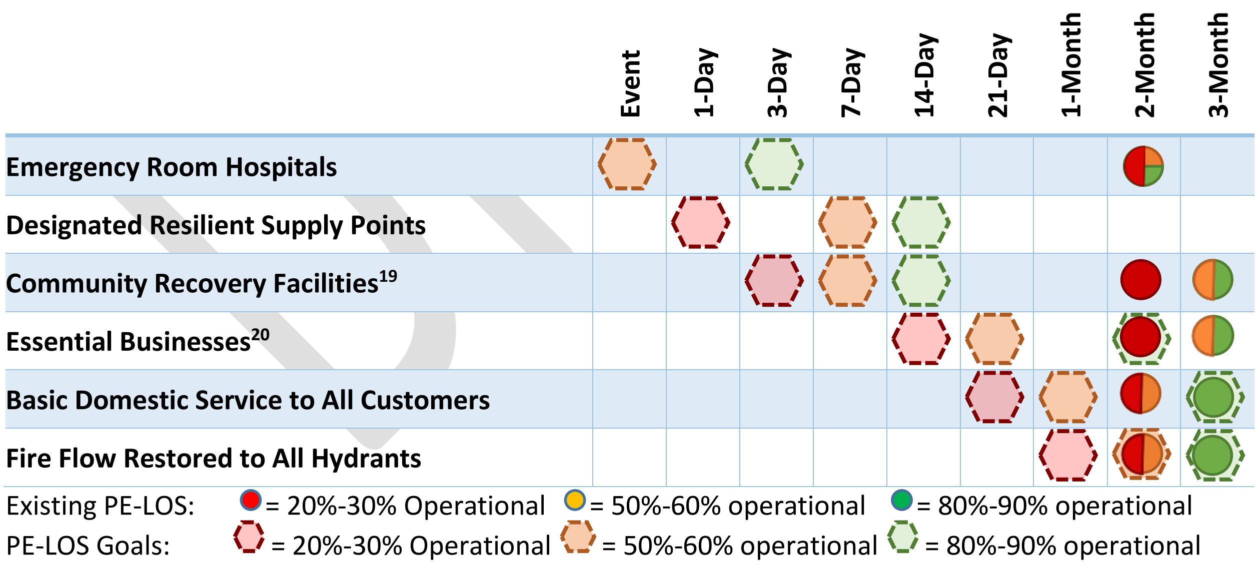


Figure 7: Seattle Fault Zone Event – 2050 PE-LOS Goals



[17] Designated shelters, schools, urgent care and dialysis clinics, other emergency services, vulnerable housing, etc
[18] Grocery stores, pharmacies, etc
[19] Designated shelters, schools, urgent care and dialysis clinics, other emergency services, vulnerable housing, etc
[20] Grocery stores, pharmacies, etc

Figure 8: Seattle Fault Zone Event – 2070 PE-LOS Goals

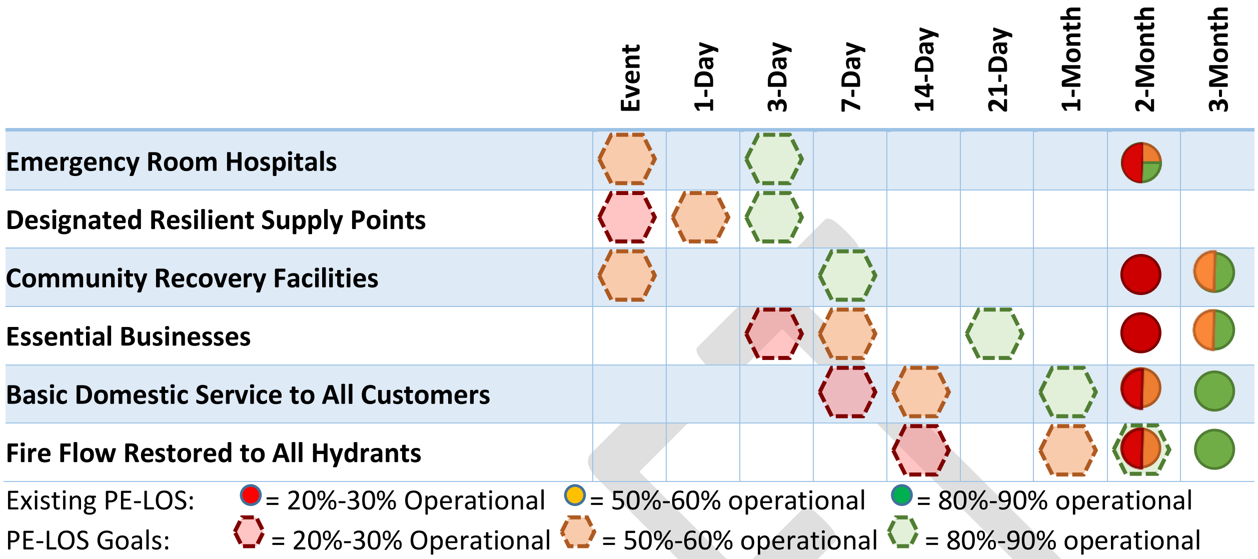
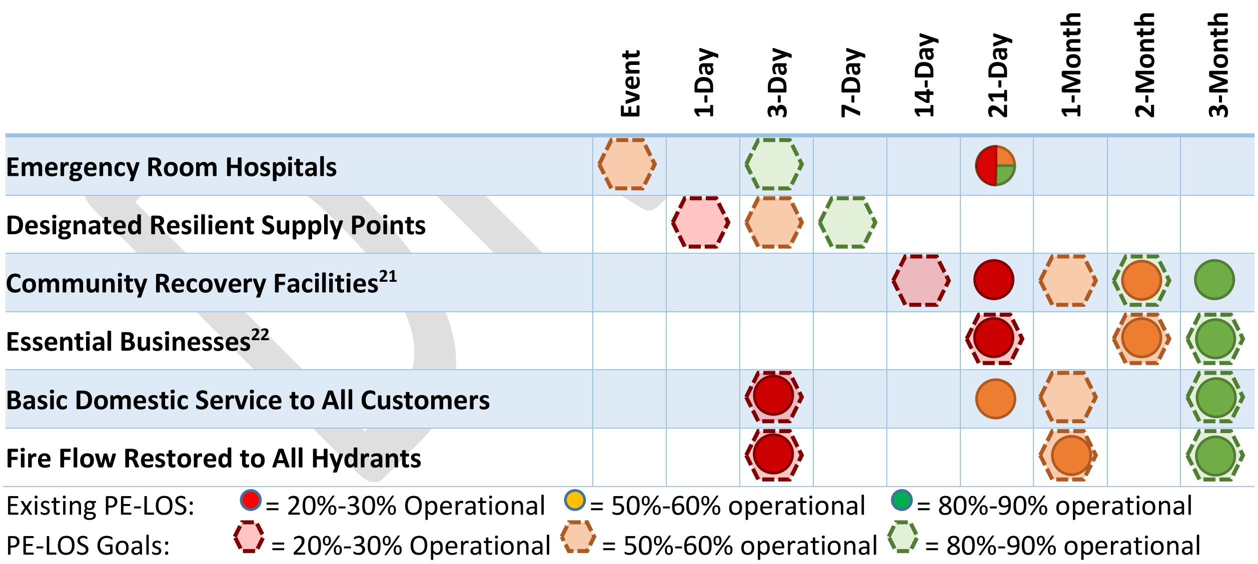


Figure 9: Cascadia Subduction Zone Event – 2035 PE-LOS Goals



[21] Designated shelters, schools, urgent care and dialysis clinics, other emergency services, vulnerable housing, etc
[22] Grocery stores, pharmacies, etc

Figure 10: Cascadia Subduction Zone Event – 2050 PE-LOS Goals

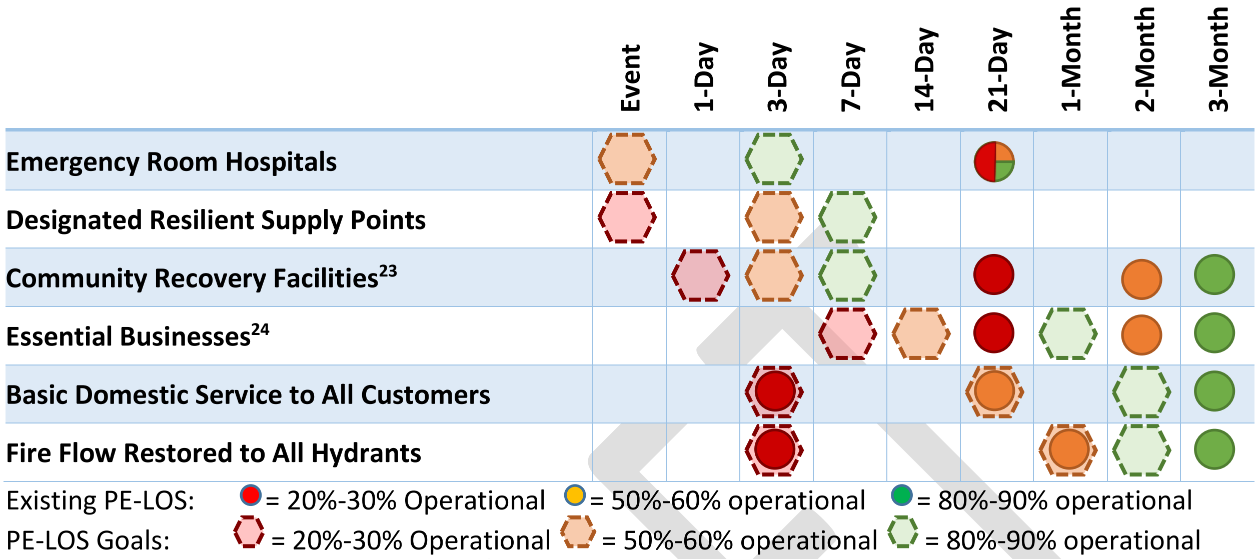
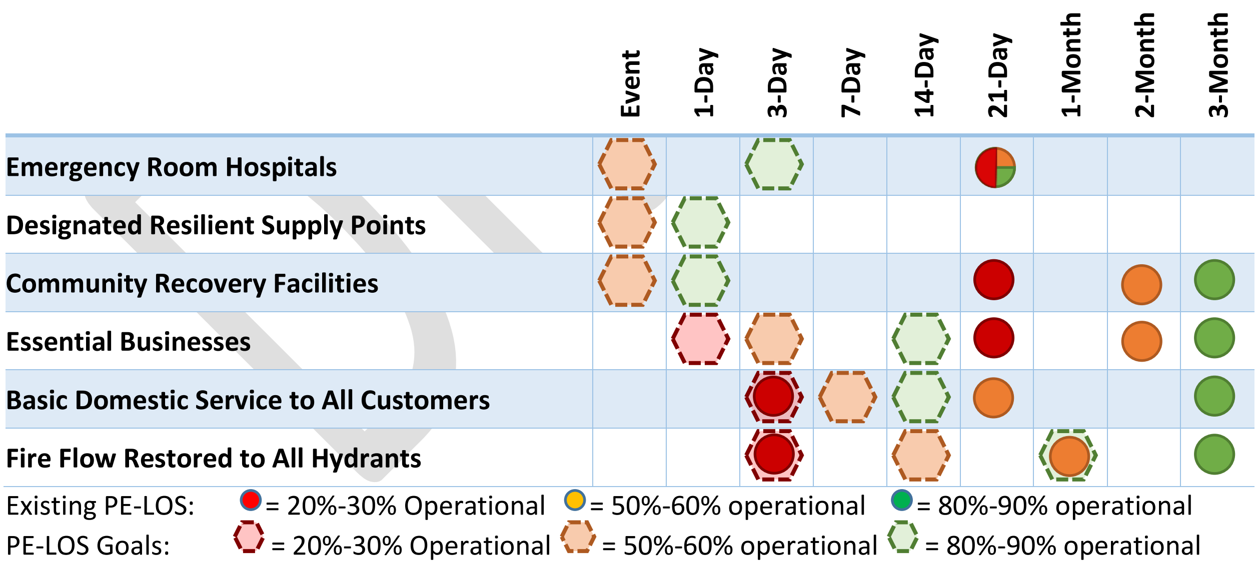


Figure 11: Cascadia Subduction Zone Event – 2070 PE-LOS Goals



[23] Designated shelters, schools, urgent care and dialysis clinics, other emergency services, vulnerable housing, etc
[24] Grocery stores, pharmacies, etc

2.11 Groundwater Supplies

The City should invest continued capital and maintenance to provide reliable and resilient wells.

Guiding Principles: Resilience, Resource Conservation

Groundwater wells provide viable, local and independent water supply redundancy to support the community following a disaster. Wells require investment to maintain capacity and readiness.

2.12 Well Head Protection

Restrict land use and establish Critical Areas near wells to preserve water quality.

Guiding Principles: Public Safety, Resource Conservation

WAC 246-290-135 requires certain source water protection measures, including a sanitary control area of at least 100-feet radius around the well, and a Well Head Protection Area. Sanitary controls generally include restrictions on land use, and must be recorded by covenant to the property. Well head protection areas are larger (ten-year groundwater travel distance) but less restrictive, and may still require agreements pertaining to use of potential contaminants such as pesticides, fertilizers, or industrial chemicals.

This policy should be considered and communicated when siting new wells, and when improving existing well sites. It augments and supports BCP critical area policies.[25,26,27,28]

[25] BCP EN-81: "Use the best scientific information available in an adaptive management approach to preserve or enhance the functions and values of critical areas through regulations, programs, and incentives."
[26] BCP EN-83: "Recognize critical area function in preparing programs and land use regulations to protect critical areas and to mitigate the lost function due to unavoidable impacts."
[27] BCP EN-88: "Develop partnerships with land conservation organizations to acquire critical areas and buffers to protect and restore critical areas functions."
[28] BCP EN-89: "Explore opportunities for public acquisition and management of key critical areas of valuable natural and aesthetic resources, and fish and wildlife habitat sensitive to urbanization through a variety of land acquisition tools such as conservation easements and fee-simple purchase."

DRAFT

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3. Hazards and Impacts

Numerous hazards threaten the reliability of the City's water supply and distribution network, and create risks for the local community.

3.1 Existing Infrastructure

The City's water service area (shown in Figure 1) includes the Cities of Clyde Hill and Medina, the Towns of Hunts Point and Yarrow Point, and the entire City of Bellevue except the Hilltop Community. The City serves a population of roughly 150,000 residents and over 150,000 jobs. The distribution system includes over 600 miles of pipe, approximately 72 pressure zones, 150 pressure-reducing valve (PRV) stations, 6,000 fire hydrants, 10,500 main isolation valves, over 41,000 customer meters, 24 active reservoirs, and 21 pump stations. Bellevue also owns a share of 4 additional reservoirs that are maintained by neighboring utilities. More information on the City's water system is provided in Chapter 1 of the 2016 Water System Plan (WSP).

The City's Infrastructure, particularly buried piping, was planned and constructed prior to an understanding of the relevant hazards, resulting in significant vulnerabilities.

Currently, the regular supply of water comes from Seattle Public Utilities' (SPU's) Tolt and Cedar watersheds. After treatment, this water is delivered to the City's service area by transmission mains owned and operated by SPU.

Originally, the sole supply of water to Bellevue's service area was wells, shown in Figure 12. Although the City's primary supply of water today comes from SPU, the Water District #97 (WD97) wells 3, 5, 6 and 7 are still controlled and maintained by the City. These wells are not currently equipped to provide potable water, but are approved by Washington State Department of Health (DOH) for emergency use.

Existing Water Supply Facilities

Figure 12

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3.2 Hazards

A cursory assessment of numerous potential hazards has been performed, including floods, source water quality problems, terrorism, and others. As described below, earthquakes appear to be the highest-risk hazard by far for Bellevue, based on known information.

Flood

Despite Bellevue having over 19 miles of shoreline[29], including lakes, sloughs and other water bodies, flooding does not appear to be a significant risk to the City's water distribution system due to local topography. As shown in Figure 13, local floodplain areas are limited, and do not include any reservoirs, pump stations, pressure-reducing valves or inlet stations.

The City does have approximately 10 miles of water mains, 20 fire hydrants and 8 blow-offs in flood plain areas.

Earthquake

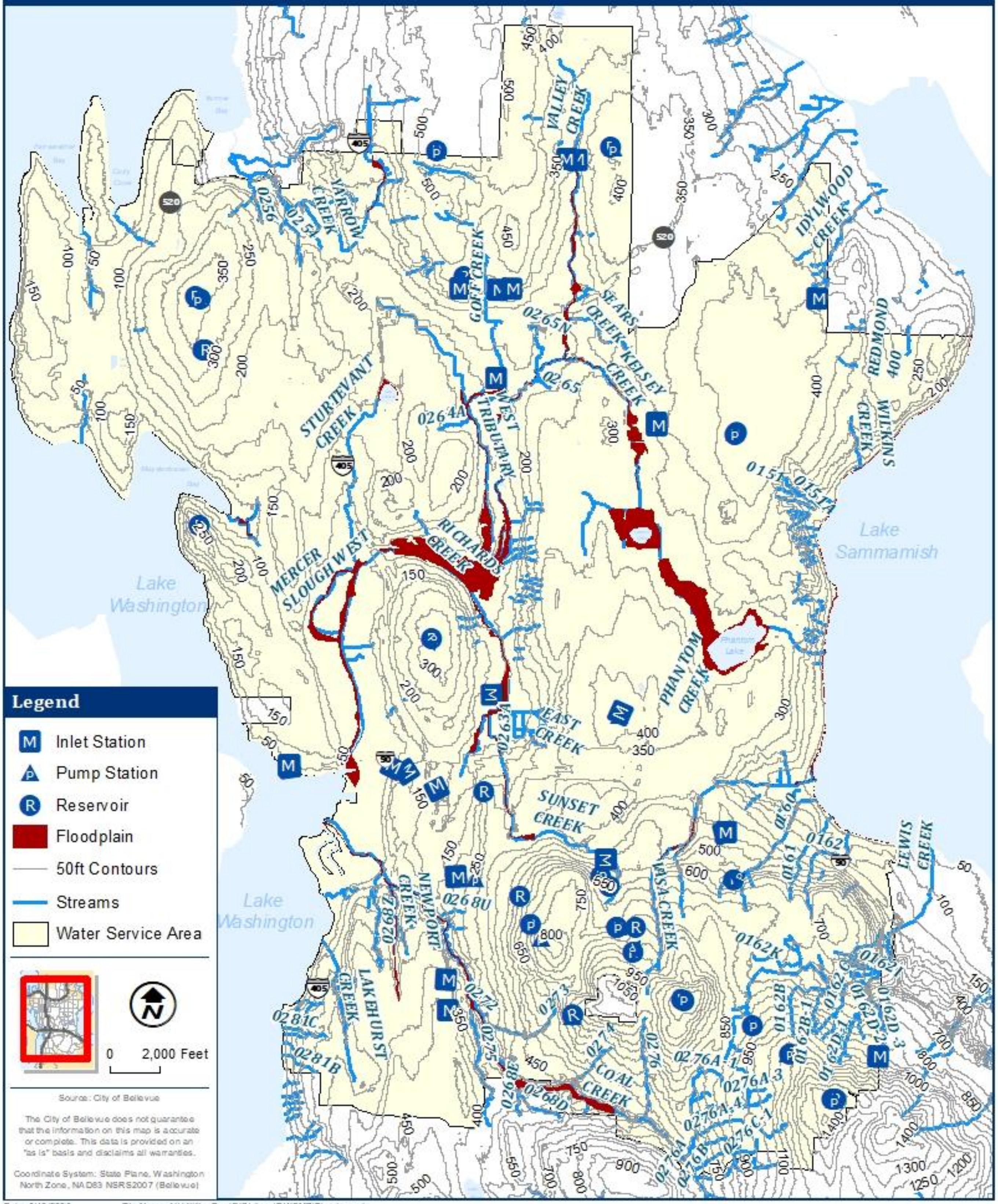
Recent geological discoveries in Western Washington have revealed hazards that were not understood during development of regional and local water infrastructure. SPU has estimated[30] a 15% to 20% likelihood in next 50-years of losing all water supply due to either a Seattle Fault Zone (SFZ) or Cascadia Subduction Zone (CSZ) earthquake.

As part of the SVA, the City's consultants evaluated local seismic threats and defined the highest-risk seismic event scenarios to be evaluated. This evaluation is documented in Attachment 1-A, including maps of shaking intensity, liquefiable soils, and seismically-induced landslide risks.

[29] City of Bellevue Comprehensive Shoreline Master Program Update – Conditional Approval, Resolution Number 8922. June 1, 2017 letter from Washington State Department of Ecology.
[30] *Water System Seismic Study Summary Report*. Seattle Public Utilities, 2018

Flood Plains and Elevation

Figure 13



Landslides and Erosion

The primary landslide risks to Bellevue's water supply are along regional water transmission pipelines managed by Seattle Public Utilities, outside of Bellevue's jurisdiction or control. Within Bellevue, although singular landslides present risks to nearby infrastructure and property, they are not a threat to overall water supply. For these reasons, this Plan focuses on landslides only in the context of a major earthquake, where multiple seismically-induced landslides could occur simultaneously.

Seismically-induced landslide hazards specific to the SFZ and CSZ earthquakes are mapped in Attachment 1-A. Water infrastructure potentially vulnerable to seismically-induced landslides in Bellevue include some water distribution mains, and the following major facilities:

- Factoria Reservoir, due to its location on sand fill atop a 25%-30% slope
- Forest Hills Reservoir and Pump Station, due to their location atop a steep slope (>40%) critical area
- Parksite Reservoir and Pump Station, due to being at the base of a steep slope (>40%) critical area

Actions to mitigate risks to the facilities listed above are discussed in chapter 6. Local distribution mains are less critical than major facilities, and will be mitigated according to the risk-based water main replacement program prioritization.

Source Water Quality Event

Bellevue's primary source water supplies (managed by Seattle Public Utilities) are in protected watersheds and generally not susceptible to contamination from industrial pollution or other unnatural contamination. However, algae blooms, forest fires, volcanic ash, and other natural events do pose some risk to SPU's supplies.

Occasional algae events occur in SPU's unfiltered Cedar water supply, typically with only minor impacts to system operations in Bellevue. Such events would generally only impact service if severe enough that SPU determined its facilities could not effectively treat the source water, and a source shutdown was required. In that instance, it is unlikely that the Tolt and Cedar supplies would both be impacted.

Mitigation measures for a severe source water quality event that impacts supply would be common with those for a seismic event, because Bellevue only manages water distribution (not treatment). Therefore, for Bellevue's planning, water quality events should represent some additional level of risk (and greater benefit from mitigation), but likely not result in additional types of mitigation measures. Some specific response actions are appropriate (e.g. accelerated cleaning of strainers in PRV stations), but beyond the scope of the Master Plan.

Intentional Acts

The City evaluated the threat of intentional acts of sabotage as part of America's Water Infrastructure Act (AWIA) compliance. This included physical sabotage and cyber attacks.

Physical attacks are generally expensive, difficult to execute, and have limited, localized impacts. They are also considered to be very unlikely except during war or rebellion. One of the best mitigation actions for physical attacks is to reduce criticality through robust physical and operational redundancy, allowing continuous operation even if a facility is destroyed. Redundancy improvements are logical to mitigate a wider disaster (such as a severe earthquake), and simply to provide operational flexibility for maintenance activities, but threat reduction from physical attacks should also be considered as one of the benefits to add redundancy.

Physical security at above-ground facilities is another mitigation tactic. The City has already adopted and continues to implement physical security measures.

The threat of cyber attacks is increasing, due to the widespread availability of sophisticated cyber-warfare technologies on the open market, and the lowering cost, effort and knowledge required to mount an attack. Cyber attacks are a pervasive financial threat, but that is outside the scope of this Master Plan. The potential water supply operational impacts of cyber attacks vary widely, but can be mitigated by many of the same network security measures used to mitigate financial threats, and by the infrastructure improvements used to impacts of power outages or other emergencies.

Other Events

A health crisis such as a global pandemic can have significant impacts to Bellevue's Utilities Department, such as illness, mandatory social distancing, and demands on staff for City-wide response (e.g. the Emergency Operations Center). In addition, the increased emphasis on sanitation during such a crisis makes reliable water service even more important. However, this type of event does not pose a direct threat to water infrastructure. Although concurrent pandemic during another type of emergency would severely hamper the City's ability to respond to both, the likelihood of simultaneous catastrophic events is unreasonably small. Pandemic response is addressed in the City's Continuity of Operations Plan.

3.3 Impacts

Community impacts due to severe earthquakes have been evaluated. Impacts due to other hazards have not been analyzed in detail, because they carry significantly lower risk as described above, and because those impacts would be mitigated by the same actions taken to mitigate earthquake impacts.

Service Impacts

As part of the SVA, post-earthquake customer service levels in Bellevue have been simulated based on known geological hazards, current system information, and observed water system response from past worldwide earthquake events. For the CSZ and SFZ events, separate probabilistic, 10,000-iteration "Monte Carlo" simulations were performed to estimate the most likely failures and service impacts throughout the system. Another simulation was then performed to estimate the service restoration time after the event, based on available labor and prioritized main break repairs to benefit the maximum number of customers. Table 1, Figure 14 and Figure 15 show anticipated impacts to the existing water system following either of these two severe local earthquake scenarios.

Table 1: Simulated Earthquake Customer Service Impacts with Existing Infrastructure

Event	Frequency	Pipe Repairs	Customer Service Restored (%) after: 3 days	30 days	45 days	70 days	90 days
Cascadia Subduction Zone	500 yr	220	35%	40%	70%	100%	100%
Seattle Fault Zone East	800 yr*	540	0%	5%	22%	60%	100%

* Estimated 50% likelihood of full Seattle Fault eastern rupture during 800-year event

Economic Impacts

The economic impacts to the community of a complete loss of water supply would be severe and long-lasting. [Cite references with sensitivity factors; potential for permanent business relocation; indirect vs. direct to exclude losses due to other factors].

As shown in Figure 16, HDR Engineering, Inc estimated[31] a cumulative $960,000,000 system-wide loss in wages and business activity in Bellevue from only a 3-week water supply disruption (not based on any specific event). SPU estimates a 15% to 20% likelihood of such an event to occur in next 50-years[32] (0.3% to 0.4% chance each year).

Subsequently, as part of the SVA a more detailed evaluation of both the SFZ and CSZ earthquake impacts was performed, with results shown in Table 1. Cumulative annual risk to the community is estimated at $9.8 Million per year. This evaluation considered the restoration times shown in Figures 14 and 15, and estimated economic impacts using population (for residents) or tax revenues and water dependency (for businesses).

[31] *Bellevue Emergency Water Supply Master Plan – Economic Losses Due to Potential Water Outage*. HDR, 5/4/2018.

[32] *Water System Seismic Study Summary Report*. Seattle Public Utilities, 2018

Figure 14: CSZ Event Simulated Service Restoration Time with Existing Infrastructure

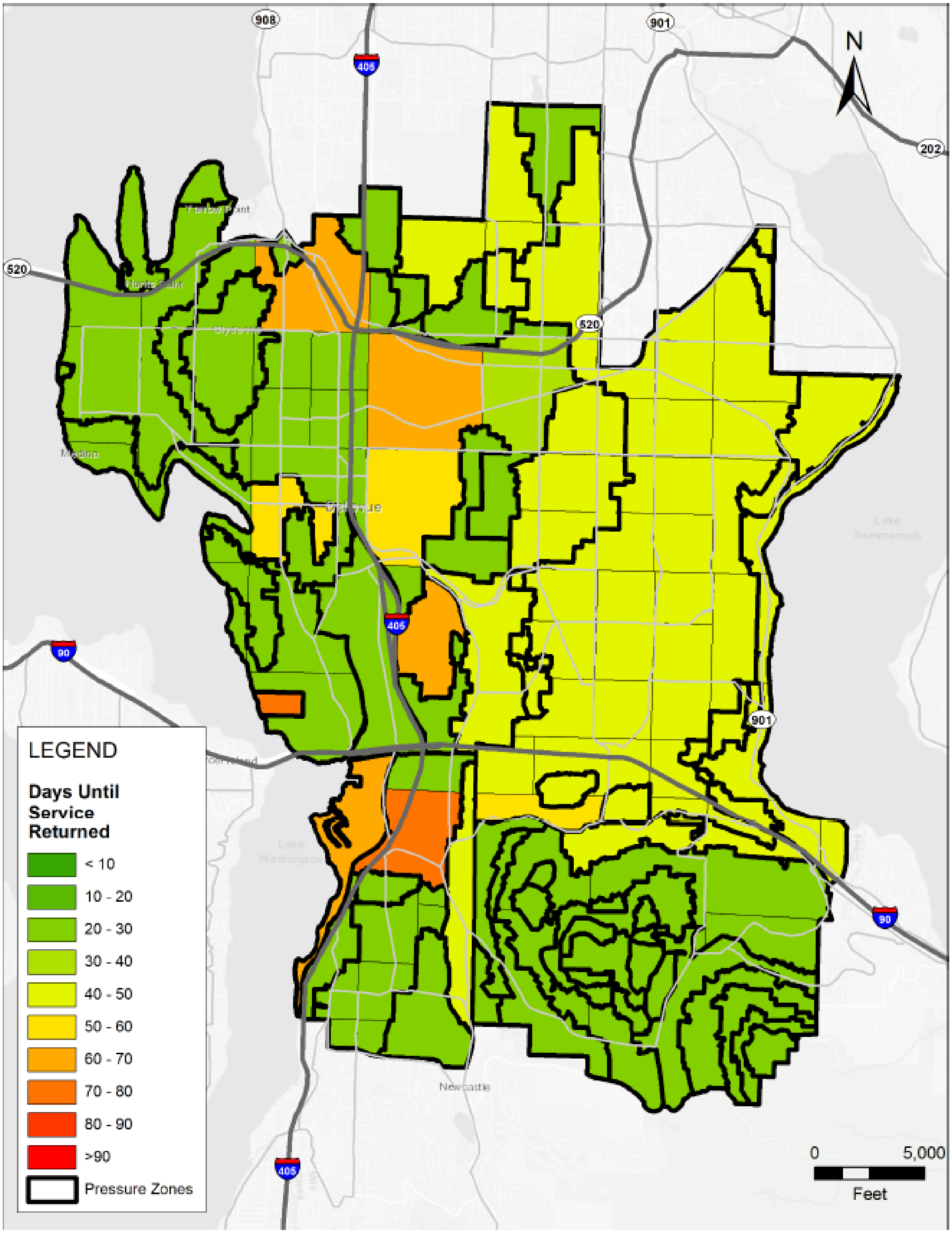


Figure 15: SFZ Event Simulated Service Restoration Time with Existing Infrastructure

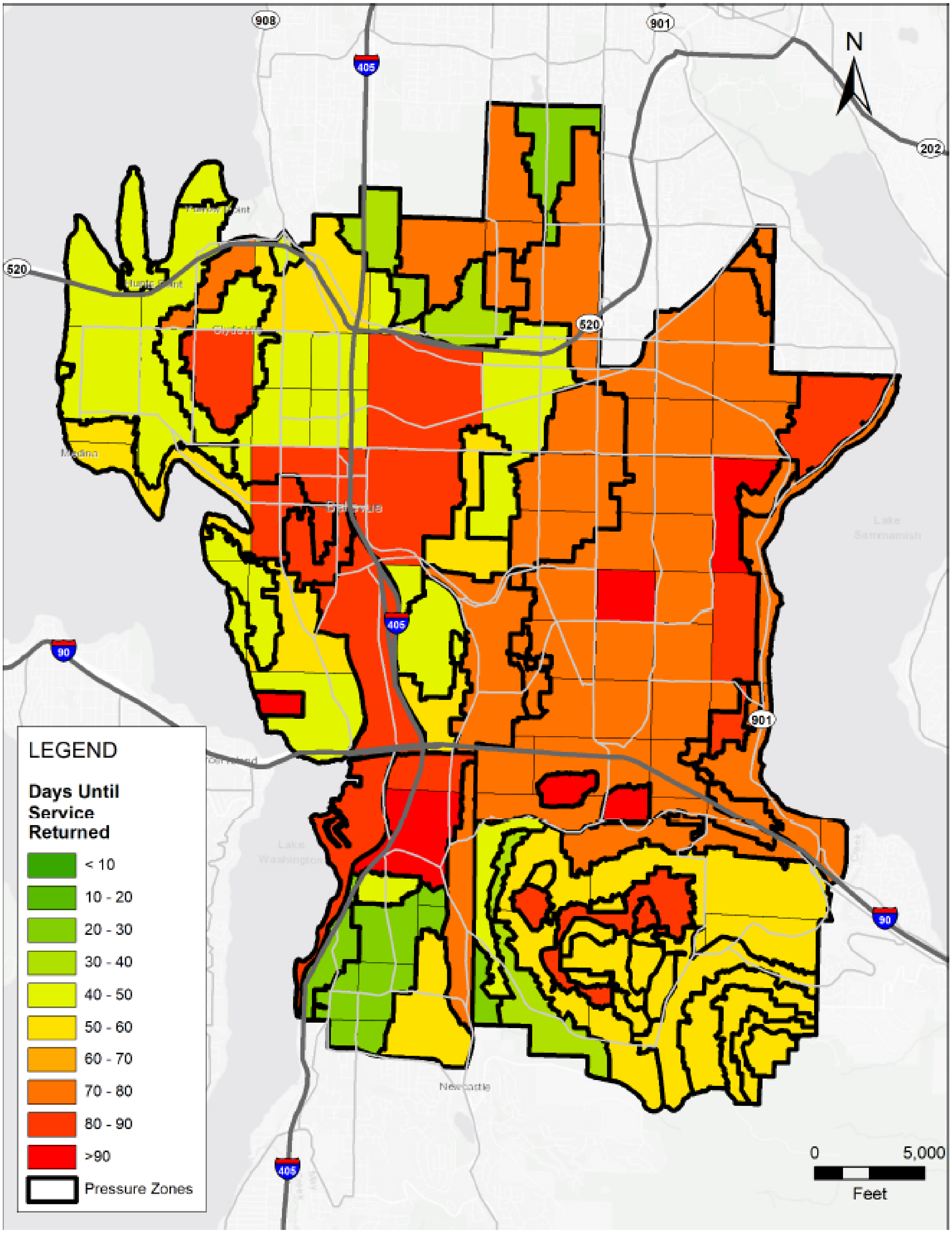


Figure 16–- Economic Impact of Complete Water Supply Disruption to Bellevue (2019 dollars)

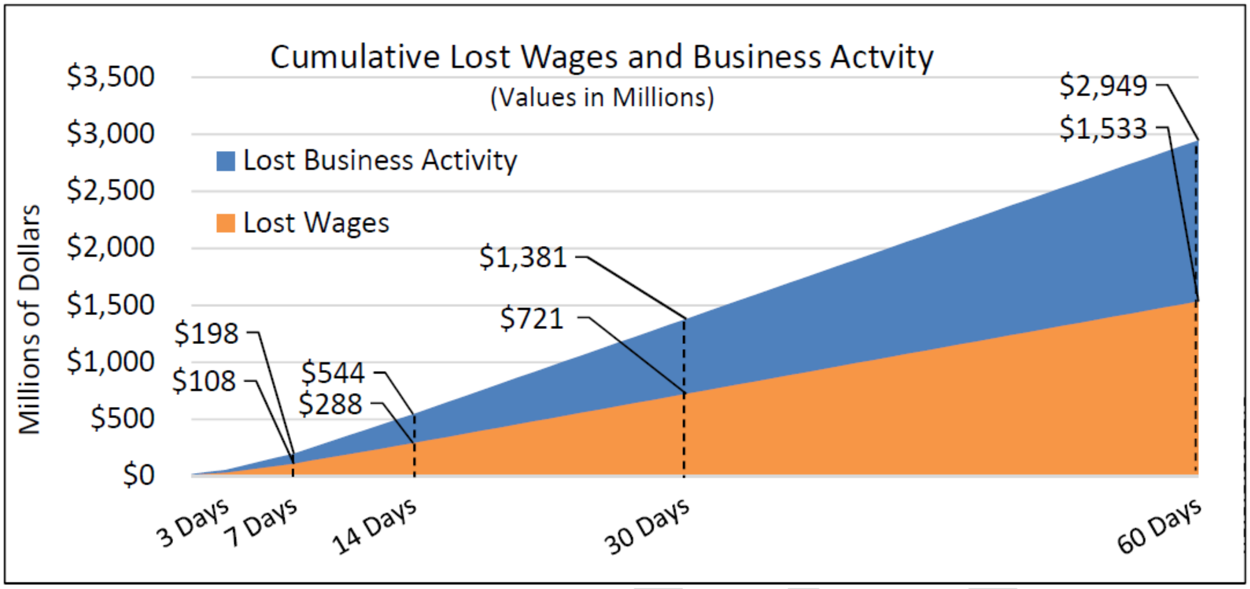


Table 2: Simulated Earthquake Economic Impacts with Existing Infrastructure

Event	Frequency	Economic Damage	Annualized Risk
Cascadia Subduction Zone	500 yr	$2.3 Billion	$4.6 Million/year
Seattle Fault Zone East	800 yr*	$8.3 Billion	$5.2 Million/year
Cumulative			$9.8 Million/year

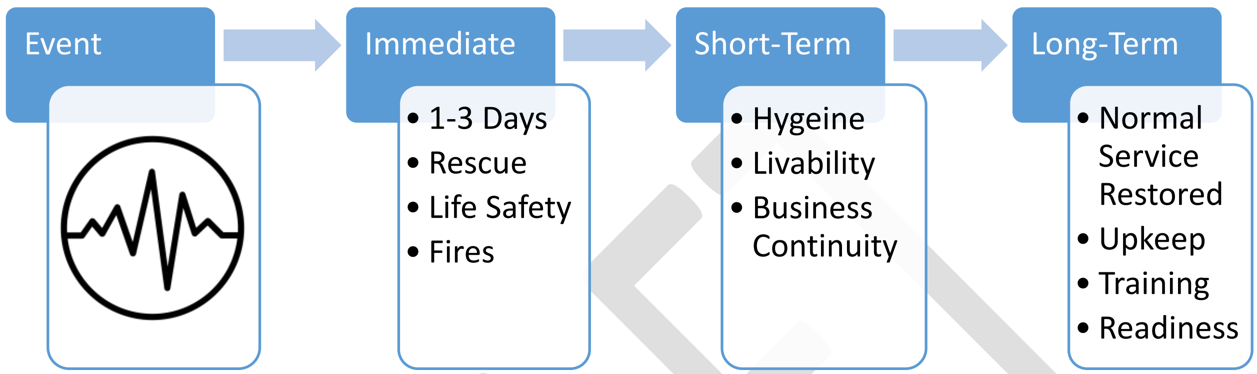
* Estimated 50% likelihood of full Seattle Fault eastern rupture during 800-year event

Both the CSZ and SFZ events are anticipated to re-occur, so the annualized risk of these separate events is cumulative, for a total annualized risk of $9.8 Million/year.

4. Emergency Water Needs

Bellevue’s emergency water supply needs have been evaluated based on type of use, urgency, location, quantity, and other relevant factors. For the purpose of planning, needs have been categorized by time periods – Immediate, Short-Term and Long-Term – as shown in Figure 17 and described below.

Figure 17: Summary of Emergency Water Needs



4.1 Public Engagement

To understand customer values, assess personal preparedness, and inform development of the Master Plan, the City created an on-line open house and survey in late 2021. The survey was promoted system-wide via social media, press release, and the Cit''s website, and was translated into several languages. While the survey was open to all, postal invitations were also mailed to a randomized sub-set of 5,000 customers. A detailed summary of survey results is provided in Attachment 3.

In late 2021, the City held a workshop with staff from several community-based organizations, representing historically under-served populations, including immigrant, minority, youth and senior services. Feedback included several lessons learned during the COVID-19 response, as opportunities for the City and other government agencies to improve coordination and service:

- Some COVID-19 vaccination sites were difficult to access for residents who do not own a personal vehicle. This problem would be exacerbated for distributing heavy emergency supplies (especially water), which would need to transported from the site. By siting emergency water supply distribution points in neighborhoods with relatively low car ownership, the City can provide better access to services.
- Some translation of COVID-19 public messaging was either missing (impeding access to information) or redundant with CBO staff (needlessly diverting their limited resources). The demand for translation resources was demonstrated by the Cit''s survey itself based on the use of translated versions (e.g. 7% of respondents completed the survey in Chinese). By improving coordination and offering greater translation services, the City can improve cultural competency and access to emergency services.

4.2 Immediate Needs

Immediate needs are life safety related, and primarily driven by the needs of first responders and vulnerable populations. These water demands may be directly caused by the event, though not necessarily (e.g. unrelated medical emergencies).

Hospitals provide emergency and ongoing life-saving care, and require water to stay in operation. For this reason, emergency room hospitals are considered critical customers by the Water Supply Forum, Oregon Resilience Plan, etc., and are recommended as a priority for Bellevue (see Chapter 2). As an example of the importance of water supply, following Hurricane Katrina multiple hospitals were forced to evacuate due to loss of water pressure and/or indirect water-related failure (e.g. impacted wastewater service)[33]. Interviews with local medical facility staff in Bellevue

Firefighting is another immediate need, as demonstrated by numerous historical examples of conflagrations caused by earthquakes[34]. Documented number of ignitions include 149 after the 1971 San Fernando earthquake, 58 following the 1989 Loma Prieta earthquake, 92 after the 1994 Northridge earthquake, and approximately 100 following the 1995 Hanshin (Kobe) earthquake. Major observed causes of ignition have been electric arcing (due to short circuits or normal activity) combined with natural gas leaks, flame from gas appliances, and cooking activity during the earthquake. In all of these events, firefighting was severely impaired by depressurization caused by water main breaks and leaks in local water systems.

Vulnerable populations include residents who may be unable to help themselves following an emergency. Some characteristics recognized as increasing the likelihood that an individual will suffer diminished access to life-sustaining commodities are[35]:

- Age 65 years and older, or 4 years and younger
- Functional needs
- Serious chronic health condition or multiple conditions (including heart disease, high blood pressure, psychiatric, or cognitive disorders)
- Living near, on, or below the poverty line
- Language barriers

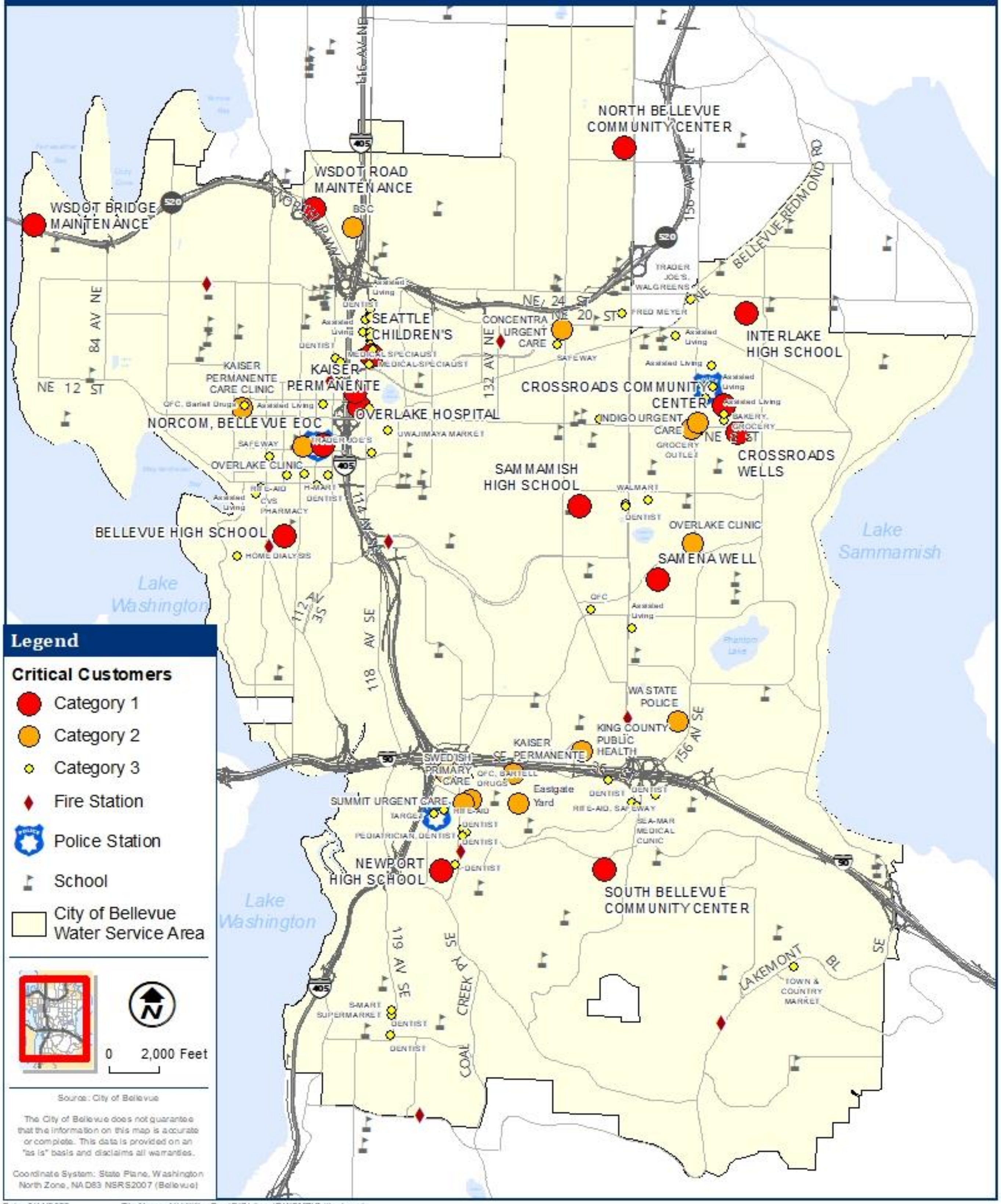
Based on these criteria, assisted living facilities, urgent care and dialysis facilities, and community shelters have been identified as critical customers. Higher prioritization to mitigating impacts is also recommended in areas with relatively higher poverty rates.

Figure 18 shows critical customers identified during the development of the Plan.

[33] Gray and Hebert. *After Katrina – Hospitals in Hurricane Katrina: Challenges Facing Custodial Institutions in a Disaster*. The Urban Institute, 2006.
[34] Charles Scawthorn, John M. Eidinger, Anshel Schiff. *Fire Following Earthquake*. ASCE Publications, 2005.
[35] *Disaster Logistics: Point of Distribution Manual*. Bay Area Regional Logistics Program, February 2014.

Critical Water Customers

Figure 18



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4.3 Short-Term Needs

Short-term needs support community recovery, to avoid cause for widespread evacuation while the normal system is repaired. The short-term period of emergency water needs begins as immediate concerns abate (e.g. fire suppression), and ends with restoration of the normal regional water supply. This is estimated to take 2 to 3 months with existing infrastructure, or 2 to 4 weeks based on proposed PE-LOS goals.

During this short-term period, the City would be reliant on emergency water supplies. Priorities include basic service for hygiene and sanitation, general livability and community recovery, and business continuity. To support these priorities, water-sensitive “essential businesses” (e.g. grocery stores, non-urgent medical facilities, etc.) as defined by Washington State Governor Inslee’s COVID-19 “Stay Home, Stay Healthy” Proclamation 20-05 are identified as Category 3 critical customers (see Figure 18).

Water Quality

Following a disaster, with normal supplies unavailable, customer expectations for water quality are likely to change. For instance, non-potable supplies are sufficient for many essential uses such as toilet flushing, and could be treated at the point of use (boiling or personal filtration) for cooking and drinking. Typical emergency water supply planning assumes temporarily reduced water quality while the normal potable water supplies are being repaired[36].

Water Quantity

The City performed a needs assessment of system-wide water demands following a catastrophic emergency[37]. This estimated a reduced, post-event system-wide domestic water demand of 9 million gallons per day (MGD), compared to a typical winter day demand of 12 MGD, and average day demand of 16 MGD. This assumes:

- 12 MGD represents the current basic domestic needs (no irrigation) for all customers
- Emergency per capita demands are curtailed through public messaging after an event
- Water demand is further reduced by lower occupancy, due to building damage or because some portion of the population leaves the area

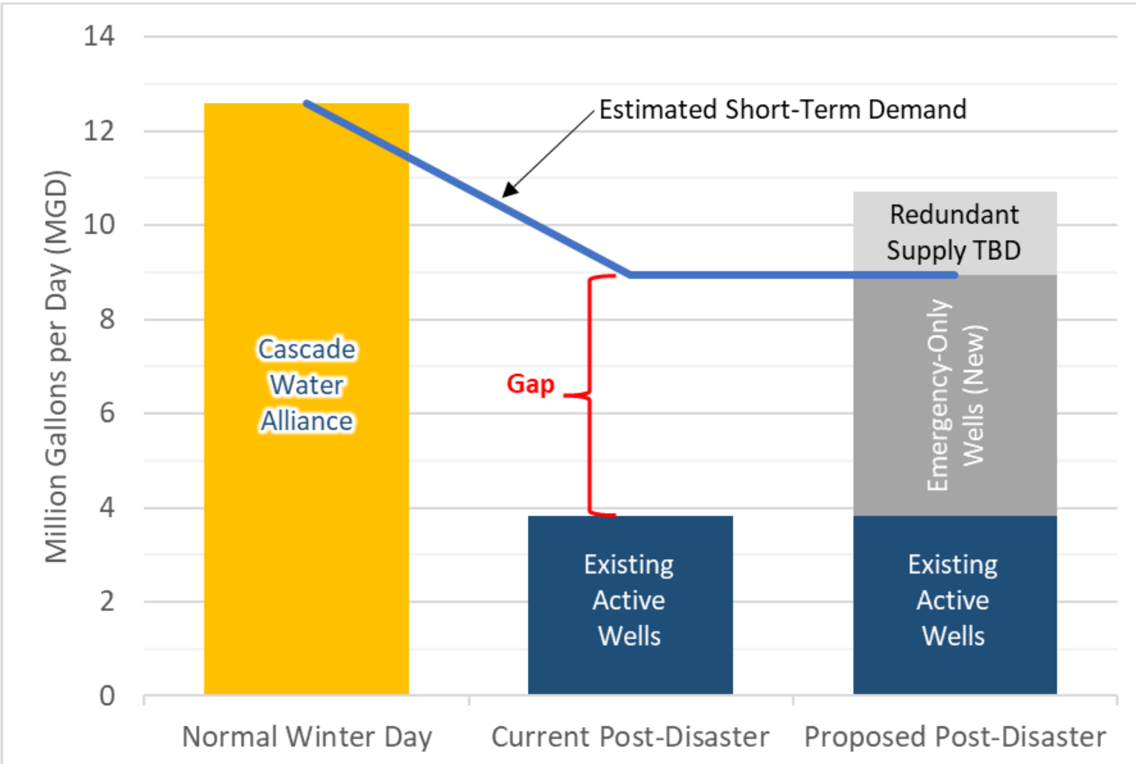
In addition to domestic demands, the City should also consider the following when considering the appropriate amount of emergency supply:

- Future population growth
- Increased leakage and other non-revenue water demands (e.g. pipe flushing)
- Redundancy (additional capacity in case one or more supply is inoperable)

To account for these additional factors, a “firm” capacity (assuming the largest emergency supply is inaccessible or out of service) of 9 MGD is recommended. If the largest emergency supply is 1 MGD (e.g. Crossroads Well #7), then the total installed capacity would be 9 + 1 = 10 MGD.

[36] *Regional Water Supply Resiliency Project, Phase 2 Summary Report – Appendix A: PE-LOS and Mitigation Measure Assessment*. Water Supply Forum, July 2018.
[37] *Bellevue Emergency Water Needs Assessment Technical Memorandum*. HDR, 5/14/2019.

Figure 19: Estimated Short-Term Emergency Supply Needs



4.4 Long-Term Needs

After normal water supply is restored, long-term needs begin. The long-term emergency water supply needs described here are not actually water demands, but are ongoing tasks necessary to maintain readiness for future emergencies. It is important to recognize, plan for and budget these tasks.

Equipment Maintenance

Equipment maintenance and exercise is a required, ongoing cost that should be considered when evaluating mitigation alternatives. This is true for portable equipment (jumper hoses, bulk delivery, portable treatment) and permanent facilities such as groundwater supplies.

Exercise is particularly challenging for new wells that cannot be used for municipal purposes, because the City would not be able to make any beneficial use of the equipment except during an emergency. The inability to regularly use a well may affect the feasibility of installing permanent equipment, including treatment systems and pumps at these locations.

Staffing

The City would need to have Washington State certified Water Treatment Plant Operators (WTPO) on staff to operate any treatment system that might be used to supply potable water. This is true even when operating as a non-potable supply (as proposed for the Crossroads wells), if potable water is to be supplied during an emergency. Uncertified operators can gain experience towards WTPO certification by assisting with regular maintenance.

Storage and Land

Spare parts and portable emergency-response equipment added to the City's inventory will require additional storage. The cost of real estate and building square footage should be considered during space planning and while evaluating alternatives for procuring equipment.

5. Regional Coordination

Coordination between City departments and across agencies in multiple levels of government is essential for planning and responding to any catastrophic event. All infrastructure sectors, including transportation, communications, power supply, and others will all be impacted in different, but intersecting ways.

The City's Emergency Operations Center (EOC) uses the NIMS/ICS[38] structure, which treats all staffing, equipment, supplies, etc. as modular and shared, allowing for the most effective use of resources. During a water supply emergency, this means that the Utilities Department can and should remain focused on the objective of restoring normal water service, while relying on others to meet some community needs (e.g. bottled water distribution). This approach is also recommended by the USEPA:

> "One of the primary goals of utilities in the aftermath of an emergency should be to restore piped water service. A good Emergency Drinking Water Plan should avoid resource allocation conflicts (i.e., personnel and equipment) during a disaster in order to allow the utility to focus on restoring piped water service expeditiously."[39]

Roles and responsibilities for distributing commodities is discussed more in Chapter 6, under the context of community points of distribution (CPODs or PODs).

5.1 Adjacent Water Utilities

Bellevue coordinates with regional water suppliers and adjacent water utilities as part of normal operations and as part of long-term planning, including water system plans and emergency response plans.

Regional Water Supplies

Bellevue frequently coordinates with SPU and Cascade Water Alliance regarding pressure, flow, shutdowns, metering/billing, and other operational needs at supply inlets. In addition, Bellevue participates with SPU and Cascade as part of the Water Supply Forum and other regional efforts.

Influencing or incentivizing SPU to prioritize the TESSL and CESSL through Bellevue would improve Bellevu''s resilience and allow for faster accomplishment of the PE-LOS goals (see Chapter 6).

Local Interties

Bellevue has ongoing coordination with adjacent water utilities regarding local interties, primarily in the context of water audits for non-revenue flow or other normal operations. For emergency purposes, there are limited opportunities to add resilience with interties, as discussed in Chapter 6.

During an emergency, Bellevue will need to coordinate public messaging with adjacent utilities to provide consistent and accurate information. Bellevu''s Emergency Response Plan includes provisions for this coordination.

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[38] National Incident Management System / Incident Command System

[39] *Planning for an Emergency Drinking Water Supply*. USEPA (600/R-11/054), 2011.

5.2 Mutual Aid

Pre-arranged mutual aid contracts improve resiliency and response time, by having a framework in advance to allow rapid sharing of resources. Mutual aid contracts are also required for successful cost reimbursement from the Federal Emergency Management Agency (FEMA).

WA-WARN

The City is a member of the Washington Water/Wastewater Agency Response Network (WA-WARN). This network provides for rapid mutual aid and assistance between utilities in Washington, through a pre-established agreement. WA-WARN's structure is consistent with the National Incident Management System (NIMS), and mutual aid through WA-WARN is eligible for FEMA disaster reimbursement.

Bellevue School District

The City has a mutual aid agreement[40] with Bellevue School District (BSD), which allows for the use of schools as shelters and other limited sharing of equipment and facilities. Some schools have also been designated as CPODs, as discussed in Chapter 6. Due to the role of shelters and CPODs in meeting basic housing needs in an emergency, followed by the ongoing role of schools in supporting community recovery and restoring normal routines, public high schools have been identified as critical water customers. Middle schools and in particular elementary schools are more numerous and distributed widely in lower-density areas farther from water sources (see Figure #), so restoration time at these smaller facilities will vary.

5.3 Infrastructure Sector Inter-Dependencies

The Cybersecurity and Infrastructure Security Agency (U.S. Department of Homeland Security) defines 16 critical infrastructure sectors. These sectors have varying degrees of inter-dependency with Bellevue's water system, as shown in Table 3.

Table 3: Sixteen Critical Infrastructure Sectors

Critical Water Customers	Less Water Sensitive	In Bellevue, but not Water-Sensitive	No Significant Presence in Bellevue
Emergency Services, Healthcare, Water & Wastewater	Commercial, Financial, Food, Government, Info Technology, Transportation*	Communications*, Energy*	Chemical, Dams, Defense, Manufacturing, Nuclear

* Bellevue's water system is highly dependent on these sectors

Coordination as part of the Master Plan has focused on sectors that are highly water-sensitive, or will most impact the water system during a failure.

Related facilities identified as critical water customers below, despite not being high-volume water consumers, because they could be impacted by loss of fire suppression (Fire Code and occupancy rules), and by limited sanitation during a water outage.

[40] Emergency Assistance Mutual Aid Agreement. The City of Bellevue and Bellevue School District. 6/14/2017.

Logistics will be impacted due to transport and delivery disruption, supply chain interruption, and a spike in demand for labor, supplies, parts and equipment as other utilities cope with the impacts of the same event.

Healthcare

All healthcare facilities have been identified as critical customers, with varying tiered Categories depending on function. As shown in Figure 18, most healthcare providers are clustered along 11^{6t}h Ave NE, Crossroads, or Eastgate/Factoria, such that improved service would be shared, regardless of category. Emergency room hospitals are the most critical “Category 1” due to their role in providing immediate life-saving care, and their requirement to stay in operation. Urgent care, dialysis centers, and similar facilities are designated “Category 2”, because they meet urgent medical needs, but may not be open following an event, and are less sensitive to a loss of supply compared to hospitals. Providers of elective procedures and non-urgent care such as pharmacies and dentists have been assigned “Category 3”, as important customers that support community recovery, but not in an urgent, life-saving capacity.

Early in Master Plan development, the City met with multiple health care providers to better understand their water needs and emergency preparation. Dialysis centers are completely water-dependent. Hospitals with inpatient services have sterilization boilers for surgical equipment, laboratory needs, and other highly water-sensitive functions, in addition to normal domestic water uses. Urgent care facilities have fewer water needs, but would still require water for normal hygiene and sanitation. All providers could have building occupancy challenges with non-functioning fire suppression systems, depending on post-event enforcement of Fire Code.

Emergency Services

Emergency services include EOCs, 911 dispatch (e.g. Norcom), law enforcement, fire response, emergency medical services (part of Bellevue Fire Department), and other services. Hospitals and medical facilities are discussed above as part of the healthcare sector.

Bellevue City Hall plays a role in all aspects of emergency services, and the City also maintains a backup EOC at Bellevue Service Center. Both facilities have been identified as critical customers.

Police stations are clustered along with healthcare facilities in Downtown, Crossroads and Factoria (see Figure 18), so will benefit from mitigation to improve service at surrounding critical customers. Washington State Patrol also has a facility in Bellevue that includes 911 dispatch, and is identified as a critical customer.

Power

Bellevue’s electricity provider is Puget Sound Energy (PSE). PSE has its own backup EOC located in Bellevue, which has been identified as a critical water customer due to PSE’s role in supporting community recovery and water service restoration.

PSE has performed their own seismic evaluations to identify earthquake hazards, and has also identified lessons learned and sector inter-dependencies observed during widespread power outages in 2006. For instance, during that event, power failure at traffic signals in Bellevue caused traffic backups that blocked I-405, which then impeded PSE’s crews ability to get to damaged locations to perform repairs. These same power and transportation impacts would also affect the ability of Bellevue’s water crews to get to work, and to reach water main repair sites.

Following a future widespread regional outage, PSE would seek to restore the maximum number of customers to power, beginning with transmission lines, then substations, and then the local circuits, depending on the situation. Bellevue is not assuming that PSE would prioritize water pump stations because power restoration activities would focus on the locations of highest impact and benefit (e.g. density), and due to competing sectors (healthcare, corrections, etc) and the needs of the regional economy. To mitigate the loss of power to the water system, Bellevue's strategy is to provide local, independent backup power.

Although most of Bellevue's water supply is gravity-fed (does not require pumping), roughly 20% of local water demands do require pumping. For electrical reliability, the City has receptacles at each pump station to connect a portable generator. The City's water utility shares backup generators with the wastewater utility, and in a declared emergency under NIMS/ICS protocols, generators may be shared with other City departments or even other agencies. Transporting and operating backup generators also requires significant labor that may not be available in a widespread disaster. To help mitigate these limitations, permanent on-site backup generators are being added at key stations as they are rehabilitated, including Horizon View 1 (complete 2017), Horizon View 2 (planned for 2023) and Parksite (planned after 2030) along backbone route "O" (see Chapter 6).

At gravity-fed facilities with no pumps and therefore low power demands (e.g. inlet stations, reservoirs), 24V batteries provide backup power for local monitoring and control equipment. For SCADA-connected valves with solenoid controls (pressure-reducing valves, flow control valves, etc), backup hydraulic controls that do not require power will take over during an extended power outage, and maintain predetermined, manual default settings.

Communications

Cellular communication sites are critical infrastructure, but often (e.g. towers) are unstaffed and have no water demands, so are not considered to be critical water customers. Cellular sites typically have limited backup power supplies, but are vulnerable to extended electrical outages, so are inter-dependent with the electric grid.

Bellevue monitors and controls water distribution through a supervisory control and data acquisition (SCADA) system. Bellevue's water system SCADA is being transitioned to a private cellular network, which will be reliant on local telecommunications infrastructure. However, impacts to water facilities are mitigated or avoided by programming the local controls equipment to revert to default settings during a loss of communications. Although water system operators would be unable to monitor or control local equipment, pre-determined operational settings will be maintained while cellular service is unavailable.

The City also coordinates emergency preparation and response with telecommunications providers as part of the Bellevue Utilities Emergency Management and Response Plan.

Transportation

Washington State Department of Transportation (WSDOT) has two maintenance facilities in Bellevue's water service area, including a bridge maintenance office, and a roadway maintenance facility that also functions as a backup EOC. The Bellevue Transportation Department shares its major facilities with the Utilities Department (e.g. City Hall and Bellevue Service Center). All of these locations have been identified as critical water customers due to their role in supporting community recovery.

Local streets are not as important as freeways for City-wide recovery, but local streets are critical for access to specific water system facilities. The Utilities and Transportation Departments regularly coordinate operations and planning, as well as emergency preparation and response through the City's EOC.

The highway system is critical for every aspect of overall water system restoration. WSDOT maintains three freeways through Bellevue (I-405, I-90 and SR-520) that are critical for moving emergency workers, materials, and equipment. In the 1990s, WSDOT identified seismic lifeline routes state-wide and is retrofitting bridges along the lifeline to mitigate earthquake impacts over time. I-405 through Bellevue was chosen as the north-south seismic lifeline through the Seattle area instead of I-5, due to the relative high cost to retrofit I-5 through Seattle.

After an event, WSDOT performs tiered inspections based on apparent level of damage prior to opening a bridge. For the CSZ and especially SFZ earthquakes, it is anticipated that some number of bridges may need to be closed for an extended time for repairs, or demolished and rebuilt. A Transportation Recovery Annex is maintained to provide predetermined detour routes. These impacts will slow the recovery of the water system.

As part of the City's SVA, emergency response information gathered from WSDOT informed development of the iterative models used to estimate water service restoration time (See Chapter 3).

Bellevue also coordinates with WSDOT and the City's Transportation Department to improve water system resilience opportunistically with transportation projects. For instance, the City is partnering with WSDOT to install an earthquake-resistant 16" water main crossing I-405 at the new Main Street bridge in 2022-2023, as part of a proposed backbone pipeline route "M" (See Chapter 6). Seismically-resilient pipe is also proposed for a new bridge over Sunset Creek along SE 3^{6t}h Street, as part of backbone route "C". The Utilities Department routinely replaces aging pipes with more resilient water mains as part of local paving or sidewalk projects managed by the City's Transportation Department.

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6. Mitigation Alternatives

The SVA evaluated a variety of improvement packages to achieve the desired PE-LOS goals.

Several potential alternative water supplies and distribution methods are discussed below.

Industry standards[41] recommend that any emergency preparedness measure have Standard Operating Procedures (SOPs), initial & refresher training, and periodic exercises to establish and maintain readiness.

Most mitigation measures are equally effective in reducing risk for all hazards.

SPU has water supply redundancy, such that some level of water supply could be maintained with the loss of one watershed.

6.1 Water Supply

As described in Chapter 3, the regional water transmission system may be disrupted for weeks following a SFZ or CSZ earthquake. Reducing the duration of this outage and/or meeting short-term demands with temporary, alternative water supplies would mitigate community and economic impacts.

Regional Water Supply Resilience

Bellevue does not control the regional transmission system, but can exert influence and lobby regional partners as part of Cascade Water Alliance.

SPU developed a risk-based 50-year resilience plan[42] similar to the strategy recommended in this Plan. Their plan prioritizes resilience along the Cedar supply to maximize the benefit for SPU's overall regional customer base, since the Cedar has higher capacity and provides roughly 2/3 of SPU's total wholesale and retail water volumes. SPU's Tolt supply provides the remainder of SPU's normal water supply.

The Cedar source supplies roughly 20% of Bellevue's water volumes under normal system configurations (80% typically Tolt supply). However, SPU has facilities in Bellevue to pump water from the Cedar to the Tolt system, so the relative prioritization of SPU's supplies may or may not have significant effects on Bellevue's service area in an emergency.

Bellevue would benefit most from replacement of the TESSL and CESSL pipelines through Bellevue. These are bar-wrapped concrete pipes installed circa 1960, which are particularly susceptible to corrosion and seismically vulnerable. It is recommended that the City and other local partners (e.g. Cascade, Redmond, Kirkland, etc) lobby SPU for prioritized mitigation or improvement of the TESSL and CESSL pipelines that benefit local customers.

[41] AWWA Standard G440-17. *Emergency Preparedness Practices*. AWWA, 2017.

[42] *Water System Seismic Study Summary Report*. Seattle Public Utilities, 2018.

Portable Surface Water Treatment Systems

Portable emergency surface water treatment equipment is commercially available to provide potable water, and is also maintained by some emergency response agencies such as FEMA. These systems can treat a limited capacity of surface water for on-site pickup.

Challenges associated with portable treatment systems include:

- Capacity: Portable surface water treatment systems can typically treat tens of gallons per minute (gpm). Bellevue's reduced water demands following a regional disaster are estimated to be roughly 10 MGD (see Chapter 4), or about 7,000 gpm. Hundreds of small portable systems would be needed to replace the volume lost following a total water supply disruption.
- Storage and hauling: Permanent indoor storage space and dedicated trucks would be required.
- Maintenance, exercise and training: Regular use and testing of the system is necessary to maintain functionality and readiness.
- Access to Source Water: The system would need to have clear access to surface water, so may only be usable at boat ramps or similar locations.
- Proximity to Customers: Portable systems would rely on customers to be aware of the system and have the ability to pick up and transport water.
- Staffing: During an emergency, trained volunteers or emergency response staff would be required to operate the system.

Similar to bulk water delivery (discussed below), portable surface water treatment systems may be appropriate to maintain for use during an emergency that impacts only a small portion of the water system, or to supplement supply after normal service is partially restored. However, due to their small capacity and inability to distribute (only treat) water, they should not be relied upon as a mitigation strategy for a system-wide disaster, when restoring the normal supply should be the first priority.

Community Points of Distribution (CPODs)

CPODs (or simply PODs) are temporary sites prepared to distribute commodities such as food, water, sanitation items and other essentials following a disaster. CPODs would typically be managed by the incident commander from the City's EOC or another agency, and not the Utilities Department, as described in Chapter 5. However, many CPODs are identified as critical water supply customers (see Chapter 4). In addition, multiple alternative water supplies described on the following pages could support or be co-located with CPODs, so coordinated CPOD site planning is relevant to Utilities.

Standard layouts for CPODs have been designed that can accommodate 5,000, 10,000 or 20,000 people per day at each site[43]. CPODs can be configured for either vehicular or pedestrian traffic, though not both due to safety concerns [44].

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[43] *Emergency Support Function (ESF) #3 Field Guide*. US Army Corps of Engineers, 2012.

[44] *Disaster Logistics: Point of Distribution Manual*. Bay Area Regional Logistics Program, February 2014.

The City has developed a CPOD Annex[45] to guide CPOD staffing, setup, roles and responsibilities. Specific sites identified include the following, as shown on Figure 20:

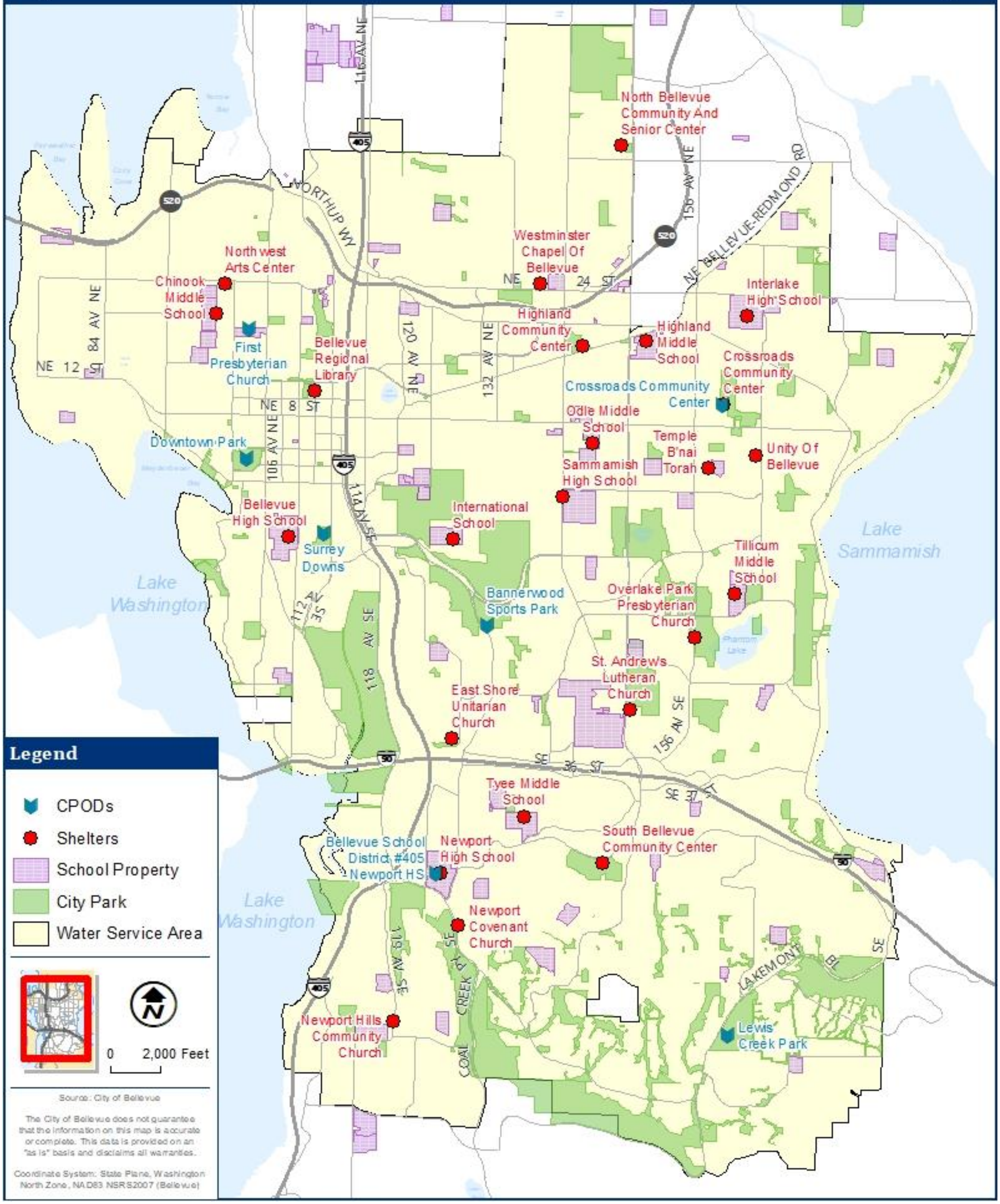
- Surrey Downs
- Bellevue Downtown Park
- First Presbyterian Church
- Bannerwood Sports Park
- Crossroads Community Center
- Lewis Creek Park
- Newport High School

The City may consider further coordination with BSD to facilitate planning for potential CPOD sites in addition to Newport High School.

[45] City of Bellevue CPOD Plan – December 2011.

Potential Community Points of Distribution

Figure 20



Alternative Water Sources for Fire Fighting

The Bellevue Fire Department can use “drafting” to obtain water for fire fighting. Drafting is a tactic commonly used by rural fire departments where no water distribution network is available. Trucks are equipped to draw from either a pressurized supply (e.g. private hydrant or a well pump), or to pump surface water from a pool, pond, or other water body, provided that the suction lift (vertical distance from water to pump) is relatively small. Water can be pumped directly to fight a fire within a limited radius from the source, or pumped into a tank for hauling to the fire location.

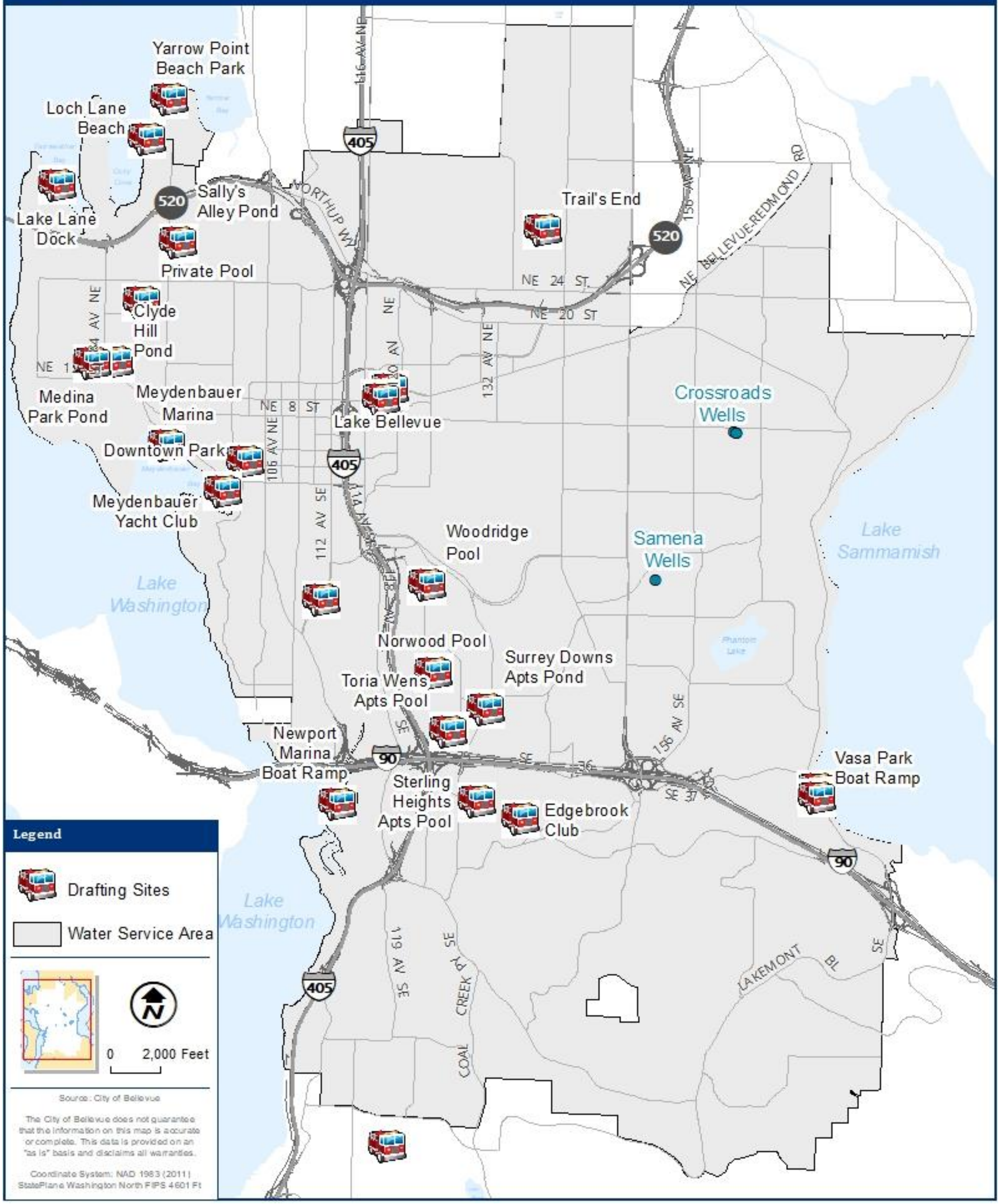
Fire Truck Drafting Operation with Suction (Black) and Discharge (Brown) Hoses

There are significant limitations to drafting, primarily related to access and water volumes. Drafting cannot replace the superior protection provided by automatic fire suppression systems (sprinklers) that would be lost with a water supply disruption. Drafting is most effective for fires near large, accessible surface water bodies, or for very small fires where a tanker truck provides enough volume to control the fire. Drafting alone cannot provide enough water for large fires except when located near boat ramps or other access points where crews can directly reach the fire with hoses (without hauling). Most of Bellevue’s water customers are too far from surface water access points to benefit substantially from drafting.

Locations that have already been identified as potential drafting sites are shown in Figure 21. Crossroads wells are also proposed as a potential future alternative source of fire-fighting water, as discussed below. Additional, emergency-only wells placed in key, distributed locations could also improve fire protection coverage at higher ground (away from surface water), filling in gaps evident in Figure # and providing better emergency service to more of the service area during a water supply disruption.

Pre-Determined Surface Water Drafting Sites

Figure 21



Existing Groundwater Wells

Groundwater served as the original water supply to Bellevue in the 1950s and 1960s, and remains a viable source of water, despite some challenges. Existing wells are shown in Figure 12.

Groundwater Quality

Compared to the current supply of water from Seattle Public Utilities' Tolt and Cedar watersheds, existing wells in Bellevue produce water high in iron, manganese, and other minerals common to groundwater. This can make groundwater aesthetically unappealing due to taste, discoloration or odor, and can lead to water chemistry problems if blended with surface water (such as SPU's supplies). Confluence Engineering Group LLC evaluated samples of water from Bellevue's existing wells, and recommended treatment prior to supplying groundwater as a potable supply, not only for aesthetic reasons but to avoid public health risks such as metals release into water, and to protect infrastructure[46].

If an emergency well is intended to provide potable water, Washington State Department of Health (DOH) requires physical separation from the distribution system under normal circumstances, and periodic sampling, inspection and operation of the well to verify readiness and suitable water quality[47].

Non-potable water provided via drive-up points of distribution (PODs) may be combined with personal point-of-use treatment such as boiling (if gas or electricity service is available), chemical treatment (hypochlorite tablets, iodine, etc) or personal filtration devices such as Lifestraw® or backpacking filters[48].

Groundwater Capacity

Local groundwater hydrology in Bellevue includes confined aquifers made of outwash, sand and gravel, underneath an "aquitard" (low-conductivity layer) of glacial till. Based on observed pumping rates, the confined aquifer overall has adequate capacity and hydraulic conductivity to meet Bellevue's emergency water supply needs, but only if there are several wells or well fields dispersed throughout the service area. Aquifer conductivity is not high enough to meet the entire need through one localized wellfield. [49]

Confined aquifers are not recharged directly by vertical surface water infiltration, but recharge laterally through the soil. The aquifer used by Bellevue's Crossroads and Samena wells are recharged by connections to Lake Sammamish, Kelsey Creek, and other tributary streams. Groundwater modeling suggests that prolonged high-volume pumping from this aquifer could impact stream flows and fish populations[50].

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[46] *Water Quality Analysis Technical Memorandum*. Confluence Engineering Group LLC, 2018.
[47] *Emergency Drinking Water Sources*. WA DOH (331-317), January 2017.
[48] *Planning for an Emergency Drinking Water Supply*. USEPA (600/R-11/054), 2011. p. 15.
[49] *City of Bellevue Emergency Water Supply Plan – Aquifer Characterization and Well Yield Assessment*. Golder Associates, 9/18/2019.
[50] *City of Bellevue Emergency Water Supply Plan – Aquifer-Stream Delineation and Assessment*. Golder Associates, 4/9/2019

Existing Well Configuration Alternatives

Three emergency supply configuration alternatives have been identified[51] for the City's existing wells, and further evaluated[52]. Table 4 lists some advantages and disadvantages of each:

1. Stand-Alone CPOD: Emergency walk-up/drive-up community point of distribution (CPOD), plus regular non-potable uses with raw groundwater (treatment at point of use)
2. Quick-Connect Emergency Backup: Full capacity pumps and treatment, normally disconnected from the potable system by an air gap, plus regular non-potable uses
3. Normal Potable Supply: Full-time potable supply for all municipal water uses.

Regular non-potable uses indicated above may include local irrigation, a tanker truck fill station (for remote/off-site use), consumer fill station, or other non-potable municipal purpose.

Table 4: Comparison of Existing Well Site Configuration Alternatives

Alternative	Advantages	Disadvantages
1. Stand-Alone CPOD	• Drive-up/walk-up access to water • Inexpensive	• No restoration of piped water service in emergency • Limited use of groundwater resource • May be inequitable (car needed)
2. Quick-Connect Backup	• Drive-up/walk-up CPOD access • More regularly use resource • Staff training and readiness • Rapidly available to local piped system in emergency • Allows for Alt #3 in future with minimal modification	• More expensive • Requires more staffing, with additional qualifications (Water Treatment Plant Operator, WTPO)
3. Normal Potable Supply	• Maximize water resource • Potential to delay regional water supply development	• Former fuel tank; on-site soil contamination concerns • Stream flow & fish impacts • Water chemistry/quality, blending, aesthetics problems • Staffing, additional qualifications

At the Crossroads wells site, Alternative #2 is recommended for numerous reasons:

- Alternative #2 has the optimum balance of most advantages and fewest disadvantages shown in Table 4.
- Crossroads Park is across the street, and could be supplied with irrigation water, which would allow for more regular exercise of the equipment and staff training.

[51] City of Bellevue Groundwater Resource Development Analysis. Robinson-Noble, 1/6/2015.
[52] Attachment 2-G: Bellevue Emergency Water Alternatives Analysis. HDR, 12/20/2019.

- A designated CPOD (Crossroads Community Center) is across the street and could be used for drive-up/walk-up water distribution.
- Crossroads wells are near numerous critical customers that would benefit from the ability to quick-connect to the piped distribution system.
- The site is located on an arterial, which may allow for a tanker fill station.
- A fill station at Crossroads would help to fill a large gap in coverage for known Fire Department emergency "drafting" sites (see Figure #).
- Compared to Bellevue's service area, the local neighborhood has the highest USEPA Demographic Index[53], a measure of demographic indicators including low income and people of color. Emergency water supply access in this area may improve equity of services.

At the Samena Well site, Alternative #2 is also recommended. However, it would not be suitable for as many uses as Crossroads due to its location on a residential street and lower available capacity. Therefore improvements at the Samena site should be a lower priority than Crossroads.

Backbone piping is proposed to connect both the Crossroads and Samena wells sites to critical customers, as described in Section 6.2

Future Emergency-Only Wells

Two well alternatives listed above have also been identified for future, emergency-only wells:

- Stand-Alone CPOD:
- Quick-Connect Backup Emergency Backup: (with or without treatment, etc)

It is recommended that the City:

- Develop total well capacity (existing plus emergency-only) of 10 million gallons per day (MGD). This assumes demands are curtailed through public messaging, and some portion of the population leaves the area (Bellevue's average day demand is approximately 16 MGD).
- Initially plan to distribute a minimum 5-gal/day/person, or approximately 0.75 MGD total spread over 6 or more PODs, of non-potable water with home treatment provisions to meet basic drinking, food preparation, and hygiene needs. This assumes that local distribution piping is damaged and that it may take weeks or months to restore service for home delivery.

Although 10-MGD of water cannot be feasibly distributed to Bellevue's population via PODs, installing this higher well capacity at relatively low additional upfront cost would allow for the option to provide larger pumps, treatment and storage in the future to connect the emergency supply to the distribution system. If more resilient piping is installed, customers may then receive water from the emergency supply in their homes for bathing, dishwashing, and other normal uses.

Interties

Interties are connections with adjacent water utilities, separate from the regional supply. Bellevue's existing interties are shown on Figure 12.

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[53] USEPA. EJScreen Version 2.0. Retrieved: March 14, 2022. www.epa.gov/ejscreen

Interties with adjacent water utilities can be used to add supply redundancy in some situations. For Bellevue, interties provide only limited benefits for a widespread emergency, because neighboring utilities are dependent on the same regional water supplies and have their own needs to meet. However, interties could provide some redundancy during localized outages when the regional supply system is still operational, as described below.

Redmond

Redmond and Bellevue have an interwoven water distribution system in the Overlake and Lake Hills vicinity, with many connection points rather than discrete interties. Customers in Redmond's Overlake-Viewpoint Service Area (see Figure 12) are supplied via jointly-owned pipelines and facilities in Bellevue's distribution system. Redmond is dependent on Bellevue to convey water to these areas, and there is no alternative source in Redmond that could supply water to Bellevue with existing infrastructure.

Kirkland

Bellevue has one regular intertie and three emergency interties with the City of Kirkland. A portion of Bellevue's Bridle Trails neighborhood adjacent to Bellevue Golf Course is served through a one-way intertie from Kirkland. An emergency intertie on 13^{2n}d Ave NE will automatically (via pressure-reducing valve) serve Pikes Peak at reduced capacity in the case of a local loss of supply. A manual emergency intertie on Points Drive can be used to supply Yarrow Point from Kirkland at reduced pressure, if the normal supply (SR-520 crossing from Clyde Hill) is interrupted. Another manual intertie on Northup Way provides an emergency supply to the vicinity of 10^{8t}h Ave NE and Northup Way.

Coal Creek Utility District

Bellevue has 8 interties with CCUD. The Newport Hills and Newport Shores neighborhoods of Bellevue are dependent on water supply from CCUD. Bellevue does have some limited ability to supply water south into CCUD, but only at low elevations along Lake Washington.

Issaquah

Bellevue has 3 interties with the City of Issaquah. The Montreux and Lakemont Triangle interties operate in one direction, serving Issaquah neighborhoods that are dependent on Bellevue (not connected to the rest of Issaquah's water system), so Bellevue has ongoing responsibility for reliable service to these areas. The third intertie (serving South Cove) is currently dependent on Bellevue, but Issaquah is planning an alternative source, so that it could be converted to a 2-way emergency intertie. The cities are currently negotiating the potential for the South Cove intertie to provide backup supply to a limited number of Bellevue customers along Lake Sammamish.

Bulk and Bottled Water

Bulk water supply entails transport (via truck) of potable or non-potable water from an off-site source, or from a functional area of the distribution system to an impacted area. This method of water delivery depends on passable roads and highways, an accessible source, and may not be available immediately following an event. Typically bulk water is supplied at a POD with a piped manifold allowing for multiple fill stations (unless water is pre-bottled). Water can be packaged multiple ways:

- Bottles loaded on pallets
- Large bladders, blivets or portable tanks
- Tanker trucks

Piped Manifold Connected to Portable Blivet

Tanker trucks used solely for potable water or milk are preferred, but other food grade tanks may be acceptable[54]. Trucks that may have transported contaminated water in the past should not be used. For this reason tanker trucks maintained by fire departments, construction contractors, etc, might not be acceptable for emergency water delivery.

Bottled water is a commodity with a supply chain and distribution network outside the expertise and capability of the Utilities Department to manage during an emergency:

> "In a large-scale emergency, local resources would likely be overwhelmed and outside assistance for the procurement and distribution of emergency drinking water would be required. In that case, utilities would have to focus their own resources on restoring service."[55]

Likewise, other bulk water delivery equipment such as portable blivets and temporary distribution manifolds require substantial labor to clean, transport, fill, set up, supervise, and refill, while only benefitting a small number of customers. Involving water maintenance crews with bulk water delivery during a widespread emergency would detract from the higher-priority, specialized work of restoring normal, piped water service. Therefore bulk water delivery is not recommended as a mitigation strategy for large-scale disasters.

Bulk water delivery systems may be practical if staffed by other agencies or by volunteers, or during a smaller water emergency that affects only a small portion of the system, where there are fewer high-priority demands on crews. It may be a useful tactic during recovery, after part of the normal system has been restored, but some areas lack service. Therefore some inventory of bulk water and distribution manifold equipment may be appropriate for the City to maintain for use in smaller emergencies.

The City should also encourage other agencies to develop pre-authorized contracts with the following to have vendors ready to assist the EOC during an emergency:

- Large retailers and beverage bottling plants: These companies warehouse large inventories of bottled water, and have a distribution network that can deliver supplies.
- Water, beverage and food delivery services: Tanker trucks approved to handle potable water or beverages (e.g. milk) could be useful for bulk water transfer.

[54] *Planning for an Emergency Drinking Water Supply*. USEPA (600/R-11/054), 2011. p. 11.
[55] *Planning for an Emergency Drinking Water Supply*. USEPA (600/R-11/054), 2011. p. 5.

The City should also identify additional POD sites (e.g. Parks, large parking lots, etc), develop any necessary agreements, and train on the setup and deployment of existing POD sites such as schools.

Personal Preparedness

Washington State Emergency Management Division and King County Emergency Management recommend that residents store 2-weeks of supplies, including water. As shown in Chapter 3, disruption of water supplies would be much longer than 2-weeks with existing infrastructure, but having this much water at home would allow residents to shelter in place for some time while temporary supplies are not yet available.

It is recommended that the City and its partners (e.g. Cascade Water Alliance) communicate the known risks to the system and encourage customers to store at least 2-weeks of water, consistent with emergency management agencies.

Some residents, particularly those with lower incomes, may be unable to store 14-days of water due to lack of storage space at small apartments and other housing arrangements. This equity concern is another reason to potentially prioritize emergency well and/or CPOD sites close to lower-income customers, in addition to the concerns described in Chapter 4.

6.2 Seismic Backbones

Seismic “backbones” are corridors of more resilient infrastructure that can be expected to out-perform the surrounding distribution system. Following an event, damaged portions of the distribution system would be isolated for repair, while the backbones would be relied on to stay in service, conveying water to key locations and less-damaged areas, while improving restoration time to heavily impacted areas as repairs are made.

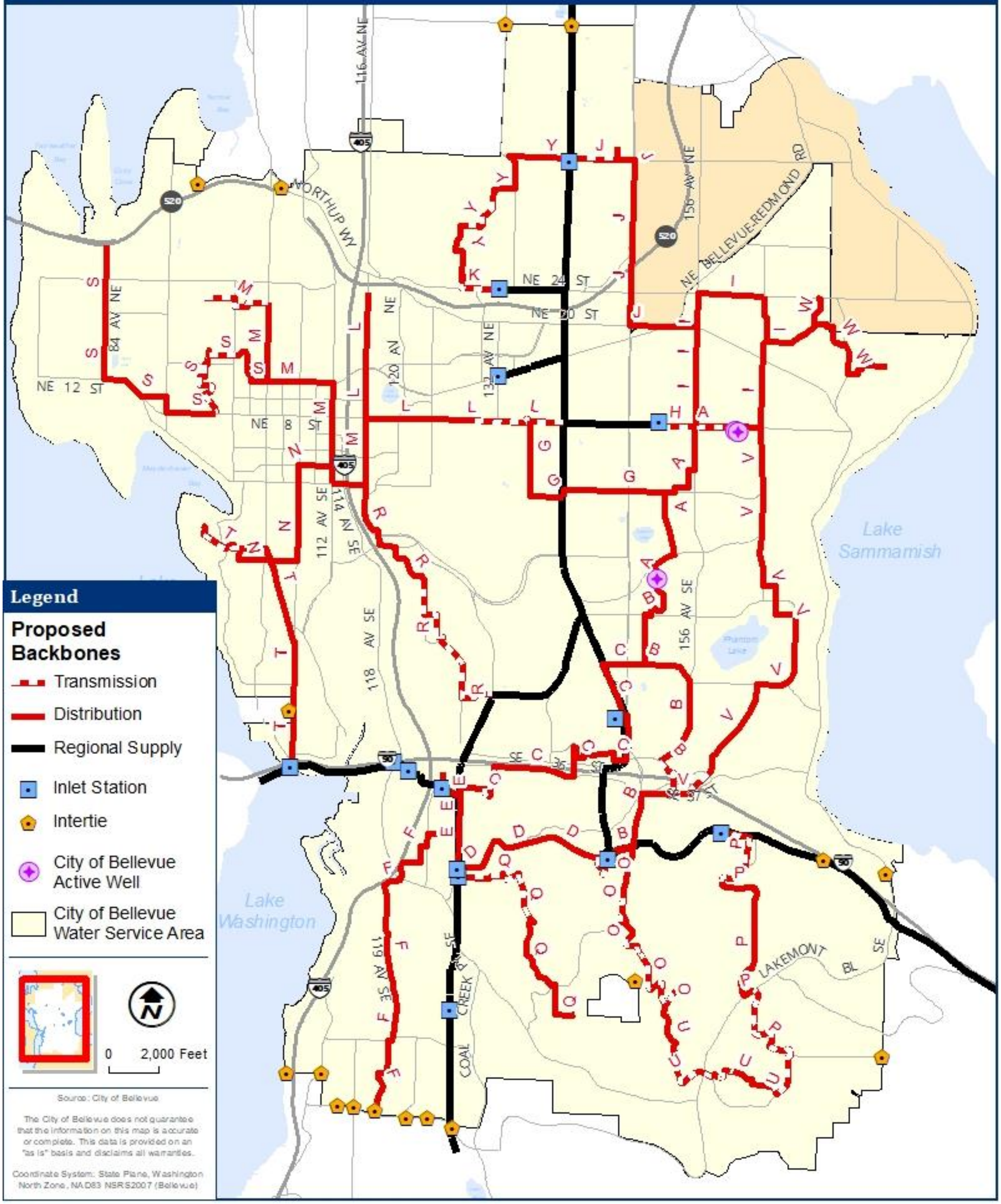
Potential backbone routes were proposed and evaluated as part of the SVA, as shown in Figure 22. Modeling was performed to estimate the improved system restoration time and resulting economic benefit, and the backbones were prioritized based on optimal benefits per cost. The following routes are recommended for prioritization based on this evaluation:

- A Crossroads to Samena Well
- B Samena Well to Parksite/SBCC
- G LH520 to BV400
- L 13^{6t}h Ave Inlet to Hospitals
- M Bel-Red/Downtown/Clyde Hill

The other backbone routes do provide some benefit for reducing recovery time, and can be constructed opportunistically (e.g. in combination with other drivers such as existing pipe age or failure, overlapping projects, etc), but the seismic mitigation benefits alone do not warrant proactive replacement. The City’s renewal & replacement program should factor in the value of the other backbone routes along with other benefits when prioritizing pipe replacement.

Proposed Backbone Routes

Figure 22



6.3 Distribution System Resilience

Although restoring water supply is a higher priority following a severe earthquake, far more time and labor will be required to repair distribution system infrastructure. Therefore, most of the opportunities to reduce restoration time come from improved distribution system resilience.

Water Main Replacement

The SVA found that predicted post-earthquake performance can be improved by replacing water mains with more resilient pipe.

Most of Bellevue's water mains were installed before local seismic risks were understood, so earthquake resilience was not considered during design or construction. Furthermore, earthquake-resistant pipe was not commercially available in the United States until the late 2010s.

Bellevue manages over 600 miles of water mains, with a total replacement cost of more than $2 billion. A main replacement program (CIP W-16) has been in place since the 1990s, however there are significant constraints on the feasible rate of pipe replacement, such as:

- Community impacts of pipeline construction
- Contractor availability
- City staff availability (project management, inspection, operations and maintenance, etc)
- Affordability

Due to these limitations, a risk-based strategy is applied to prioritize mains for replacement at an attainable rate. The current rate of replacement is 5 miles/year, which is viewed as a stable, sustainable rate of replacement assuming an average life of 100-125 years for the Cit''s 600+ miles of pipe.

Figures 23 and 24 show the current and future projected composition of pipe materials in Bellevue's system. All pipe materials are vulnerable to seismic hazards, but asbestos cement (AC) pipe is predicted to have the highest break rate. By continuing the City's existing program and installing newer ductile iron (DI) pipe throughout the system, predicted pipe failures during the SFZ earthquake are reduced by roughly 50%, from 460 to 220 failures in the median simulations (of 10,000), along with substantial reduction in the time it takes to restore service.

Figure 23: Existing System (% of Pipe by Length)

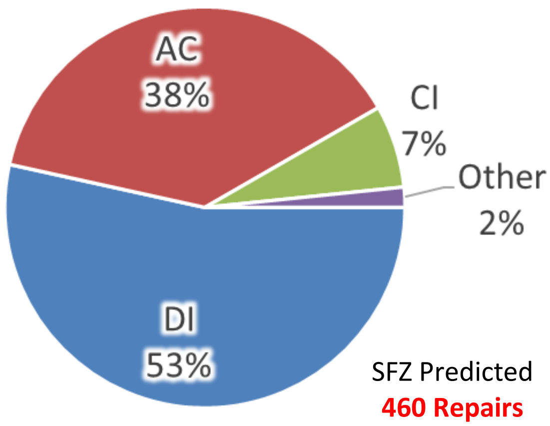
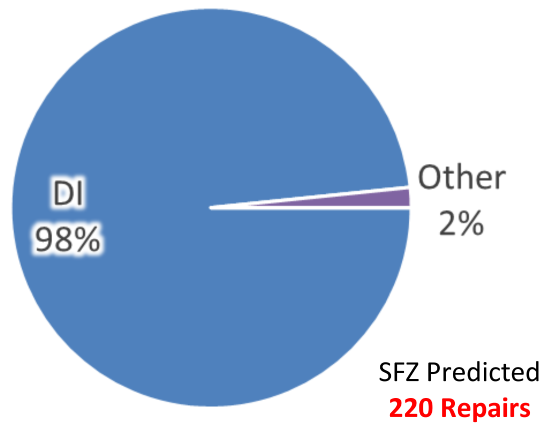


Figure 24: Future System (% of Pipe by Length)



The SVA also evaluated the benefits of different DI pipe joints, including standard non-restrained, restrained (RJ), and earthquake-resistant (ERDIP). Simulated performance improves substantially in liquefiable soils (4% of Bellevue's system by length) with ERDIP, demonstrating a clear benefit. However, in non-liquefiable soils only a nominal difference is predicted between non-restrained, RJ and ERDIP joints. There are numerous additional, non-seismic benefits of RJ and ERDIP pipe that make them appropriate, such as limiting service shutdowns during future construction, eliminating some thrust blocks, reducing break risk where access is limited, resisting pull-out on steep slopes, etc. However, seismic performance alone may not justify the added cost to install RJ or ERDIP in non-liquefiable soils.

Pump Station Rehabilitation

The majority of Bellevue's water service area is supplied by gravity, such that pumping is not necessary. In most cases, pressure needs to be reduced from the regional transmission pipelines.

However, certain higher-elevation areas do require pumping for service. This includes:

- All customers south of Newport Way and east of Coal Creek Parkway (South Operating Area)
- Some portions of Eastgate south of I-90 (Eastgate 590 and Horizon View 590 zones)
- A portion of the Clyde Hill vicinity (Clyde Hill 500 zone)
- Customers in the Pikes Peak and Bridle Trails neighborhoods, seasonally due to high summer demands (served by gravity most of the year)

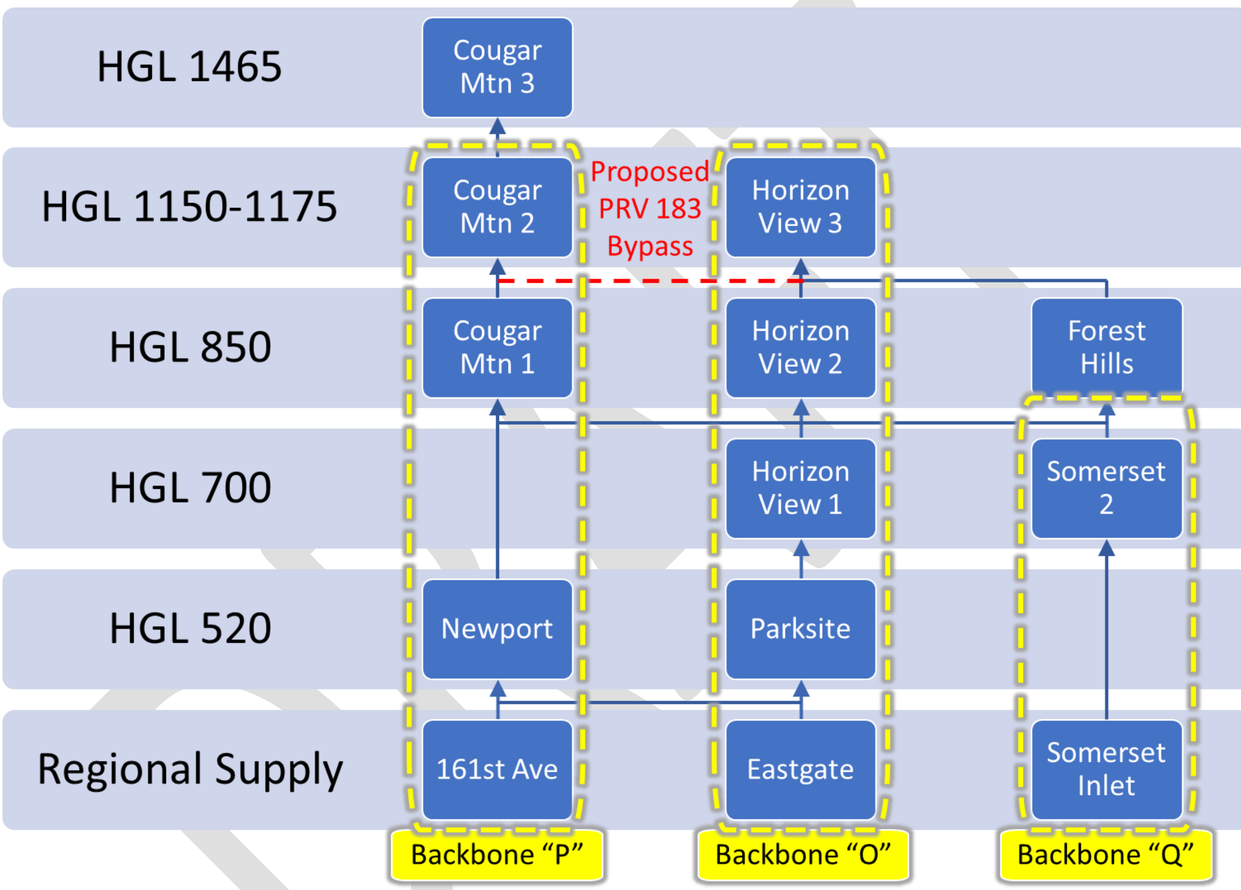
For these areas, the SVA found that impacts and service restoration times following a severe earthquake can be significantly reduced by improving the resilience, survivability and redundancy of pump stations.

In the South Operating Area, some redundancy has already been designed into the system, as shown in Figure 25. The largest pressure zone, Somerset 850 (SS850) is supplied via 3 separate corridors, proposed as backbones O, P and Q (See Figure #). The Horizon View 1175 (HV1175) zone can be fed independently by Horizon View 2 or Forest Hills pump station. However, Forest Hills Pump Station may be vulnerable to seismically-induced landslide (discussed in Chapter 4), and the Cougar Mountain 1150

(CM1150) zone lacks a redundant supply. To address these concerns, the following mitigation actions are proposed:

- Assume Forest Hills may not be reliable following a SFZ or CSZ event, so prioritize resilience through Horizon View 2 (Backbone "O").
- For emergency redundancy between CM1150 and HV1175, install bypass piping around PRV station #183, and size Cougar Mountain #1 pumps (pending rehabilitation) to allow emergency pumping to HV1175.

Figure 25: South Operating Area Pump Stations



Customers in the Eastgate 590 (EG590) and Horizon View 590 (HV590) zones are normally supplied via pressure reducing valves from the Horizon View 700 zone (HV700), as part of the South Operating Area (not shown in Figure #). They will benefit from Parksite Pump Station replacement as part of Backbone O. In addition, check valves from the Lake Hills 520 (LH520) provide redundancy to meet basic domestic supply at reduced pressure in case HV700 is impacted. No additional facilities are recommended for EG590 or HV700.

The Clyde Hill 500 Zone (CL500) is supplied by Clyde Hill Pump Station, with only about one day of water stored in the 465 standpipe. Due to the lack of redundant supply and existing seismic vulnerabilities, Clyde Hill Pump Station should be replaced.

The Pikes Peak and Bridle Trails neighborhoods are supplied by two redundant pump stations, Cherry Crest and 670 Pump Station. Pumping is required during warmer seasons, when demands are high and pressure drops in the regional Tolt Eastside Supply Line (TESSL). However, during winter when TESSL pressure is higher, these neighborhoods are supplied by gravity. Cherry Crest Pump Station was replaced in 2021 with a more resilient facility. The 670 Pump Station is very vulnerable to the SFZ or CSZ event, and should be replaced at the next rehabilitation (current scheduled after 2030), however this does not need to be a top priority given that pumping may not be necessary after an event (TESSL conditions similar to winter due to water use curtailment), and redundancy with Cherry Crest.

Reservoir Rehabilitation

Reservoirs are required to operate any water distribution system, and serve an important role during normal operations, brief emergencies and planned shutdowns. They are critical infrastructure facilities that require ongoing maintenance and occasional rehabilitation, and should be designed to stay in service following an earthquake.

However, the SVA found that following a major regional disaster with extended loss of water supply, reservoirs will be fully depleted within days. During the recovery period, the performance of empty reservoirs is less critical to basic service restoration than supply and transmission infrastructure. Therefore, while reservoir performance is important, from the standpoint of disaster mitigation and post-earthquake service restoration they should not prioritized as highly as the pipelines, inlet stations, and (where applicable) pump stations that deliver the water.

Reservoir seismic resilience is important to eventually restore normal service, and the City has had a reservoir seismic and structural rehabilitation program (CIP W-85) in place since the 1990s. As a result of this program, reservoir seismic resilience in Bellevue has improved.

Jumper Hoses

Jumper hoses do not provide any supply, but during a localized outage due to main break or other interruption can be used to temporarily connect nearby piping to maintain some level of service. Jumper hoses could also be used to restore service sooner to some customers during recovery following a widespread major event such as an earthquake.

A major disadvantage of jumper hoses is that they take substantial time and effort to transport, deploy, disinfect, connect, and then drain and store. In most main break situations, the break itself could be repaired in less time that it would take to put a jumper hose into service. Jumper hoses also have a limited shelf life, require storage space, and entail ongoing staff training to maintain readiness.

Another limitation of jumper hoses is that they only act to convey water between customers within a particular pressure zone. They cannot provide service to customers at higher elevations without a portable pump, or service to customers at lower elevations without a pressure reducing valve.

The City has a limited supply of jumper hose available. It was procured via a Urban Area Security Initiative (UASI) grant, and is jointly-owned with other regional utilities. This hose was successfully used along with other measures to maintain service during a water main replacement project in 2017, reducing a shutdown from over 300 customers to less than 20. The pictures below are from that event.

Unspooling jumper hose

Jumper hose in service

As demonstrated by successful deployment in 2017, jumper hoses can be useful to temporarily maintain service in certain situations. This could include similar, planned shutdowns where a large number of customers could be impacted due to a lack of isolation valves or redundant piping, and there is adequate time to plan for the event. Jumper hoses may also be useful following a main break that cannot be quickly repaired (e.g. creek crossings or other sensitive areas). However, for most main breaks in accessible locations, the time required to repair the main and restore normal service can be less than that required to install a jumper hose.

It is recommended that the City maintain some stock of jumper hoses as an available tool to assist in providing temporary service where appropriate, depending . However, it is not apparent that procuring jumper hose on a larger scale would have a significant benefit.

6.4 Improvement Timetable

Regardless of which capital, maintenance, or other technical mitigation actions are taken, there are numerous alternatives for how quickly to make these improvements.

Figure 26: Improvement Timetable Alternatives

1: Do Nothing (Never Improve)	• Accept declining performance • Accept $9.8M (and rising) annual risk
2: Minimal (100+ years)	• Replace assets on existing R&R schedule • Slow, generational improvement
3: Risk-Based (20-50 Years)	• New, targeted mitigation projects • Prioritize ongoing R&R to reduce risk
4: Aggressive (< 20 years)	• Replace vulnerable assets as soon as feasible • Ignore costs

Alternative 1: Do nothing

This alternative conflicts with both City policy and the U.S. America's Water Infrastructure Act, and is not recommended.

Alternative 2: Minimal

This alternative does not add any new projects or mitigation actions, but continues the existing R&R program at its current schedule, replacing water mains, pump stations and reservoir with more resilient infrastructure at the end of useful life (often 100 years). Projects are scheduled and prioritized based on non-emergency criteria such as age, obsolescence, and operational deficiencies. This strategy is viable, but accepts an annual economic risk currently estimated to be +/- $9.8 Million per year with existing infrastructure, and lags behind similar utilities' approach to seismic resiliency. Substantial improvement in PE-LOS may not occur within our lifetimes.

Alternative 3: Risk-Based

This alternative seeks to balance measurable improvements in PE-LOS with affordability, by making the most efficient, beneficial, and critical resiliency improvements over a reasonable timeframe. This strategy is the most consistent with other local and regional utilities.

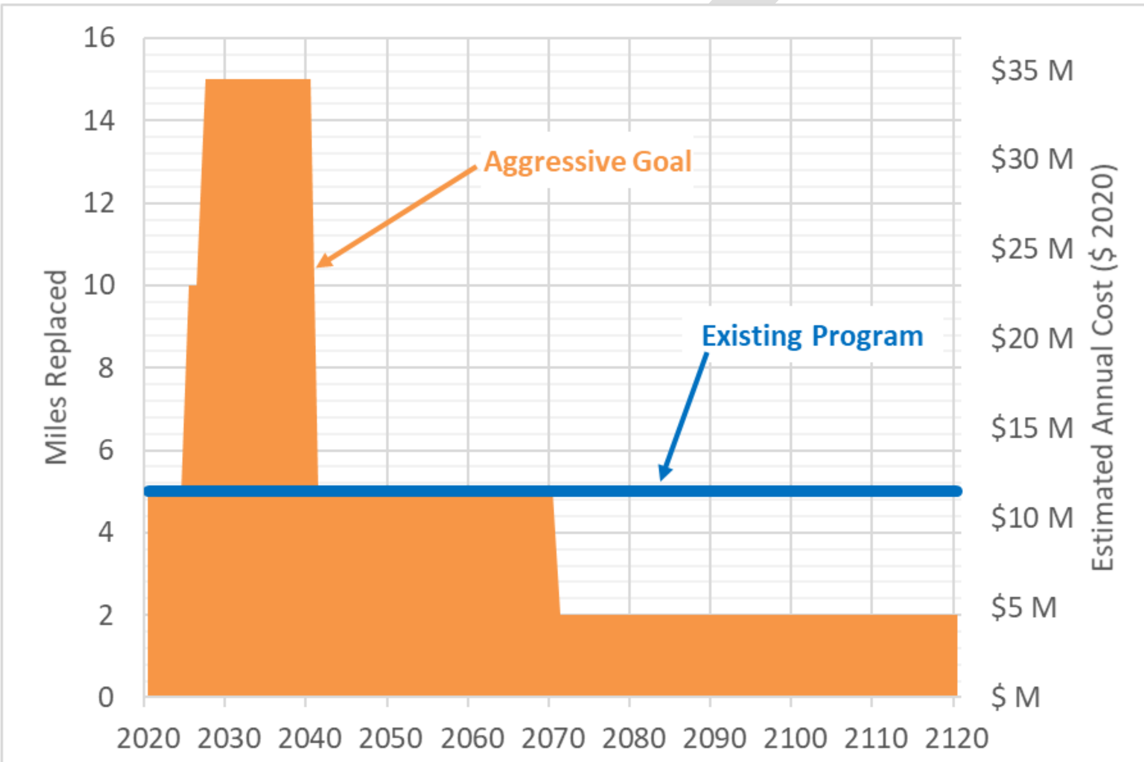
Alternative 4: Aggressive

This alternative takes a "moon shot" approach to rapidly improving seismic resilience. It is disproportionate with industry practices, is likely not feasible or affordable, and may not be defensible based on the estimated risk and event return periods.

As mentioned in Section 6.3, there are many practical limits on the amount of water main that can be replaced on an annual basis. In order to achieve the aggressive timetable, the City would have to substantially increase water rates, substantially increase the Utilities Department's Engineering Division staffing, triple the amount of pipe replaced each year, and accelerate pump station replacement and reservoir projects.

Figure 27 illustrates the logistical and feasibility challenges that the aggressive timetable would entail for water main replacement. The aggressive and existing schedules would replace the same length of pipe over 100 years, but the aggressive schedule would triple the rate from 5 to 15 miles/year through 2041.

Figure 27: Aggressive Pipe Replacement Schedule vs. Existing Schedule



7. Recommendations

This chapter summarizes the recommendations presented throughout the Master Plan, the anticipated system performance following those improvements, and anticipated costs.

7.1 Summary of Recommendations

Figure 28 summarizes infrastructure (capital) improvements that are recommended to meet the proposed PE-LOS goals within the 50-year timeframe. More detail is provided in the following pages.

Figure 28: Summary of Recommended Infrastructure Improvements

Category	Short-Term (S1)	Mid-Term (M2)	Long-Term (L3A)
Supply Improvements	Emergency Wells	7-day SPU Supply	
Facility Improvements	Clyde Hill Cougar Mountain 1 Cougar Mountain 2 Cougar Mountain 3 Horizon View 2 Parksite	Forest Hills Newport 670	Woodridge
Distribution Strengthening		LH 520 FA 293	BV 400 SS 850 EG 330
Backbone System	Partial Backbone		Expanded Partial Backbone

General mitigation actions:

- Implement a 50-year, risk-based improvement timetable, consistent with other Pacific Northwest water utilities.
- Develop a roster of Washington State certified Water Treatment Plant Operators (WTPO), as needed to maintain and operate proposed groundwater well treatment systems.
- When prioritizing and siting locations for improvements, consider equitable, inclusive, and culturally competent access for vulnerable or under-represented residents. For instance consider residents who lack a vehicle to pick up water, language barriers, and other factors.
- When evaluating resilience and redundancy improvements, consider the risks (likelihood and consequence) of all hazards and threats cumulatively, including intentional acts, natural hazards, and failures due to age or deterioration.
- The Utilities Department should not rely on any of the following as mitigation for widespread regional disasters or any complete disruption of water supply:
  - Portable surface water treatment
  - Bulk water storage and delivery (e.g. blivets, distribution trailers, etc)
  - Jumper hoses

  These measures <u>should</u> be considered as tools to address small, localized, planned or unplanned shutdowns or emergencies, so a small inventory may be appropriate. However, they require substantial storage space, maintenance, exercise and training, they lack substantial capacity, and following a major disaster they would divert water utility staff from higher-priority service restoration tasks (see Chapter 6).

- Evaluate Federal grant programs for mitigation funding opportunities, if and where the value provided exceeds the application and compliance requirements, and when Bellevue's application would likely be competitive.
- Encourage emergency response agencies to execute pre-authorized contracts with water delivery services, to have vendors potentially available to truck bulk water (tankers) or bottled water (large retailers) when the need arises. (See Chapter 5)
- Develop Standard Operating Procedures (SOPs), perform initial & refresher training, and conduct periodic exercises to establish and maintain readiness for alternative supply and delivery methods.
- Inform and encourage residents to store 14 days of water, if possible.
- Provide translation of public messaging, signage and other media related to emergency preparation and response, to improve cultural competency and access to emergency services.

Water Supply:

- Encourage SPU to prioritize improvements to the TESSL and CESSL, in coordination with Cascade Water Alliance.
- Improve the Crossroads and Samena well sites to allow for:
  - Rapid conversion of the local distribution system to groundwater supplies in an emergency
  - Well head protection meeting current standards
  - Staff readiness and more effective use of resources for non-emergency demands
- Further evaluate local hydrogeology to understand and mitigate potential risks to stream flow from pumping groundwater.
- Perform a siting study to identify potential new (emergency-only) well sites.
- Implement best practices for well head protection at the Crossroads site, including site improvements, further remediation of contaminated soils, land use changes, and a sensitive area designation, if appropriate and applicable.

Water Distribution:

- Continue the existing pump station rehabilitation program (CIP W-91), and prioritize renewal or replacement of the pump stations listed in Figure 28.
- Enhance the required seismic design criteria for pump stations and reservoirs (see Attachment 1-H, Table 4).
- Require earthquake-resistant pipe in liquefiable soils (see Attachment 1-H, Section 5.3).
- Continue the existing water main replacement program (currently 5 miles per year), using earthquake risk reduction as part of the prioritization criteria. This should add higher priority to pipeline replacement in the Lake Hills 520 (LH520) and Factoria 293 (FA293) zones in the mid-term period (by 2050), due to large numbers of critical customers, population density, equity benefits, and relative vulnerability. The Bellevue 400 (BV400), Somerset 850 (SS850) and Eastgate 330 (EG330) zones should be prioritized in the longer-term (by 2070). See Attachment 1-I, Section 6.2.

- Incorporate post-earthquake recovery into the risk model for prioritizing water main replacements. In particular, increase priority for the most critical zones (e.g. BV400, FA293 and LH520) and for the most vulnerable pipeline (e.g. in liquefiable soils).

Backbone:

- Install seismically-resilient backbone piping, as described in Section 6.2. Prioritize the following backbone routes (see Figure 22 for locations), which have positive benefit/cost ratio based on seismic risk reduction alone:
    - A Crossroads to Samena Well
    - B Samena Well to Parksite/SBCC
    - G LH520 to BV400
    - L 136th Ave Inlet to Hospitals
    - M Bel-Red/Downtown/Clyde Hill

  Other backbone routes provide value, but do not provide enough seismic risk reduction benefit to justify early replacement. They can be installed opportunistically in combination with other benefits (e.g. renewal and replacement) or as cost efficiencies arise (e.g. overlapping projects).

7.2 Anticipated Level of Service Improvements

As described in Section 3.3, iterative, Monte-Carlo models were developed to simulate service restoration times throughout the service area after the SFZ and CSZ events with existing infrastructure. The same simulations were performed to develop the above recommendations and meet the PE-LOS goals in Chapter 2. Figures 29 and 30 show the results with existing infrastructure (2020), and with recommended short-term (2035), mid-term (2050) and long-term (2070) improvements.

Figure 29 - Simulated SFZ Restoration Time with Proposed Improvements

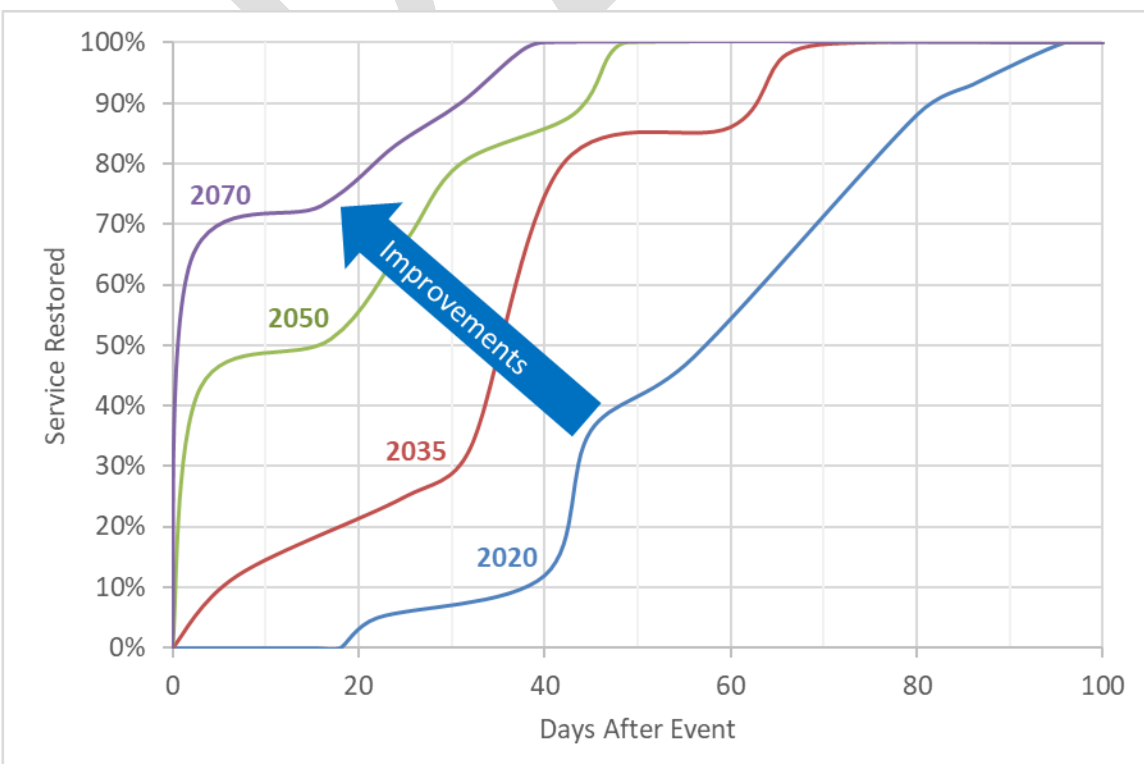
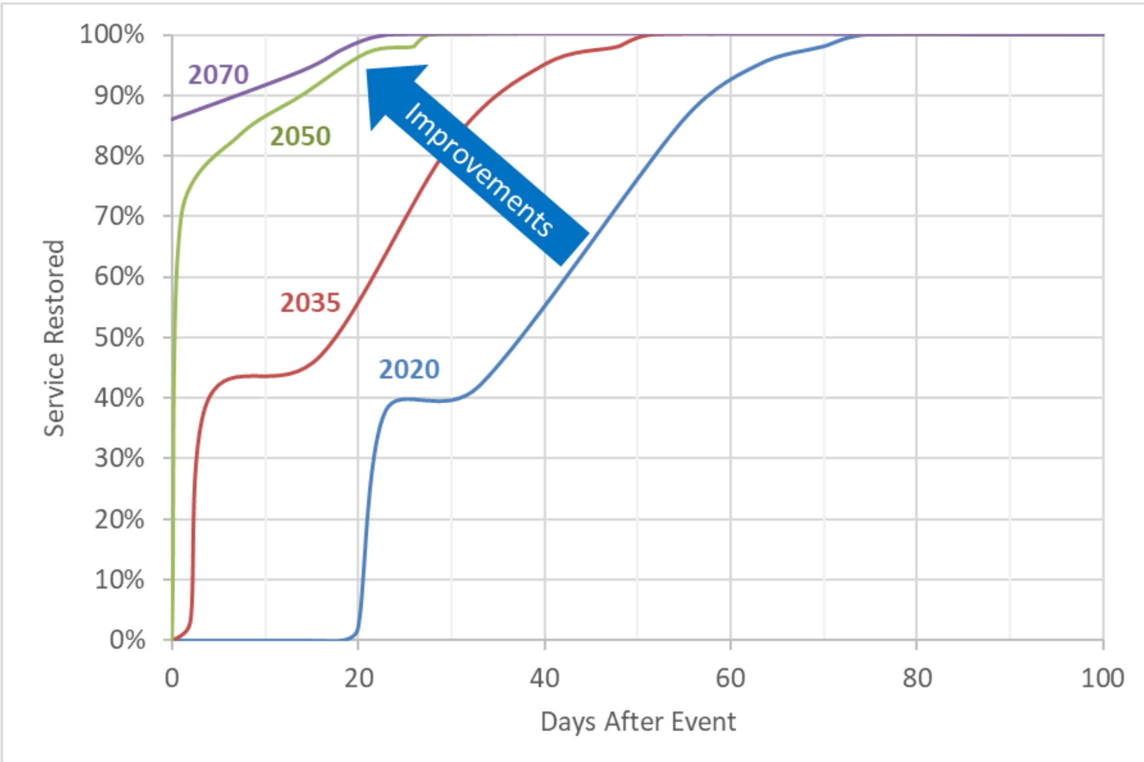


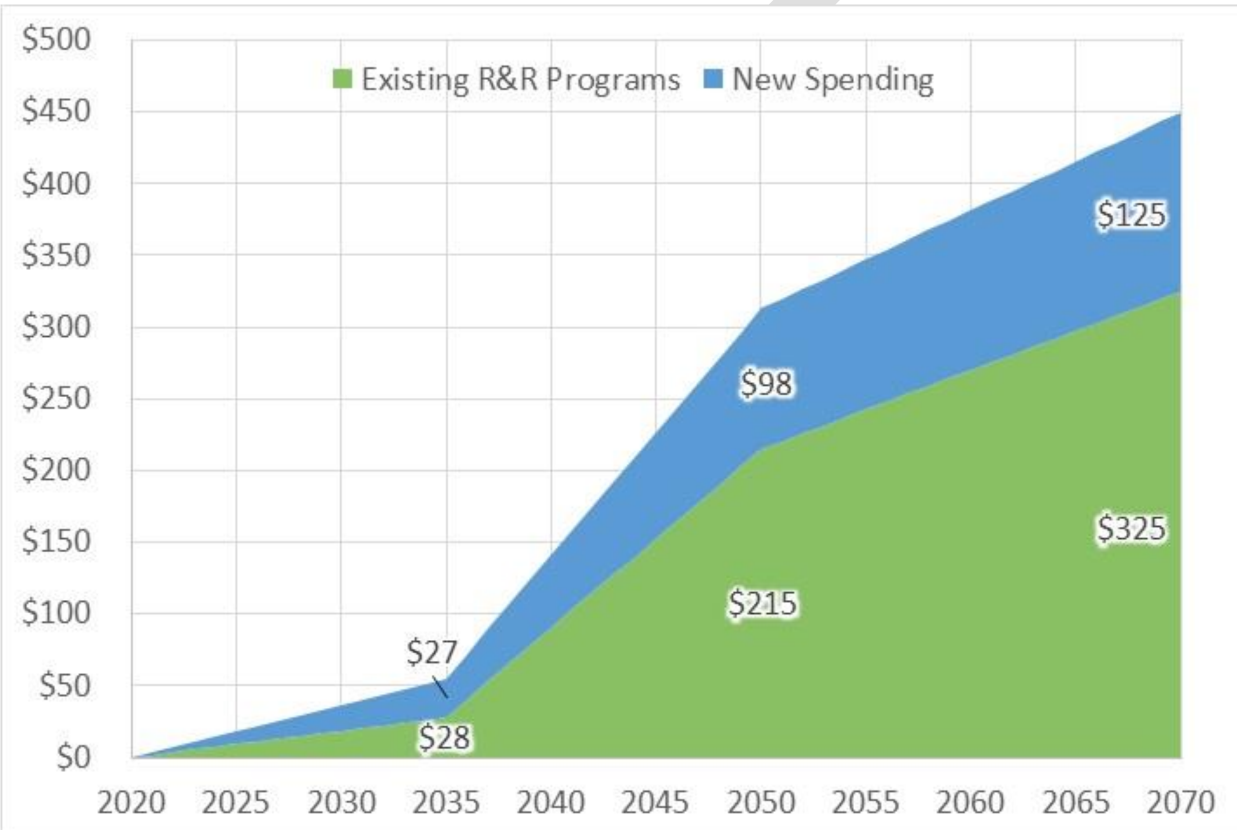
Figure 30 - Simulated CSZ Restoration Time with Proposed Improvements



7.3 Anticipated Benefits vs. Cost of Improvements

As noted in Chapter 6, most of the recommended mitigation actions involve continuing existing annual CIP programs (W-16 water main replacement and W-91 pump station rehabilitation or replacement), with some changes to project criteria and prioritization. As a result, most of the recommended improvements do not represent new spending, but provide additional justification for already planned renewal and replacement work. Some new spending is proposed, including the addition of new emergency wells, and backbone piping above and beyond planned pipeline replacement. Figure 31 shows the estimated cumulative costs for the recommended improvements.

Figure 31 - Proposed Cumulative Spending on Improvements ($ 2019, uninflated)



Costs shown in Figure 31 are based on 2019 costs, prior to COVID-related inflation and supply chain challenges. Due

To quantify the basis for recommended projects, benefit/cost ratios specific to earthquake mitigation were estimated, as shown in Table 5. Benefit is estimated as reduced risk, using 100-year net present value assuming 2% inflation and 5% discount rate. Benefit/cost ratios only account for seismic-related benefits, so total benefit/cost (including existing programs) is higher considering other benefits for programs that are already budgeted.

Table 5: Seismic Benefit / Cost Ratio for Recommended Projects

Timeframe	Seismic Benefit / New Spending	*Added* Seismic Benefit / New + Existing Spending**
Short-Term (15-year)	5.2	2.6
Mid-Term (30-year)	2.4	0.7
Long-Term (50-year)	2.5	0.7

**Only considers seismic benefits. Ongoing benefits for existing R&R programs (increased reliability, streamlined operations, reduced life-cycle costs, etc) are not included and would be cumulative. Total benefits/cost ratios are higher.